Waikato Header Sheet

11178

Box Name: EKMT-00022

Subject: 54/30/1 (Vol.2) - Auckland Admin District Policy - Erosion (1985)

MINUTE SHEET

Department: ....

Subject:

Section: ....

File No. 54/30/1

34694F–1[illegible]pads/4/85MK

Date: 5/12/85

To–

filenote

final report 'Shoreline fluctuations and an assessment of a coastal hazard zone along Pauanui Beach'.
J. G. Gibb and J. H. Aburn

~~n [illegible] in~~

– Copy in HeF library
n° 431

file

Item 504

54/30/1

4 December 1985

The Regional Secretary
AUCKLAND

HARBOURS AND FORESHORES SECTION :
REPORT ON SEMINAR ON PAUANUI COASTAL HAZARD ZONES

Thank you for your report regarding the seminar on Pauanui Coastal Hazards.

It is agreed that the Ministry could object to the next review of the Thames-Coromandel District Council's district scheme if the suggested measures are not incorporated. However, we must in general be careful when making objections that we are able to sustain them with supporting information.

RMB

R. Murray-Brown
for Secretary for Transport

04L5/Trl

FILE
5/12/
Initials: RMB

DISPATCHED
- 4 DEC 1985
by RECORDS

SED(H&F)

54/30/1

Copy to
S.E. of Harbours and Foreshores
Head Office
For your information

54/14/22

HARBOURS & FORESHOREs

15 November 1985

REPORT ON SEMINAR ON PAUANUI COASTAL HAZARDS AND RELATED MATTERS HELD IN THE THAMES-COROMANDEL DISTRICT COUNCIL CHAMBERS ON 13 NOVEMBER 1985

1. BACKGROUND

Discussion centred around the implications for Pauanui beach sub-division and other low lying coastal sub-divisions of a report prepared by the M.W.D. (Gibbs/Aburn) which predicts a rise in MSL of from 1.5mm - 7mm yr for the next one hundred years, equating to an anticipated rise of from 15 - 70cm. Present were representatives from the District Council, Pauanui residents, Pauanui beach developers, Hauraki Catchment Board, M.W.D. (Including the author of the report, Lands & Survey and M.O.T.

This rise in MSL has implications for all low lying coastal areas in New Zealand. The essential conclusions of the Gibbs/Aburn report stressed that the sand spit of Pauanui appeared to be currently in a state of dynamic equilibrium, but that overseas data points towards a rise in MSL that will lead to a coastal hazard zone of from 54 - 116m wide along Pauanui beach.

Debate centered around the validity of the report, especially on the accuracy of this predicted sea level rise. The author acknowledged that it is difficult to predict with any certainty the actual likely increase in MSL, but stressed that the rise is already taking place and that the best scientific evidence would suggest it wise to plan for such a hazard.

2. DEVELOPMENT IN PAUANUI BEACH

Began over 18 years ago and now all but one of theseventy odd sites within the hazard zone identified by Gibbs/Aburn have been built upon. In 1980 a beach cycle studyby Carryer/Raudkivi identified a hazard line representing a buffer of $400M^3$ of sand per M of beach. The District Council applied this line as a building setback line for all new building permit applications after this time, applying Section 641A of the Local Government Act 1974 which requires buildings to be relocatable before B.P's can be issued for "hazardous sites". Unfortunately, by the Council's own admission, Council did not apply this proviso rigidly and as a result most of the buildings built on Pauanui beach since a coastal hazard line was identified are not built of "relocatable" materials and/or are hemmed in by other houses, making relocation extremely expensive.

3. POSSIBLE SOLUTIONS DISCUSSED AT SEMINAR

Mr Gibbs outlined the nature of financial support from Government that can automatically be advanced to aid hazard prone dwellings.

Development prior to 1971 are eligible for a 30% subsidy on capital value for various purposes such as protection works. Development after 1971 is not eligible for any subsidy, the rational being that since 1971 people should be aware of the hazards of constructing close to ocean beaches. Subsidy is advanced by the National Soil and Water Conservation Authority.

Interestingly enough the local residents were quite aware of the possible consequences of building close to an ocean beach and appeared resigned to the fact that little help could be expected. Pauanui beach developers even went as far to say that "cavaet emptor" should apply and that people should be able to build what and where they like at their own risk without Council restriction. It should be emphasised that in many ways the report is too late for Pauanui as it has already been almost fully developed.

4. OPTIONS ARE

1. Do nothing and let residents worry about their own problem as it arises.

2. Investigate the possibility of beach protection works.

   MOT officials stressed the undesirability of these hard measures, adding that beach walls offer increased erosion and spoil the beach for "outside" visitors (refer MOT policy pamphlet - "policies for the coast')

3. A soft engineering option was suggested, involving the dumping of sand on the beach from Tairua harbour. This seems a sensible measure for use when the time comes, but should be entirely financed by the residents themselves.

5. THE USE OF DEVELOPMENT CONTROLS WITHIN THE DISTRICT SCHEME

The final hour of the seminar centered over what controls the Council should insert in their coming review of the District Scheme.

Mr Gibbs strongly advocated the insertion of the coastal hazard zone map in the District Scheme, as well as recommendations 2 to 4 of his report (see copy attached).

The TCDC planner expressed unwillingness to place the map in the District Scheme, preferring instead to call the area a "special development policy zone" which entailed controls relating to the beach's priceless national asset role. In effect the TCDC planner appeared to be more concerned about Controlling amenity of the area (height of buildings, spacing of units) rather than drawing attention to the fact that the sub-division is likely to be inundated in the next hundred years.

6. RECOMMENDATIONS

TCDC DISTRICT SCHEME REVIEW

1. That the TCDC District Scheme in its forthcoming review incorporate all 4 recommendations contained in the Gibbs/Aburn report.
   see attached Appendix.

2. That further development within the coastal hazard zone be rigidly restricted to truely transportable units, all at the owners risk to be recorded on the title.

3. That the scheme contain mention of the undesirability of any hard engineering solutions to the problem of erosion at Pauanui beach, as these often execrabate erosive processes and spoil the beach for other users.

4. That the Council should help Pauanui residents to set up a ratepayer funding programme designed to make possible the cartage of sand from Tairua harbour for Pauanui beach when houses become threatened.

5. That Council investigate the implications of this study for other coastal sub-divisions within their District, so that preventative planning measures may be taken to safeguard future coastal development from a similar rise in sea level.

6. That the Ministry of Transport should object to TCDC's reviewed district scheme if their measures are not incorporated.

   (or this can be achieved in callaboration with the Ministry of Works Town and Country Planning Division).

7. RATIONAL - HARBOURS & FORESHORES

Where studies are available which point out the strong possibility of coastal erosion affecting present and future coastal development, conservative planning approaches should be taken by Local Councils thereby reducing as far as possible the risk of future sub-divisions becoming threatened by erosion.

Such conservative planning should reduce the need for Councils and/or residents to apply to the Harbours and Foreshores Section for permission to construct sea walls, groynes etc which do little for our coast from an amenity point of view.

These policies are consistent with the policies of the MWD's Town and Country Planning Division.

MS.

Michael Smythe
Acting Section Officer
Harbours & Foreshores
AUCKLAND

are subject to the coastal hazards of long and short-term sea erosion, wind erosion and deposition of sand, and tsunami inundation. The Moderate Risk Zone is subject to sea-erosion resulting from a 700 to 880 mm predicted rise in global sea-level.

Appendix – extract from Gibbs/Aburn report MWD 1985

RECOMMENDATIONS

1. The Pauanui Beach Coastal Hazard Zone should be incorporated into the Thames-Coromandel District Council (TCDC) Planning Scheme to satisfy both the provisions of the Second Schedule, clause 8a of the Town and Country Planning Act 1977 and the July 1981 policy on Natural Hazards of the National Water and Soil Conservation Authority.

2. In the long-term public interest TCDC should develop a policy to effectively apply the requirements of sections 274, 641 and 641A of the Local Government Act 1974 for the control of further subdivision; residential, commercial and industrial development; and additions and alterations to existing development, of property and assets lying within the CHZ.

3. Hauraki Catchment Board and Thames-Coromandel District Council should continue to monitor Pauanui Beach and use the techniques developed here to reassess the Pauanui Beach CHZ every five years.

4. Should sea erosion directly threaten beachfront property and assets then the assets will either need to be relocated inland or a coastal engineering solution found. An engineering solution such as a seawall could destroy Pauanui Beach, a priceless national asset. Beach

replenishment from Tairua Harbour sand, however, could maintain beach volumes whilst protecting property and should seriously be considered as a possible long-term solution, particularly along southern Pauanui Beach.

ACKNOWLEDGEMENTS

We gratefully acknowledge the following for invaluable assistance with this part of the Pauanui Coastal Hazard Survey: The Hydrographer, Royal New Zealand Navy, for making available Lieutenant IFP Martin and his able crew and the RNZN Operational Diving Team under the supervision of Warrant Officer P. Kneebone; the District Commissioner of Works, Ministry of Works and Development, Hamilton for making available the survey section of the Hamilton District Office and Dr T. M. Hume of the Water Quality Centre, Hamilton; the Chief Engineer of the Hauraki Catchment Board for making available Mr P. Dell. Funding for the project was carried mostly by the Ministry of Works and Development and partly by the Thames Coromandel District Council. The assistance of Mr Ian Hopper who funded the 3 bore-holes drilled by Thames Valley Welldrillers and provided us with much useful local data, is gratefully acknowledged. Constructive criticisms of the draft manuscript were made by Mr Hopper, Dr Hume, Mr Dell, Mr Le Marquand (Water and Soil Directorate), Mr J. W. D. Hessel, Superintendent of Climatology, New Zealand Meteorological Service, and Mr F. Easdale, Registered Surveyor, F. Easedale and Partners.

1 October 1985

The General Manager
Thames-Coromandel District Council
Private Bag
THAMES

Attention: Mr Fenton

File

Dear Sir

PROPOSED SEMINAR ON PAUANUI COASTAL HAZARDS

The Regional Secretary has forwarded to me your letter, reference V11/102, and copy of report by J G Gibb and J H Aburn.

A representative from the Ministry will be available to attend the proposed seminar. Could you please advise our Regional Secretary, Auckland, of the date and timing of the seminar when available. At this stage we have no suggestions for any amendments to the proposed purpose of the seminar.

Yours faithfully

B A Ranger
for Secretary for Transport

DISPATCHED
2 - OCT 1985
by RECORDS

The Regional Secretary
MOT
AUCKLAND
Attention: Harbours & Foreshores

Copy for your information. Returned herewith copy of correspondence and report. Could you please arrange for P Spackman to attend the Seminar when it is held. Meantime we are seeking assistance in assessing the report and what are the relevant questions that need to be asked and areas that need to be clarified before guidelines and safeguards promulgated. When we have looked at the report we will ask that P Spackman attend a briefing session at H.O.

B A Ranger
for Secretary for Transport

FILE
5/12/ Please return to
Initials: MB SEO H+F

MINUTE SHEET

Subject Pauanui Beach Shoreline fluctuations Report by J.G. Gibb & J.H. Aburn

Department: ....

Section: ....

File No. ....

Date: 15/10

To–

General comments.

1. The case has been argued that, over the past approx. 90 years, the shoreline at Pauanui has been in 'dynamic equilibrium', ie has been fluctuating about a fixed point without net erosion or accretion. This means that the shoreline has been able to adjust itself to the slowly rising sea level over the period, as there has ~~too~~ been sufficient sediment input to offset the erosive potential of the slight increase in sea level.

In my view, from the data presented, there is no evidence to the contrary.

2. If the rate of sea level rise over the next 100 years increases as predicted, then the predicted erosion of the shoreline will probably occur.

3. The central point is, will sea level rise as predicted over the next 100 years? ~~suggested~~ I think the report by NAS should be obtained, with comments sought from the met. service, as they should be able to provide informed comment.

FILE
5/...
Initials: MB

Item 503

23162C–150,000/9/84MK

MINUTE SHEET

Department: ....

Subject

Section: ....

File No. ....

Date: ....

To—

3. I agree with J. Gibb's recommendations that:

(1) a coastal hazard zone should be established within the local district planning scheme) and that it should be reviewed periodically; and

(2) the most effective counter to long-term erosion is beach replenishment. The Tairua River may supply the necessary supply of sand.

4. It is unlikely that any action in this regard will need to be taken over the medium term (10-20 years). The predicted accelerated rise in sea level will not become noticeable for some time, and the beach probably has a 'buffer zone' by which it is able to absorb further

immediate increases in the rate of sea level rise. The Catchment board should continue monitoring of the beach, with plans devised for the importation of sand, if this is required.

5. My own personal view is that the size of the CHZ's are erring on over-caution, but I suppose it is better to amend down than up.

Item 503

23162C—150,000/9/84MK

R. Murray-Brown

MINUTE SHEET

Department: ....

Subject:

Section: ....

File No. ....

Date: ....

To–

EO

Please get Robert to go attached report and list questions that need to be asked or statements that need to be clarified.

At this stage we do not go outside the Dept.

The meeting is likely to be the week 11-15 Nov. so we will need something done by 14 Oct

FILE

5 / 12 / ....

Initials: DMB

Item 504

MINUTE SHEET

Department: ......

Section: SEO(A)

Subject

File No. ......

Date: 29/9/85

To–

SEO (H+F)

1 Please get an overview of the report with a list of the relevant questions which need to be asked

2. Arrange for assistance in assessing or explaining main features

3. Advise Peter S at AK that we would like him to attend & he should also be briefed in H/O. (eg he could attend H/O sessions for 1 & 2 above)

SEO (A)

FILE

5/12/

Initials: AMB

Item 503

13414A–140,000pads/3/84MK

MINUTE SHEET

Subject:

Department: ....

Section: ....

File No. ....

Date: ....

21132E-[redacted]0pads/8/84MK

To—

CEO (A)

(W+S MWD)

- We can talk to J. Gibb about his report
- We can discuss with Catchment Bd
- Robert with his background should be able to steer us towards the questions we should be asking
- Marine Works Engineer may be able to help us in interpretation
- some of it I hope I would be able to understand - might be basic.

- We would deny any responsibility for full funding However, if we ~~[illegible]~~ really considered funding ~~report~~ was necessary for policy formulation we may say that a small contribution was available to get

Item 504

MINUTE SHEET

Department: ....

Subject:

Section: ....

File No. ....

21132E–[illegible]0pads/8/84MK

Date: ....

To–

things going (only if everybody came to the party)

Yes I think Peter could handle without committing MOT to funding – it would pay to keep an eye on what TCDC are up to.

24/9/85

Item 504

MINUTE SHEET

Subject

Department: ....

Section: ....

File No. ....

Date: ....

To—

SEO(HaT)

Do we have any specific individual who could advise the Ministry on this report - or do we have access to any Govt agency which can provide guidance on the probability of the occurrence & how serious the increase in sea level will be elsewhere?

I would also like to know what our responsibility is for funding any work involved & why. - what about other areas?

Could Peter Sparkman handle this on an observe & report basis - he could always claim that he has no authority to agree to funding & knowing how eager AK is to give out grants it may be better to keep to H/O

FILE

5/12/85

Initials: MB

Item 503

13414A—140,000pads/3/84MK

MINUTE SHEET

Department: ....

Section: ....

File No. ....

Date: ....

Subject:

21132E-6[illegible]0pads/8/84MK

To—

CEO(A)

I have not read all the papers attached, but having regard to the problems we have had in the past with TCDC and with Pauanui I think we should attend.

B.A. Ranger
SEO H+F
19/9/85

FILE
5 / 12 / 85
Initials: AMS

Item 504

SEO (H&F) MINUTE SHEET

FILE HELD BY
AAO (PP)
4.7.85

Department: 2/11/88

Section:

Subject: PROPOSED SEMINAR PALMANUI COASTAL HAZARDS

File No. 1/1/23/243.

49918A–15[illegible]ads/7/80 MK

Date: 16/9/85

To–
HEAD OFFICE
SEO (H&BR)
ATTN
MISS RANSER

RE ATTACHED LETTER FROM TCDC & REPORT.

ARE YOU INTERESTED IN ANYONE ATTENDING THIS PROPOSED SEMINAR?

IF MOT WAS REPRESENTED I THINK WE WOULD NEED TO DETERMINE BEFOREHAND OUR LEVEL OF ASSISTANCE.

P. D. SPACKMAN
for Reg. Sec.

RECEIVED
18 SEP 1985
H.O., MINISTRY OF TRANSPORT
No. 1

FILE
5/12/85
Initials: MB

Item 504

1/1/23/243

Thames - Coromandel District Council

TELEPHONE: 86-025 THAMES

PLEASE ADDRESS ALL CORRESPONDENCE TO: THE GENERAL MANAGER,

PRIVATE BAG, THAMES, N.Z.

KCF:AH

If calling, please ask for MR FENTON

Please quote reference. V11/102

10 September 1985

The Marine Division,
Ministry of Transport,
Private Bag,
AUCKLAND

ATTENTION: REGIONAL SECRETARY

Dear Sir,

PROPOSED SEMINAR ON PAUANUI COASTAL HAZARDS

Earlier this year, Council received the report prepared by Messrs J.G. Gibb and J.H. Aburn entitled "Shoreline Fluctuations and an Assessment of Coastal Hazard Zone along Pauanui Beach, Eastern Coromandel Peninsula, New Zealand". A copy of this report is attached for those addresses who have not yet received one.

After receiving the report, Council decided to convene a seminar at which all interested parties could be represented to discuss the report and its recommendations, and bring finite proposals to Council to confirm Council policy arising from the report.

The short and long term erosion, expressed as an annual rate, had been assessed in the past by various methods, but the Gibb/Aburn report also included substantial consideration of an acceleration of predicted rise in sea level resulting from a carbon dioxide build-up in the Earth's atmosphere.

The predicted rate of rise of sea level, 7mm ± 0.18mm per year, has been contested by the developers of Pauanui, on the grounds that there is insufficient evidence to prove or disprove that rate. However, the Gibb/Aburn report quotes sources of high credential including the U.S. National Research Council, which is the research arm of the National Academy of Sciences (NAS).

In/

In order to make some progress towards evaluating the implications to Pauanui (and Tairua) of rise in sea level and other erosion/inundation forming processes, it is thought necessary to accept the predicted rate, as:

a. There seems unlikely that there is any substantial evidence to the contrary currently available; and as

b. Any plans made or actions taken to ameliorate such effects would be progressive and evolutionary; and as

c. Current acceptance of this rate does not affect development of lots defined in the report to be in the hazard zone, as these have all been built on with the exception of one.

It is thought that the purpose of the seminar might be:

a. To identify the consequential effects of such a rise in sea level on public and private property and amenities of the Pauanui sandspit (and possibly also include the effects on low lying parts of Tairua).

b. To discuss the formulation of guidelines and safeguards that might need to be promulgated in due course to assist the public.

c. To identify possible sources of funding that would be required during the 100 year period of predicted rise in sea level and inundation or erosion.

For your information, I enclose a copy of some notes on the proposed seminar.

Would you please advise whether a representative of your organisation would be prepared to attend the seminar and whether you would like to suggest any amendments to the proposed purpose of the seminar.

Would the Director, Water & Soil Division, Ministry of Works & Development, please advise dates that Dr. J.G. Gibb might find suitable for the seminar later this year. For action of MMDonly

Yours faithfully,

K.C. FENTON
CHIEF ENGINEER
THAMES-COROMANDEL DISTRICT

ENCL.

PROPOSED SEMINAR ON ASSESSMENT OF COASTAL HAZARD ZONE AT PAUANUI

INTRODUCTION

1. As there is unlikely to be any substantial evidence to the contrary currently available, it is accepted that conclusion 5 of the report is applicable to the Pauanui sandspit. i.e. a predicted minimum of 7mm ± 0.18mm year global rise in sea level occurring over the next 100 years, resulting in a reversal from dynamic equilibrium to long-term erosion along the entre 2.65 km-long Pauanui Beach with erosion increasing in both rate and extent southwards.

2. As the report did not cover the Tairua River estuary, the effects of this global rise in sea-level on the estuarine side of the sandspit were not assessed. However, the views of the Hauraki Catchment Board have now been given on this aspect; affecting as it does not only the total risk to Pauanui, but also the shoreline developments of Tairua township. See attachment.

IMPLICATIONS

General

3. The entire coastal hazard zone at Pauanui comprises the land coloured purple plus the land coloured red on Ministry of Works & Development Plan 2/973/1 2204 Sheet 9. The zone of immediate risk (coloured purple) which was measured inland from the top seaward edge of the present foredune, does not include any residential buildings while the red coloured part of the coastal hazard zone includes within its boundaries residential buildings at the southern end of the beach. A total of 20 or so existing buildings would be included in the red (rise in sea level) part of coastal hazard zone.

4./

Private Property

4. As all affected lots with the exception of lot 804 are built on, recommendation 8 of the report (that building permits be refused) would have limited application. However, the protection of these residential properties in the long term remains a major implication.

Public Reserves

5. Apart from the protection of property in individual ownership, the question of the availability of ocean beach public reserve above future mean high water arises. Development was permitted to proceed in the belief that the attrition of public reserves, if it did occur, would be at a relatively slow rate due to an annual rise in sea level of about 1.5mm per year.

6. The purpose of ensuring the provision of these public reserves was to enable the general public to enjoy unimpeded access to the foreshore and have enough space between tidal waters and private property for recreational pursuits. The future restoration of existing reserves to present dimensions and location would appear impracticable, but some scope may be available for relocation and reprovision of ocean beach public reserves, albeit to a much reduced dimension. In retrospect it may be concluded that the dimensions of the public reserves originally provided were not quite as generous as would have been desired in the light of current knowledge on rise in sea level.

Estuarine Reserves & Properties

7. The predicted rise in sea level would affect both the Tairua River estuary/harbour as well as the ocean beach. The Hauraki Catchment & Regional Water Board has now amended the Board's report entitled "Tairua River Discharge Investigation - March 1976" to reassess the threat to the adjacent subdivision now being compounded by the predicted rise in sea level.

8. The rise in sea level may prove beneficial to the recreational amenities of the Tairua harbour, now experiencing limitations due to the siltation of the harbour and estuary consequential to developments within the watershed but will adversely attract lowlying areas.

RESPONSIBILITIES

9. If actions are to be taken to ameliorate the effects of rise in sea level, then substantial capital outlay is indicated. As the attrition due to sea level rise would be progressive, it may be that funding can be progressive. However, plans need to be formulated to ensure that individual and corporate responsibilities are agreed early in the time scale. Moreover, some cognizance needs to be taken of concurrent events and actions associated with development in the general area, that might be prejudicial to amelioration plans.

10./

10. Sources of funding would need to be identified as available from the following:

Local Government
Central Government
Individual Property Owners.

11. Guidelines and safeguards would need to be discussed, agreed and promulgated through available channels such as correspondence with ratepayers and public documents including the District Scheme.

12. Participating organisations likely to make substantive contributions in policy formulation and/or finance might include:

Thames-Coromandel District Council - including Committees and Community Councils

Hauraki Catchment Board

Ministry of Transport

Land & Survey Department

Ministry of Works & Development and National Water & Soil Organisations

HAURAKI CATCHMENT BOARD

YOUR REF: VII /102 OUR REF: 1/20/4

27 August 1985

RECEIVED

RECEIVED 1985

30 AUG 1985

THAMES COROMANDEL DISTRICT COUNCIL

YES NO

M13/101/10

Chief Engineer,
Thames-Coromandel District Council,
Private Bag,
THAMES.

Dear Sir,

TAIRUA RIVER - SEA LEVEL CHANGES

With regard to the Tairua River the Board has not been in a position to date to undertake a full, detailed reassessment of the 'proposed 100 year flood profile' as given on Hauraki Catchment Board drawing no. 1435 sheet 2. It is envisaged that such a review will take place within the next five years, in relation to the possible flood protection of some specific areas of the lower Tairua River Valley. The effect of the predicted sea level rise of 0.7 m ± 0.18 m could then be more accurately assessed at this time. The Board will endeavour to keep your council informed of progress in this regard.

A review of the hydrology of the Tairua River has however been undertaken by the Ministry of Works and Development in conjunction with the recent waterway approval application for their proposed Tairua River bridge located at approximately x-section 12.0 km. Their findings, based on a further 8 years of records at the Hauraki Catchment Board Broken Hills recorder site indicate that the estimated peak discharge of 2070 cumecs given in the earlier report 'Tairua River Discharge Investigation' March 1976, is probably on the conservatively high side. The Ministry of Works and Development estimate for the equivalent catchment area is some 1750 cumecs ± 250 cumecs.

Also, hydraulic calculations in the immediate vicinity of the bridge indicate that under the existing river/berm configuration the 100 year peak flood level at x-section 12.0 km could be at approximately R.L. 17.0 metres. This peak flood level is some 0.9 metres lower than that given in the earlier report suggesting that the 100 year flood profile may in fact, be closer to the estimated 1926 and 1936 flood profiles' line. However, at this stage it is not recommended that the flood profile should be reduced significantly before a backwater analysis of the full river reach in question is undertaken. This particularly applies in relation to the long time span being considered in this exercise, where other factors may have changed significantly e.g. confinement of floodway with stopbanking, silting of the estuary etc.

In the lower estuary in the vicinity of Tairua and Pauanui the approximate nature of the above river flood flow characteristics is unlikely to be of great consequence. In this region the tide level is the dominating factor such that a 0.7 m rise in sea level would of necessity lift the flood level at the mouth of river by this same amount. This difference in flood level would then gradually reduce upstream, converging with the existing 100 year flood profile line at approximately x-section 7.0 km.

/2

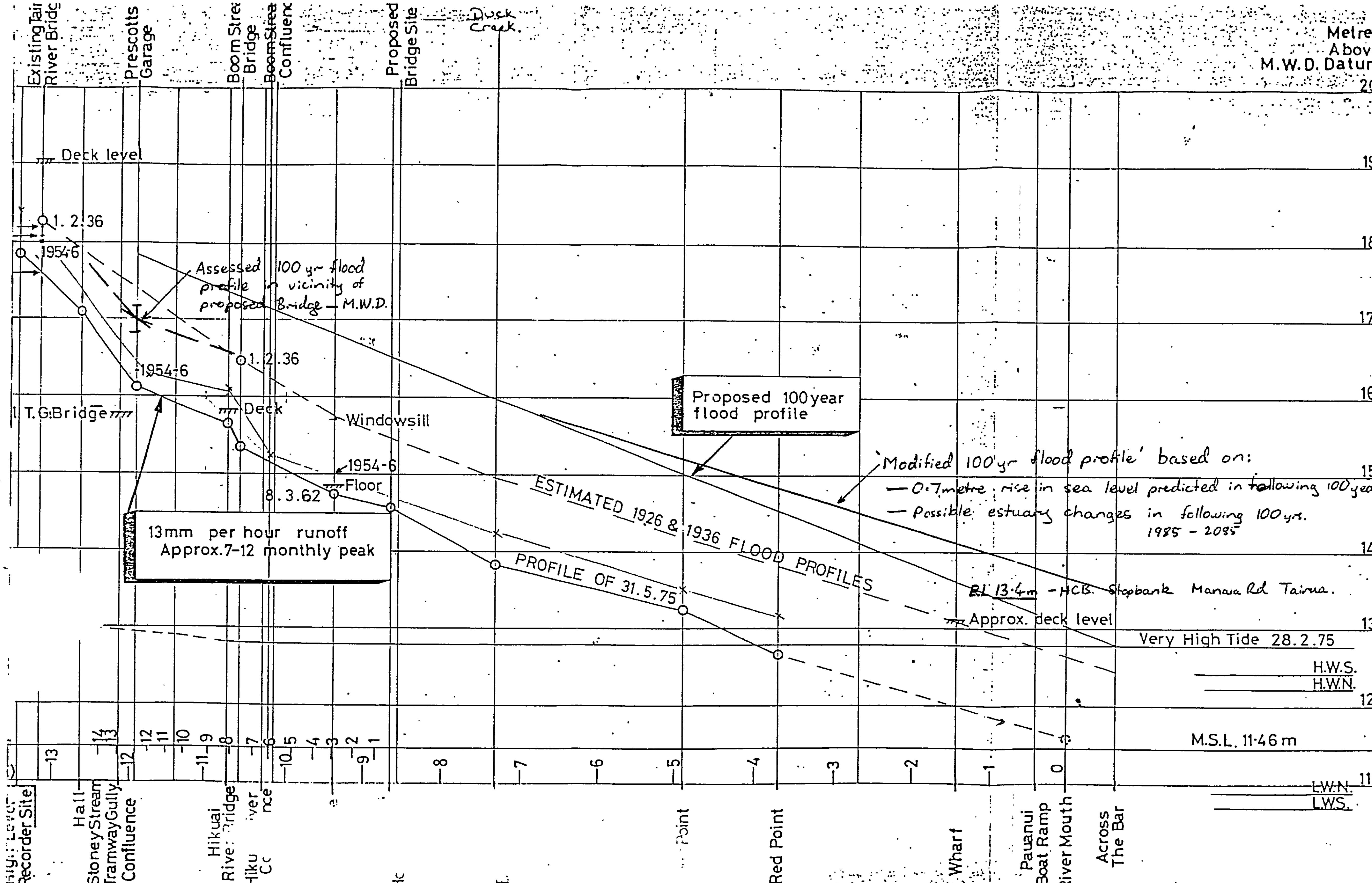
59 WHITAKER STREET, TE AROHA, NEW ZEALAND, P.O. BOX 246, TELEPHONE (0819) 48099, TELEGRAPHIC "CATCHMENT".

The 'modified 100 year flood profile', shown on the attached drawing no. 1435 sheet 2, is considered to be a reasonably conservative estimate of the likely flood profile based on the predicted sea level changes over the following 100 years, and as such should be quite satisfactory for your preliminary planning purposes.

Yours faithfully
D.H. Smith
ACTING GENERAL MANAGER

per... D.S. Fowlds ....
D.S. Fowlds
Deputy Design Engineer

dsf:cac



SURVEYED		
DESIGNED		
DRAWN	M.B.Tait	18. 11. 75
Reduced	N.G.H.	9. 1. 76

HAURAKI CATCHMENT BOARD

TAIRUA RIVER

CATCHMENT No.

SCALES

FIELD BOOK No.

LEVEL BOOK No.

DRAWING No.

SE(p)

SHORELINE FLUCTUATIONS AND AN ASSESSMENT OF A COASTAL HAZARD ZONE ALONG PAUANUI BEACH, EASTERN COROMANDEL PENINSULA, NEW ZEALAND

By

Jeremy G. Gibb[1] and John H. Aburn[2]

JULY 1984

(1) *Geologist*, Water and Soil Directorate, Ministry of Works and Development, P O Box 12-041, Wellington North

(2) *District Surveyor*, Ministry of Works and Development District Office, Private Bag, Hamilton,

SHORELINE FLUCTUATIONS AND AN ASSESSMENT OF A COASTAL HAZARD ZONE ALONG PAUANUI BEACH, EASTERN COROMANDEL PENINSULA, NEW ZEALAND

By

Jeremy G. Gibb[1] and John H. Aburn[2]

JULY 1984

(1) *Geologist*, Water and Soil Directorate, Ministry of Works and Development, P O Box 12-041, Wellington North

(2) *District Surveyor*, Ministry of Works and Development District Office, Private Bag, Hamilton,

CONTENTS

SUMMARY

Investigations and data analyses during 1983-84, including an analysis of shoreline movements over the last 5000 years and the last 88 years, have shown that the 2.65 km-long Pauanui Beach foredune and adjacent nearshore seabed have reached a state of dynamic equilibrium and that the shoreline is now delicately poised between erosion and accretion. Short-term storm-induced shoreline fluctuations up to 30 m have, and will continue to occur with gains and losses of sand to the foredune of the order of 2200 m^3/km/year. In order of severity, coastal erosion, tsunami inundation and wind erosion are identified as potential hazards most likely to damage or destroy beach front properties and assets at Pauanui. Over the next 100 years a reversal to long-term erosion is predicted for the entire 2.65 km-long beach frontage with erosion increasing in both rate and extent southwards. The erosion will be caused principally by an acceleration in global sea-level rise from 1.5 mm/year to 7.0 $\pm$ 1.8 mm/year as a result of CO_2 build-up in the Earths atmosphere. Should the West Antarctic ice sheet disintegrate as a result of global warming then predicted erosion rates will increase by an order of magnitude caused by a 50 to 70 mm/year rise in sea-level. For the southern 1 km of Pauanui Beach a 50 to 70 m-wide coastal hazard zone is recommended, reducing to 30 to 35 m for the next 1.35 km north, increasing to 85 m for the final 0.3 km of the 2.65 km-long beach frontage.

SHORELINE FLUCTUATIONS AND AN ASSESSMENT OF A COASTAL HAZARD ZONE ALONG PAUANUI BEACH, EASTERN COROMANDEL PENINSULA, NEW ZEALAND

by

Jeremy G. Gibb and John H. Aburn

INTRODUCTION

Comparing past positions of the shoreline in space and time provides a useful basis for assessing present, and predicting future shoreline movements along a particular stretch of coast. From such comparisons the pattern and rate of movement may be determined, the rate being calculated by dividing the amount of horizontal shoreline displacement by the time interval between successive surveys. In general however, the siting of many coastal settlements around New Zealand has not been based on such assessments so that houses have been placed too close to the beach. The consequences of such bad planning have been either the loss of housing and services to the sea or the construction of very expensive coastal protection works often resulting in the eventual destruction of the very asset the people chose to live next to, the beach.

Pauanui Ocean Beach Resort, Eastern Coromandel Peninsula, is situated about 100 km from both Auckland and Hamilton Cities (Figure 1). Since the area was first subdivided in 1967 there are now more than 70 beach front sections bordering the 2.65 km - long Pauanui Beach. Beach front sections are presently selling for $100,000 or more and harbour front sections for around $50,000 (Mr Ian Hopper, developer, Pauanui, pers. comm. 1984). All the houses are architecturally designed and the present capital value of the first line of beach front properties is estimated here to total about $15,000,000. Between the seaward boundaries of these properties and the beach there is a recreation reserve which is presently 32 to 55 m from the top seaward edge of the foredune north of Pauanui Airfield and 26 to 47 m to the south.

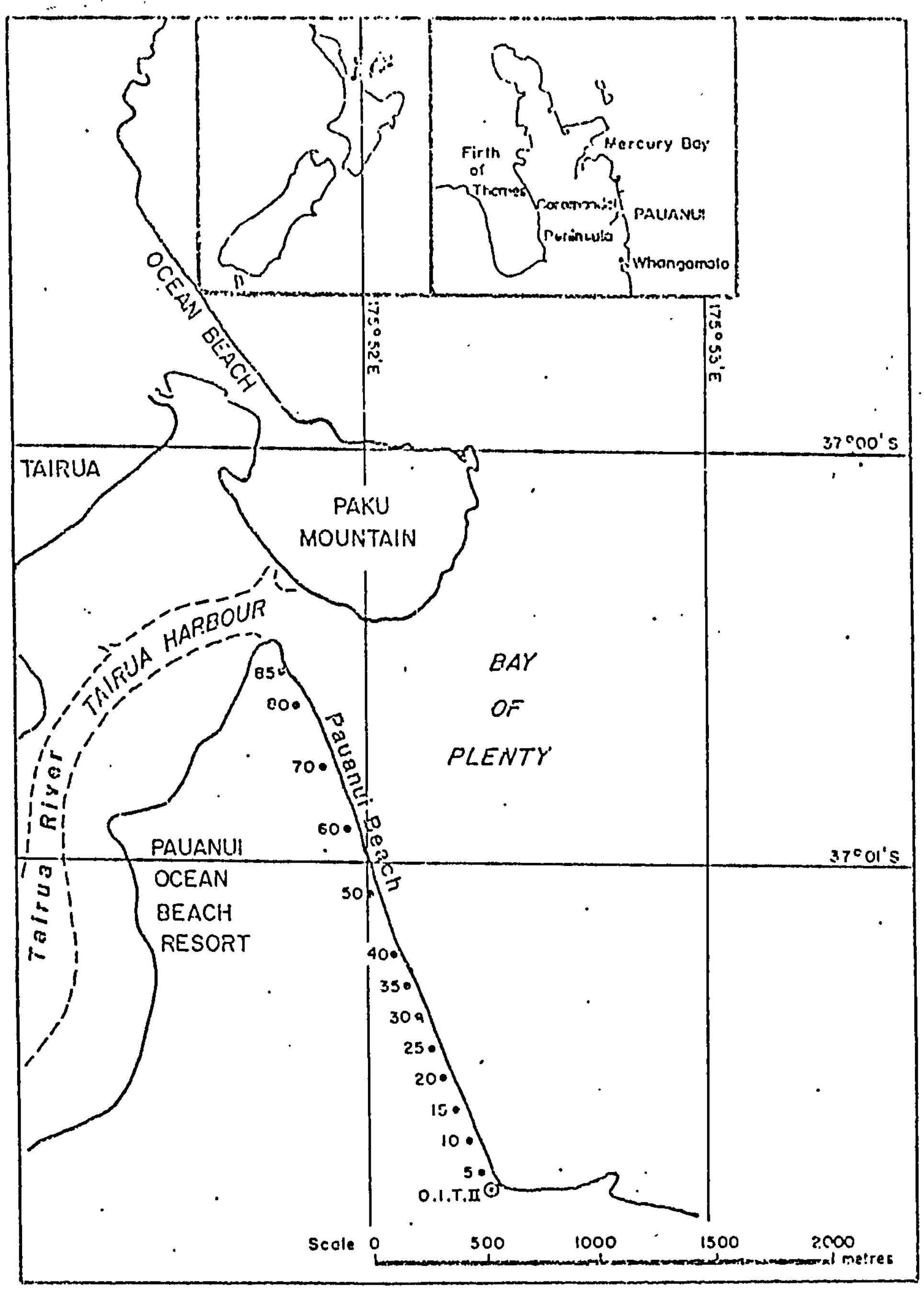


FIGURE 1: Sketch map showing the location of Pauanui Beach, Eastern Coromandel Peninsula, New Zealand, and MWD beach survey cross-sections referred to in the text and Tables 3, 5 and 6.

In 1982 a controversy arose concerning the long-term stability of Pauanui Beach. A trend of long-term slow erosion was argued by Hauraki Catchment Board with the eroded sand being lost into Tairua Harbour (Healy *et al.* 1981). Conversely, Pauanui Ocean Beach Resort Ltd, supported a long-term trend of accretion with the eroded sand lost offshore being replaced by sand supplied from the harbour (Carryer 1980). In October 1982, the Director of Water and Soil Conservation, Ministry of Works and Development requested Dr J G Gibb to resolve the controversy. As such an investigation was commenced in November 1982 and completed in December 1983, during which, data relevant to the long-term stability of Pauanui Beach were collected and analysed. In this paper, we report on our findings in relation to past shoreline fluctuations and predicted future trends along Pauanui Beach. Based on the new data an assessment of a coastal hazard zone (CHZ) is made, combining techniques developed by Bruun (1962; 1983), Dubois (1975; 1976; 1977) and Gibb (1981; 1983a).

SHORELINE MOVEMENTS

Before the shoreline can be fixed it must first be defined. In New Zealand, the "official" shoreline, or seaward boundary of any land, is defined as mean high water mark (MHWM) (Kelly 1971). As MHWM is located on the beach it is subject to displacements of several tens of metres during one or a number of tidal cycles coupled with severe onshore storms. Therefore, as an indicator of real gains and losses of "dry" land, MHWM is an unreliable reference shoreline to adopt. For coastlines such as Pauanui Beach that are backed by sand dunes it is better to adopt the seaward toe of the foredune as the reference shoreline, an approach followed in this study.

Coastlines of the world that are composed of unconsolidated sand or gravel move in and out in response to changing atmospheric, sea and land conditions. Such coastlines are dynamically balanced between the forces of nature. For example, a coastline with a history of accretion may suddenly reverse to erosion if there is a reduction in sediment supply, rise in sea-level or a change in configuration of the adjacent headlands and nearshore seabed. Conversely, a coastline with a history of erosion may reverse to accretion if there is an increase in sediment supply or fall in sea-level. An apparent change in sea-level may occur if the coastline is raised or lowered by tectonic movements or compaction.

Although a long-term trend of either shoreline advance, retreat or dynamic equilibrium may be discerned in most places from survey and geologic data spanning the last several millenia, research by Gibb (1978) revealed that the process is not regular along unconsolidated sedimentary coasts but takes place in a series of episodic short-term movements (Figure 2) of the order of 15 - 350 m (Gibb 1983a). Such movements are mostly unpredictable and are likely to occur within a period as short as one year.

For each of the three trends shown in Figure 2, (R) is the net rate of accretion or erosion and (S) the *maximum* range of short-term fluctuations. Factor (R) varies according to such influences as fluctuations in sediment supply, changes in sea-level and modifications to the coastline and nearshore seabed. Factor (S) varies according to the magnitude of either one or a cluster of severe onshore storms superimposed on the long-term trend. It is a well known fact that beaches erode by combinations of storm tides and storm waves and build up with normal or low tides and by swells (Bruun 1984).

Assessing the extent of any CHZ must take into account both (R) and (S) factors and whether the past trend is likely to continue into the future or reverse. First, therefore we need to ascertain whether Pauanui Beach is eroding, accreting or in dynamic equilibrium. Second, we must judge whether the past trend is likely to continue into the future or change. Third, we must establish the magnitude of storm-induced erosion.

PREVIOUS WORK

For Pauanui Beach, cadastral surveys fixing the toe of the foredune were made in 1895 (Survey Office Plan, S.O. 6910D[2]) and 1967 (Deposited Plan, D.P. S11962), and vertical sequential black and white aerial photographs covering the beach and dunes were taken in 1944, 1963, 1971, 1975, January and September 1978 and 1982. From a selection of these data several reports have been produced since 1980 assessing the stability of Pauanui Beach.

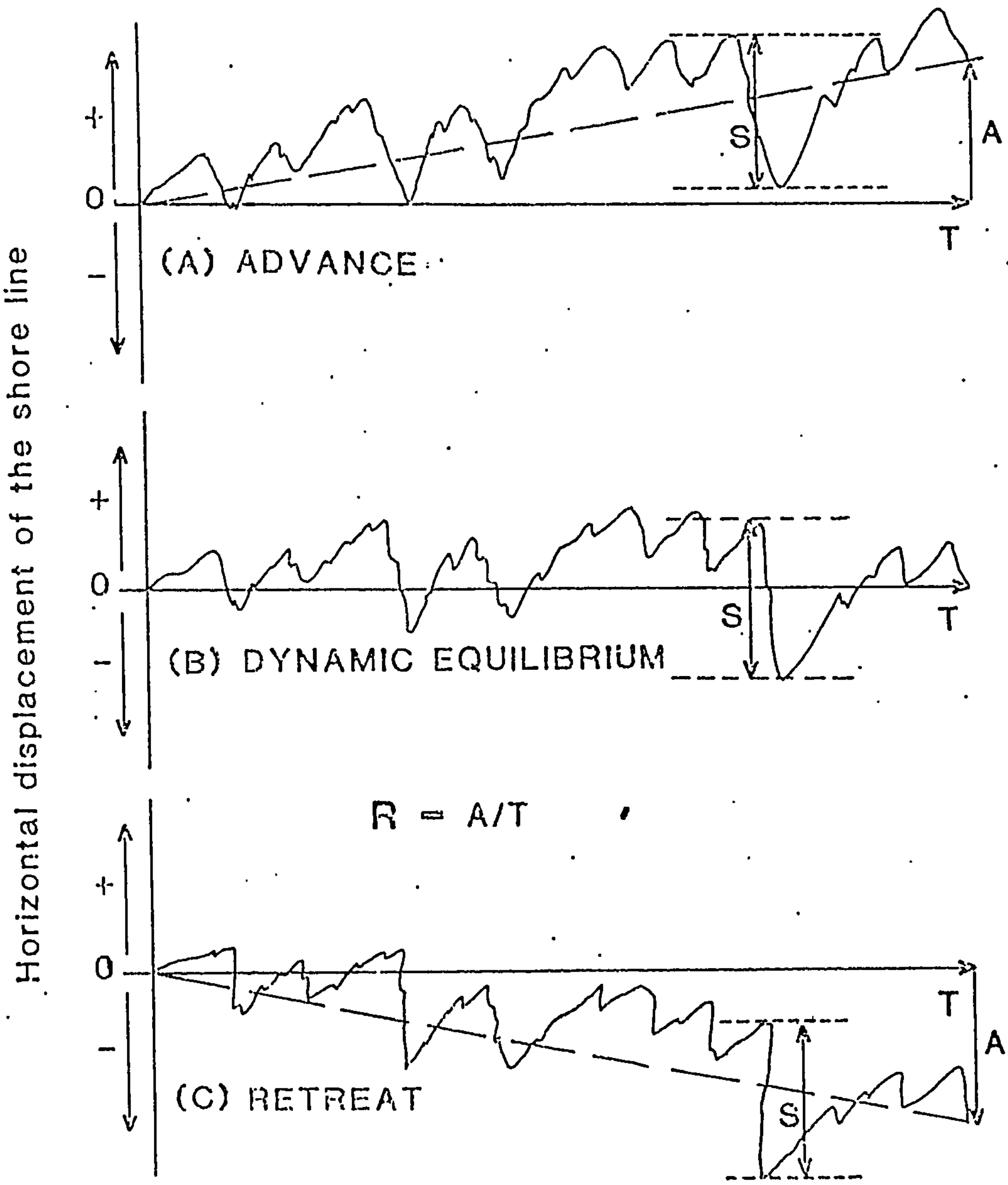


FIGURE 2: Diagrams showing short-term fluctuation "S" in the position of the shoreline (foredune seaward toe), and long-term trend, "R", where "R" is the net rate of movement in m/year calculated by dividing the horizontal distance "A", by the survey time interval, "T". (A) Advance seaward from net accretion. (B) Fluctuating about a mean position indicating dynamic equilibrium. (C) Retreat landward from net erosion.

Carryer (1980) compared the 1895, 1967 and 1977 MHWM positions concluding 20 - 40 m accretion from 1895 to 1967 and that Pauanui was "in a phase of dynamic equilibrium" with sediment lost offshore during erosion being compensated by replenishment from Tairua Harbour. Healy *et al.* (1981) and Dell and Healy (1982) compared the 1944, 1963 and 1978 dune toe positions recording 5 - 25 m erosion from 1944 to 1963 and 4 - 7 m accretion from 1963 to 1978, noting 19 - 30 m short-term erosion during a severe storm in July 1978. Based on a net erosion of 5 - 18 m over the 34 year period, these authors concluded that long-term slow erosion was likely to continue with the eroded sand being lost into Tairua Harbour. Raudkivi (1982) compared the relative positions of the 1895, 1944, 1963, 1967, 1971 and 1975 "shorelines", concluding a "zero trend" along Pauanui Beach over the 80 year period and that "there is no evidence to suggest a long-term (century) erosional trend", nor "a significant accretional trend".

METHODS

For the study of shoreline fluctuations along Pauanui Beach the following data were collected between November 1982 and May 1984.

Controlled aerial survey completed December 1982
Controlled hydrographic survey completed June 1983
Bore-holes completed July 1983
Controlled ground surveys completed December 1983
Volumetric analysis completed March 1984
Radiocarbon dating completed May 1984

The aerial survey (SN 8143) was carried out by New Zealand Aerial Mapping Ltd (NZAM); the hydrographic survey (HI 122) by the Hydrographic Branch of the Royal New Zealand Navy (RNZN); the bore-holes by Thames Valley Welldrillers; the ground surveys and volumetric analysis by the survey section of Ministry of Works and Development (MWD), Hamilton district office, and the radiocarbon dating by the New Zealand Radiocarbon Dating Laboratory of the Institute of Nuclear Sciences, DSIR. Mr J Aburn, MWD, co-ordinated the aerial and ground surveys and supervised the volumetric analysis. Lieutenant I F P Martin, RNZN, co-ordinated the hydrographic survey. Mr P Dell, Hauraki Catchment Board, co-ordinated studies of the nearshore currents discussed elsewhere (Dell 1983) and assisted with aspects of the hydrographic and ground surveys. As Project Leader, Dr J G Gibb, MWD, co-ordinated and directed the entire study.

AERIAL SURVEY

From the aerial survey conducted by NZAM, Photogrammetric Branch of the Department of Lands and Survey produced two planimetric rectified photo-maps at 1:2000 scale (Aerial Plan No. 1469, sheets 1 and 2). On the sheets, trained operators of the branch using sophisticated stereoplotting instruments plotted the foredune toe from the 1944, 1971 and January 1978 sequential black and white aerial photography. The shorelines were mapped with respect to both the New Zealand Map Grid and Mount Eden Meridional Circuit.

The stereoplotting instruments compensate or eliminate the effects of all inherent errors in the photographs and have the capacity to make accurate measurements to $\pm$ 0.1 mm or better (Gibb 1983b). At the adopted map scale of 1:2000, shorelines were plotted to an accuracy of $\pm$ 1.0 m on the ground. Because of scale limitations and poor quality the aerial photography of 1963, 1975 and September 1978 was found by Photogrammetric Branch to be unsuitable for planimetric mapping. Most if not all of these photographs were used by Healy *et al*. (1981), Dell and Healy (1982) and Raudkivi (1982) for their measurements.

HYDROGRAPHIC SURVEY

During the period 9 May to 3 June 1983 a 5-strong party under the command of Lieutenant I F P Martin (RNZN), carried out, amongst other tasks, a precise hydrographic survey of the study area from the sounding motor boat *"Pandora"* (Martin 1983). Baselines for the control of the survey were established along the coastline by the MWD survey section including the establishment of 89 beach cross-sections along Pauanui Beach, spaced at 30 m intervals. Every fifth cross-section was surveyed at low water to -0.8 m below mean sea level (MSL) to provide an adequate gradient overlap with the inshore sounding lines surveyed at high water by *"Pandora"*. All soundings and heights in this study are in terms of MSL Moturiki Datum.

Soundings were controlled from ashore using theodolite transits plumbed over the established traverse pegs. An AGA Geodimeter 140 Total Station instrument, manned by both MWD and RNZN personnel, was used to rigorously control the sounding lines from ashore. The geodimeter was used for all distance measurements out to an offshore limit of 2500 m and fixes were made at approximately every 60 m along each sounding line. In total, about 185 km of lines were run at 60 m spacings normal to the coast to an accuracy of ± 1.5 m. Sounding lines were aborted whenever the boat diverged from the observed transit by ± 2.0 m. From a portable Atlas Deso 10 echo sounder consistent soundings were obtained to an accuracy of ± 0.2 m (Martin 1983).

Based on the soundings, a 1:6000 scale bathymetric chart of the area was produced by the Hydrographic Branch, RNZN (figure 3). The chart accurately delineates the coastline and intertidal zone and shows depth contours at one metre intervals out to the 23 m depth contour. Nearshore topographic changes to the seabed were investigated by the Hydrographic Branch by comparing the 1983 bathymetry with a previous survey conducted by the RNZN in 1971.

BORE-HOLES AND RADIOCARBON DATING

Three shallow bore-holes (see Figure 4) were drilled across the base of Pauanui Spit using a truck-mounted rotary auger drill. For the bore-holes, heights above MSL and distances from the present shoreline were determined by the MWD survey team and logging of the stratigraphy and sampling was carried out by Dr T M Hume of the Water Quality Centre, MWD, Hamilton.

Bore-hole 1 was 375 m inland, 10.4 m deep and the ground surface was 6.28 m above MSL; bore-hole 2 was 740 m inland, 7.9 m deep and 5.18 m above MSL, and bore-hole 3 was 120 m inland, 14.9 m deep and 5.77 m above MSL. Broken shell from past shoreline deposits was collected from each bore-hole by catching washings flushed up from the bottom of the holes from the recirculating drilling fluids. Seven selected samples were then despatched to the New Zealand Radiocarbon Dating Laboratory for radiocarbon dating.

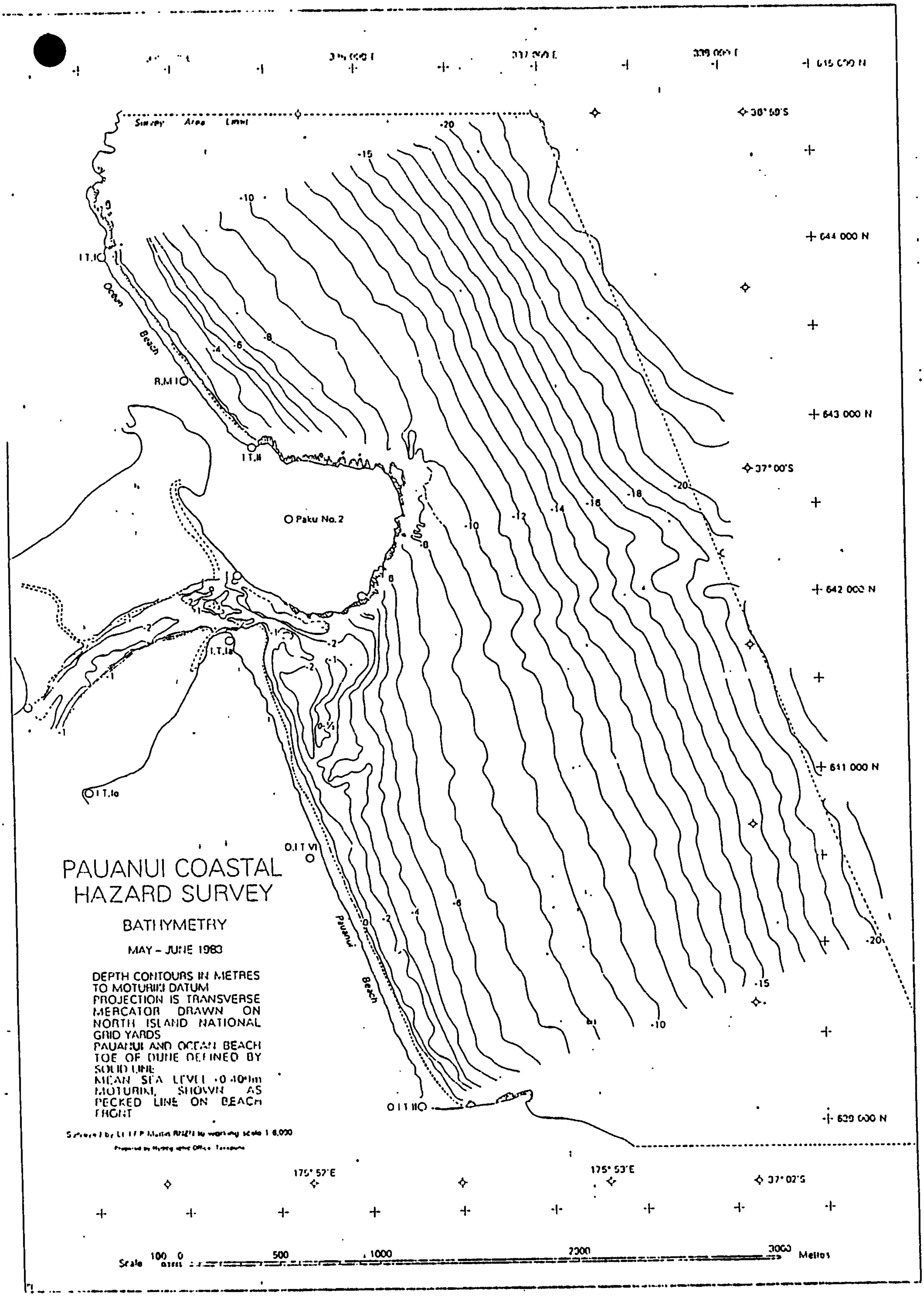


FIGURE 3: Bathymetric chart of the nearshore seabed between Pauanui and Ocean Beaches, surveyed by Lieut. JFP Martin RNZN during May-June 1983.

FIGURE 4: Shoreline positions over the last 5000 years along Pauanui Spit and locations of the 3 boreholes, plotted on vertical aerial photograph Run 975, photo 32, flown 22 May 1944 (Aerial photograph published by permission of Department of Lands and Survey).

GROUND SURVEYS AND VOLUMETRIC ANALYSIS

During the period November 1982 to December 1983 the MWD, Hamilton district office survey section under the supervision of Mr J H Aburn, district surveyor, carried out the following surveys in the study area:-

(a) Survey control for photogrammetric mapping.

(b) Establishment of baselines for the control of the hydrographic survey.

(c) Establishment of control points around Paku headland.

(d) Tairua Harbour channel control.

(e) Plotting and calculations.

Details of these surveys (Appendix I) for Pauanui including a Coastal Hazard Zone are recorded on Sheets 1 to 9 of Ministry of Works and Development, Hamilton District Office Survey Plan Number 2/973/1/2204.

Six historical shoreline positions are shown on sheets 7 and 8 at 1:2000 scale covering Pauanui Beach for the period 1895 - 1983. The 1895 and 1967 shorelines are plotted from cadastral surveys and the 1944, 1971 and 1978 shorelines are traced from Aerial Plan Number 1469 sheets 1 and 2. The 1983 shoreline position was fixed in the field by the MWD survey team in December 1983. Also shown on Sheets 7 and 8 are property boundaries, the extent of the recreational reserve, the 1967 position of MHWM adopted from D.P. S11962, the top seaward edge of the foredune in 1983, the survey baselines, traverse lines and 89 beach cross-section positions.

The 1895 cadastral survey recorded on S.O. 6910D[2] was the first along Pauanui Beach and is recorded in Lands and Survey Department Field Book 961. Although the early surveyor recorded the Pauanui Beach seaward boundary as high water mark (HWM), page 13 of his field book shows landward offsets up to 80 links (16 m) from his traverse line to HWM. Rather than run his traverse line along the wet sand below HWM it is far more likely that the early surveyor would have made the traverse along the dry sand between HWM and the seaward toe of the foredune. Assuming this to be the case then landward offsets suggest the fixing of another boundary such as the toe of the foredune or edge of vegetation. In a memorandum dated 14 December 1967 the Land Transfer Surveyors Office, Department of Justice, Hamilton, support this contention. On this basis the 1895 HWM boundary is inferred to represent the seaward toe of the foredune at that time.

The only other cadastral survey of Pauanui Beach was made in 1967 for the purposes of the present development and is recorded on D.P S11962 and in Lands and Survey Department's Field Book S133. The surveyors report notes that the height of MHWM "was determined by tidal observations and obvious demarcation line on the foreshore". Both MHWM and the "edge of vegetation" were fixed by the surveyor along offsets at the time of the survey. The width of the present recreation reserve between MHWM and the seaward property boundaries was also determined.

Based on the relative positions of the 6 historical shorelines and the survey cross-sections, volumes of sand either accreted to, or eroded from the foredune between the toe and the crest, were calculated for each of the 5 survey periods between 1895 and 1983. The gains and losses of sand thus calculated are recorded on sheet 4 for the 2.65 km-long Pauanui foreshore.

RESULTS

GEOLOGICAL TRENDS

Table 1 lists 7 radiocarbon dated beach and nearshore deposits, sampled from the 3 bore-holes across the base of Pauanui Spit. Of particular importance here are the 3 radiocarbon dated beach deposits which gave ages of 2020 $\pm$ 50 years B.P. (NZ6500B), 4120 $\pm$ 70 years B.P. (NZ6467B) and 5060 $\pm$ 60 years B.P. (NZ6522B) in terms of the new half life ($T^{1/2}$ 5730 $\pm$ 40 years B.P., after Godwin 1962). The dated beach deposits overly older dated (table 1) and undated nearshore seabed deposits that have been progressively buried by the seaward advance of Pauanui Beach during the Holocene Epoch.

Although afforestation of Pauanui after about 1950 and residential development after 1967 have largely obliterated the pattern of Holocene

TABLE 1 : Radiocarbon dated shell beds from three bore-holes across the base of Pauanui Spit, Eastern Coromandel Peninsula.

* - secular correction unreliable (Column K)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
LOCALITY	NZ ^{14}C	NZ FOSSIL RECORD NO	NZMS GRID REF. (Sheet N.49)	DIST. INLAND FROM H.W.M. (m)	DATED SAMPLE	DEPOSITIONAL ENVIRONMENT	HEIGHT MSL MOTURIKI (m)	RADIOCARBON AGE (YEARS B.P.) OLD T½	NEW T½	CALIBRATED
Hole 3. Bonanza Place	6500	T11/f36	361395	120	Shell	Beach	- 0.93	1960 ± 40	2020 ± 50	*
Hole 3. Bonanza Place	6501	T11/f37	361395	120	Shell	Nearshore	- 4.63	2150 ± 50	2220 ± 50	*
Hole 3. Bonanza Place	6502	T11/f38	361395	120	Shell	Nearshore	- 6.43	3410 ± 40	3510 ± 50	3760 ± 70
Hole 3. Bonanza Place	6514	T11/f39	361395	120	Shell	Nearshore	- 7.63	3500 ± 80	3600 ± 80	3910 ± 120
Hole 1. Beaumont Green	6467	T12/f11	358393	375	Shell	Beach	- 0.12	4010 ± 70	4120 ± 70	4620 ± 150
Hole 1. Beaumont Green	6521	T12/f12	358393	375	Shell	Nearshore	- 4.12	4220 ± 70	4350 ± 70	4900 ± 140
Hole 2. Traffic Island	6522	T12/f13	353392	740	Shell	Beach	- 1.22	4920 ± 50	5060 + 60	5600 ± 60

dune ridge growth of the spit, the 1944 vertical aerial photography taken prior to these developments provides an excellent record of dune morphology. Based on the pattern of dune ridges recorded by the 1944 photography it is possible to reconstruct the original positions of the 3 radiocarbon dated shorelines (Figure 4). The early dated shorelines are inferred to lie where a particular dune ridge intersects one of the 3 bore-holes.

Figure 4 indicates that over the last 5000 years there has been a progressive eastward translation and clockwise rotation of the dune ridges forming Pauanui Spit, with accretion of ridges over the last 2000 years remaining essentially parallel to the strike of the 1944 shoreline. The ridges have also progressively increased in length to constrict the entrance to Tairua Harbour against Paku Mountain.

Based on data in Table 1 and Figure 4, Table 2 sets out accretion rates for Pauanui Beach for the last 5000 years. Table 2 indicates a net accretion rate of 0.15 m/year over the last 5000 years, the rate decreasing progressively with time from 0.4 m/year (5000 - 4000 years B.P.), to less than 0.1 m/year for the last 2000 years B.P. The decrease of accretion rates with time indicates a shoreline steadily approaching a state of long-term dynamic equilibrium (see Figure 2B).

HISTORICAL TRENDS

Table 3 lists the magnitude of erosion-accretion along Pauanui Beach for the 5 survey periods between 1895 and 1983 and sets out net rates (Factor "R") for the entire 88-year period. Figure 5 shows the pattern of shoreline fluctuations to the foredune for the same periods and Table 4 provides details on the volumetric fluctuations. Net erosion-accretion rates (Table 3) have an uncertainty of ± 0.03 m/year based on our assumption that the foredune toe can only be fixed in the field to an accuracy of ± 1.5 m. Therefore, when comparing the 1895 and 1983 surveys to compute net rates, the combined error is ± 3 m (± 0.03 m/year over the last 88 years).

TABLE 2 : Geologic net rates of accretion along Pauanui Beach, based on data in Table 1.

^{14}C YEARS B.P.(NEW $T^{1}/_{2}$)	PERIOD (years)	ACCRETION AMOUNT (m)	ACCRETION (+) RATE (m/year)
5060 - 4120	940	365	+ 0.39
4120 - 2020	2100	255	+ 0.12
2020 - Present	2020	120	+ 0.06
5060 - Present	5060	740	+ 0.15

TABLE 3 : Historical net rates of coastal erosion and accretion at 13 selected MWD beach cross-sections along Pauanui Beach, measured from sheets 7 and 8 of MWD, Hamilton District Office Survey Plan Number 2/973/1/2204. Cross-sections are spaced at either 150 m (profiles 5-10 etc.) or 300 m (profiles 40-50 etc.). Net rates have an uncertainty of ± 0.03 m/year.

CROSS-SECTION NO.		5	10	15	20	25	30	35	40	50	60	70	80	85
km NORTH FROM O.I.T.II		0.09	0.24	0.39	0.54	0.69	0.84	0.99	1.14	1.44	1.74	2.04	2.34	2.49
SURVEY INTERVAL	PERIOD (years)	MAGNITUDE OF ACCRETION (+) AND EROSION (-) IN METRES												
1895-1944	49	-2	-6	0	-4	+2	-2	+3	+10	+12	+7	+25	+17	+7
1944-1967	23	+13	+15	+17	+17	+16	+17	+16	+12	+12	+16	+9	+26	+48
1967-1971	4	+9	+5	-2	-3	-2	-4	-4	-5	-7	-5	-6	-4	-12
1971-1978	7	0	-7	-6	-4	-13	-8	-4	-12	-5	-15	-12	-11	-12
1978-1983	5	-18	-17	-15	-9	+6	+4	+7	+16	+12	+20	+16	+2	-3
1895-1983	88	+2	-10	-6	-3	+9	+7	+18	+21	+24	+23	+32	+30	+28
NET RATE metre/year	88	+0.02	-0.11	-0.07	-0.03	+0.10	+0.08	+0.21	+0.24	+0.27	+0.26	+0.36	+0.34	+0.32

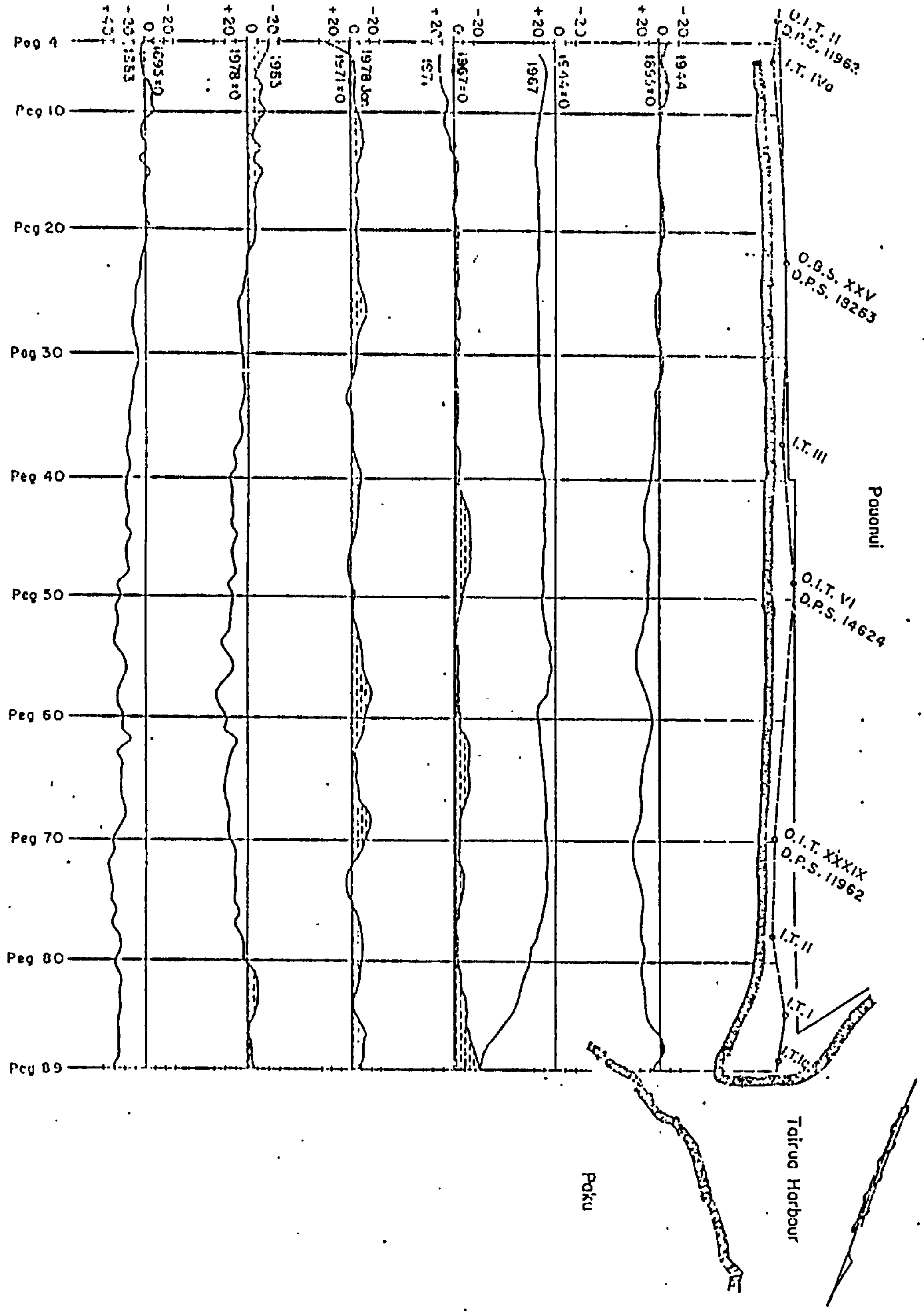


FIGURE 5: Horizontal fluctuations to the 2.65 km-long Pauanui Beach foredune between 1895-1983 for 5 survey periods and for the entire 88 year period. Figure is adapted from Sheet 4R^2, MWD Hamilton District Office Survey Plan Number 2/973/1/2204, completed March 1983.

Two of the 5 survey periods are dominated by short-term erosion (1967-1971; 1971-1978) up to 12 m, and the other 3 are dominated by short-term accretion (1895-1944; 1944-1967; 1978-1983) up to 48 m. Since 1895 the pattern of build-up has been a northerly trend from very slow net erosion at -0.03 to -0.11 m/year along the southern 24% of the 2.65 km - long Pauanui foredune to very slow net accretion at 0.08 to 0.36 m/year along the northern 76% of foredune (Table 3). The greater build-up to the north over the 88-year period is consistent with the pattern over the last 5000 years of progressive eastward translation and clockwise rotation of the dune ridges.

Table 4 inidcates that over the last 88 years about 50 000 m^3 of sand have accumulated to the Pauanui foredune at a very low net rate of 214 m^3/km/year. Of this volume, 43 100 m^3 (306 m^3/km/year) have accumulated along the northern 1.60 km of foredune and only 6900 m^3 (75 m^3/km/year) along the southern 1.05 km. In fact without the accretion recorded between 1944 and 1967 the southern foredune would have shown a net loss of sand over the last 88 years.

The pattern of nearshore circulation and current velocities measured during this study (Dell 1983) helps to explain the very small accumulation of sand along the southern foredune. Although Dell found a general southerly flow in the nearshore, especially during ebb tides, the velocities dropped markedly from 0.5 m/s near the Tairua Harbour entrance to less than 0.1 m/s south of Pauanui Airfield. According to Dell the airfield represents the southern limit of sediment transport by tidal currents in association with northeast seas.

Volumes of sand up to +2226 m^3/km/year (1978-1983) and -2170 m^3/km/year (1967-1971) accreted to, and eroded from, the Pauanui Beach foredune respectively are recorded (Table 4). The short-term gains and losses of sand to and from the foredune balance each other, thus indicating that the present foredune is in dynamic equilibrium, confirming the long-term trend indicated by the geologic data.

A major limitation of comparative shoreline data is that they do not provide a true indication of the magnitude and extent of short-term shoreline fluctuations (Factor "S") that may have occurred between surveys. According to local inhabitants, severe storms in the late 1960s and 1970s

TABLE 4 : Historical volumetric changes and rates along the 2.65 km-long Pauanui Beach foredune and percentage of short-term coastal erosion and accretion for each survey period, based on Sheets 4R[2], 7 and 8 of MWD, Hamilton district office Survey Plan Number 2/973/1/2204.

SURVEY INVERVAL	PERIOD (years)	EROSION (% Coast)	ACCRETION (% Coast)	VOLUMETRIC CHANGE (m^3)					
				SOUTHERN 1.05 km	RATE m^3/km/year	NORTHERN 1.60 km	RATE m^3/km/year	TOTAL 2.65 km	NET RATE m^3/km/year
1895-1944	49	23	88	– 2 500	– 49	+23 000	+ 293	+20 500	+ 158
1944-1967	23	0	100	+17 200	+712	+25 800	+ 701	+43 000	+ 705
1967-1971	4	85	15	– 300	– 71	–22 700	–3 547	–23 000	–2 170
1971-1978	7	95	5	– 4 000	–544	–16 000	–1 429	–20 000	–1 078
1978-1983	5	31	69	– 3 500	–667	+33 000	+4 125	+29 500	+2 226
1895-1983	88	12	88	+ 6 900	+ 75	+43 100	+ 306	+50 000	+ 214

eroded the foredune toe back to the present top seaward edge (erosion scarp) shown on sheets 7 and 8 of MWD Hamilton District Office Survey Plan Number 2/973/1/2204. During the 1980s, eroded sand stockpiled in both offshore bars and ebb-tide delta has migrated back to the beach, eventually building a 1.60 km-long incipient foredune north of Pauanui Airfield. South of the airfield the foredune has not recovered.

To define the maximum extent of Factor (S) we scaled distances on sheets 7 and 8 from the top seaward edge of the old erosion scarp to the most seaward historical position of the toe of the foredune. For all but the north end and central parts of Pauanui Beach we recorded distances up to 30 m which is in agreement with the findings of Healy *et al.* (1981) who recorded up to 30 m short-term erosion during a severe storm in July 1978. For the north end of the beach we recorded a short-term fluctuation of 70 m which is almost certainly associated with changes in the form and position of the entrance channel to Tairua Harbour and the ebb-tide delta. For central Pauanui Beach we recorded a very small movement of 10 m by the airfield which may possibly be associated with a nodal point along the beach between erosion-accretion.

PHOTOGRAPHIC EVIDENCE

Along the northern half of Pauanui Beach there are several large Pohutukawa trees 11 - 16 m high with 0.4 - 0.6 m wide trunks at the base. The Pohutukawas grow along the seaward property boundaries and are presently 32 - 55 m from the top seaward edge of the foredune. Several of these trees are shown on historical photographs of Pauanui Beach taken from Paku Mountain in 1909 and from Tairua Township in 1904 and about 1880. These photographs are held at the Pauanui Information Centre, Pauanui, and at the Turnbull Library, Wellington.

The survival of the Pohutukawas indicates that short-term storm-induced erosion has not transgressed inland past the seaward property boundaries along northern Pauanui Beach during at least the last 100 years. Along southern Pauanui Beach there are also several Pohutukawas along the seaward property boundaries but they are 8 - 11 m high and much younger. Although some are shown on the 1944 vertical aerial photograph they are not evident on the historical ground photographs. The age of these trees, therefore, is older than 40 years (1944 - 1984) and younger than 75 years (1909 - 1984). Like the trees to the north, their survival indicates that short-term erosion has not transgressed inland past the seaward property boundaries for, perhaps, the last 50 years.

SEABED CHANGES

According to Martin (1983) direct comparison of the 1983 seabed topography with the 1971 survey was not possible owing to different datum sites being used for each survey. However, five profile depth comparisons of the 1971 and 1983 hydrographic surveys were made between Ocean (three profiles) and Pauanui (two profiles) beaches by the Hydrographic Branch, RNZN. For the 13 year period the Pauanui profiles show -0.4 to -0.7 m erosion with a mean variation of -0.5 $\pm$ 0.2 m. The mean variation of -0.5 m is thought by Martin (1983) to be due to the differences in datums between the 1971 and 1983 surveys, the former having a relatively higher datum.

If we accept this explanation, then a comparison of the depth contours off Pauanui Beach shows no significant variation in depth seaward of the 5 m contour since 1971. Between the 5 m depth contour and the beach, however, significant changes have occurred to the morphology of the ebb-tide delta along the northern half of the beach. In 1971 the delta was a regular shaped barrier running from Paku to mid Pauanui Beach but by 1983 it had contracted some 400 m in length. A "boomerang" shaped outer sand bar now extends further seaward than in 1971 with a foreshore channel cutting its way from south (see Figure 3) into a small lagoon behind the bar (Martin 1983).

The data indicate a relatively static nearshore seabed seaward of the 5 m contour over the last 13 years. According to Dr T W Hume, however, (pers. comm. 1984) short-term fluctuations in seabed levels from storm events can be of the order of a few decimetres off Pauanui. For example, during a storm in October 1983, Hume observed 150 mm erosion of the seabed off Paku Mountain in 10 m water depth followed by aggradation of 80 mm over the next two weeks.

As one might expect the ebb-tide delta is anything but stable and is likely to change in shape and volume depending on such factors as the frequency of floods and storm-waves. Our studies have shown that sand is supplied to Pauanui Beach via the ebb-tide delta (Gibb 1983c).

DISCUSSION

Our findings suggest that the Pauanui Beach foredune and adjacent seabed have reached a state of dynamic equilibrium. The 2.65 km-long foredune is now delicately poised between advance and retreat. Short-term fluctuations of the order of 2200 m^3/km/year have, and will continue to occur along the foredune with incursions up to 30 m along most of the beach and up to 70 m at the northern end.

Our findings agree in general with the deductions of Carryer (1980) and Raudkivi (1982) but we disagree in part with the findings and deductions of Healy *et al.* (1981) and Dell and Healy (1982). For Pauanui Beach, Healy *et al.* (1981) and Dell and Healy (1982) recorded erosion for the period 1944 - 1963 and accretion for the period 1963 - 1978 concluding that "in the long-term such beaches are likely to continue slow erosion". Had these authors taken into account the cadastral surveys of 1895 and 1967 their conclusions may well have been exactly the opposite. Their approach highlights the dangers of extrapolating a long-term trend of shoreline movement from short-term data. The determination of a long-term trend must always be based on a consideration of *all* available reliable historic and geologic data and any other relevant information.

We recorded accretion for the period 1944 - 1967 and erosion for the period 1967 - 1978 (Tables 3, 4) which is the opposite to the findings of Healy *et al.* (1981) and Dell and Healy (1982). For the periods concerned we used the 1967 cadastral survey and the January 1978 aerial survey rather than the aerial surveys of 1963 and September 1978 used by these authors. Based on an assessment by Photogrammetric Branch of the Department of Lands and Survey of all existing vertical aerial photographs of Pauanui, both the 1963 and September 1978 aerial surveys were considered by them to be unsuitable for the planimetric mapping carried out in this study. Inaccurate plotting of the 1963 dune toe position further landward than its true position by Healy *et al*. (1981) and Dell and Healy (1982) is a possible explanation for the differences in results.

THE FUTURE

Should the same conditions prevail in the Tairua-Pauanui area for the next 100 years as they have for the last 100 years then the state of dynamic equilibrium along the Pauanui foreshore should persist. The main factors that could upset the long-term state of balance are either a significant reduction in the amount of sediment supplied to the beach system, or a real or apparent rise in sea-level.

SEDIMENT SUPPLY FACTOR

According to Gibb (1983c) the Tairua River is the major supplier of sand to Pauanui Beach via the ebb-tide delta. A small amount of sand is also supplied from the nearshore seabed and from biogenic sources from within the harbour and along the adjacent coast. In all these source areas, there is presently an abundance of sand, particularly in the 13.5 km - long tidal reach of the Tairua River bed between Hikuai and the sea. Each time there is a flood such as occurred in April 1981, the tidal reach sand banks migrate toward Tairua Harbour and most if not all of the flood tide delta is washed out to sea (Gibb 1983c).

Our investigations have revealed that sediment has accumulated at rates averaging 1 - 4 mm/year since 1910 over much of the Tairua and Pauanui central tidal flats. Accelerated sedimentation rates from local fluvial inputs have occurred near the mouths of Pepe Stream (7 mm/year) and Grahams Creek (11 mm/year) and just inside the harbour entrance (14 mm/year), from marine sediments transported into the harbour during flood tides (Hume and Gibb, in prep.). The accumulation of some 500 000 m^3 of sand since 1910 is thought to be supplied in roughly equal proportions from the Tairua River, Pepe Stream, Grahams Creek, the ebb-tide delta, and from the natural attrition of shell beds (Gibb 1983c).

Much of the Tairua River contribution since 1910 probably results from accelerated catchment erosion following the milling of Kauri trees and subsequent burning off between 1864 and 1907, and to a lesser extent from the construction of the Kopu-Hikuai Road across the Coromandel Ranges in 1967. Experience has shown that the weathered volcanic rocks of the Tairua River catchment are extremely susceptible to erosion and landslip once the ground is opened up and the hills lose their protective vegetative cover. Regeneration of vegetation since both deforestation and road construction is evident today, hence we can expect both a reduction in catchment erosion and sedimentation rates in the long-term.

How much Tairua River derived sand is transported out to sea is not known at present. Rates of accretion along Pauanui Beach of 0.08 - 0.36 m/year for the last 88 years show excellent agreement with the geologic rates of 0.06 - 0.39 m/year for the last 5000 years (Tables 2, 3). Therefore, man's impact on the Tairua River catchment has had comparatively little effect in accelerating the long-term supply of sand to Pauanui Beach. The present abundance of sand offshore and in the lower Tairua River bed suggests no significant reduction is likely to occur in the volume of sediment supplied to the beach in the forseeable future.

SEA-LEVEL FACTOR

A change in sea-level is *real* when the land is known to be stable, and *apparent* when sea-level is known to be fixed while the land is rising or falling. Bruun (1962; 1983) has shown that where the sea floor is in equilibrium with sea-level, a rise in sea-level promotes coastal erosion. Field and laboratory investigations (Schwartz 1965, 1967; Dubois 1975, 1976; Rosen 1978) have confirmed the theory that a rise in water level can cause such erosion.

For New Zealand tectonic downdrop of the coastline during major earthquakes coupled with differential compaction of underlying sediments are the factors most likely to cause an apparent local sea-level rise. However, for the Tairua-Pauanui area geologic evidence indicates tectonic stability for at least the last 125,000 years and certainly for the last 6500 years during which period Pauanui Spit was constructed (Gibb 1983c). A comparison of the bore-hole data (Table 1) with a New Zealand regional sea-level curve derived by Gibb (in press) shows no evidence for compaction of underlying sediments during spit formation either. Therefore, the lack of evidence for both tectonism and differential compaction rules out *apparent* sea-level rise from land lowering as a contributing factor to long-term erosion at Pauanui.

There is unequivocal evidence from many tide gauges throughout the world, however, for a *real* net global rise in sea-level during the past century on the order of 1.2 - 1.5 mm/year (Gutenberg 1941; Fairbridge and Krebs 1962; Gornitz *et al.* 1982; Barnett 1983). The most recent study by Barnett (1983) from tide gauge records around most of the world's continental margins and on a few islands, recorded an average rise in global sea-level of 1.51 $\pm$ 0.15 mm/year since 1900. No evidence was found by Barnett for an accelerating rate of rise of sea-level in recent times.

Since 1903, automatic tide gauges at Auckland and Wellington have continuously recorded tidal levels providing a valuable record of long-term trends in MSL. Lee (1953) analysed the records from both these ports for the period 1909 - 1946 finding no significant change for the 37-year period. Gibb (1979) analysed mean tide levels from the same sites for the period 1903 - 1977 recording a sea-level rise of 1.6 mm/year at Auckland and 2.4 mm/year at Wellington for the 75-year period. The differences in results may possibly be explained by the fact that most of the sea-level rise recorded by Gibb (1979) occurred after 1944, which followed the period analysed by Lee (1953). However, the higher rate of sea-level rise at Wellington is suspect, as the tide gauge is sited on a wharf pile driven into marine muds and the pile may be slowly sinking.

If we accept a real net rise in global sea level of 1.5 mm/year during the past century then our findings show that the long-term erosion likely to be caused by such a factor at Pauanui has been offset by an adequate supply of sand to the beach from the Tairua River. The resultant effect has been a beach in dynamic equilibrium. Should sea-level rise continue at the present rate then we believe that the state of dynamic equilibrium will most likely persist. Should the rate of sea-level rise increase, however, then the state of dynamic equilibrium will more than likely reverse to a long-term trend of erosion.

Atmospheric Carbon Dioxide and Sea-Level

It is thought in some quarters that the earth's climate is likely to become warmer because of a build-up of carbon dioxide (CO_2) in the atmosphere that will continue well into the next century. The build-up is likely to produce a "greenhouse effect" that traps re-radiated heat in the atmosphere. Uncertainty characterises many aspects of this global problem and has given rise to considerable speculation that varies all the way from fears of impending disaster to the belief that there is no problem (World Meteorological Organisation 1981).

Recently the White House Office of Science and Technology Policy requested the National Research Council (US), the research arm of the National Academy of Sciences (NAS), to study both the rate at which atmospheric CO_2 could be expected to increase and the likely effects of such increases on global climate, agricultural productivity, sea-level, and other parameters. A report entitled *Changing Climate*, compiled by the Carbon Dioxide Assessment Committee (National Academy of Sciences 1983) was released on 21 October 1983 (Ryan 1984).

Although the current level of atmospheric CO_2 concentration is about 340 parts per million by volume (ppmv), the NAS report predicts that atmospheric CO_2 could pass 600 ppmv in the third quarter of next century and that there is about a 1-in-20 chance that doubling could occur before 2035 A.D. (National Academy of Sciences 1983). In another report the dates on which CO_2 content is predicted to double range from 2035 to 2085 A.D. (MacDonald 1982). Both reports agree that a doubling of atmospheric CO_2 would cause a global surface air warming of between 1.5°C and 4.5°C although the Carbon Dioxide Assessment Committee suggest that values in the lower half (1.5° - 3.0°C) are more probable (National Academy of Sciences 1983). Warming is inferred to be 2 to 3 times as great over the polar regions as over the tropics and to be significantly greater over the Arctic than over the Antarctic (National Research Council US 1982). However, the occurrence of temperature changes attributable directly to increasing atmospheric CO_2 concentration remains as yet undetected (National Academy of Sciences 1983; Hansen *et al.* 1983).

Because of melting of glacial ice and the expansion of upper ocean waters as they heat up from global warming, sea-level rise is predicted to increase sharply. A rise of 0.3°C in sea surface temperature should increase sea-level by approximately 27 mm due to thermal expansion and a change of only 0.1% in the global land ice cover will produce a sea-level change of over 50 mm (Clark 1982).

The NAS report warns that if global warming of about 3 or 4°C were to occur over the next 100 years, a global sea-level rise of about 700 ± 180 mm is likely to occur between 1980 and 2080, compared to the rise of 150 mm between 1880 and 1980. The predicted 700 mm rise is made up of 400 mm from melting continental and alpine glaciers and 300 mm from thermal expansion of the upper ocean waters (National Academy of Sciences 1983). For the thermal expansion factor Gornitz *et al.* (1982) estimated a rise of 200 to 300 mm during the next 70 years in response to global warming. Further, progressive global warming could eventually result in the disintegration of the marine-based part of the West Antarctic ice sheet, causing a 5 to 7 m rise in global sea-level in the next several hundred years (Clark 1983; National Academy of Sciences 1983). For the occurrence of this event minimum estimates of between 200 and 500 years have been made by Bentley (1983) and Hughes (1983).

According to the NAS report the large uncertainty of ± 180 mm for the predicted 700 mm rise in sea-level is due to uncertainty over the causes of the current rise in sea-level, an inability to predict whether changes in atmospheric circulation will cause more or less snow to fall on the ice caps, an ignorance of the conditions for advance or retreat of alpine glaciers, and a lack of understanding of the physical processes associated with the flux of heat to the ocean (National Academy of Sciences 1983).

Although the reaction to the NRC report has been that it is "conservative" in nature (Ryan 1984), the fact remains that an accelerated rise in sea-level averaging about 7 mm/year would have a major impact on the long-term stability of the unconsolidated sedimentary coastlines of New Zealand including the Pauanui - Tairua area.

COASTAL HAZARD ZONE (CHZ) ASSESSMENT

The potential hazards most likely to damage or destroy beach front property and assets along Pauanui Beach are:

(a) Retreat of foredune from coastal erosion.

(b) Inundation of property by tsunamis.

(c) Burial of property and assets by wind-blown sand.

Of these three, (c) poses the least threat at present and is easily controlled by maintaining a dense protective vegetative cover over the sand dunes in the foreshore recreation reserve. Should the present foredune be breached, however, by for example, concentrated pedestrian usage or point discharges of stormwater, then blow-outs will quickly develop leading to differential retreat of the foredune and eventual encroachment of wind-blown sand on to properties and assets.

TSUNAMI HAZARD

Tsunamis are waves with an extremely long wave length that originate from submarine disturbances such as faulting, landslides, volcanic eruptions, or possibly from earthquake vibrations (Gibb 1979). They have a small wave height in the open ocean which increases dramatically on reaching shallow water. A review of historical New Zealand tsunamis by de Lange and Healy (1982) showed that those locally generated are potentially larger than distantly generated tsunamis.

According to de Lange and Healy (1982) insufficient detailed data exist to allow the definition of potential tsunami hazard zones for most parts of the New Zealand coast. They recognise the following four major volcanic sources within the Bay of Plenty which could generate large local tsunamis, suggesting the use of numerical models for hazard assessment to overcome the lack of historical data.

(a) White Island, an active andesitic volcano.

(b) Mayor Island, a dormant rhyolite volcano which last erupted less than 1000 years ago.

(c) The Okataina Volcanic Centre from which ignimbrites flowed over the land and into the sea about 150 - 200,000 years ago.

(d) The Rumble group of submarine volcanoes seaward from Whakatane of which Rumble III is intermittently active.

Of these, White Island is potentially the most dangerous and Weir and White (1982) have mathematically modelled volcanic tsunamis generated by a range of volcanic eruptions. They found the height of widespread tsunami runup about the Bay of Plenty to be insignificant in all cases considered, with breaking wave heights typically less than 1.5 m. Only the most catastrophic Krakatoa-type eruption produced significantly large tsunamis with breaking wave heights of 3-6 m. Weir and White (1982), however, believe such catastrophic eruptive events at White Island are unlikely to occur.

Similar predictions were obtained by de Lange and Healy (1982) who produced a numerical model to evaluate tsunamis generated by a pyroclastic flow from Mayor Island, the closest volcanic centre to Pauanui. Their results showed a maximum wave-height of less than 1 m.

Neither Weir and White (1982) nor de Lange and Healy (1982) were able to assess the probability of the *causative* mechanism, a volcanic eruption, occurring. Indeed, this would be very difficult without an intensive study of the volcanic histories of each source area. Nevertheless, their models predict that for all but the most catastrophic event, most tsunami breaking wave heights in the Bay of Plenty are not likely to exceed 1.5 m. It is of interest to note that Harris *et al.* (1983) have calculated an average significant wave height of 1.55 m for the Bay of Plenty for *wind*-generated waves.

Our surveys show that the present-day heights of the foredunes along Paunanui Beach average about 7 m above MSL, ranging from 3.4 to 8.9 m. According to local inhibitants the foredune is not frequently overtopped by 1.5 m-high waves, hence it is unlikely that tsunamis of that height will do so. However, it is possible that minor overtopping could occur if a 1.5 m tsunami coincided with a high spring tide and a severe onshore storm. It is not possible for us to assess the probability of such a combination of events occurring. Predictions to date, however, suggest that the risk to beach front properties from tsunami overtopping along Pauanui Beach is likely to be negligible.

COASTAL EROSION HAZARD

Provided the same coastal processes occur at Pauanui over the *next* 100 years as have occurred during the *past* century, the state of dynamic equilibrium punctuated by short-term fluctuations up to 30 m should continue. If, however, the predicted acceleration of global sea-level rise from 1.5 mm/year to 7.0 $\pm$ 1.8 mm/year occurs then the past trend of dynamic equilibrium may well reverse to long-term retreat from erosion. Although tide gauges in New Zealand have yet to register a marked acceleration in the rise of sea-level (Gibb 1979) we believe the Carbon Dioxide Assessment Committee's predictions (National Academy of Sciences 1983) should not be ignored. To assess the extent of a CHZ along Pauanui Beach, therefore, we must take into account the rate of erosion predicted to be caused by the accelerated global sea-level rise (X), the long-term erosion-accretion rate (R), an assessment period (T) and the maximum short-term erosion-accretion (S). Based on a technique derived by Gibb (1981; 1983a) and taking the above factors into account, the width of a CHZ (in metres) may be calculated as follows:

$$CHZ = (X + R)T + S \tag{1}$$

For our assessment we first need to test whether the past trend of dynamic equilibrium is going to continue or change to long-term erosion or accretion. If (X + R)T is zero the long-term prediction is dynamic equilibrium; if positive the prediction is accretion, and if negative it is erosion. Should the prediction be either a continuation of dynamic equilibrium or accretion [(X + R)T: positive or zero], then a minimum CHZ width of (S) should be adopted. The reason for this is that the short-term fluctuations (S) are independent of the long-term trend (R) and will occur irrespective of whether the shoreline is advancing, retreating or in dynamic equilibrium.

CHZ CALCULATION

Table 5 provides values for (X) along Pauanui Beach for an acceleration in global sea-level rise of 5.5 mm/year. As the rise of 1.5 mm/year has not caused any appreciable erosion at Pauanui over the last century we must compute the impact of an increase to 7 mm/year, a difference of 5.5 mm/year. To quantify the amount of erosion likely to occur from such an increase we have used the Bruun Rule (Bruun 1962) which states that "for a shore profile in equilibrium, as sea-level rises, beach erosion takes place in order to provide sediments to the nearshore so that the nearshore seabed can be elevated in direct proportion to the rise in sea-level". The Bruun Rule (Figure 6) relating shoreline erosion to sea-level rise is based on the relationship:

$$X\ (b + d) = ac \qquad (2)$$

where: X = rate of shore retreat (m/year)

b = shore elevation (m) above MSL

d = limiting depth (m) below MSL between predominant nearshore and offshore material.

a = rate of sea-level rise (m/year)

c = distance (m) to limiting depth from shore

To calculate the rate of coastal erosion (X) caused by a rise in sea-level Bruun (1983) has developed the following simple equation (3):

$$X = \frac{la}{h} \qquad (3)$$

Where X = rate of shore retreat (m/year)

l = length (m) of the profile of exchange

TABLE 5: Predicted net rates of erosion (X) at 13 selected MWD beach cross-sections along Pauanui Beach for a sea-level rise of 5.5 mm/year using the Bruun (1983) formula:

$$X = \frac{la}{h}$$

Where; l and h are in metres and a and X are in m/year.

CROSS-SECTION No.	5	10	15	20	25	30	35	40	50	60	70	80	85
a	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
l	690	685	705	680	685	700	700	720	730	820	815	865	950
h	12.5	12.6	12.9	12.7	13.4	13.7	14.7	14.2	14.0	14.3	13.4	13.4	11.7
la	3.795	3.768	3.878	3.74	3.768	3.85	3,85	3.96	4.015	4.51	4.483	4.758	5.225
X	-0.30	-0.30	-0.30	-0.29	-0.28	-0.28	-0.26	-0.28	-0.29	-0.32	-0.33	-0.36	-0.45

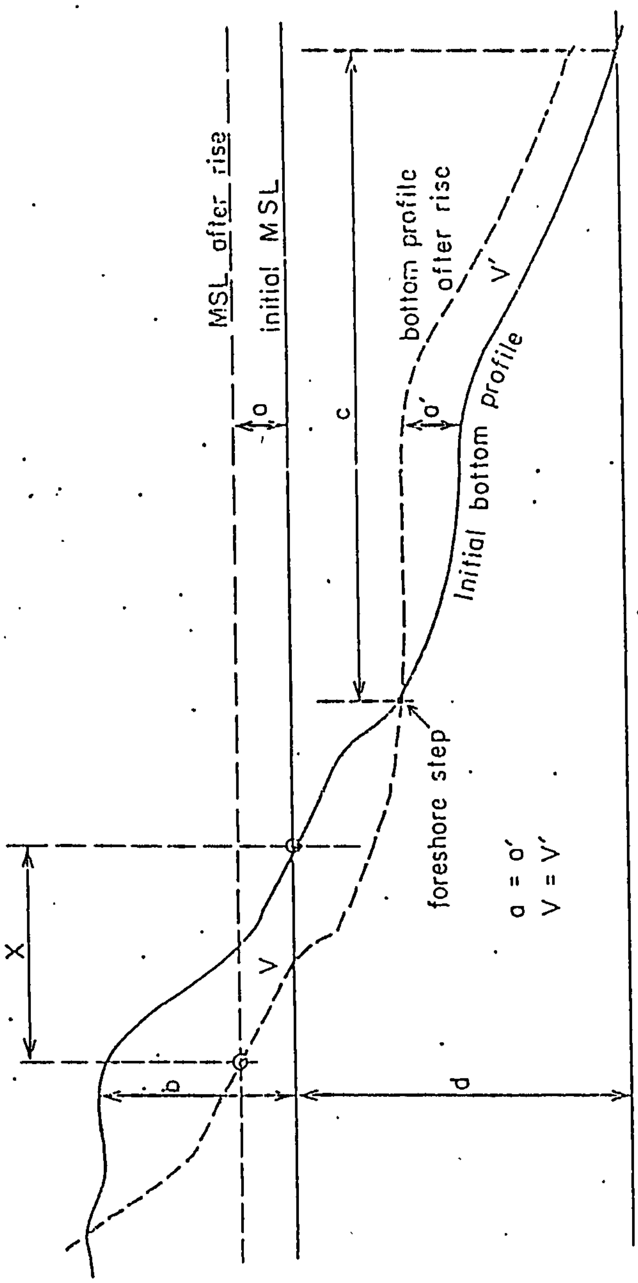


FIGURE 6: Diagram showing the response of the beach and near-shore zone to rising sea-level according to Bruun (1962). V = volume; a = sea level rise; X = erosion amount; b = height of foredune; d = limitng depth of beach sediment; c = distance to limiting depth from foreshore step.

a = rate of sea-level rise (m/year)

h = maximum depth (m) of exchange of material between the nearshore and offshore

The Bruun Rule is two-dimensional, assuming a closed material balance system between firstly the beach and nearshore and secondly, the offshore bottom profile as illustrated in Figure 7. That is, for a given length of shoreline the rule assumes that the volume of longshore drift moving in is equal to the volume moving out. At Pauanui, however, there is a longshore disequilibrium caused by most if not all sediment being supplied to the north end of the beach via the Tairua River. The longshore disequilibrium, which has resulted in differential rates of coastal erosion - accretion along the beach (see Table 3), is the third-dimension not allowed for in equations (2) and (3). All three dimensions are taken into account however, in equation (1) for the assessment of the extent of a CHZ, with (R) taking account of the third-dimension.

Based on equation (3), Table 5 gives values for (X) where the distance (l) was measured from the crest of the foredune to the limiting depth (h). Horizontal distances range from 0.69 to 0.95 km generally increasing in width northwards. The limiting depth (h) is the crest height of the foredune (above MSL) plus 7 m, the maximum depth of exchange based on observations made at Pauanui during the study following a prolonged period of beach accretion. Although SCUBA diver observations supported by sedimentologic evidence (Gibb 1983c) indicated the 6 m depth contour to be the limiting depth, the bathymetry (Figure 3) shows a subtle change in offshore gradient at about the 7 m depth contour. If our observations had been made after storm-induced beach erosion during which beach sediments may have been transported further offshore then the limiting depth would most likely be nearer 7 m. For the Gold Coast, Chapman and Smith (1983) found from repetitive surveys since 1974, that the "active beach" extended 0.5 km offshore to 6.2 m water depth. Under stormy conditions they found that the active zone extended temporarily into deeper water. An uncertainty of ± 0.5 m is ascribed here to (h), thus giving rise to an uncertainty of ± 200 m for (l).

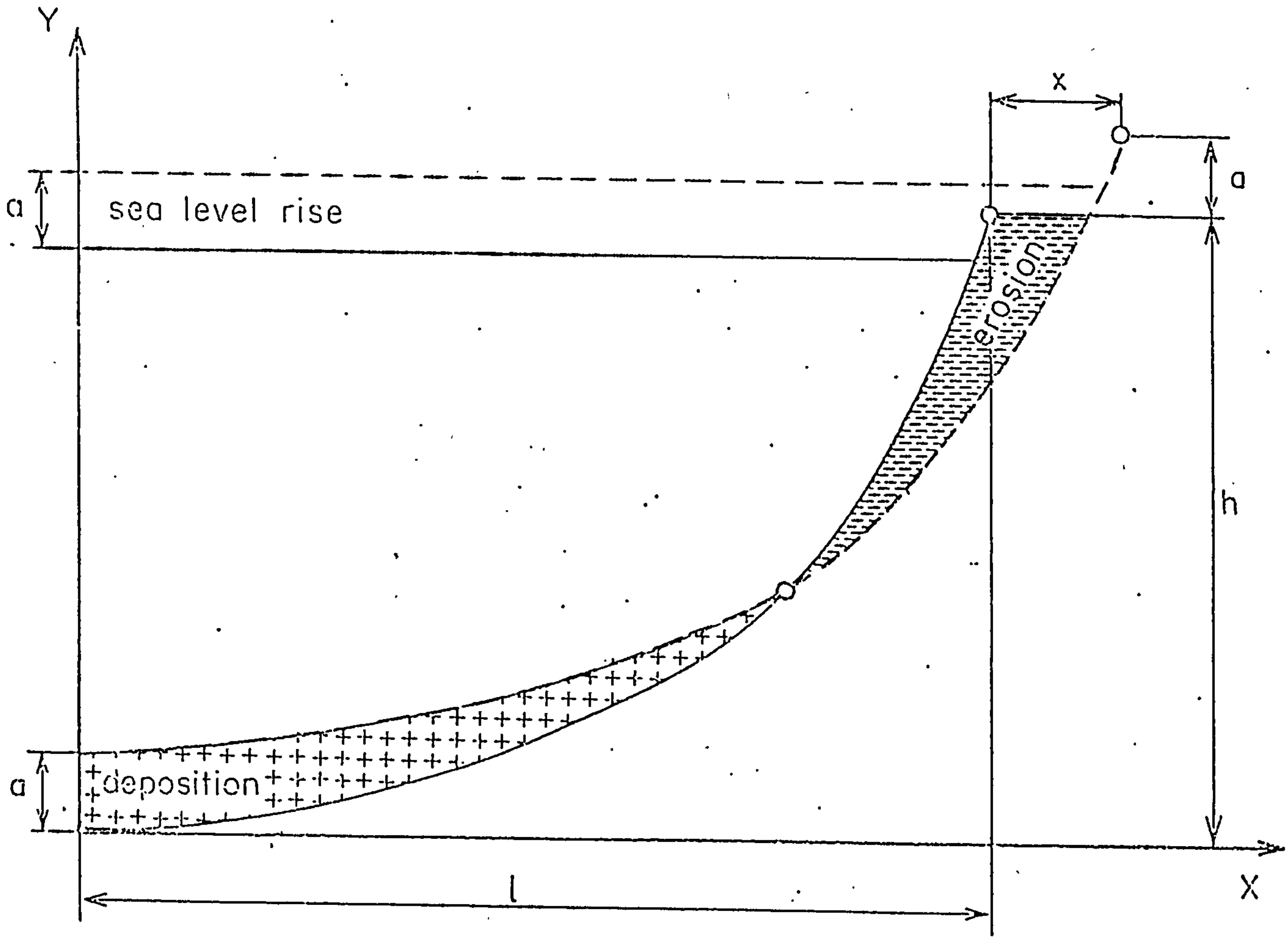


FIGURE 7: Diagram showing the Bruun's effect - translation of the beach provile, resulting in shore erosion and deposition of sediments. (Adapted from Bruun 1983, Figure 1).
a = sea level rise; h = limiting depth of beach sediment; l = distance to limiting depth; X = erosion amount.

Values in Table 5 show that net rates of coastal erosion from a rise in sea-level of 5.5 mm/year are predicted to range from -0.26 to -0.45 m/year, averaging -0.31 m/year. As one might expect from the Bruun model (Figure 7), higher erosion rates are predicted where the foredune elevation is low and the active beach zone wide (cross-section 85), compared to lower rates where the foredune is high and the active beach zone narrow (cross-section 35).

CHZ ASSESSMENT

Having calculated (X) in Table 5 we can now test whether the past trend at Pauanui is going to continue into the future or change, and assess the width of a CHZ for erosion (Table 6) and upper and lower limits of uncertainty (Appendix II). For (S) we assume that historical short-term erosion up to 30 m (Table 6) may occur at any point along the 2.65 km-long Pauanui Beach in the future. For (R) we assume that the historical net erosion-accretion rates (Table 3) are principally a function of sediment supply and that this supply will continue at roughly the same rate for the next 100 years. For (T), a 100-year assessment period is adopted here to accommodate the *minimum* useful life of new buildings and services and to allow for the occurrence of damaging coastal storms with return periods up to 100 years. Such a storm has a 63% probability of occurring within the 100-year planning period compared with, say, a 50-year event which has an 87% probability (Gibb 1983a).

Values of (X + R)T in Table 6 indicate the onset of a long-term trend of coastal erosion along the 2.65 km-long Pauanui Beach over the next 100 years, the amount increasing significantly south of Pauanui Airfield. Irrespective of the differential rates of long-term erosion the entire 2.65 km-long foredune will be subject to short-term storm-induced episodic erosion on the order of 30 m but up to 70 m at the north end of Pauanui Beach in the recreation reserve.

Taking these factors into account we recommend CHZ widths (Table 6) ranging between 50 and 70 m for the 1 km of beach frontage south of Pauanui Airfield reducing to 30 to 35 m along the northern 1.35 km increasing again to 85 m for the final 0.3 km of recreational reserve at

TABLE 6 : Assessment of coastal Hazard Zone (CHZ) widths for coastal erosion along Pauanui Beach at 13 selected MWD beach cross-sections. Where (X + R)T is positive, CHZ width is (S). Where (X + R)T is negative, CHZ = (X + R)T + S. Factor (R) is from Table 3 and a uniform value of 30 m is adopted for Factor (S) for cross-sections 5-80, and 70 m for cross-section 85. Factor (T) is 100 years. Recommended CHZ widths are rounded to the nearest 5 m. Positive (+ve) and negative (-ve) CHZ uncertainty values are from Appendix II.

LOCATION		Pauanui Beach Road	Mountain Vista Place	McLiver Place	Bonanza Place	Champion Place	Jacksons Claim	Pauanui Airfield	Pauanui Boulevard	Prescott Place	Claxton Ave	McCall Ave	Vista Paku	Recreation Reserve
CROSS-SECTION NO.		5	10	15	20	25	30	35	40	50	60	70	80	85
CHZ FACTORS	S	30	30	30	30	30	30	30	30	30	30	30	30	70
	X	-0.30	-0.30	-0.30	-0.29	-0.28	-0.28	-0.26	-0.28	-0.29	-0.32	-0.33	-0.36	-0.45
	R	+0.02	-0.11	-0.07	-0.03	+0.10	+0.08	+0.21	+0.24	+0.27	+0.26	+0.36	+0.34	+0.32
	T	100	100	100	100	100	100	100	100	100	100	100	100	100
	(X+R)T	-28	-41	-37	-31	-18	-20	-5	-4	-2	-6	+3	-2	-13
	CHZ	58	71	67	61	48	50	35	34	32	36	30	32	83
RECOMMENDED CHZ WIDTH (in metres)		+25 60 -21	+27 70 -18	+23 70 -23	+29 60 -16	+24 50 -20	+25 50 -18	+23 35 -5	+23 35 -5	+26 30 -0	+26 35 -5	+24 30 -0	+29 30 -0	+31 85 -15

the northern extremity of the beach. The CHZ is shown on sheet 9 of MWD Hamilton District Office Survey Plan Number 2/973/1/2204 of which Figure 8 is a reduction. The CHZ and upper and lower limits of uncertainty were measured inland from the top seaward edge of the present foredune and are shown in relation to beach front properties and the foreshore reserve.

It is important to realise that the coastal erosion predicted here from an accelerated sea-level rise of 5.5 mm/year is based on the latest research into the long-term impacts of increasing atmospheric CO_2 on global sea-level. Should the rise in global sea-level exceed the 700 mm predicted by the NAS report for the next 100 years, then coastal erosion will accelerate proportionately. Equally, if the predicted rise is less than 7 mm/year then the extent and rate of coastal erosion will also be proportionately less at Pauanui.

Published reports to date, however, consistently predict a rise in global surface temperatures of 3 $\pm$ 1.5°C over the next 100 years which will certainly accelerate the present rise of global sea-level. If the West Antarctic ice sheet disintegrates as a result of the global warming then a 5 to 7 m rise in sea-level will occur which will devastate low lying coastlines, harbours and estuaries around New Zealand. For example, using values for (l) and (h) in Table 5, a 5 m rise in sea-level (0.05 m/year) would cause net erosion rates along Pauanui Beach of -2.38 to -4.05 m/year, generally averaging -2.8 m/year. For a 7 m rise (0.07 m/year) net rates would increase to -3.33 to -5.68 m/year, averaging -3.9 m/year. Such rates could wipe out more than 50% of Pauanui Ocean Beach Resort during the next 100 years. However, minimum estimates of between 200 and 500 years have been made for such an event. Based on existing data we strongly recommend the adoption of the CHZ (Table 6) for the predicted minimum 0.7 $\pm$ 0.18 m rise in sea-level which seems more likely to occur during the next 100 years.

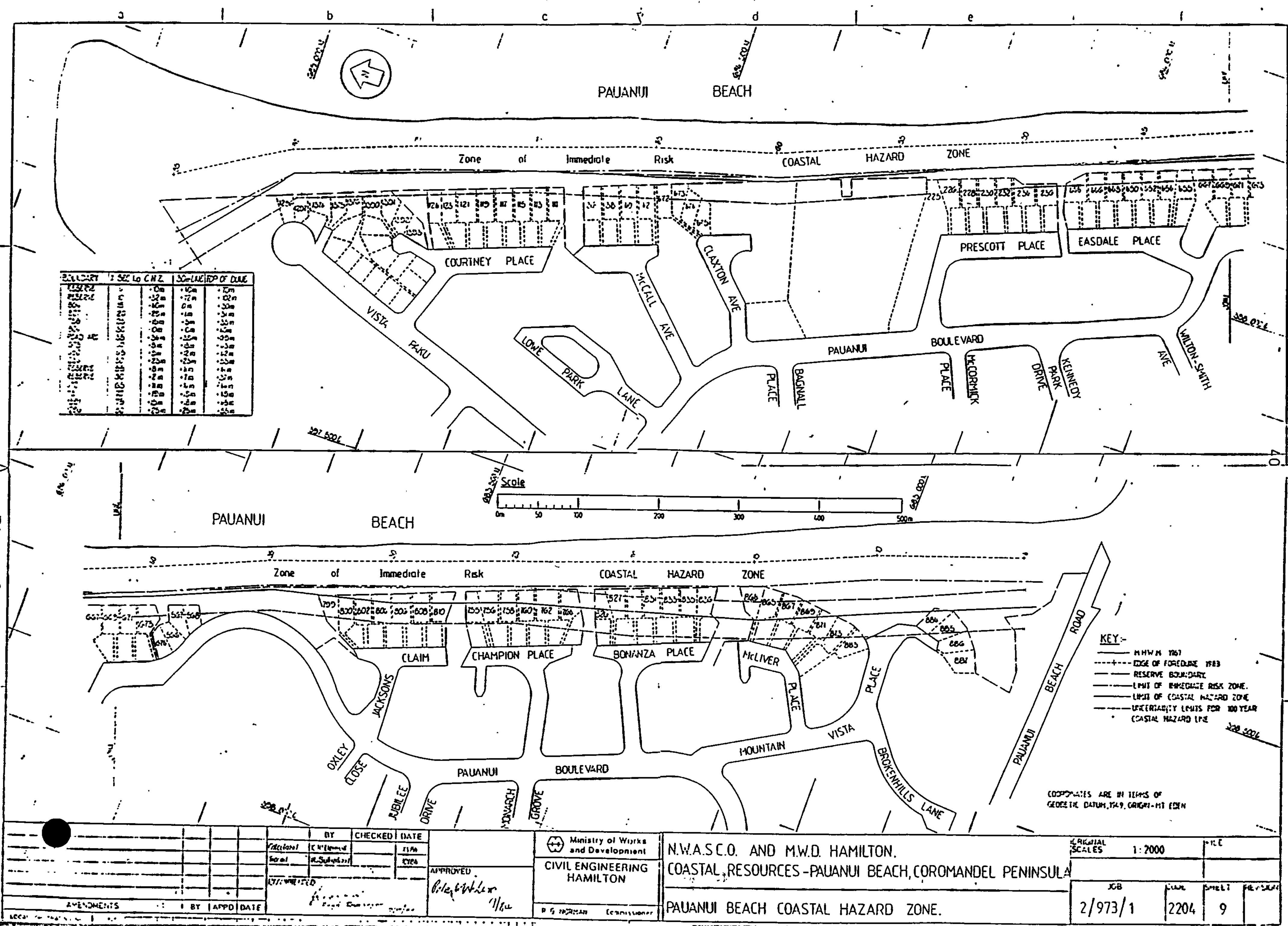


Figure 8 : Coastal Hazard Zone.

CONCLUSIONS AND RECOMMENDATIONS

1. Over the last 5000 years Pauanui Beach has accreted at the very slow net rate of 0.15 m/year, the rate decreasing progressively with time from 0.4 m/year (5000-4000 years B.P.) to less than 0.1 m/year for the last 2000 years.

2. During the last 2000 years the nearshore seabed and foredune have reached a state of dynamic equilibrium, punctuated by short-term fluctuations of up to 30 m in the position of the dune toe. Short-term volumetric gains and losses of sand to and from the foredune on the order of 2200 m^3/km/year have, and will continue to occur.

3. Potential hazards most likely to damage or destroy beach front property and assets along Pauanui Beach are, in order of severity, coastal erosion, tsunami inundation and wind erosion. Of these, the risk from tsunami inundation and wind erosion is considered negligible compared to the risk from coastal erosion.

4. Provided long-term factors such as sediment supply from the Tairua River and global sea-level rise remain the same over the *next* 100 years as they have for the *past* 100 years the state of dynamic equilibrium should persist along Pauanui Beach, punctuated by short-term movements up to 30 m.

5. The predicted increase in the rate of global sea-level rise from 1.5 mm/year to 7.0 $\pm$ 1.8 mm/year will result in a reversal from dynamic equilibrium to long-term erosion along the entire 2.65 km-long Pauanui Beach with erosion increasing in both rate and extent southwards.

6. For the southern 1 km of Pauanui Beach a 50 to 70 m-wide coastal hazard zone (CHZ) is calculated, reducing to 30 to 35 m for the next 1.35 km north, increasing to 85 m for the final 0.3 km. For CHZ widths, maximum and minimum upper and lower uncertainty limits are 116 m and 30 m respectively.

7. For land within the Zone of Immediate Risk the territorial local authority should refuse to approve any scheme plan for a proposed sub-

division under Section 274 (a), (d), (e) and (f) of the Local Government Act 1974, as the land has, and will continue to be subject to both short-term erosion and inundation by the sea. In the long-term public interest, however, further subdivision of land for residential purposes should not be permitted in the entire Coastal Hazard Zone.

8. For land within the entire Coastal Hazard Zone the territorial local authority should refuse to approve building permits under sections 641 and 641A of the Local Government Act 1974 as the land will be subject to both long-term erosion and inundation by the sea.

9. The Pauanui Beach Coastal Hazard Zone should be incorporated into the Thames-Coromandel District Planning Scheme to satisfy the provisions of the Second Schedule, clause 8a of the Town and Country Planning Act 1977.

10. Hauraki Catchment Board and Thames-Coromandel District Council should come to an arrangement for continued monitoring of Pauanui Beach and use the techniques developed here for assessing Coastal Hazard Zones in other critical areas.

ACKNOWLEDGEMENTS

We gratefully acknowledge the following for invaluable assistance with this part of the Pauanui Coastal Hazard Survey: The Hydrographer, Royal New Zealand Navy, for making available Lieutenant IFP Martin and his able crew and the RNZN Operational Diving Team under the supervision of Warrant Officer P Kneebone; the District Commissioner of Works, Ministry of Works and Development, Hamilton for making available the survey section of the Hamilton District Office and Dr T M Hume of the Water Quality Centre, Hamilton; the Chief Engineer of the Hauraki Catchment Board for making available Mr P Dell. Funding for the project was carried mostly by the Ministry of Works and Development and partly by the Thames Coromandel District Council. The assistance of Mr Ian Hopper who funded the 3 bore-holes drilled by Thames Valley Welldrillers and provided us with much useful local data, is gratefully acknowledged. Constructive critercisms were made by Mr Hopper, Dr Hume, Mr Dell, Mr Le Marquand (Water and Soil Directorate) and Mr JWD Hessel, Superintendent of Climatology, New Zealand Meteorological Service.

REFERENCES

BARNETT, T. P. 1983: Global sea-level: Estimating and explaining apparent changes. *Coastal Zone '83. Proceedings of the third Symposium on Coastal and Ocean Management. American Society of Civil Engineers.* Volume III:2777-2783.

BENTLY, C. 1983: The West Antarctic Ice Sheet: Diagnosis and prognosis. *Proceedings: Carbon Dioxide Research Conference. Carbon Dioxide, Science, and Consensus DOE Vol. 21, conf. 82 0970.*

BRUUN, P. 1962: Sea level rise as a cause of shore erosion. *Journal of the Waterways and Harbours Division, Proceedings of the American Society of Civil Engineers 88* (WW1) : 117 - 130

BRUNN, P. 1983: Review of conditions for uses of the Bruun Rule of erosion. *The Dock and Harbour Authority* 64 (753) : 79 - 82

BRUUN, P. 1984: Beach and dune erosion during storm surges -- discussion. *Coastal Engineering* 8 : 171 - 188

CARRYER, S. J. Unpublished 1980: Report on the proposed foreshore setback for building protection at Pauanui, Coromandel Peninsula. Report to Pauanui Ocean Beach Resort Ltd, Auckland. 15 p

CHAPMAN, D. M. and SMITH, A. W. 1983: Gold Coast swept prism-limits. *Proceedings of the Sixth Australian Conference on Coastal and Ocean Engineering*, Gold Coast 13 - 15 July: 132 - 138.

CLARK, W. C. (Editor) 1982: *Carbon Dioxide Review 1982.* Oxford University Press, New York. 469 p

DELL, P. M. and HEALY, T. R. 1982: Investigation into the erosion - accretion of eastern Coromandel beaches. *Collected Preprints. Coastal Zone Management Seminar 1982 Mount Maunganui. Commission for the Environment* : 1 - 14

DELL, P. M. 1983: The offshore and nearshore current circulation at Pauanui and Tairua. *Hauraki Catchment Board - Report 142*. 22 p

DE LANGE, W. and HEALY, T. R. 1982: The evaluation of tsunami hazards for coastal management: An example for the Bay of Plenty using Numerical Models. *Collected Preprints. Coastal Zone Management Seminar 1982 Mount Maunganui. Commission for the Environment*: 1 - 15.

DUBOIS, R. N. 1975: Support and refinement of the Bruun Rule on beach erosion. *Journal of Geology* 83: 651 - 657

DUBOIS, R. N. 1976: Nearshore evidence in support of the Bruun Rule on shore erosion. *Journal of Geology* 84: 485 - 491.

DUBOIS, R. N. 1977: Predicting beach erosion as a function of rising water level. *Journal of Geology 85* : 470 - 476

FAIRBRIDGE, R. W. and KREBS, O. A. 1962: Sea level and the southern oscillation. *Geophysical Journal of the Royal Astronomical Society* 6 : 532 - 545

GIBB, J. G. 1978: Rates of coastal erosion and accretion in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 12(4) : 429 - 456

GIBB, J. G. 1979: Late Quaternary shoreline movements in New Zealand. Unpublished Ph.D thesis lodged in the library, Victoria University of Wellington, Wellington. 217 p

GIBB, J. G. 1981: Coastal hazard mapping as a planning technique for Waiapu County, East Coast, North Island, New Zealand. *Water and Soil Technical Publication 21* : 63 p

GIBB, J. G. 1983a: Combating coastal erosion by the technique of coastal hazard mapping. *New Zealand Engineering 38*(1) : 15 - 19

GIBB, J. G. In STEVENS, P. R. (Editor) 1983b: Application of vertical sequential black-and-white, colour and colour infrared aerial photography to map coastal resources. In, Remote Sensing for Soil Conservation (Workshop Proceedings, 29 June - 1 July 1982): A Remote Sensing Manual for Soil Conservators. *Water and Soil Miscellaneous Publication* 52 : 159 - 172

GIBB, J. G. Unpublished 1983c: Geology and sedimentology of the Tairua Pauanui area, Coromandel Peninsula, and provenance of the sediments. Report to Water and Soil Directorate, Ministry of Works and Development, Wellington. 46 p

GIBB, J. G. In press: A New Zealand regional Holocene eustatic sea-level curve and its application to determination of vertical tectonic movements. *Proceedings of the International Symposium on Recent Crustal Movements in the Pacific Region. Bulletin of the Royal Society of New Zealand.*

GODWIN, H. 1962: Half-life of radiocarbon. *Nature* 195 (4854): 984 p.

GORNITZ, V. S., LEBEDEFF and HANSEN, J. 1982: Global sea level trend in the past century. *Science 215* : 1611 - 1614

GUTENBERG, B. 1941: Changes in sea level, postglacial uplift, and mobility of the Earth's interior. *Geological Society of America Bulletin 52* : 721 - 772

HANSEN, J., LACIS, A. and RIND, D. 1983: Climate trends due to increasing greenhouse gases. *Coastal Zone '83. Proceedings of the Third Symposium on Coastal and Ocean Management. American Society of Civil Engineers*. Vol. III:2796-2810.

HARRIS, T.F.W., HUGHES, T. S. and VALENTINE, E. M. 1983: Deepwater waves off Hicks Bay and the north-east coast, North Island. *Water & Soil Miscellaneous Publication* 56: 83 p.

HEALY, T. R., DELL, P. M. and WILLOUGHBY, A. J. 1981: Coromandel coastal survey. Volume 1 Basic survey data. *Hauraki Catchment Board Report 114*. 233 p

HUGHES, T. 1983: Respondents Paper. *Proceedings: Carbon Dioxide Research Confernece: Carbon Dioxide, Science, and Consensus. DOE Vol. 21, conf. 82 0970*.

HUME, T. M. and GIBB, J. G. in preparation. Sedimentation rates from a "wooden-floored" estuary, Tairua, eastern Coromandel Peninsula, New Zealand - Note. *New Zealand Journal of Geology and Geophysics*.

KELLY, E. M. 1971: "Summary of the law relating to land surveying in New Zealand". Fourth edition. Revised by B. H. Davis. Hutcheson, Bowman and Stewart, Wellington. 296 p.

LEE, L. P. 1953: Mean sea level and mean high water mark. *New Zealand Survey Draughtsmen's Journal* 9(1) : 325 - 345

MACDONALD, C. J. (Editor) 1982: *The long-term impacts of increasing atmospheric carbon dioxide levels*. Ballinger, Cambridge, Massachusetts. 252 p

MARTIN, I. F. P. Unpublished 1983: Report on survey - HI122 - Pauanui Coastal Hazard Survey 1:6000. Report to the Hydrographic Office, RNZN, Takapuna. 16 p

NATIONAL RESEARCH COUNCIL (US) 1982: "Carbond Dioxide and Climate: A Second Assessment". Report of the CO_2/Climate Review Panel. National Academy Press, Washington, DC. 71 p.

NATIONAL ACADEMY OF SCIENCES 1983: "Changing Climate". Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C 496 p.

RAUDKIVI, A. J. Unpublished 1982: Coromandel Coastal Survey Pauanui Beach. Report to Thames-Coromandel District Council, Thames. 6 p

ROSEN, P. S. 1978: A regional test of the Bruun Rule on shoreline erosion. *Marine Geology* 26: M7 - M16.

RYAN, P. R. 1984: High sea-levels and temperatures seen next century. *Oceanus* 26(4): 63-67

SCHWARTZ, M. L. 1965: Laboratory study of sea-level rise as a cause of shore erosion. *Journal of Geology* 73: 528 - 534

SCHWARTZ, M. L. 1967: The Bruun Theory of sea-level rise as a cause of of shore erosion. *Journal of Geology* 75: 76 - 92.

WEIR, G. J. and WHITE, S. P. 1982: Mathematical modelling of volcanic tsunamis. *New Zealand Journal of Marine and Freshwater Research* 16: 373 - 382.

WORLD METEOROLOGICAL ORGANISATION 1981: The Carbon Dioxide/Climate Issue. A statement - 1980. Prepared by a joint WMO/ICSU/UNEP group of Experts. *World Meteorological Organisation* No. 373.

APPENDIX I

Annotated list of Sheets 1 to 9 of Ministry of Works and Development Hamilton District Office Survey Plan Number 2/973/1/2204. Each sheet covers part or all of Pauanui Beach and are held by the District Surveyor, MWD, Private Bag, Hamilton.

(a) Sheets 1 and 2. Compiled plans showing the HWM from S.O. $6910D^2$ (1895), MHWM from D.P. S11962 (1967) and vegetation line as from the field notes held in Chief Surveyor's office, Department of Lands and Survey, Hamilton of the 1967 survey DPS 11962.

(b) Sheet 3. The survey control for cross-sectioning of Pauanui Beach showing the baseline adopted for the survey and the 89 pegged intercepts on the survey traverse line.

(c) Sheet $4R^2$. A plan showing the periodic movements of the toe of the foredune 1895-1983 based on 4 aerial surveys and ground survey of May 1983, checked in the field December 1983, and the volume of sand movement over those years.

(d) Sheets 5 and 6. The photogrammetric plot by the Department of Lands and Survey Photogrammetric Branch of the foredunes of Pauanui Beach based on the 1944, 1971, 1978 photos and related to the 1895 and 1967 surveys as compiled on Sheets 1 and 2.

(e) Sheets 7 and 8. A composite plan of the toe of dune as on Sheets 5 and 6, the baseline and traverse pegging, reserve boundary and subdivisional survey fronting Pauanui Beach used in conjunction with cross-sections of the beach to arrive at the volume calculations on Sheet 4.

(f) Sheet 9. A plan showing the Pauanui Beach Coastal Hazard Zone in relation to beach front property boundaries, foreshore reserve and the top seaward edge of the foredune.

APPENDIX II: Upper and lower limits of uncertainty for Coastal Hazard Zone (CHZ) widths for predicted erosion along Pauanui Beach at 13 selected MWD cross-sections. For each factor, uncertainties have been added or subtracted from values in Tables 5 and 6 to obtain upper and lower limits respectively. Uncertainties are: sea-level rise (a) = ± 0.0018 m/year; profile length (l) = ± 200 m; profile depth (h) = ± 0.5 m; erosion rate (R) = ± 0.03 m/year. Factor (T) in (X + R)T, is 100 years, and CHZ = (X + R)T + S.

	CROSS SECTION No.	5	10	15	20	25	30	35	40	50	60	70	80	85
UPPER LIMITS (CHZ_1)	a_1	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073
	l_1	890	885	905	880	885	900	900	920	930	1020	1015	1065	1150
	h_1	12	12.1	12.4	12.2	12.9	13.2	14.2	13.7	13.5	13.8	12.9	12.9	11.2
	X_1	-0.54	-0.53	-0.53	-0.53	-0.50	-0.50	-0.46	-0.49	-0.50	-0.54	-0.57	-0.60	-0.75
	R_1	-0.01	-0.14	-0.10	-0.06	+0.06	+0.05	+0.18	+0.21	+0.24	+0.23	+0.33	+0.31	+0.29
	$(X_1+R_1)T$	-55	-67	-63	-59	-44	-45	-28	-28	-26	-31	-24	-29	-46
	S	30	30	30	30	30	30	30	30	30	30	30	30	70
	CHZ_1	85	97	93	89	74	75	58	58	56	61	54	59	116
LOWER LIMITS (CHZ_2)	a_2	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037
	l_2	490	485	480	485	485	500	500	520	530	620	615	615	750
	h_2	13	13.1	13.4	13.2	13.9	14.2	15.2	14.7	14.5	14.8	13.9	13.9	12.2
	X_2	-0.14	-0.14	-0.13	-0.14	-0.13	-0.13	-0.12	-0.13	-0.14	-0.16	-0.16	-0.16	-0.23
	R_2	+0.05	-0.08	-0.04	0.0	+0.13	+0.11	+0.24	+0.27	+0.30	+0.29	+0.39	+0.37	+0.35
	$(X_2+R_2)T$	-9	-22	-17	-14	0	-2	+2	+14	+16	+13	+23	+21	+12
	S	30	30	30	30	30	30	30	30	30	30	30	30	70
	CHZ_2	39	52	47	44	30	32	30	30	30	30	30	30	70

Hxf.a

54/30/1

67/1/1

NEW ZEALAND EMBASSY

MAURITSKADE 25
2514 HD THE HAGUE
THE NETHERLANDS

TELEPHONE: (070) 469324
TELEX: 31557 TAU NL

RECEIVED 29 APR 1985 H.O. MINISTRY OF TRANSPORT No.1

28 March 1985

FILED BY
FILER No.

The General Manager
New Zealand Railways
WELLINGTON

cc DSIR
Transport (Marine Div)
Environment
Foreign Affairs

DUTCH HYDRAULIC EXPERTISE : MARLBOROUGH SOUNDS

If our recollection is correct there is a problem of shore erosion in the Marlborough sounds where water traffic is heavy, and Railways, as operator of the inter-island ferries, has an interest in the problem.

2 The problem came to mind when we visited the Delft Hydraulics Laboratory (near The Hague) recently. The Laboratory is involved in contract work world-wide and might well be able to carry out research and advise on appropriate solutions. The Delft Hydraulics Laboratory does not lay claim to areas of expertise that cannot be found in other similar institutions around the world, but it does rate the quality of its services highly. (All Dutch feel, with fair justification, that they know the sea, and hydraulics, as well as any people.) The Laboratory has extensive testing facilities able to carry out, for example, tests on up to a 1 : 1 scale on sea shore and embankment constructions.

3 We do not know about testing facilities in New Zealand, or even whether the problem in the Marlborough sounds is such that this line of resort is appropriate. If, however, you think it worth taking enquiries a little further with the Delft Hydraulics Laboratory we should be happy to put you in touch with the people concerned. Incidentally, it is apparent that the laboratory foresees a fall-off in contracts in the near future, and is looking for new work. We would mention also that New Zealand has used Dutch expertise and consultancy advice in other areas, e.g. energy, apparently to our satisfaction.

4 A leaflet which outlines the organisation and work of the Delft Hydraulics Laboratory and a copy of the journal Hydro Delft are enclosed for your information.

J A Howell
for Ambassador

Encl