A New Technique for Measuring Runup Variation Using Sub-Aerial Video Imagery

A thesis submitted in partial fulfilment of the requirements for the Degree of

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By

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Frontispiece: Oblique view of the Tairua and Pauanui embayment.

This work is dedicated to my beautiful children; Tuumanako and Maia

Abstract

Video monitoring of beaches is becoming the preferred method for observing changes to nearshore morphology. Consequently this work investigates a new technique for predicting the probability of inundation that is based on measuring runup variation using video. Runup is defined as the water-level elevation maxima on the foreshore relative to the still water level and the waterline is defined as the position where the MWL intersects the beach face. Tairua, and Pauanui Beaches, on the north east coast of the North Island of New Zealand, were used as the field site in this study and represent two very different beaches with the same incoming wave and meteorological conditions. Tairua is most frequently in an intermediate beach state, whereas Pauanui is usually flatter in nature.

In order to rectify runup observations, an estimate of the runup elevation was needed (Z). This was estimated by measuring the variation of the waterline over a tidal cycle from time-averaged video images during a storm event and provided beach morphology statistics (i.e. beach slope (α) and beach intercept (b)) used in the rectification process where $Z=aX+b$. The maximum swash excursions were digitized from time-stacks, and rectified to provide run-up timeseries with duration 20 minutes. Field calibrations revealed a videoed waterline that was seaward of the surveyed waterline. Quantification of this error gave a vertical offset of 0.33m at Tairua and 0.25m at Pauanui.

At Tairua, incident wave energy was dominant in the swash zone, and the runup distributions followed a Rayleigh distribution. At Pauanui, the flatter beach, the runup distributions were approximately bimodal due to the dominance of infragravity energy in the swash signal. The slope of the beach was a major control on the runup elevation; runup at Pauanui was directly affected by the deepwater wave height and the tide, while at Tairua there was no correlation. Overall, the results of the study indicate realistic runup measurements, over a wide range of time scales and, importantly, during storm events. However, comparisons of videoed runup and empirical runup formulae revealed larger deviations as the beach steepness increased. Furthur tests need to be carried out to see if this is a limitation of this technique, used to measure runup. The runup statistics are consistently higher at Tairua and suggests that swash runs up higher on steeper beaches. However, because of the characteristics of flatter beaches (such as high water tables and low drainage efficiencies) the impact of extreme runup elevations on such beaches are more critical in regards to erosion and/ or inundation.

The coastal environment is of great importance to Maori. Damage to the coast and coastal waahi tapu (places of spiritual importance) caused by erosion and inundation, adversely affects the spiritual and cultural well-being of Maori. For this reason, a chapter was dedicated to investigating the practices used by Maori to protect and preserve the coasts in accordance with tikanga Maori (Maori protocols). Mimicking nature was and still is a practice used by Maori to restore the beaches after erosive events, and includes replanting native dune plants and using natural materials on the beaches to stabilize the dunes. Tapu and rahui (the power and influence of the gods) were imposed on communities to prohibit and prevent people from free access to either food resources or to a particular place, in order to protect people and/ or resources. Interpretations of Maori oral histories provide insights into past local hazards and inform about the safety and viability of certain activities within an area. Environmental indicators were used to identify and forecast extreme weather conditions locally. Māori knowledge of past hazards, and the coastal environment as a whole, is a valuable resource and provides a unique source of expertise that can contribute to current coastal hazards management plans in New Zealand and provide insights about the areas that may again be impacted by natural hazards.

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Chapter 1

Introduction

1.1 Background

The effects of climate change may be significant. However like any weather forecast, these effects are difficult to predict with certainty. Already witnessed, is the increased occurrence of inundation as a result of the intensification in the severity and frequency of storms and cyclones. Our coastal environment changes dramatically with the passing of these storm events. Large waves and the currents that are associated with them, scour out the beach face, decimate shellfish populations, cause dramatic shifts in rip currents, and can change the whole orientation of the coastline.

At present there are no mathematical models that have the ability to predict inundation accurately enough in the New Zealand environment to be used as a tool for preparing our selves for the eventuality of climate change. Without such a tool, we cannot predict how much of the dune systems might be in danger of erosion and to what degree. Nor can we predict the impact on developments, habitats and waahi tapu (places of spiritual importance to Maori) associated with the coast, or most importantly the risk to human lives from inundation. Without a clear understanding of the potential hazard, it is not possible to develop plans to enhance the resilience of coastal communities.

Coastal dunes often provide the final defense line for coastal developments and properties against wave induced erosion. The amount of erosion depends on the water level height relative to the elevation of the fronting beach. This elevation is composed of the predicted astronomical tide level, storm surge associated with the inverse barometer effect and wind, wave set-up and wave run-up, (STOCKDON *et al.*, 2006), with the latter being the most poorly understood, (Figure 1.1). Wave run-up is responsible for causing much of the erosion of the beach and foredune (RUGGIERO *et al.*, 2001). Moreover, if dune overtopping occurs this may lead to coastal flooding, resulting in loss of property and possibly lives. It is therefore important to accurately predict the magnitude and probability of occurrence of run-up.

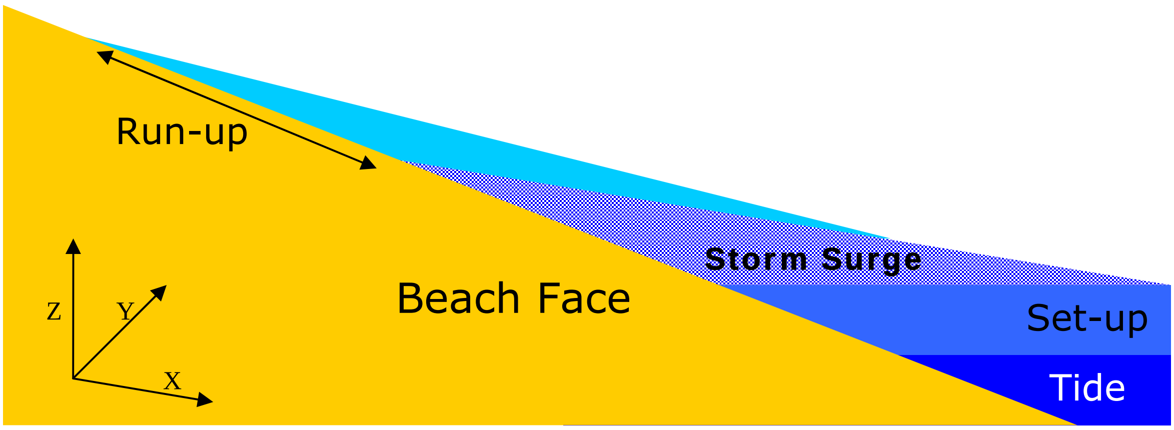

Figure 1.1: A schematic of the components which control the elevation of the waterline

One of the main impediments to making valid run-up predictions is the difficulty of obtaining observations of run-up over a wide range of storm wave conditions and beach types. In principle, run-up should vary with changes to the character of the incoming wave spectrum, but also with localized changes to surf-zone hydrodynamics, (such as rip current patterns), morphology, (such as foreshore slope), and sediment properties. Most in situ run-up experiments are conducted at a single location on the beach, and only over several weeks. Capturing a storm event over this time period is purely a matter of chance.

This thesis investigates a new technique for predicting the probability of inundation that is based on measuring run-up variation during storm events using sub-aerial video imagery on a given beach.

1.2 Maori and the Coast

The coasts and estuaries are also of great importance to Maori, and especially coastal Maori. As a source of mataitai (seafood), it has immense cultural value as an offering to manuhiri (visitors), as well as a food and economic resource. The coast also provides Maori with weaving materials from plants such as Harakeke and Pingao, and plants which act as natural breeding, nursery and feeding grounds, such as Mangroves. The sand dunes may contain many important cultural sites including, middens, remains of general living areas with stained sands from ovens, and also urupa (cemeteries).

For Maori, the world is viewed as a unified whole where all elements, including the human presence, are interconnected. The changes brought on by a warming climate directly affect the balance between the cultural and spiritual values of the environment in which we live. Much Maori land is situated on or near the coast which has, or will in the near future, become prone to flooding and erosion. With an increase in flooding events, the likelihood of damage to waahi tapu, archaeological sites and other areas of cultural significance is also increased. Due to the linkage through whakapapa (family genealogy) this adversely affects Maori tupuna (ancestors) and therefore the cultural and spiritual well-being of Maori.

For these reasons this study is of particular relevance to Maori as a whole and a chapter is dedicated to exploring and understanding ways in which to sustainably manage existing and future coastal developments, and other taonga (treasures) in accordance with Maori tikanga (Maori protocols). This was achieved by consultation with people who are knowledgeable in the historical and/or contemporary management methods of coastal Maori. The outcome of this is to

- contribute to the development of new technologies or practices in accordance with Maori tikanga that will benefit and sustain the coastal environment, and;
- contribute a tool that will aid in implementing kaitiakitanga (guardianship) priorities including the planning and supervision of all coastal developments with iwi and hapu.

1.3 Field Site

Tairua and Pauanui beaches on the Coromandel Pennisula, on the north east coast of the North Island of New Zealand (Figure 1.2), were used as the field site for the study because they represent two very different beaches with the same incoming wave and meteorological conditions. Tairua is an embayed beach that is constrained by headlands at either end of the beach. It is a tombolo, most frequently in an intermediate beach state (varying between longshore bar and trough and transverse bar and rip) and is composed of medium-coarse sands (BOGLE *et al.*, 2001), (Figure 1.3). Pauanui Beach is a dune barrier beach enclosing an estuary. It is a long, flat beach, with relatively fine sand and is most frequently in a more dissipative state (Figure 1.4).

Both beaches have a northeast aspect and are therefore exposed to northerly and easterly swells. Significant wave heights are generally low (<1.5 m), but can exceed 6m during cyclone events. The tidal range is ≈ 2 metres with little spring-neap variation (BOGLE *et al.*, 2001). Tairua Beach is also backed by a natural reserve, which is often threatened by on-going erosive events. These two beaches encompass the extremes in beach type found along the Coromandel Peninsula and along Auckland and Northland's east coast. Accordingly, the technique used to measure runup in this study will have a more universal application and will be able to forecast run-up at beaches with similar climates and sediment properties.

1.4 Storm Events

The National Institute of Water and Atmospheric Research (NIWA) provided over seven years of video image data and camera calibration statistics for both sites for use in this work (between years 2001 and 2007). The footage from the video was used to identify all storms analysed in this study. Whenever the shoreline reached the toe of the dunes in the images, this was considered to be a storm event and was recorded as such. The thirteen storm events chosen from either site, were determined by simply choosing the images with the highest waterlines.

For purposes of this study it was decided that the day the storm was most intense, and a day either side of this day, would be used as a representation of the whole storm, no matter its duration. The day of highest intensity was defined as the day with the highest recorded wave height over the three day period. Ten storms at Tairua Beach and three storms from Pauanui Beach were identified and used. The dates of the storms, the mean wave heights and the tidal ranges over the duration of the storms are detailed in Table 1.1. The three storms at Pauanui coincide with the dates of three of the storms at Tairua (i.e. storms 7, 8 and 10 respectively), for comparison between the two sites.

Table 1.1: Storm dates and their respective mean deepwater wave heights and tidal ranges over the duration of the storm.

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Location	Storm Event	Date of Storm	Mean Deepwater Wave Height (m)	Tidal Range (m)
Tairua	1	03/04/2001	1.99	0.56-1.86
	2	07/07/2001	3.46	0.40-1.81
	3	31/08/2001	3.48	0.58-1.77
	4	10/01/2003	3.39	0.57-1.91
	5	02/08/2003	3.71	0.38-1.89
	6	13/08/2003	2.61	0.35-1.92
	7	02/02/2006	2.05	0.24-2.23
	8	25/04/2006	3.58	0.45-1.89
	9	07/08/2006	1.64	0.46-1.84
	10	10/09/2006	1.78	0.25-2.19
Pauanui	11	02/02/2006	2.05	0.24-2.23
	12	25/04/2006	3.58	0.45-1.89
	13	10/09/2006	1.78	0.25-2.19

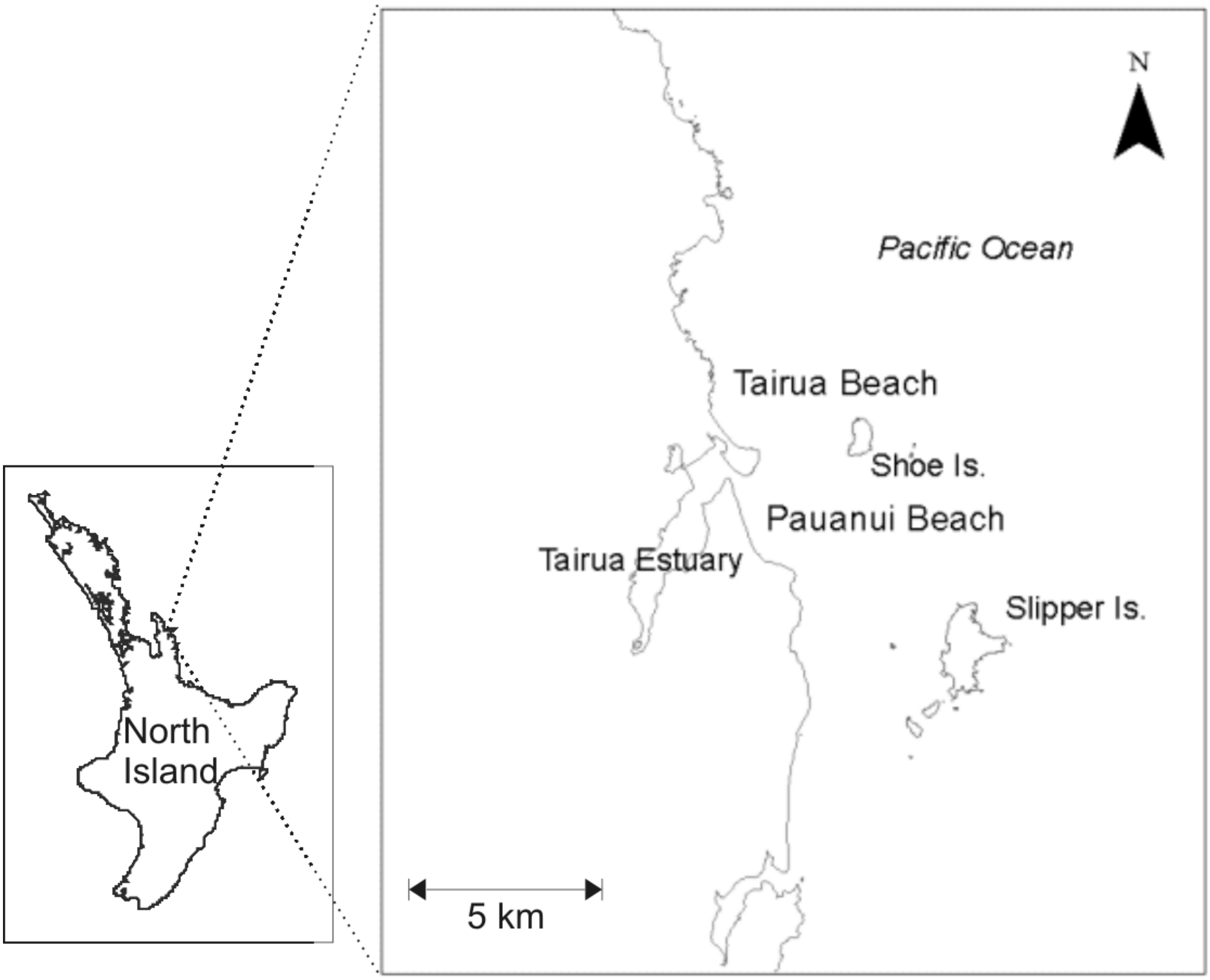


Figure 1.2: Map of New Zealand showing the location of the Tairua and Pauanui embayments in the Coromandel Peninsula

Figure 1.3: Video image of Tairua Beach, averaged over a 15 minute period, taken using the Tairua Imaging Station situated on Paku Hill, on the 26/04/2006 (source: NIWA, 2006).

Figure 1.4: Video image of Pauanui Beach, averaged over a 15 minute period, taken using the Pauanui Imaging Station situated on Pauanui Mountain, on the 26/04/2006 (source: NIWA, 2006).

1.4.1 Tide, Wave and Atmospheric Pressure Data

The concurrent wave, atmospheric pressure and tidal characteristic data for the relevant day, and time of the storm, were extracted from the NIWA wave database, the NIWA atmospheric pressure database and the NIWA tidal forecaster respectively. These values were used as input for the computer routine used to find and rectify the waterline within the averaged video images. All data sourced to calculate runup in this study is relative to chart datum.

1.5 Thesis Aims and Objectives

The aim of this study was to create a new technique for predicting the probability of inundation that is based on measuring run-up variation using sub-aerial video imagery of a beach. This was achieved by measuring waterline variations over a complete tidal cycle during storm events, by collecting pixels from video images along a cross-shore transect (timestack). The maximum swash excursions were then digitized from the timestacks, and rectified to provide runup timeseries.

The principal advantage of this technique is the fact that quantitative data will be measured from video which will effectively eliminate the difficulties associated with insitu experiments, as discussed in Chapter 2. Validation of this technique included carrying out field work at both sites with the purpose of making comparisons between surveyed and videoed results. Furthur validation consisted of comparisons of videoed results with those found using empirical runup formulae.

The specific objectives of this study are to:

i) create a Matlab computer routine to digitize maximum swash excursions from timestacks to provide run-up timeseries with duration 15 minutes;

ii) create a Matlab computer routine to rectify run-up elevation by measuring the variation of the waterline over a tidal cycle from time-averaged video images during a storm event;

iii) test how the run-up predictions from the computer routines compare with field calibrations and empirical run-up predictions, and;

iv) produce a tool that will contribute to implementing kaitiakitanga (guardianship) priorities including the planning and supervision of all coastal developments and other taonga (important resources) with iwi and hapu (Maori tribes and sub-tribes).

1.6 Thesis Structure

Following the introductory chapter, this thesis is divided into 6 additional chapters.

Chapter 2: This chapter discusses video imaging systems, rectification processes and the Collinearity Equations, along with the modifications made as part of this study. It also describes the Matlab computer routines which are used to:

- i) identify shorelines within the image (using gradients in the ratio of different light or hue intensities in the image);
- ii) rectify images, and;
- iii) provide runup timeseries over a wide range of spatial and temporal ranges using video timestacks

Chapter 3: This chapter details the field work carried out at each site to test the accuracy of the runup results obtained using the computer routines, by quantifying the error associated with mapping the waterline with video.

Chapter 4: This chapter analyses the runup results obtained using video and from field work. This section also details the runup results obtained using existing empirical run-up formulae for contrast against videoed runup results and discusses the comparability between the two methods.

Chapter 5: This chapter details information gathered from various sources around New Zealand, and relevant literature, regarding mitigation measures employed by Maori to protect and preserve coastal waahi tapu against inundation.

Chapter 6: This section specifies the conclusions of the study and discusses further research relevant to this work which should be carried out for validation purposes.

1.7 Definitions

There are a wide variety of definitions for runup and the shoreline in the literature which causes the results of studies to be interpreted differently. For purposes of this study, runup is defined as the water-level elevation maxima (NIELSEN and HANSLOW, 1991; STOCKDON *et al.*, 2006) measured on the foreshore with respect to the still water level (SWL). For a given set of wave conditions, the runup elevation can be divided into two components; set-up and swash. Set up is defined as the mean water surface elevation above the SWL, while swash is taken as the time-varying vertical fluctuation about the set-up level (GUZA and THORNTON, 1982; STOCKDON *et al.*, 2006). Many studies have used the term runup to describe discrete maximum elevations rather than a continuous process, and have made no distinction between setup and swash (HOLLAND and HOLMAN, 1993). This is not representative of the true nature of runup and so for this work the swash maxima is defined as the elevation between *any* crest in runup elevation and the setup level as shown in Figure 1.5. This definition of local swash maxima is different to the zero-crossing definition, commonly used in other research, which does not account for waves with elevations below the SWL and therefore only allows for positive maxima.

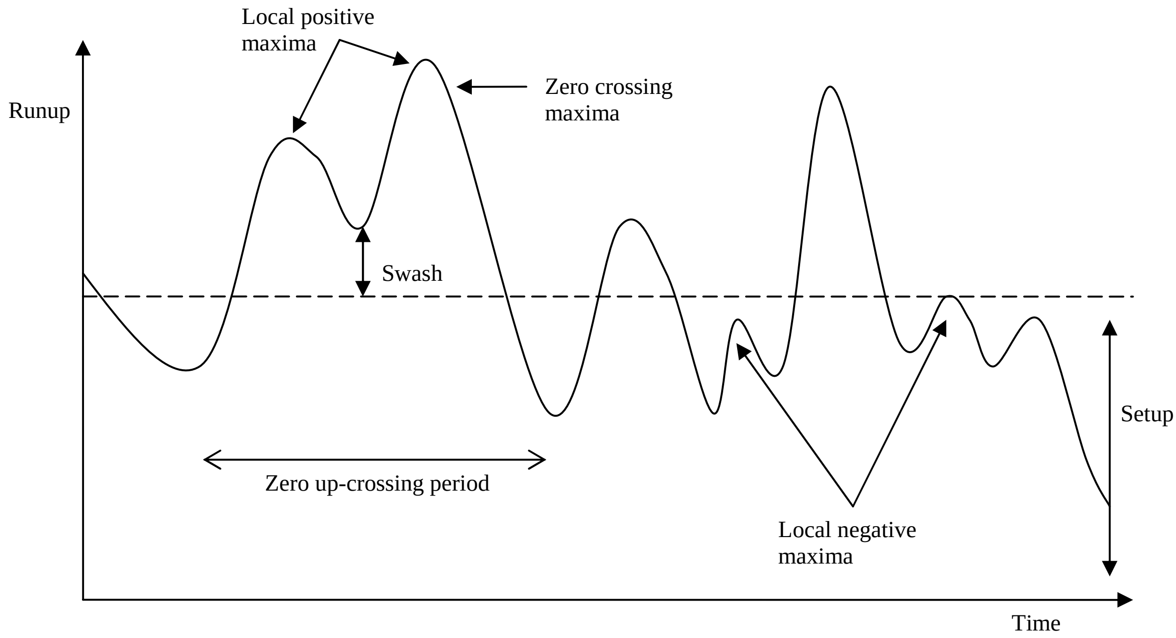


Figure 1.5: Definition of runup variables (Re-drafted after HOLLAND and HOLMAN, 1993)

In this paper the terms run-up and swash will be used interchangeably to refer to the continuous oscillations of water across the beach-face. All runup statistics estimated by video include set-up which is calculated using the formula by BOWEN *et al.*, (1968) (detailed in the following chapter).

In order to accurately determine runup it is important to define the shoreline so that swash excursions along the foreshore slope can be converted into meaningful vertical swash elevations (HOLMAN *et al.*, 1991). Figure 1.6 illustrates the various definitions of the shorelines used in the literature. An idealized definition of the shoreline is that it coincides with the physical interface of land and water (DOLAN *et al.*, 1980). Despite its apparent simplicity, this definition is a challenge to apply in practice. In reality, the shoreline position changes continually through time and so it must be considered in a temporal sense, and the time scale chosen will depend on the context of the investigation (BOAK and TURNER, 2005).

The waterline detection techniques used in this study analyse time-averaged colour video images to identify a beach contour which corresponds to some location within the swash zone, as yet unknown, which is associated with a particular level of swash exceedence (AARNINKHOF *et al.*, 2003). This location would ideally be the MWL. The definition of the MWL is trivial at positions where the bed is at all times covered by water. However, between the extreme positions of the instantaneous waterline, various definitions might be possible. In all cases in this study, the shoreline is referred to as the waterline and is defined as the position where the MWL intersects the beach face (i.e. where the surface elevation of the water is equal to the elevation of the beach face). As noted by NIELSEN (1989), this definition of the waterline is different from the average position of the waterline, which is in fact not even a position on the beach face unless the beach face is straight.

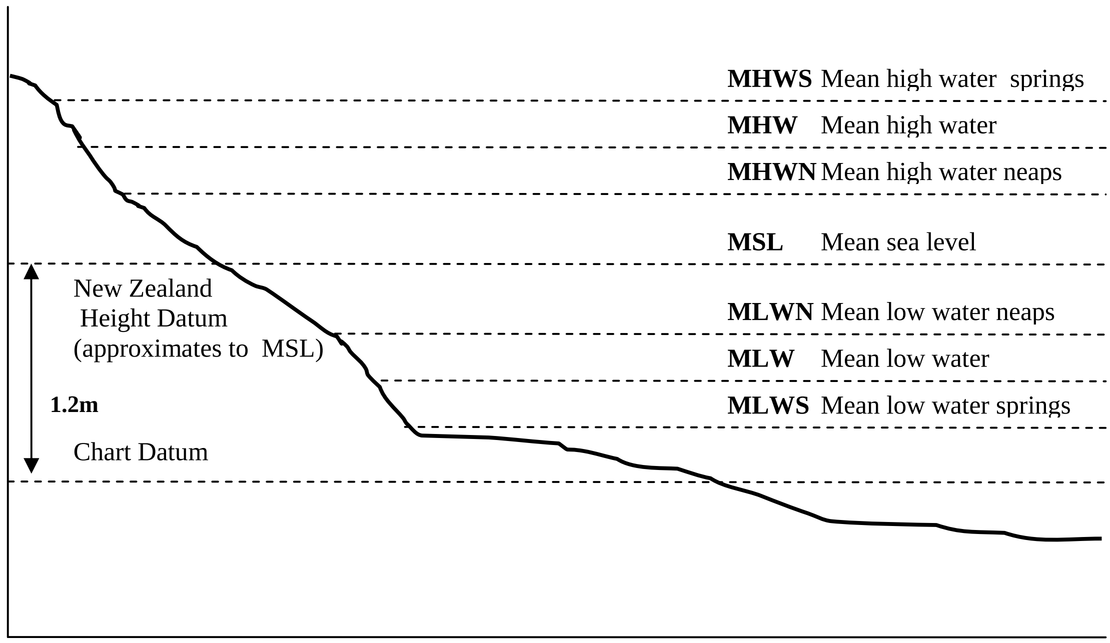


Figure 1.6: Definitions of the shoreline (Re-drafted after BOAK and TURNER (2005).

Chapter 2

Video Image Analysis

2.1 Introduction

Instrument deployment in the very active and unpredictable nearshore coastal region can be extremely difficult, time-consuming and expensive. Because of this, video monitoring of beaches is quickly becoming a preferred technique for observing changes to nearshore morphology over a wide range of spatial and temporal scales. In contrast to other measurement techniques, video imaging is relatively in-expensive, extremely reliable and low maintenance. Video techniques are particularly appealing in the documentation of nearshore oceanographic processes since the subaerial location of the instrument (distance from the ocean surface) alleviates some difficulties associated with *in situ* instrumentation, namely flow disturbance, biofouling, and sensor deterioration under adverse wave conditions (HOLLAND, 1997). This chapter describes the processes used to extract quantitative information, associated with locating the waterline (MWL) and determining runup elevations, within the video images.

The video imaging station overlooking Tairua is situated on the southern headland, Paku Hill, which is 70.5 m above chart datum. The system at Pauanui is also located on the southern headland, Pauanui Mountain, which is 122m above chart datum. Both systems consist of a camera and computer which automatically collect a time-series of images at set intervals every daylight hour and offer a view which covers an area of dunes, beach and surfzone (BOGLE *et al.*, 2001). The automated collection of the images is controlled by the on-site computer which also undertakes the initial processing of the images before it stores and archives them.

2.2 Types of Video Images

The full colour images are made up of an array that defines red, green and blue components for each pixel within the images. (i.e. RGB colour space). The colour of each pixel can be ascertained by the combination of the red, green and blue intensities stored in each of the three colour planes at the pixels location. On the basis of this, it is assumed that each pixel within an image has distinctive intensity characteristics which will assist in identifying various features within the images. The technique used in this work takes advantage of this fact to enable delineation of the waterline using video.

Initial processing of the 760 x 570 images performed automatically by computer produces three types of images:

1) snapshots,

2) averaged images, and;

3) timestacks.

Averaged images and timestacks were used in this study.

2.2.1 Averaged Images

Averaged images are a series of snapshots averaged over 15 minutes, (Figure 2.1). The averaging eliminates the variability in the run-up height of individual waves giving a stable image (LIPPMANN and HOLMAN, 1989) and a clear indication of the average height of the run-up. This enables identification of the occurrence of erosive events. These images were used to measure the variation of the waterline over a tidal cycle during storm events by collecting pixels along a cross-shore transect and supplied measurements of the beach slope which ultimately were used to make estimates of the run-up elevations.

2.2.2 Timestacks

These are timeseries of pixels collected over 15 minutes covering a cross-shore transect on the beach face (i.e. (x,y) = (95,248) to (760,248) at Tairua and (x,y) = (248,243) to (760,243) at Pauanui where x and y are the horizontal and vertical pixel dimensions in the image. The origin (0,0) is at the top lefthand corner of the image), (Figure 2.2). These images were used to measure runup elevation by collecting pixels corresponding to the highest level of the swash (i.e. the swash maxima).

Figure 2.1: Averaged video image taken at Pauanui Beach during a storm event occurring on 6/8/2006.

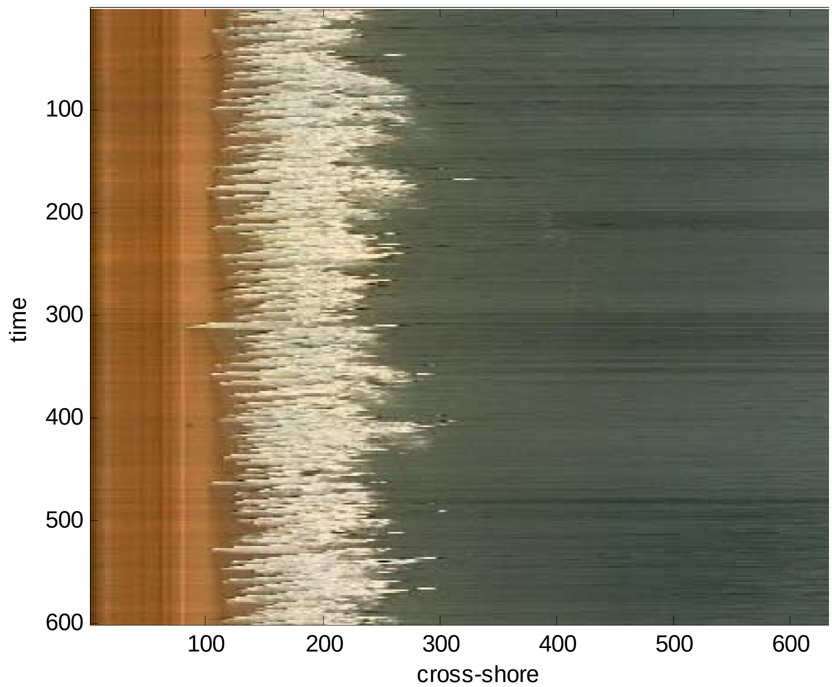


Figure 2.2: Timestack video image showing the cross-shore location of the runup edge (where the time units = 1.5 seconds).

2.3 Image Analysis I: Determining the Waterline

For this study, Matlab computer programs were written to determine the waterline at Tairua and Pauanui. In the case of finding the waterline at Tairua, a computer routine was created which searched the images for gradients in colour intensity based on work done by SMITH and BRYAN (2007). Differentiation using a constant colour ratio did not work well, consistently finding a waterline either landward or seaward of the assumed waterline, so an interactive system was developed that searched the image for gradients in the ratio of red to green light. The rationale behind this is that the sand should have a higher ratio of red colour due to the high shell content on the beach and the sea should have a higher ratio of green colour. This was achieved by examining a small area of the beach in the image to investigate the average ratio of red to green light in the chosen area, (Figure 2.3). This value was used as a representative of the ratio for the whole beach in the image. This was repeated within the surfzone to obtain a representative of the mean ratio for the surf in the image. Providing the image was clear enough (i.e. weather conditions were good) to distinguish between colour intensities, the waterline could be accurately determined.

Figure 2.3: Video image showing a digitised shoreline at Tairua Beach found using a Matlab computer routine which identified gradients in the ratio of red to green light intensities within the image by sampling a portion of the beach sand and the surf (marked boxes in this case).

The shell content at Pauanui Beach is not as abundant as it is at Tairua, so the computer routine used to detect differences in light intensities did not work as well here. Therefore, another program was written (based on work by AARNINKHOF *et al*,. 2003) that delineated a waterline feature by converting the raw image intensities in RGB colour space in the image to Hue-Saturation-Value (HSV) colour space. In HSV images the hue component of the pixels varies from red, through yellow, green, cyan, blue, magenta and then back to red; the colours within each pixel become saturated (meaning they contain no white component); and the value (i.e. the brightness) within the image is increased to its maximum value. This method enabled distinctions of pixel characteristics to be made and therefore waterlines to be successfully determined (Figure 2.4). The thresholds used for both of the waterline finding routines are detailed below.

2.3.1 Finding a Threshold for the Waterlines

On both beaches, a user defined threshold was used to differentiate beach and surf pixels. Ideally the threshold should be as objective as possible. Through trial and error it was found that an accurate threshold for Tairua was:

threshold = mean(surf) + 0.5 * (mean(beach)-mean(surf))

where "surf" and "beach" are the average red-to-green ratios of the surf and beach respectively. For Pauanui Beach a hue threshold of 1.5 was used.

Both thresholds were tested on a diverse range of images and gave robust results accept on rare occasions. For example, if the image was very dark, or if the camera lens was covered with rain droplets due to rain, fog and the like, it became very difficult for the computer program to distinguish differences in pixel characteristics. Because of this, part of the computer routine allowed the shoreline to be manually digitised. Unfortunately, when this was necessary, the problem of subjectivity regarding determining the waterline introduced a possible source of error.

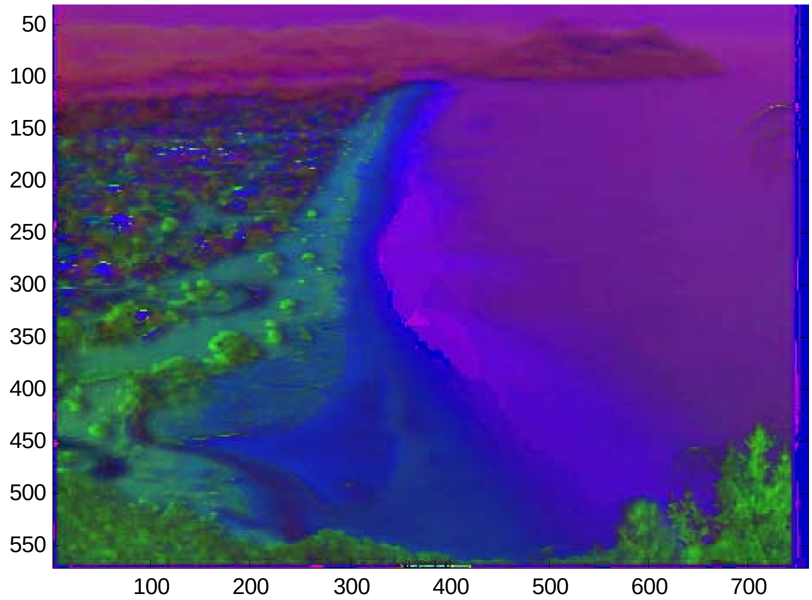


Figure 2.4: Top: Video image showing the variation in the hue component identified using the Pauanui shoreline finding computer routine. Bottom: Averaged video image showing a digitised shoreline at Pauanui Beach found by detecting variation in the hue component within the image.

2.4 Rectification

Although video images are useful for collecting qualitative data, rectification of the image must first be carried out in order to extract quantitative data. Rectification involves photogrammetric transformations which enable pixels (2-D image coordinates) to be converted into spatial scales of units of metres (3-D reference coordinates), allowing collection of useful coastal state information. Two sets of parameters are involved in this transformation. The first gives the geometrical description of the camera, where known ground-control points (Figure 2.5) are used to derive optimal values for the camera position and orientation (external camera parameters). The other set gives the physical characteristics of the lens, the camera and the hardware used (internal camera parameters), (HOLLAND *et al.*, 1997). Internal camera calibrations provide estimates of the effective focal length (*f*), aspect ratio, optical centre and distortion coefficients. This was performed using software provided by HEIKKILA and SILVEN (1996).

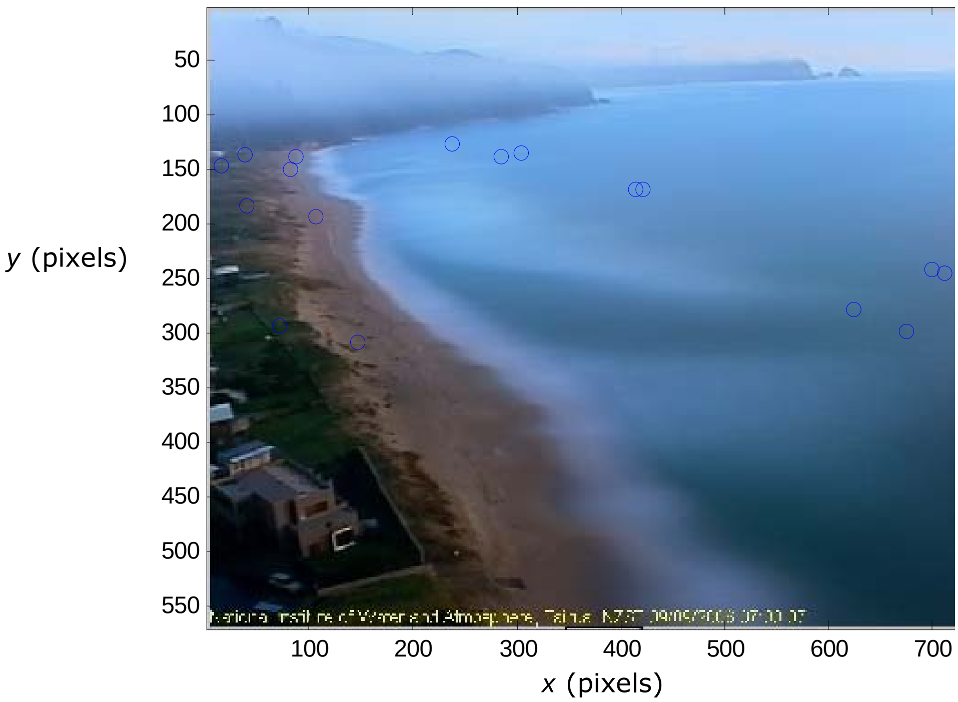


Figure 2.5: Averaged video image showing the surveyed ground control points used at Tairua Beach

The combination of the internal and external camera calibrations provided estimates of the camera position (X_0, Y_0, Z_0, where Z is the vertical dimension) and orientation (swing, φ, tilt, τ, and azimuth, σ) which were used to transform between image coordinates (x,y) into real-world coordinates (X,Y,Z). This transformation was accomplished using the collinearity equations.

2.4.1 Collinearity Equations

Multi-camera algorithms are founded on the theory of a central perspective projection. The associated theory enables sets of equations to be written which relate each point on an object to a set of measurements made in the image space (Figure 2.6). These equations are known as collinearity equations and many examples of their derivation exist in literature. Each collinearity equation contains several unknowns such as camera position and orientation as mentioned above. The collinearity equations are

$$X = (Z - Z_0).Q + X_0, \tag{1}$$

$$Y = (Z - Z_0).P + Y_0, \tag{2}$$

where,

$$Q = \frac{(m_{11}x + m_{21}y - m_{31}f)}{(m_{13}x + m_{23}y - m_{33}f)}, \tag{3}$$

and

$$P = \frac{(m_{12}x + m_{22}y - m_{32}f)}{(m_{13}x + m_{23} - m_{33}f)}, \tag{4}$$

where m_{ij} are the elements of the 3x3 orthogonal rotation matrix M and are known as direction cosines that can be derived in terms of three successive rotations about the angles swing tilt and azimuth, as explained by HOLLAND *et al.*, (1997).

$$M = \begin{pmatrix} \cos(\alpha) & \sin(\alpha) & 0 \\ \sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\tau) & -\sin(\tau) \\ 0 & \sin(\tau) & \cos(\tau) \end{pmatrix} \begin{pmatrix} -\cos(s) & -\sin(s) & 0 \\ -\sin(s) & \cos(s) & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{5}$$

In order to use the collinearity equations to transform between x,y and X,Y a known value of Z (the vertical dimension) must be supplied.

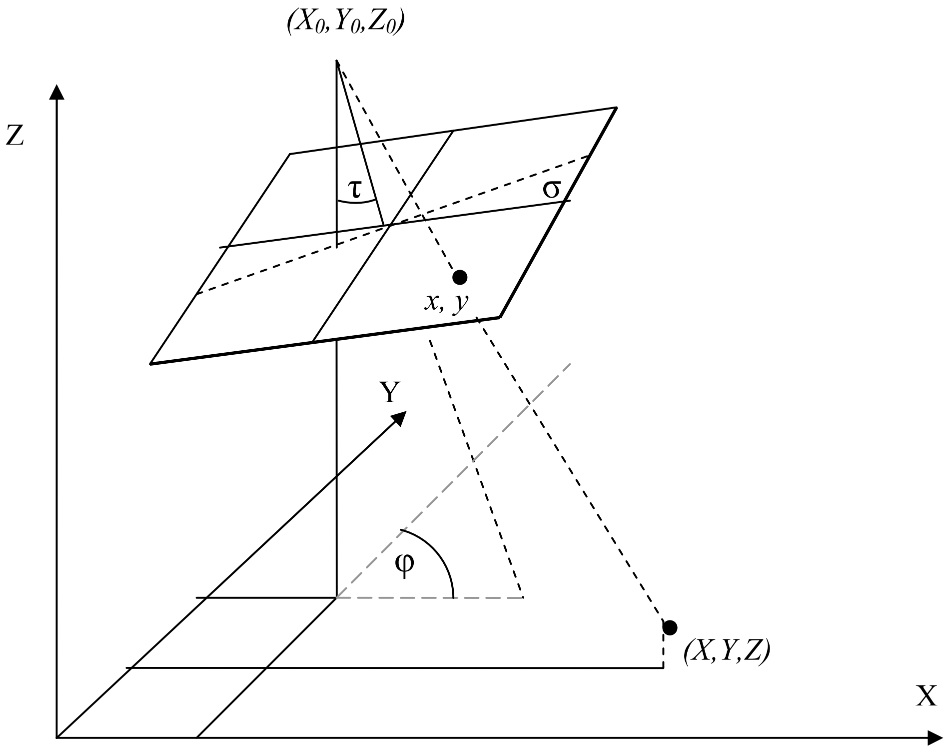


Figure 2.6: Collinearity relationship between camera *((X_0,Y_0,Z_0))* and image *(x,y)*, and world coordinates *(X,Y,Z)* and rotation angles *(τ,φ,σ)* used in the orientation definition (Re-drafted after HOLLAND *et al*., 1997)

2.5 Camera Movements

In 2001 and 2003 at Tairua, and in 2004 at Pauanui, camera calibrations were carried out by NIWA in order to calculate the internal and external camera parameters necessary for rectification. As a result of such things as vandalism, overgrown trees and shrubs, and being too exposed to the weather, slight camera movements occurred and as a consequence the camera parameters changed. Unfortunately calibrations were not carried out to account for these movements. This meant that the camera parameters were no longer known for any images taken after the dates of these movements. For this reason, tests were carried out to find when the movements had occurred and adjustments were carried out accordingly. It was necessary to do this so that the waterline statistics attained through rectification of the images were relevant to accurate locations in the real world.

By digitising landmarks within the images (rooftops and the mountain range in this case) taken directly after the respective camera calibrations were carried out, the pixel coordinates were collected. The same landmarks, in a representative image of each storm used in the study, were also digitised and the data collected. By overlaying these digitised points over the top of the calibrated data it is possible to see the offset between the two (Figure 2.7). Adjusting the tilt, swing and azimuth angles (internal camera parameters associated with camera orientation) within the waterline finding computer routine, allowed corrections to be made, so that pixel coordinates within every image could be accurately rectified.

Figure 2.7: Averaged image showing digitised landmarks from a 2004 video image overlain onto a 2006 image (with the same digitised landmarks). This shows how much the camera has moved.

2.6 Foreshore slope

In the case of estimating run-up from video, we do not want to make a prior assumption of the value of Z (vertical elevation of the foreshore). Ideally, we would like to use the information supplied by video to infer Z as well as X and Y. It is possible to collect information on the foreshore slope by tracking the edge of the waterline in the time-averaged images as the tide ranges from low to high (or vice versa). If the beach face is linear, this information can be used to define foreshore slope, a, and intercept, b, where

$$Z = aX + b \tag{6}$$

which provides an estimate of the Z value needed for rectification.

Comparison with beach surveys at Tairua and Pauanui have shown that this provides a fairly accurate estimate of foreshore slope, and that both beaches do have linear intertidal regions as necessitated by the method. Combining Equations (1), (2), and (6) gives:

$$X = \frac{Qb - QZ_0 + X_0}{(1 - aQ)}, \tag{7}$$

and

$$Y = \frac{Pb - PZ_0 + Y_0}{(1 - aP)}, \quad . \tag{8}$$

which provides the runup excursions (which can be converted into elevations using Equation (6)) with no prior knowledge of Z.

2.6.1 Wave Set-up and the Inverse Barometer Effect

In order to obtain accurate results, the Z used in determining slope and intercept in equation (6) should also include the influence of set-up (η_{setup}) and the inverse barometer effect. Set-up causes an elevated water level inside the surf zone. In the absence of measurements of set-up and detailed surf-zone wave information, empirical formulae are used to calculate wave set-up. In this study the formula by BOWEN *et al.*, (1968) is used which assumes normally incident shallow-water waves whose height is limited to a constant fraction of the water depth within the surf zone. The resulting equation is:

$$\eta_{setup} = \frac{3}{8}\gamma^2 \frac{(h_b + \eta_{tide})}{\left(1 + \frac{3}{8}\gamma^2\right)^2} \qquad (9)$$

where η_{tide} is the the tidal input and h_{b} is the shallow-water water depth, defined as

$$h_b = \frac{H_{rms}}{\gamma} \ , \qquad (10)$$

and H_{rms} is the deepwater root mean square wave height. A γ of 0.4 is used which is roughly consistent with observations (e.g. RUESSINK *et al.*, 2003).

The inverse barometer effect was included in the water level as a 0.1 metre sea level rise for every 10 hPa drop in atmospheric pressure that occurred during the passage of the low-pressure systems associated with each storm event. Appendix 1 details the tide, set-up, atmospheric pressure, and wave height data measurements, for all of the storms referred to in this study, at both sites for reference.

2.7 Rotating the Shorelines

After rectification, the shorelines were rotated so that the cross-shore profiles used to define the slope and intercept, in equation 6, were aligned along the profile that the timestack was taken. This was achieved by plotting the shorelines within a storm event and through trial and error, adjustments were made to the value of the azimuth (one of the camera orientation parameters) to rotate the shorelines. These results are recorded in Table 2.1. Figures 2.8 show the plotted shorelines at Tairua Beach before (Figure 2.8 (top)) and after they are rectified and rotated (Figure 2.8 (bottom)).

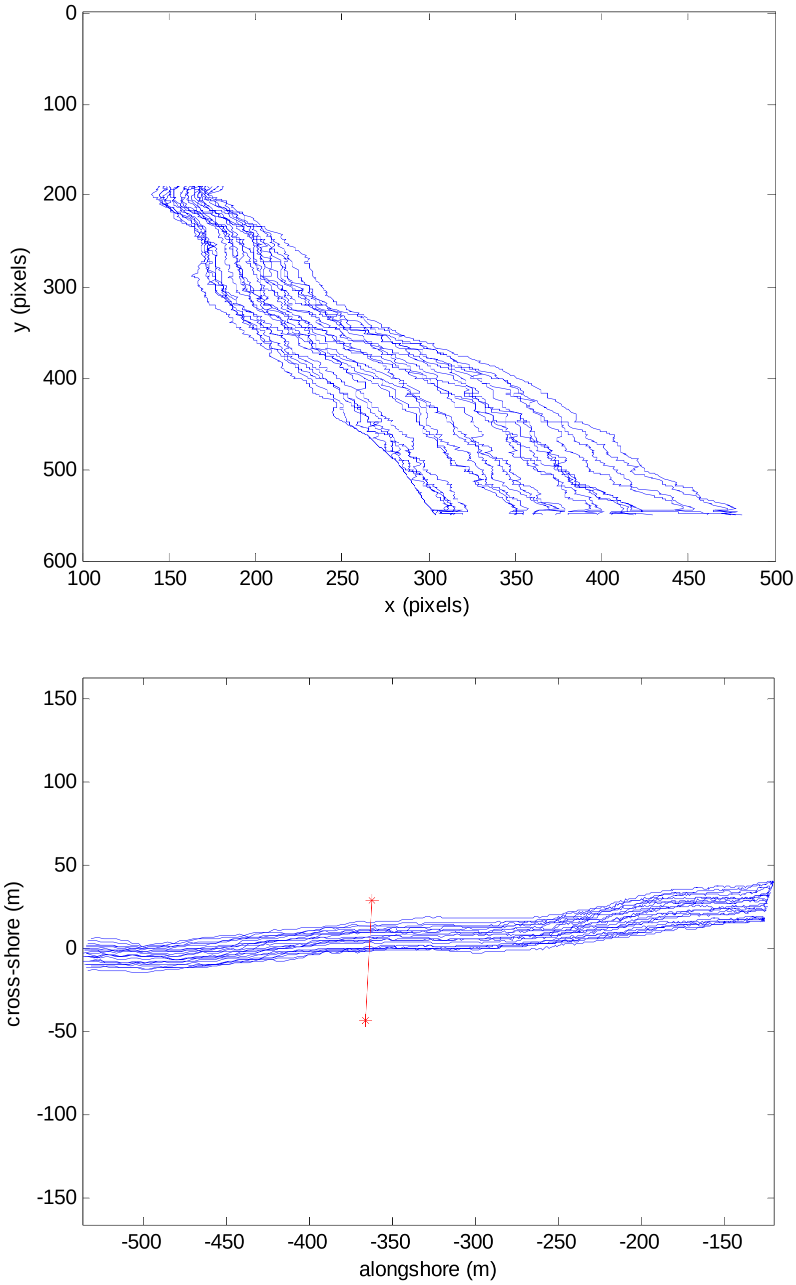


Figure 2.8: Top: Full tidal cycle of unrectified and unrotated shorelines for a storm event at Tairua Beach. Bottom: After rectification, adjustments were made to the azimuth angle so that cross-shore profiles were ligned along the profile within the timestack. (The red line indicates the position of the transect used in the timestack video images).

Table 2.1: Rotation angles (degrees) applied to an internal camera parameter (azimuth) to rotate shorelines.

Tairua		Pauanui	
Year	Rotation	Year	Rotation
2001	56.5	2006	69.0
2003	59.0	2007	70.0
2006/ 2007	61.5		

Theoretically, if the measurements are rectified to NZMG (New Zealand Map Grid) coordinates, the images should always be rotated by the same amount since the beach should not change its general orientation. The difference between rotation angles is most likely the result of adjustments made to images after corrections were made to the camera orientation parameters after movements occurred.

2.8 Results

The data was collected over a tidal range of 1.98m (min 0.23m, max 2.21m), and a wave height range (significant offshore wave height) of 1.5 to 4m. Beach slopes and intercepts for each storm are recorded in Table 2.2 and 2.3 below. The beach slopes at Tairua are varied and as expected mostly correspond to angles associated with an intermediate beach state (i.e. between 0.05-0.20, or longshore bar and trough/ transverse bar and rip intermediate beach slopes (WRIGHT and SHORT, 1984)). However some of the estimated beach slopes suggest the beach can be reflective and near dissipative at times, in agreeance with COCO *et al.*, (2004). The Pauanui beach slope values were quite high considering this beach appears to have a low slope and this implies that at times this beach can be in an intermediate beach state. The intercept results are dependent on the value of the rotation angle input into the computer program. As long as the rotation angle is consistent this should not cause a problem.

Goodness of fit statistics (r^2) between the waterline elevations and the cross-shore location (at the longshore location of the timestack) were also carried out to test the reliability of the data, (Figure 2.9). The regressions for most storms were good and all storms at both sites had $r^2 > 0.5$ (refer Table 2.2).

Table 2.2: Beach slopes, beach intercepts and r^2 results for Tairua Beach.

Storm Event	Beach Slope	Beach Intercept	r^2
1	-0.0733	2.5855	0.9703
2	-0.0866	2.1722	0.8935
3	-0.0852	2.3845	0.8755
4	-0.0787	2.3535	0.5179
5	-0.1437	2.6947	0.7789
6	-0.1470	2.5472	0.8624
7	-0.1004	2.6592	0.6797
8	-0.0708	2.3769	0.7142
9	-0.0753	2.1512	0.699
10	-0.0831	1.8676	0.6228
11	-0.1072	1.4922	0.7836
12	-0.1386	1.2995	0.954
Overall Mean	-0.0992	2.2154	0.7793
Overall Minimum	-0.1470	1.2995	0.5179
Overall Maximum	-0.0708	2.6947	0.9703

Table 2.3: Beach slopes, beach intercepts and r^2 results for Pauanui Beach.

Storm Event	Beach Slope	Beach Intercept	Regression
1	-0.0362	1.6111	0.5973
2	-0.0698	1.1224	0.5326
3	-0.0692	1.1951	0.6963
4	-0.0928	1.4482	0.7973
Overall Mean	-0.067	1.3442	0.655875
Overall Minimum	-0.0928	1.1224	0.5326
Overall Maximum	-0.0362	1.6111	0.7973

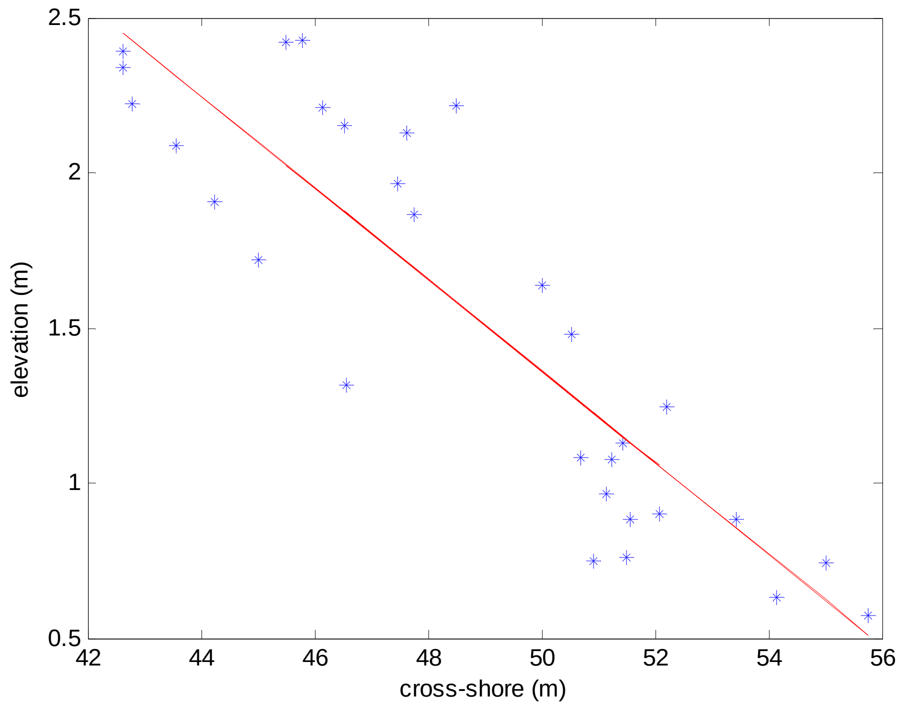


Figure 2.9: Waterline heights versus cross-shore location at the longshore location at which the timestack was collected (pixel coordinate y = 248 where y is the vertical pixel coordinate in the image) for a storm event at Tairua Beach (r^2 = 0.78).

2.9 Indistinct Shorelines

It is important to note that whenever it became apparent that the waterline finding computer routine was not accurately finding a shoreline within an image, the image was discarded from analysis. Most of the images that were cut were done so due to blurring caused by poor weather conditions (i.e. fog, cloud and rain). However in some instances, when lens issues were not a concern, the distinction of the shoreline was still difficult to determine due to what appears to be an incoherent waterline (Figure 2.10). To ensure accurate statistics the regression data was checked for any outliers that coincided with these images.

Figure 2.10: Averaged video image showing an indistinct waterline which may make it difficult for the computer routine to find an accurate waterline. This shoreline showed as an outlier within the regression data for this storm (shown in Figure 2.11).

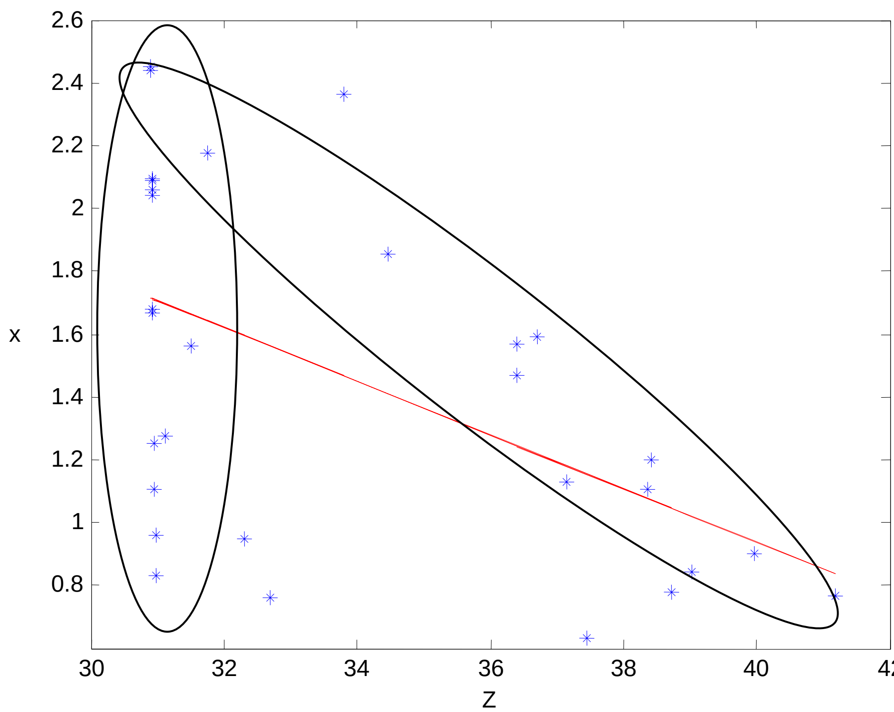


Figure 2.11: Regression showing two trends within the shoreline data for a storm event at Tairua Beach.

In Figure 2.11 it is clear that there are two trends in the regression data (circled) that indeed coincided with images with indistinct shorelines. In this case, this is assumed to be due to infragravity energy present in the swash signal (discussed in Chapter 4) at the height of the storm (which is at low tide in this case) because infragravity wave heights and orbital velocities increase towards the waterline (AAGAARD and MASSELINK, 1999). The waterline detected in the image by the computer routine therefore appears to be higher than it would actually be. This mostly occurred in the images of Pauanui Beach. ROZYNSKI (2007) found that the beginning of storm recession guarantees a strong presence of infragravity waves on dissipative shores and this may be the reason behind the incoherency of the waterline at this site.

Other reasons for shoreline tracking inaccuracies include foam accumulation associated with high energy conditions, (BAILEY and SHAND, 2005) and the development of a seepage face (this is especially relevant on more dissipative beaches with finer grain sizes, such as Pauanui, and is explained in more detail in the following chapters).

2.10 Video Image Analysis II: Run-up Elevations

The most difficult part of this study, and indeed for all studies involved in determining wave runup, is to establish the position of the shoreline in the runup distribution (related to finding an accurate beach slope and beach intercept in this case). By doing so it is then possible to ascertain what percentage of the waves are expected to exceed the shoreline (NEILSEN and HANSLOW, 1991) and furthermore enable coastal management groups to make accurate assessments of extreme runup elevations and their probability of occurrence on beaches.

Here we define run-up as the maximum swash excursion and include set-up determined using the empirical formula by BOWEN *et al.*, (1968). Run-up variations were measured by collecting pixels from the video images along a cross-shore transect (i.e from the timestack images (Figure 2.12)). In the case of Tairua, the image coordinate equivalent to the real-world ground coordinate for the cross-shore transect in the timestack is $(x,y) = (95,248)$ to $(760,248)$, where x and y are the horizontal and vertical image coordinates (Figure 2.13 (left)). At Pauanui the image coordinates are (x,y) = (248,243) to (760,243) (Figure 2.13 (right)). Each swash maxima were digitised and the intertidal bathymetry data (i.e. beach slope and intercept) were used to rectify them onto the plane of the beach. This provided data applicable to the real world and supplied run-up timeseries with duration 15 minutes for analysis.

For each storm, on the day when the storm was most intense, runup measurements were digitised over a complete tidal cycle so comparisons between the two tidal extremes could be investigated. Figure 2.14 shows examples of the histograms of runup swash maxima collected at a specific tidal level (low tide in this case) where runup elevations are plotted against the frequency of the occurrence of the runup elevations, and zero is the MWL. In some cases however, the timestacks relating to the day of highest storm intensity could not be used. This was mainly because the images were unclear due to rain or fog present at the time the images were taken. Because the video images are only recorded during daylight hours, in some instances a full tidal cycle was not available for analysis on the day of highest intensity. When one of the mentioned problems occurred, another day (a day either side of the day of highest intensity) was chosen for analysis.

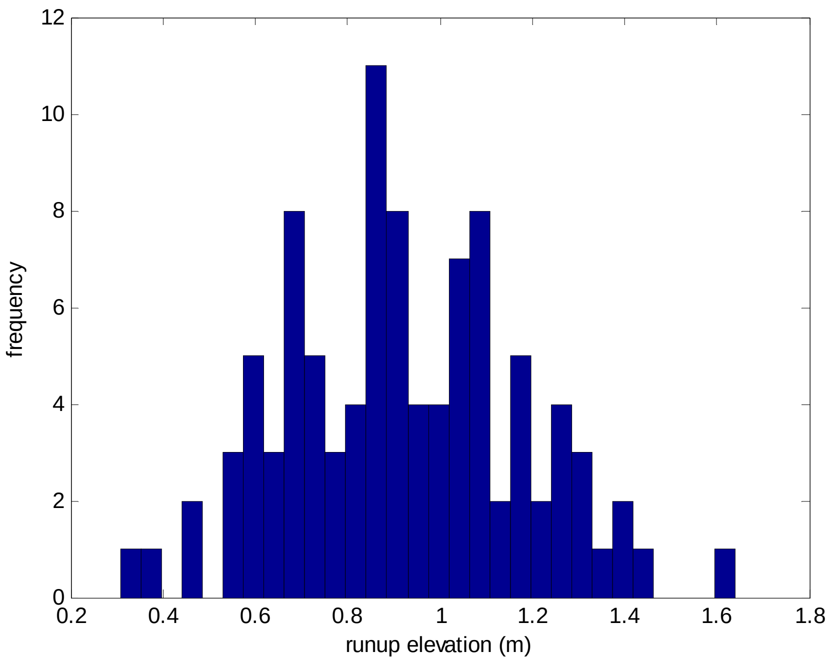


Figure 2.14: Histogram of low tide runup elevations (collected by digitizing the highest elevation of the swash within the timestack images) against the frequency of the occurrence of the runup elevations.

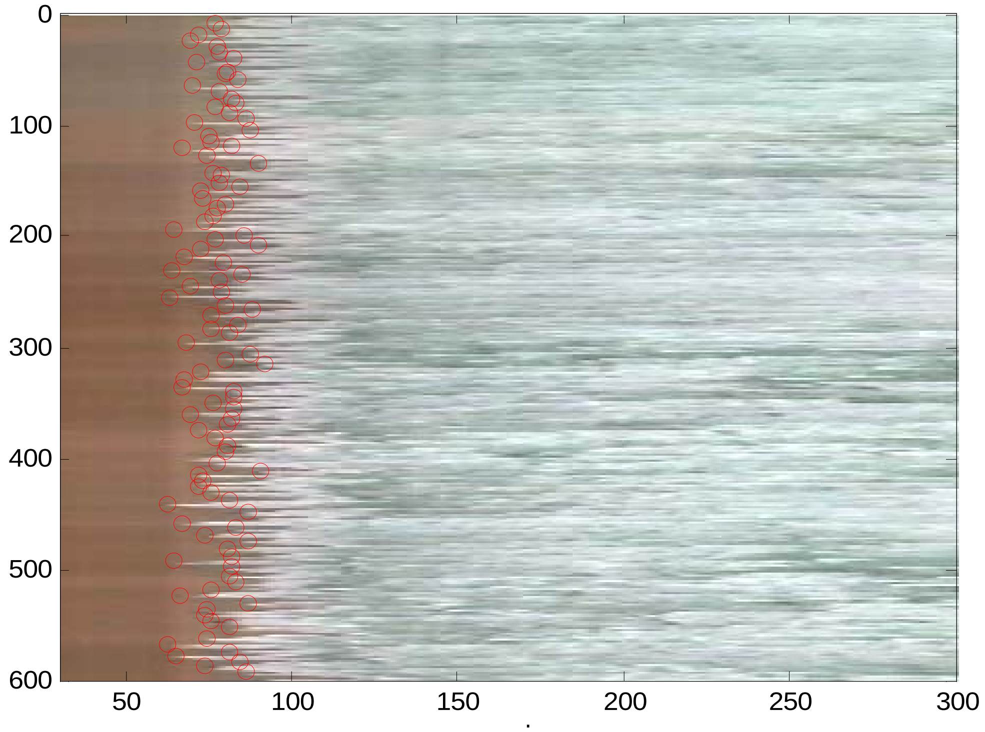


Figure 2.12: Waterline variation (run-up timeseries duration 15 minutes) manually digitized using a Matlab computer routine (time is shown on the vertical axis and the cross-shore in pixel coordinates is shown along the horizontal axis).

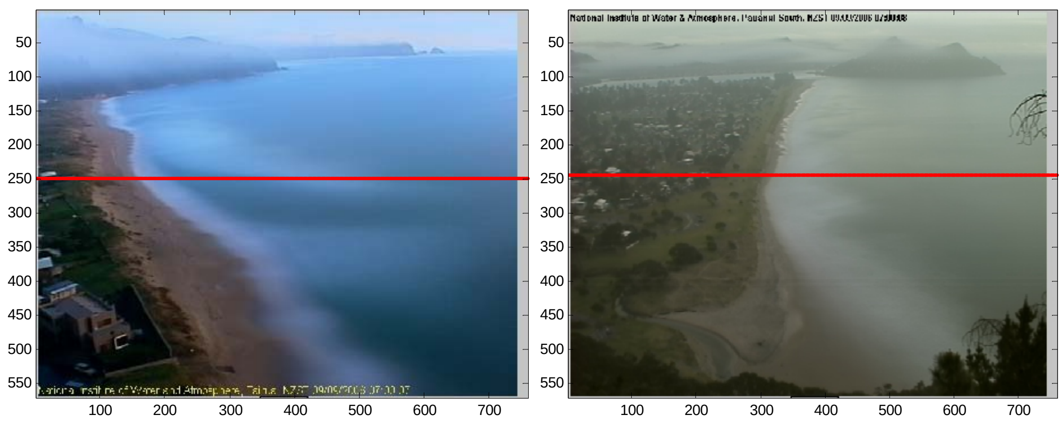


Figure 2.13: Averaged video image of Tairua Beach (left) and Pauanui Beach (right) showing position at which timestacks are taken (i.e. (x,y)=(95, 248) to (760,248) and (x,y) = (248,243) to (760,243) respectively, where x and y are the horizontal and vertical axes (units are image coordinates).

2.11 Possible Errors

Errors associated with video runup measurements are discussed by HOLMAN and GUZA (1984); HOLMAN and SALLENGER (1985); HOLLAND *et al.*, (1995), and BAILEY and SHAND (2005). These are detailed below:

i) *Variations in Digitization*: Some of the images were blurry or unclear due to, for example, rain, and fog. This meant that in some instances the shoreline needed to be manually digitized. Because these shorelines were not determined using the objective computer routines, the position of the shoreline was estimated by the programmer and therefore introduced an element of subjectivity. This in turn can introduce bias in beach morphology and run-up statistics. However, this was rare (3%) and most of the images were clear enough for analysis.

ii) *Position of Camera*: Cameras are often positioned on top of high buildings, towers, radio antenna sections, or in this case, on mountains, that are difficult to survey and may change orientation slightly over time or abruptly during intense winds. Even after proper design, it is difficult to maintain a stable target in such a hostile environment. This did in fact occur in this case (high winds caused a slight change in camera orientation) however these movements were accounted for (discussed earlier) so that any camera movements did not significantly affect the rectification process needed to attain quantitative data.

iii) *Ground Control Points (GCPs)*: Perhaps the biggest limitation for nearshore studies using video cameras is that only a small portion of the field of view may contain GCPs given that the majority of the view is ocean. However, to overcome this, both Tairua and Pauanui used waterbased GCPs.

iv) *Image Resolution*: In the video images the ground footprint of pixels farther from the camera cover a larger area than those pixels closer to the camera. As a result, any data analysed in the pixels furthest from the camera are less accurate than those that are closer.

v) *Algorithm Inaccuracies*: In this study this relates mainly to changes in light conditions and hue saturation values. Slight variations in the colour or hue of the beach sand relative to the water caused by lighting and breaking variations can cause inaccuracies in the waterline finding program, along with blurring in the image caused by fog and rain on the lens. However the computer routines used in this study accounted for this by sampling regions from both the sand and beach within the images and the results collected are reliable.

vi) *Tracking Errors*: These are associated with video images with rain and cloud induced low contrast, foam accumulations caused by high energy conditions, camera vibrations caused by high winds, infragravity wave action and groundwater seepage which all make the images less distinct and therefore increase the probability of estimation error. These images were discarded from the study.

2.12 Summary

Video monitoring of beaches is becoming the preferred technique for observing changes to nearshore morphology over a wide range of spatial and temporal scales. This chapter described the processes used to extract quantitative information, associated with locating the waterline (MWL) and determining runup elevations, within the video images. Computer programs were written to determine the waterline at Tairua, by searching the images for gradients in colour intensity, and at Pauanui, by converting the raw image intensities in RGB colour space in the image to Hue-Saturation-Value (HSV) colour space.

The Collinearity Equations, which relate each point on an object to a set of measurements made in the image space, were used to convert 2-D image coordinates (x,y) into 3-D reference coordinates (X,Y,Z), (i.e rectification). However, in order to use the equations the vertical reference coordinate (Z) had to be supplied. This was achieved by tracking the edge of the waterline in the time-averaged images throughout a tidal cycle. This information was used to define foreshore slope, a, and intercept, b, where $Z = aX + b$, and provided an estimate of the vertical dimension needed for rectification. Goodness of fit statistics of the waterline elevations against the cross-shore location (at the longshore location of the timestack) were > 0.5 for all storms and proving the data collected was reliable.

The second part of the chapter described the process related to determining runup elevations from video. Run-up variations were measured by collecting pixels from the video images along a cross-shore transect in the time-stacks. Each swash maxima was digitised and the beach slope and intercept data was used to rectify them onto the plane of the beach. This provided run-up timeseries for analysis.

Chapter 3

Field Calibration

3.1 Introduction

Field work was carried out at each site to compare insitu and video analysis results. Calibrating the videoed results was achieved by comparing the waterline transgression statistics (i.e. the percentage of waves that transgress the MWL) in the field against waterline transgression statistics digitised from timestack images. The field experiments were based on those conducted by AAGAARD and HOLM (1989), and NIELSEN and HANSLOW (1991) where runup data was collected by counting the number of waves passing markers (i.e. pipes and stakes in this case) of known elevations. The markers were dug into the beach face between the low and high tide mark (Figure 3.1, top and bottom) along the cross-shore transect corresponding to the position of the transect within the timestacks.

The field experiments were carried out on different days; 25/10/2007 at Tairua, and 7/11/2007 at Pauanui. The swash maxima data were collected one hour after low tide for 15 minutes, and every hour for 15 minutes after that, until one hour before high tide (5 hours in total). The waterline (or MWL) for each hour in the field was measured using a length of pipe (1.3m in length, 5cm diameter) with one end of the pipe covered with mesh. The pipes were dug into the sand and their positions were surveyed. The permeability of the mesh allowed water to seep up through the sand and into the pipe. The pipe blocked out any affects of wave action on water level measurements, allowing truthful measurements of the MWL to be obtained.

Figure 3.1: (Top and Bottom) Pipes and stakes were dug into the beachface between the high and low tide levels to measure the mean water levels and the mean water level transgression rates. These pictures were taken at Tairua Beach.

The days of the field experiments were both calm days. The offshore wave heights at Tairua and Pauanui ranged between 0.48-0.51m, and 0.55-0.58m respectively. Tidal ranges were 0.45-2m, and 1-1.9m and relative to chart datum (i.e. where mean sea level = 1.2 metres). Using a Total Station, the beach profile was surveyed at the site of the cross-shore transect position in the timestack images (i.e. pixel coordinates (95,248) and (760,248) for Tairua and pixel coordinates (248,243) and (760,243) for Pauanui). As expected the beach surveys show that Tairua is steeper and narrower in the cross-shore than Pauanui Beach, (Figure 3.2).

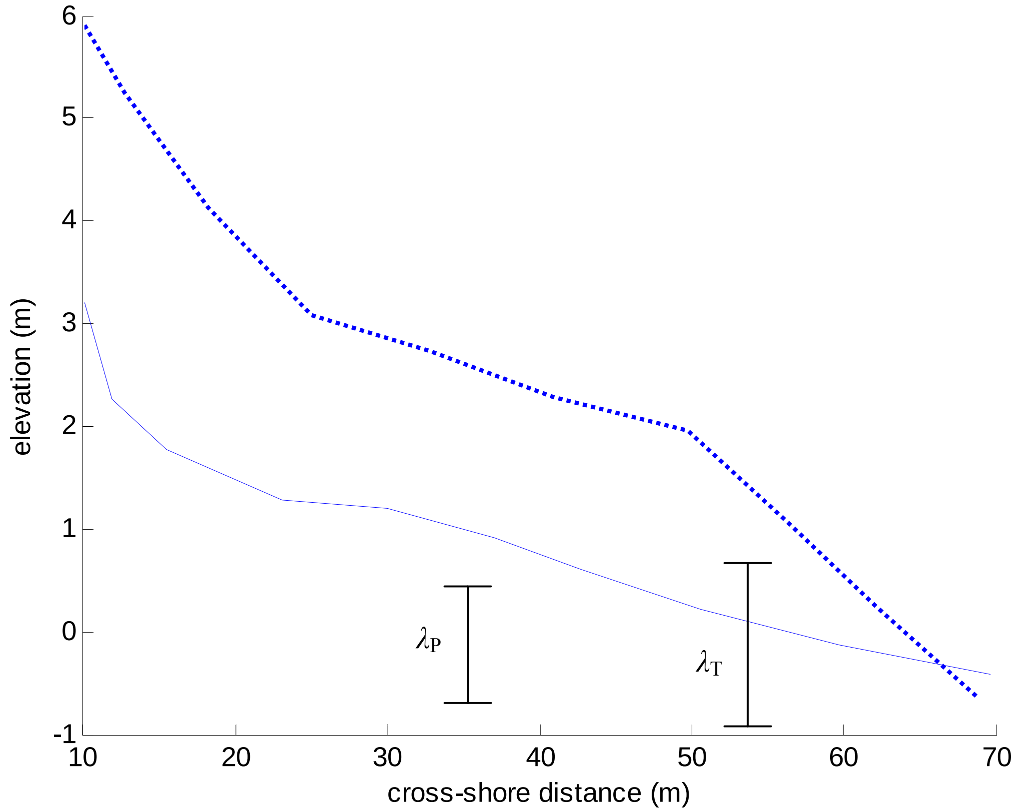


Figure 3.2: Beach profiles of Tairua (dashed line) and Pauanui (unbroken line) relative to NZ chart datum where zero is equal to the mean water level. Intertidal regions for Tairua and Pauanui are shown (λ_T and λ_P respectively). Intertidal beach slopes were 0.1375 at Tairua and 0.039 at Pauanui.

3.2 Beach Slope and Intercept

Achieving accurate runup results using video is dependant on locating an accurate waterline. To achieve this, it was important to obtain the correct beach slope and especially the correct beach intercept at the time of the storm (which were then used to find the vertical dimension of the waterline in real-world coordinates, (i.e. $Z = aX + b$, where a is the beach slope and b is the beach intercept). The primary difficulty with natural beaches is the fact that the meaning of beach slope is not trivial (NEILSEN and HANLSOW, 1991). For reflective and intermediate beach types the problem of determining the beach slope is significant due to large slope variations in the alongshore, and between the beach face and the surf zone. For dissipative beaches the overall nearshore slope compared to the beach face slope is typically small and so definitions are not as difficult. Ideally the beach slope should be representative of the whole nearshore region because variations in slope will affect the physical characteristics of runup (i.e. the vertical elevation of the runup) and therefore influence the runup statistics. However, surveying within the surfzone, especially during storm events, is difficult and therefore not always possible. For purposes of this study, the slope of the intertidal beach face is used to define the beach slope because this is the slope that the video is finding.

The surveyed waterline elevations enabled determination of the intertidal beach slopes at the two sites: 0.14 and 0.032 for Tairua and Pauanui respectively. Waterline measurements from video for the corresponding field date estimated a beach slope of 0.15 at Tairua and 0.39 at Pauanui which are very comparable. The slight variations in slope are either associated with inaccurate waterline positions found by video or an error associated with surveying at a location that is slightly different to the cross-shore transect used within the timestack (i.e. because alongshore variations in beach slope are so great). However, every effort was made to avoid this, and easting and northing positions were determined by rectifying the pixel coordinates in the timestacks in order to locate the position on the ground using a GPS.

Finding an inaccurate beach intercept means the waterline will either be landward or seaward of the real position of the waterline. Consequently, this will affect the swash exceedency results. Assessing the accuracy of the videoed beach intercept statistics involves determining the waterline transgression statistics from video and survey and finding the offset between the two, in units of metres. To enable this, the waterline in the field must firstly be located.

3.3 Locating the Waterline in the Field

On the days of the insitu experiments, the water levels inside the pipes were measured every hour, one hour after low tide until one hour before high tide, using a dipwell plumb. Figures 3.3 and 3.4 show the surveyed beach profile data and water heights collected over the five hour period at the two sites. In the Figures the intersection between the water and the sand is clear (i.e. the MWL). Digitisation of these points gave the horizontal and vertical locations of the MWL at the time of the recording interval. Also apparent in the Figures is the presence of a seepage face around the low tide mark which is the result of a high water table.

A seepage face is a dynamic feature and by definition is the region where the waterline and the water table intersect with the beach face (ROBINSON, 2004), (Figure 3.5). The elevation of groundwater increases with fine sediments, increasing tidal range and increasing exposure to waves. Not only does the presence of a seepage face make infiltration of tidal input slower, it is likely to present problems in regards to determining the position of the waterline in the video images at any position lower than the exit point of the groundwater. In reality the development of a seepage face will also increase wave set-up because the drainage of this input is less efficient if the water table is high. However, this is not accounted for in this study when calculating set-up (using the formula by BOWEN *et al.*, 1968).

Unfortunately, the field data was surveyed from an arbitrary location on the top of the foredune so direct comparisons between field and video data (relative to chart datum) could not be achieved. Instead, waterline transgression statistics were used to assess the waterlines found using the two methods.

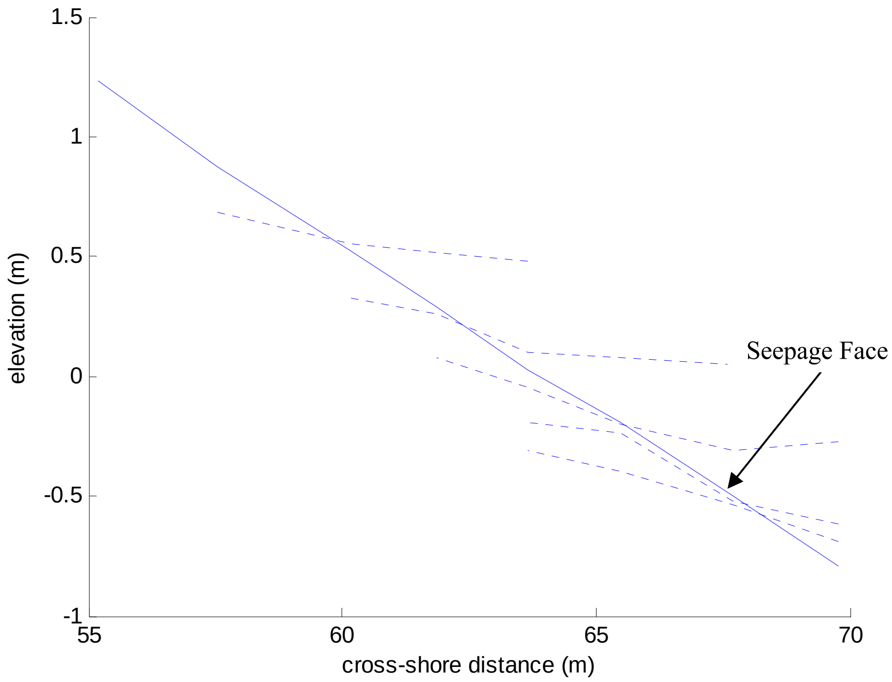


Figure 3.3: Cross-section of Tairua Beach (25/10/2007) showing the beach profile (unbroken line) and the surveyed mean water levels (dashed lines) recorded over a 5 hour period between low and high tide.

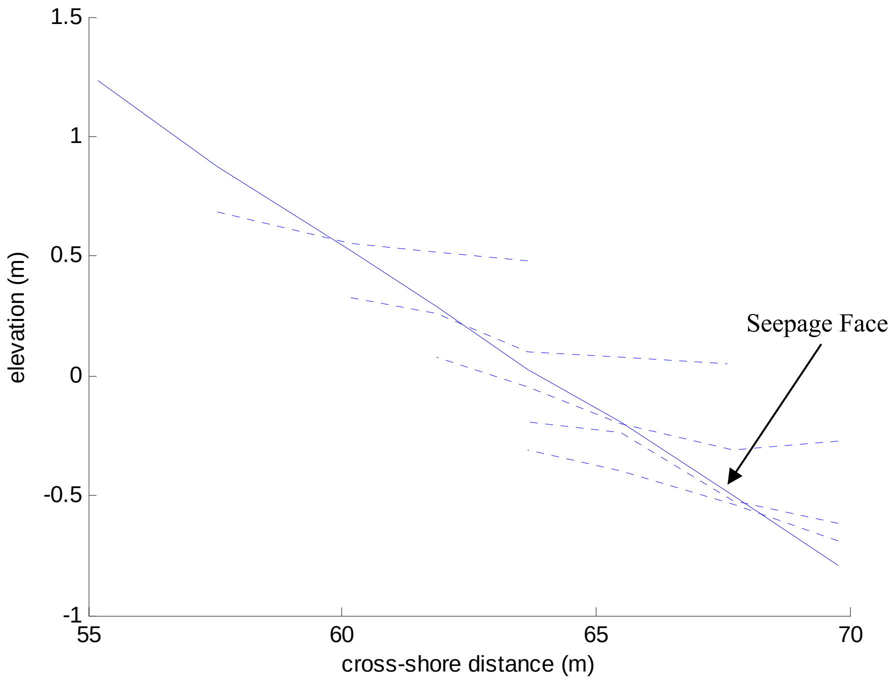


Figure 3.4: Cross-section of Pauanui Beach (7/11/2007) showing the beach profile (unbroken line) and the surveyed mean water levels (dashed lines) recorded over a 5 hour period between low and high tide.

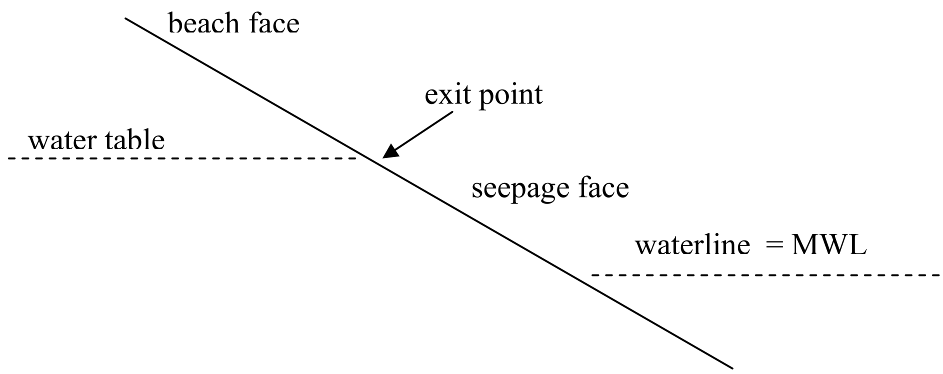


Figure 3.5: Cross section of a beach that has developed a seepage face due to a high water table (Re-drafted after ROBINSON, 2004).

3.4 Assessments of the Videoed Waterline

The waterline that is measured using video is ideally the MWL as discussed in Chapter 2. By determining the probability of swash maxima exceedence (i.e. the number of waves that transgress the MWL at the time the data is collected) using video and in the field, for the same day and times, assessments of the accuracy of the videoed waterlines can be made. In other words, if the probabilities of exceedence are the same, then the waterlines that the computer routines are finding are reliable. However, if the probabilities are biased, then the routines are finding a waterline that is either landward or seaward of the actual waterline and this error needs to be quantified. Consequently, this correction will be used for the remainder of the study.

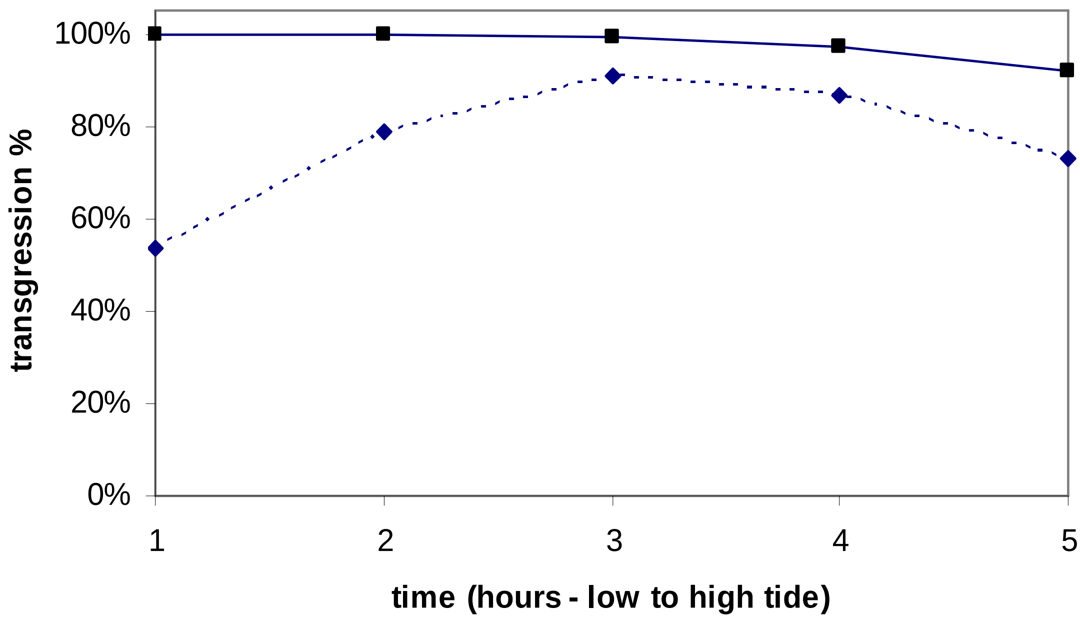
Firstly, the waterline transgression percentages, using the two methods (i.e. video and survey), at the two sites were determined. In the field, this was achieved by counting the number of waves running up past each of the markers (n_i) and dividing this number by the total number of waves recorded during the recording interval (N). Because the elevations of the markers were known, the location on the beach that corresponded to a particular percentage of waterline transgressions could be calculated. (For example, if over a 15 minute recording interval we count a total number of 100 waves and 50 of these waves run up past the second marker, we know that 50% of the waves run up to a position that is between the location of the second and third markers). Since the horizontal and vertical locations of the MWL are also known, it is possible to calculate the percentage of waves that run up past this point and attain transgression statistics relative to the MWL.

The digitised swash maxima from video (timestacks) gave swash maxima data relative to the (assumed) MWL. By removing the tide from the digitised data it was possible to determine the percentages of waterline transgressions by dividing the total number of swash that are greater than zero (i.e. the MWL) by the total number of digitised swash for that recording interval. The exceedence percentages of the assumed MWL measured using video, and the surveyed MWL for the 5 hours in the field (i.e. 1 hour after low tide to 1 hour before high tide) at each site are shown in Figure 3.6 (top and bottom).

Comparisons show that the videoed waterline transgressions are consistently higher than surveyed waterlines and this corresponds to a waterline that is seaward of the actual waterline. Determining the offset between the videoed and surveyed waterlines involves quantifying the vertical offset (in units of metres) of the two waterline finding methods (i.e. determining the correct beach intercept value, 'b') as discussed later in the chapter.

The surveyed swash exceedency rates at Tairua are consistently higher than at Pauanui, at all levels throughout the tidal cycle and this is most likely because Tairua is the steeper of the two beaches. NEILSON and HANSLOW (1991) concluded in their work that beach steepness affects the waterline transgression statistics due to the drainage efficiency of the sediments associated with the various beach states. Steeper beaches drain more efficiently than flatter beaches and therefore the MWL establishes itself at a comparatively low position relative to the runup distribution. Consequently, most of the waves transgress the MWL. At dissipative beaches with fine grain sands, such as Pauanui, the drainage of water infiltrated from runup will be much slower and MWLs are located relatively close to the runup limit. Transgression of the waterline is therefore decreased.

The offset at Pauanui is fairly consistent throughout the tidal cycle with only slight deviations, however at both beaches the offset at and around the low tide mark is greater than the offsets occurring at other levels of the tide. This is most likely a result of the seepage faces present at both beaches at the time of the surveys.



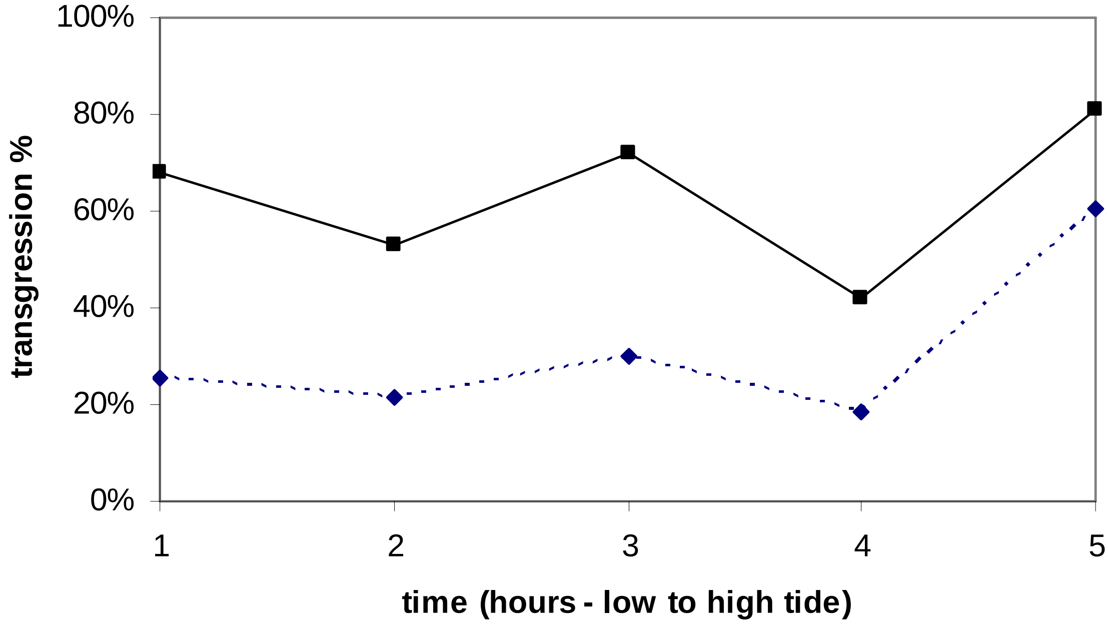


Figure 3.6: Comparisons of the transgression distributions for runup at Tairua Beach (top) and Pauanui Beach (bottom) measured by survey (dashed line) against measurements estimated by video (unbroken line) at corresponding times throughout a tidal cycle (low to high tide).

3.5 Error Quantification

In the field, the total number of waves for each recording period (duration 15 minutes) were counted. The individual number of waves running up past each marker, of known elevations, on the beach face, and the position of the MWL for each recording period, is also known. Subsequently, it is possible to calculate the position on the beachface that corresponds to a certain number of waterline transgressions. For example, If 80% of the waves transgress the MWL found using video and 50% of the waves transgress the MWL found by survey for the same date and time, then it is possible to determine the offset between the videoed and surveyed waterlines by finding the elevations equivalent to the positions on the surveyed beachface that correspond to the 50% and 80% waterline transgression positions. By subtracting one from the other gives the offset (b_{offset}) between the two waterline finding methods for that particular tidal level (i.e. $b_{\text{offset}} = \Delta Z_{\text{survey}} - \Delta Z_{\text{video}}$, where ΔZ_{survey} and ΔZ_{video} are defined as the vertical elevations, corresponding to a particular waterline transgression statistic relevant to the MWL at a certain tidal level, determined using survey and video respectively), as illustrated in Figure 3.7.

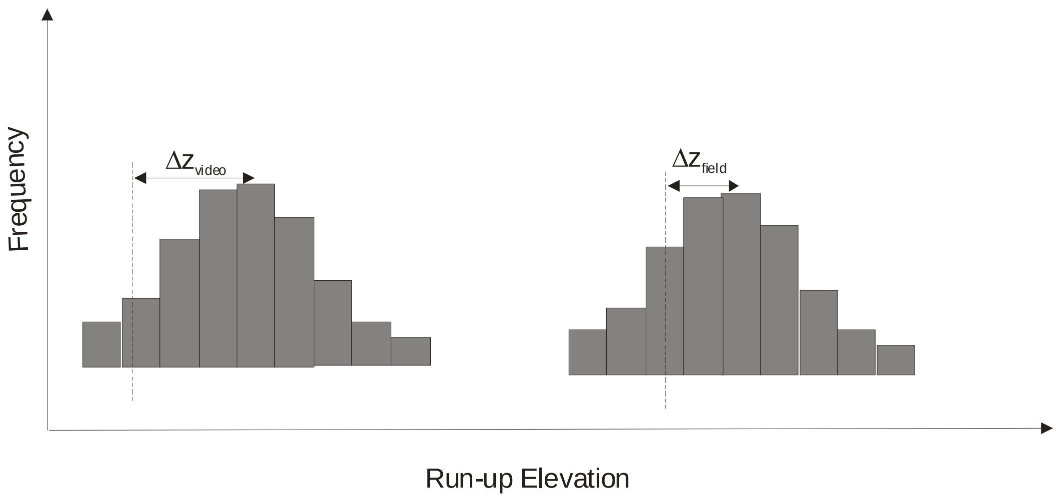


Figure 3.7: A schematic showing the different positions of the MWL within the runup distributions found using video (left) and in the field (right). The offset (b_{offset}) is given as $b_{\text{offset}} = \Delta Z_{\text{survey}} - \Delta Z_{\text{video}}$, where ΔZ_{survey} and ΔZ_{video} are defined as the vertical elevations, corresponding to a particular waterline transgression statistic relevant to the MWL at a certain tidal level, determined using survey and video respectively).

Because the exact elevation of each swash maxima counted in the field was not known (because each maxima occurred between two markers), the distance between the relevant markers was averaged to find an approximate offset in units of metres (Figure 3.8).

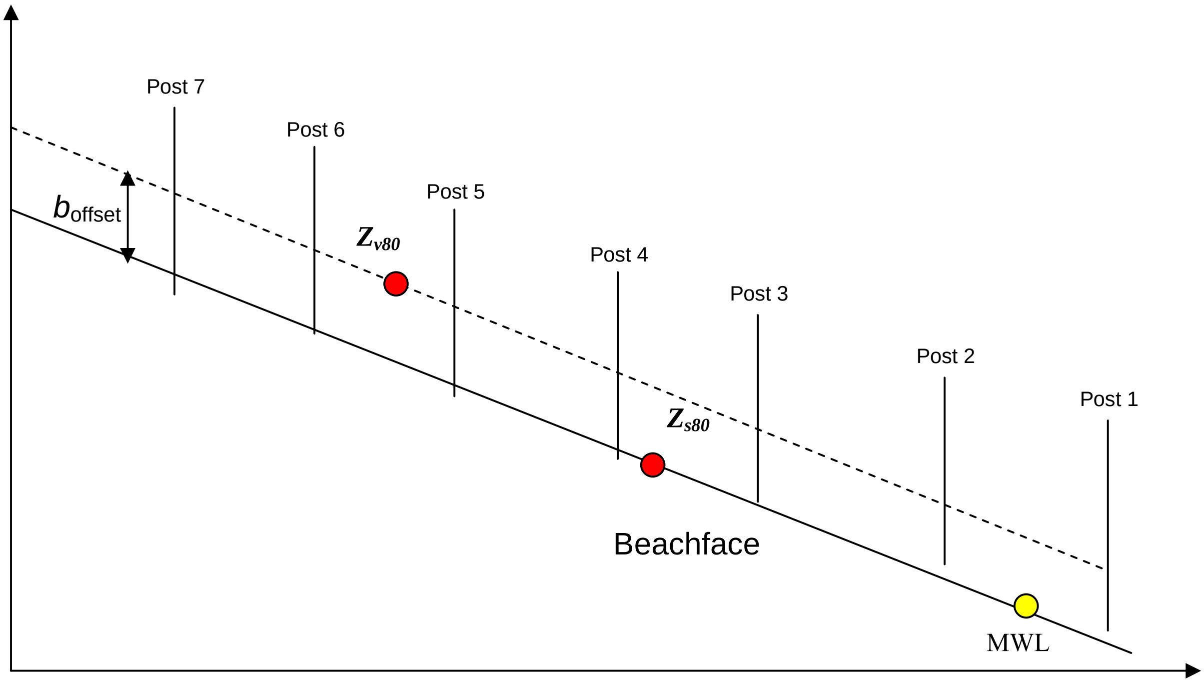


Figure 3.8: Schematic of the surveyed beach profile (unbroken line), the positions of the poles on the beachface, and the measured MWL (yellow circle). The red circles represent the elevations at which 80% of the waves transgressed the surveyed (Z_{s80})and the videoed (Z_{s80}) MWLs revealing a waterline that is seaward of the real waterline (dashed line). The offset between the two (i.e. b_{offset}) is the vertical difference between the two waterlines, in units of meters.

Table 2.1 below details the offsets of the surveyed and videoed waterlines determined through field calibrations. Calculations revealed a mean vertical offset equivalent to 0.33 metres at Tairua and 0.25 metres at Pauanui. It makes sense that Tairua has the bigger vertical offset because this is the steeper of the two beaches. However, this corresponds to a horizontal offset that is much bigger at Pauanui (6.95 metres compared to 2.43 metres at Tairua) because of its flatness and the associated characteristics of flat beaches (i.e. low drainage efficiency and high water tables), which has obviously made it more difficult for the video to find the actual waterline in the images. It is important to note that it is the horizontal dimension of the runup that is the most significant to coastal management groups, because this concerns how high the swash will runup on the beach face.

Table 3.1: Wave exceedency percentages at Tairua (T) and Pauanui (P) measured by survey (s) and estimated by video (v), and the offsets (b_{offset}) between the two waterlines (in units of metres) measured using the two techniques.

Tide Level	T(s)	T(v)	T(b_{offset})	P(s)	P(v)	P(b_{offset})
low+1	67.9%	100.0%	0.52	25.5%	67.8%	0.10
low+2	56.1%	100.0%	0.49	21.7%	53.0%	0.35
low+3	90.7%	99.0%	0.15	30.2%	71.9%	0.19
low+4	86.7%	97.0%	0.18	18.4%	42.0%	0.29
low+5	73.1%	92.0%	0.33	60.7%	81.1%	0.34
Average Offset (T)			0.33	Average Offset (P)		0.25

The offset (i.e. b_{offset}) between the surveyed and videoed waterlines, at both sites, are quantified and will be applied to all analyses of runup statistics for the remainder of the study, so that the vertical elevation of the waterline (Z) is now represented as

$$Z = aX + b + b_{offset}.$$

At Tairua this means

$$Z = aX + b + 0.33,$$

and at Pauanui

$$Z = aX + b + 0.25.$$

Both of these corrections are approximations to the real correction.

Seepage
Face

3.6 Summary

Field work was carried out at each site to compare insitu and video statistics associated with finding an accurate waterline and consequently an accurate beach slope and intercept. Surveys of the beach profiles were carried out along a cross-shore transect corresponding to the transect used in the timestacks. The mean water levels at each level of the tide (over a 5 hour period) were measured and recorded, and waterline transgression data was collected by counting the number of waves passing markers of known elevations on the beachface. These statistics enabled comparisons between surveyed and videoed beach slopes and intercepts (which relates to the vertical scale of the waterline and can be determined by comparing the waterline transgression statistics).

The beach slopes found by video were comparable to those determined in the field and the differences between the two are negligible; however the waterline transgressions statistics found using video were consistently higher for every hour throughout a tidal cycle at both sites. This meant that the waterline found by video was seaward of the real waterline at both locations. Quantification of this error revealed a vertical offset of 0.33m at Tairua which corresponds to a horizontal offset of 2.43m. The vertical offset at Pauanui is 0.25m with a horizontal offset of 6.95m. The corrections, are approximations to the real correction, and will be applied to all beach intercept values used to measure runup using video for the remainder of the study, to account for the waterline finding error.

Chapter 4

Runup Observations

4.1 Introduction

Here runup is defined as the water-level elevation maxima on the foreshore relative to the still water level (SWL). The runup elevation can be divided into two components; set-up and swash, where set up is defined as the mean water surface elevation (MWL) above the SWL, and swash is the time-varying vertical fluctuation about the set-up level. Setup is at all times included in the runup statistics analysed in this chapter, and is calculated using the empirical formula by BOWEN et al., (1968). The swash maxima are defined as the elevation between *any* wave runup crest and the setup level, including the elevations of wave crests below the MWL, and so allows for both positive and negative maxima.

The quantification of the offset between the videoed and surveyed waterlines in the previous chapter enables analysis of the runup statistics measured using video. The accuracy of these results are important in regards to assessing the risk of inundation at any given beach and will provide a tool for coastal management groups to utilise when determining coastal hazard zones. The corrections (i.e. 0.33m at Tairua and 0.25m at Pauanui) have been applied to all runup elevations used for analysis in this chapter.

The mean, minimum, and the maximum swash excursion heights were recorded for each hour, over a full tidal cycle for each storm, at both sites, for comparison within and between events and between sites (See Appendix 2). The recorded mean values for each level of the tide were then averaged to give an overall mean of the runup heights throughout a tidal cycle for each storm (Ω_M). The highest (Ω_H) and lowest (Ω_L) runup values recorded over a complete tidal cycle for each storm were also recorded allowing the runup variance (Ω_V) to be calculated. These statistics for each storm at

Tairua and Pauanui are shown in Table 4.1 and Table 4.2 respectively.The beach slopes (β) and the standard deviations (Ω_S) for each storm are also detailed.

Table 4.1: Summary of the runup statistics for storm events at Tairua Beach (where β is beach slope, Ω_M is the mean runup over a tidal cycle, Ω_H and Ω_L are the highest and lowest elevations recorded over a tidal cycle respectively, Ω_S is the runup standard deviation and Ω_V is the runup variance). All data is in units of metres.

Storm	(β)	(Ω_M)	(Ω_H)	(Ω_L)	(Ω_S)	(Ω_V)
1	0.073	0.75	-0.33	1.46	0.22	1.79
2	0.087	0.69	-2.37	2.38	0.66	4.75
3	0.085	0.69	-1.01	1.86	0.41	2.87
4	0.079	0.77	0.04	1.48	0.19	1.43
5	0.144	0.45	-0.39	1.25	0.20	1.65
6	0.1470	0.52	-0.18	1.17	0.19	1.35
7	0.065	0.22	-0.70	1.12	0.27	1.82
8	0.083	0.67	-0.61	2.47	0.49	3.08
9	0.107	0.77	0.16	1.51	0.19	1.35
10	0.139	0.24	-0.33	1.18	0.23	1.50
Overall Mean	0.101	0.57	-0.53	1.54	0.29	2.07
Overall Min	0.065	0.22	-2.37	1.05	0.09	1.13
Overall Max	0.101	0.77	0.16	2.47	0.66	4.75

Table 4.2: Summary of the runup statistics for storm events at Pauanui Beach (where β is beach slope, Ω_M is the mean runup over a tidal cycle, Ω_H and Ω_L are the highest and lowest elevations recorded over a tidal cycle respectively, Ω_S is the runup standard deviation and Ω_V is the runup variance). All data is in units of metres.

Storm	(β)	(Ω_M)	(Ω_H)	(Ω_L)	(Ω_S)	(Ω_V)
11	0.069	-1.78	-5.14	0.76	0.66	5.90
12	0.070	-0.34	-4.17	1.47	0.94	5.64
13	0.093	-1.20	-6.85	1.15	0.61	8.01
Overall Mean	0.08	-1.11	-5.39	1.13	0.74	6.52
Overall Min	0.69	-1.78	-6.85	0.76	0.61	5.64
Overall Max	0.093	-0.34	-4.17	1.47	0.94	8.01

4.2 The Statistical Distribution of Runup

Tests were carried out to examine whether the runup distributions followed a Gaussian (standard normal) or Rayleigh distribution. To test for a standard normal distribution, the runup maxima probability density function given a Gaussian distribution was investigated (Figure 4.1).

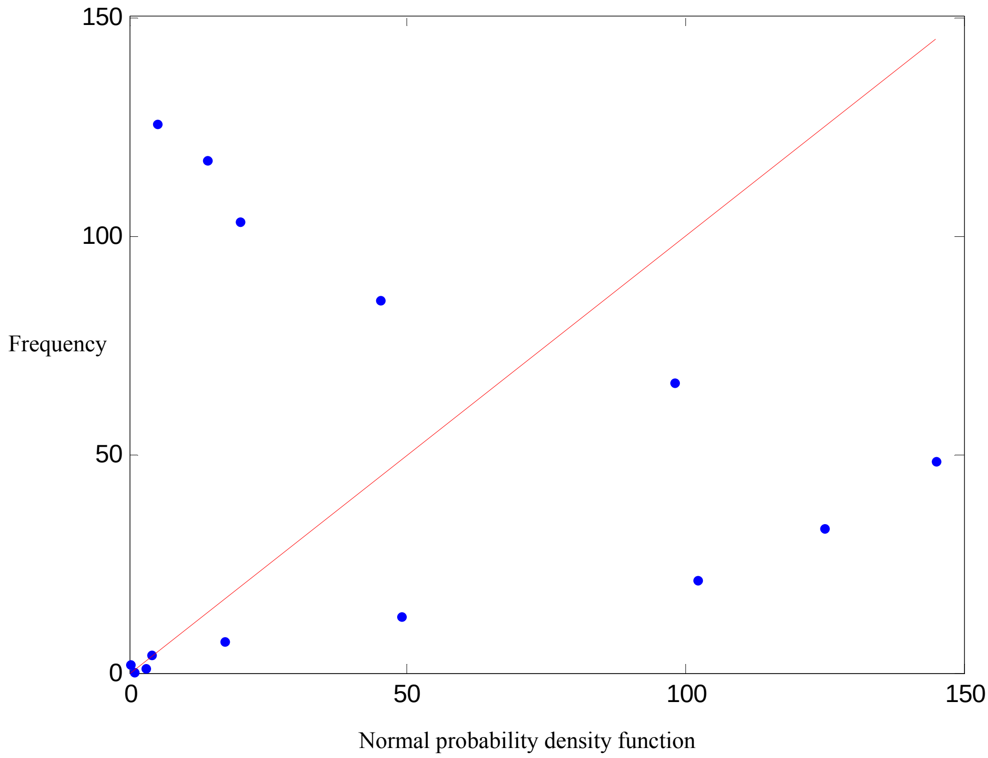


Figure 4.1: Runup data measured using video, for a storm at Tairua, 31/08/2001, showing the non-Gaussian nature of swash excursions.

For all storms at both sites the results displayed non-Gaussian characteristics. This was also noted by HOLMAN and GUZA (1984) who observed distinctly non-Gaussian distributions with high probabilities of low runup and low probabilities of high runup at the site they investigated. HOLLAND and HOLMAN (1993) agreed that the fundamental assumption of a linear Gaussian process is not strictly justified for swash motions. STOCKDON *et al.* (2006) tested the skewness and kurtosis of swash distributions at nine sites and compared these to values defining Gaussian distributions (i.e. skewness = 0, kurtosis = 3). They found a mean kurtosis of 2.9 and a mean skewness of 0.19 signifying the slight skewness of natural swash. The skewness and kurtosis statistics for all storm events at the two sites were calculated and also revealed noticeably non-Gaussian characteristics especially at Pauanui Beach (Tables 4.3 and 4.4).

Table 4.3: Skewness and kurtosis results of runup distributions estimated by video for storm events at Tairua

Storm	Skewness	Kurtosis
1	-0.12	1.43
2	-0.95	1.52
3	-0.68	0.56
4	0.03	-0.81
5	-0.03	-0.21
6	0.01	0.01
7	0.21	0.87
8	0.46	0.37
9	0.07	-0.10
10	0.26	-0.37
Mean	-0.07	0.33

Table 4.4: Skewness and kurtosis results of runup distributions estimated by video for storm events at Pauanui

Storm	Skewness	Kurtosis
11	-0.22	-0.98
12	-0.90	0.19
13	-0.81	-0.77
Mean	-0.64	-0.52

According to NEILSEN and HANSLOW (1991) runup distributions are assumed to follow a Rayleigh Distribution and this was tested by plotting the waterline transgression statistics measured in the field against the scaled elevations of the occurrence of the transgressions. That is

$$\sqrt{-1n\left(\frac{n_i}{N}\right)}, \tag{11}$$

where n_i is the number of waves that transgress the MWL and N is the total number of waves in a recording interval, was plotted against

$$\frac{z_i - SWL}{\sqrt{\frac{H_{orms}}{L_o}}}, \tag{12}$$

where z_i is the elevation of the MWL at the time of data collection, H_{orms} is the deepwater root mean square wave height, and L_o is the deepwater wave length. In this case a Rayleigh distribution corresponds to a straight line.

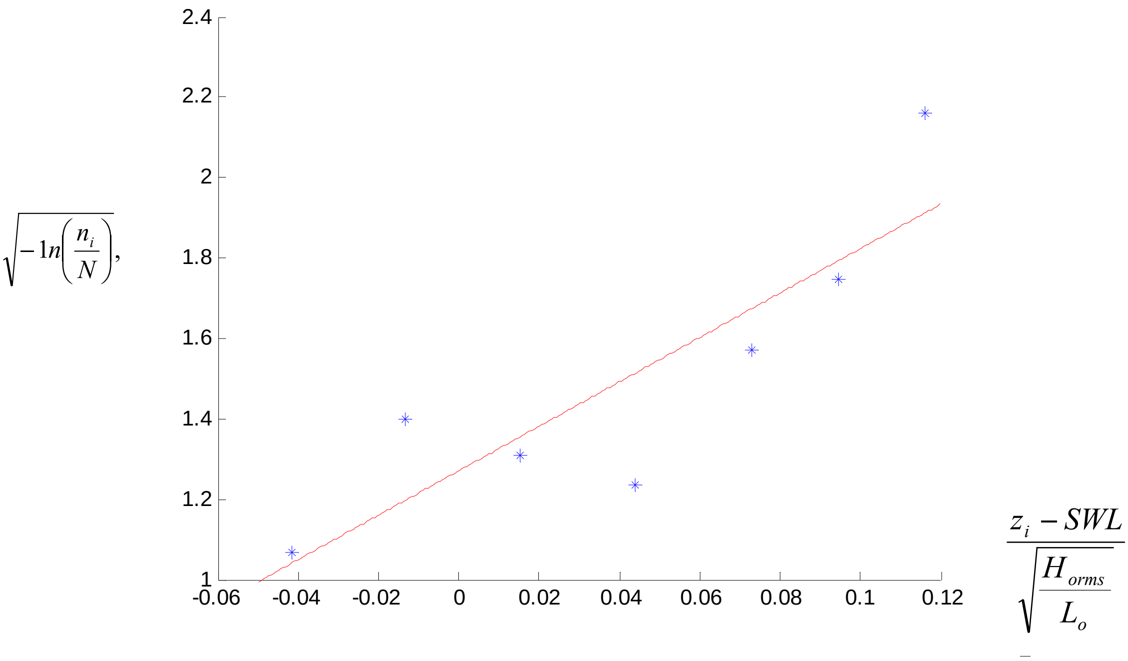


Figure 4.2: Runup data collected in the field at Tairua, 25/10/2007. The Rayleigh distribution provides a reasonable model (r2=0.76).

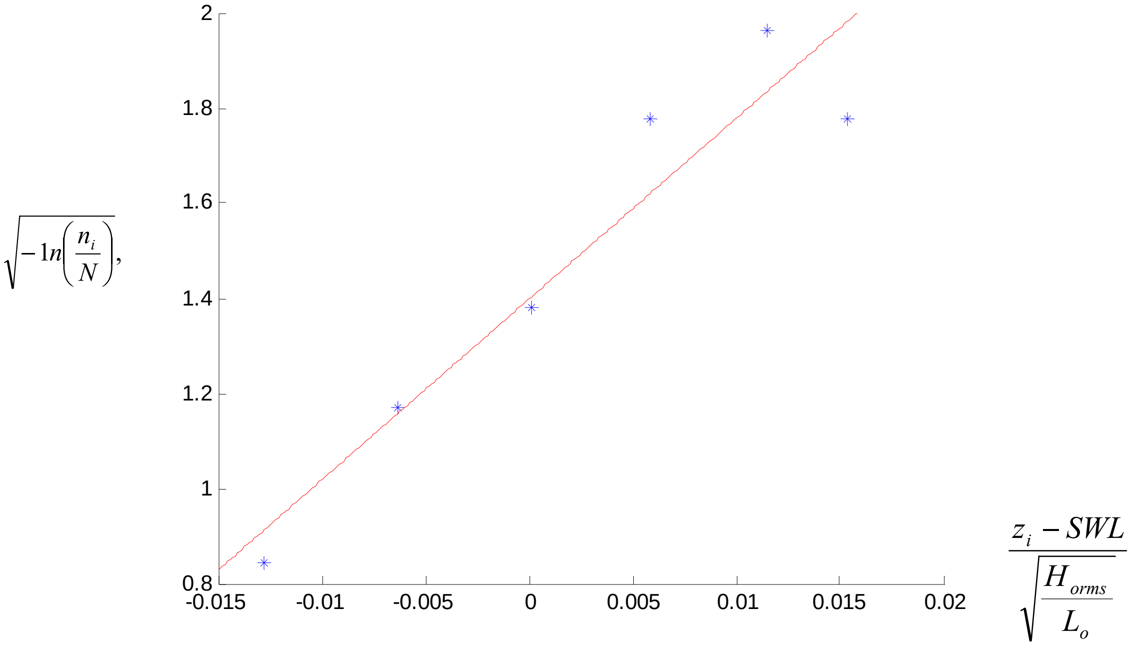


Figure 4.3: Runup data collected in the field at Pauanui , 25/10/2007 (r2= 0.91).

As illustrated in Figures 4.2 and 4.3, the results of the tests indicate the Rayleigh distribution provides a reasonable description for runup distributions, for both sites, especially at Pauanui (r^2 at Tairua = 0.76, r^2 at Pauanui = 0.91) on calm days. Histograms of the videoed runup elevations plotted against the frequency of the occurrence of runup also indicate a Rayleigh distribution for most storms at Tairua (Figure 4.4). However, video estimates of the runup elevations during the storm events at Pauanui provided runup distributions that were not characteristic of a Rayleigh distribution. In fact, when plotted the videoed runup distributions show approximately bi-modal runup elevations for all of the three storms analysed at this site (Figure 4.8). This is most likely due to infragravity energy and the reasons for this are explained later in the chapter.

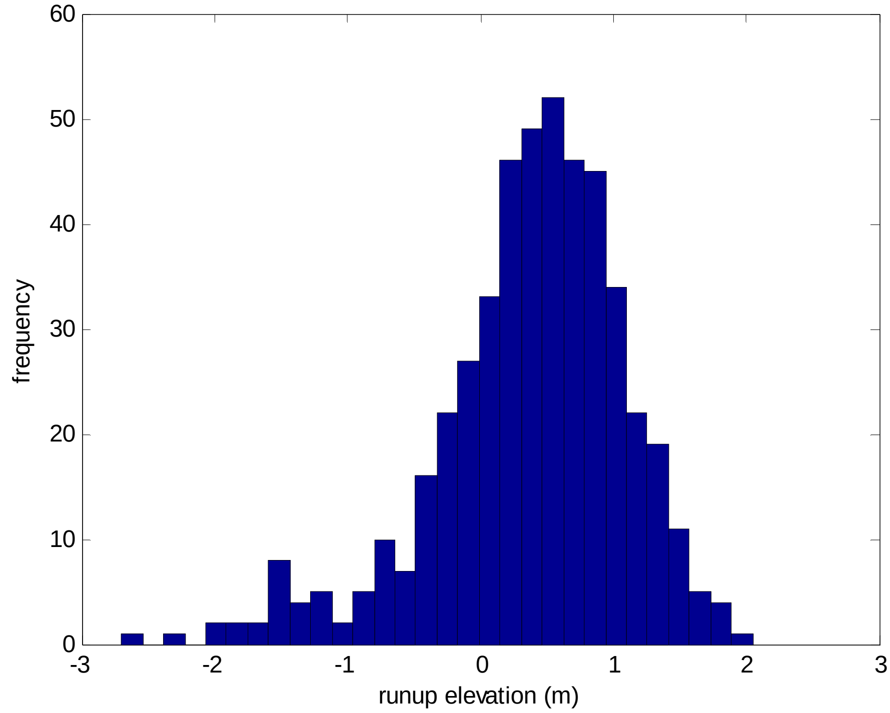


Figure 4.4: Histogram of runup elevations vs the frequency of the occurrence of the runup elevations for a storm event at Tairua (6/07/2001). The runup distribution follows a Rayleigh distribution.

4.4 Waterline Transgression Statistics

NIELSEN (1989) concluded that the shoreline, defined as the intersection between the MWL and the beach, is always a finite distance seaward of the runup limit if the beach is porous. However, for most of the storms at Tairua and all of the storm events at Pauanui, the runup data collected at, and about low tide, gave negative runup statistics (meaning that some of the runup elevations were below the mean water level). The literature suggests the reasons for this are either one or a combination of the following: 1) beach steepness, 2) groundwater seepage (both discussed in Chapter 3) and/ or (most likely) 3) infragravity energy as discussed below.

4.4.1 Beach Steepness and Groundwater Seepage

NEILSON and HANSLOW (1991) found in their work that steep beaches drain more efficiently (i.e. have a higher infiltration velocity) than flatter beaches, and therefore the mean water surface establishes itself in a position close to the runup distribution. As a result most of the waves transgress the MWL. At dissipative beaches with fine grain sands, such as Pauanui, the drainage of water infiltrated from runup will be much slower and wave transgression decreases. Similarly, infiltration velocities are decreased on flatter beaches where the water tables are much higher and groundwater seepage is prevalent. Indeed for all storms throughout a complete tidal cycle at Tairua, the waterline (MWL) transgression rate was consistently higher (Figure 4.5 and 4.6).

4.4.2 Infragravity Swash Motions

Runup elevation is affected by the incoming wave spectrum. It has been proven that infragravity wave frequencies (0.004-0.05 Hz) are present, and indeed may dominate the energy spectrum near the beach face during storm events (HOLMAN, 1981; GUZA and THORNTON, 1982; GUZA *et al.*, 1985; SALLENGER and HOLMAN, 1985; HOLMAN and SALLENGER, 1985), especially on dissipative beaches (RUESSINK *et al.*, 1998; RUGGIERO *et al.*, 2001; RUGGIERO *et al.*, 2004). These low frequency signals pump swash up and down the beach face influencing the number of waves that transgress the shoreline.

Infragravity waves are surface waves resulting from second-order interactions with incident wind waves (HOWD *et al.*, 1991). The variance of infragravity swash motions can be divided into specific energy partitions, (HOLLAND and HOLMAN, 1999). These partitions are related to cross-shore standing waves that are strongly reflected at the shoreline (HUNTLEY *et al.*, 1981, GUZA and THORNTON, 1985), edge wave modes (HUNTLEY *et al.*, 1981; HOWD *et al.*, 1991), bound waves formed by displacement of the free water surface by the structure of wave groups (GUZA *et al.*, 1984; ELGAR and GUZA, 1985), and non-gravity waves (or shear waves), (HOLLAND and HOLMAN, 1999).

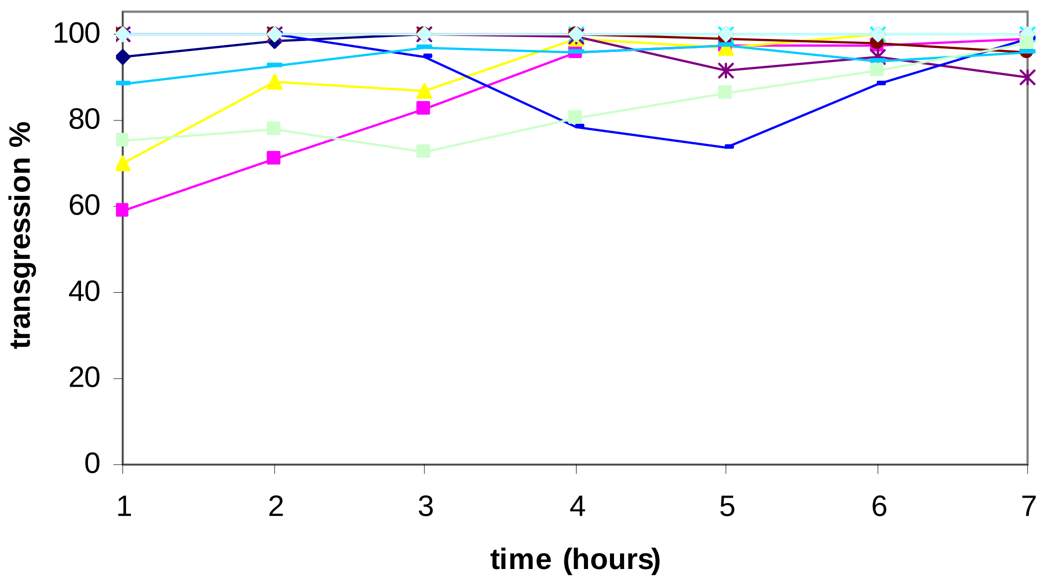


Figure 4.5: Waterline transgression percentages for all storms throughout a tidal cycle at Tairua

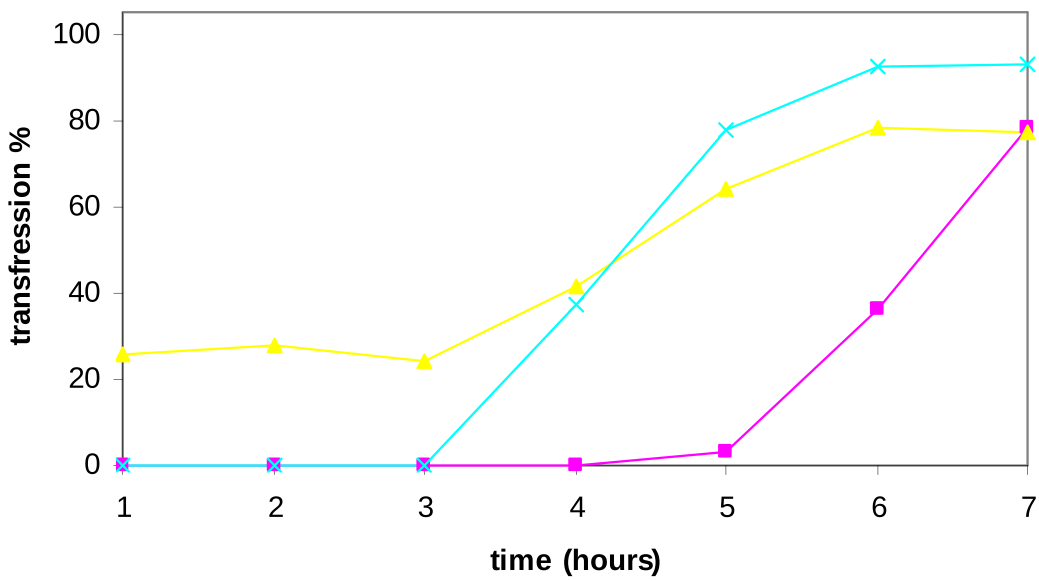


Figure 4.6: Waterline transgression percentages for all storms throughout a tidal cycle at Pauanui.

The swash signal at dissipative beaches is especially dominated by energy in the infragravity band. HOLMAN (1986) noted "the beach slope is itself a function of the incident wave characteristics", and that beaches with lower Irribarren numbers corresponded to swash with lower frequencies and vice versa. RUGGIERO *et al.* (2004) also established the dependency of runup spectra on beach slope, where higher frequencies coincided with steeper foreshore slopes and lower frequencies coincided with shallower foreshore slopes. Figure 4.7 shows how individual swash and groups of swash excursions run high and then low on the beachface.

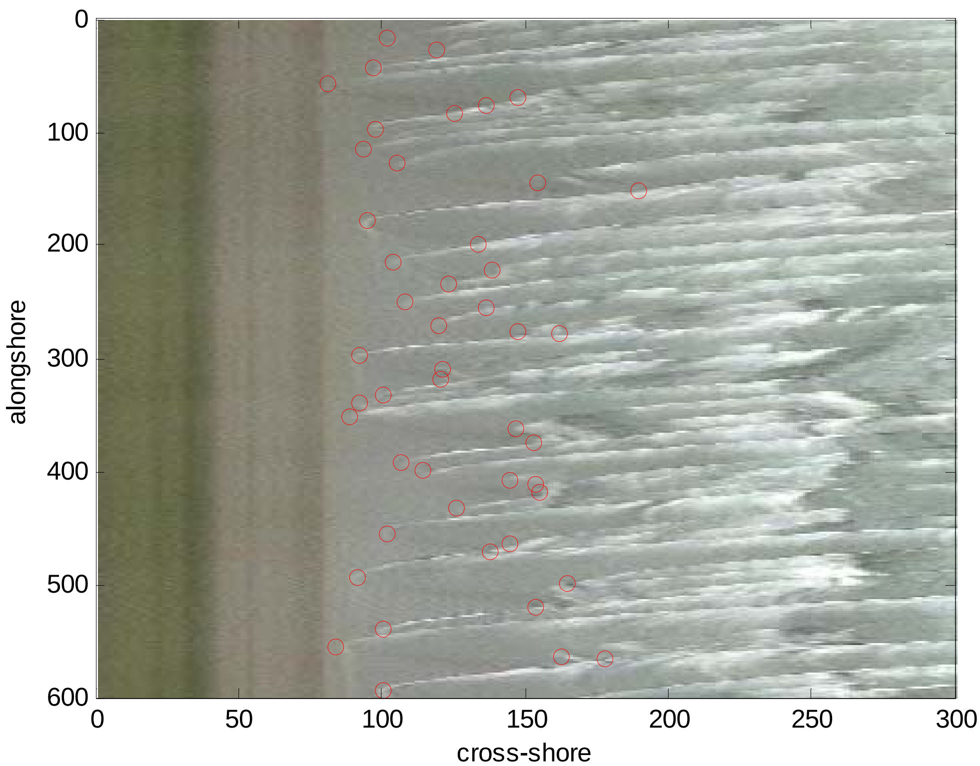


Figure 4.7: Timestack showing digitised swash maxima as it pumps up and down the beachface due to low frequency signals

4.5 Comparison Between Sites

Three of the storm events at Tairua corresponded to the dates of the four storm events at Pauanui for comparison between sites (Storms 8, 7 & 10 and Storms 11,12, & 13 respectively). All values of runup (mean, minimum and maximum data) were higher at Tairua than at Pauanui (refer Tables 4.1 and 4.2). This is not surprising considering the dissipative nature of surf zones at flatter beaches. However, in saying this, because of the decreased infiltration velocities on flatter beaches, the impact of the runup in regards to dune erosion and inundation is most likely more critical at Pauanui.

When comparing the runup distributions between the two sites it is apparent that the Pauanui distributions are approximately bi-modal for all three storms (Figure 4.11). This perfectly illustrates the nature of runup on flatter beaches during storm events as predicted in the literature. The two peaks within the Pauanui distributions are representative of the presence of infragravity energy (which is dominant on flatter beaches) as the swash runs high and then low on the beachface. This produces high negative values of swash maxima which greatly reduce the mean values of the runup elevations and also decrease the waterline transgression percentages. The runup under the first peak of the bi-modal distribution roughly coincides with the negative swash maxima values which occur as a result of infragravity energy within the swash spectrum.

The distributions at Tairua are not bi-modal (Figure 4.11) and confirm the notion that as the beach gets steeper, infragravity waves in the surfzone occur at higher frequencies. The amount of infragravity wave energy decreases and incident short wave energy increases. As a result, the occurrence and magnitude of negative swash maxima is reduced and the waterline transgression statistics increase.

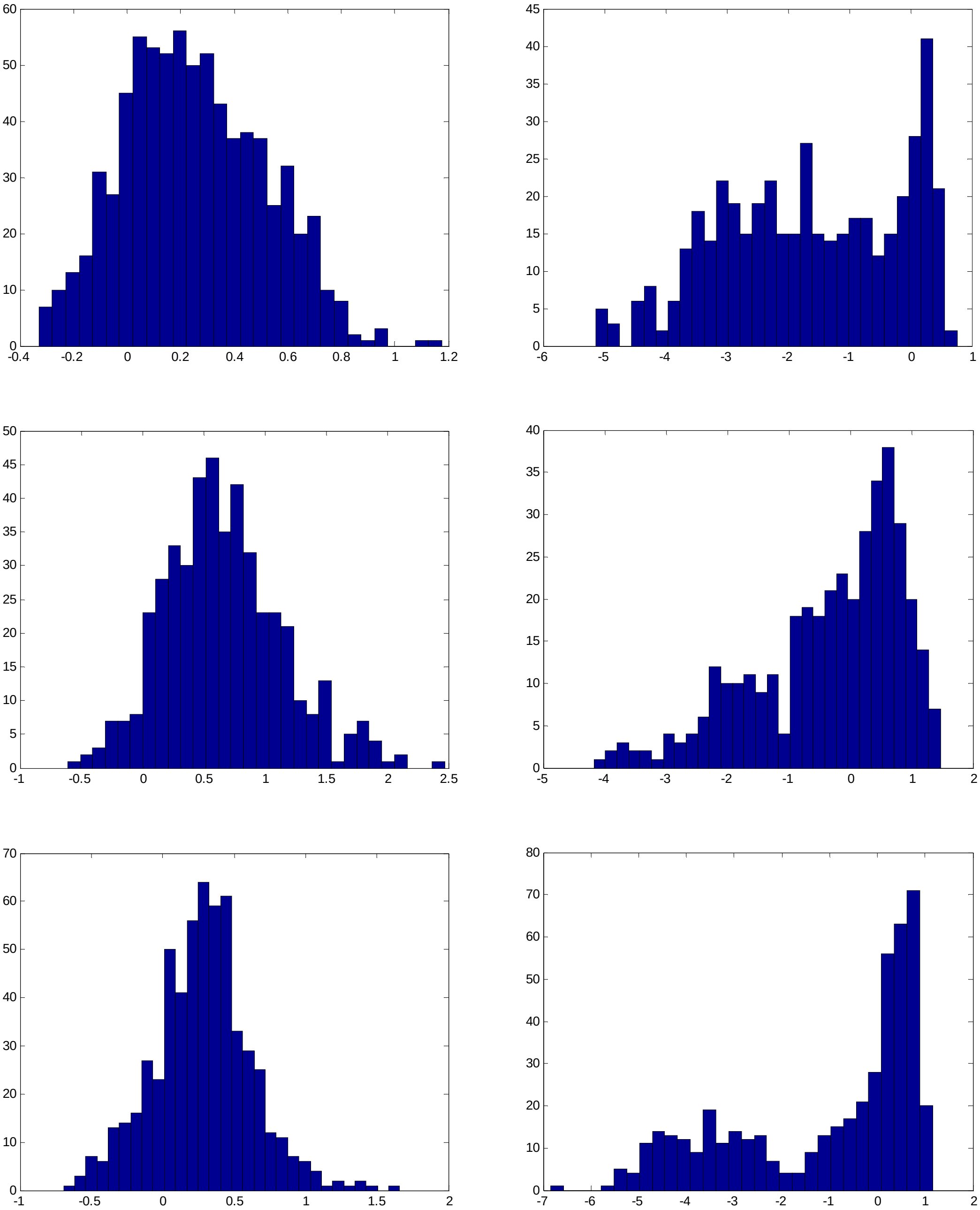


Figure 4.8: Runup distributions for corresponding storms at Tairua (left) and Pauanui (right). The distributions at Tairua follow a Rayleigh distribution, while the distributions at Pauanui are approximately bimodal.

4.6 Negative Swash Maxima

HOLLAND and HOLMAN (1993) deduced that as the spectral width of the swash increases, the proportion of negative swash maxima also increases. The maxima distribution then, is dependant upon the relative width of the spectral peak. This could explain why the magnitude of the negative swash maxima is so much greater for the three Pauanui storms, and suggests at the time of these storms the swash spectrum was highly broad-banded (i.e. containing energy in both the infragravity and incident frequency bands). Storms featuring only positive maxima or positive maxima with small negative maxima values are most likely those with narrow-banded swash spectra (where infragravity energy is not as dominant).

The mean total runup variance at Tairua and Pauanui is 2.2 ± 1.1m and 6.6 ± 1.3m respectively. It is noted that the runup variance of the storms with broad-banded swash spectra are far greater than the other storms (refer Table 4.1 and 4.2). This indicates that the scale of the runup variance is also indicative of the presence of infragravity energy, so that a higher runup variance value corresponds to higher infragravity energy in the swash signal. The results also show that as the runup variance increases at Pauanui, the runup distributions become more distinctly bimodal and the occurrence of individual swash excursions increase. This is not apparent at Tairua however. Also important is the fact that increases in runup variance at Tairua coincide with the highest runup elevations.

4.7 Runup, Tide and Wave Height Correlations

The relationships between runup and tide, and runup and wave height statistics, for both sites were investigated and plotted below in Figures 4.12 and 4.13. Studies have shown that the vertical swash height increases until it reaches a threshold value. Additional wave energy input is consequently dissipated in the surf zone and the vertical swash height ceases, meaning the swash is saturated (MICHE, 1951; HUNTLEY et al., 1977; GUZA and THORNTON, 1982, and; RAUBENHEIMER and GUZA, 1996).

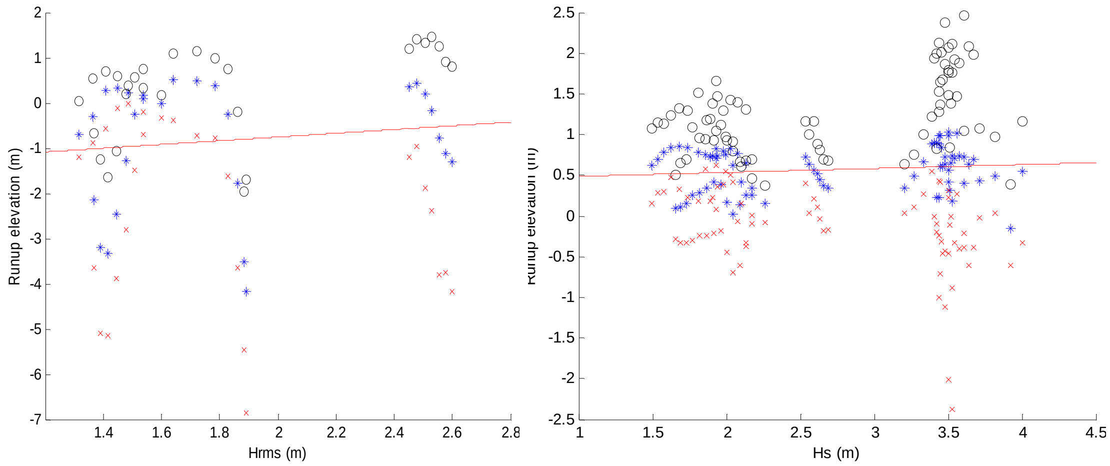


Figure 4.9: Runup vs Hrms wave height at Pauanui (left) and Tairua (right). The solid line is the best fit linear line: R = 0.30 H_s -1.6 and R = 0.048 H_s + 0.44 for Pauanui and Tairua respectively, where R is the runup elevation and H_s is the significant deepwater wave height) (circles are runup maximums, asterisks' are runup means and crosses are runup minimum values).

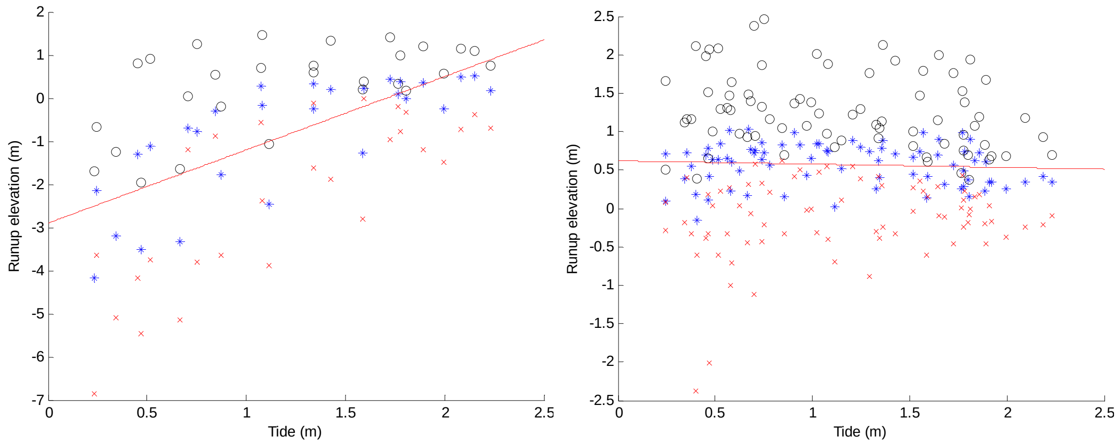


Figure 4.10: Runup elevation vs Tide at Pauanui (left), and at Tairua (right). The solid line is the best fit linear line: R = 1.7x -2.9 and R = -0.043x + 0.62 for Pauanui and Tairua respectively, where R is the runup elevation and x is the level of the tide) (circles are runup maximums, asterisks are runup means and crosses are runup minimum values).

For runup excursions at incident frequencies (>0.05 Hz), it has been found that the swash is typically saturated and therefore independent of the offshore wave height (GUZA and THORNTON, 1982; HOLMAN and SALLENGER, 1985; HOLLAND et al, 1995, and; RUESSINK et al., 1998). Conversely, RAUBENHEIMER and GUZA (1998) concluded from their work that swash at infragravity frequencies are unsaturated and therefore increase approximately linearly with increasing offshore wave height. HOLMAN (1981), and GUZA and THORNTON (1985) also found a dependency between the magnitude of infragravity wave oscillations and the offshore wave height, and HOWD et al., 1991 have shown that cross-shore infragravity oscillations are much more affected by the offshore wave height than they are affected by either incident wave action or beach morphology.

Figure 4.12 supports these findings, where Tairua, a steeper beach associated with incident wave energy, shows little dependence on wave height, and Pauanui, a flatter beach associated with infragravity wave energy, shows a definite correlation between swash height and offshore wave height. The relationship between these two parameters, at Pauanui, improves when the root mean square deepwater wave height is used (i.e. the linear relationship is: $R = 0.41H_s - 1.6$, where R is the runup elevation and H_s is the significant deepwater wave height). The same is true when comparing runup and the level of the tide. Swash height is dependent on the height of the tide at Pauanui, but independent at Tairua. In fact, the correlation at Pauanui is significant, and this is most likely due to the flatness of the beach.

Given the observed dependence of swash height on tide and wave height at Pauanui, it is fair to assume that beach slope is an important factor affecting runup. As a result, the runup statistics were plotted against the Irribarren number to test this theory. Because scatter is expected in the data when it is plotted dimensionally, all runup statistics were normalized by the significant deepwater wave height (Figure 4.11).

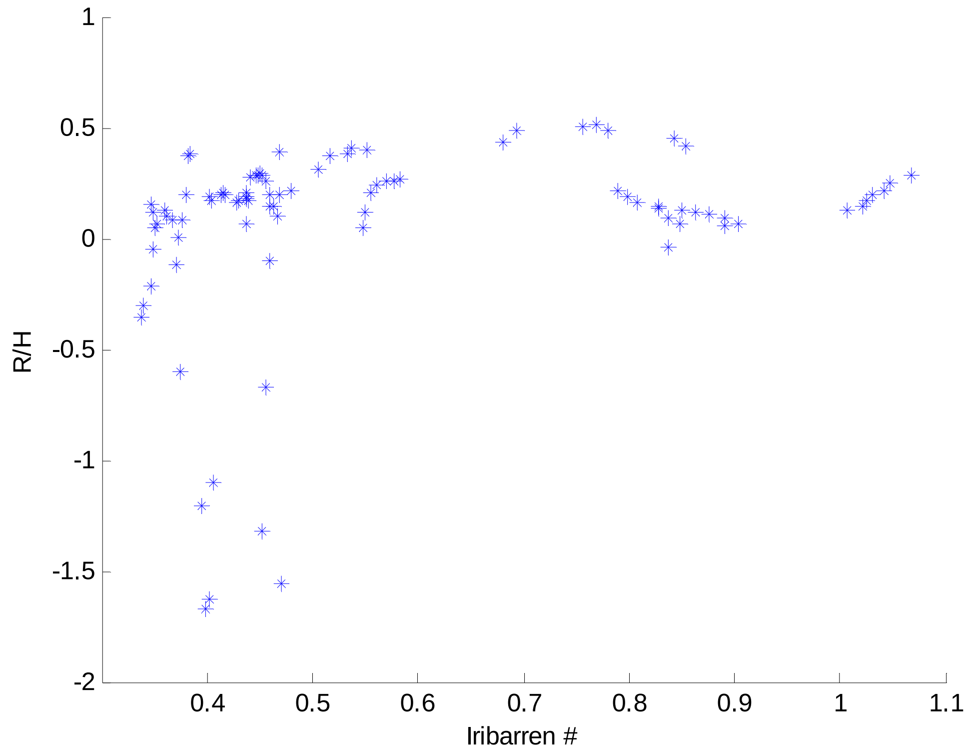


Figure 4.11: Normalised runup data plotted against Iribarren number. The plot shows that for beaches with Iribarren numbers >0.5 there is a correlation with runup height. For beaches with lower Iribarren numbers the runup is independent of beach slope.

The non-dimensional run-up is clearly a function of the Iribarren number for natural beaches. Commonly, lower wave heights are associated with higher Iribarren numbers and therefore a higher nondimensional run-up. It seems however, that this relationship is only true for beaches with Iribarren numbers > 0.5. For beaches with lower Iribarren numbers, the relationship with non-dimensional runup shows a lot of scatter and suggests that runup is not dependent on slope at flatter beaches. This was also found by NIELSEN and HANSLOW (1991).

4.8 Calibrations against Empirical Runup Formulae

Calibrations against well known empirical runup formulae were carried out to test the modeled results. The Neilson and Hanslow Equation (1991), for the vertical scale of the runup distribution, was used for comparison. Determining the extreme elevations of runup are important for assessing the risk of inundation on a given beach and so the 2% exceedence statistics are calculated using the formula by STOCKDON et al., (2006) and used to compare the 2% exceedence statistics obtained using video.

4.8.1 Vertical Elevation of the Runup Distribution

The Hunt Equation, in the form of equation 15, is expressed in terms of the Iribarren number and includes a coefficient K to account for the porosity and friction of the slope.

$$R = K\xi_o H_o, \tag{13}$$

Here, R is the vertical run-up statistic, H_o is the deep water wave height, K is the proportionality constant allowing for percolation and ξ_o is the iribarren number, where:

$$\xi = \frac{\tan\beta}{\sqrt{\frac{H_o}{L_o}}}, \tag{14}$$

and;

$$L_o = 1.56T_o^2 \tag{15}$$

NEILSEN and HANSLOW (1991) regard the Hunt equation to be a fairly reliable empirical formula. However, they found that its validity is limited to somewhat steeper slopes where the dissipation of energy by spilling breakers far from the shoreline is insignificant. Consequently, they came up with two formulae to calculate the vertical elevation of the runup distribution that accounted for beach slopes of all gradients. The vertical scale of the runup distribution, L_{zwm}, represents the vertical elevation of the swash as it runs up the beach face, and is equal to the root mean square value of the maximum waterline elevation reached by an individual wave (z_{wm}) less the highest elevation transgressed by 100% of the waves (z_{100}). NEILSEN and

HANSLOW found that L_{zwm} is proportional to beach slope ($\tan\beta_F$) for beaches with slopes >0.10 so that

$$L_{zwm} = 0.6(H_{orms}L_o)^{0.5}\tan\beta_F . \qquad \text{for } \tan\beta_F > 0.10, \tag{16}$$

where H_{orms} is the root mean square deepwater wave height and L_o is the deepwater wave length. For flatter beaches, they found that the runup distribution seems to scale directly with $(H_{orms}L_o)^{0.5}$ and this relationship is given by

$$L_{zwm} = 0.05(H_{orms}L_o)^{0.5} \qquad \text{for } \tan\beta_F < 0.10. \tag{17}$$

Since, it is the highest levels of runup that are of interest to those managing the coast, the runup elevations measured by video at high tide for all storms have been compared against runup calculated using the formula by NIELSEN and HANSLOW (1991) and are detailed in Table 4.5.

Table 4.5: The vertical scale of runup at high tide calculated from video ($R_v(V)$) and the vertical scale of runup at high tide calculated using the parameterization by NIELSEN and HANSLOW (1991), ($R_v(F)$) for both sites. (The coloured squares represent the storms at Tairua and Pauanui with the same dates and times).

Tairua Storm	1	2	3	4	5	6	7	8	9	10
$R_v(V)$	0.38	0.64	0.39	0.21	0.30	0.36	0.31	0.74	0.33	0.44
$R_v(F)$	0.49	1.15	0.90	0.95	1.86	1.62	0.58	0.90	0.77	0.90
Pauanui Storm	11	12	13							
$R_v(V)$	0.61	1.09	0.64							
$R_v(F)$	0.58	0.90	0.60							

Overall the statistics between formula and video statistics at Pauanui were very similar with a mean deviation of 0.09 ± 0.09 metres. Results from Tairua statistics were not as comparable with a mean deviation of 0.60 ± 0.47 metres. It seems the largest deviations at this site occur when the beach is at its steepest (i.e. storms 5 and 6) and decrease as the beach gets flatter. This suggests the accuracy of the runup statistics measured using video become less reliable when the beach steepness increases. Although the deviations at Tairua are not huge, this may be a limitation of the video technique and further investigations of storms on steep beaches need to be carried out to verify this.

4.8.2 Extreme Runup Elevation

It is important to be able to determine the extreme high value of runup for use in scaling the impacts of severe storms on beaches. The 2% exceedence value (R_2) is commonly used to determine elevations of extreme runup and according to STOCKDON *et al.*, (2006) is assumed to be approximately equal to

$$R_2 = 1.1\left(0.35a\left(H_o L_o\right)^{0.5} + \frac{\left[H_o L_o\left(0.563a^2 + 0.004\right)\right]^{0.5}}{2}\right) \quad (18)$$

where a is the beachface slope, H_0 is the deepwater wave height and L_0 is the deepwater wave length. This formula was used to assess the extreme runup elevations obtained using video, for each storm, at both sites. Calculations of R_2 are given in Table 4.5.

The mean difference between the videoed 2% exceedence values and the 2% exceedence values calculated using the formula by STOCKDON *et al.*, (2006) at Tairua, was -0.15 ± 0.57 metres, indicating the parameterization tends to slightly underestimate the elevation of the swash maxima. This is very similar to the findings of STOCKDON *et al.*, (2006) who found a mean difference of -0.17 metres when testing their formula against data collected in the field. The deviations between the 2% exceedence values at Pauanui are 0.16 ± 0.15 metres and the formula tends to overestimate the elevation of the runup in this case. Again, this is most likely the result of infragravity energy present in the swash signal and although the parameterisation by STOCKDON *et al.*, (2006) was tested on beaches with low slopes, the deepwater wave heights were not as high as the wave heights present during the storm events at Pauanui used in this study. In fact, in some cases they were much smaller and representative of calm conditions, and the infragravity energy was probably very small or absent. As a result, it is assumed that the parameterisation does not account for the dominance of low frequency signals in the swash zone.

Table 4.6: 2% exceedence runup values calculated from video (R_2(V)) and the 2% exceedence values calculated using the parameterization by STOCKDON et al., (2006), (R_2(F)) for both sites. (The coloured squares represent the storms at Tairua and Pauanui with the same dates and times).

Tairua Storm	1	2	3	4	5	6	7	8	9	10
R_2 (V)	1.28	1.89	1.46	1.35	0.91	0.93	1.03	1.81	1.19	0.78
R_2 (F)	1.02	1.79	1.42	1.50	2.26	1.89	0.82	1.40	1.02	1.06
Pauanui Storm	11	12	13							
R_2 (V)	0.50	1.24	0.95							
R_2 (F)	0.83	1.30	1.04							

It is also noted that the deviations between statistics from video and the parameterisation are largest when the beach is at its steepest, again suggesting the video has more difficulty determining runup on beaches with higher slopes.

4.9 Summary

All values of runup (mean, minimum and maximum data) were consistently higher at Tairua. This is not surprising considering the dissipative nature of surf zones on flatter beaches. The Rayleigh distribution provides a reasonable description for runup distributions at both sites on calm days, and at Tairua during most of the storm events. However, video estimates of the runup elevations during the storm events at Pauanui provided runup distributions that were approximately bi-modal in nature. This perfectly illustrates the nature of runup on flatter beaches during storm events where infragravity energy (which is dominant on flatter beaches) causes the swash to run high and then low on the beachface. This produces high negative values of swash maxima which reduces the mean values of the runup elevations and also decreases the waterline transgression statistics.

The scale of the runup variance is also indicative of the presence of infragravity energy, where a higher runup variance corresponds to higher infragravity energy in the swash signal. The results also show that as the runup variance increases at Pauanui, the runup distributions become more distinctly bimodal. The fact that the distributions at Tairua follow a Rayleigh distribution during storm events, confirms the notion that as the beach gets steeper, incident waves become more dominant in the surfzone (if the assumption is made that bi-modal distributions are representative of higher levels of infragravity energy present in the swash signal). As a result, the occurrence and magnitude of negative swash maxima is reduced, the runup variance is reduced, and the waterline transgression probabilities increase.

At Tairua, the steeper beach associated with incident wave energy, there is no relationship between swash height and wave or tide heights. On the other hand, at Pauanui, the flatter beach associated with infragravity wave energy, there is a definite correlation between swash height and offshore wave height, and swash height and tide level. Subsequently, it was assumed that beach slope is an important factor affecting runup and so the runup data was plotted against the Iribarren number. This revealed that the runup on steeper beaches is dependent on beach slope (for beaches with Iribarren numbers >0.5). For flatter beaches however, there seemed to be no correlation between the two.

Calibrations against empirical runup formulae were carried out to test the videoed runup results. The Neilson and Hanslow Equation (1991) was used to compare the vertical scale of the runup distribution, and the formula by STOCKDON et al., (2006) was used to compare the 2% exceedence statistics. Comparisons against runup formulae gave comparable results for both sites, and especially at Pauanui. The largest deviations between parameterisations and videoed results occurred when the beach was at its steepest and this suggests there may be difficulties associated with accurately determining runup using video on beaches with higher slopes. Furthur validation is needed to test whether this is true however. The comparisons of the 2% exceedence statistics at Tairua were similar to those found by STOCKDON *et al.*, (2006). However, the parameterisation overestimated the runup heights at Pauanui and this is most likely because the formula is not reliable under certain circumstances (i.e. when infragravity energy is dominant in the swash signal). Furthur validation is needed to test this.

Overall, the results of the study indicate realistic runup measurements over a wide range of time scales and during storm events when collecting information in the field is difficult. The runup statistics are consistently higher at Tairua (videoed data, surveyed data, the vertical scale of the runup and the 2% exceedence statistics), and suggests that swash runs up higher on steeper beaches. However, because of the characteristics of flatter beaches (such as high water tables and low drainage efficiencies) the impact of extreme runup elevations on such beaches are more critical in regards to erosion and/ or inundation.

Chapter 5

Impact Assessment: Inundation and Maori Tikanga

5.1 Introduction (Te Timatanga)

The coasts and estuaries are of great importance to Maori, as are all things within the natural world. Maori have a holistic view of the world which is based on whakapapa (family genealogy), and all things, including the land and oceans, have inherent links to tangata whenua (people of the land). For this reason, it is the tangata whenua who have a responsibility to these taonga (treasures) to ensure their protection, preservation and enhancement in accordance with tikanga Maori (Maori protocol).

Historically, Maori tribal welfare was determined by the wealth of the resources available to, not only themselves, but also to manuhiri (visitors). If offerings could not be given to manuhiri, this brought shame to the whanau (family)/ hapu (sub-tribe)/ iwi (tribe). As a result, those with abundant resources were those that flourished and those without were those that perished (KING *et al.*, 2007). As a means of survival then, it was imperative for Maori to manage and maintain the resources available to them, including the resources of the coasts.

With an increase in inundation comes the additional likelihood of damage to waahi tapu (places of spiritual importance), archaeological sites and other areas of cultural significance. Due to the linkage through whakapapa this adversely affects Maori tupuna (ancestors) and therefore the spiritual and cultural well-being of Maori. Matauranga Maori enables a look into the past and provides knowledge of historical events passed down through the generations. This knowledge is usually not recorded in writing but is passed down orally and is therefore knowledge that is only known to those who have lived, or have ancestors who have lived, within the region for many years, such as kaumatua and appointed kaitiaki. Their knowledge can provide useful and important information of previous events of inundation and mitigation measures carried out by iwi (tribes) and hapu (sub-tribes) in the face of such events.

This chapter explores the ways in which coastal iwi dealt/deal with innundation in a historical and contemporary sense. By doing so, practices carried out by Maori in the coastal environment, in association with inundation, will hopefully be better understood, and as an outcome will be supported and implemented in all coastal management plans. This chapter aims at encouraging a "two culture model" of environmental management which compliment each other (Chamberlain, 2006) and most importantly achieve the purpose of the Resource Management Act (1991); promoting "the sustainable management of natural and physical resources".

Information was gathered from people of various iwi that are knowledgeable in the historical and/ or contemporary mitigation practices carried out by Maori in regard to inundation. This information concerned, historical mitigation measures used by Maori, the effects of climate change, the current practices carried out by non-Maori coastal management groups, and kaitiakitanga (guardianship) and the role of the kaitiaki (guardian) within the coastal environment; all of which are discussed below. It should be understood that the information provided here is only a fraction of the history and knowledge of Maori pertaining to coastal management and flooding and is given as a representation of some of the opinions of Maori in relation to this topic.

5.2 Historical Practices

Most coastal pa (fortified villages) and kainga (unfortified villages) were usually situated on headlands so that inundation and coastal erosion were not usually a problem in terms of damage to homes, or communal living areas. However, some kainga and nohoanga (temporary campsites used for seasonal gathering of food) were located on the sand dunes and the remains of the general living areas, with stained sands from ovens, have been unearthed due to erosion and inundation. Excavations of such sites have shown that the occupation of these living areas were usually brief and this may have been due to occurrences of flooding or simply knowledge of the dangers of living so close to the coast. When asked about techniques used by Maori to mitigate against flooding, one person replied "Don't build whare (houses) which challenge Tangaroa (the god of the sea). He may invite himself into your marae (traditional meeting house)". This statement implies that such occurrences had taken place and the practice of building a distance from the ocean was learned, or that to some it was just common sense to do so and applied as a means of avoiding inundation.

However, many other places of spiritual importance to Maori (i.e. waahi tapu) are situated on the coast, including middens, battle sites, tauranga waka (canoe landing sites), mahinga kai (places for gathering kai) and urupa (cemetaries). The increased rate of coastal erosion in New Zealand has resulted in damage to an alarming number of these archaeological sites. When occurrences of erosion occurred historically, this adversely affected the whakapapa of the Maori and so mitigation measures were invented and employed by Maori. These measures mimicked nature, out of respect to all the atua (gods) whose domains the Maori occupied and interacted with. These measures included planting Pingao and other native plants naturally occurring along the coastline. Restoration of vegetation eroded away by the waves was also carried out. Using materials and objects found naturally on beaches were also used to help stabilise the foredunes (such as sticks and branches). Many Maori still believe that mimicking nature is the best way to avoid and/ or mitigate the effects of erosion and inundation, and that engineered solutions which may be foreign to the coastal environment (such as seawalls and breakwaters) will eventually cause damage. This is actually true in many cases and occurrences of damage caused by seawalls and the like are well documented.

Stories detailing the causes and impacts of past natural hazards are detailed in *mōteatea* (laments), *pepeha* (quotations), *whakataukī/whakatauāki* (proverbs) and *waiata* (songs) and provide important information on local coastal environments (KING *et al.*, 2007, KING and SKIPPER, 2006). These stories include occurrences of "great waves caused by storms, inundation caused by incantations, and land or marine water beings or giant lizards known as *taniwha* causing death, destruction and peril for people living near water" (KING *et al.*, 2007). The stories record such things as the locations of the events, and usually an indication of the date of the events are given (i.e. the dates of the events are usually determined through recognition of peoples names and other events or happenings occurring at the time of the hazard that are also mentioned in the tale). The stories commonly record loss of life, and serve as warnings about the sometimes destructive nature of the coastal environment.

The rules surrounding tapu and rahui were used as another means of protecting both individuals and the environment from harm. Tapu is the power and influence of the gods, and prohibits specific activities at specific times. All things have inherent tapu because all things were created by the gods (Chamberlain, 2006). Tapu has far reaching influences which entered/ enters into all aspects of Maori life and no one was/ is exempt from its stringent rules (BEST, 1952). Rahui, a form of tapu, is an institution used by Maori to protect the resources of various environments, by prohibiting and preventing people from free access to either food resources or to a particular place. Disregarding the rules of tapu and rahui involved punishment from the gods, and people who did so were either directly inflicted by a serious illness/ condition (or even death), or the protection of the gods was simply withdrawn from them (BEST, 1952). Because of the harshness of the punishments, tapu and rahui encouraged rational and coherent behaviour and therefore represents some of the earliest forms of hazard mitigation used in New Zealand.

5.2.1 Environmental indicators (Nga tohu o taiao)

Environmental indicators are effectively signs or inconsistencies in nature that signify or warn others of changes occurring in the environment. For a person to recognize these sometimes subtle changes, they would have to be extremely familiar and intimate with their surroundings, as were/ are the Maori. These indictors were, and are still to this day, widely used by Māori to make predictions regarding changes in the environment. Many of the indicators are associated with changes in the weather and climate, which enabled Maori to prepare for the arrival of storms, floods and other extreme whether events. KING *et al.*, (2007), detailed in his work a few of the environmental indicators used by Maori, and these are list in Table 5.1.

Table 5.1: A selection of environmental indicators, the expected outcomes, and their tribal origins (Source: KING *et al.*, 2007).

Name	Indicator	Expected Outcome	Iwi Origin
Ngā ngaru (waves)	The booming sound of waves across the land	Rainfall is approaching	Te Roroa: NW North Island
Pūkeko (swamp hen)	Pūkeko head for higher ground	Imminent storm and flooding	Ngāti Wai: NE North Island
Kākā (native parrot)	Kākās begin acting up, twisting and squawking above the forest	A storm is on its way	Ngāti Pare: NE North Island
Whakaari (White Island)	The plume flattens and the end breaks off	Extreme weather is expected	Te Whānau a Apanui: E North Island
Matuku (bittern)	The continuing cry of the matuku as it moves around at night	Floods are likely	Ngāti Ruanui: SW North Island
Kōtuku (heron)	The kōtuku are plentiful in summer	Gales and a heavy winter will follow	Ngāti Apa: N South Island
Rā (sun)	A vivid halo encircles the sun	A storm is approaching	Kāi Tahu: E South Island
Rawaru (blue cod)	Stones in the belly of the rawaru	Bad weather is coming	Ngāti Koata: N South Island

5.3 Climate Change (Huringa Ahua o te Rangi)

With an increase in climate, comes the inevitable rising of the seas and most likely an increase in the occurrence of erosion and inundation. It is important for Maori to preserve the mauri (life force) of the coast and the effects of climate change will adversely impact on this. Dune blowouts force dunes inland and encroach on productive lands and developments, and important native dune plants. The distribution and abundance of shellfish may be adversely impacted due to these changes. Flooding of tidal mudflats, and the increase in sediment loading which accompanies this, may make the ecological niche of shellfish, such as pipi, uninhabitable. Coastal flora and inshore fisheries could also be negatively impacted.

The concerns of Maori towards climate change are reflected in the fact that many iwi and hapu have included it within their management plans. Through consultation, it was found that the most significant concerns for Maori was the potential damage to coastal waahi tapu as a result of sea level rise, and the measures that would be employed by coastal management groups to prepare for and mitigate against such adversities, and indeed for any other adverse effects associated with climate change. Many expressed their opinions regarding how the coast and its resources should be managed in the face of climate change. These views are listed below.

i) The inclusion of tribal protocols, principles and policies into all coastal management plans in respect to climate change.

ii) The protection, preservation and enhancement of waahi tapu, and indigenous species and ecosystems is paramount, and policies regarding climate change do not take precedence over this.

iii) The establishment of iwi and hapu resource management units that are trained to work with archaeological and other cultural resources to ensure waahi tapu are managed in accordance with tikanga Maori.

iv) The holistic view of Maori, and the principles of the treaty, in regard to protecting and preserving the environment, are recognized and provided for in all proposed climate change policies, plans and legislations, by all levels of governance (national, regional, local).

v) Information on climate change is readily accessible to improve community awareness and to assist Maori in managing their environmental resources.

vi) The active involvement and education of communities in planning for climate change and its potential impacts.

vii) The collaboration of traditional Māori knowledge and western based science incorporated into policies associated with climate change.

viii) The appointment of kaitiaki:
- with the rights to exercise power regarding seafood take and rahui;
- to educate others on the potential risks of climate change;
- to monitor the coastal environment; and,
- to achieve better management strategies within their rohe moana (coastal area) to ensure environmental sustainability through iwi and hapu relationships with the land and sea.

5.4 Non-Maori Coastal Management Groups

Most of the coastal environment is governed by regional councils (from low to high water mark) and local authorities (from mean high water mark to the road side), which as one person stated "alienates our kaitiaki status. Having no control over it (the coastal environment) means no kaitiakitanga over it". Through consultation, opinions were expressed in regard to the current management practices used by non-Maori coastal management groups to protect the coasts from natural hazards, such as storm surge, erosion and inundation. The biggest concern of those spoken to was the fact that the traditional methods of the Maori associated with protecting and preserving the coastal environment, both its character and its resources, were not being accounted for by non-Maori coastal management groups.

Views given by Maori indicated that the management plans used to mitigate against hazards, needed to have regard to kaitiakitanga, the cultural aspects of Maoridom, and the principles of the Treaty of Waitangi, in accordance with the RMA (1991). To achieve this involves:

i) recognising the spiritual and historic association between Maori and the coast;

ii) recognising that the coastal and inland environments are interconnected and changes to one may impact the other (this includes urban development, land use intensification and diversion of water, all of which will affect the (cultural) health of the coast, ()) and consequently may increase the risk of erosion and/ or inundation;

iii) controlling coastal subdivision, residential development, forestry, farming, mineral extraction, tourism and general pubic access in order to protect vulnerable dune systems () which act as natural buffers against the sea;

iv) actively supporting the re-establishment and restoration of indigenous plants in coastal dune systems;

v) avoiding activities that may be harmful to coastal dune systems.

vi) promoting the sharing of information, consultation and collaboration between Maori and non-Maori groups with links to the coastal environment and its management; and,

vii) supporting continued research into coastal erosion and inundation.

The key issue raised by those who shared their knowledge and opinions for purposes of this study, was the importance of consultation. Consultation provides a forum for all interested parties to express their views regarding certain areas of interest and promotes the strengthening of relationships with tangata whenua and other management groups. Most importantly however, it enables the concerned parties to share information and knowledge, and subsequently allow identification of potential problems that may arise, before certain changes are made to the coastal environment (For Maori, this especially includes knowledge regarding locations of waahi tapu, and knowledge of past hazards occurring in the area of interest).

5.5 Kaitiaki

The role of the kaitiaki is to ensure the mauri of their taonga is healthy and strong. Traditionally there was an obligation and responsibility to protect and care for tribal estates, interests and resources. Allowing the kaitiaki more access to information and tools, such as the new technique used in this study to measure runup using video, will enable Maori to achieve better management strategies within their rohe moana (coastal area) and environmental sustainability through iwi and hapu relationships with the land and sea. Giving the local communities the power to govern their own environments, will ensure the interests of those that will be affected by local change, are met. The essential characteristic is that the community are encouraged to accept responsibility for environmental management issues. "The role of the statutory agencies becomes less focused on that of a decision maker and more focused on empowering or facilitating the community as the decision maker", Dahm et al., (2005).

5.6 Summary

It is evident that Maori, through a shared and intimate relationship with the coastal environment, have developed a detailed knowledge in relation to the occurrence of, and the management of natural hazards. Locating pa and kainga on hills and headlands, was not only advantageous to Maori as a means of defense against outsiders, it effectively ruled out the possibility of flooding of their homes. Planting native plants and using natural occurring materials in the coastal environment to help stabilize dune systems were traditionally used to mitigate the effects of erosion to dunes, and dune vegetation, caused by extreme weather conditions. Many Maori still believe that mimicking nature is the best practice in regard to protecting and preserving the coastal environment.

Interpretations of Maori oral histories, (including songs, laments, proverbs, quotations and stories) provide insights into past local hazards and inform about the safety and viability of certain activities within an area. Environmental indicators are useful for identifying and forecasting extreme weather conditions locally and such knowledge is significant in regards to hazard prevention and mitigation.

In regard to climate change, the biggest concern for Maori was the potential damage to coastal waahi tapu as a result of sea level rise. Associated with this, is the concern of how coastal management groups would deal with such occurrences and whether Maori would have the power to exercise tino rangatiratanga (autonomy) in such cases.

The views expressed in relation to the current practices carried out by non-Maori coastal management groups, with regard to the coastal environment, indicated anxieties over the inclusion of the traditional methods of the Maori associated with protecting and preserving the coastal environment. Consultation was recognised as a key task to be carried out before any decisions were made regarding the coast, to ensure all interested parties were aware of the nature of the changes/ developments, and could comment on any potential problems and/ or risks involved before plans were carried out.

Overall, Māori knowledge of past hazards and the coastal environment as a whole, is a valuable resource and provides a unique source of expertise that can contribute to current coastal hazards management plans in New Zealand and provide insights about the areas that may again be impacted by natural hazards, (KING et al., 2007).

Chapter 6

Conclusions and Furthur Research

6.1 Conclusions

Video monitoring of beaches is becoming the preferred technique for observing changes to nearshore morphology over a wide range of spatial and temporal scales. This study investigated the possibility of extracting runup data from video. The Collinearity Equations, which relate each point on an object to a set of measurements made in the image space, were used to convert 2-D image coordinates (x, y) into 3-D reference coordinates (X,Y,Z), known as rectification. This involved determining the vertical reference coordinate (Z) from video. This was achieved by tracking the edge of the waterline in the time-averaged images throughout a tidal cycle and used to define foreshore slope, α, and intercept, b, where $Z = aX + b$.

Determining the runup elevations from video involved collecting pixels from the video images along a cross-shore transect in the time-stacks. Each swash maxima was digitised and the beach morphology data (i.e. slope and intercept data) was used to rectify them onto the plane of the beach. This provided run-up timeseries for analysis.

Field work was carried out at each site to compare insitu and video statistics to assess the waterline finding technique using video. Surveys of the beach profiles were carried out along a cross-shore transect corresponding to the transect used in the timestacks. The mean water levels at each level of the tide were measured and recorded, and waterline transgression data was collected by counting the number of waves passing markers of known elevations on the beachface.

The beach slopes found by video were comparable to those determined in the field. However the waterline transgressions statistics found using video were consistently higher throughout the tidal cycle at both sites. This indicated that the waterline found by video was seaward of the real waterline at both locations. Quantification of this error revealed a vertical offset of 0.33m at Tairua and 0.25m at Pauanui. These offsets were applied to all runup statistics used in the reminder of the study to ensure accurate results.

The runup statistics were consistently higher at Tairua than at Pauanui. This was not surprising considering the dissipative nature of surf zones on flatter beaches. The Rayleigh distribution provided a reasonable description for the runup distributions at Tairua, however, at Pauanui the distributions were approximately bi-modal in nature. This perfectly illustrates the nature of runup on flatter beaches during storm events where infragravity energy (which is dominant on flatter beaches) causes the swash to run high and then low on the beachface. This produces high negative values of swash maxima which reduces the mean values of the runup elevations and decreases the waterline transgression statistics. The scale of the runup variance is also indicative of the presence of infragravity energy, where a higher runup variance corresponds to higher infragravity energy in the swash signal and as a result the runup distributions become more distinctly bimodal.

At Tairua, the steeper beach associated with incident wave energy, there was no relationship between swash height and wave or tide heights. On the other hand, at Pauanui, the flatter beach associated with infragravity wave energy, there is a definite correlation. Subsequently, it was assumed that beach slope was an important factor affecting runup and tests revealed that runup on steeper beaches is dependent on beach slope (for beaches with Iribarren numbers >0.5). For flatter beaches however, there seemed to be no correlation between the two.

Calibrations against empirical runup formulae were carried out to test the videoed runup results. The Neilson and Hanslow Equation (1991) was used to compare the vertical scale of the runup distribution, and the formula by STOCKDON et al., (2006) was used to compare the 2% exceedence statistics. Comparisons against runup formulae gave comparable results for both sites, and especially at Pauanui, however, there were large deviations between parameterisations and videoed when the beach was at its steepest. This suggests there may be difficulties associated with accurately determining runup using video on beaches with higher slopes and furthur validation should be carried out to test this. The comparisons of the 2% exceedence statistics at Tairua were similar to those found by STOCKDON *et al.*, (2006), however, the parameterisation overestimated the runup heights at Pauanui. Furthur tests should be carried out to test whether the formula is reliable when infragravity energy is dominant in the swash signal.

Overall, the results of the study indicate realistic runup measurements over a wide range of time scales and during storm events when collecting information in the field is difficult. The runup statistics are consistently higher at Tairua (videoed data, surveyed data, the vertical scale of the runup and the 2% exceedence statistics), and suggests that swash runs up higher on steeper beaches. However, because of the characteristics of flatter beaches (such as high water tables and low drainage efficiencies) the impact of extreme runup elevations on such beaches are more critical in regards to erosion and/ or inundation.

Through consultation and research it became evident that Maori, through a shared and intimate relationship with the coastal environment, have developed a detailed knowledge in relation to the occurrence of, and the management of natural hazards. Location of villages on hills and headlands, planting native plants and using natural occurring materials in the coastal environment to help stabilize dune systems were traditionally used to mitigate against erosion and inundation caused by extreme weather conditions. Many Maori still believe that mimicking nature is the best practice in regard to protecting and preserving the coastal environment, and hard solutions such as seawalls will eventually cause damage.

The biggest concerns for Maori in regards to coastal management were;

i) the potential damage to coastal waahi tapu as a result of sea level rise due to climate change; and,

ii) the inclusion of tikanga Maori into coastal management plans.

Consultation was recognised by Maori as a key task to overcoming these concerns, as it enables an open forum in which all parties can share their knowledge and express their opinions. Importantly, the reasons behind undertaking certain measures are understood and appreciated by others.

Oral histories of Maori, inform about the safety and viability of certain activities within an area, and detail the occurrences of previous hazards which provide insights into the possibility of future hazards. Environmental indicators are useful for identifying and forecasting extreme weather conditions locally and such knowledge is significant in regards to hazard prevention and mitigation.

Overall, Maori knowledge of past hazards provides a unique source of expertise that can contribute to current coastal hazards management plans in New Zealand and provide insights about the areas that may again be impacted by natural hazards.

6.2 Future Research

The definition of the waterline must also consider alongshore variation. Most studies of waterline variation consider discrete transects or points and monitor how these change through time. However, this method of sampling can introduce additional uncertainty if the points of interest are not representative of the whole beach (e.g. morphological features, such as beach cusps, which distort the alongshore average waterline position, (BOAK and TURNER, 2005)). The significance of alongshore variability to shoreline investigation was demonstrated by ELIOT and CLARKE (1989), who found that survey records from small segments of beach could not be used to accurately represent total beach change. Consequently, a next step to accurately measuring runup involves accounting for alongshore variation.

Furthur validation studies will need to be carried out to test the robustness of the technique used in this study to measure runup from video. The next logical step is to make comparisons over a wider range of storm conditions and beach morphologies. Investigations that measure runup on flatter beaches, where infragravity energy is dominant in the swash signal, is also important to validate the results of this work. Evaluations of modeled runup estimates should also be carried out.

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Appendix 1

Storm Data

TAIRUA:

Storm 1: 2/04/2001 (Beach slope 0.0733).

Time	8	9	10	11	12	13	14
Tide+Setup+Pressure	0.96	1.08	1.34	1.66	1.98	2.21	2.29
Tide	0.56	0.68	0.93	1.25	1.55	1.78	1.86
Setup	0.30	0.30	0.31	0.32	0.34	0.35	0.35
At. Pressure (P)	1003.50	1003.70	1003.90	1004.10	1004.40	1005.40	1005.70
P(m)	0.10	0.10	0.09	0.09	0.09	0.08	0.08
H_o	2.13	2.08	2.03	1.98	1.94	1.91	1.89
Z (vertical elevation)	1.01	1.05	1.24	1.73	1.97	2.22	2.26
Hrms	1.51	1.47	1.43	1.40	1.37	1.35	1.33
T_o	8.06	8.13	8.36	8.47	8.11	7.07	5.76
L_o	101.32	103.11	109.06	111.99	102.60	77.98	51.76

Storm 2: 2/04/2001 (Beach slope 0.0866).

Time	8	9	10	11	12	13	14
Tide+Setup+Pressure	2.21	2.04	1.74	1.38	1.05	0.82	0.76
Tide	1.81	1.65	1.36	1.02	0.70	0.47	0.40
Setup	0.45	0.44	0.43	0.41	0.40	0.39	0.39
At. Pressure (P)	1018.30	1018.40	1018.60	1018.60	1018.60	1017.70	1016.50
P(m)	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	-0.03
H_o	3.41	3.42	3.44	3.46	3.48	3.51	3.53
Z (vertical elevation)	1.98	1.80	1.79	1.41	1.26	0.66	0.47
Hrms	2.41	2.42	2.43	2.44	2.46	2.48	2.50
T_o	9.94	9.86	9.76	9.65	9.57	9.53	9.52
L_o	154.05	151.66	148.57	145.38	142.87	141.61	141.35

Storm 3: 2/04/2001 (Beach slope 0.0852).

Time	11	12	13	14	15	16	17
Tide+Setup+Pressure	1.02	1.02	1.20	1.46	1.77	2.06	2.26
Tide	0.58	0.58	0.74	1.00	1.29	1.57	1.77
Setup	0.39	0.39	0.41	0.42	0.43	0.44	0.44
At. Pressure (P)	1008.70	1009.10	1008.70	1008.30	1008.10	1008.00	1008.00
P(m)	0.05	0.04	0.05	0.05	0.05	0.05	0.05
H_o	3.44	3.45	3.48	3.52	3.53	3.50	3.44
Z (vertical elevation)	1.03	0.89	1.00	1.30	1.67	1.80	1.90
Hrms	2.43	2.44	2.46	2.49	2.50	2.48	2.43
T_o	7.63	7.66	7.68	7.70	7.73	7.77	7.80
L_o	90.89	91.53	92.05	92.56	93.21	94.08	94.85

Storm 4: 2/04/2001 (Beach slope 0.0787).

Time	7	8	9	10	11	12	13
Tide+Setup+Pressure	1.01	1.10	1.35	1.66	1.98	2.24	2.38
Tide	0.57	0.67	0.90	1.21	1.52	1.78	1.91
Setup	0.40	0.40	0.41	0.42	0.43	0.44	0.44
At. Pressure (P)	1009.00	1010.10	1009.50	1009.90	1010.20	1010.80	1010.90
P(m)	0.04	0.03	0.04	0.03	0.03	0.02	0.02
H_o	3.56	3.51	3.45	3.39	3.33	3.27	3.20
Z (vertical elevation)	1.36	1.61	1.60	1.95	2.28	2.36	2.35
Hrms	2.52	2.48	2.44	2.40	2.36	2.31	2.26
T_o	8.60	8.57	8.55	8.53	8.52	8.52	8.50
L_o	115.37	114.69	114.04	113.55	113.22	113.24	112.78

Storm 5: 6/07/2001 (Beach slope 0.1437).

Time	10	11	12	13	14	15	16
Tide+Setup+Pressure	2.42	2.21	1.87	1.48	1.13	0.90	0.88
Tide	1.89	1.68	1.35	0.97	0.63	0.40	0.38
Setup	0.45	0.45	0.44	0.43	0.42	0.41	0.41
At. Pressure (P)	1005.10	1005.20	1005.10	1005.00	1004.70	1004.50	1004.30
P(m)	0.08	0.08	0.08	0.08	0.09	0.09	0.09
H_o	3.43	3.52	3.61	3.71	3.82	3.92	4.00
Z (vertical elevation)	2.04	1.94	1.70	1.28	1.15	1.05	1.12
Hrms	2.42	2.49	2.55	2.63	2.70	2.77	2.83
T_o	9.31	9.31	9.27	9.27	9.27	9.23	9.23
L_o	135.21	135.21	134.06	134.06	134.06	132.90	132.90

Storm 6: 31/08/2001 (Beach slope 0.1470).

Time	8	9	10	11	12	13	14
Tide+Setup+Pressure	2.27	2.13	1.83	1.44	1.05	0.75	0.61
Tide	1.92	1.80	1.52	1.15	0.78	0.49	0.35
Setup	0.41	0.41	0.39	0.37	0.35	0.33	0.32
At. Pressure (P)	1019.90	1020.50	1020.70	1020.90	1020.90	1020.10	1019.70
P(m)	-0.07	-0.07	-0.07	-0.08	-0.08	-0.07	-0.06
H_o	2.69	2.66	2.64	2.61	2.59	2.56	2.54
Z (vertical elevation)	2.22	2.23	1.74	1.41	1.08	1.10	0.69
Hrms	1.90	1.88	1.86	1.85	1.83	1.81	1.79
T_o	8.99	9.07	9.07	9.07	9.14	9.14	9.26
L_o	126.08	128.33	128.33	128.33	130.32	130.32	133.77

Storm 7: 2/04/2001 (Beach slope 0.0733).

Time	11	12	13	14	15	16	17
Tide+Setup+Pressure	2.66	2.41	1.98	1.48	1.00	0.66	0.56
Tide	2.23	1.99	1.59	1.11	0.67	0.34	0.24
Setup	0.40	0.38	0.35	0.32	0.29	0.27	0.26
At. Pressure (P)	1009.80	1009.70	1009.80	1009.10	1008.80	1008.20	1007.90
P(m)	0.03	0.04	0.03	0.04	0.04	0.05	0.05
H_o	2.17	2.13	2.09	2.04	2.00	1.96	1.93
Z (vertical elevation)	2.29	1.68	0.95	0.65	1.02	0.76	0.63
Hrms	1.54	1.51	1.48	1.45	1.42	1.39	1.37
T_o	6.27	6.27	6.27	6.53	6.53	6.53	6.52
L_o	61.33	61.33	61.33	66.52	66.52	66.52	66.32

Storm 8: 2/04/2001 (Beach slope 0.0733).

Time	10	11	12	13	14	15	16
Tide+Setup+Pressure	0.95	1.02	1.27	1.62	1.98	2.30	2.47
Tide	0.45	0.52	0.75	1.08	1.43	1.72	1.89
Setup	0.40	0.40	0.41	0.42	0.44	0.45	0.46
At. Pressure (P)	1003.70	1003.20	1002.40	1001.80	1001.40	1001.00	1000.80
P(m)	0.10	0.10	0.11	0.11	0.12	0.12	0.12
H_o	3.68	3.65	3.61	3.58	3.54	3.51	3.47
Z (vertical elevation)	1.59	1.49	1.63	1.81	2.01	2.15	2.38
Hrms	2.60	2.58	2.55	2.53	2.51	2.48	2.45
T_o	7.43	7.43	7.57	7.57	7.57	7.71	7.71
L_o	86.03	86.03	89.40	89.40	89.40	92.73	92.73

Storm 9: 2/04/2001 (Beach slope 0.0733).

Time	10	11	12	13	14	15	16
Tide+Setup+Pressure	0.90	0.97	1.20	1.53	1.89	2.20	2.41
Tide	0.46	0.53	0.74	1.04	1.36	1.65	1.84
Setup	0.26	0.26	0.27	0.28	0.29	0.31	0.32
At. Pressure (P)	995.70	994.80	993.70	991.90	989.60	988.60	988.00
P(m)	0.18	0.18	0.20	0.21	0.24	0.25	0.25
H_o	1.81	1.74	1.68	1.63	1.58	1.54	1.49
Z (vertical elevation)	1.19	1.24	1.45	1.73	2.08	2.29	2.48
Hrms	1.28	1.23	1.19	1.15	1.12	1.09	1.06
T_o	6.84	6.84	7.32	7.32	7.32	7.80	7.80
L_o	72.99	72.99	83.59	83.59	83.59	94.91	94.91

Storm 10: 2/04/2001 (Beach slope 0.0733).

Time	8	9	10	11	12	13	14
Tide+Setup+Pressure	2.61	2.54	2.23	1.77	1.27	0.86	0.62
Tide	2.15	2.08	1.78	1.34	0.87	0.47	0.23
Setup	0.40	0.41	0.39	0.38	0.35	0.34	0.32
At. Pressure (P)	1007.10	1007.60	1007.80	1008.50	1008.50	1008.00	1007.50
P(m)	0.06	0.06	0.05	0.05	0.05	0.05	0.06
H_o	2.32	2.43	2.52	2.59	2.63	2.66	2.68
Z (vertical elevation)	2.39	2.42	1.92	1.89	0.83	1.12	1.17
Hrms	1.64	1.72	1.78	1.83	1.86	1.88	1.89
T_o	6.30	6.30	6.30	6.37	6.37	6.37	6.63
L_o	61.92	61.92	61.92	63.30	63.30	63.30	68.57

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Storm 11: 2/04/2001 (Beach slope 0.0733).

Time	11	12	13	14	15	16	17
Tide+Setup+Pressure	2.66	2.41	1.98	1.48	1.00	0.66	0.56
Tide	2.23	1.99	1.59	1.11	0.67	0.34	0.24
Setup	0.40	0.38	0.35	0.32	0.29	0.27	0.26
At. Pressure (P)	1009.80	1009.70	1009.80	1009.10	1008.80	1008.20	1007.90
P(m)	0.03	0.04	0.03	0.04	0.04	0.05	0.05
H_o	2.17	2.13	2.09	2.04	2.00	1.96	1.93
Z (vertical elevation)	2.29	1.68	0.95	0.65	1.02	0.76	0.63
Hrms	1.54	1.51	1.48	1.45	1.42	1.39	1.37
T_o	6.27	6.27	6.27	6.53	6.53	6.53	6.52
L_o	61.33	61.33	61.33	66.52	66.52	66.52	66.32

Storm 12: 2/04/2001 (Beach slope 0.0733).

Time	10	11	12	13	14	15	16
Tide+Setup+Pressure	0.95	1.02	1.27	1.62	1.98	2.30	2.47
Tide	0.45	0.52	0.75	1.08	1.43	1.72	1.89
Setup	0.40	0.40	0.41	0.42	0.44	0.45	0.46
At. Pressure (P)	1003.70	1003.20	1002.40	1001.80	1001.40	1001.00	1000.80
P(m)	0.10	0.10	0.11	0.11	0.12	0.12	0.12
H_o	3.68	3.65	3.61	3.58	3.54	3.51	3.47
Z (vertical elevation)	1.18	1.27	1.92	1.91	2.09	2.22	2.21
Hrms	2.60	2.58	2.55	2.53	2.51	2.48	2.45
T_o	7.43	7.43	7.57	7.57	7.57	7.71	7.71
L_o	86.03	86.03	89.40	89.40	89.40	92.73	92.73

Storm 13: 2/04/2001 (Beach slope 0.0733).

Time	9	10	11	12	13	14	15
Tide+Setup+Pressure	2.61	2.54	2.23	1.77	1.27	0.86	0.62
Tide	2.15	2.08	1.78	1.34	0.87	0.47	0.23
Setup	0.40	0.41	0.39	0.38	0.35	0.34	0.32
At. Pressure (P)	1007.10	1007.60	1007.80	1008.50	1008.50	1008.00	1007.50
P(m)	0.06	0.06	0.05	0.05	0.05	0.05	0.06
H_o	2.32	2.43	2.52	2.59	2.63	2.66	2.68
Z (vertical elevation)	2.39	2.42	1.92	1.89	0.83	1.12	1.17
Hrms	1.64	1.72	1.78	1.83	1.86	1.88	1.89
T_o	6.30	6.30	6.30	6.37	6.37	6.37	6.63
L_o	61.92	61.92	61.92	63.30	63.30	63.30	68.57

Appendix 2

Runup Data

Raw Data – TAIRUA

Storm 1

0.8583	0.5384	0.6867	0.627	0.5027	0.3483	0.5066
0.7491	-0.0636	0.9231	0.7906	0.7571	0.6026	0.5066
0.6033	0.7752	1.1594	0.4087	0.9749	1.0382	0.7608
0.6944	1.0845	0.9231	0.8087	0.6481	1.1108	0.6882
0.6398	0.8298	0.7594	0.8087	0.8479	1.2559	0.8334
-0.0536	0.848	0.5775	0.9723	0.5391	0.5118	0.8697
0.7673	0.3379	0.8867	0.4997	1.102	0.9112	0.5974
0.8765	0.429	0.9595	0.7906	0.6481	0.53	0.8697
0.2933	0.5384	0.5957	0.3905	0.9205	0.9838	0.543
0.4575	0.6113	1.123	0.6088	0.6299	0.8567	0.5611
0.7309	0.6841	0.6321	0.6815	0.7026	0.9112	0.4703
0.5669	0.9026	0.6503	1.172	0.9568	0.7297	0.906
1.00	0.5566	0.6867	0.4451	0.4119	0.6571	0.3795
0.22	0.7387	0.8504	0.3905	0.6118	0.6026	1.1962
0.79	1.0117	0.723	0.8451	0.5573	0.9475	0.7971
0.51	0.5566	0.8686	0.8996	0.8297	0.6934	0.7971
0.6762	0.5566	0.8867	1.172	1.4648	0.7841	0.5793
0.7673	0.848	0.8322	0.4633	0.7389	1.1289	0.5793
1.2041	0.7934	0.7412	0.8451	0.4846	0.9656	0.7245
-0.0354	0.9208	0.8686	1.1902	0.9568	0.9656	0.67
0.6762	0.6477	0.6321	0.7361	0.9023	0.4573	0.67
0.3116	0.7752	0.5046	0.7361	0.5573	0.6752	0.6156
0.5304	0.9026	0.6867	0.8087	0.9568	0.3665	0.7971
0.5851	0.9935	0.814	0.6452	0.7752	1.147	0.6882
0.7309	0.9208	1.1049	0.9178	0.8842	1.0201	0.8152
0.7673	0.8298	0.814	0.7724	0.8297	0.3665	0.8152
0.8765	0.7934	0.814	0.6088	0.5754	0.2938	0.6156
0.7309	0.4473	0.9413	1.2265	0.4482	0.6571	0.8697
0.6033	0.7569	1.123	0.4451	0.6844	1.0201	0.8515
0.5851	0.939	0.723	0.9541	0.866	0.4755	0.7426
0.7491	0.5384	0.6321	0.5906	0.7389	0.4573	0.9423
0.6215	0.9753	0.814	0.6452	0.4482	0.7115	0.8515
0.6762	0.848	1.1594	1.2809	0.6663	0.53	0.6337
0.8219	0.9571	0.8322	0.5906	0.8115	0.893	0.7608
0.658	0.8116	0.6685	0.9178	0.6481	0.7115	0.4885
0.913	0.4837	0.7412	0.7906	0.5209	0.8023	0.1797
1.0586	0.7934	0.7958	1.2809	0.4119	0.3847	0.7789
0.7673	0.7752	0.7594	0.6088	0.4664	0.8386	0.5974
0.658	0.5748	0.9958	0.8633	0.5391	0.5663	0.5066

0.7126	1.2481	0.7412	0.8087	0.9749	0.766	0.8878
0.6762	0.8662	0.9595	0.7542	0.9568	0.5481	0.5611
1.004	0.8298	0.8504	0.6815	0.4846	0.6571	0.8515
0.5486	0.8116	0.6503	0.6815	0.8842	0.421	0.5611
0.5851	0.8116	0.8322	0.7542	0.5027	0.421	0.8878
0.348	1.03	0.8686	0.8814	0.3573	0.7841	0.9423
0.2386	0.4837	0.5046	0.8814	1.3197	0.893	0.8878
0.8583	0.7023	0.7412	1.0812	0.7934	1.0745	0.8697
0.9858	0.9208	0.9958	0.8633	0.5209	0.8204	0.7789
0.6944	0.8298	0.6139	1.0812	0.6844	0.3483	0.5066
0.9312	0.7205	0.7958	0.8633	0.7207	0.4755	1.0511
0.5669	0.939	1.1049	0.8996	1.0838	0.7478	0.67
0.4575	0.6841	0.7594	0.4997	0.9386	0.9475	0.6519
0.6215	0.7752	1.0685	0.5906	0.6299	0.766	0.8152
0.6398	0.9208	0.7958	1.0267	0.7571	0.6389	1.1418
1.3132	0.7205	0.723	0.9359	1.0294	0.3483	0.8697
0.8948	0.8662	0.6503	0.6633	0.5573	0.5118	0.6156
0.421	1.0117	0.8686	1.2628	1.102	0.7478	0.543
0.6398	0.8298	1.0685	0.8996	0.7752	0.7841	0.7063
0.2933	0.6659	0.7594	0.5543	0.6844	0.6752	0.9604
0.5304	0.8298	0.7776	0.7542	0.7571	0.4936	0.7789
-0.3279	0.8298	0.9413	0.8814	0.8479	1.2922	0.4703
0.5486	0.6841	0.9231	1.2991	0.5573	0.4392	0.6156
0.5851	1.3935	0.6139	0.7179	1.0475	0.6934	0.5793
0.8037	0.8298	0.9595	0.8814	0.7934	0.9112	0.3795
0.9312		0.9595	0.6633	0.4119	0.3665	0.8515
1.0586		0.8686	0.6815	0.5936	0.3847	0.5248
0.4757		0.7048	0.8633	0.866	0.8204	0.9423
0.7126		0.7958	0.7724	0.7026	0.8567	0.5793
0.7673		0.814	0.8087	0.9749	0.6571	0.7245
0.5851		1.1412	1.0086	0.6118	1.2922	0.8334
0.5304		1.0685	0.7361	1.0838	0.7297	0.8334
1.1131		0.5229	0.627	0.8842	0.7297	0.7063
1.3132		0.7594	0.5543	0.5391	0.6571	0.5248
0.7126		0.7776	0.6815	0.9023	1.2922	0.8515
0.6215		0.7412	0.5724	0.4119	0.8386	0.543
-0.145		0.723	0.6633	0.7571	0.5844	0.543
		1.4318	1.0994	0.4664	0.6752	0.5611
		0.7776	0.8087	0.9023	0.6934	0.67
		1.3592	1.0267	1.0475	1.147	0.7245
		0.5593	0.8633	0.3937	0.5663	1.1418
		0.8867	0.8633	0.4119	0.7478	0.7971
		0.6139	1.2083	1.1383	0.4573	0.8515
		0.9958	0.627	0.8842	0.766	0.8515
		0.7412	1.0086	1.1746	0.766	0.7971
		1.1049	0.5543	0.8297	1.3829	0.7063
		0.6321	0.7179	0.7752	0.766	0.7245
		0.8686	0.7542	0.5027	0.8749	0.4703

		0.7412	0.6633	0.5573	0.8567	0.6519
			0.8633	0.5754	0.8386	0.7971
			0.5906	0.866	1.0563	0.5793
			0.6633	0.4301	0.6934	0.6337
			0.8087	0.7026	0.8386	0.3977
			1.0631	1.102	0.6026	0.8697
			0.7724	0.9749	1.0926	0.6519
			0.8814	0.5391	0.6389	1.0511
			0.8814	0.5391	0.6389	0.6337
			0.9904	0.9386	0.2211	0.9241
			0.4815	0.6844	0.7841	0.8697
			0.5361		0.5663	0.5793
					0.5663	0.8334
					0.6208	0.9967
					1.2377	
					0.8567	

Storm 2

0.64	1.6462	1.6979	-0.321	1.1712	0.2283	0.3843
0.2098	1.324	0.2527	1.5422	0.521	0.359	-0.1398
1.6732	1.324	0.4043	0.9597	0.7381	0.5767	0.8628
0.1449	1.6248	1.8912	0.8515	1.6032	-1.2632	1.729
1.2009	0.9583	0.5773	0.8083	0.1294	1.011	-1.5923
0.5336	0.6781	1.2677	0.5701	2.0126	1.2277	0.602
0.7706	0.7428	1.0523	1.5853	0.4775	-0.2523	1.0582
0.6198	1.9894	0.4692	1.1109	1.2794	-0.5811	-1.2386
0.8568	0.9583	1.3323	1.6068	0.7814	0.3808	2.1172
1.3942	0.7644	0.7934	0.8083	1.5385	1.1628	0.1007
0.4473	0.5486	0.6854	0.5918	0.1512	2.07	1.1015
1.4801	0.8721	0.9013	0.223	0.1512	0.6854	0.1662
0.253	0.4407	1.0738	-0.0379	0.4123	1.3359	0.3843
1.523	1.0444	0.8581	0.8515	0.9765	1.1411	0.689
0.3394	1.367	2.1272	1.6714	0.6079	-0.2742	0.8411
1.3942	1.0013	1.16	0.8948	-0.7668	0.359	-1.1944
1.2654	0.5055	0.3177	0.4617	1.4306	1.1411	-0.3368
0.7491	0.8506	-0.1378	1.0893	2.3782	-1.5283	0.5149
0.2962	0.6997	0.9013	1.2188	0.2601	0.6202	0.9063
1.2009	0.138	1.3969	0.938	-0.1541	-2.0159	0.7977
1.3298	1.0229	1.2246	1.2188	1.0847	0.8158	0.4278
0.7706	1.3885	1.3323	0.4401	1.1929	-0.4714	-0.3588
0.7922	0.9583	0.6638	1.1541	1.2361	0.6854	0.6455
1.0934	1.238	0.5989	0.4617	2.0126	0.3808	0.7325
0.3825	0.9367	0.4043	0.9164	0.6947	1.2927	-1.3269
0.0152	1.2595	0.7286	0.8732	1.1063	1.4873	1.8801
1.3298	1.5174	1.0738	0.7217	0.3906	-0.143	-2.3699
1.2009	1.195	1.0954	1.779	0.521	1.3576	-0.0523
0.4904	0.4191	0.8797	0.2013	1.1929	-0.2305	0.7107
1.0934	0.9583	0.5989	0.0709	0.3254	-1.0428	0.6238

0.5767	0.829	1.5044	0.5918	0.8682	1.8328	-0.4465
1.2009	0.4407	0.5557	1.6499	1.1496	0.0755	-1.0401
1.0074	1.324	1.3108	0.6784	-0.0231	0.5767	1.2749
1.0504	0.5486	1.6549	0.3316	1.7111	0.4897	-0.644
1.6732	1.281	0.8581	1.3698	0.1948	0.01	-1.1724
0.8137	1.1305	0.6422	1.456	-0.3288	0.2283	0.3843
1.4801	0.4623	0.6206	0.3967	0.8465	0.6637	1.1449
0.8998	0.7859	1.2677	0.7001	1.7757	1.4008	-0.8859
0.1449	1.1735	0.6854	1.3698	0.3689	-0.2305	-0.622
0.7706	1.7321	0.8365	0.1796	-1.0303	0.5332	-0.3807
1.4587	-0.1002	0.1443	0.5051	0.3689	0.6202	-1.1724
0.706	0.0081	0.4908	0.938	0.5427	1.011	1.1882
1.0719	0.829	1.4829	0.2882	1.301	0.9894	-0.2273
1.3513	0.0514	1.3323	0.8299	0.7598	0.7723	0.2534
0.8137	1.1735	1.1385	1.3267	1.3226	-0.4933	0.5149
0.8568	1.3455	0.166	0.0274	1.1929	0.2719	0.7759
1.5874	1.3885	0.7502	0.8732	-0.8546	1.3792	0.7542
0.4904	1.0013	1.0738	1.2188	0.8682	0.7723	-0.3807
1.1149	0.6134	0.815	0.9813	1.7542	-1.175	0.689
0.1449	0.5702	1.1816	0.8299	1.4522	1.6602	-0.0086
0.9213	0.9367	0.8581	0.8083	-0.3507	0.6202	0.8411
1.1794	1.775	0.5773	-0.1249	-0.1759	1.5954	1.1449
1.5016	0.7859	0.9013	1.262	0.9981	-1.4841	1.4696
-0.0065	0.311	1.0954	0.5268	1.4738	-0.0774	-1.6144
0.9429	1.152	1.4829	0.5051	0.7598	-0.3837	-1.1503
0.7922	0.2029	1.3108	1.5422	1.0414	0.9243	-0.0304
0.5551	0.2029	0.0793	2.0155	1.3874	1.7465	0.8846
0.1666	1.5603	0.296	0.0926	-0.0668	0.359	-0.974
1.1579	1.6033	1.1816	1.1972	0.7598	0.6419	1.1449
0.8998	0.3327	1.7838	0.1578	-0.0013	-0.4714	-0.9079
1.0074	0.1813	0.8365	0.3316	-1.1183	1.5522	2.0957
0.1233	0.5055	0.966	0.8948	0.521	-0.8227	1.0365
1.6303	1.0659	0.0793	1.6283			-0.4465
1.1794	0.4407	-0.2465	1.2404			0.057
1.9305	1.8393	1.0954				1.7506
0.2746	1.3025	1.0954				-0.9299
1.0074	-0.0135	0.5341				-1.1062
0.2746	0.7644	1.2462				0.6673
0.7276	0.7428	0.6206				
1.0074	1.0874	0.6206				
1.0289	1.0444	0.2744				
0.9859	0.6997	1.4829				
1.3728	0.635	0.6206				
1.0719	0.311	0.9013				
0.8568		0.8581				
		0.7934				

Storm 3

0.1081	1.1929	0.6951	0.6744	0.847	0.6336	0.7493
0.6262	0.9802	0.4607	0.1419	0.5924	0.9301	1.0664
0.7555	0.746	0.546	0.1419	1.2494	1.3316	0.7705
0.7085	-0.1949	0.2472	0.419	0.2735	1.2472	0.5376
0.0491	0.9802	0.8228	0.9718	1.2282	0.4003	1.383
0.0491	0.60	0.3113	1.1839	0.5499	1.057	0.8128
0.0727	0.4473	0.5246	0.8869	0.8046	1.1415	0.9185
0.685	0.1908	-0.1379	0.6531	0.2097	0.6124	0.707
0.2613	0.3191	1.5658	0.5042	0.6773	1.2683	0.6012
0.8377	0.3405	0.2686	0.5893	0.9106	1.2049	0.9607
-0.3647	0.4046	1.0567	1.0567	1.0165	0.7395	1.1297
-0.0808	0.1266	0.5886	0.5893	1.1012	0.9301	0.7705
-0.6135	0.9802	0.012	0.3977	0.2948	0.9512	1.2142
0.3203	1.1291	0.012	0.6531	0.3374	1.1204	0.6223
0.8024	0.49	0.3753	0.1632	0.8258	0.9512	0.8128
0.5321	-0.1091	-0.1379	0.7382	1.6509	1.2894	0.8762
-0.1045	0.5754	0.7164	-0.0076	0.8682	0.7607	1.172
1.2129	1.4052	-0.1379	0.7169	0.7622	0.57	1.1297
0.0727	0.0838	0.8867	0.2272	0.4862	1.226	0.8762
0.5909	1.0866	-0.2236	1.0991	0.7834	1.1838	0.8762
1.2831	-0.6032	0.9079	0.8656	0.5287	0.8666	0.8973
-0.8034	0.49	-0.2021	0.5893	0.6136	1.057	1.003
-0.1163	0.7034	0.6738	0.9293	0.9318	0.676	0.8762
0.2731	0.746	0.3753	0.4829	0.4649	1.2683	0.9185
0.6615	0.4687	-0.0094	0.1845	0.6348	0.5488	1.404
-0.7203	1.2991	0.5673	0.2485	-0.0247	0.9089	0.9396
0.8611	-0.7109	0.7377	0.9293	1.0377	0.7819	1.0241
-0.4594	1.2991	0.0548	0.7169	0.6773	1.3739	0.4953
0.4968	0.1908	0.1403	0.1845	0.8046	1.2683	1.383
0.2378	0.5327	0.9717	1.1203	0.5711	1.2472	0.6012
0.8494	0.9377	-0.3523	0.4403	1.0801	0.2304	0.8339
-0.1636	0.9802	0.5886	0.6106	0.8258	1.4372	0.5376
0.5909	0.6607	0.3326	1.0355	1.4185	1.395	1.2142
0.8259	-0.2163	1.3751	0.1845	0.4224	0.9512	0.8973
-0.1399	0.6607	-0.1593	0.9718	0.231	0.676	0.8973
-1.0056	-0.0233	1.714	0.6531	0.9318	1.3316	1.4462
0.3438	0.7886	-0.4381	0.7594	0.847	0.5064	0.707
1.1074	0.682	0.9717	0.2485	0.9106	0.9512	1.3408
-0.9223	1.1291	0.3753	1.0142	1.2494	1.1415	0.9185
0.8494	0.4046	-0.3523	0.4829	0.1458	1.0147	0.6223
0.2967	0.7886	0.993	1.3746	0.2948	0.8666	1.0664
-0.1872	0.9377	0.993	0.2272	1.2282	1.1415	1.2775
0.9198	0.682	1.4811	0.993	1.0589	0.9512	0.4529
-0.5305	1.2141	0.9292	0.4403	1.1859	0.8454	0.8762
1.0371	0.8312	1.3115	0.9081	1.0377	1.0781	1.0875
-0.4002	0.7673	0.4393	0.7594	0.3586	1.226	0.7282
0.5321	0.49	0.6951	0.6957	0.5287	0.464	1.2564
0.2967	1.3415	0.3113	0.7382	0.953	0.7395	1.1086

0.2378	0.746	0.6312	0.6106	0.1884	1.0358	0.9607
0.5086	-0.3237	0.3326	0.6957	0.9953	1.395	1.2142
0.6145	0.6181	0.993	0.993	1.2282	0.7183	0.8762
0.3203	0.3832	0.4393	0.9081	0.5074	0.9089	1.2564
0.6967	0.4046	1.0992	0.7594	1.2705	0.9301	1.2564
0.1317	0.3191	0.6525	1.0142	0.7622	1.4794	0.9819
0.2496	0.1908	-0.2236	0.5042	1.7564	1.1415	1.2986
-0.2463	0.5754	1.2054	1.2475	0.741	0.5276	1.4462
-0.1045	1.0015	0.1831	0.0138	0.7197	0.9512	0.8762
-0.3173	1.2566	0.6951	0.2059	0.9953	1.1415	1.0453
0.5439	1.0653	1.0992	0.9718	-0.8801	0.9089	1.172
0.638	0.7886	0.3113	0.4616	0.847	1.3527	0.9185
-0.0808	0.8951	0.7803	1.2475	0.9318	1.0781	0.4317
0.5792	0.2977	1.0142	0.5255	0.4862	1.0147	1.2564
-0.0218	0.8099	1.1629	1.0567	1.1859	1.1415	1.1931
0.167	0.682	1.3751	0.419	0.5074	0.9089	0.8339
0.0727	1.6385	1.4599	0.6106	0.3161	1.2472	1.3619
-0.4002	0.2122	0.5886	1.2263	1.2917	0.8666	0.8551
0.5674	-0.1305	1.3115	0.7594	0.6136	1.6059	1.5305
0.2967	0.255	1.8621	0.5042	0.1458	0.5276	0.707
-0.4476	0.8951	0.3113	0.2698	0.4649	0.5912	1.1086
0.332	0.0838	0.8228	0.1419	1.3762	1.1626	0.58
0.6732	0.8738	1.0142	0.8019	0.3374	0.6972	0.707
-0.6847	1.0015	1.0142	0.7169	1.1436	1.2894	1.1297
0.7555	0.5754	1.2478	0.2485	0.5924	0.57	0.7705
0.8259	0.041	0.1403	1.0779	0.953	1.0781	1.0453
0.226	0.3405	1.0355	0.8656	0.4012	0.5488	0.8762
-0.4476	1.3203	0.9505	0.6957	0.4012	0.8666	1.0241
0.2496	0.148	1.3327	0.0992	1.0377	1.1204	1.0241
0.8377	0.9802	0.9505	1.0567	0.1245	0.5912	1.2564
0.1317	1.2991	1.2266	0.6106	1.2494	1.4161	1.4251
0.226	-0.3022	0.8867	0.568	0.3161	1.2049	1.0453
-0.2818		0.6951	0.7169	0.7834	1.0358	1.0453
0.3909		0.0976		0.953	0.9089	1.2353
0.1081				0.5499	0.5912	0.8762
-0.8747				0.5499	1.5638	0.6223
0.1199				0.847	1.1838	1.1086
0.3556				1.2705	0.5912	1.2142
0.8377				0.3799	0.676	1.003
0.2731				-0.0247	0.9089	1.1086
-0.6135					0.9512	0.7282
0.1552					1.1204	0.7493
					0.57	1.4462
					0.4215	1.1297
					0.8242	1.1297
					1.0992	1.4462
					1.3105	1.2775
					1.7957	0.4953

						1.1931
						0.707
						1.1931
						1.1508
						0.7493
						1.0875

Storm 4

0.8747	1.4065	0.5931	0.5705	0.8204	0.1093	0.3936
1.0155	0.9149	0.9622	1.2016	0.4875	0.495	0.236
0.7338	0.9149	1.0675	0.7812	0.7504	0.4775	0.5861
1.0507	1.4416	1.0675	1.0966	0.7504	0.4424	0.6386
0.7514	0.545	0.9096	0.7987	0.9604	0.4424	0.2009
0.8923	1.0907	0.9271	1.0441	0.6102	0.67	0.2885
0.9803	0.3155	1.1026	0.6934	0.6453	0.6525	0.3236
1.3844	1.1258	1.1552	0.7636	0.7679	0.74	0.4986
1.0331	0.7037	1.1552	0.9039	0.7679	0.705	0.4811
1.3493	1.2838	0.9622	0.7636	0.7679	0.4074	0.2885
1.0858	0.7565	0.9973	1.1666	0.5576	0.705	0.271
0.9099	0.8269	0.9096	0.9915	0.9079	0.3198	0.3936
1.2088	1.3189	0.9271	0.7636	0.5927	0.3724	0.306
1.2264	0.6332	1.1727	0.9214	0.7504	0.46	0.236
1.4019	0.8445	0.7339	0.8688	0.7504	0.5125	0.4111
1.2966	1.3013	0.9622	0.7812	0.4524	0.495	0.3761
0.2746	1.0907	1.0851	0.711	0.8729	0.4424	0.6211
1.3142	1.0731	1.3129	0.7987	0.6628	0.2496	0.2184
1.0507	0.9149	0.9622	0.9039	0.505	0.6	0.1658
1.3317	1.1082	0.6283	1.1316	0.7854	0.6175	0.5861
0.9099	0.9501	1.0324	0.8864	0.5927	0.2496	0.271
1.2791	1.2311	0.7514	0.8688	0.7329	0.635	0.1658
0.3807	0.5803	1.05	0.7285	0.47	0.4074	0.5336
1.1561	1.4241	1.1903	0.7285	0.8554	0.4249	0.236
0.8923	0.9149	0.7163	1.0616	0.3471	0.46	0.4811
1.0858	1.2311	0.9798	1.0616	0.8904	0.4249	0.271
0.7867	0.6332	0.892	0.8338	0.6628	0.2496	0.2535
0.9979	0.8973	1.1201	0.8162	0.7854	0.565	0.4111
1.0155	1.30	0.6283	0.9214	0.505	0.53	0.3936
1.121	0.8269	1.2954	0.553	0.3471	0.67	0.1483
0.575	1.1082	0.7163	0.711	0.7329	0.3724	0.2885
0.6985	1.3364	1.2604	1.0266	0.6453	0.5125	0.2009
1.1737	0.9852	0.5051	0.8162	0.3998	0.2496	0.4461
1.4195	0.7917	1.0675	1.0441	0.6102	0.4775	0.1658
1.1737	1.0907	1.1727	1.0266	0.3822	0.6	0.4461
0.769	1.0907	1.3305	0.9565	0.5226	0.3198	0.1658
1.1737	1.0907	0.8217	0.6759	0.8029	0.6175	0.4461
1.3493	0.8973	1.1026	0.7461	0.6278	0.46	0.306
0.7867	0.9149	0.417	1.1491	0.4875	0.6175	0.5161
0.9979	1.3013	1.1903	0.6232	0.8554	0.5125	0.271

1.1034	0.9325	0.769	0.939	0.6278	0.3198	0.3586
1.1737	0.8797	0.5931	0.8338	0.5401	0.705	0.4111
0.575	1.0204	1.05	0.9039	0.6803	0.4074	0.2885
1.2088	1.0204	1.2078	0.8864	0.4875	0.197	0.271
1.2615	1.3715	0.8042	0.7987	0.7154	0.53	0.3411
0.4868	0.7741	0.9798	1.0266	0.4875	0.6175	0.0957
0.9803	1.4767	1.0675	0.6408	0.8029	0.4074	0.3586
1.0507	1.1785	1.3129	0.7285	0.3822	0.6	0.5511
1.1034	1.0555	0.6283	1.1666	0.8029	0.6	0.2885
0.9451	1.1082	0.9271	0.9915	0.8904	0.5475	0.1308
0.6809	1.038	1.0675	1.0616	0.4875	0.46	0.6386
1.0331	0.8445	1.2253	0.7285	0.5927	0.3724	0.2885
1.1034	1.1785	1.0149	0.553	0.5927	0.6525	0.271
1.121	1.0555	0.9271	0.939	0.6978	0.4249	0.4111
0.5221	0.7917	1.2604	0.7812	0.8379	0.53	0.1834
1.2088	0.8445	0.8217	1.1316	0.4875	0.7575	0.4636
1.0507	1.2136	1.0324	0.6232	0.8029	0.1619	0.271
1.0858	1.2662	0.9622	0.9915	0.505	0.5825	0.5161
1.0858	0.9149	1.1201	0.7812	0.2769	0.53	0.4111
1.4195	1.0731	0.9271	1.009	0.8554	0.3373	0.3411
1.4721	1.1609	0.892	0.6057	0.7154	0.3198	0.3236
0.8923	1.0204	0.9798	1.1141	0.7679	0.3899	0.5161
1.2791	0.8973	0.9798	1.1666	0.6978	0.5825	0.271
0.8043	0.8445	1.1903	0.8338	0.6628	0.3899	0.3761
0.8043	0.8621	1.1552	1.009	0.9954	0.565	0.3411
0.8219	0.8973	1.0324	0.974	0.5226	0.3198	0.1834
0.9275	1.1258	0.7514	0.9915	0.7679	0.4249	0.4461
	1.389	0.892	1.009	0.6628	0.4249	0.2184
	1.1082	0.9447	1.0266	0.47	0.3373	0.5686
	0.9325	0.9271	0.7285	0.7854	0.4424	0.1308
	1.1082	1.3129	1.0266	0.6102	0.3373	0.5511
	1.1434	0.9622	0.7987	0.7854	0.4424	0.1483
	1.2487	1.2429	1.2191	0.8379	0.5825	0.0606
	1.1258	1.1026	0.9565	0.5401	0.3198	0.6036
		1.1903	0.7636	0.6453	0.6875	0.2885
		1.3655	0.8338	0.6978	0.4424	0.2885
		0.6811	0.8338	0.8029	0.495	0.4286
		1.05	1.2016	0.8729	0.7225	0.1308
		1.0675	0.8688	0.5927	0.3373	0.3761
		0.9622	0.6057	0.7504	0.6525	0.0957
		1.1377	0.7812	0.5927	0.6	0.5336
			0.939	0.6102	0.3899	0.0431
			1.0966	0.6978	0.5825	0.4286
			0.6934	0.5226	0.3899	0.236
			0.8338	0.8204	0.6175	0.3936
			0.6583	0.505	0.5825	0.1308
			1.009	0.9779	0.1619	0.3411
			0.8513	0.6102	0.4249	0.4811

				0.8729	0.74	0.0782
				0.5752	0.7575	0.4286
				0.7679	0.3548	
				0.4349	0.3548	
				0.6628	0.53	
				0.6628	0.3899	
				0.7854	0.7225	
				0.5401	0.5825	
				0.8729	0.3724	
					0.5825	

Storm 5

-0.0317	0.2405	0.734	0.4382	0.2283	0.1565	0.5748
0.3823	0.0485	0.6065	0.4382	0.3261	0.8088	0.4444
0.0641	0.1766	0.1577	0.5027	0.586	0.8088	0.6074
0.414	0.5589	0.734	0.5993	0.7154	0.8088	0.9641
0.0003	0.4954	0.5107	0.3736	0.1957	0.4511	0.4444
0.2871	0.0806	0.1577	0.6314	0.9732	0.7115	0.5423
0.0641	0.4318	0.2542	0.2442	0.6184	0.5815	0.8671
0.1916	0.8437	0.7659	0.7919	0.4238	0.5489	0.6399
0.0003	0.3362	0.0933	0.2118	0.4238	0.8412	0.7049
0.1916	0.4636	0.6065	0.5027	0.6831	0.5164	0.7699
0.2553	0.4636	0.893	0.8879	0.6184	0.614	0.5423
-0.0317	0.0165	0.4147	1.0794	0.5536	0.2549	0.8671
0.3188	0.5906	0.6384	-0.0157	0.5536	0.8736	0.4444
0.2553	0.2724	1.0514	0.4059	0.2936	0.5815	0.5748
0.1279	0.4318	0.4467	0.0169	0.586	0.7115	0.6399
0.3506	0.1126	0.7022	0.3413	0.3261	0.5164	0.8347
0.096	0.3999	0.3185	0.309	0.6831	0.9059	0.4444
0.096	0.3681	0.5746	0.6957	0.3912	0.5164	0.7699
0.414	0.3043	0.5107	0.082	0.4887	0.5489	0.5097
0.414	0.5906	0.6065	0.3413	0.4887	1.1639	1.061
0.2553	0.4318	0.0933	0.5027	0.6831	0.5815	0.477
0.1279	0.6223	0.4467	0.5349	0.163	0.5815	0.4444
0.3188	0.3043	0.5746	0.1144	0.3912	0.5815	0.4444
0.414	0.0485	0.1899	0.9837	0.3912	0.6466	0.4444
0.1598	0.2724	-0.0036	0.1794	0.6831	0.3531	0.8671
0.1279	0.5589	0.8612	0.5027	0.4562	0.744	0.5097
0.0322	-0.0477	0.5107	0.7919	0.7477	0.3858	0.7699
0.4457	0.3681	0.3506	0.1469	0.7154	0.614	1.2541
0.1598	0.2724	0.6703	0.7919	0.4562	0.614	0.477
0.4774	0.0485	0.0933	0.3413	0.2936	0.2877	0.6399
0.096	0.1446	0.6384	0.5349	0.8767	0.9382	0.6399
0.3188	0.2724	0.3506	0.2118	0.4887	0.5164	0.3136
-0.1277	0.4318	-0.0682	0.4705	0.6184	0.5164	0.6399
0.096	0.3681	0.1577	0.309	0.4887	0.744	0.5748
0.414	0.3043	0.5746	0.5671	0.2283	0.614	0.7699
0.0641	0.3043	0.2221	0.5349	0.7154	0.3858	0.6399

0.2553	0.5271	0.2221	0.1794	0.5536	0.6466	0.8023
0.1598	-0.0156	0.6384	0.6314	0.6831	0.3858	0.5423
0.3188	0.3999	0.2542	0.4382	0.261	0.5489	0.6399
0.2871	0.4636	0.2542	0.3736	0.586	0.614	0.6399
0.2871	0.4636	0.5107	0.4705	0.586	0.3204	0.4117
0.1916	0.4954	0.7022	0.0494	0.7154	0.614	0.6399
0.0003	0.0806	0.0933	0.3413	0.163	0.7764	0.6399
0.2553	-0.0477	0.5427	0.1144	0.3912	0.614	0.9964
0.1598	0.3043	0.1899	0.5671	0.7477	0.3858	0.4117
0.0003	0.3999	0.7022	0.309	0.261	0.4838	0.477
0.1598	0.0806	-0.1006	0.1469	0.586	0.2222	0.7049
0.2553	0.3362	0.5746	0.6957	0.4238	0.8088	0.5097
0.0003	0.1126	-0.0036	0.0169	0.7154	0.679	0.6399
0.5722	0.2724	0.5427	0.5993	0.7154	0.5815	0.7699
0.414	0.2724	0.1255	0.3413	0.3587	0.5815	0.6074
0.3188	0.3999	0.3506	0.3413	0.3261	0.8412	0.7049
-0.0317	0.3999	0.6703	0.7598	0.2936	0.7764	0.5748
-0.0317	0.4318	0.7977	0.3413	0.0976	0.9705	0.5748
0.4457	0.3362	-0.3929	0.6314	0.4238	0.679	0.8671
0.414	0.3681	0.3506	0.309	0.78	0.679	0.8023
0.3823	-0.112	0.3506	0.5349	0.2283	0.4511	0.6725
0.509	0.654	0.1899	0.5027	0.2283	0.4511	0.9641
0.4774	-0.0477	0.5427	0.3413	0.7154	0.3858	0.5423
-0.0317	0.3362	0.7659	0.1144	0.261	0.5164	0.5748
0.3188	0.6223	0.1899	0.5671	0.586	0.8088	0.5748
0.4457	0.3999	0.6384	0.2442	0.7154	0.5489	0.7374
0.0641	0.5271	-0.0682	0.2442	0.4562	0.614	0.8347
0.1598	0.5271	-0.0682	0.7278	0.1303	0.7764	0.8023
-0.0317	0.5271	0.1255	0.3413	0.9089	0.679	0.7699
0.2235	0.1446	0.3506	0.3413	0.1303	0.2877	0.7699
0.2553	0.3362	0.5107	0.3413	0.4887	0.5815	0.4444
0.4774	0.1126	0.1255	0.5349	0.163	0.5815	0.5423
0.509	0.4954	0.5746	0.8559	0.6184	0.5489	0.5748
0.096	0.4954	0.1255	0.3413	0.5536	0.5489	0.8671
0.096	0.2405	0.2864	0.4705	0.7477	0.7764	0.477
0.3506	0.3681	0.6065	0.6314	0.4238	0.3858	0.4444
0.1279	0.3999	0.5427	0.0494	0.6184	0.7115	0.5097
0.3823	0.3999	0.2864	0.7598	0.4562	0.8736	0.7699
0.3188	0.4636	0.5746	0.1794	0.5536	0.5489	0.5097
0.414	0.0165	0.4467	0.1794	0.6184	0.9059	0.6074
0.1916	0.4318	0.2864	0.5349	0.3587	0.5489	0.7374
0.0641	0.2086	0.734	0.7919	0.4238	0.5489	0.8995
0.1916	0.4318	0.4147	0.1144	0.4238	0.7115	1.061
0.1598	0.0806	0.4147	0.7278	0.6184	0.744	0.6074
-0.1598	0.5271	0.2221	0.1469	0.7477	0.614	0.379
0.1279	0.0165	0.5427	0.3736	0.3261	0.614	0.477
-0.0317	0.3681	0.6703	0.3736	0.0321	0.5164	0.9318
0.0641	0.3043	0.2864	0.4382	0.3261	0.5164	0.5097

0.1279	0.6857	0.6065	0.7598	0.8445	0.5164	0.4444
-0.1277	0.3681	0.6065	0.6957	0.3261	0.9705	0.6399
0.2553	0.3043	0.2221	0.4059	0.4238	0.5489	0.5097
0.8244	0.3362	-0.0682	0.309	0.8123	0.4838	0.5748
0.3506	0.2724	0.3185	0.5027	0.6184	0.4185	0.7049
-0.1918	0.3681	0.3185	0.4382	0.5536	0.3531	0.3136
0.1279	0.3681	0.6384	0.5993	0.3912	0.614	0.477
0.1916	0.6223	0.9247	0.6957	0.6831	0.8412	0.6074
0.3188	0.1766	0.1899	0.6636	0.2936	0.7115	0.5748
0.6038	0.3999	0.3506	0.1144	0.6831	0.8412	0.6399
0.2553	0.3999	0.4467	0.4705	0.2283	0.614	0.5097
0.096	0.0485	0.2542	0.5027	0.6184	0.8412	0.8995
0.414	0.2724	0.6703	0.7598	0.5212	0.5164	0.477
0.4774	0.5271	0.4147	0.2442	0.6831	0.8412	0.8995
0.3506	0.3043	0.2864	0.6636	0.5212	0.4838	0.8347
-0.0317	0.1446	-0.1978	0.1469	0.6184	0.4838	0.6074
0.3506	0.1446	0.3826	0.2118	0.2936	0.8088	0.4444
0.4457	0.3999	0.1577	0.3736	0.8123	0.5164	0.5097
0.096	0.2086	0.3506	0.3413	0.3587	0.8736	
0.3823	0.0165	0.6065	0.5027	0.4562	0.5489	
0.41	0.3362	0.6065	0.3736	0.163		
0.2235	-0.0799		0.7598	0.163		
0.414	0.3681		0.4382	0.2936		
0.2871	0.0806					
0.3506						
0.3188						
0.1916						
0.1916						
0.5406						
0.1279						
0.414						
0.0641						
0.2553						
0.1279						

Storm 6

-0.0724	0.5347	0.3293	0.3016	0.7045	0.5344	0.6378
0.5451	0.5023	0.2966	0.4333	0.6386	0.6673	0.5379
0.0908	0.4375	0.7202	0.8262	0.5725	0.7666	0.6378
0.2535	0.5671	0.5902	0.7283	0.5064	0.7004	0.4378
0.6419	0.1119	0.3946	0.4333	0.7045	0.7666	1.1674
0.4804	0.3075	0.7202	0.8588	0.6056	0.033	0.9364
0.3509	-0.0189	0.4599	0.4333	0.6715	0.4012	0.7708
-0.1706	0.5671	0.5577	0.6301	0.2411	0.7335	0.6046
0.221	-0.1828	0.7202	0.4004	0.8361	0.4345	0.9033
0.0256	0.3075	0.2966	0.4333	1	0.6673	0.8371
0.3833	0.1119	0.5251	0.6629	0.3076	0.4345	0.8702
0.221	0.4375	0.2638	0.5318	0.3076	0.5011	0.8702

0.221	0.6317	0.5577	0.3675	0.7045	0.6341	0.9364
0.156	0.3725	0.0012	0.7609	0.7703	0.7666	0.6378
0.3185	0.1772	0.3946	0.6956	0.5064	0.7666	0.6378
0.2535	0.5023	0.8174	0.4004	0.6386	0.8328	0.7044
0.3185	0.2098	0.4599	0.3675	0.6715	0.7666	0.7376
0.3509	0.47	0.5577	0.6629	0.6056	0.6673	0.4378
0.2535	0.5671	0.1655	0.7609	0.5725	0.3345	0.7044
0.4157	0.5671	0.3946	0.4004	0.6386	0.1672	0.6046
0.156	0.4375	0.4925	0.3675	0.2411	0.6009	0.804
0.5773	0.2098	0.8174	0.7609	0.374	0.8328	0.8371
0.3833	0.275	0.2966	0.7283	0.5725	0.9978	0.8371
0.3185	0.5023	0.0341	0.7609	0.4733	0.7335	0.7044
0.3509	0.3075	0.4599	0.6956	0.4733	0.7997	0.6711
-0.0071	0.1446	0.1655	0.3016	0.8032	0.7335	0.9033
0.2535	0.4375	0.3946	0.1034	0.7045	0.5011	0.5045
0.5127	0.1772	0.4925	0.7609	0.7374	0.7997	0.7376
0.6419	0.5671	0.8174	0.3675	0.5725	0.7335	1.0356
0.4481	0.34	0.4599	0.3675	0.4733	0.5677	0.8371
0.4804	0.5994	0.2311	0.8588	0.8032	0.6341	0.804
0.3185	0.275	0.4925	0.3675	0.4071	0.4679	0.9033
0.5451	0.1772	0.6227	0.5974	0.6715	0.7335	0.7044
0.4481	0.5023	0.2311	0.3016	0.5395	0.6673	1.0356
0.6096	0.34	0.6552	0.4662	0.6056	0.6341	0.5712
0.5451	0.6317	0.3946	0.5646	0.7374	0.7004	0.7376
0.5127	0.275	0.3946	0.2357	0.374	0.9319	0.6046
0.156	0.5671	0.4599	0.5646	0.4402	0.6009	0.6046
0.156	0.34	0.4925	0.6956	0.4402	0.5344	0.6046
0.286	0.1446	0.1983	0.8262	0.3408	0.5344	0.6711
0.1885	0.1772	0.362	0.5646	0.7045	0.8658	0.7044
0.6096	0.0793	0.6877	0.2687	0.6056	0.6009	0.9033
0.6096	0.5347	0.3946	0.5318	0.4402	0.7335	1.1674
0.5773	0.2424	0.5577	0.5318	0.5725	0.3011	0.7376
0.156	0.2098	0.5577	0.7609	0.5725	0.5011	0.5045
0.2535	0.4699	0.6877	0.8262	1.1635	0.9648	0.5712
0.5451	0.4699	0.4599	0.2687	0.6056	0.5344	0.9364
0.5127	0.1119	0.785	0.6629	0.2411	0.7997	0.5712
0.6741	0.4699	0.6227	0.4004	0.5725	0.3345	0.6378
0.1885	0.5347	0.4273	0.2026	0.3408	0.5011	0.4378
0.5451	0.5347	0.3946	0.2357	0.6386	0.5011	0.4043
-0.0724	0.1119	0.5577	0.4333	0.6056	0.4679	0.8702
0.5451	0.5671	0.362	0.4333	0.5395	0.8658	0.6046
0.286	0.34	0.1983	0.6629	0.6715	0.8328	0.6711
0.156	0.5023	0.3946	0.2687	0.7374	0.8658	
0.5451	0.5023	0.2638	0.499	0.3076	0.8989	
0.286	0.34	0.4273	0.4333	0.2078	0.5677	
0.4804	0.34	0.5902	0.5974	0.4402		
0.156	0.3725	0.1983	0.4004	0.8032		
0.0256	0.1446	0.2311	0.5318	0.4733		

0.5127	0.6317	0.6877	0.8914	0.4071		
0.221	0.5023	0.362	0.4333	0.5725		
0.286	0.5023	-0.0317	0.3675	0.4071		
0.4157	0.405	0.6877	0.499	0.7703		
0.3185	0.2098	0.2311	0.6956	0.374		
0.4481	0.6963	0.362	0.3675	0.3408		
0.221	0.405	0.362	0.7936	0.5395		
0.3185	0.5994	0.4925	0.4004	0.9017		
0.4804	0.4375	0.4925	0.4333			
0.4804	0.3075	0.4273	0.6956			
0.0256	0.6317	0.4925	0.3016			
0.0908	0.2098	0.5902	0.499			
0.3833	0.5671	0.6552	0.6301			
0.1885	0.2424	0.2311	0.6956			
0.4804	0.5023	0.3946	0.2687			
0.3509	0.34	0.5902	0.3016			
0.5127	0.3725	0.5577	0.499			
0.5127	0.4375	0.1655	0.5974			
0.286	0.1446	0.2966	0.2687			
0.2535	0.1446	0.1983	0.5974			
0.6096	0.1446	0.5251	0.2357			
0.156	0.4699	0.6227	0.4004			
0.3509	0.34	0.6227	0.4333			
0.2535	0.34					
0.6096	0.405					
0.6096	0.405					
0.3509	0.5994					
	0.4699					
	0.3725					
	0.5671					
	0.34					
	0.5023					

Storm 7

0.4555	0.5713	0.2941	0.0879	0.312	0.2887	0.409
0.1289	0.1125	0.1312	-0.2275	0.1289	0.8483	0.521
0.5474	0.6734	0.0803	-0.4616	0.1085	0.2073	0.7448
0.3023	0.0106	0.4672	0.4848	0.1085	0.4515	0.7753
0.3636	0.3061	0.2941	-0.1054	0.2103	-0.0675	0.6329
0.5985	-0.0199	0.233	-0.5328	-0.0746	0.4311	0.928
0.3023	0.2042	0.3858	0.5458	0.1187	-0.1286	0.9483
0.0677	0.5816	0.4672	0.3423	-0.0136	0.1462	0.7652
0.5781	0.3163	0.1617	0.2914	0.1391	0.3701	0.4803
0.4248	0.6122	0.121	-0.3903	0.4341	0.421	0.6024
0.1595	0.5407	-0.6117	-0.2886	-0.156	0.655	0.6532
0.5372	0.3673	0.0498	0.1998	-0.2476	0.5125	0.0834
0.2819	0.3673	0.2432	0.5153	0.8615	-0.0675	1.0806
0.435	0.2857	0.2432	-0.431	0.0678	0.8076	0.3276

0.4044	0.3367	0.0091	-0.0139	0.9226	0.0241	0.175
0.3432	0.3367	0.4163	0.4135	-0.1764	0.7873	0.3785
0.3432	0.3877	-0.0011	-0.2988	-0.441	0.0851	0.7041
0.0371	0.2857	0.0701	-0.4005	0.3833	0.3497	0.6227
0.4759	0.4081	0.1821	0.7189	0.0577	0.4922	0.2258
0.2819	0.4999	-0.2962	-0.2275	0.6376	-0.1897	1.1925
0.3432	0.194	0.671	0.4644	0.2001	0.482	0.5922
0.5474	0.4183	0.2432	-0.1258	0.3527	0.1157	0.7245
0.4963	0.3673	0.1516	-0.0953	0.7089	0.3904	0.8364
0.1187	0.6428	-0.3064	-0.543	-0.0645	0.5227	0.3073
0.2411	0.0412	0.2228	-0.1054	0.078	0.6753	1.0704
0.3125	-0.2236	0.3043	0.0675	0.8005	-0.0879	0.7346
0.3125	0.4897	-0.1334	0.444	-0.2476	0.5227	0.4497
0.3942	0.4489	0.1719	0.0879	-0.0136	0.4108	1.2027
0.3942	0.0514	0.4061	-0.0749	0.3324	0.3396	0.6329
0.2105	0.1023	0.2636	0.3525	0.0271	0.1971	0.9076
0.384	0.245	-0.0215	-0.3903	-0.3189	0.3396	0.8262
0.5168	0.3571	0.508	-0.197	0.0577	0.655	0.6227
-0.0953	0.2653	0.5793	0.4033	-0.0136	0.482	0.6634
0.0677	0.2653	-0.4285	0.4033	0.7089	0.309	0.6838
0.5065	0.1431	0.0701	0.2405	-0.2375	0.5227	0.8567
0.2615	0.2246	0.3145	-0.3191	0.2205	0.309	0.9381
0.5576	0.4387	0.2126	0.1082	0.424	0.4718	0.1648
0.384	0.3877	-0.1131	0.3219	-0.1968	0.1157	0.755
0.4555	0.3163	0.3348	0.3117	0.8208	0.4311	0.4701
0.2615	0.5203	0.2228	-0.3802	-0.2375	0.7059	1.0806
0.3738	0.5816	0.3043	-0.37	-0.3291	0.1055	0.6024
0.1085	0.0514	-0.0215	0.1998	0.3629	0.1971	1.3452
0.2921	0.0514	-0.1232	-0.1054	0.2815	0.3294	0.6838
0.5985	0.2144	0.4163	0.7291	0.4748	1.1231	0.3378
0.2411	0.4795	-0.1436	-0.6956	-0.2273	0.075	1.3961
0.4248	0.3163	0.0192	0.1489	-0.0441	-0.0574	0.9992
0.1391	0.2653	0.1312	0.6273	0.2103	0.5736	1.0195
0.4555	0.2552	0.3959	-0.5023	-0.095	0.3701	0.3276
0.3227	0.0106	0.121	0.0777	-0.1459	0.6448	0.4701
0.3023	0.245	-0.1843	0.1998	0.424	0.0546	0.3073
0.4453	0.2857	-0.0927	0.0574	0.1696	-0.0065	1.0297
0.2819	-0.1421	0.3756	0.1286	0.2306	0.5125	0.6125
0.3942	0.4999	0.1108	0.0879	-0.1764	1.0213	0.409
0.3125	-0.0301	0.5386	-0.1563	0.1187	0.1055	1.3655
0.6087	0.245	0.06	0.0777	0.2713	0.4922	0.5718
0.3738	-0.0199	0.5691	-0.1767	-0.0237	0.4108	0.3378
0.2411	0.2144	-0.164	-0.1665	-0.2782	0.0648	0.4701
0.4248	0.3163	0.0701	0.4339	-0.1052	0.7059	0.5718
0.4044	0.0514	0.4163	0.2303	0.3731	0.136	0.9687
0.2819	-0.1014	0.2126	-0.5837	0.3324	0.3294	0.6939
0.3738	0.5816	0.4367	0.271	-0.1968	0.6652	1.4673
0.4759	-0.1218	0.3552	0.1998	0.1289	0.2785	0.4497

0.7008	0.3469	0.0294	0.8004	0.1391	0.6143	1.0399
0.0473	0.3163	0.0701	0.1795	0.2306	0.6855	1.6608
0.5168	0.1023	0.3145	0.3016	0.2205	0.0444	0.175
0.3329	0.3775	-0.1131	-0.4717	0.5969	-0.0472	0.816
0.2207	0.2144	-0.0317	-0.3802	0.4545	0.9094	0.9076
0.4657	0.1023	-0.2047	0.3626	0.4545	0.2785	0.5413
0.4657	0.3061	0.3348	-0.1054	0.078	0.6753	0.7957
0.1697	0.0615	0.3348	-0.3395	0.4647	0.5532	1.0195
0.2411	0.2552	-0.4997	-0.3191	0.2815	0.5227	0.5311
0.2921	0.194	-0.1538	-0.0851	0.2815	0.6448	0.8262
0.4759	-0.2949	0.2737	0.4339	0.1085	0.7466	
0.0881	-0.0199	-0.1436	-0.2886	0.3934	0.4108	
0.619	0.194	0.1719	0.6374	-0.0034	0.4413	
0.0779	0.3469	0.2941	-0.4819	0.017	0.5125	
0.2105	0.3265	0.1617	0.5662	0.312	0.421	
0.4555	0.2144	0.1617	0.0268	0.485	0.6753	
0.3534	0.1023	-0.3166	-0.5226	0.7597	0.6448	
0.1901	0.3061	0.06	-0.0953	0.0373	0.0139	
0.6803	0.0819		-0.3802	0.078		
0.2309	0.2857		0.0472	0.1492		
0.1493	0.2552		-0.2377			
0.3227	-0.3763		-0.3802			
0.2921	0.4999		0.0777			
0.2921			0.2812			
0.4044						
0.1697						
0.3329						
0.0058						
0.2187						

Storm 8

0.5874	0.9197	1.1322	1.2557	0.6279	0.1666	0.0389
0.4557	1.1494	0.3856	0.7975	0.7424	0.0232	0.1392
0.8243	1.7153	0.7305	0.5394	0.2194	0.188	0.9474
-0.2579	0.1206	1.2683	1.5203	0.4058	0.3456	1.4405
0.3238	-0.6104	0.7808	0.3312	0.4775	0.546	0.8188
1.9782	0.6107	0.011	0.1731	0.2911	0.4172	0.5614
-0.0593	-0.1322	1.1322	1.8777	0.9785	0.5532	0.6257
1.9128	0.7761	0.4431	-0.2012	0.0974	-0.2064	0.5256
0.4293	0.301	0.9458	1.1627	1.4503	0.7963	1.076
-0.1388	1.1924	0.5006	0.905	0.162	0.7749	0.0962
-0.2844	0.8192	0.5078	0.1947	0.7424	0.8893	-0.1546
1.8997	0.1784	1.1394	1.4988	1.1716	0.3957	0.1464
0.3238	1.6223	0.6084	0.3671	1.7719	0.8535	0.7401
-0.3905	0.6179	0.0326	0.5681	0.7711	0.6891	0.4255
0.2974	0.6107	1.125	-0.1363	0.4417	-0.0055	0.59
0.7191	0.0773	0.4575	0.245	0.2696	0.3886	0.5614
0.6927	0.4019	1.0534	0.5035	0.9285	0.925	1.4691

0.982	0.8264	-0.0756	1.27	0.9142	0.5317	0.2895
0.8243	0.5819	0.0038	1.041	0.3843	0.4745	1.6765
0.4557	0.1351	0.4143	0.0653	-0.3338	-0.465	0.2752
1.5069	0.034	1.1895	1.2056	1.2717	0.5031	0.0676
1.7688	0.7761	0.148	0.9479	0.4202	0.8178	0.4255
0.337	0.9269	1.0462	0.1156	0.5706	0.8964	0.3182
0.4952	0.4811	0.6228	1.0339	1.0214	0.2239	0.6186
-0.1917	1.0203	0.5078	1.5274	0.2768	1.3753	0.3754
1.3758	1.8298	0.6874	0.1588	0.6709	0.3456	0.5614
0.0993	0.0773	1.0462	0.6542	1	0.6033	0.0318
0.5611	0.7257	0.2848	0.6542	1.1215	0.5389	0.6543
0.6927	0.8479	0.709	0.5824	0.4703	0.4387	0.5828
0.5874	0.7114	0.6731	0.4748	-0.039	1.3681	0.6758
0.4952	0.4091	0.0687	0.3384	0.2194	0.9751	0.1106
0.8243	0.1712	0.8526	0.6183	0.2266	0.4029	0.5757
1.1659	0.0484	1.0749	0.7545	0.6852	0.2597	0.5757
0.1125	0.5963	0.2056	0.6111	1.05	0.639	0.1249
0.482	0.7832	0.4934	0.9193	1.922	0.3026	0.404
1.0608	0.9557	0.1119	1.4345	1.7862	1.0108	0.6329
1.4151	0.1495	0.5797	0.2091	0.6565	0.6104	0.8331
0.9163	0.7617	0.7736	0.4963	0.2481	0.9894	0.783
0.4293	0.5171	0.9817	0.2881	0.8999	0.5675	1.1118
0.7717	1.6509	0.4071	0.7975	0.499	-0.07	0.7473
1.8081	0.099	1.812	1.2342	0.6995	0.925	0.2895
0.205	-0.1684	0.5869	0.6828	1.193	0.6962	0.4327
1.0477	0.2289	0.3784	0.3097	1.729	0.4244	1.5192
1.3889	0.5531	1.1465	0.8548	1.0572	0.3026	-0.0399
-0.2712	**0.98**	1.5403	1.1412	0.5276	0.2454	0.8259
0.89	0.9485	0.1624	0.4748	0.7353	0.5603	0.8045
1.0608	-0.2263	1.2182	1.5131	1.0715	0.8821	0.5471
1.4675	1.1924	1.1322	0.5035	0.7997	0.9822	0.7115
0.9032	-0.0816	-0.2055	1.2056	0.8641	0.2597	0.7544
0.7322	1.1709	0.2704	0.7115	0.2696	0.0662	1.0903
1.2971	0.6035	0.5294	0.6972	0.8927	1.7684	0.7616
0.4161	1.7297	0.8669	0.9193	0.7711	0.5818	0.2752
1.0214	1.2498	0.7736	0.324	0.5706	0.5746	0.7187
0.4293	0.0845	0.0398	0.9623	0.6279	-0.1346	0.3253
1.3233	1.3	0.8669	0.8333	0.6565	0.2239	0.7902
0.3502	0.8479	2.4696	0.4892	0.9785	0.7677	1.269
0.2182	0.099	1.0964	0.2809	1.5075	0.9107	0.6758
0.5347	0.5171	1.483	0.6326	0.1046	0.639	0.8402
0.4161	0.4019	0.1624	1.0124	0.8641	0.4673	1.0046
0.1654	0.1856	0.9888	0.9265	0.327	0.8535	-0.456
	0.7976	0.4647	1.2271	0.7854	0.4244	0.4756
	2.0801	2.0837	-0.4031	0.4632	1.1895	0.0891
	0.1423		1.3916	0.2337	0.3026	1.0403
	0.7114		0.6685	0.9642	0.4172	0.7401
			1.0911	0.1405	0.5532	0.2895

			1.2557		0.2597	1.1475
					1.5039	0.8259
					0.4244	0.6043
					0.5389	
					0.016	
					1.1895	
					0.41	
					1.1609	
					0.6533	

Storm 9

1.0728	0.8971	0.7784	0.6287	0.7766	0.6089	0.3078
0.6264	0.4781	1.047	0.8969	0.7674	0.7469	0.5563
0.7755	0.7298	0.5182	0.9985	0.749	0.4154	0.5563
0.5424	1.092	0.3318	0.7953	0.8135	0.2862	0.3723
0.9336	0.4688	0.936	0.7398	0.9332	1.0682	0.5104
0.5238	0.8414	1.0563	0.7398	0.795	0.7745	0.6666
0.7196	0.65	0.7134	0.6843	0.8227	0.7561	0.4644
0.822	0.7577	1.3149	0.8785	0.7397	0.4062	0.6115
1.2304	0.8786	0.973	0.6657	0.8319	0.655	0.4552
0.9707	1.2586	0.5368	0.9431	0.7121	0.9306	0.7217
1.0543	0.4595	0.8618	1.0538	0.4997	0.6458	0.74
0.673	0.5621	0.6484	0.8969	0.629	0.3878	0.7033
1.1933	0.9436	0.8989	0.4804	0.8043	0.6642	0.8043
0.7196	0.6273	0.6484	0.536	0.7213	0.6458	0.6482
0.7755	1.0734	0.7413	0.5546	0.5736	0.7745	0.7125
0.4864	0.6739	0.6484	0.4711	0.8779	0.7469	0.685
0.5518	0.2725	0.8804	0.8969	0.8135	0.5721	0.6941
0.7475	0.8878	0.7598	0.8323	0.7028	0.6642	0.5471
0.7475	0.8414	0.5275	0.7398	0.7397	0.6642	0.7584
1.1563	0.8693	1.0655	1.0999	0.8227	0.7837	0.6299
0.421	0.6273	0.8804	0.6657	0.3054	0.4892	0.7584
1.0357	1.1846	0.6484	0.5638	0.7397	0.7285	0.8684
0.7103	0.5434	0.8433	1.063	0.6383	0.6274	0.6758
0.5424	1.1568	0.834	0.8415	0.749	0.5537	0.5747
1.0357	0.9157	0.973	0.9154	0.3332	0.9215	0.3355
0.5331	0.8507	1.1395	1.0538	0.749	0.7561	0.5471
0.9336	0.8971	0.7505	0.7028	0.5736	0.6366	0.74
0.5891	0.2257	0.7784	0.638	0.6383	1.0957	0.8226
0.8871	0.4595	0.732	0.638	0.7858	0.48	0.492
1.5078	0.646	0.4064	0.9154	0.9516	0.5353	0.74
1.2767	1.0178	0.5926	0.8045	0.7305	0.7285	0.5563
0.5611	0.9157	1.2411	0.9246	0.9424	0.5537	0.7951
1.0172	0.7949	1.1118	0.7028	0.7766	0.7377	0.9967
1.2767	1.1939	0.7134	1.063	0.7674	0.5997	0.8226
0.9429	0.8135	0.8248	0.8507	0.8319	0.7837	1.0059
0.4771	0.8228	0.6484	0.7675	0.6198	0.701	0.8868
0.8871	0.8786	0.7598	0.9339	0.7121	0.5169	0.4736

0.9893	0.7949	1.1765	0.7213	0.8227	0.6642	0.6666
0.5891	0.8507	1.2226	0.6657	0.629	0.7653	0.5655
0.5891	1.0549	1.0655	0.712	0.749	0.6918	0.639
0.7103	1.0549	0.8155	0.6287	0.7121	0.7745	0.7217
0.5518	0.9157	0.5182	0.6287	0.8227	0.6918	0.9234
1.0636	0.8042	1.1672	0.86	0.8227	0.7837	0.639
0.701	0.6553	1.0285	0.86	0.7305	0.5721	0.5379
0.8871	0.8414	0.7134	1.0354	1.0159	0.848	0.5931
0.7662	0.6273	0.973	0.9339	0.7582	0.5261	1.0699
0.3368	0.6273	0.9915	1.0077	0.8135	0.4523	0.74
1.3137	0.7391	0.6205	0.6472	0.9516	0.848	1.0791
0.8685	0.8971	0.9082	1.0077	0.6659	0.6918	0.9601
1.0543	0.8414	0.7505	0.7398	0.7674	0.7377	0.6482
0.5331	0.925	1.0285	0.823	0.4627	0.655	0.3723
0.1775	1.0178	0.8062	0.7305	0.8135	0.7653	0.5471
0.7662	0.7205	0.574	1.0907	0.7121	0.8388	0.5379
1.1007	0.8693	0.936	0.6287	0.6013	0.7653	0.317
0.8313	1.0456	1.0563	0.8045	1.1262	0.7745	0.4644
0.5051	0.4968	0.6762	0.8045	0.7028	0.7653	0.6574
0.5144	1.0734	0.4251	1.1552	0.6106	0.7561	0.3723
0.915	1.0085	1.047	1.0446	0.924	0.8756	0.5839
0.701	0.5714	0.8155	0.9708	0.8595	0.6458	0.5379
0.7848	0.6367	0.8433	0.8138	0.9792	0.701	0.685
0.9707	1.1105	0.4996	0.9339	0.795	0.3878	0.3078
0.8964	0.5248	0.8618	0.8323	0.9056	0.5721	0.9875
0.7662	0.6739	0.8433	0.9616	0.8227	0.848	0.639
0.9336	0.7019	0.7784	0.7305	0.6198	0.9398	0.6941
0.4023	1.1012	0.6298	0.9062	0.9424	0.4892	0.5563
0.9243	0.8414	1.047	0.9339	0.7582	0.8205	0.5196
0.7103	0.5621	0.7691	0.8138	0.8871	0.9398	0.2894
0.701	0.9621	0.9082	0.7398	0.5736	0.8664	0.6115
0.6357	0.8321	1.047	0.6843	0.749	0.8664	0.3907
0.7382	0.9343	0.7505	0.749	1.0067	0.9215	0.5655
0.6637	1.2124	0.6762	0.638	0.9424	0.5813	0.4644
1.1377	0.7019	0.834	1.0723	0.7305	0.5169	0.7217
0.8499	1.2956	0.8989	0.8415	0.924	0.9765	0.6482
0.9336	0.9157	0.4716	0.5175	0.6383	0.6274	0.6941
0.7289	0.646	1.2134	1.0169	0.8779	0.7561	0.6666
1.1285	0.8693	0.574	0.5546	0.8135	1.1415	0.5471
0.7475	0.6273	1.0193	0.7583	0.4535	0.7837	0.4644
0.915	1.0364	0.5554	0.9246	0.6198	0.7102	0.5931
0.4584	0.7949	0.6205	1.0354	0.7582	0.8572	0.5471
0.6171	1.0364	0.8248	1.0354	0.629	0.5353	0.5655
1.1748	0.9621	0.9915	0.786	0.9516	0.5076	0.5471
0.8313	1.0734	1.121	0.7398	0.6198	0.6734	0.6482
0.7941	0.9993	1.3241	0.8045	0.8135	0.9306	0.9051
1.1285	1.0271	0.8896	1.2012	0.4165	0.8296	0.5287
0.8778	0.6832	0.7041	1.0538	0.8779	0.7285	0.5471

0.9336	0.9993	0.6948	1.2289	1.0435	0.5445	0.6941
0.4116	0.4968	1.0563	0.6287	0.6383	0.4892	0.4828
0.3462	0.9343	1.0748	1.0723	0.9976	0.6734	0.3631
0.4584	0.9807	0.8804	0.749	1.0803	0.6274	0.4644
0.5798	0.8228	1.0748	0.9892	0.8871	0.655	0.5196
0.8313	1.0271	1.0008	0.9892	1.0803	0.8296	0.5563
0.5611	0.9064	0.8896	0.8692	0.7674	0.5353	0.5471
0.2244	1.0456	0.8804	0.6657	0.7121	0.7561	0.7033
0.4677	1.1476	1.0008	0.9062	0.6383	0.5353	0.5104
0.7568	0.8878	0.7691	0.7675	1.0067	0.7929	0.6941
0.7289	0.8042	1.0748	1.0907	0.9792	0.7653	0.6941
0.8592	0.86	1.047	0.86	0.8135	0.7745	0.4736
1.1099	0.9529	1.1118	0.786	0.924	0.4892	0.8501
	1.0734	1.0193	0.8692	0.6659	0.5905	0.5931
			0.7305	0.7858	0.5905	0.6207
			0.7305	0.8595	0.8388	0.685
			0.7953	1.0067	0.4984	0.5931
			0.86	0.5552	0.7102	0.3999
			0.86	1.0251	0.9582	0.3999
			0.9431	0.8411	0.4247	0.1603
				0.7213	0.7561	0.5012
				0.6383	0.8021	0.9875
				0.8135	0.5997	0.3539
				0.8595	0.8847	0.6941
					0.7193	0.3815
					0.7929	0.9418
						0.6023

Storm 10

0.1365	0.4868	0.9585	0.175	0.4307	0.0413	0.0149
0.3365	0.2045	0.5945	0.7218	0.1785	0.2111	0.1246
0.5124	0.1573	0.1929	0.1869	0.1303	-0.2022	0.1246
0.313	0.7094	0.5592	-0.1003	0.6938	-0.056	0.3797
0.313	0.2281	0.3113	0.163	0.2146	0.0413	0.4403
0.6412	0.4985	0.5474	0.3776	0.3948	0.199	0.1124
0.5007	0.0865	0.0624	-0.0284	0.3228	0.3442	0.0149
0.828	0.4516	0.2876	0.5321	0.4547	-0.0074	0.1367
0.4656	0.4868	0.6063	0.1391	0.0942	0.017	0.1611
0.7813	0.1809	0.2758	-0.0643	0.5863	0.1141	0.0637
0.4069	0.4046	-0.1637	0.1869	0.4307	-0.0682	0.1246
0.5944	0.5454	0.0505	0.5796	0.4068	0.102	-0.0095
0.36	0.0511	0.6651	0.2346	0.3588	0.017	0.1246
0.4304	0.6977	0.7356	0.4133	-0.0506	0.3442	0.2584
0.3482	0.522	0.0505	0.2823	0.5146	0.2111	0.2827
0.5827	0.5806	0.6533	0.4609	-0.1353	0.1626	-0.2052
0.0657	0.686	0.2639	0.3062	-0.0144	0.0291	-0.0828
0.5593	0.0747	0.4058	0.1988	-0.0265	0.5733	0.0271
0.36	0.334	0.3231	0.5203	0.1424	0.1141	0.2584

0.4069	-0.1501	0.1217	0.0195	0.3588	0.0898	0.0149
0.6646	0.522	0.1217	0.7218	-0.1474	0.0048	0.1124
0.36	0.4985	0.003	0.2227	-0.099	0.3442	0.2219
0.6529	0.4398	0.5474	0.1988	0.1665	0.0898	0.2705
0.313	0.3223	0.394	0.6152	-0.0385	0.0413	0.0758
0.6763	0.8146	0.5827	0.5084	-0.2686	0.199	0.3069
0.571	0.4633	0.4294	0.3419	0.1905	0.4769	0.0637
0.1247	0.0274	0.3349	-0.2084	-0.2686	0.3079	-0.034
0.4304	0.4516	-0.0684	0.6152	-0.2079	0.0656	0.2948
0.4187	0.2987	0.5709	-0.0883	-0.0748	0.102	0.1367
0.5593	0.7094	-0.2472	0.3181	0.1303	0.0534	0.4524
0.5593	-0.1383	0.3822	0.0913	0.3588	0.2232	0.1246
0.5007	-0.2094	0.1692	0.2585	0.3948	-0.0317	0.4766
0.489	0.1927	0.5592	0.0195	0.0701	0.1262	0.3069
0.4187	0.4868	0.1336	0.6863	0.058	0.0048	0.1854
0.3247	0.2281	0.6063	-0.0883	-0.0385	0.2958	0.3312
0.4304	0.4516	0.1336	0.7454	0.1905	0.1384	0.2705
0.2189	0.5454	0.7004	0.2823	0.1303	-0.1047	0.0027
0.0421	0.4163	-0.0565	1.0876	0.3948	-0.0925	0.0027
0.5593	0.5103	0.7239	0.2346	-0.099	0.102	0.0027
0.266	0.6158	0.6651	0.3419	0.2627	0.0898	-0.0217
0.1247	0.2045	-0.0089	0.163	0.0821	-0.0195	0.3312
0.4069	0.7679	0.4884	0.2346	-0.0265	0.2111	0.1733
0.2189	0.1691	0.3349	0.1391	0.2387	0.2111	-0.0217
0.2307	0.6743	0.0505	0.5796	0.5983	0.0898	0.0393
0.863	0.3576	0.2639	0.3538	0.4427	0.0777	0.1124
0.6178	0.0274	-0.0922	0.5796	0.4187	0.4408	-0.1073
0.8163	0.1337	0.0149	0.1391	0.2627	0.1141	0.5008
0.7813	0.2987	0.0743	0.3062	0.1183	-0.0438	-0.1684
0.2424	0.4398	-0.1279	0.5203	0.1303	0.0777	0.3191
0.7813	0.522	0.3822	0.5203	0.4667	0.102	0.0637
0.2424	0.3811	-0.116	-0.0763	0.0942	0.4046	0.2705
0.3482	0.2045	0.5002	0.6152	-0.0023	0.3321	0.0515
0.313	0.2045	0.3704	0.5203	-0.1958	-0.2633	-0.2297
0.723	0.6743	0.453	0.2943	0.046	0.0534	-0.0217
0.5476	0.0747	0.2876	-0.1123	0.058	-0.3244	0.0149
0.4069	-0.0317	0.6533	0.0076	-0.0869	-0.0317	0.088
0.0657	0.2516	0.2284	-0.1723	-0.1232	0.0048	-0.1562
0.571	0.6392	0.618	0.4965	0.2387	0.6575	-0.1684
0.1836	0.0629	0.0743	0.6507	0.1785	0.2958	-0.0828
0.0893	0.7094	0.5002	-0.0164	0.1183	0.2837	-0.291
0.4304	0.5572	0.5002	0.0076	0.2867	0.2595	-0.1195
0.1836	0.0038	0.1692	0.2466	0.6222	0.0413	0.0758
0.2189	0.2045	0.6769	0.3538	0.1785	0.2958	0.1976
0.9329	0.334	-0.2114	0.4846	0.0339	-0.1047	0.088
0.5827	0.1101	0.2166	0.0435	0.3228	0.0898	0.0637
0.758	0.8146	0.0624	0.4609	0.5983	-0.2877	0.1611
0.7113	0.3928	0.3822	-0.2445	-0.2928	-0.0317	0.0758

0.2189	0.1691	0.0743	0.0794	0.1905	-0.0438	0.2948
0.7697	0.3811	0.4412	0.4846	0.0339	0.3804	0.0027
0.2777	0.2634	0.098	0.3181	0.2026	0.2837	0.2219
0.3717	0.3458	0.6886	0.2585	-0.1595	0.0656	0.1124
0.3365	0.4398	0.2876	0.0674	0.3828	0.0898	0.0027
0.6529	0.7328	0.2403	0.2108	0.2867	0.1626	0.1733
0.6529	0.3105	0.1336	0.9344	0.0218	0.1384	0.0637
0.4538	0.5103	0.7709	0.0554	-0.3292	0.1384	-0.0828
0.3365	0.1809	0.1573	0.0674	0.046	0.0413	0.2341
0.1954	0.4985	-0.0565	0.0435	0.2266	-0.2511	0.3797
0.6646	0.7912	0.7356	-0.0284	0.5863	-0.1413	0.1854
0.1011	0.1691	0.3586	-0.3046	0.1665	-0.1047	-0.0706
0.4421	0.5689	0.4058	0.2823	0.3228	0.017	-0.1562
0.6061	0.1691	0.0861	0.3776	0.1544	0.1505	0.0027
0.7463	0.5923	0.1455	-0.1003	-0.0748	0.1262	0.0758
0.3482	0.8963	0.5474	-0.1363	0.4547	0.2353	0.2341
0.6178	-0.2094	0.0861	0.4252	0.3228	0.0291	0.0393
0.2895	0.4751	0.6769	0.8046	0.0218	0.2837	-0.0462
0.6178	0.287	0.2758	-0.2445	0.2026	0.0291	-0.1807
0.6178	0.2045	0.0386	0.163	-0.0144	0.32	-0.1684
0.0657	0.4633	0.3349	0.5084	0.1544	0.2958	0.2341
0.6412	0.4516	0.2047	0.4014	-0.099	0.0534	-0.2542
0.0067	0.0983	0.2047	-0.1003	0.2026	-0.0804	
0.4187	-0.0672	0.4766	0.0674	0.4667		
0.0775	0.686	0.3586	0.2704	0.3588		
0.5827	-0.0909	0.4648	-0.1844	-0.099		
0.0775	0.5806	0.6651	0.2346	0.1062		
0.4773	0.2045	0.3704	-0.1123	-0.0385		
0.3012	0.5923	-0.1875	0.4252	-0.1595		
0.3717	0.2516	-0.0446	-0.1003	-0.2928		
-0.2062	0.4398	0.1455	0.1869	0.2747		
0.4069	0.2634	-0.0089	0.2704	0.0218		
0.5476	0.2399	0.2876	0.0195	0.2266		
0.6295	1.1756	0.0861	0.6981	0.0218		
0.5359	0.2516	0.1929				
0.3717	0.1573	0.0505				
0.2071	0.5103	0.3231				
0.07	0.1219	0.2284				
0.6646	-0.0435	0.0386				
0.1836	0.5689	0.394				
0.0185	0.7562	-0.1398				
0.3365	0.1455	-0.1041				
0.2895	0.2516	-0.0089				
0.36	0.3105	0.4176				
-0.0996	-0.1146	0.1099				
0.1836	0.0393	0.2521				
0.3835	0.4985	0.0268				
0.4538	-0.245	0.7121				

0.3952	0.2281	0.5356				
0.2895						
0.6879						
0.5944						
0.4538						
0.2307						
0.1365						
0.6529						
0.36						
0.2071						
0.5944						
-0.1825						
0.6412						
0.5476						
0.2542						
0.6529						
0.5476						
0.2542						
0.0657						
0.4656						

Runup Raw Data – TAIRUA
Storm 11

-0.3248	0.1237	-0.646	-3.0175	-3.7511	-4.8916	-2.7991
0.2001	0.5434	-0.8045	-2.5855	-2.4433	-3.888	-2.963
0.305	0.3686	-1.3869	-1.4606	-5.0645	-3.6119	-2.165
-0.0622	-0.5773	-1.5993	-3.1259	-4.2844	-1.779	-2.8173
-0.1147	0.3336	-1.6879	-1.8342	-2.9312	-1.9767	-3.1272
0.7592	-0.7002	-1.4399	-2.6214	-2.3173	-2.3191	-1.8047
-0.0447	-0.911	-1.3692	-1.8877	-4.1922	-4.9478	-2.9812
-0.1847	0.1587	-2.7922	-1.5672	-3.623	-3.6487	-2.5267
0.3749	0.5259	-0.6285	-1.7095	-2.0298	-2.3191	-1.7508
0.1826	0.2112	-0.0838	-1.9412	-3.8427	-3.3552	-2.7991
0.1652	0.1062	-0.2593	-3.4517	-3.0037	-3.5752	-1.0528
0.305	-1.0342	-1.6701	-2.7293	-4.9898	-2.3914	-3.6038
0.5147	0.0537	-1.7233	-2.1555	-2.9856	-1.2598	-2.7991
-0.6928	-0.5597	-0.8397	-3.0536	-5.1393	-3.4285	-3.0907
0.5321	-0.244	-0.8397	-2.0126	-2.5515	-3.4102	-2.7809
0.305	-0.4194	-1.9541	-1.9055	-2.6598	-5.098	-1.267
-0.3948	0.2637	-0.0838	-3.162	-2.5695	-4.7606	-1.6431
0.4448	0.5609	-0.3999	-3.343	-2.9675	-1.7431	-2.0748
0.2526	-0.209	-0.5933	-2.5676	-3.7328	-2.9355	-1.8047
-0.3948	-0.9462	-1.9185	-2.9454	-3.3309	-4.4064	-2.3276
0.3924	0.2287	-0.8926	-1.159	-3.0037	-3.7774	-2.1289
-0.2898	-0.2265	0.1266	-2.5137	-2.1196	-2.7537	-1.7149
0.34	-0.2791	-1.6524	-2.6214	-3.3309	-3.1907	-2.418
0.0253	-0.8583	-1.6879	-1.852	-2.2453	-3.0448	-0.6788
0.6369	0.456	-1.016	-2.2807	-3.4586	-3.4468	-1.6252

-0.3073	-0.0163	-1.4399	-3.2705	-2.9131	-4.0912	-2.9812
0.4273	**0.54**	-1.0336	-2.1734	-3.8611	-4.1652	-2.5086
0.2176	-0.2791	-1.1042	-1.763	-3.3309	-3.0266	-0.9993
-0.0622	0.1237	-1.3515	-2.7833	-3.1308	-3.063	-2.0207
0.305	-0.1389	-0.8045	-2.4958	-4.4508	-2.3191	-1.7868
0.3574	-0.8231	-1.5638	-3.7061	-3.2945	-4.5366	-1.0528
0.2875	0.0362	-0.5053	-2.7293	-3.5316	-4.1652	-1.2313
0.0078	0.1762	-1.6347	-1.8699	-4.5063	-1.7431	-2.8537
0.2176	-0.6826	-1.1748	-2.1019	-4.3583	-4.2022	-2.5267
0.3924	-1.2278	-1.2102	-2.6753	-3.5316	-4.2393	-2.2553
0.3924	0.5084	0.1967	-2.1913	-2.2633	-3.3369	-3.5487
-0.2372	-0.5597	-2.2921	-2.227	-3.5316	-3.5018	-2.3818
0.3574	-0.911	-1.9363	-2.9274	-2.3173	-3.0448	-2.3999
0.27	-0.174	-0.7341	-3.1078	-2.3533	-3.3369	-1.0884
0.1652	0.2287	-1.6524	-2.3165	-3.4951	-1.5459	-1.3028
0.1127	-0.5773	-1.7411	-3.3611	-3.0945	-3.4651	-1.8587
0.5147	-0.174	-0.7341	-2.9995	-4.5063	-4.0172	-1.5176
0.1127	-0.6826	-1.6701	-1.0704	-4.1737	-2.1568	-2.69
-0.2197	-0.999	-1.5816	-2.3882	-2.1914	-1.2956	-1.5355
0.305	-0.5071	-1.1395	-3.3973	-2.1734	-3.5752	-3.5671
0.0078	0.1412	-1.493	-2.6933	-3.5498	-3.2821	-2.2733
0.34	-0.5948	-1.1219	-2.2986	-2.6779	-3.3552	-1.8407
0.2351	0.0012	-0.6988	-2.7653	-3.5864	-3.0995	-1.5534
0.2001	0.0712	-2.3812	-2.084	-1.636	-2.5543	-0.8745
0.0428	0.2812	-1.7943	-2.1019	-4.9338	-2.8446	-3.6406
-0.0272	-0.5948	-1.2455	-2.4061	-4.3398	-2.5361	-2.8173
0.0428	-1.4746	-0.7693	-2.6394	-2.6237	-3.4102	-1.267
0.4099	0.3861	-2.4704	-2.7293	-3.5864	-2.9355	-0.6966
0.1826	-0.8934	-1.1925	-1.6561	-3.8978	-3.1542	-2.5449
0.305	0.2812	-0.9807	-2.3882		-3.3919	-2.0387
0.305	-0.5597	-2.2387	-1.6384		-3.4468	-0.9993
0.27	-0.2966	-2.3277	-3.4699		-1.7611	
-0.2022	-0.5071	-1.0513	-1.5494			
0.305	-0.8934	-1.6701	-2.8013			
0.2176	-0.1915	-1.1395	-3.162			
0.305	-0.0514	-1.4399	-1.9769			
0.0428	-0.911	-1.2808	-1.7273			
0.2875	-0.2265	-0.8926	-3.1801			
0.0602	-0.209	-1.2631	-3.8883			
0.3225	-0.788	-1.7765				
0.2176	0.1062					
0.3225	-0.7353					
0.1127	-0.1214					
0.3225	-0.4544					
0.4099	-0.0514					
0.1652	-0.7002					
0.2526	-0.174					
0.1172						

0.4842						
0.1696						
-0.1102						
-0.0402						
0.4667						

Storm 12

-0.19	-0.6722	-0.4833	-0.7757	0.2882	0.6683	0.3937
-0.82	0.9011	1.1901	-0.3384	0.5487	0.4776	-0.0227
-3.77	-1.8209	-2.0177	1.0188	-0.9668	-0.1822	0.0988
-1.3315	-1.4484	-2.0177	-0.3559	1.1728	-0.6522	0.6536
0.1803	0.6226	-1.6984	-0.1639	0.2013	0.6336	0.0467
0.5295	0.518	-0.4833	-1.796	-0.2859	0.8589	-0.5964
-2.4888	-1.2362	0.8775	-0.4083	0.9475	-0.1127	0.948
-2.0241	-3.7628	-0.9045	-1.232	1.1035	0.0784	1.0345
-1.5618	-1.4838	-1.7516	-0.1988	-0.3905	1.1359	0.2723
-1.0664	-0.9186	-1.0276	-0.3559	-0.2337	0.4602	0.8095
0.4248	-3.1643	-1.3625	0.4109	-0.4602	0.8589	0.619
-0.1872	-2.1414	-1.6807	-0.4782	1.3286	0.2868	0.3937
0.5295	0.3087	0.46	1.4695	-0.6871	0.4776	0.1856
0.1104	0.6923	-1.8225	-0.8809	0.3924	-0.5303	0.7056
-2.866	-0.1809	-0.2382	-0.6006	-1.4226	0.3215	0.7575
-4.1741	-1.8209	0.024	1.3309	0.7395	0.3215	0.2376
0.3899	-2.1057	0.3206	-0.8108	0.5139	0.4776	0.619
-1.935	-2.2842	-1.4508	-1.5665	0.6875	0.0784	0.8787
-1.935	-1.2185	-0.5884	-1.2496	0.2882	0.9455	0.7229
-1.5441	0.5529	-1.3272	-0.286	0.9302	1.2225	0.6363
-0.1872	-1.2362	-0.0633	0.2195	-0.8094	0.5643	0.6883
-1.8283	-1.9276	1.086	1.0015	-0.0248	1.3263	-0.7705
-1.0311	-1.8921	-0.9748	0.7237	-0.8619	0.6683	0.3937
-1.9528	-2.4094	-0.5534	-1.5136	1.2594	-0.7045	0.619
-0.3099	-0.8657	-2.1244	0.1847	0.1665	-0.0779	1.1903
-1.8638	0.5529	1.0339	0.8106	-0.2511	0.5469	0.4457
-0.6787	-1.5193	-1.6276	-0.6882	-0.8094	0.8762	-0.0574
-2.2204	-2.3378	-3.8132	1.1576	1.0862	0.7896	0.012
-2.1133	-1.5902	-3.4147	0.4805	0.4792	-0.9663	0.307
0.6341	0.0466	-0.0459	0.2717	0.4792	0.6856	0.7749
-0.9077	0.5877	-0.3607	-0.8458	0.4098	1.1705	0.4457
-1.19	0.8663	-0.6411	0.55	0.1318	0.7376	0.9134
0.2502	0.2388	-1.5922	-0.1813	-0.5126	0.5123	0.4283
0.4772	-2.0701	-0.2207	-0.6882	-1.4928	0.4602	0.9826
0.7212	-2.9298	-0.5709	-0.4957	0.8435	1.0493	0.6536
-2.0241	-3.472	1.2422	0.8974	0.8262	-0.1127	-0.6312
-2.3635	-0.9538	0.6514	0.6716	1.0169	0.3562	0.3417
-0.2748	-2.5347	-2.2668	-2.3807	0.5834	0.5123	1.0345
-0.8019	0.6748	-2.9105	0.55	0.8609	0.7203	0.6363
-2.0776	-2.75	0.1287	0.4631	-0.4428	0.8242	0.411

-2.5247	-2.2664	-3.6136	0.3935	1.294	0.6509	0.5323
-2.5067	-2.2485	-0.5709	0.4457	-0.757	0.1479	0.7575
-1.19	-1.1126	-0.7113	1.1229	0.1839	1.4128	0.3243
-1.8283	0.0641	0.3206	-1.5489	0.8609	0.0784	-0.179
0.0929	-1.6966	1.1901	-0.7932	-0.6871	0.9108	0.0467
-2.2026	-2.1414	-0.3432	-0.6531	-0.3033	0.8589	1.1903
-1.4732	-0.0583	-0.0983	-0.6882	1.0515	-0.5477	-0.5442
0.5121	-0.7425	0.9818	-0.4083	1.1035	-0.5477	0.9826
-3.3538	-0.5141	-0.7113		0.2534	1.3263	0.2376
-2.8841	-1.68	-0.1507		-1.88	0.3562	0.7749
-2.7221	0.6923	-1.3449		0.566	-0.1474	0.0641
-2.3277	-0.4614	-0.8166		0.1665		0.619
0.1279	0.518	-2.4272		0.2882		-0.1443
0.7909	-2.2485	-0.3081				-0.1095
-2.7221						-0.2833
-3.5534						0.7229
-3.8996						1.0519
0.1803						0.1509
						0.5323
						-0.3354
						-0.2833
						0.619
						-0.179
						-1.1893
						-0.2659
						0.255

Storm 13

0.37	0.5102	0.351	-0.5617	-0.4906	-2.7542	-3.5159
0.07	0.5333	0.4897	-0.1881	-0.8433	-3.1904	-4.2541
0.79	0.7176	0.7206	0.4165	-2.9634	-3.7759	-3.6384
-0.1139	0.2102	0.8359	0.4861	-1.3155	-5.0607	-1.701
0.6708	1.0625	0.3973	-0.0483	-3.2532	-3.9966	-4.626
0.6938	0.4641	0.7206	-0.7724	-3.2532	-1.9605	-4.4522
0.5787	0.2102	0.3279	0.7408	-0.9611	-4.4154	-4.7505
0.279	0.1178	0.7206	-0.4448	-0.7962	-3.6536	-4.925
0.2328	1.1543	-0.1821	0.1611	-1.4576	-4.0704	-3.4425
0.4404	0.7636	-0.1821	-0.4915	-2.6505	-2.9236	-4.6012
0.3251	0.1178	0.05	0.0681	-2.0998	-2.6817	-4.7505
0.4404	0.6715	-0.0428	-0.1881	-0.1858	-3.5558	-4.4026
0.1404	0.2564	0.7206	0.0448	-0.9847	-4.218	-3.7366
0.4174	0.6485	0.1195	-0.1414	-3.617	-4.3907	-5
0.7168	0.6485	0.6052	0.5093	-2.2192	-2.3925	-5.4264
0.6938	0.2333	-0.7641	-0.4681	-0.7962	-2.8509	-2.7365
0.6478	0.6024	0.5359	0.5556	-1.9091	-2.9963	-3.467
0.5787	0.7636	0.2816	-0.4681	-2.8911	-3.4826	-5.3761
0.7168	0.9016	0.905	-1.0539	-0.8669	-3.678	-4.8502
0.5096	0.7866	0.3741	-0.0949	-2.3149	-3.2391	-4.975

-0.1371	-0.2063	0.351	-0.6318	-0.6315	-4.366	-3.5894
0.5096	0.7406	-0.0892	0.3933	-1.1264	-2.7059	-4.5763
0.5556	0.7636	-0.3448	-0.4448	-2.9634	-2.9478	-6.8512
1.0845	0.3257	-0.0196	-1.1715	-0.4436	-5.2605	-4.1305
0.3251	0.8326	0.4897	0.4165	-2.4346	-4.095	-4.3036
0.8318	0.6254	0.6514	-0.0483	-2.0759	-2.3203	-5.05
0.1866	0.6485	0.7667	0.4397	-0.7727	-3.507	-4.7754
0.1635	0.2795	0.4435	-0.3747	-1.1972	-3.4095	-3.9825
0.9927	0.7636	0.6052	-1.4777	-3.4471	-3.7759	-4.3531
0.0711	1.1543	0.1195	0.5093	-3.6414	-4.2427	-3.3448
0.9467	0.2564	0.9971	-0.4681	-1.15	-3.1904	-4.6509
0.5556	0.6024	0.8359	-1.3363	-3.0116	-3.0933	-3.8841
0.8778	0.8326	0.3047	0.3933	-2.1953	-5.4609	-3.3203
0.4635	0.1409	0.1427	0.1146	-1.15	-2.8994	-4.8502
0.6247	0.5102	0.9511	-0.1881	-2.0998	-4.9113	-4.477
0.7168	**0.65**	0.1427	-1.2185	-2.5305	-3.507	-3.5894
-0.3456	0.2795	-0.7408	-0.6084	-0.7491	-3.6291	-3.5894
0.5787	0.9016	0.559	0.0913	-1.6474	-3.2634	-3.9333
0.8548	0.8326	0.9511	-0.0716	-2.7707	-3.7025	-4.5763
0.4635	0.0021	-0.4844	-0.1181	-0.3967	-3.312	-3.0036
0.7168	-0.7171	0.4204	-0.7489	-1.9567	-2.5611	-4.5763
0.9467	0.6945	-0.6941	-0.4681	-2.867	-2.7784	-4.5763
0.1404	0.6945	0.8589	0.0216	-2.4826	-4.0458	-4.9001
0.6478	0.5333	-0.0892	-0.913	-1.15	-3.2147	-2.7608
0.1173	0.5333	0.9511	-0.328	-1.4813	-2.4888	-4.477
0.8088	0.8556	0.2353	0.1378	-0.6785	-3.5314	-4.2046
0.1866	0.1871	-0.275	0.254	-0.3264	-2.6093	-4.6012
0.8088	0.3488	0.6975	-0.5383	-2.1237	-3.8494	-4.5515
0.7398	0.3488	0.6283	-0.5617	-3.1082	-3.8494	-4.4274
0.3482	0.6715	0.351	-0.4681	-2.0759	-2.8268	-2.7123
0.3712	0.9016	0.7667	-0.1181	-0.655	-4.7621	-2.5187
0.6247	0.7176	-0.1124	0.3237	-1.2682	-3.9475	-4.95
0.7398	0.6715	-0.0428	-0.913	-1.1027	-3.2877	-5.2756
0.8088	0.3949	0.8359	0.5093	-1.4339		-3.3936
0.4865	0.7406	0.4204	0.0216	-2.4346		-4.0318
0.6708	0.5333	0.882	-1.6194	-3.3986		-4.5763
0.6478	0.3718	-0.2053	-1.4305	-2.4107		-4.4274
0.7398	0.6715	0.928	0.2773	-0.7962		-4.2788
0.1635	0.5794	0.2585	-1.1244	-1.1972		-4.0318
0.7628	-0.021	0.6283		-1.79		-2.3738
-0.3688	0.5102	0.1658		-1.4813		-5.6027
0.8318	0.2564	0.4897		-2.3628		-4.477
0.2328	0.1871	0.5821		-1.0319		-4.0318
0.3943	0.2102	0.8359		-1.5762		-2.6397
0.5326	0.8096	0.3279				-3.9333
0.9238	0.4641	0.5128				-5.05
-0.392	0.3949	0.6975				-3.0279
0.9238	-0.0904	-0.066				

0.3712	0.7636	0.6052				
0.5096	-0.2758	0.351				
0.6938	1.0165	0.928				
0.5787	-0.1136	0.351				
	0.1178					
	0.2564					
	0.0253					
	0.7176					
	0.5333					
	0.5102					
	0.1409					
	0.4641					

Vertical Scale of Runup at High Tide - TAIRUA
(S = Storm)

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
0.23	0.46	0.22	0.25	0.12	0.07	0.39	0.35	0.11	0.25
0.23	0.15	0.44	0.14	0.41	0.51	0.16	0.42	0.28	0.39
0.41	1.19	0.23	0.38	0.19	0.18	0.46	0.99	0.28	0.51
0.36	0.11	0.07	0.42	0.43	0.30	0.28	1.34	0.15	0.37
0.46	0.85	0.67	0.11	0.14	0.57	0.33	0.90	0.25	0.37
0.49	0.38	0.26	0.17	0.34	0.46	0.49	0.72	0.36	0.60
0.30	0.55	0.34	0.20	0.19	0.37	0.28	0.76	0.22	0.50
0.49	0.44	0.19	0.32	0.28	0.00	0.12	0.69	0.32	0.74
0.26	0.61	0.12	0.31	0.14	0.28	0.48	1.08	0.21	0.48
0.27	0.99	0.37	0.17	0.28	0.14	0.37	0.39	0.40	0.70
0.21	0.32	0.49	0.16	0.32	0.39	0.18	0.21	0.41	0.44
0.51	1.05	0.23	0.25	0.12	0.28	0.45	0.42	0.39	0.57
0.14	0.18	0.55	0.19	0.37	0.28	0.27	0.84	0.46	0.40
0.72	1.08	0.13	0.14	0.32	0.23	0.38	0.62	0.35	0.45
0.44	0.24	0.26	0.26	0.23	0.35	0.36	0.74	0.39	0.40
0.44	0.99	0.31	0.24	0.39	0.30	0.31	0.72	0.37	0.56
0.28	0.90	0.52	0.41	0.21	0.35	0.31	1.36	0.38	0.20
0.28	0.53	0.49	0.12	0.21	0.37	0.10	0.52	0.28	0.55
0.39	0.21	0.31	0.09	0.43	0.30	0.41	1.51	0.43	0.40
0.35	0.85	0.31	0.38	0.43	0.41	0.27	0.51	0.34	0.44
0.35	0.94	0.32	0.16	0.32	0.23	0.31	0.37	0.43	0.62
0.31	0.55	0.40	0.09	0.23	0.53	0.46	0.62	0.50	0.40
0.44	0.56	0.31	0.35	0.37	0.39	0.42	0.55	0.37	0.61
0.36	0.78	0.34	0.14	0.43	0.35	0.15	0.76	0.30	0.37
0.45	0.28	0.68	0.31	0.25	0.37	0.24	0.59	0.13	0.63
0.45	0.02	0.35	0.16	0.23	0.11	0.29	0.72	0.28	0.55
0.31	0.94	0.41	0.15	0.16	0.30	0.29	0.34	0.41	0.24
0.49	0.85	0.04	0.26	0.46	0.48	0.35	0.78	0.47	0.45
0.48	0.35	0.67	0.25	0.25	0.57	0.35	0.73	0.24	0.45
0.40	0.78	0.12	0.07	0.48	0.44	0.22	0.80	0.41	0.55
0.54	0.41	0.28	0.17	0.21	0.46	0.34	0.40	0.28	0.55
0.48	0.85	0.07	0.11	0.37	0.35	0.44	0.73	0.45	0.50
0.32	0.72	0.55	0.28	0.05	0.51	0.00	0.73	0.59	0.50
0.41	0.75	0.32	0.09	0.21	0.44	0.12	0.41	0.47	0.45
0.22	1.19	0.32	0.28	0.43	0.55	0.43	0.61	0.60	0.38
0.00	0.58	0.71	0.09	0.19	0.51	0.25	0.77	0.52	0.45
0.42	1.05	0.19	0.28	0.32	0.48	0.46	0.91	0.22	0.30
0.30	0.64	0.64	0.19	0.25	0.23	0.34	0.87	0.36	0.18
0.23	0.11	0.34	0.33	0.37	0.23	0.39	1.11	0.29	0.55
0.50	0.55	0.13	0.16	0.34	0.32	0.25	0.85	0.34	0.34
0.27	1.04	0.44	0.22	0.34	0.25	0.33	0.52	0.40	0.24
0.48	0.50	0.59	0.26	0.28	0.55	0.15	0.63	0.54	0.44
0.27	0.76	0.01	0.17	0.14	0.55	0.28	1.39	0.34	0.30
0.50	0.96	0.31	0.16	0.32	0.53	0.49	0.29	0.27	0.31
0.54	0.58	0.46	0.21	0.25	0.23	0.24	0.90	0.31	0.76
0.50	0.61	0.20	0.04	0.14	0.30	0.37	0.89	0.65	0.59
0.49	1.13	0.58	0.22	0.25	0.51	0.17	0.71	0.41	0.73
0.42	0.35	0.47	0.36	0.32	0.48	0.39	0.82	0.65	0.70
0.23	0.79	0.37	0.17	0.14	0.60	0.30	0.85	0.57	0.32
0.62	0.11	0.55	0.06	0.54	0.25	0.28	1.09	0.35	0.70
0.35	0.66	0.31	0.42	0.43	0.51	0.38	0.86	0.15	0.32
0.33	0.84	0.58	0.17	0.37	0.07	0.27	0.51	0.28	0.40

0.45	1.07	0.58	0.16	0.12	0.51	0.35	0.83	0.27	0.37
0.68	0.00	0.38	0.26	0.12	0.32	0.29	0.55	0.11	0.66
0.49	0.67	0.61	0.10	0.46	0.23	0.50	0.88	0.22	0.54
0.31	0.56	0.71	0.30	0.43	0.51	0.33	1.22	0.35	0.44
0.26	0.40	0.31	0.16	0.41	0.32	0.24	0.80	0.15	0.20
0.37	0.12	0.43	0.33	0.50	0.46	0.37	0.91	0.30	0.55
0.55	0.82	0.52	0.26	0.48	0.23	0.36	1.03	0.27	0.28
0.42	0.64	0.34	0.21	0.12	0.14	0.27	0.00	0.37	0.21
0.21	0.72	0.00	0.20	0.37	0.48	0.33	0.66	0.11	0.45
0.31	0.09	0.58	0.33	0.46	0.28	0.41	0.38	0.59	0.28
0.28	1.16	0.53	0.16	0.19	0.32	0.57	1.06	0.34	0.30
0.14	0.84	0.28	0.24	0.25	0.41	0.10	0.84	0.38	0.81
0.48	1.37	0.65	0.21	0.12	0.35	0.44	0.52	0.28	0.56
0.24	0.20	0.29	0.10	0.30	0.44	0.31	1.13	0.26	0.69
0.54	0.72	0.77	0.28	0.32	0.28	0.23	0.90	0.09	0.65
0.28	0.20	0.19	0.12	0.48	0.35	0.40	0.75	0.32	0.30
0.39	0.52	0.47	0.37	0.50	0.46	0.40		0.17	0.69
0.46	0.72	0.10	0.06	0.21	0.46	0.19		0.29	0.35
0.46	0.73	0.19	0.36	0.21	0.14	0.24		0.22	0.41
0.37	0.70	0.49	0.07	0.39	0.18	0.28		0.40	0.39
0.24	0.98	0.23	0.01	0.23	0.39	0.41		0.35	0.61
0.48	0.76	0.43	0.40	0.41	0.25	0.13		0.38	0.61
0.26	0.61	0.31	0.17	0.37	0.46	0.51		0.36	0.47
0.26		0.41	0.17	0.43	0.37	0.13		0.28	0.39
0.27		0.41	0.27	0.28	0.48	0.22		0.22	0.29
0.35		0.58	0.06	0.19	0.48	0.39		0.31	0.62
0.39		0.70	0.24	0.28	0.32	0.32		0.28	0.22
0.68		0.43	0.04	0.25	0.30	0.20		0.29	0.46
0.44		0.43	0.35	0.03	0.55	0.55		0.28	0.58
0.48		0.56	0.00	0.23	0.23	0.23		0.35	0.68
0.48		0.31	0.27	0.12	0.37	0.18		0.53	0.40
0.44		0.13	0.14	0.19	0.30	0.30		0.26	0.59
0.37		0.47	0.25	0.23	0.55	0.28		0.28	0.35
0.39		0.55	0.06	0.05	0.55	0.28		0.38	0.59
0.21		0.40	0.21	0.32	0.37	0.36		0.23	0.59
0.33		0.47	0.31	0.72		0.19		0.15	0.20
0.44		0.20	0.02	0.39		0.31		0.22	0.60
0.28		0.22	0.27	0.00		0.07		0.26	0.15
0.32		0.71		0.23		0.22		0.28	0.45
0.15		0.49		0.28				0.28	0.20
0.49		0.49		0.37				0.39	0.56
0.33		0.71		0.57				0.25	0.20
0.62		0.59		0.32				0.38	0.49
0.32		0.04		0.21				0.38	0.36
0.53		0.53		0.43				0.22	0.41
0.49		0.19		0.48				0.49	0.00
0.28		0.53		0.39				0.31	0.44
0.46		0.50		0.12				0.33	0.54
0.58		0.22		0.39				0.37	0.60
		0.46		0.46				0.31	0.53
				0.21				0.17	0.41
				0.41				0.17	0.30
				0.43				0.00	0.20
				0.30				0.24	0.62
				0.43				0.59	0.28
				0.34				0.14	0.16
				0.39				0.38	0.39

				0.37				0.16	0.35
				0.28				0.56	0.40
				0.28				0.32	0.08
				0.52					0.28
				0.23					0.42
				0.43					0.47
				0.19					0.43
				0.32					0.35
				0.23					0.64
									0.57
									0.47
									0.31
									0.25
									0.61
									0.40
									0.30
									0.57
									0.02
									0.60
									0.54
									0.33
									0.61
									0.54
									0.33
									0.20
									0.48

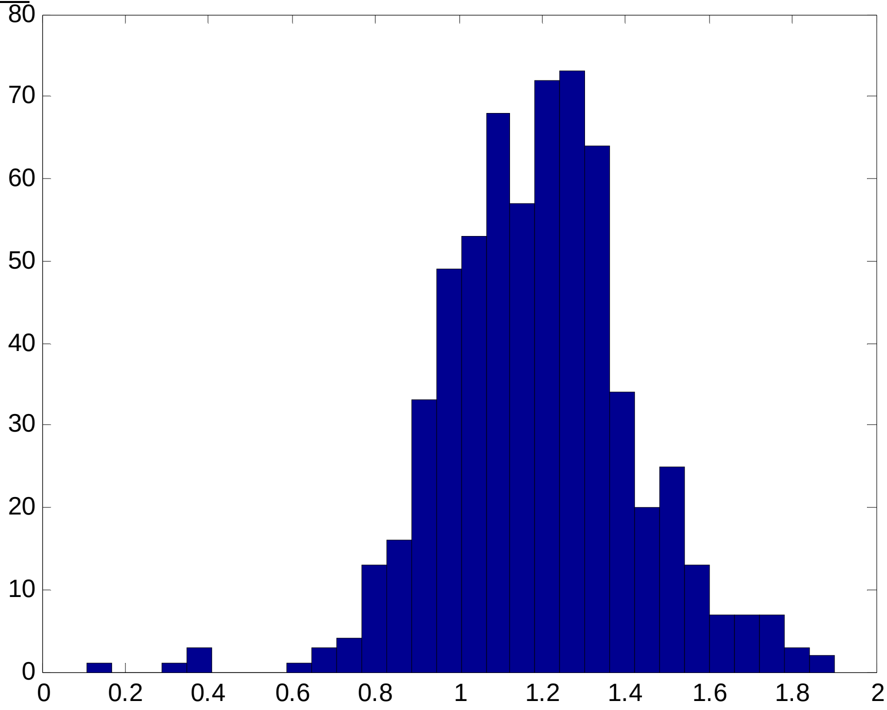
Vertical Scale of Runup at High Tide – PAUANUI (S=storm)

S11	S12	S13
0.26	0.84	0.54
0.63	0.84	0.91
0.71	0.84	0.99
0.45	0.84	0.73
0.41	0.84	0.69
1.03	0.84	1.31
0.46	0.84	0.74
0.36	0.84	0.64
0.76	0.84	1.04
0.62	0.84	0.90
0.61	0.84	0.89
0.71	0.84	0.99
0.85	0.84	1.13
0.00	0.84	0.28
0.87	0.84	1.15
0.71	0.84	0.99
0.21	0.84	0.49
0.80	0.84	1.08
0.67	0.84	0.95
0.21	0.84	0.49
0.77	0.84	1.05
0.29	0.84	0.57
0.73	0.84	1.01
0.51	0.84	0.79
0.94	0.84	1.22
0.27	0.84	0.55
0.79	0.84	1.07
0.64	0.84	0.92
0.45	0.84	0.73
0.71	0.84	0.99
0.74	0.84	1.02
0.69	0.84	0.97
0.50	0.84	0.78
0.64	0.84	0.92
0.77	0.84	1.05
0.77	0.84	1.05
0.32	0.84	0.60
0.74	0.84	1.02
0.68	0.84	0.96
0.61	0.84	0.89
0.57	0.84	0.85
0.85	0.84	1.13
0.57	0.84	0.85
0.33	0.84	0.61
0.71	0.84	0.99
0.50	0.84	0.78
0.73	0.84	1.01
0.66	0.84	0.94
0.63	0.84	0.91
0.52	0.84	0.80

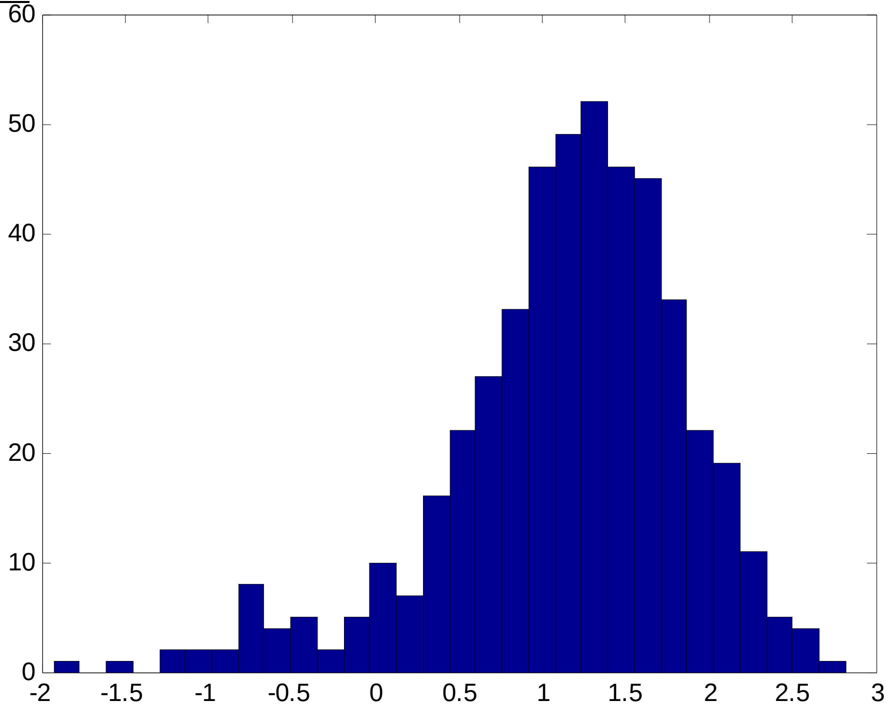
0.47	0.84	0.75
0.52	0.84	0.80
0.78	0.84	1.06
0.62	0.84	0.90
0.71	0.84	0.99
0.71	0.84	0.99
0.68	0.84	0.96
0.35	0.84	0.63
0.71	0.84	0.99
0.64	0.84	0.92
0.71	0.84	0.99
0.52	0.84	0.80
0.69	0.84	0.97
0.53	0.84	0.81
0.72	0.84	1.00
0.64	0.84	0.92
0.72		1.00
0.57		0.85
0.72		1.00
0.78		1.06
0.61		0.89
0.67		0.95
0.57		
0.83		
0.61		
0.41		
0.46		
0.82		

Histograms of Runup Distributions - Tairua

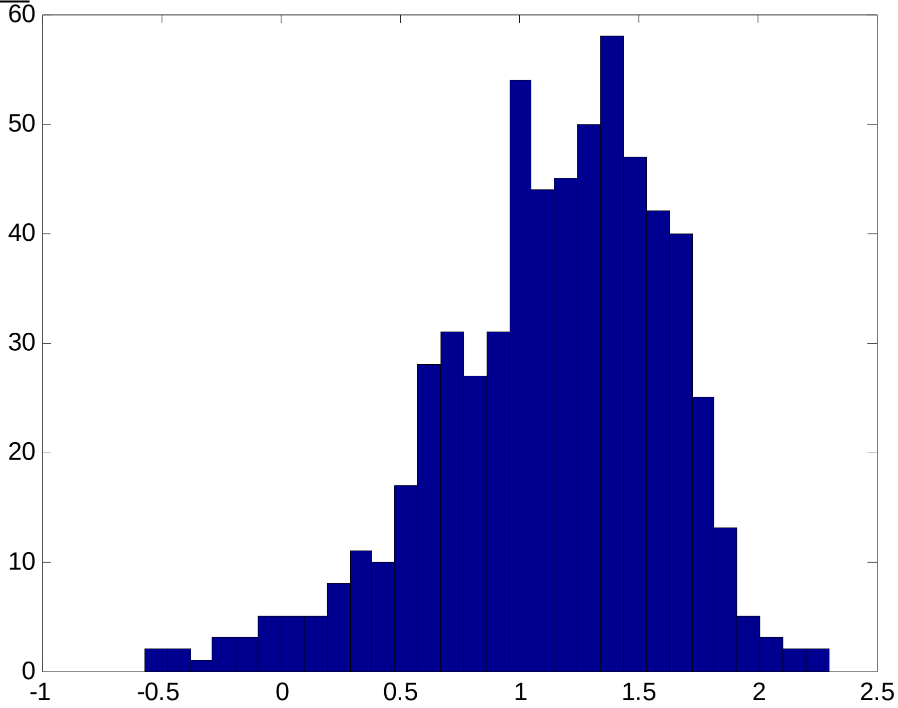
Storm 1



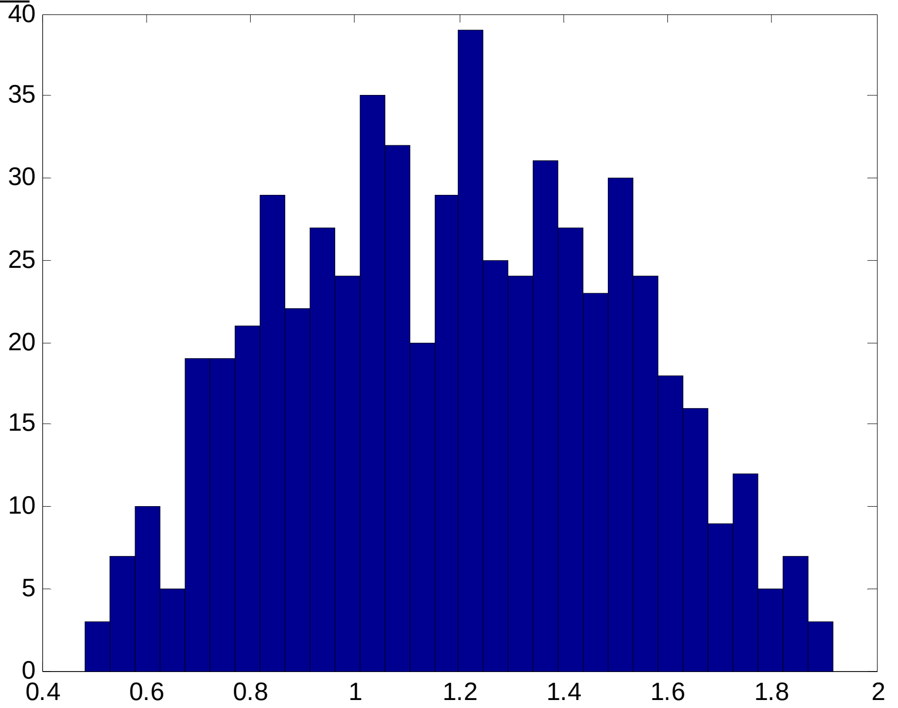
Storm 2



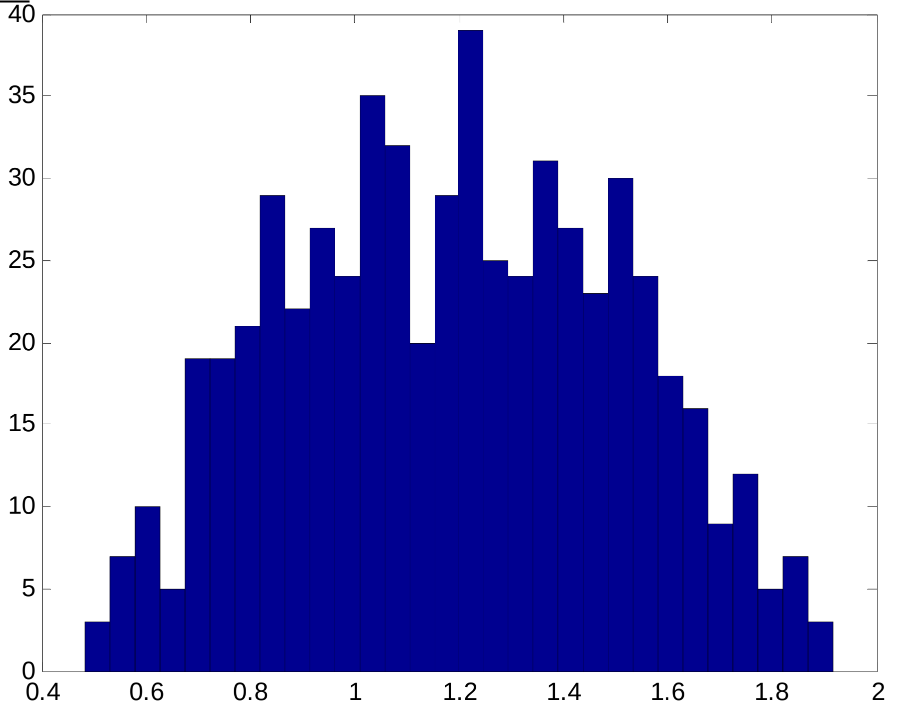
Storm 3



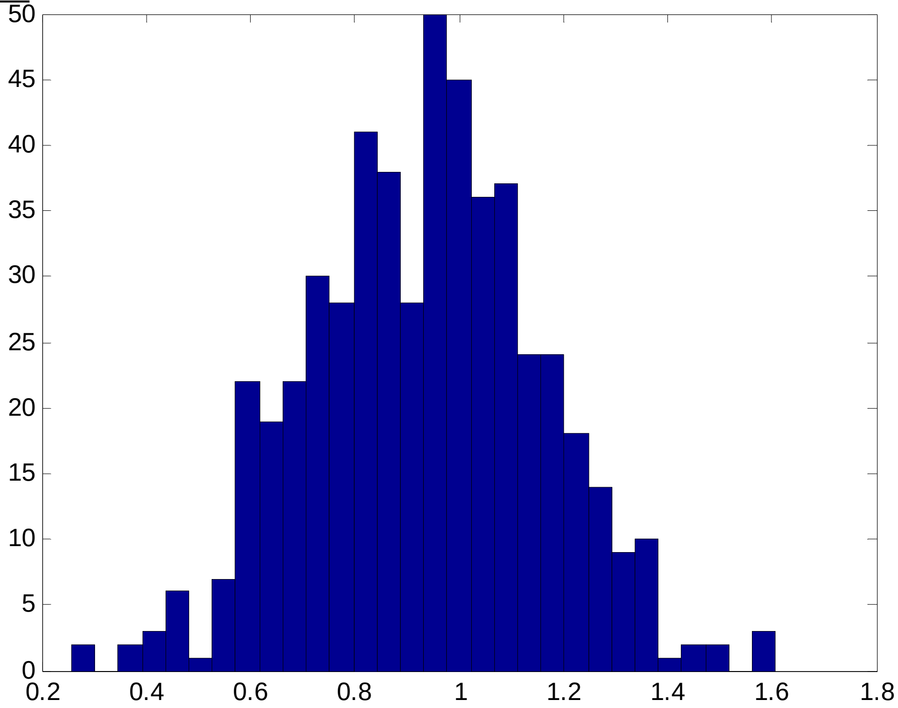
Storm 4



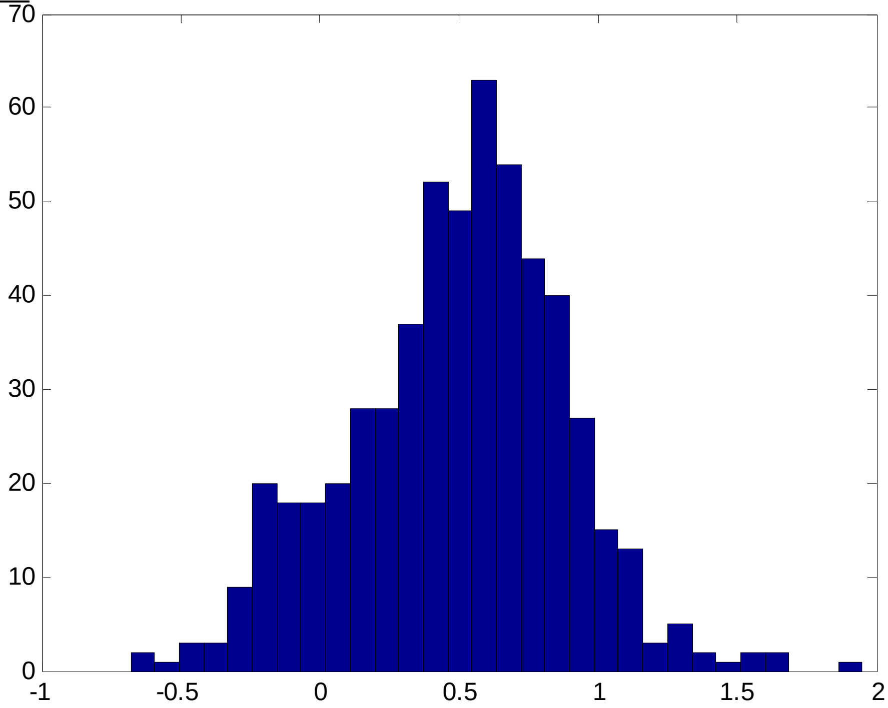
Storm 5



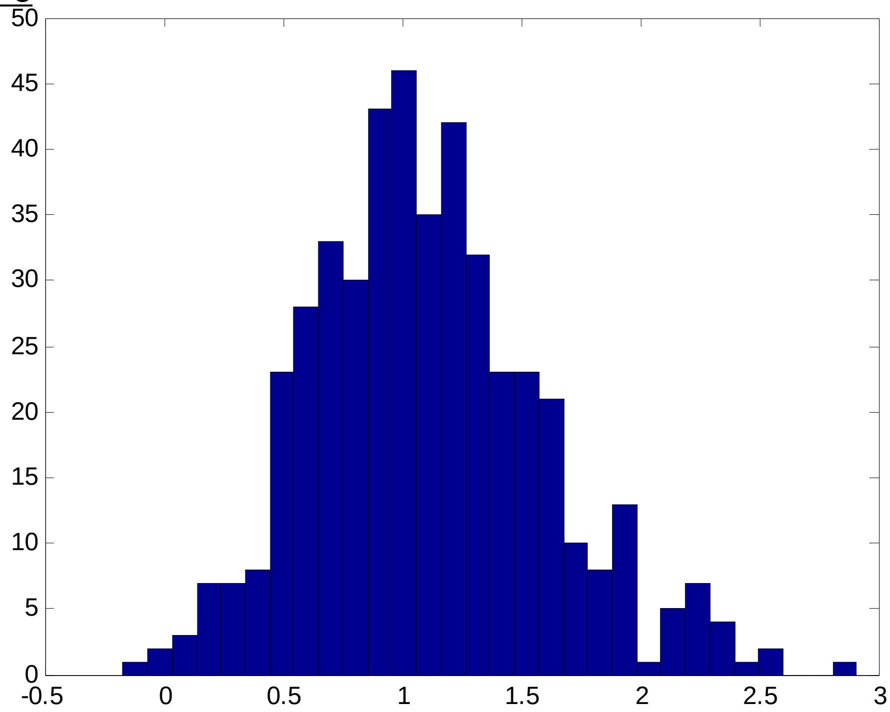
Storm 6



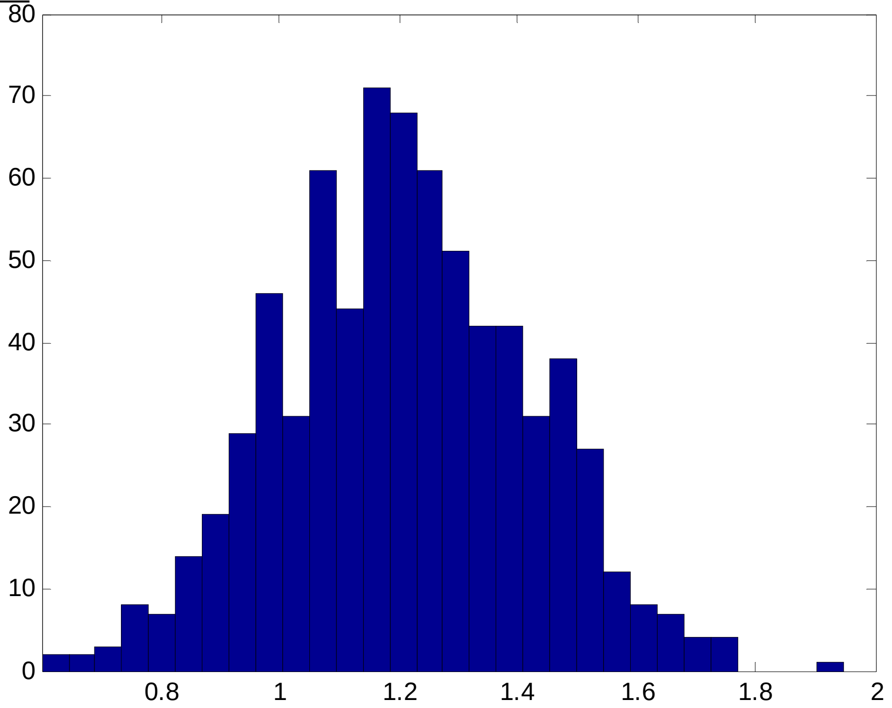
Storm 7



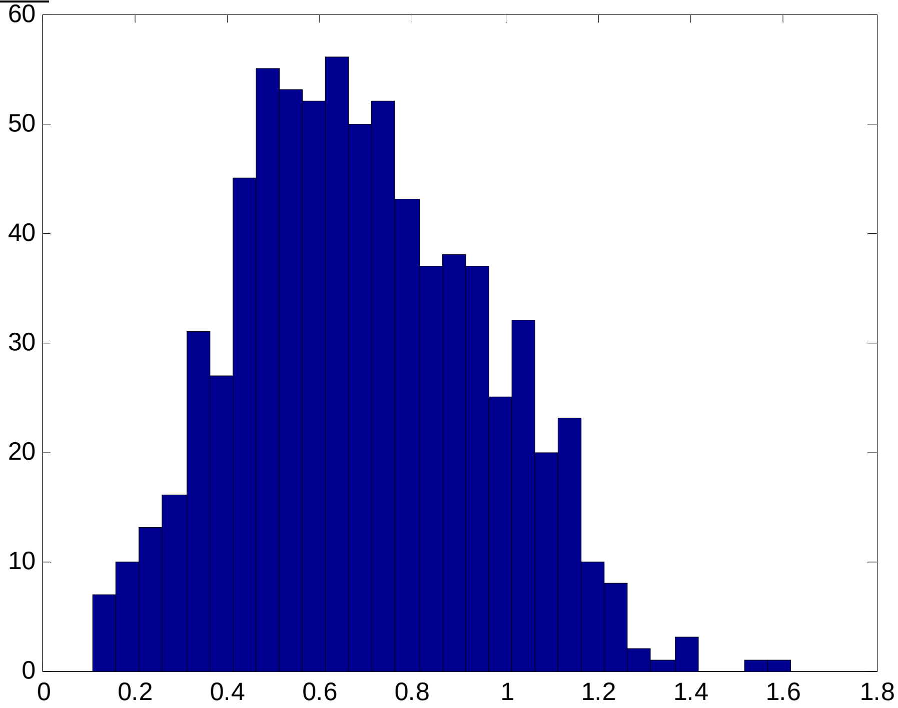
Storm 8



Storm 9

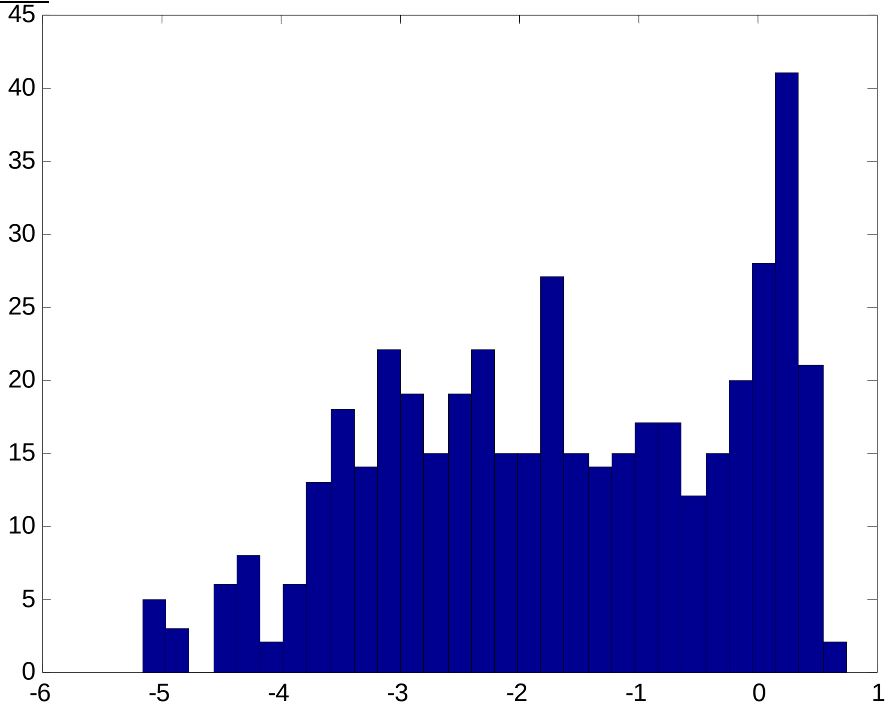


Storm 10

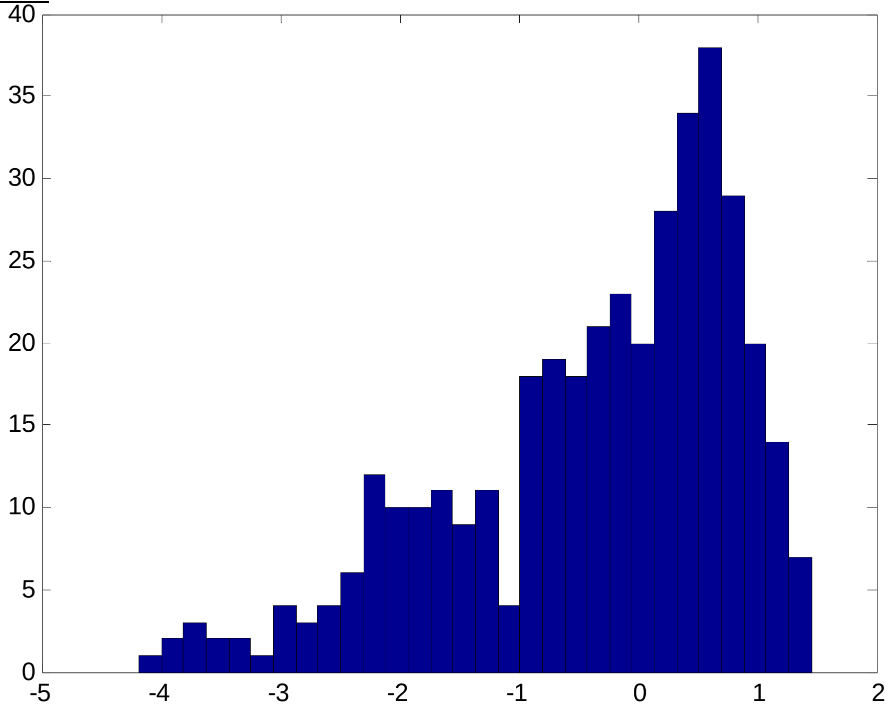


Histograms of Runup Distributions - Pauanui

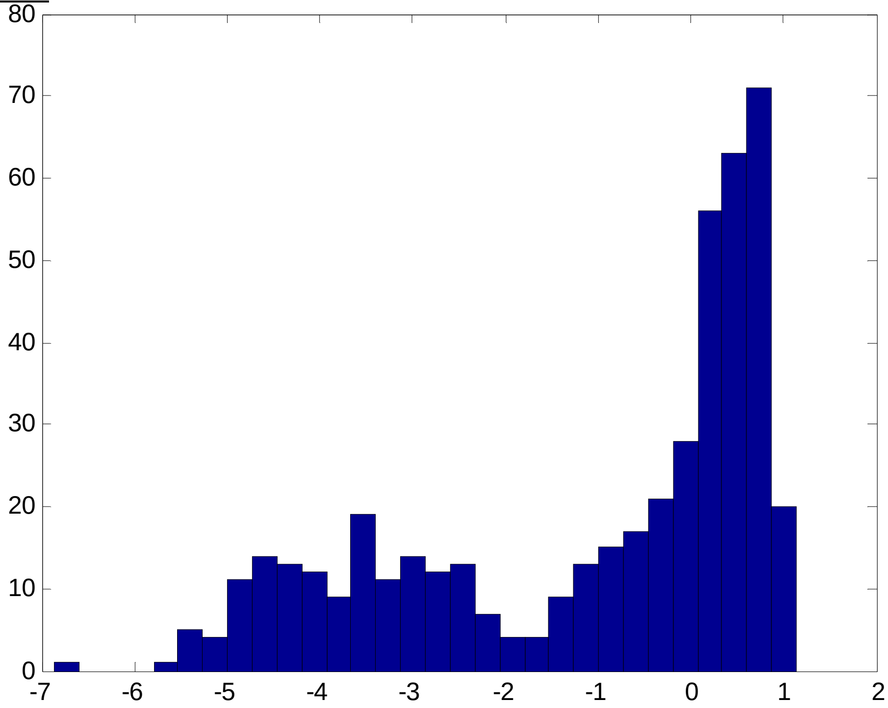
Storm 11



Storm 12



Storm 13



Vertical Scale of Runup at High Tide - TAIRUA
(S = Storm)

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
0.23	0.46	0.22	0.25	0.12	0.07	0.39	0.35	0.11	0.25
0.23	0.15	0.44	0.14	0.41	0.51	0.16	0.42	0.28	0.39
0.41	1.19	0.23	0.38	0.19	0.18	0.46	0.99	0.28	0.51
0.36	0.11	0.07	0.42	0.43	0.30	0.28	1.34	0.15	0.37
0.46	0.85	0.67	0.11	0.14	0.57	0.33	0.90	0.25	0.37
0.49	0.38	0.26	0.17	0.34	0.46	0.49	0.72	0.36	0.60
0.30	0.55	0.34	0.20	0.19	0.37	0.28	0.76	0.22	0.50
0.49	0.44	0.19	0.32	0.28	0.00	0.12	0.69	0.32	0.74
0.26	0.61	0.12	0.31	0.14	0.28	0.48	1.08	0.21	0.48
0.27	0.99	0.37	0.17	0.28	0.14	0.37	0.39	0.40	0.70
0.21	0.32	0.49	0.16	0.32	0.39	0.18	0.21	0.41	0.44
0.51	1.05	0.23	0.25	0.12	0.28	0.45	0.42	0.39	0.57
0.14	0.18	0.55	0.19	0.37	0.28	0.27	0.84	0.46	0.40
0.72	1.08	0.13	0.14	0.32	0.23	0.38	0.62	0.35	0.45
0.44	0.24	0.26	0.26	0.23	0.35	0.36	0.74	0.39	0.40
0.44	0.99	0.31	0.24	0.39	0.30	0.31	0.72	0.37	0.56
0.28	0.90	0.52	0.41	0.21	0.35	0.31	1.36	0.38	0.20
0.28	0.53	0.49	0.12	0.21	0.37	0.10	0.52	0.28	0.55
0.39	0.21	0.31	0.09	0.43	0.30	0.41	1.51	0.43	0.40
0.35	0.85	0.31	0.38	0.43	0.41	0.27	0.51	0.34	0.44
0.35	0.94	0.32	0.16	0.32	0.23	0.31	0.37	0.43	0.62
0.31	0.55	0.40	0.09	0.23	0.53	0.46	0.62	0.50	0.40
0.44	0.56	0.31	0.35	0.37	0.39	0.42	0.55	0.37	0.61
0.36	0.78	0.34	0.14	0.43	0.35	0.15	0.76	0.30	0.37
0.45	0.28	0.68	0.31	0.25	0.37	0.24	0.59	0.13	0.63
0.45	0.02	0.35	0.16	0.23	0.11	0.29	0.72	0.28	0.55
0.31	0.94	0.41	0.15	0.16	0.30	0.29	0.34	0.41	0.24
0.49	0.85	0.04	0.26	0.46	0.48	0.35	0.78	0.47	0.45
0.48	0.35	0.67	0.25	0.25	0.57	0.35	0.73	0.24	0.45
0.40	0.78	0.12	0.07	0.48	0.44	0.22	0.80	0.41	0.55
0.54	0.41	0.28	0.17	0.21	0.46	0.34	0.40	0.28	0.55
0.48	0.85	0.07	0.11	0.37	0.35	0.44	0.73	0.45	0.50
0.32	0.72	0.55	0.28	0.05	0.51	0.00	0.73	0.59	0.50
0.41	0.75	0.32	0.09	0.21	0.44	0.12	0.41	0.47	0.45
0.22	1.19	0.32	0.28	0.43	0.55	0.43	0.61	0.60	0.38
0.00	0.58	0.71	0.09	0.19	0.51	0.25	0.77	0.52	0.45
0.42	1.05	0.19	0.28	0.32	0.48	0.46	0.91	0.22	0.30
0.30	0.64	0.64	0.19	0.25	0.23	0.34	0.87	0.36	0.18
0.23	0.11	0.34	0.33	0.37	0.23	0.39	1.11	0.29	0.55
0.50	0.55	0.13	0.16	0.34	0.32	0.25	0.85	0.34	0.34
0.27	1.04	0.44	0.22	0.34	0.25	0.33	0.52	0.40	0.24
0.48	0.50	0.59	0.26	0.28	0.55	0.15	0.63	0.54	0.44
0.27	0.76	0.01	0.17	0.14	0.55	0.28	1.39	0.34	0.30
0.50	0.96	0.31	0.16	0.32	0.53	0.49	0.29	0.27	0.31
0.54	0.58	0.46	0.21	0.25	0.23	0.24	0.90	0.31	0.76
0.50	0.61	0.20	0.04	0.14	0.30	0.37	0.89	0.65	0.59
0.49	1.13	0.58	0.22	0.25	0.51	0.17	0.71	0.41	0.73
0.42	0.35	0.47	0.36	0.32	0.48	0.39	0.82	0.65	0.70
0.23	0.79	0.37	0.17	0.14	0.60	0.30	0.85	0.57	0.32
0.62	0.11	0.55	0.06	0.54	0.25	0.28	1.09	0.35	0.70
0.35	0.66	0.31	0.42	0.43	0.51	0.38	0.86	0.15	0.32
0.33	0.84	0.58	0.17	0.37	0.07	0.27	0.51	0.28	0.40

0.45	1.07	0.58	0.16	0.12	0.51	0.35	0.83	0.27	0.37
0.68	0.00	0.38	0.26	0.12	0.32	0.29	0.55	0.11	0.66
0.49	0.67	0.61	0.10	0.46	0.23	0.50	0.88	0.22	0.54
0.31	0.56	0.71	0.30	0.43	0.51	0.33	1.22	0.35	0.44
0.26	0.40	0.31	0.16	0.41	0.32	0.24	0.80	0.15	0.20
0.37	0.12	0.43	0.33	0.50	0.46	0.37	0.91	0.30	0.55
0.55	0.82	0.52	0.26	0.48	0.23	0.36	1.03	0.27	0.28
0.42	0.64	0.34	0.21	0.12	0.14	0.27	0.00	0.37	0.21
0.21	0.72	0.00	0.20	0.37	0.48	0.33	0.66	0.11	0.45
0.31	0.09	0.58	0.33	0.46	0.28	0.41	0.38	0.59	0.28
0.28	1.16	0.53	0.16	0.19	0.32	0.57	1.06	0.34	0.30
0.14	0.84	0.28	0.24	0.25	0.41	0.10	0.84	0.38	0.81
0.48	1.37	0.65	0.21	0.12	0.35	0.44	0.52	0.28	0.56
0.24	0.20	0.29	0.10	0.30	0.44	0.31	1.13	0.26	0.69
0.54	0.72	0.77	0.28	0.32	0.28	0.23	0.90	0.09	0.65
0.28	0.20	0.19	0.12	0.48	0.35	0.40	0.75	0.32	0.30
0.39	0.52	0.47	0.37	0.50	0.46	0.40		0.17	0.69
0.46	0.72	0.10	0.06	0.21	0.46	0.19		0.29	0.35
0.46	0.73	0.19	0.36	0.21	0.14	0.24		0.22	0.41
0.37	0.70	0.49	0.07	0.39	0.18	0.28		0.40	0.39
0.24	0.98	0.23	0.01	0.23	0.39	0.41		0.35	0.61
0.48	0.76	0.43	0.40	0.41	0.25	0.13		0.38	0.61
0.26	0.61	0.31	0.17	0.37	0.46	0.51		0.36	0.47
0.26		0.41	0.17	0.43	0.37	0.13		0.28	0.39
0.27		0.41	0.27	0.28	0.48	0.22		0.22	0.29
0.35		0.58	0.06	0.19	0.48	0.39		0.31	0.62
0.39		0.70	0.24	0.28	0.32	0.32		0.28	0.22
0.68		0.43	0.04	0.25	0.30	0.20		0.29	0.46
0.44		0.43	0.35	0.03	0.55	0.55		0.28	0.58
0.48		0.56	0.00	0.23	0.23	0.23		0.35	0.68
0.48		0.31	0.27	0.12	0.37	0.18		0.53	0.40
0.44		0.13	0.14	0.19	0.30	0.30		0.26	0.59
0.37		0.47	0.25	0.23	0.55	0.28		0.28	0.35
0.39		0.55	0.06	0.05	0.55	0.28		0.38	0.59
0.21		0.40	0.21	0.32	0.37	0.36		0.23	0.59
0.33		0.47	0.31	0.72		0.19		0.15	0.20
0.44		0.20	0.02	0.39		0.31		0.22	0.60
0.28		0.22	0.27	0.00		0.07		0.26	0.15
0.32		0.71		0.23		0.22		0.28	0.45
0.15		0.49		0.28				0.28	0.20
0.49		0.49		0.37				0.39	0.56
0.33		0.71		0.57				0.25	0.20
0.62		0.59		0.32				0.38	0.49
0.32		0.04		0.21				0.38	0.36
0.53		0.53		0.43				0.22	0.41
0.49		0.19		0.48				0.49	0.00
0.28		0.53		0.39				0.31	0.44
0.46		0.50		0.12				0.33	0.54
0.58		0.22		0.39				0.37	0.60
		0.46		0.46				0.31	0.53
				0.21				0.17	0.41
				0.41				0.17	0.30
				0.43				0.00	0.20
				0.30				0.24	0.62
				0.43				0.59	0.28
				0.34				0.14	0.16
				0.39				0.38	0.39

				0.37				0.16	0.35
				0.28				0.56	0.40
				0.28				0.32	0.08
				0.52					0.28
				0.23					0.42
				0.43					0.47
				0.19					0.43
				0.32					0.35
				0.23					0.64
									0.57
									0.47
									0.31
									0.25
									0.61
									0.40
									0.30
									0.57
									0.02
									0.60
									0.54
									0.33
									0.61
									0.54
									0.33
									0.20
									0.48

Vertical Scale of Runup at High Tide – PAUANUI
(S=storm)

S11	S12	S13
0.26	0.84	0.54
0.63	0.84	0.91
0.71	0.84	0.99
0.45	0.84	0.73
0.41	0.84	0.69
1.03	0.84	1.31
0.46	0.84	0.74
0.36	0.84	0.64
0.76	0.84	1.04
0.62	0.84	0.90
0.61	0.84	0.89
0.71	0.84	0.99
0.85	0.84	1.13
0.00	0.84	0.28
0.87	0.84	1.15
0.71	0.84	0.99
0.21	0.84	0.49
0.80	0.84	1.08
0.67	0.84	0.95
0.21	0.84	0.49
0.77	0.84	1.05
0.29	0.84	0.57
0.73	0.84	1.01
0.51	0.84	0.79
0.94	0.84	1.22
0.27	0.84	0.55
0.79	0.84	1.07
0.64	0.84	0.92
0.45	0.84	0.73
0.71	0.84	0.99
0.74	0.84	1.02
0.69	0.84	0.97
0.50	0.84	0.78
0.64	0.84	0.92
0.77	0.84	1.05
0.77	0.84	1.05
0.32	0.84	0.60
0.74	0.84	1.02
0.68	0.84	0.96
0.61	0.84	0.89
0.57	0.84	0.85
0.85	0.84	1.13
0.57	0.84	0.85
0.33	0.84	0.61
0.71	0.84	0.99
0.50	0.84	0.78
0.73	0.84	1.01
0.66	0.84	0.94
0.63	0.84	0.91
0.52	0.84	0.80

0.47	0.84	0.75
0.52	0.84	0.80
0.78	0.84	1.06
0.62	0.84	0.90
0.71	0.84	0.99
0.71	0.84	0.99
0.68	0.84	0.96
0.35	0.84	0.63
0.71	0.84	0.99
0.64	0.84	0.92
0.71	0.84	0.99
0.52	0.84	0.80
0.69	0.84	0.97
0.53	0.84	0.81
0.72	0.84	1.00
0.64	0.84	0.92
0.72		1.00
0.57		0.85
0.72		1.00
0.78		1.06
0.61		0.89
0.67		0.95
0.57		
0.83		
0.61		
0.41		
0.46		
0.82		

Appendix 3

Field Survey Data

Tairua (all units are metres)
Beach Profile
Vertical Distance

1st	2nd	**Average**
-3.5040	-3.5160	**-3.5100**
-4.4850	-4.4620	**-4.4735**
-5.5940	-5.5970	**-5.5955**
-6.6490	-6.6220	**-6.6355**
-6.9650	-6.9990	**-6.9820**
-7.4380	-7.4270	**-7.4325**
-7.7660	-7.7610	**-7.7635**
-8.6590	-8.6680	**-8.6635**
-9.4880	-9.4990	**-9.4935**
-10.3690	-10.3800	**-10.3745**

Horizontal Distance

1st	2nd	**Average**
8.7020	8.6870	**8.6945**
12.7390	12.7080	**12.7235**
18.2760	18.3010	**18.2885**
24.9730	24.9790	**24.9760**
32.7900	32.8110	**32.8005**
40.9350	40.9010	**40.9180**
49.8320	49.7970	**49.8145**
56.3720	56.3750	**56.3735**
62.1760	62.1550	**62.1655**
68.8440	68.8090	**68.8265**

Pole Survey
Vertical Distance

1st	2nd	Average
-10.5210	-10.5230	-10.5220
-10.2270	-10.2220	-10.2245
-9.9230	-9.9220	-9.9225
-9.6970	-9.6990	-9.6980
-9.4450	-9.4340	-9.4395
-9.2010	-9.2090	-9.2050
-8.8500	-8.8570	-8.8535
-8.4900	-8.5040	-8.4970

Horizontal Distance

1st	2nd	**Average**
69.7830	69.7540	**69.7685**
67.6850	67.6940	**67.6895**
65.4950	65.4930	**65.4940**
63.6540	63.6960	**63.6750**
61.8710	61.8550	**61.8630**
60.1690	60.1450	**60.1570**
57.5550	57.5260	**57.5405**
55.2020	55.2030	**55.2025**

Height of Pole (m)	Vertical Height Top of Pole (m)	Pole measure below ground
0.8940	**-9.6280**	0.4060
0.8980	**-9.3265**	0.4020
0.8570	**-9.0655**	0.4430
0.8480	**-8.8500**	0.4520
0.8920	**-8.5475**	0.4080
0.7630	**-8.4420**	0.5370
0.8630	**-7.9905**	0.4370
0.8100	**-7.6870**	0.4900

Dipwell Measurements

Tide Time	**Pole 1 Lowest**	**Pole 2**	**Pole 3**	**Pole 4**	**Pole 5**	**Pole 6**	**Pole 7**	**Pole 8 Highest**
Low +1hr	0.79	0.94	1.06	1.19	0			
Low +2hrs	0.715	0.925	0.9	1.07	0			
Mid-Tide	0.375	0.71	0.86	0.92	1.099			
High-2hrs		0.35	0.585	0.78	0.92	0.955		
High-1hr				0.4	0.66	0.73	1.05	0

Vertical Height of Water Levels

Tide Time	**Pole 1**	**Pole 2**	**Pole 3**	**Pole 4**	**Pole 5**	**Pole 6**	**Pole 7**	**Pole 8**
Low +1hr	-10.4180	-10.2665	-10.1255	-10.0400	nil			
Low +2hrs	-10.3430	-10.2515	-9.9655	-9.9200	nil			
Mid-Tide	-10.0030	-10.0365	-9.9255	-9.7700	-9.6465			
High-2hrs		-9.6765	-9.6505	-9.6300	-9.4675	-9.3970		
High-1hr				-9.2500	-9.2075	-9.1720	-9.0405	nil

Wave Count

Tide Time	**Pole 1**	Stake 1	**Pole 2**	Stake 2	**Pole 3**	Stake 3	**Pole 4**	Stake 4	**Pole 5**	Stake 5	**Pole 6**	Stake 6	**Pole 7**	Stake 7	**Pole 8**	Stake 8
Low +1hr	34	15	19	23	9	5	1									
Low +2hrs	9	17	28	25	21	10	9	2	2							
Mid-Tide				10	15	26	14	18	10	5						
High-2hrs							6	10	31	34	22	10	7			
High-1hr										7	21	22	34	9	10	1

<u>Pauanui</u>

Wave count

Tide Time	**Pole 1**	**Stake 1**	**Pole 2**	**Stake 2**	**Pole 3**	**Stake 3**	**Pole 4**	**Stake 4**	**Pole 5**	**Stake 5**	**Pole 6**	**Stake 6**	**Pole 7**	**Stake 7**	**Pole 8**	**Stake 8**	**Pole 9**	**Stake 9**
Low +1hr	23	12	7	2	1	2												
Low +2hrs		6	14	11	9	13	8	1	4									
Low+3hrs					3	3	7	14	18	14	4	1						
High-2hrs								9	34	22	10	6	2					
High-1hr												8	25	13	18	16	3	1

Beach Profile

Vertical Distance

1st	2nd	**Average**
-1.0620	-1.0620	**-1.0620**
-1.7840	-1.7860	**-1.7850**
-3.7400	-3.7330	**-3.7365**
-4.2130	-4.2140	**-4.2135**
-4.7210	-4.7040	**-4.7125**
-4.7960	-4.7970	**-4.7965**
-5.0770	-5.0780	**-5.0775**
-5.3930	-5.3910	**-5.3920**
-5.7800	-5.7850	**-5.7825**
-6.1300	-6.1210	**-6.1255**
-6.3990	-6.4040	**-6.4015**

Horizontal Distance

1st	2nd	**Average**
5.4720	5.3830	**5.4275**
7.9820	8.0010	**7.9915**
11.8750	11.8950	**11.8850**
15.5160	15.4710	**15.4935**
23.0720	23.0160	**23.0440**
29.9630	29.9080	**29.9355**
37.0240	36.9690	**36.9965**
42.6540	42.6410	**42.6475**
50.6030	50.5810	**50.5920**
59.6420	59.6480	**59.6450**
69.6110	69.6370	**69.6240**

Pole Survey

Vertical Distance

1st	2nd	Average
-6.6900	-6.6930	-6.6915
-6.4960	-6.4920	-6.4940
-6.3230	-6.3150	-6.3190
-6.2080	-6.1960	-6.2020
-6.0710	-6.0690	-6.0700
-5.8190	-5.8140	-5.8165
-5.5410	-5.5510	-5.5460
-5.3210	-5.3320	-5.3265
-5.0940	-5.0990	-5.0965

Horizontal Distance

1st	2nd	**Average**
77.1240	77.1120	**77.1180**
70.8770	70.8700	**70.8735**
65.6450	65.5900	**65.6175**
61.8100	61.7900	**61.8000**
57.3810	57.3680	**57.3745**
51.1970	51.1590	**51.1780**
45.7220	45.7410	**45.7315**
41.4020	41.3660	**41.3840**
36.9440	36.9050	**36.9245**

Height of Pole from ground	Vertical Height Top of Pole (m)
1.0900	**-5.6015**
1.0200	**-5.4740**
1.0600	**-5.2290**
1.0900	**-5.1220**
1.0800	**-4.9800**
1.0900	**-4.7365**
1.0800	**-4.4560**
1.0900	**-4.3065**
1.0200	**-4.0765**

Dipwell Measurements

Tide Time	**Pole 1 Lowest**	**Pole 2**	**Pole 3**	**Pole 4**	**Pole 5**	**Pole 6**	**Pole 7**	**Pole 8**	**Pole 9 Highest**
Low +1hr	0.98	1.02	1.07	1.11	1.15				
Low +2hrs	0.87	1	1.06	1.09	1.11				
Low+3hrs			0.93	1.02	1.05	1.17	nil		
High-2hrs					0.9	1.05	1.17	nil	
High-1hr							1.05	1.13	nil

Vertical Height of Water Levels

Tide Time	**Pole 1**	**Pole 2**	**Pole 3**	**Pole 4**	**Pole 5**	**Pole 6**	**Pole 7**	**Pole 8**	**Pole 9**
Low +1hr	-6.5815	-6.4940	-6.2990	-6.2320	-6.1300				
Low +2hrs	-6.4715	-6.4740	-6.2890	-6.2120	-6.0900				
Low+3hrs			-6.1590	-6.1420	-6.0300	-5.9065			
High-2hrs					-5.8800	-5.7865	-5.6260		
High-1hr							-5.5060	-5.4365	nil