Analysis of shoreline variability and erosion/accretion trends: June - October 2008 report 9 Palm Beach coastal imaging system

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Publication details:
Report No. UNSW Water Research Laboratory Technical Report No. 2008/32

Publication Date:
2008

DOI:
https://doi.org/10.4225/53/58e1cc8a5705f

THE UNIVERSITY OF NEW SOUTH WALES

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ANALYSIS OF SHORELINE VARIABILITY AND EROSION/ACCRETION TRENDS: JUNE - OCTOBER 2008

REPORT 9
PALM BEACH COASTAL IMAGING SYSTEM

by

M J Blacka, D J Anderson and L Mallen Lopez

Technical Report 2008/32
November 2008

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THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
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Technical Report No	2008/32
Report Status	Final
Date of Issue	November 2008
WRL Project No.	06037.02
Project Manager	Doug Anderson

Title	Analysis of Shoreline Variability and Erosion/Accretion Trends: June – October 2008 Report 9 - Palm Beach Coastal Imaging System
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CONTENTS

LIST OF FIGURES

1. INTRODUCTION

This report was prepared by the Water Research Laboratory (WRL), of the University of New South Wales for Gold Coast City Council (GCCC). It is the ninth in a series of six-monthly reports, to describe, quantify and analyse the regional-scale coastline variability and erosion/accretion trends that occur at Palm Beach, Queensland, Australia. It is intended that this database of qualitative and quantitative coastal monitoring information will inform and enhance the current and future management of the Palm Beach embayment.

1.1 General

In June of 2004, an ARGUS coastal imaging system became operational at the Palm Beach site for an initial period of three years. This leading-edge technology was selected by Gold Coast City Council to provide regional-scale, continuous and long-term monitoring of this central Gold Coast coastal embayment. It is the ability to provide quantitative as well as qualitative information that distinguishes the ARGUS coastal imaging system from conventional 'webcam' or 'surfcam' technology.

The Gold Coast was the first of several coastal management sites in Australia that now utilise coastal imaging technology and associated digital image analysis techniques to monitor regional-scale coastal response to natural and engineered coastal impacts. A coastal imaging station has been operating at Surfers Paradise to the north of the Palm Beach site since 1999, and in 2002 four ARGUS coastal imaging stations were installed along the southern Gold Coast, to assist with the operation and monitoring of the Tweed River sand by-passing system.

The analysis of beach changes during the preceding six-month monitoring periods are detailed in:

- WRL Report 2004/38: June 2004 to November 2004 (Turner, 2004)
- WRL Report 2005/22: December 2004 to May 2005 (Turner, 2005)
- WRL Report 2005/36: June 2005 to November 2005 (Turner, 2006a)
- WRL Report 2006/14: December 2005 to May 2006 (Turner, 2006b)
- WRL Report 2006/37: June 2006 to November 2006 (Turner, 2006c)
- WRL Report 2007/21: December 2006 to May 2007 (Blacka *et al.*, 2007)
- WRL Report 2007/40: June2007 to November 2007 (Blacka *et al.*, 2008a)
- WRL Report 2008/18: December 2007 to May 2008 (Blacka *et al.*, 2008b).

Electronic copies of all monitoring reports are made freely available for public viewing and download in PDF format at:

→ *www.wrl.unsw.edu.au/coastalimaging/public/palmqld* (link: monitoring reports).

The purpose of this ninth report is to present the results of shoreline change analysis and erosion/accretion trend analysis for the five-month monitoring period June to October 2008, and to assess the net changes that have occurred within the Palm Beach embayment since the commencement of the monitoring program 53 months ago in June 2004.

1.2 Maintenance, Upgrades and Operational Issues

In September 2005 the Body Corporate of the Royal Palm Building (atop which the Palm Beach ARGUS station is housed) requested that the cameras be temporarily removed while major roof restoration works were undertaken at the site. The ARGUS station was turned off on September 16th, and re-installed again on 12th December 2005. Unfortunately, unscheduled rectification works to correct several defects in the roof repairs necessitated the moving of the cameras again on the 19th December. Defect repairs continued through January 2006, with the ARGUS station finally re-installed and re-surveyed on 31st January 2006.

A major coastal storm struck the Gold Coast in early March 2006 and the electrical system within the host building suffered damage, causing a failure of the ARUGUS power supply. This was subsequently repaired and the system became operational again in the second half of March. From March 2006 the Palm Beach ARGUS station remained fully operational through until July 2007, with routine maintenance including cleaning of the camera housings being undertaken in mid March 2007.

In July 2007 the Palm Beach ARGUS station went offline for several weeks due to a faulty modem power cable, although routine scheduled image collection continued to occur, with the images stored locally at the site. This was rectified during a site visit in early August 2007, and all stored image data transferred to the remote server at WRL for the offline period. During a second visit to the station late in August, the remote power management device was reprogrammed, cameras were cleaned, and a spare computer was stored at the station.

The ARGUS server located at WRL suffered catastrophic failure on 18th October 2007, and was subsequently replaced by the 24th October. All data that had been stored on the failed server was restored using backup copies. Image data continued to be collected during this period, except for the day of the 18th October.

In January 2008 WRL staff inspected the Palm Beach station, cleaned the cameras, and re-stocked supplies at the site. For the first six months of 2008 the station operated without fault, until July, when the system switched itself off after failing to reboot from a video error. A technician restarted the system on the 11th of July, before the system again shut down on the 12th. The power supply to the system was replaced by a technician on the 12th, with the new power supply failing immediately. WRL staff configured a new system at the laboratory and installed it at the site on the 22nd of July, as well as cleaning the cameras.

1.3 Report Outline

Following this introduction, Section 2 of this report provides a brief description of the Palm Beach embayment, and an overview of engineering works completed at Palm Beach since commencement of the monitoring program in mid 2004.

Section 3 contains a summary description of the ARGUS coastal imaging system, including the image types that are collected on a routine basis, and an overview of the digital image processing techniques used to analyse the images. The reader requiring more detailed information is referred to Report 1 Palm Beach Coastal Imaging System entitled *System Description, Analysis of Shoreline Variability and Erosion/Accretion Trends: June 2004 - November 2004* (Turner, 2004).

The web site which is used to promote and distribute the images collected by this monitoring program is introduced in Section 4. This description includes the web-based image archive that provides unrestricted public access to all images, weekly-updated quantitative analysis of current coastline conditions, and 'time-lapse' animation files that can be generated on-demand by GCCC staff.

Section 5 introduces the beach morphodynamic classification model of Wright and Short (1983), which is then used to describe in a qualitative manner the beach changes observed using the time-series of daily images for the five month period covered by this report.

The quantitative analysis of shoreline change for the current monitoring period is detailed in Section 6. This is followed in Section 7 by the corresponding analysis for the total 53 month period since monitoring commenced in mid 2004.

The application of an image analysis technique that enables patterns of beach erosion and accretion to be identified and quantified along the Palm Beach embayment on a regular (monthly) basis is presented in Section 8. Section 9 summarises the major findings of this ninth monitoring report for Palm Beach.

2. BACKGROUND

2.1 Environmental Setting

Palm Beach is located along the central Gold Coast, south-east Queensland (Figure 2.1). The 5 km long embayment is located between Burleigh Headland to the north and Currumbin Headland to the south. As shown in Figure 2.2, the southern training wall of Tallebudgera Creek adjacent to Burleigh Headland marks the northern extent of the sandy beach. The trained entrance to Currumbin Creek and associated sand shoals, adjacent to Currumbin Headland, occur at the southern end of the Palm Beach embayment. Palm Beach is typical of the Gold Coast, with beachfront development running the length of the beach, and the beach patrolled by three surf life saving clubs along the oceanfront. In addition to the creek training walls at both the northern and southern ends of the embayment, two short rubble-mound groynes have been constructed, the northern groyne located at 21st Street, and the more southern groyne at 11th Street. A near-continuous and largely buried boulder wall runs the length of the beach from Tallebudgera Creek in the north, to the sand spit adjacent to Currumbin Creek in the south.

2.2 Nearshore Sand Nourishment

Nearshore sand nourishment was undertaken along the southern region of Palm Beach between 2004 and 2006. The monthly volumes of sand nourishment and the placement of this sand resource along the southern region of the Palm Beach embayment are summarised in Figure 2.3. The lower panel shows the location of the nearshore "dump boxes", while the upper panel shows the volume of sand placed per month. Each nourishment campaign is described in Sections 2.2.1 and 2.2.2 below.

2.2.1 2004 Campaign

A campaign of nearshore sand nourishment commenced in April 2004 and was completed in December 2004. The first stage of sand nourishment was undertaken during April and May, and the second stage from October to December. This campaign of sand nourishment, sourced from offshore sand resources, comprised a total of **145,445 m^3**.

2.2.2 2005/2006 Campaign

From June to September 2005 a total of **22,870 m^3** of sand dredged from the entrance to the Tweed River was placed within the nearshore zone at Palm Beach. Commencing in

October sand was sourced from the offshore region of the Palm Beach embayment, and during October 2005 – April 2006 a total of **240,217 m^3** of this sand was placed within the nearshore zone. Referring to Figure 2.3, since June 2004 approximately **385,668 m^3** of sand had been placed within the nearshore region of the Palm Beach embayment, as well as the placement of Currumbin Creek dredge spoil, as described below.

2.3 Placement of Currumbin Creek Dredge Material

Gold Coast City Council has maintained a program to dredge the lower estuaries of Currumbin and Tallebudgera Creeks every year, and uses the sand from Currumbin Creek to nourish the beachface at the southern end of Palm Beach. Sand from the Tallebudgera entrance is pumped north to Burleigh Beach.

2.3.1 July – September, 2004

From July to September 2004 sand from Currumbin Creek was placed along the beachfront at the southern end of the Palm Beach embayment. The location of this sand placement is shown in Figure 2.4 (upper panel), along the sand spit that separates the creek from the ocean. In total, **28,946 m^3** of sand was placed during the six week period 19/7/04 to 2/9/04. Sand was placed at the rate of approximately 110 m^3 per hour generally between 6 am and 6 pm, with the outlet pipe being moved 20 m southward, every two working days.

2.3.2 April - June, 2005

From April to June 2005 an additional **26,493 m^3** of sand was placed at a single discharge point, shown in Figure 2.4 (lower panel). Daily delivery rates varied between approximately 200 m^3 and 1100 m^3 per day, with the engineering works being completed between 6 am and 6 pm.

2.3.3 November – December, 2005

During the period 30th November to 14th December 2005 **11,593 m^3** of sand from Currumbin Creek was placed at the southern end of the Palm Beach embayment.

2.3.4 October – November, 2006

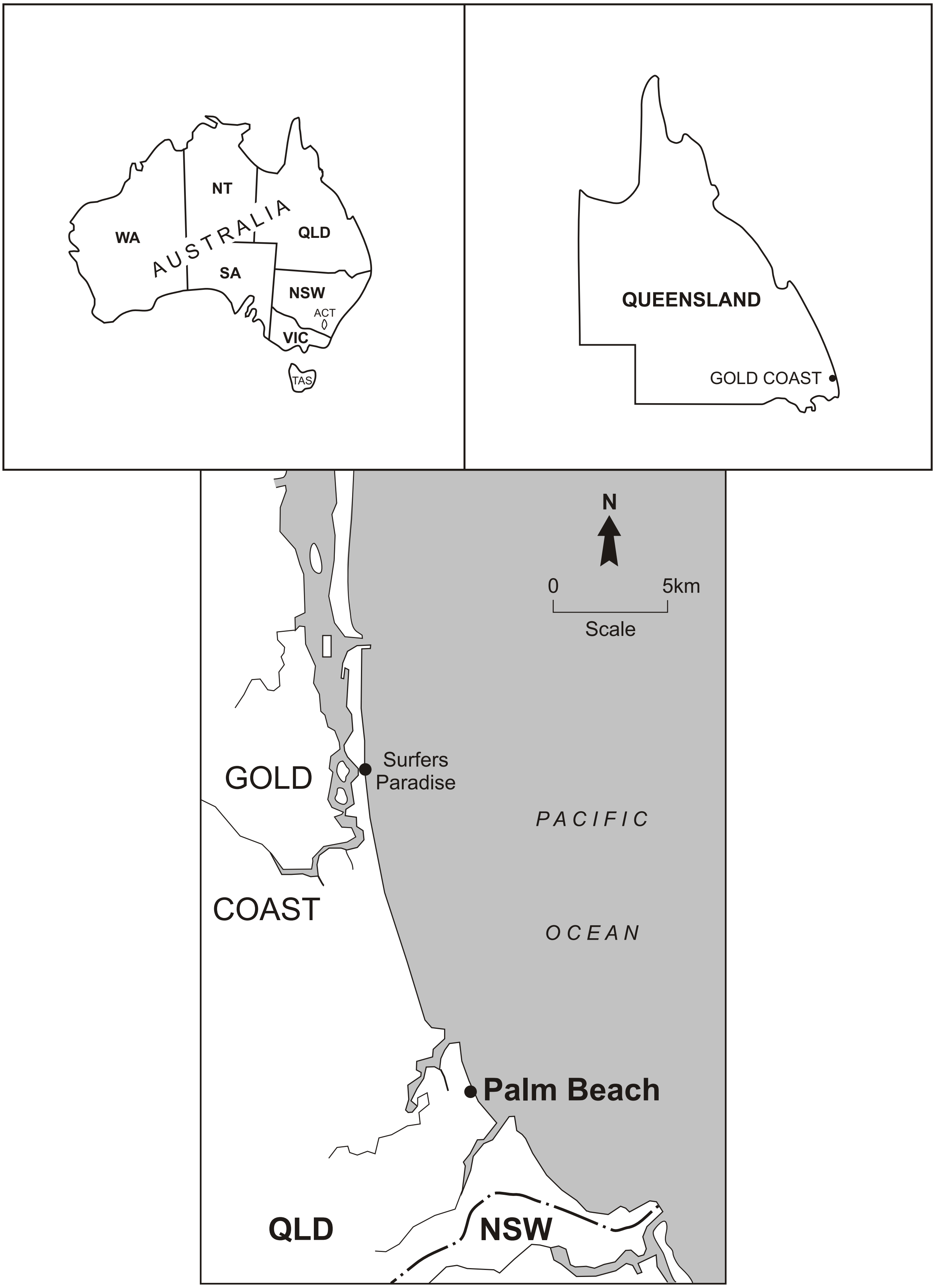
From 25th October to 15th November 2006 a further **37,724 m^3** of sand from Currumbin Creek (including 3,000 m^3 re-dredged infill) was placed at the southern end of the Palm Beach embayment.

2.3.5 October – November, 2007

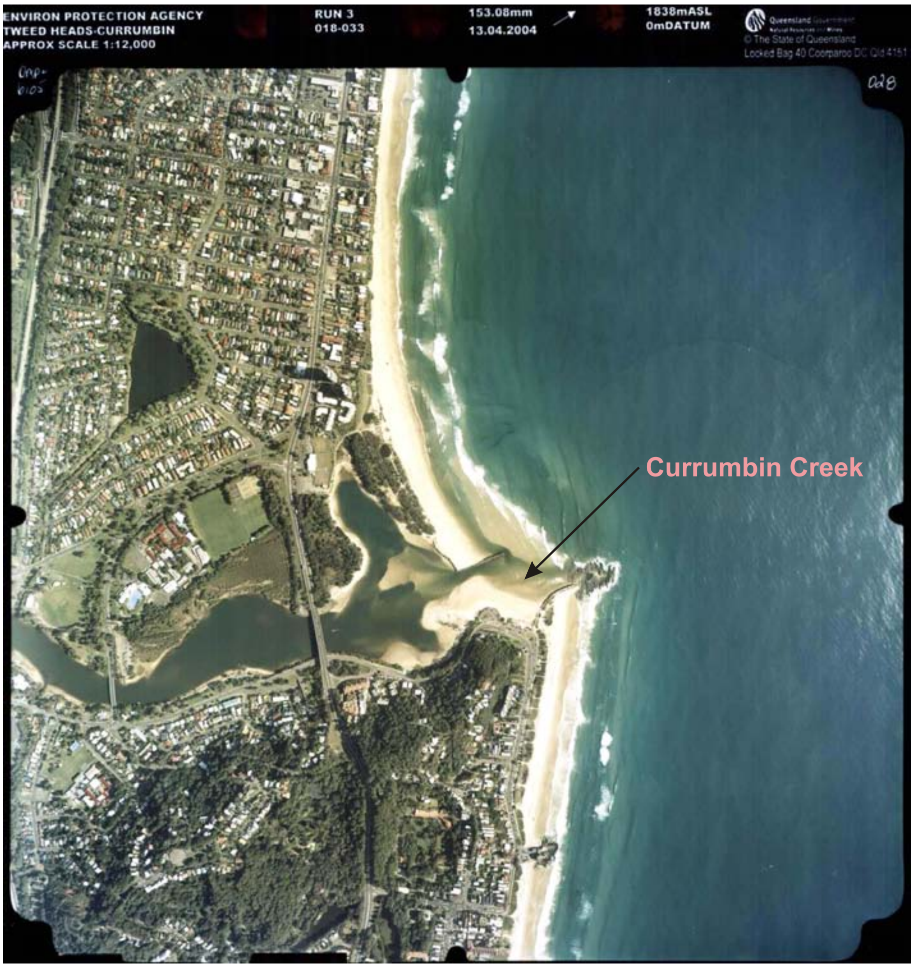
From the 4th October to the 30th November 2007 **41,910 m^3** of sand was dredged from the Currumbin Creek entrance, and placed on the spit at the southern end of the Palm Beach embayment. This is the largest quantity of material dredged from the Currumbin Creek to be placed onto the spit in any year since the monitoring program commenced in mid 2004.

2.3.6 October – November, 2008

From the 16th of October to the end of the current monitoring period at the end of October 2008, a dredge was removing material from the Currumbin Creek entrance and placing it on Palm Beach in a location approximately adjacent to Lacey's Lane. By the end of October, **11,110 m^3** of sand had been placed on Palm Beach, with more sand placed during the following month of November 2008. Figure 2.5 shows a summary of the quantity and time for placement of Currumbin Creek dredge spoil onto Palm Beach since July 2004. At the time of writing, a total of **157,776 m^3** of sand had been dredged from the entrance of Currumbin Creek and placed onto Palm Beach.



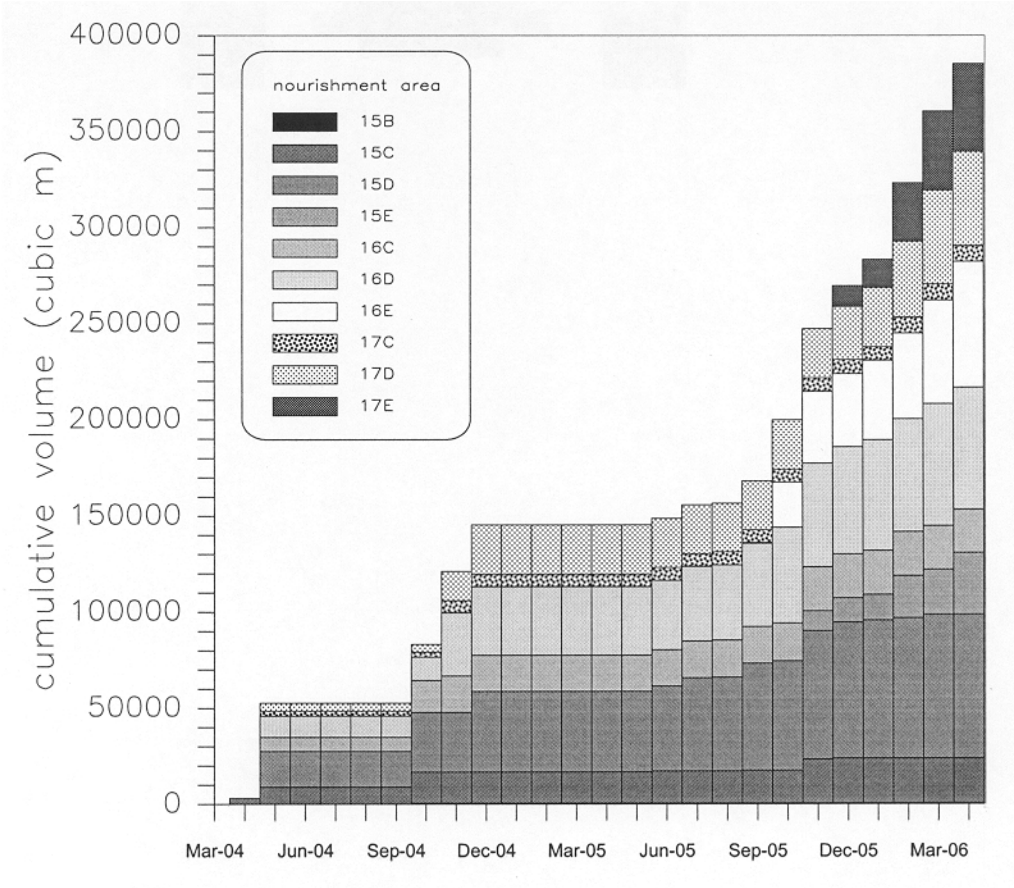
WRL Report No. 2008/32	LOCALITY	Figure 2.1 06037-2-1.cdr

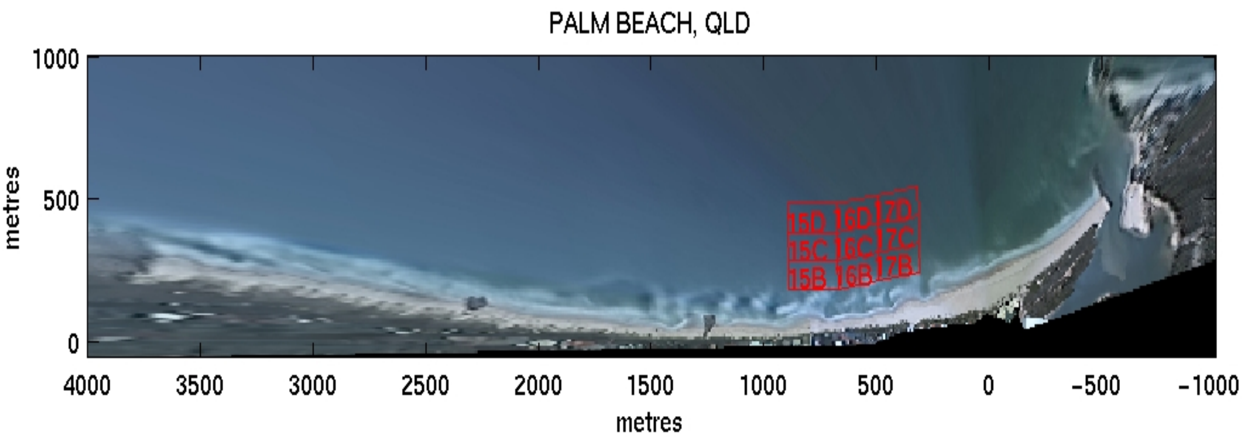


Palm Beach Embayment,
Southern Portion

Palm Beach Embayment
viewed from North

WRL Report No. 2008/32	PALM BEACH, GOLD COAST, QUEENSLAND	Figure 2.2 06037-2-2.cdr



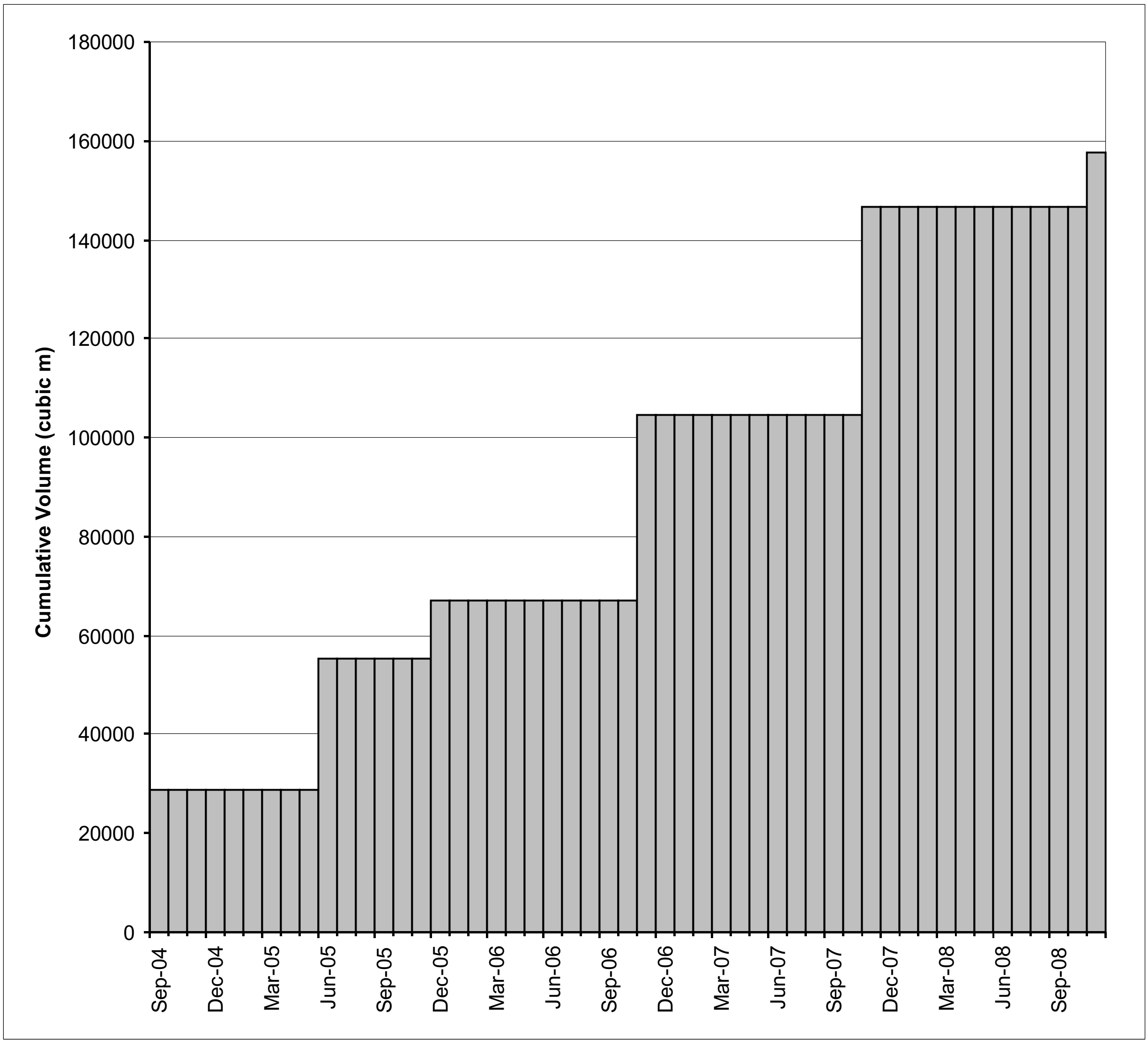


WRL Report No. 2008/32	NEARSHORE NOURISHMENT DEPOSITION AREAS AND VOLUMES	Figure 2.3 06037-2-3.cdr

SAND PLACEMENT - 2004

SAND PLACEMENT - 2005

WRL Report No. 2008/32	PLACEMENT OF CURRUMBIN CREEK DREDGE MATERIAL	Figure 2.4 06037-2-4.cdr



WRL Report No. 2008/32	CURRUMBIN CREEK DREDGE MATERIAL VOLUMES	Figure 2.5 06037-2-5.cdr

3. OVERVIEW OF COASTAL IMAGING, IMAGE TYPES AND IMAGE PROCESSING METHODS

Comprehensive descriptions of the Palm Beach coastal imaging system, image types and image processing techniques were detailed in the first Palm Beach coastal imaging report *System Description, Analysis of Shoreline Variability and Erosion/Accretion Trends: June 2004 - November 2004* (Turner, 2004). For the sake of completeness, the following section provides a brief summary of the system and the image processing techniques being used to quantify beach changes.

3.1 What is Coastal Imaging?

'Coastal imaging' simply means the automated collection, analysis and storage of pictures that are then processed and analysed to observe and quantify coastline variability and change.

Aerial photography has been the tool most commonly used by coastal managers to monitor regional-scale coastal behaviour. This is expensive and as a result, coverage is often ‘patchy’ and incomplete. Pictures are only obtained when visibility from the airplane is satisfactory, often resulting in a limited number of suitable pictures per year (at most), with no information about the behaviour of the beach between flights.

In contrast, with the development of digital imaging and analysis techniques, one or more automated cameras can be installed at a remote site and, via a telephone or internet connection, be programmed to collect and transfer to the laboratory a time-series of images. These images, taken at regular intervals every hour of the day for periods of months and years, can cover several kilometres of a coastline. Not every image need be subjected to detailed analysis, but by this method the coastal manager can be confident that all 'events' will be recorded and available for more detailed analysis as required.

3.2 The Difference between Coastal Imaging and a 'Surfcam'

At the core of the coastal imaging technique is the ability to extract quantitative data from a time-series of high quality digital images. In contrast, conventional 'surfcams' are very useful to applications where a series of pictures of the coastline is sufficient, and these types of images can be used to develop a qualitative description of coastal evolution.

The extraction of quantitative information from the coastal imaging system is achieved by careful calibration of the cameras and the derivation of a set of mathematical equations that are used to convert between two-dimensional image coordinates and three-dimensional ground (or 'real world') coordinates (refer Turner, 2004). Sophisticated digital image processing techniques are then applied to extract and quantify information contained within the images.

3.3 The ARGUS Coastal Imaging System

The ARGUS coastal imaging system has developed out of years of ongoing research effort based at Oregon State University, Oregon USA (Holman *et al.*, 1993). A schematic of a typical ARGUS station is shown in Figure 3.1. The key component of an ARGUS station is one or more cameras pointed obliquely along the coastline. The camera(s) are connected to a small image processing computer (Silicon Graphics SGI workstation), which controls the capture of images, undertakes pre-processing of images, and automatically transfers the images via the internet from the remote site to the laboratory. The cameras installed at Palm Beach are fitted with high quality lenses. A switching interface between the cameras and computer maintains synchronisation of the captured images. The SGI workstation incorporates an internal analogue I/O card that enables all images to be captured, stored and distributed in standard JPEG digital image file format.

At WRL, a dedicated host computer (dual-processor Linux workstation) stores all images as they are received from the remote site within a structured archive. This workstation is also integrated to a world-wide-web server, with the images made available to all visitors to the web site to view and download within minutes of their capture and transfer from Palm Beach to WRL. Post-processing of the images is completed using a variety of Linux and PC computer hardware and custom image processing software within the MATLAB programming environment.

3.4 Installation at Palm Beach

The ARGUS coastal imaging system was installed at Palm Beach in late May 2004. The system is located at an elevation of approximately 80 m above mean sea level, within the roof services area of the Royal Palm building (Figure 3.2). The Royal Palm is located approximately 50 m - 100 m landward of the frontal dune, approximately 500 m to the north of the Currumbin Creek entrance.

The cameras are mounted externally on a single frame that stands on the roof of the building, and are protected within weatherproof housings (Figure 3.3). The SGI workstation is housed within a pump services room, where 240 V power and a dedicated phone line connection to the internet are provided. The system is designed to run autonomously, and is self-recovering should an interruption to the mains power supply occur. Routine maintenance of the system is achieved by connection to the remote system via the internet from WRL. Occasional cleaning of the camera lenses is required.

3.5 Image Types

The ARGUS coastal imaging system installed at Palm Beach is presently configured to collect three different types of images on a routine hourly basis. A fourth image type is created by automated post-processing at the completion of each day of image collection.

Images are collected every daylight hour. The image collection procedure is fully automated and controlled by the SGI workstation at the remote site. Prior to commencing the hourly image collection routines, a test is undertaken to determine if there is sufficient daylight to proceed with image collection. If the ambient light threshold is exceeded, image collection commences. The reason for first checking for daylight conditions is to avoid unnecessary image collection at night, without excluding image collection earlier in the morning and later in the evening during extended summer daylight hours.

3.5.1 Snap-Shot 'snap' Images

The simplest image type is the snap-shot image. This is the same image obtained if a picture of the beach were taken using a conventional digital camera. Snap-shot images provide simple documentation of the general characteristics of the beach, but they are not so useful for obtaining quantitative information. An example of a snap image obtained on October 15th 2008 is shown in Figure 3.4 (upper panel).

3.5.2 Time-Exposure 'timex' Images

A much more useful image type is the time-exposure or 'timex' image. Time-exposure images are created by the 'averaging' of 600 individual snap-shot images collected at the rate of one picture every second, for a period of 10 minutes.

A lot of quantitative information can be obtained from these images. Time exposures of the shore break and nearshore wave field have the effect of averaging out the natural variations of breaking waves, to reveal smooth areas of white, which has been shown to provide an excellent indicator of the shoreline and nearshore bars. In this manner, a quantitative 'map' of the underlying beach morphology can be obtained. An example of a timex image obtained on October 15th 2008 is shown in Figure 3.4 (middle panel).

3.5.3 Variance 'var' Images

At the same time that the timex images are being collected, an image type called a variance or 'var' image is also created. Whereas the time-exposure is an 'average' of many individual snap-shot images, the corresponding variance image displays the variance of light intensity during the same 10 minute time period.

Variance images can assist to identify regions which are changing in time, from those which may be bright, but unchanging. For example, a white sandy beach will appear bright on both snap-shot and time-exposure images, but dark in variance images. Because of this, other researchers have found that variance images are useful at some specific coastal sites for analysis techniques such as the identification of the shoreline, as the (bright) changing water surface is readily identifiable against the (dark) beach. An example of a var image obtained on October 15th 2008 is shown in Figure 3.4 (lower panel).

3.5.4 Day Time-Exposure 'daytimex' Images

The fourth image type routinely created from the coastal imaging system installed at Palm Beach is referred to as a daytimex image. It is created at the end of each day of image collection, by the averaging of all hourly timex images collected that day. This has the effect of 'smoothing' the influence of tides, and for some conditions may enhance the visibility of the shore break and bar features in the nearshore.

3.6 Basic Image Processing – Merge and Rectification

As noted earlier in Section 3.2, the key feature of coastal imaging technology that distinguishes it from conventional webcam systems is the ability to extract quantitative information from the images. As described previously, this is achieved through the solution of the camera model parameters to extract 3-D real-world position from 2-D image coordinates, and the application of image processing techniques to identify, enhance and manipulate the image features of interest.

Image merging is achieved by the solution of camera model parameters for individual cameras, then the boundaries of each image are matched to produce a single composite image. Image rectification is then undertaken, whereby the dimensions of the merged image are corrected so that each pixel represents the same area on the ground, irrespective of how close to, or how far from, the camera position it may be. (In contrast, for an unrectified image the area represented by each pixel increases with increasing distance from the camera.)

Image rectification is achieved by using the calculated camera model parameters to fit an image to a regular grid that defines longshore and cross-shore distance. The rectification of merged images produces a 'plan view' of the area covered by all four cameras. This is illustrated in Figure 3.5. Also shown in this figure is a ‘pan’ image, which provides an alternative wide-angle (but distorted) image of the coastline. The merged and rectified plan image created from five oblique images is analogous to a montage of distortion-corrected photographs taken from an airplane flying directly overhead Palm Beach. For convenience, the longshore and cross-shore dimensions of this image are referenced (in metres) to the location of the cameras. The pixel resolution of the merged/rectified images created at Palm Beach is 5 m; that is, a single pixel represents an area 5 m × 5 m on the ground.

3.7 Shoreline Detection and Analysis

To map the position of the shoreline and its changing location through time, a rigorous image analysis methodology is required to enable the extraction of this information from the database of hourly ARGUS images.

3.7.1 Pixel Intensity Clustering

The shoreline mapping methodology used at Palm Beach utilises the full colour information available from ARGUS images. Called ‘Pixel Intensity Clustering’ or ‘PIC’, the technique aims to delineate a shoreline feature from 10 minute time exposure images, on the basis of distinctive image intensity characteristics in pixels, sampled across the sub-aqueous and sub-aerial beach. Raw image intensities in Red-Green-Blue (RGB) colour-space, sampled from a region of interest across both the dry and wet beach, are converted to Hue-Saturation-Value (HSV) colour space, to separate colour (Hue, Saturation) and grey scale (Value) information. The HSV intensities are filtered to remove outliers and scaled between 0 and 1, to improve the contrast between two clusters of dry and wet pixels. Iterative low-passing filtering of the spiky histogram of scaled intensity data yields a smooth histogram with two well-pronounced peaks P_{dry} and P_{wet}, which mark the locations of the two distinct clusters of dry and wet pixels (Figure 3.6).

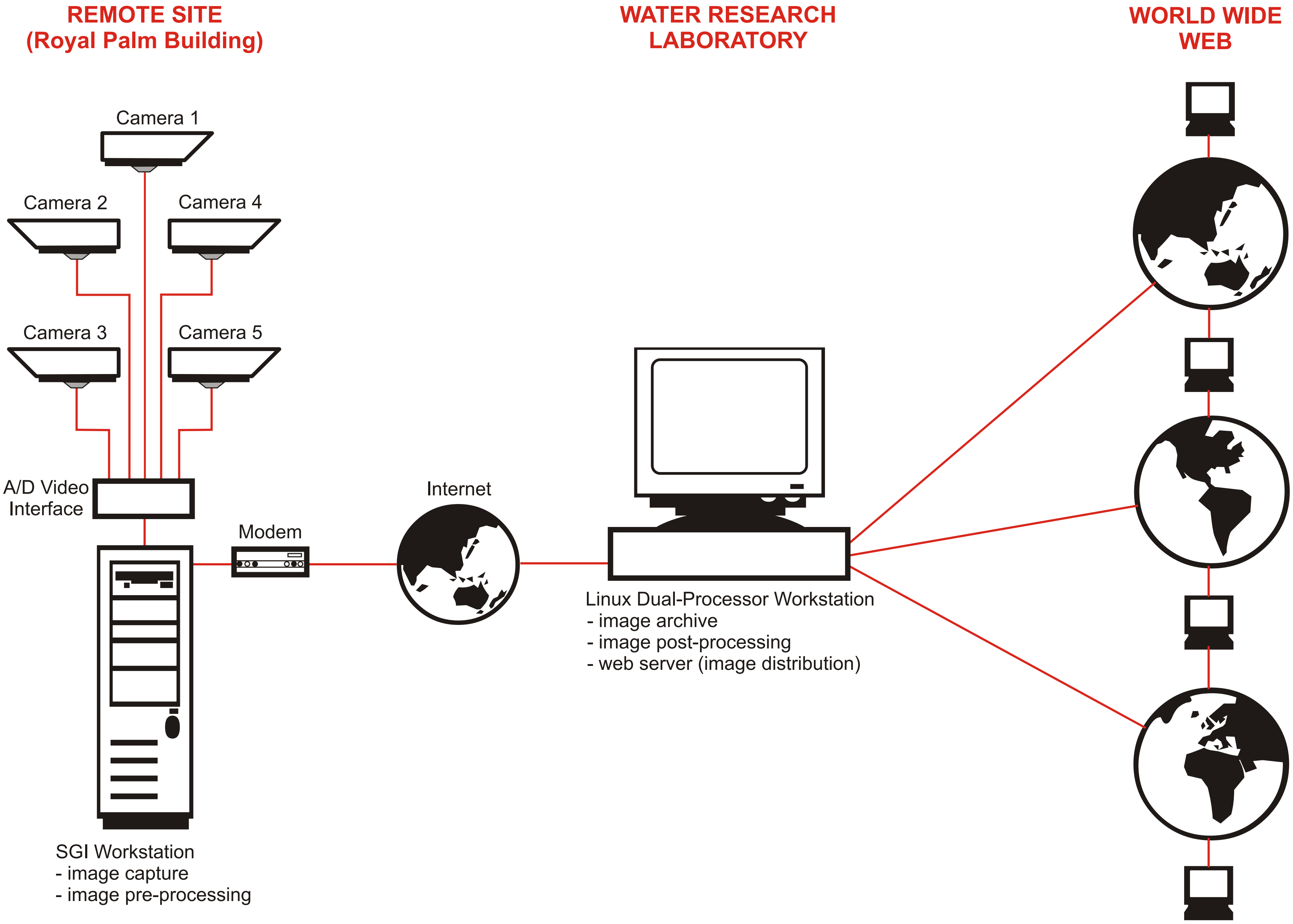
The filtered histogram is used to define a line to distinguish between Hue Saturation information used for colour discrimination (Figure 3.6a), or Value information in the case of luminance-based discrimination (Figure 3.6b). For both discriminators, the line defined in this manner crosses the saddle point of the filtered histogram, and thus provides the means to separate objectively the two clusters of dry and wet pixels within the region of interest. With the help of this line, a discriminator function Ψ is defined such that $\Psi = 0$ along this line (see Figure 3.6). The areas of dry and wet pixels are then mapped, and the boundary between the two regions defines the resulting shoreline feature of interest. Comprehensive description of the PIC shoreline identification technique is provided in Aarninkhof (2003), Aarninkhof and Roelvink (1999) and Aarninkhof *et al.* (2003).

3.7.2 Standardised Procedure for Shoreline Mapping

The procedure used to map the shoreline at the Palm Beach is summarised in Figure 3.7. At weekly (nominal seven day) intervals, observed tide information is used to determine the hourly timex images that correspond to mid-tide (0 m AHD). The corresponding merged-rectified 5-camera image is then created. The database of wave information is also searched to determine the rms ('root mean square') wave height (H_{rms}) and spectral peak wave period (T_p) that correspond to these daily mid-tide images.

Based on a seven day cycle, the corresponding mid-tide image is checked to confirm that the wave height satisfies the low-pass criteria $H_{rms} \leq 1.0$ m (Hs $\leq$ ~1.4 m). This wave height criteria is used for shoreline mapping as, above this wave height, wave run-up at the beachface increases and the width of the swash zone widens, introducing a corresponding uncertainty in the cross-shore position of the waterline. If the rms wave height is less than 1.0 m, then the shoreline is mapped. If the wave height exceeds the $H_{rms} = 1.0$ m threshold, then the mid-tide image for the preceding day is checked. If this image still does not satisfy the wave height criteria, then the following day's mid-tide image is checked. This process is repeated for up to ± 3 days from the original target weekly image, to locate a mid-tide image for which the rms wave height did not exceed 1.0 m. If no mid-tide images are available in any one seven day cycle that satisfy this criteria, then no shoreline is mapped for that week.

Once the mid-tide image to be processed has been identified, the PIC method is applied and the shoreline feature is mapped. Beach width is then calculated relative to the alignment of the existing boulder wall. By repeating this procedure every seven days, a growing database is developed that contains the time-series of weekly shoreline positions at all positions along the shore. These data are then subjected to a range of analyses as described in the following Sections 6, 7 and 8.



WRL Report No. 2008/32

SCHEMATIC OF AN ARGUS COASTAL IMAGING SYSTEM

Figure 3.1

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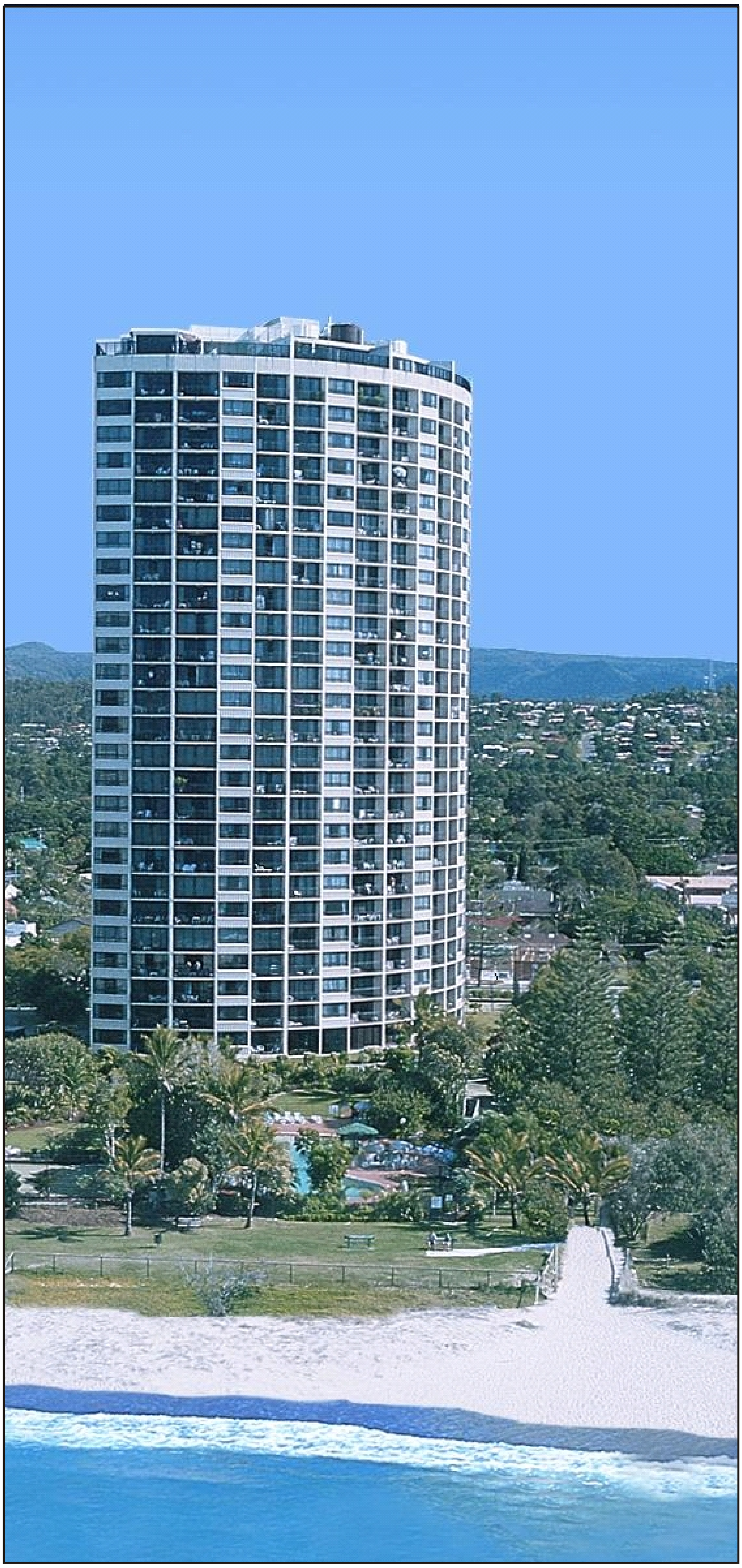
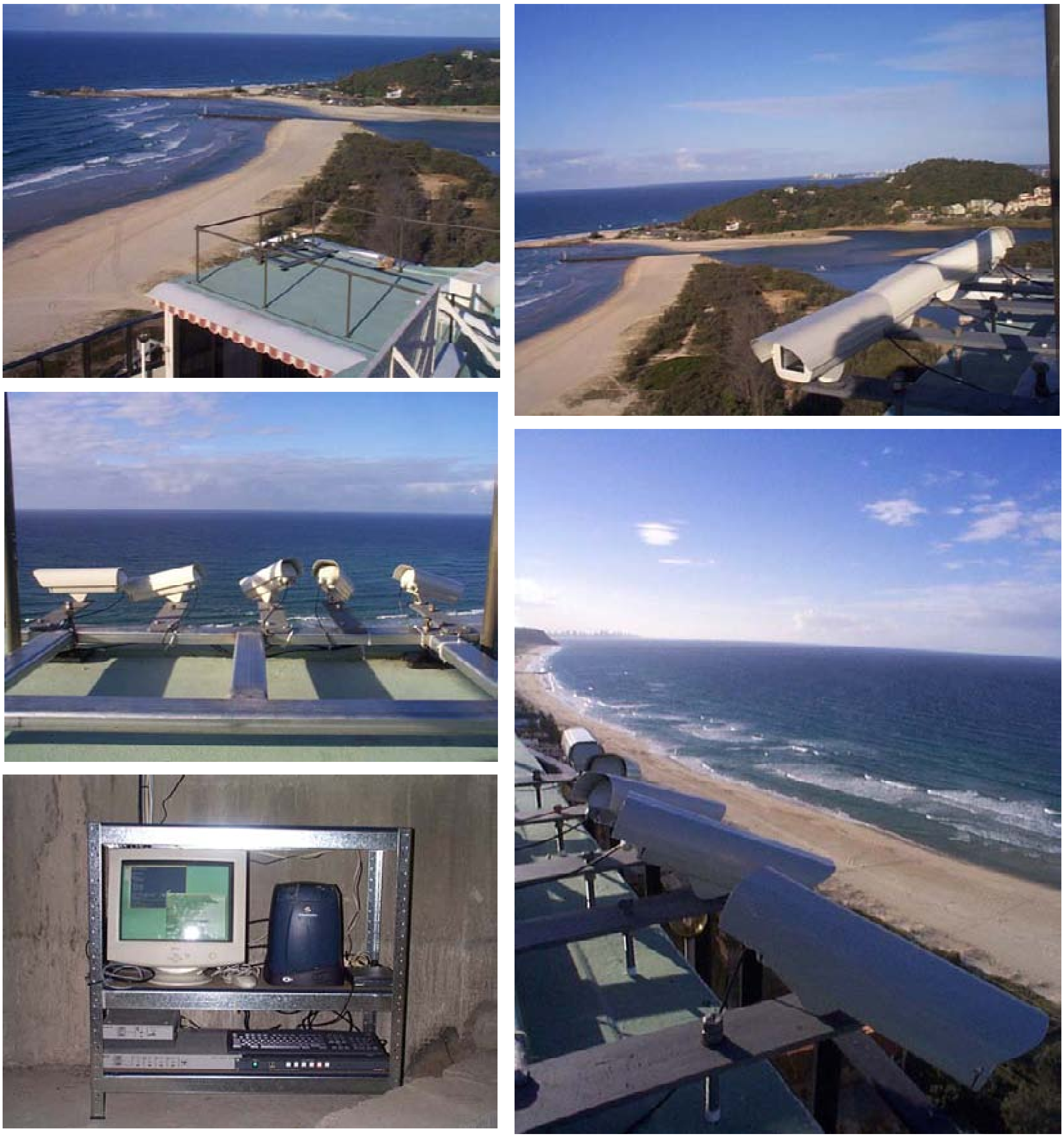


WRL Report No. 2008/32	LOCATION OF COASTAL IMAGING SYSTEM ROYAL PALM BUILDING	Figure 3.2 06037-3-2.cdr



WRL

Report No. 2008/32

CAMERAS MOUNTED AT AN ELEVATION
OF APPROXIMATELY 80 m

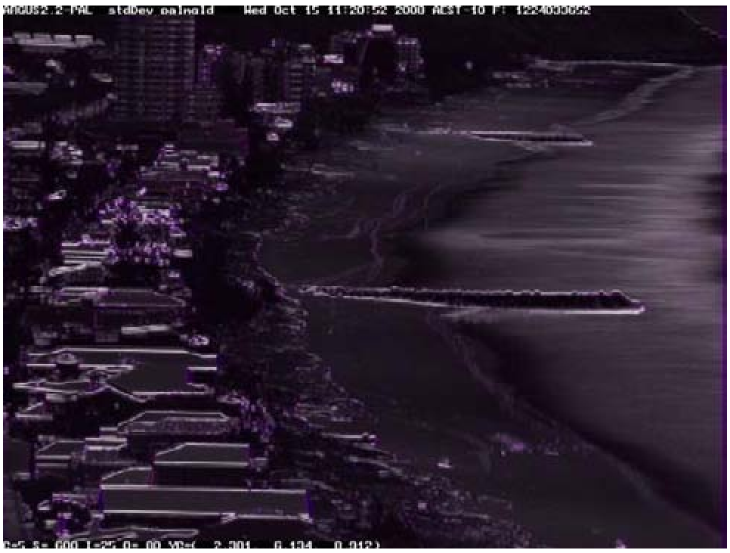
Figure
3.3

06037-3-3.cdr

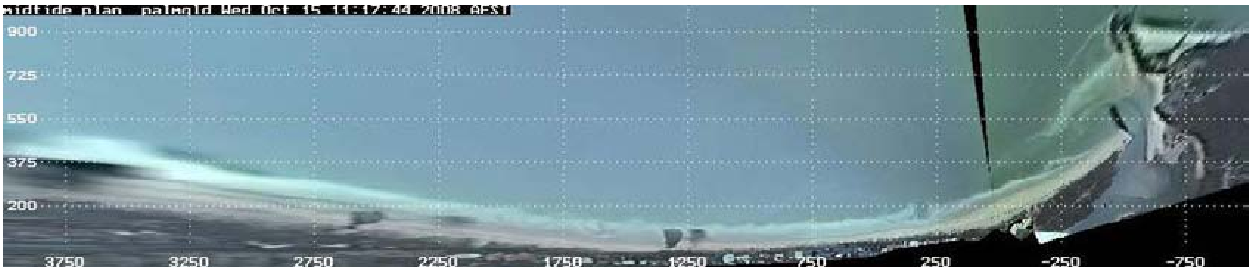
snap

timex

var



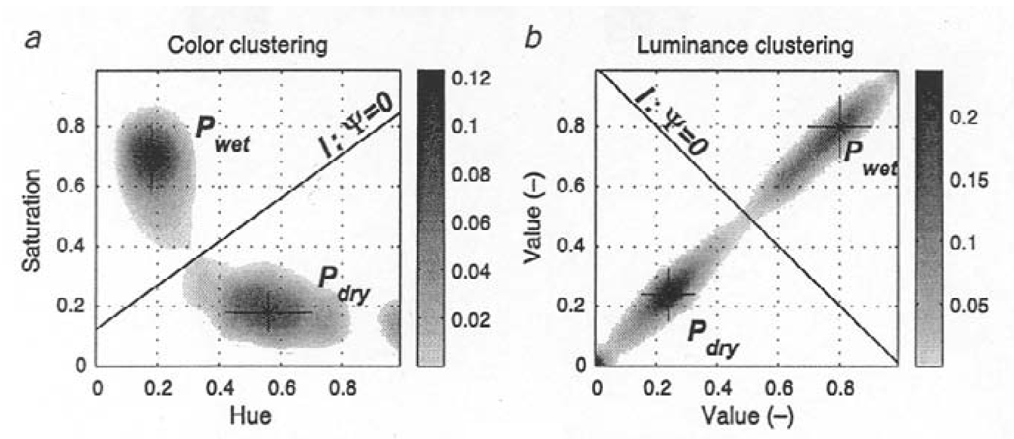
WRL Report No. 2008/32	SNAP-SHOT, TIME-EXPOSURE AND VARIANCE IMAGE TYPES (OCTOBER 2008)	Figure 3.4



WRL
Report No. 2008/32

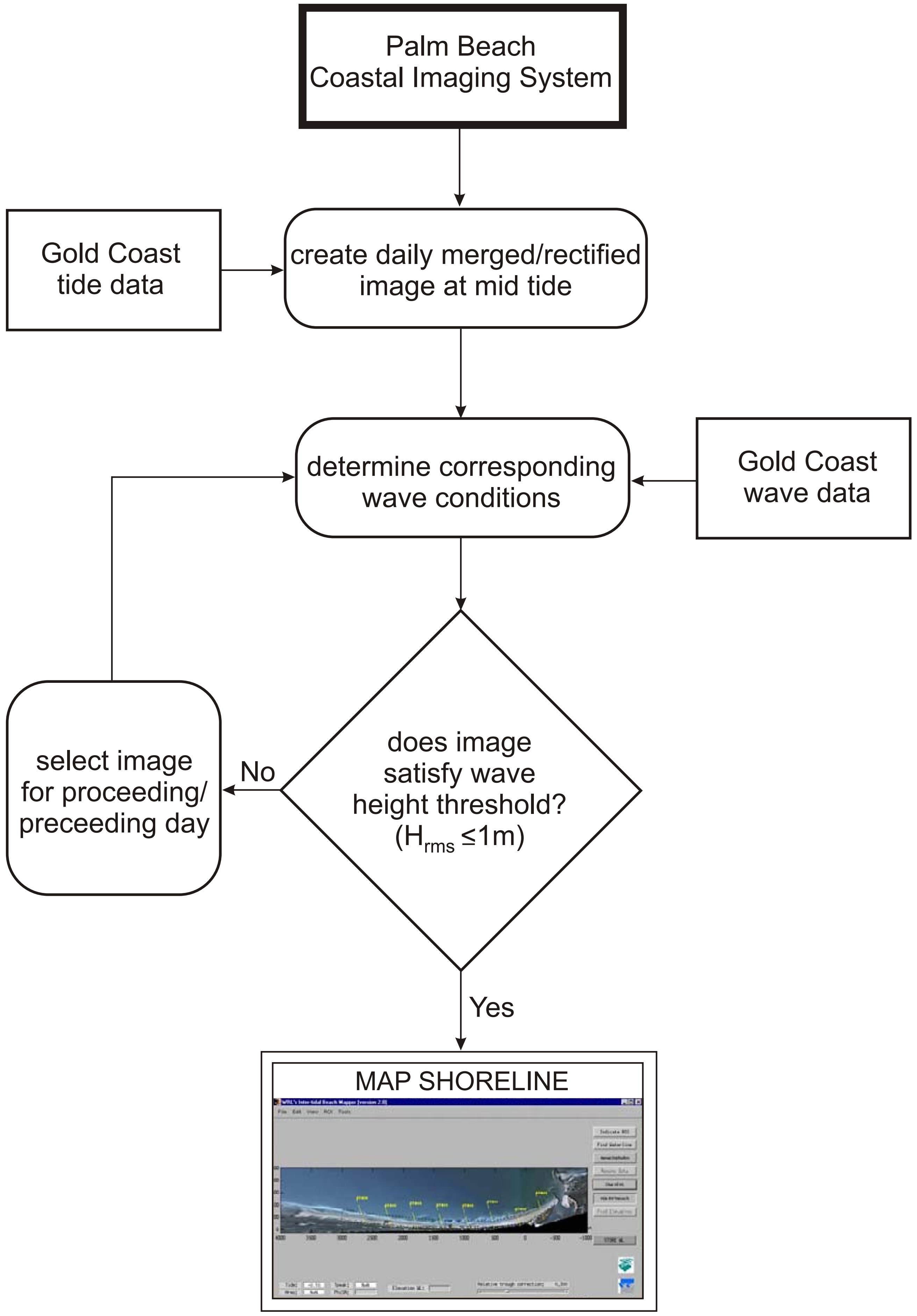
PAN AND PLAN VIEW IMAGES:
FIVE-CAMERA MERGE/RCTIFICATION (OCTOBER 2008)

Figure
3.5



Source: Aarninkhof (2003)

WRL Report No. 2008/32	IDENTIFICATION OF 'SHORELINE' FEATURE FROM COLOUR IMAGES	Figure 3.6 06037-3-6.cdr



WRL
Report No. 2008/32

STANDARDISED SHORELINE MAPPING PROCEDURE

Figure 3.7

06037-3-7.cdr

4. COASTAL IMAGING WEB SITE

4.1 Coastal Imaging Home Page

To promote the dissemination of information about the Palm Beach coastal monitoring project, to provide a convenient means to distribute images as they are collected, and to facilitate 'real-time' access to the regularly-updated results of shoreline monitoring and beach width analysis, a coastal imaging project site was established on the world-wide web at the following URL:

→ www.wrl.unsw.edu.au/coastalimaging/public/palmqld

The Palm Beach coastal imaging home page is shown in Figure 4.1. The most recent snap images are displayed here and updated every hour, enabling visitors to the site to observe the current beach conditions. This page also includes a number of links to a variety of background information including a description of the coastal imaging system, image types and image processing techniques. Links are also provided to the Gold Coast City Council web site, the waverider buoy site run by the Queensland Department of Environment, local weather information, and tidal predictions for the Gold Coast Seaway provided by the National Tidal Facility.

For general interest, a record is maintained of the number of visitors to the WRL coastal imaging web site and the countries they are from. At the time of writing, approximately **348,000 hits** to the WRL coastal imaging web pages have been recorded. Visitors from Australia account for approximately half the total visitors, with the remaining visitors coming from approximately 80 countries world-wide.

4.2 Image Archive

The current snap, timex images and var images are updated and available at the project web site every hour.

All present and past images can be accessed via the on-line image archive. This provides a convenient and readily navigable structure to quickly locate the image(s) of interest. Figure 4.2 shows an example of a daily page contained within the image archive. These images are provided freely to encourage their use by students, researchers, managers and other non-commercial organisations.

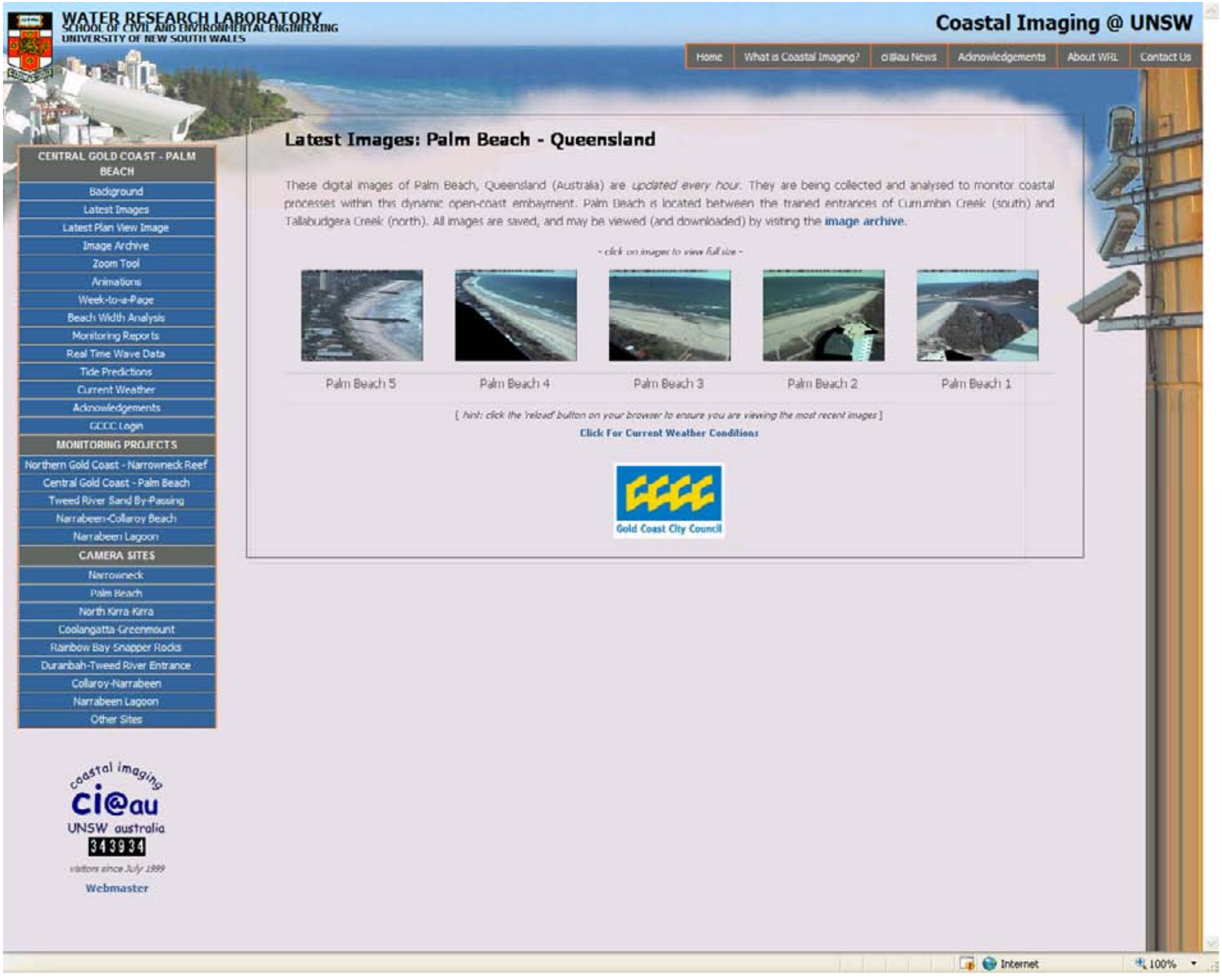
4.3 On-Line 'Beach Analysis System'

On-line access to 'real time' beach monitoring and analysis is made available at the Palm Beach coastal imaging web site. This capability results from the on-going research and development effort underway by the coastal imaging team at WRL. The purpose of this system is to provide regularly-updated results of the beach monitoring program to Gold Coast City Council and the general public on a routine basis, via the world wide web.

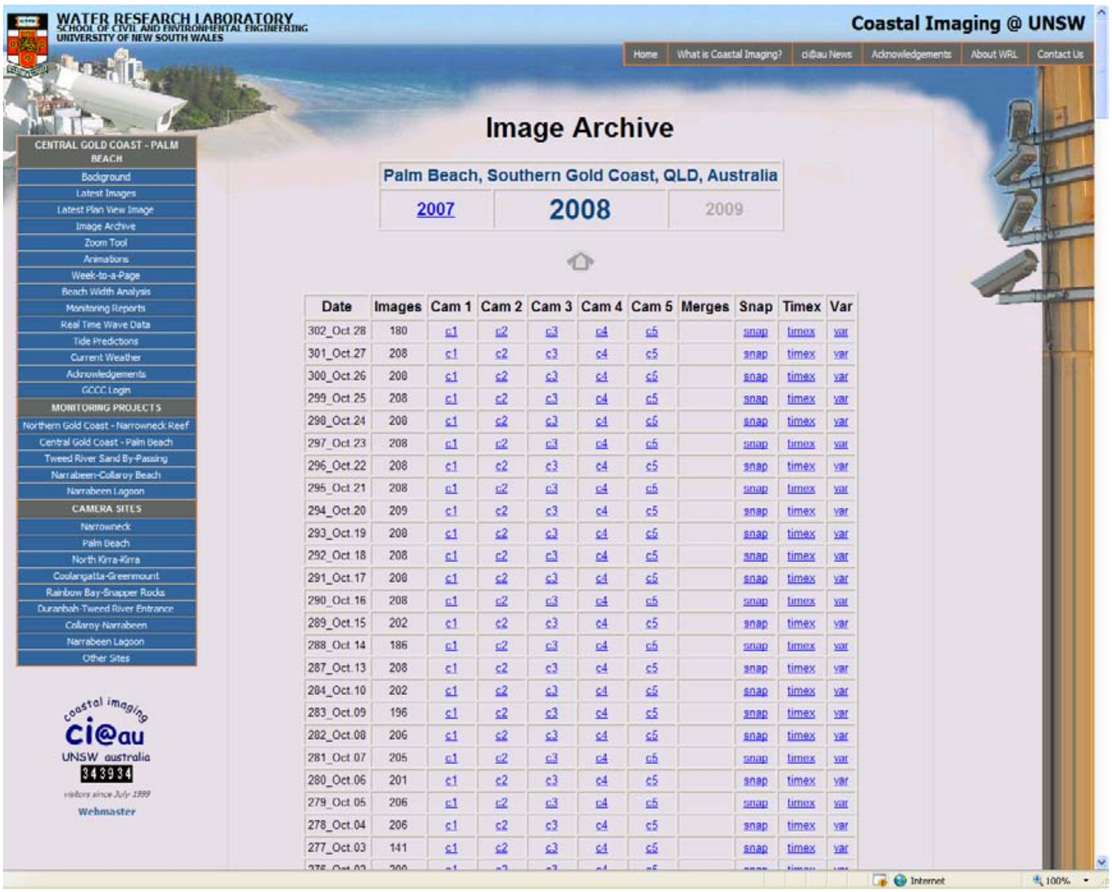
A description of the capabilities of this system was detailed in Anderson *et al.* (2003). To summarise, the features available at the project web site include the ability to view the latest mid-tide plan images; access to a zoom tool feature that enables zooming-in and panning through the current oblique and rectified images; full on-line access to all past and present monitoring reports; and two products specifically designed to assist both the qualitative and quantitative interpretation of images, shoreline data and the results of beach width analysis.

An example of the first of these products called 'week-to-a-page' is illustrated in Figure 4.3. Every Monday morning, this figure is generated and made available for viewing (and download, if required) via the project web site. The figure is pre-formatted to fit on a standard A4 page, to assist reporting. This figure compiles daily mean sea level plan view images of the entire Palm Beach study site for that week, into a compact one-page summary. A recent addition to the 'week-to-a-page' sheet is a plot showing wave and tide data for the week of interest. This product provides coastal managers a means of quickly and efficiently interpreting the daily changes in beach morphology and shoreline position, without continual recourse to the hourly images. An archive of these weekly figures is also maintained and available on-line.

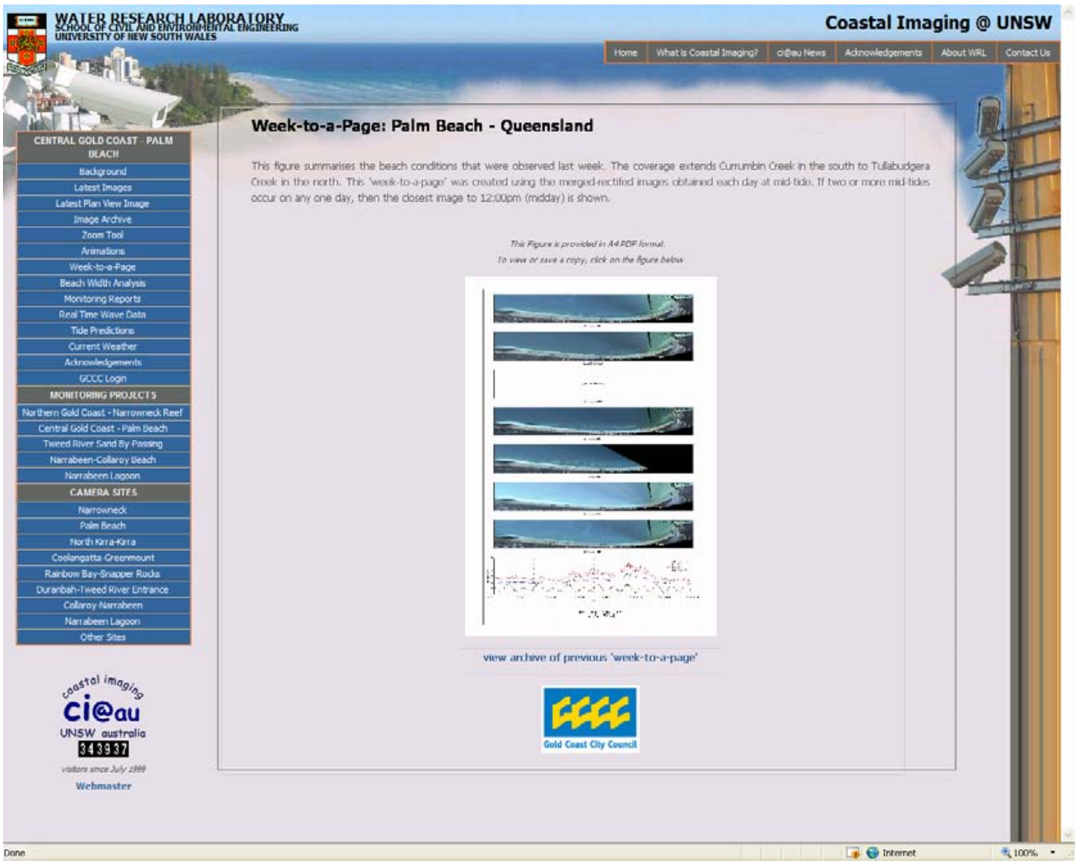
The second product that is also updated each Monday morning and made available via the project web site is 'Beach-Width-Analysis' (Figure 4.4). This figure in graphical format summarises quantitative information of the mean shoreline position for that week; shoreline variability by comparing the current shoreline position with previous weeks and months; beach width along pre-defined monitoring transects; and beach width trends throughout the history of the monitoring project. A plot indicating the wave conditions during the week of interest has also now been added to this sheet, to increase the ease of data interpretation.

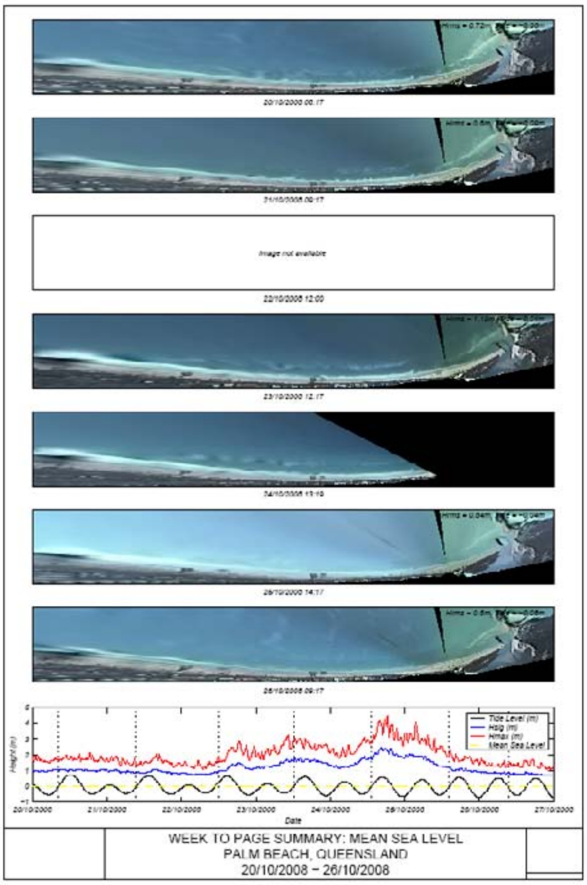


WRL Report No. 2008/32	COASTAL IMAGING WEB SITE - HOME PAGE	Figure 4.1

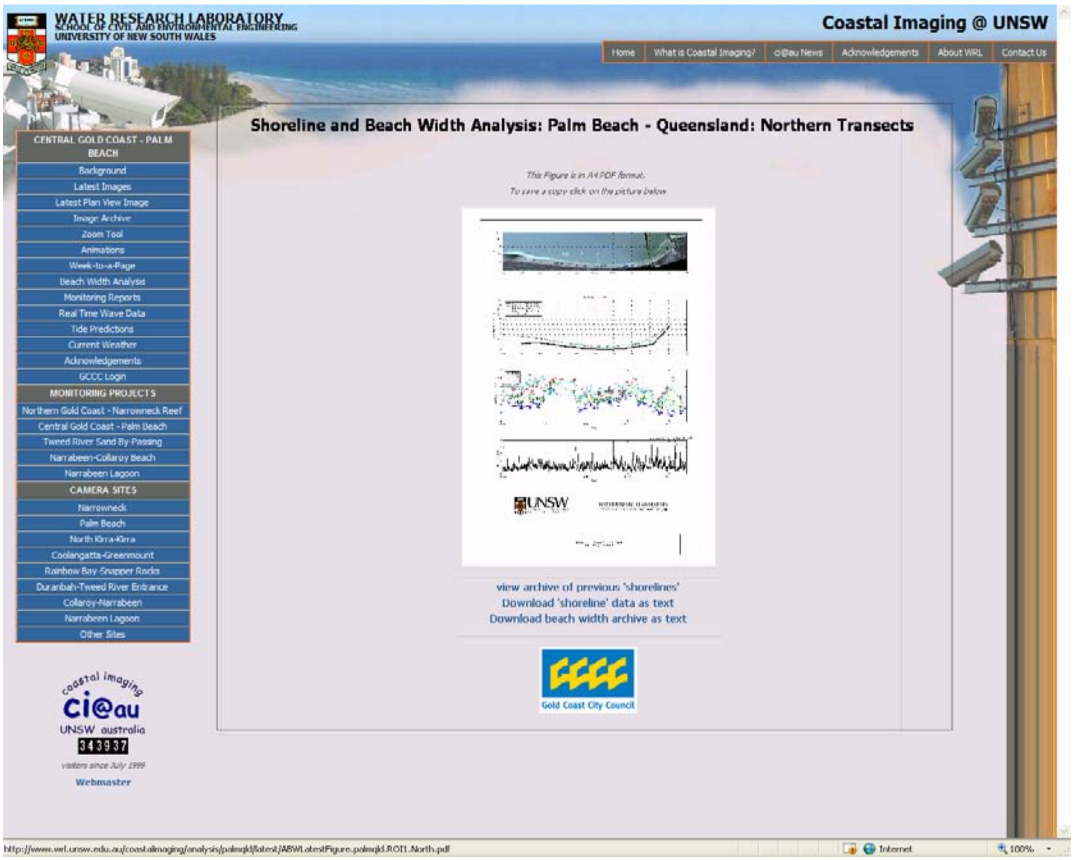


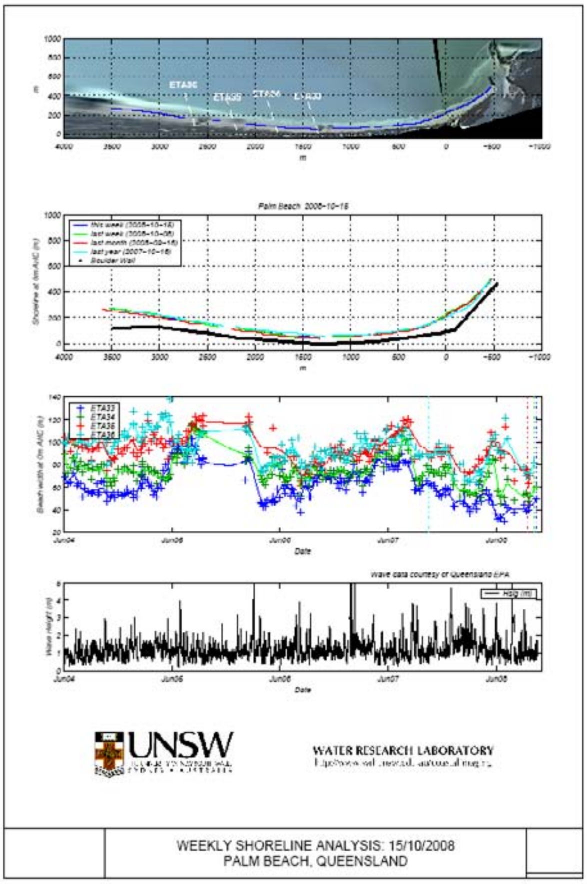
WRL Report No. 2008/32	COASTAL IMAGING SYSTEM WEB SITE – IMAGE ARCHIVE	Figure 4.2





WRL Report No. 2008/32	ON-LINE BEACH ANALYSIS SYSTEM 'WEEK-TO-A-PAGE'	Figure 4.3





WRL Report No. 2008/32	ON-LINE BEACH ANALYSIS SYSTEM 'BEACH WIDTH ANALYSIS'	Figure 4.4

5. MORPHODYNAMIC DESCRIPTION OF PALM BEACH: JUNE – OCTOBER 2008

From the daily images obtained by the ARGUS coastal imaging station atop of the Royal Palm building, it is self-evident that Palm Beach is dynamic and continually changing. Bars move onshore and offshore and vary in shape from straight to crescentic, rips emerge and disappear, and the shoreline changes shape and translates landward and seaward in response to varying wave conditions. This section is included to provide a qualitative description of the observed beach changes during the present monitoring period June to October 2008. The 'week-to-a-page' summary figures that are updated every week and made publicly available for inspection and download via the project web site, are used in this section to illustrate the observed beach changes. The objective is not to describe every characteristic of Palm Beach during this period, but rather provide an overview of general trends and predominant features that were observed during this time.

To summarise beach changes in some structured manner, it is useful to first outline a systematic beach classification scheme with which to undertake this qualitative analysis. For consistency, this same classification scheme has been used in previous reports for both the Palm Beach and Northern Gold Coast (Surfers Paradise) sites.

5.1 A Morphodynamic Classification of Beaches

Despite the seemingly endless range of changes observed at any sandy coastline, in fact it has been shown that beaches tend to exhibit certain characteristics that vary in a systematic and predictable way. One such scheme for describing these changes is the 'Morphodynamic Beach State Model' first outlined by Wright and Short (1983). This beach classification scheme was developed in Australia, and is now the most widely-used descriptive beach model internationally. The term 'morphodynamics' derives from the combination of the words 'morphology' and 'hydrodynamics', emphasising the strong linkage between the shape of a beach and the associated wave and current conditions.

Beaches can be classified as being in one of six beach 'states' at any given point in time. The generalised cross-section and plan-form characteristics of these six beach states are summarised in Figure 5.1. A brief description of each of these states is provided below.

At one extreme is the *dissipative* beach state (Figure 5.1a), which is characterised by a very low profile slope and wide surfzone. Dissipative beaches are generally composed of fine sand and occur along coastlines exposed to high wave energy. Nearshore bathymetry is usually characterised by one or more straight and shore-parallel bars. The term 'dissipative' is used to describe beaches that exhibit these characteristics because wave energy is essentially dissipated by extensive wave breaking across the surf zone, before it can reach the shoreline.

At the other end of the beach state spectrum, *reflective* beaches (Figure 5.1f) are invariably steep, with no nearshore bars. Waves tend to break close to or right at the shoreline, and hence very little wave energy is dissipated; instead it is reflected by the beachface and propagates offshore. These beaches tend to be composed of coarse sediments and/or are generally located in protected or low wave energy coastal regions.

Between the dissipative and reflective extremes, four *intermediate* beach states can be identified. These incorporate elements of both the reflective and dissipative domains. The four intermediate beach types are referred to as *longshore bar-trough* LBT (Figure 5.1b), *rhythmic bar and beach* RBB (Figure 5.1c), *transverse bar and rip* TBR (Figure 5.1d) and *low tide terrace* LTT (Figure 5.1e). Together, these intermediate beach types form a sequence of characteristic beach states related to the movement of sand onshore (decreasing wave steepness) and offshore (increasing wave steepness). The onshore-offshore movement of sand is most easily recognised by the movement and changing shape of bars within the nearshore zone.

Following the characteristic offshore movement (*i.e.*, erosion) of sediment during a major storm, typical post-storm beach recovery includes the gradual onshore migration of nearshore bars and the development of weak and then stronger rips (LBT → RBB → TBR). If low wave conditions persist, bars ultimately disappear as the bar becomes welded to the beach to form a terrace (LTT). Beaches of the moderately high energy east Australian open coast are typically observed to transfer between these four intermediate morphodynamic beach states, in response to lower wave conditions interspersed by episodic storm events.

5.2 Morphodynamic Interpretation of Daily Images

All of the available week-to-a-page figures for the period June to October 2008 are presented in Appendix A. Each of these figures shows a week (seven days) of sequential mid-tide plan images, with the date of each indicated. All images are obtained at approximately the same stage of the tide (mean sea level), to enable the direct comparison between different days and weeks. The region shown in these figures extends 5000 m alongshore, from the southern training wall at the Tallebudgera Creek entrance to the

Currumbin Headland. These images have been updated since previous reports, to now include tide and wave data plots recorded throughout each week.

To assist the interpretation of these images, Appendix B contains monthly summaries of wave height and period, obtained from the Gold Coast Waverider buoy and supplied to WRL by the Queensland Department of Environment. When data from the Gold Coast Waverider buoy has been unavailable, data from the Brisbane buoy has been substituted to fill the gap. The Gold Coast Waverider buoy is located at Latitude 27° 57.84' S Longitude 153° 26.55' E in a water depth of approximately 18 m, while the Brisbane Waverider buoy is located at Latitude 27° 29.75' S Longitude 153° 37.71' E in approximately 73 m water depth. Generally both buoys will measure similar wave conditions, however, the Gold Coast buoy measures wave heights after wave shoaling has occurred, as it is located in significantly shallower water.

5.2.1 June 2008

At the end of the previous monitoring period (December 2007 – May 2008), relatively mild wave conditions had been experienced for the first half of May 2008, before peaking with a significant wave height of approximately 3 m. The peak in wave energy during the last ten days of May saw wave breaking across a detached longshore bar along the southern half of the beach, while north of the 11th Street groyne the outer surfzone was more irregular and again typical of a RBB morphological state.

Wave energy continued to increase during the first three days of June 2008, with the significant wave height peaking at almost 4 m, before receding throughout the remainder of the first week. During the first three days of the month, the beach morphology was observed to be two-dimensional, and typical of a LBT morphological state. The decreasing wave conditions from the 4th to the 7th of June saw the detached longshore bar initially become slightly irregular in alignment and then become inactive. By the 7th, the smaller wave conditions produced a surfzone that was significantly narrower and consisting of wave breaking only immediately at the beachface.

Wave conditions again increased during the second week of June, peaking with a significant wave height of 2 m on the 9th before again receding to 0.5 m by the 14th. This fluctuation in wave energy was again repeated in the third week of June, followed by relatively consistent wave conditions with a significant wave height of 1 m for the final 10 days of June. From the 7th to the 14th of June, breaking of larger waves across a detached offshore bar was occasionally evident, with most wave energy being dissipated through a complex nearshore surfzone. South of the 11th Street groyne, the nearshore surfzone morphology was typical of a TBR morphological state, while over the northern stretches of the embayment, a nearshore bar continued to provide relatively two-dimensional surfzone conditions. During the final two weeks of June, the surfzone was very low energy and appeared somewhat inactive. Wave breaking typically occurred at the beachface, with small rips occasionally present.

5.2.2 July 2008

July 2008 started with low energy wave conditions with a 0.5 m significant wave height, before peaking on the 6th at just over 2 m. The significant wave height reduced to just under 1 m by the 9th, and then remained relatively stable through until the 22nd. Large storm wave conditions struck the Gold Coast beaches on the 22nd, with the significant wave height increasing rapidly from 0.5 m to 5 m within a 24 hour period. The high energy wave conditions continued until the 25th, with no wave data available from the 25th to the 30th. During the last two days of July, the significant wave height was seen to decrease to 1.5 m.

During the first week of July 2008 there was very little observable change in surfzone morphology from the end of June, with a very low energy surfzone consisting of breaking waves only on the immediate beachface. From the 8th to the 22nd no images were captured by the ARGUS system due to operational problems, with the image captured on the 23rd showing very different surfzone morphology to earlier in the month. The larger wave conditions experienced from the 22nd resulted in wave breaking across a wide surfzone, with most energy dissipated across a detached longshore bar. During this time, the morphology was typical of a LBT morphological state, with a very two dimensional appearance. By the end of the month, the large wave conditions had decreased, with the significant wave height once again less than 1 m. The detached longshore bar was again observed to be inactive, and the nearshore surfzone was dictated by small rip currents, spaced irregularly along the beach.

5.2.3 August 2008

The month of August 2008 was dictated by ongoing lower energy wave conditions, with the significant wave height typically in the range of 0.7 m – 1.5 m. A short burst of moderate wave conditions was experienced from the 23rd to the 27th, with the significant wave height peaking slightly in excess of 2 m.

Throughout the entire month of August there was very little observable change in beach morphology. The lower energy wave conditions resulted in a very narrow surfzone that was almost non-existent along the southern stretches of the Palm Beach embayment at times. Sand was observed to migrate from the nearshore surfzone and develop into terraces attached to the beachface. These conditions resulted in a morphological state that varied from very low energy reflective beach conditions, to low energy intermediate LTT conditions. The only period where a slightly more active surfzone was observed was from the 24th to the 26th, when larger waves were observed to break further from the shoreline across a previously formed detached bar.

5.2.4 September 2008

The first week of September saw a rapid change in beach morphology, as a burst of higher energy wave conditions with a significant wave height peaking at 3.5 m impacted the Gold Coast beaches. By the 4th of September, a detached longshore bar could be seen along full stretch of the Palm Beach embayment. A clear and wide longshore channel separated the offshore bar from the inner surfzone, providing morphological conditions typical of a LBT state.

Wave conditions again peaked to in excess of 2 m significant wave height on the 10th, and then decreased to 1 m for the following 10 days. Following the burst of higher energy conditions at the start of the month, a series of transverse nearshore bars could be seen to develop with the lower ongoing wave conditions, as sand had migrated from attached beachface terrace formations. South of the 11th Street groyne, closely spaced rip currents could be seen to separate sections of the nearshore bar, providing conditions very typical of a TBR morphological state. While a slight burst of wave energy was experienced on the 24th, the last week of September saw very low energy morphological conditions along the entire length of the Palm Beach embayment. Wave breaking was again restricted to the direct beachface, and morphological conditions were very similar in appearance to those observed one month earlier at the end of August.

5.2.5 October 2008

Wave conditions during October 2008 were generally low energy, with the significant wave height typically varying from 1 m – 1.5 m. On the 24th the significant wave height exceeded 2 m for short period of time before again decreasing to less than 1 m for the remainder of the month.

The low energy morphological beach state continued from the last week of September and throughout the entire month of October. By the 10th of October, terrace features could be seen to have developed along the beachface which were most notable along the southern Currumbin sand spit and along the region between the 11th Street and 21st Street groynes. The nearshore surfzone could be seen to develop into a complex system of cross shore rips between the transverse bars and terrace features during the second week of September. The surfzone at this point had features typical of both reflective and TBR morphological states which had developed due to the sustained period of low energy wave conditions.

Mild wave breaking over a deeper longshore bar was evident during the slight peak in wave energy experienced on the 24th. However, by the end of October 2008, the surfzone had again become almost completely reflective in appearance, with wave breaking only evident over the immediate beachface.

5.3 Visual Assessment of Beach Width Changes (June – October 2008)

Beach and nearshore conditions during the current five month monitoring period of June – October 2008 were dictated by typically lower energy wave conditions. The storm events experienced in early June and late July resulted in minor erosion of the beach, however, the ongoing low wave energy experienced from August to October saw low tide terrace features develop at the beachface, and reasonably stable beach width.

Figure 5.2 shows the snap images obtained at mid-tide from Camera 2 (south) in June and October respectively. The corresponding snap images of the northern sections of beach obtained from Camera 5, are shown in Figure 5.3. Along the southern section of beach (Figure 5.2), the beach can be seen to have increased in width very slightly during the past six months, primarily as a result of the additional sand stored in the low tide terrace features. Immediately adjacent the Currumbin Creek training wall, the fillet of sand that was present at the start of June can be seen to have eroded by the end of the current monitoring period.

Looking north along the Palm Beach embayment (Figure 5.3), the beach can be seen to have increased in width very slightly between the Argus station and the 11th Street groyne. More modest accretion has occurred on the north side of the 11th Street groyne, while immediately adjacent the 21st Street groyne on both the southern and northern sides, the beach has changed very little in width. More notable accretion appears to have occurred along the far northern stretches of the Palm Beach embayment during the present monitoring period. At all northern locations, the increased beach width is predominantly the result of a build up of sand at and just below the mid tide level in low tide terrace formations. At higher tide levels, there has been less notable change in beach width.

5.4 Visual Assessment of Total Beach Width Changes (June 2004 – October 2008)

The net beach changes to date since the commencement of monitoring at Palm Beach four and a half years ago in early June 2004 are seen in Figures 5.4 and 5.5. In these figures, mid-tide timex images of the beach looking to the south and north along the Palm Beach embayment are shown at six-monthly intervals, for the entire monitoring period June 2004 – October 2008.

During the first six months June to November 2004, along the southern beach the surfeit of sand that was observed within the intertidal and nearshore zone in June, appeared to have moved onshore by November, resulting in modest beach widening and a general straightening of the beach alignment in this southern region. Towards the north, from June to November the southern end of this region appears to have generally widened. In contrast, towards the middle and northern end of the embayment, the shoreline appears much more irregular and scalloped, with a discernable trend of a generally narrower beach.

From December 2004 to May 2005 the southern beach receded again, and from visual assessment was clearly narrower than the initial beach conditions observed twelve months earlier in June 2004. In contrast, toward the north a general trend of beach widening was observed, with the beach reverting to a more uniform alignment than was observed to develop during the preceding six month period.

From June to December 2005 a general trend of beach widening was apparent at the far southern end of the Palm Beach embayment, while in the region in the immediate vicinity of the Royal Palm building little net change in beach width is discernable. The region immediately south of the 11th Street groyne decreased in width, while the region between the 11th and 21st Street groynes increased in beach width. By December 2005 the southern beach was similar to the conditions that prevailed at the commencement of the monitoring program in June 2004, while along the central and northern regions of embayment the impacts of the nearshore nourishment campaign were clearly discernable, with the beach especially to the south and between the 11th and 21st Street groynes exhibiting a substantially wider beach and more uniform alignment alongshore.

During the period December 2005 to May 2006 a distinctive trend of beach narrowing was apparent at the far southern end of the Palm Beach embayment in the region of the

Currumbin Spit. Immediately south of the 11th Street groyne the beach had increased in width, while the region between the 11th and 21st Street groynes and to the north exhibited a general trend of beach recession. The beach conditions that prevailed at the end of May 2006 along the southern Palm Beach embayment were similar to the eroded conditions observed 12 months earlier in May 2005. Along the northern beach the conditions in May 2006 were intermediate to the accreted beach that was observed in May 2005, and the eroded beach observed six months prior to that time in December 2004.

During the period between May and November 2006, a general trend of beach widening occurred across the far southern end of the Palm Beach embayment, while a more modest trend of increasing beach width was observed in the immediate vicinity of the Royal Palm building. Minor recession occurred across the region immediately south of the 11th Street groyne, while the region immediately to the north slightly widened. In the vicinity of the 21st Street groyne and further north along the Palm Beach embayment, little net change in the beach was observed.

Between December 2006 and May 2007, notable beach recession occurred across the far southern end of the beach in the region of the Currumbin Spit, while minor narrowing of the beach in the immediate vicinity of the Royal Palm building was evident. Looking northward along the Palm Beach embayment, the beach generally widened, with significant accretion on the southern side of the 11th Street groyne, as well as in the vicinity of the 21st Street groyne and further to the north.

From June to November 2007, the southern section of beach in the region of the Currumbin Spit widened significantly, which was primarily the result of nourishment of this section of the beach during October and November. The effect of the nourishment on beach width decreases rapidly in a northward direction, with the beach actually decreasing in width in the vicinity of the Royal Palm building during the same period. Across the northern section of the Palm Beach embayment, the majority of the beach experienced a trend of erosion between June and November 2007, with the sections of beach adjacent the 11th Street groyne experiencing the most extensive narrowing, and erosion further north around the 21st Street groyne less pronounced.

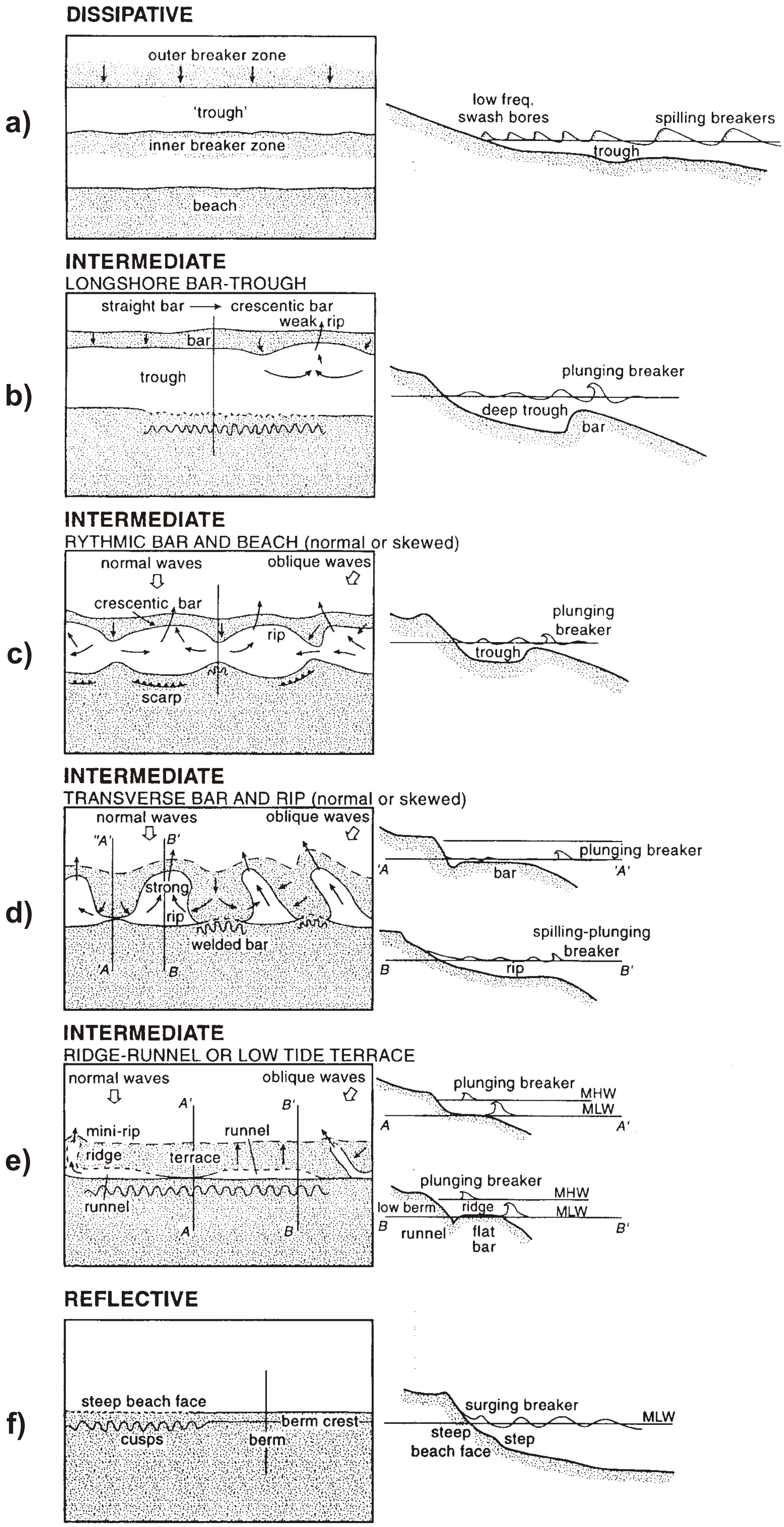
During the period between November 2007 and May 2008 the beach to the south of the Royal Palm building can be seen to slightly narrow. Further north, significant net erosion occurred in the vicinity of the 11th Street groyne and also to the north of the 21st Street groyne. The effect of the higher energy waves experienced from December 2007 to

February 2008 were evident at the end of this six month monitoring period, with the surfzone somewhat flatter and wider in May 2008 compared to November 2007.

Between May and October 2008 the beach generally widened slightly along the southern stretches, in particular the location seaward of the Royal Palm building. There was slight erosion at the far southern end of the beach, immediately adjacent to the Currumbin Creek entrance training wall. There were only very minor net changes in beach width along the northern stretches of beach, however, significant quantities of sand were seen to have developed with the growth of low tide terrace features.

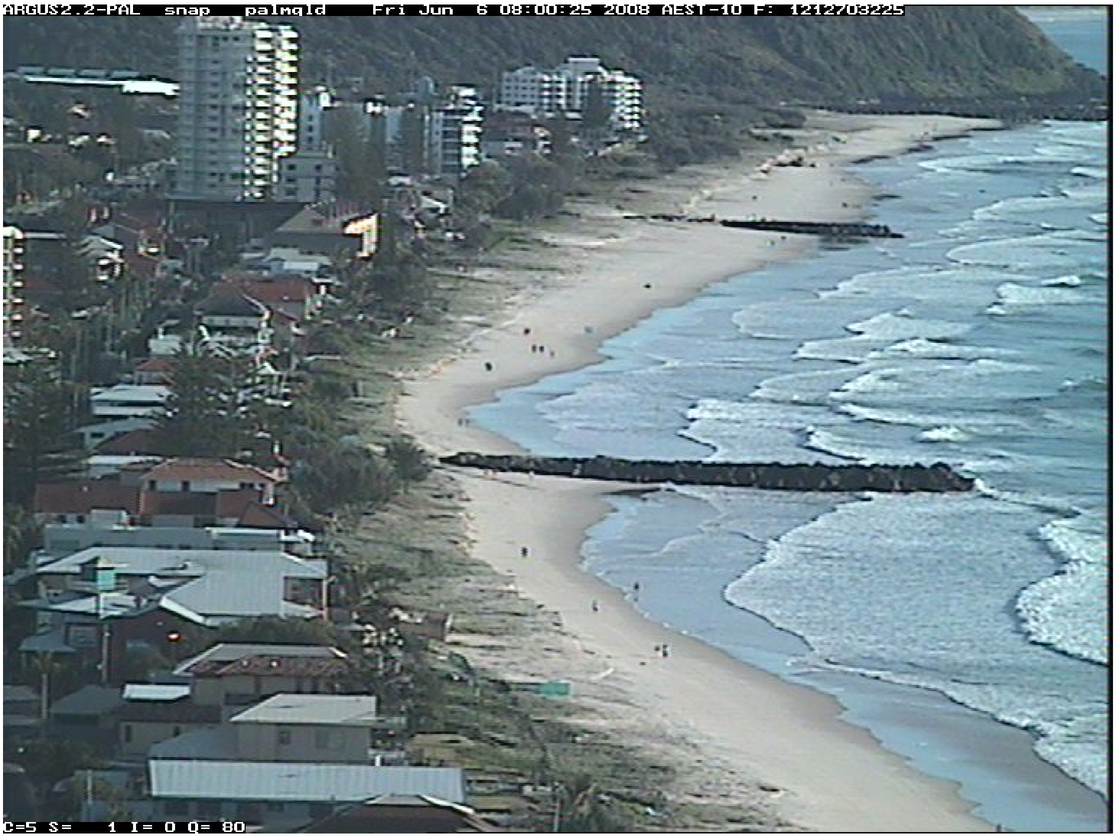
From the images shown in Figures 5.4 and 5.5, a clear cyclic trend in beach erosion/accretion is evident. Generally at the start of winter (end of May), the section of beach extending south of the Royal Palm building along the Currumbin Spit is in an eroded state. Throughout the following winter and spring, this section of beach generally increases in width and is typically much wider at the end of November, with nourishment of dredge spoil from the Currumbin Creek entrance forming the major component of this process. The erosion/accretion cycle for the northern section of the embayment is typically the reverse of the southern section, with the beach typically appearing wider at the beginning of winter, and narrower at the beginning of summer.

A more quantitative assessment of the response of Palm Beach for the period June to October 2008 is detailed in the following Section 6.



WRL Report No. 2008/32	MORPHODYNAMIC BEACH STATE MODEL (after WRIGHT and SHORT, 1983)	Figure 5.1 06037-5-1.cdr

WRL Report No. 2008/32	SNAP IMAGES FROM CAMERA 2 (SOUTH): JUNE AND OCTOBER 2008	Figure 5.2



WRL Report No. 2008/32	SNAP IMAGES FROM CAMERA 5 (NORTH): JUNE AND OCTOBER 2008	Figure 5.3

June 2004

December 2004

May 2005

December 2005

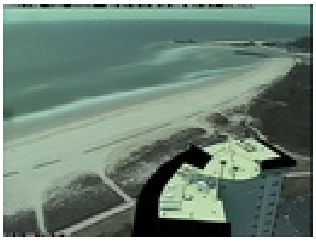
May 2006

December 2006

May 2007

November 2007

May 2008



October 2008

WRL Report No. 2008/32	SIX-MONTHLY BEACH CHANGES CAMERA 2 (SOUTH): JUNE 2004 – OCTOBER 2008	Figure 5.4

June 2004

December 2004

May 2005

December 2005

May 2006

December 2006

May 2007

November 2007

May 2008

October 2008

WRL Report No. 2008/32	SIX-MONTHLY BEACH CHANGES CAMERA 4 (NORTH): 2004 – OCTOBER 2008	Figure 5.5

6. QUANTITATIVE ANALYSIS OF SHORELINE CHANGES: JUNE – OCTOBER 2008

The primary function of the coastal imaging system installed at Palm Beach is to quantify shoreline changes and beach variability along this partially engineered coastline, to document and better understand the behaviour of this coastal embayment. In addition, the impacts of past (and possible future) beach improvement works can be assessed. Quantitative analysis of shoreline position and beach width provide an objective measure to assess both beach amenity, and the extent of the storm buffer seawards of the existing boulder wall.

6.1 Weekly Shorelines

All available weekly shorelines for the period 01/06/08 to 31/10/08 are shown in Figure 6.1 (for shoreline mapping method and procedure refer Section 3.7). For reference, these measured shorelines are overlaid on to a representative merged/rectified timex image (image date: 15th May 2008). The image represents a 5000 m length of the Palm Beach embayment, extending from the southern training wall at Tallebudgera Creek in the north, to Currumbin Headland in the south. The ARGUS station is located at coordinate [0,0], just north of the sand spit that separates the lower Currumbin Estuary from the oceanfront. For reference, the alignment of the back-beach boulder wall (used to calculate beach width) is also indicated (landward red line).

To see more clearly the range of shoreline positions mapped during this five month period, Figure 6.2 shows a plot of the position of the weekly shorelines relative to the boulder wall alignment. The distance of these shorelines from the wall alignment is plotted in the upper panel, and for convenience the alongshore position in this figure is relative to the location of the ARGUS station (0 m). In the lower panel of this figure the same mid-tide timex image used in the previous figure is shown for reference.

During the monitoring period 01/06/08 – 31/10/08, it can be seen from Figure 6.2 that the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 25 m (relative to the alignment of the back-beach boulder wall) on the northern side of the 11th Street groyne, to around 170 m at the Location of the ARGUS station on the Royal Palm building. The envelope of beach width changes along the entire embayment was in the range of 15 - 50 m during this period.

At the southern end of the boulder wall, adjacent to Currumbin Creek, the reference boulder wall alignment dips landward. In previous monitoring reports, the beach width along the Currumbin Spit has been shown to increase rapidly to the south along the spit, as a result of the width being documented relative to the end of the boulder wall. To allow for easier interpretation of the beach width further south than the boulder wall along Currumbin Spit, the reference line has been updated as an arbitrary line joining the end of the boulder wall with a fixed point on the southern training wall of the Currumbin creek. While this does result in a non-uniformity in plotted beach width relative to the reference line (Figure 6.2 top image), the data can now be interpreted more easily.

6.2 Shoreline Variability – Mean, Maximum, Minimum, Standard Deviation

The alongshore variability of the measured shoreline positions during the monitoring period 01/06/08 – 31/10/08 is further quantified in Figure 6.3. The upper panel of this figure shows a plot of the mean, maximum and minimum shoreline position at 5 m increments alongshore. For reference, in the lower panel the mean shoreline position during this period is overlaid onto a merged/rectified timex image of Palm Beach (image date: 15th October 2008).

Referring to Figure 6.3, the mean beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 35 – 85 m along much of the Palm Beach embayment. With the alignment of the boulder wall changing orientation and dipping landward at the southern sand spit, the measured beach width is observed to increase accordingly, reaching 150 m in front of the site of the cameras (i.e., distance = 0 m alongshore in Figure 6.3).

The analysis of maximum and minimum beach width (upper panel, Figure 6.3) shows that the beach shifted over a greater range of widths for the region of beach extending north of the 11th Street groyne. In the far north the maximum beach width was approximately 30 m wider than the mean width, while the minimum width was only 10 m – 15 m narrower than the mean shoreline position. South of the 11th Street groyne, the variation between maximum and minimum beach width was observed to be less than the northern half of the embayment, with both maximum and minimum widths approximately 10 m wider and narrower respectively, than the mean shoreline position.

The middle panel of Figure 6.3 shows the standard deviation (s.d.) of weekly shorelines from the mean shoreline position during the same period 01/06/08 - 31/10/08. Standard deviation of shoreline position was typically 10 m – 15 m for the section of beach north of the 21st Street groyne. Between the 21st Street and 11th Street groynes, the standard deviation was observed to decrease with further distance south along the beach, and ranged from approximately 12 m at the 21st street groyne to 5 m at the 11th Street groyne. The standard deviation of shoreline position was more variable along the southern sections of beach, with the highest standard deviation of slightly less than 20 m recorded immediately adjacent the Currumbin Creek training wall.

6.3 Time-Series of Beach Widths at Transects ETA29 - ETA36

The variations in shoreline position measured at Gold Coast City Council's ETA transects 29 - 36 for the monitoring period June to October 2008 are shown in Figures 6.4 and 6.5. Figure 6.4 plots the weekly shoreline position at the southern transects ETA29 - ETA 32, and Figure 6.5 plots the weekly shoreline position at the more northern transects ETA33 - ETA36. The alongshore position of each of these beach transects is shown in the accompanying merged/rectified image (image date: 15/10/2008).

6.3.1 Southern Transects (ETA29 – ETA32)

At the southern-most transect ETA29 located across the southern sand spit, the beach was seen to change very little in width during the current five month monitoring period. In the later months of September and October the beach increased slightly in width by approximately 10 m. The transects north of the Royal Palm building (ETA30, ETA31, and ETA32) all showed similar behaviour in terms of beach width throughout the current monitoring period. At these sections, the beach was observed to increase in width during June, and then remain relatively stable throughout the remaining four months. At the completion of the current monitoring period, the beach at transects ETA30, ETA31, and ETA32 was approximately 10 m wider than at the start of the monitoring period five months earlier.

6.3.2 Central and Northern Transects (ETA33 – ETA36)

The weekly analysis of shoreline position at the central and northern transects ETA33 to ETA36 is shown in Figure 6.5.

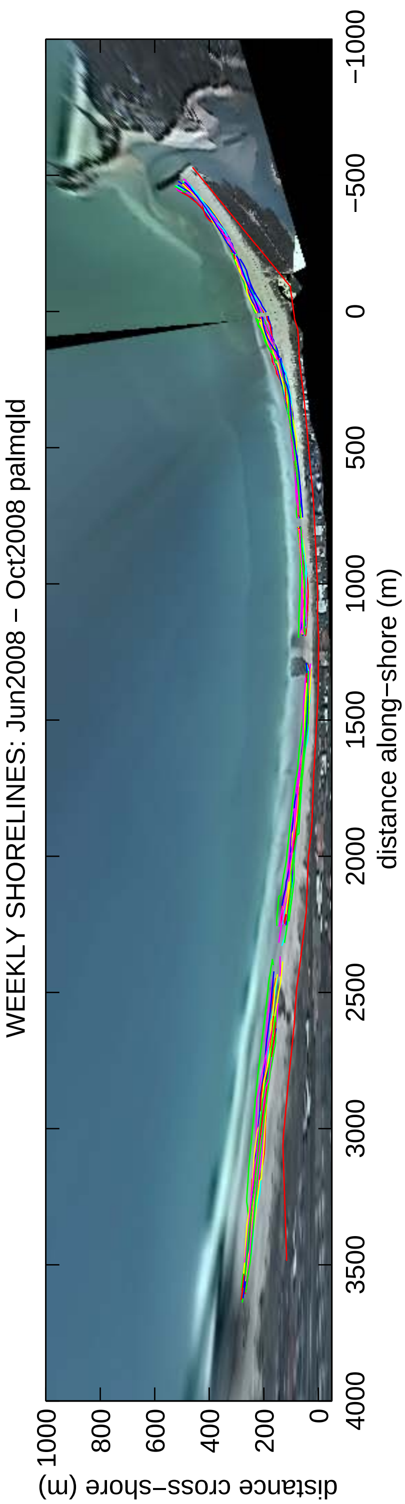
The beach width at transect ETA33 behaved similar to the transects further south, increasing in width during June/July, then remaining reasonably stable throughout the remaining months. Further north at transects ETA34 to ETA36 the beach width peaked in July then steadily decreased during August and September, before stabilising for the final month of the current monitoring period. At the completion of the current monitoring period, the beach at the northern transects had eroded by 10 m to 30 m compared with the beach width five months earlier.

6.4 Weekly Shorelines (June – October 2008) Relative to Mean Shoreline Position of Previous Monitoring Period (December 2007 – May 2008)

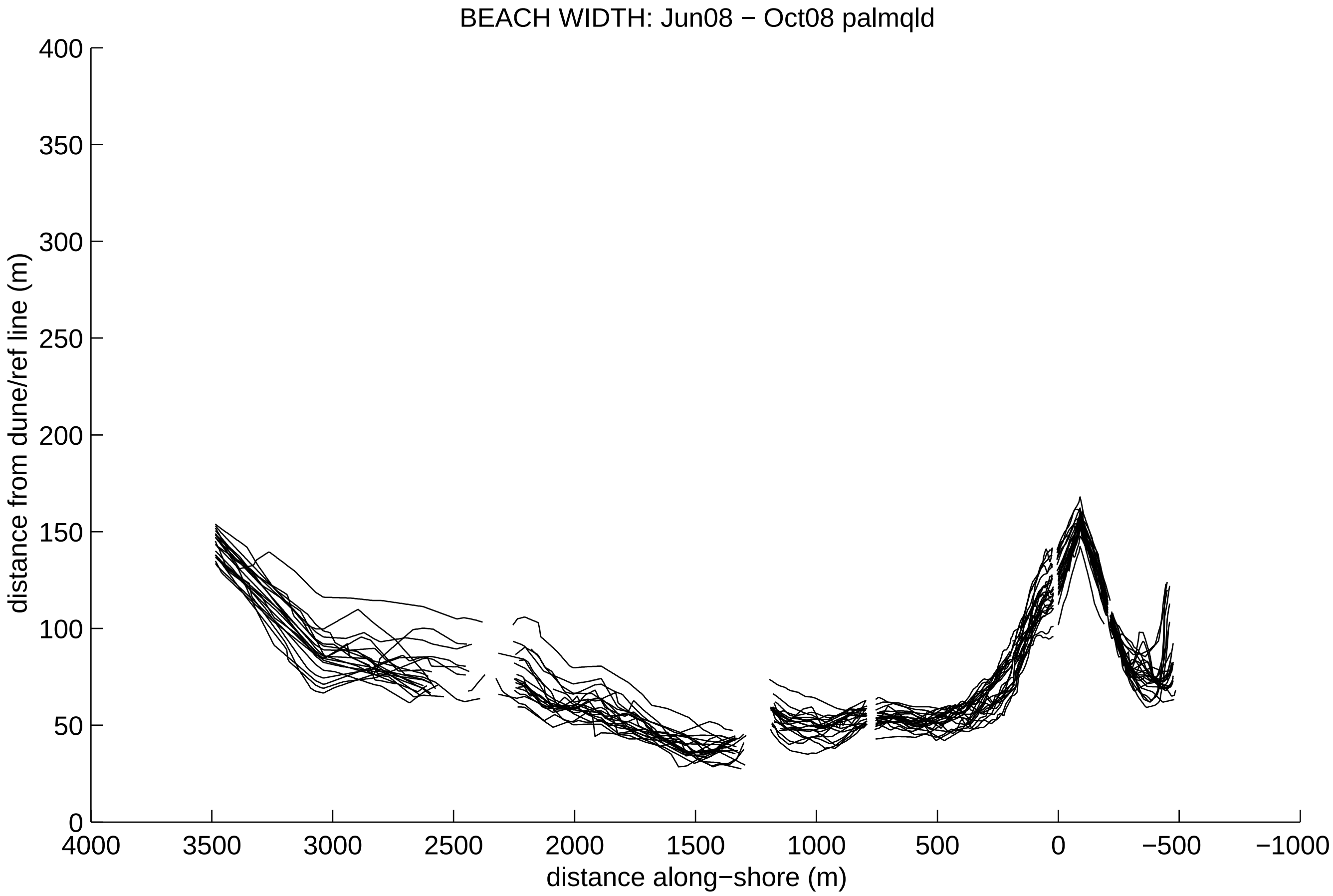
To summarise, Figure 6.6 presents the analysis of all available weekly beach widths for the period June to October 2008, relative to the mean shoreline alignment calculated for the prior six month period December 2007 to May 2008. In the upper panel the deviation of weekly shorelines from this prior mean shoreline alignment is plotted. In the lower panel this mean shoreline position for the previous monitoring period December 2007 to May 2008 is shown, along with the mean shoreline calculated for the present monitoring period.

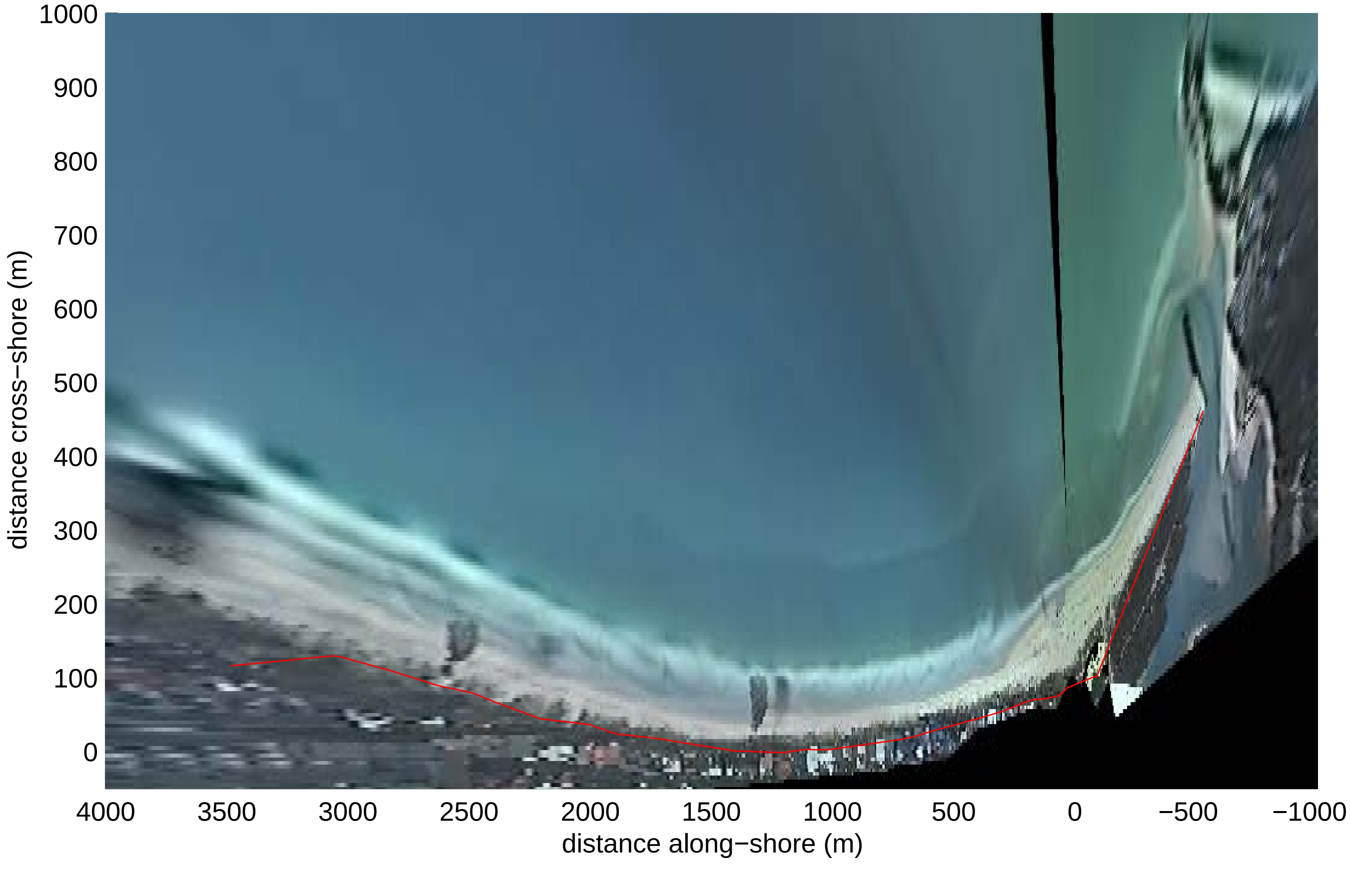
This analysis shows that, relative to the mean shoreline position for the preceding six month period, the beach was generally narrower between the Royal Palm building and the 21st Street Groyne. North of the 21st Street groyne the beach was wider during the current monitoring period than the mean shoreline position from six months earlier, with the maximum beach width between June and October 2008 being almost 40 m greater. The area immediately in front and slightly south of the Royal Palm building was also wider during the current monitoring period than six months earlier. However, at the far southern end of the Currumbin Spit, the beach was generally narrower during the current monitoring period, partially due to the sand fillet that had been established against the Currumbin Creek training wall during the previous monitoring period.

It is important to point out that the shorelines shown in the bottom panel of Figure 6.6 are the mean shorelines for the current and previous monitoring periods, and as such, they do not show the full extent of the shoreline evolution throughout the monitoring period. Instead these shorelines represent the net trend of beach evolution, spanning multiple erosive/accretionary cycles, with short term (weekly – monthly) fluctuations not shown.

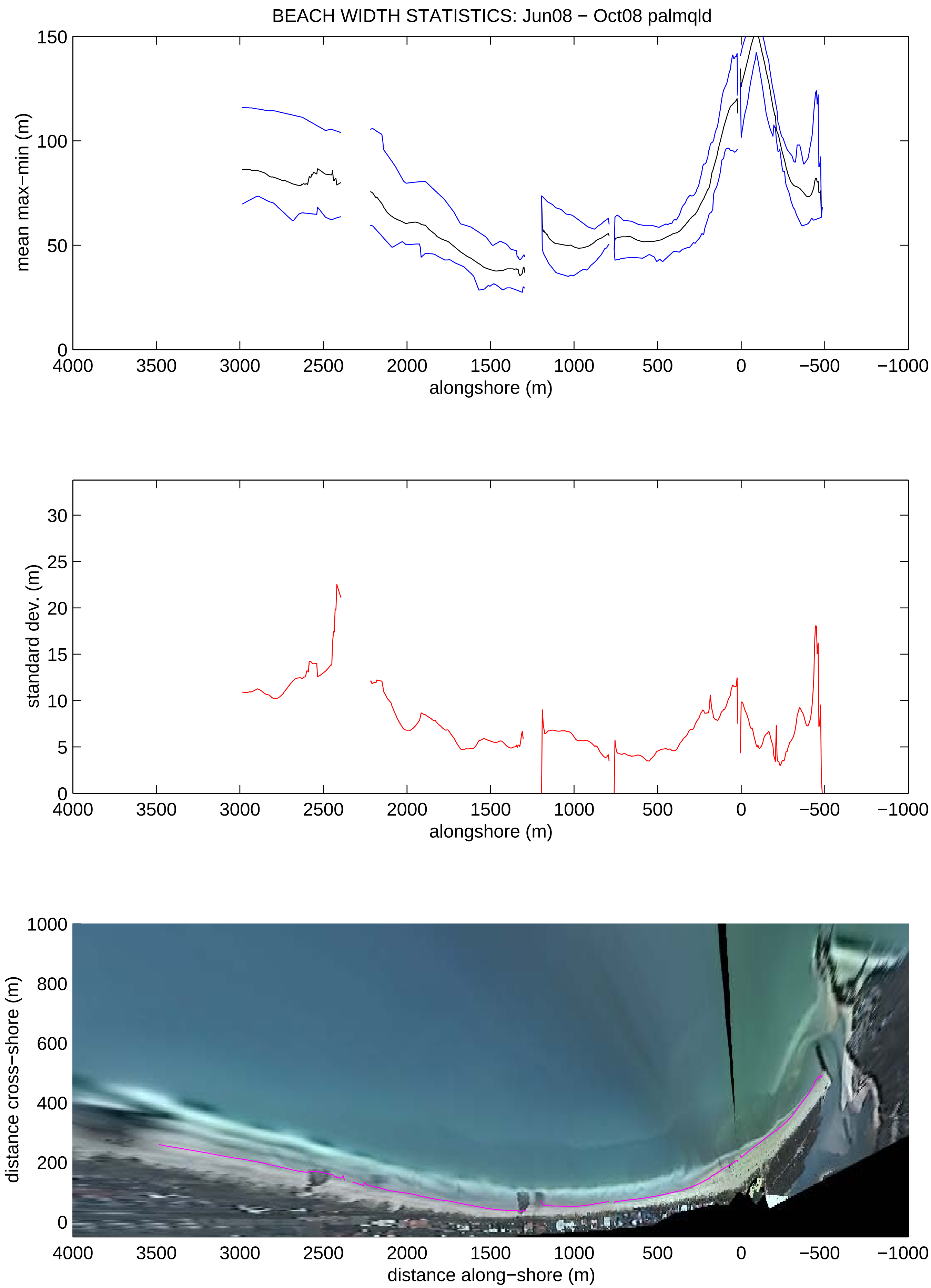


WRL Report No.2008/32	WEEKLY SHORELINES: JUNE−OCTOBER 2008	Figure 6.1





WRL Report No.2008/32	WEEKLY BEACH WIDTH: JUNE−OCTOBER 2008	Figure 6.2



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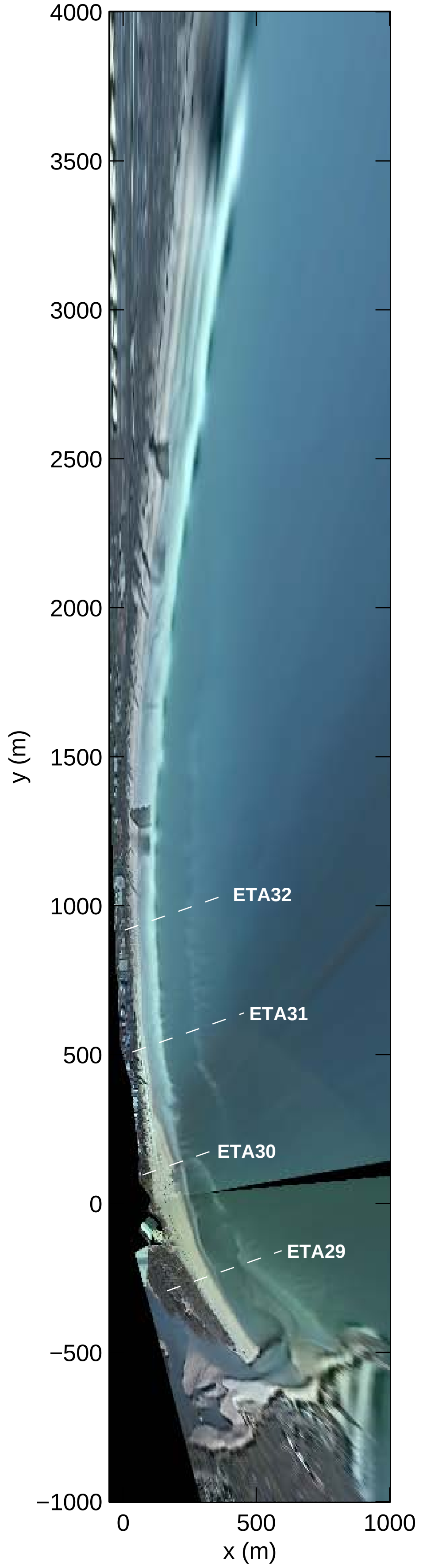
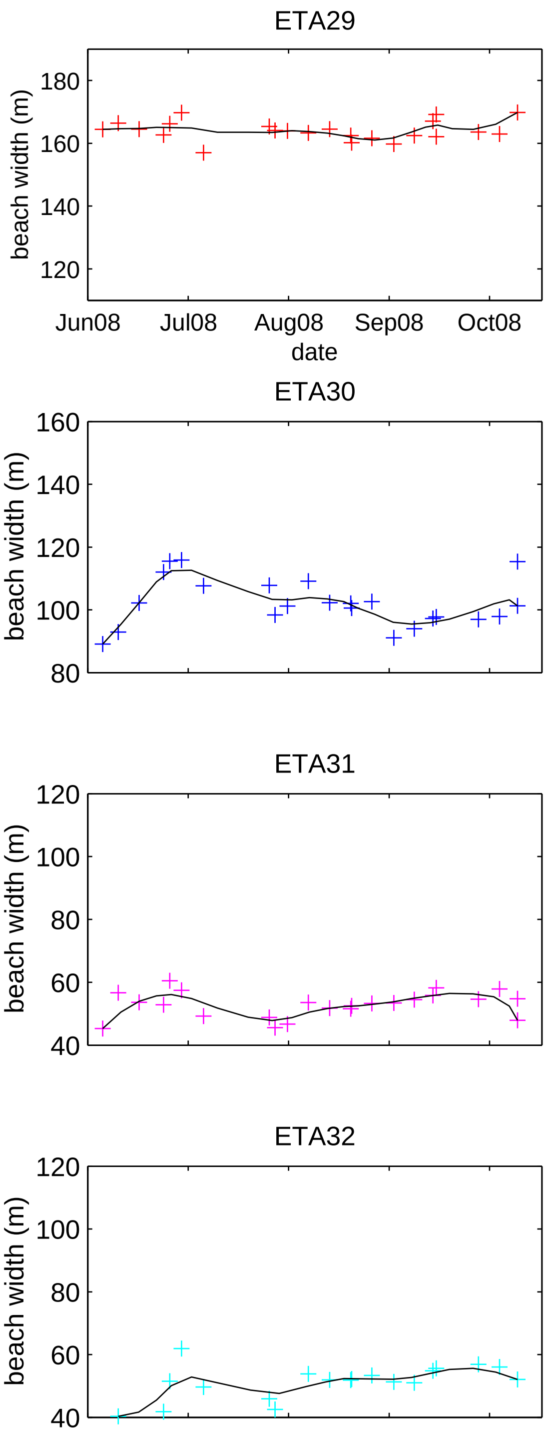
Report No.2008/32

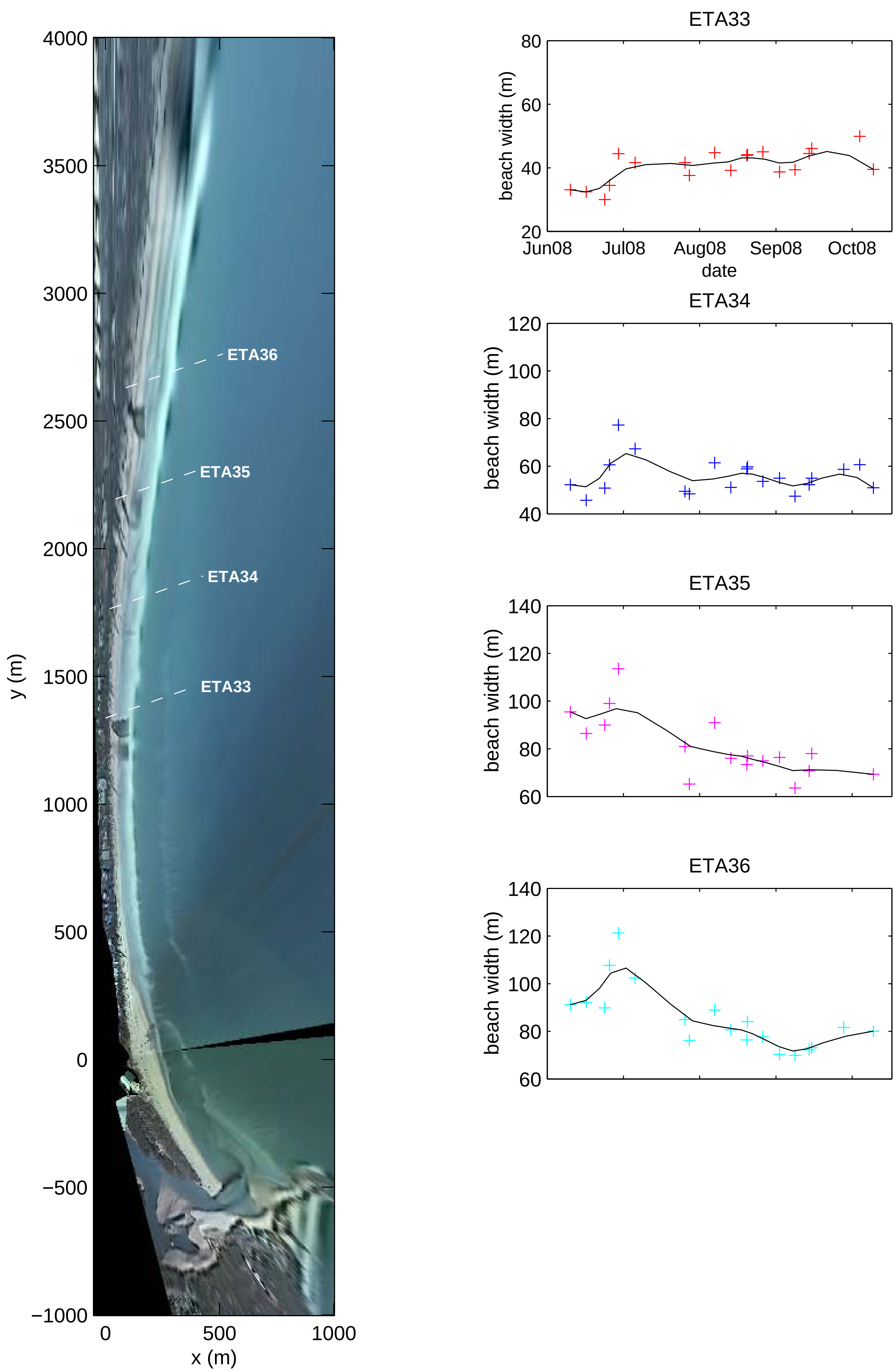
STATISTICAL SUMMARY OF BEACH WIDTH CHANGES: JUNE−OCTOBER 2008

Figure 6.3





WRL Report No.2008/32	TIME−SERIES OF BEACH WIDTH(SOUTH): JUNE−OCTOBER 2008	Figure 6.4



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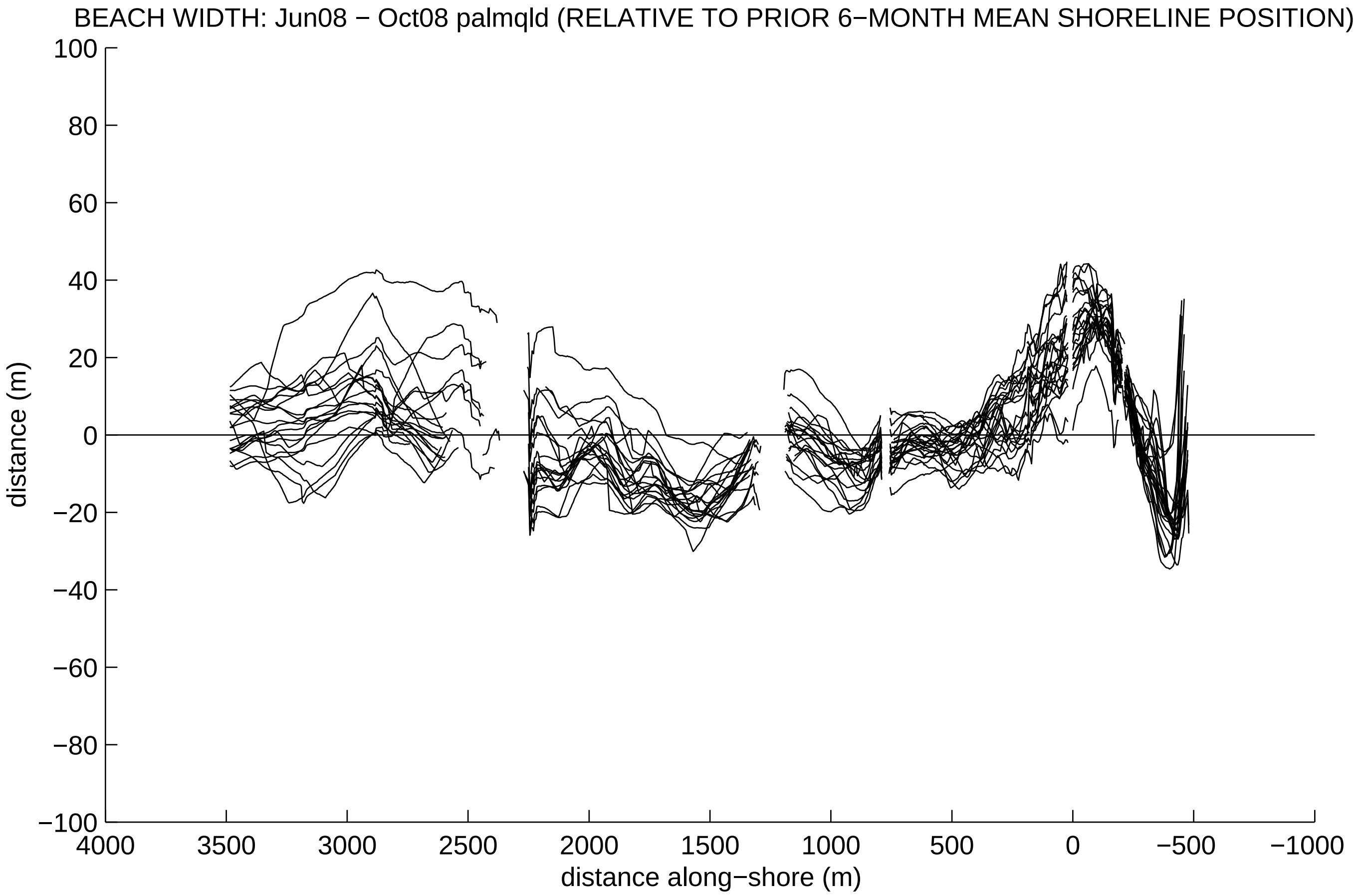
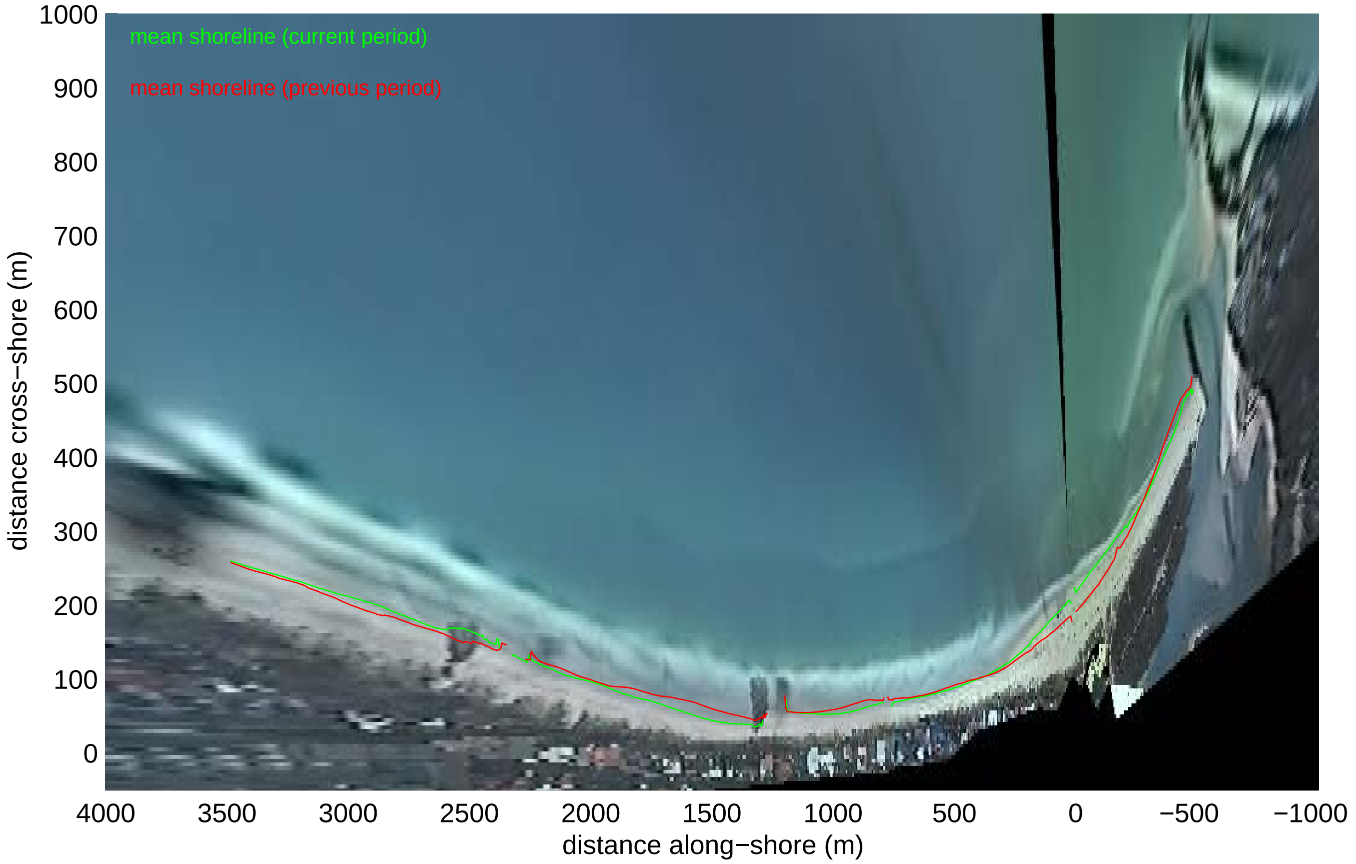
Report No.2008/32

TIME−SERIES OF BEACH WIDTH (NORTH):
JUNE−OCTOBER 2008

Figure 6.5





WRL Report No.2008/32	WEEKLY BEACH WIDTH JUNE−OCTOBER 2008 RELATIVE TO PRIOR SIX−MONTH MEAN SHORELINE POSITION	Figure 6.6

7. QUANTITATIVE ANALYSIS OF TOTAL SHORELINE CHANGES: JUNE 2004 – OCTOBER 2008

The completion of a total of almost 4.5 years (53 months) of monitoring at Palm Beach provides the opportunity to summarise and analyse longer-term shoreline changes observed to date.

7.1 Weekly Shorelines and Shoreline Variability: June 2004 – October 2008

All weekly beach widths (relative to the alignment of the back-beach boulder wall) for the 230 week period June 2004 to October 2008 are shown in Figure 7.1. As per previous figures, a merged/rectified image is shown in the lower panel for reference (image date: 15th October 2008). Since June 2004 the mid-tide beach width along the entire Palm Beach embayment generally varied in the order of 50 - 60 m, with up to 80 m beach change recorded in the vicinity of the nearshore nourishment works (refer Section 2.2) located to the south of the 11th Street groyne and in the area of dredge spoil nourishment along the Currumbin Spit.

The variations in shoreline position measured at the eight ETA survey transects for the entire period June 2004 to October 2008 are shown in Figures 7.2 and 7.3. Figure 7.2 plots the weekly shoreline position for the southern transects ETA29 to ETA32, and Figure 7.3 shows the same for the central and northern transects ETA33 to ETA36. The alongshore position of each of these representative transects is shown in the accompanying merged/rectified image (image date: 15th October 2008).

7.1.1 Southern Sand Spit

At transect ETA29 (Figure 7.2) the beach changes during the initial 12 month period June 2004 to May 2005 were dominated by an initial accretionary response to the beachfront placement of sand, then subsequent readjustment as this sand redistributed alongshore and cross-shore. From mid July 2004 to early September 2004 the beach width grew rapidly from around 160 m to 190 m in width, then from September 2004 through to the end of the May 2005 a steady decline in beach was observed, with the final width of the beach in this region at that time around 130 m. From June to November 2005 the erosion trend reversed in response to the placement at the beachface of additional sand from Currumbin Creek, with the beach width regaining around 30 m to 160 m in December. This beach width was maintained through to the end of February 2006, at which time beach erosion by some 20 m was recorded, following the onset of the major storm in early March. Beach widths increased in the period from June to November 2006 due to beachface placement of sand, so that by the end of November 2006 the beach in this region had returned to similar conditions that prevailed 2.5 years earlier in June 2004. Throughout the period from December 2006 to May 2007, the beach width at the southern sand spit steadily decreased, with a net change in width during this period of approximately 20 m. It is interesting to note that although no significant storms occurred in the first half of 2007, the extent of erosion at transect ETA29 was similar in magnitude to that which occurred during the first half of 2006, when a significant storm event occurred. During the period June to November 2007, there was a significant 35 m increase in beach width at the southern most transect (ETA29) corresponding to sand being dredged from the Currumbin Creek entrance and placed on the beach at this location. It can be observed from the beach width plot for transect ETA29, that similar increases in beach width have been observed between June and November every year since the Palm Beach monitoring program began in June 2004.

Beach widths along the southern sand spit during the period December 2007 to May 2008 were dominated by the large storm events which occurred in December 2007 and January 2008. During these months, some 30 to 40 m of beach width was lost along the Currumbin spit. This was followed by the relatively rapid recovery of the beach in this area. At the end of May 2008, the beach along the southern sand spit had recovered almost completely, to be similar in width to what it was six months earlier. During the current monitoring period June to October 2008, there was very little observable change in beach width. This five month period has been the most stable in terms of beach width, observed for this section of beach during the entire 4.5 years of monitoring.

7.1.2 Central – Southern Embayment

Fluctuations of the beach width at ETA30 (Figure 7.2) were dominated by the beachface sand placement in 2004 and a second phase in April-May 2005. From June 2004 to September 2004 the beach width in this region increased by around 40 m to be 110 m - 150 m in response to the direct placement of sand in this area. A second increase then decrease in beach width occurred during December 2004 to April 2005, as the ‘slug’ of sand placed in previous months along the central sand spit area moved northward through this region. In April – May 2005 the beach width again increased to 130 m, in response to the second phase of beachface placement, coinciding with the location of this transect.

From June to August 2005 the beach width then decreased again by around 20 m, but in September accretion by approximately 10 m was observed. At this time the beach width had returned to within 5 – 10 m of the conditions that prevailed at the commencement of monitoring in June 2004. Similar conditions were observed in February 2006, with minor recovery commencing in June, erosion again in July - August, then the commencement of a more rapid recovery phase in October – November 2006. The beach continued to widen up until the end of 2006, and maintained a relatively constant beach width of just over 120 m from January – May 2007, with only minor fluctuations in beach width of the order of 5 - 10 m occurring.

During the period June to November 2007, the beach at transect ETA30 was observed to undergo minor fluctuations in width throughout June and July, before decreasing rapidly in width in response to the storms experienced during August and September. During this period, of the order of 35 m in width was lost from the beach. Throughout the last half of September, October, and November, beach width was again relatively stable, but in a more eroded state than six months earlier, before being struck by large storms at the end of December 2007 and start of January 2008. This resulted in further rapid erosion of the beach, and left the beach narrower than had been observed at this transect ETA30 at any stage during the four years of monitoring completed previously. The beach recovered significantly during the first half of 2008, before again eroding during July and August. At the end of the current monitoring period in October 2008, the beach at monitoring transect ETA30 is very similar in width to when monitoring began four and a half years ago.

During the 12 month period June 2004 to May 2005 beach width changes at transects ETA31 and ETA32 (Figure 7.2) were dominated by the nearshore nourishment campaign completed in December 2004. Commencing November – December 2004 the beach at ETA31 and ETA32 began to increase in width, and by May 2005 this region of the Palm Beach beachfront increased in width by the order of 40 - 50 m. Commencing June 2005 and continuing through to mid September 2005, the beach at both ETA31 and ETA32 decreased by 20 – 30 m as a portion of the nourishment volume moved northward and the beach in this vicinity of the embayment adjusted toward a new equilibrium alignment.

By December 2005 the beach had recovered again, and at both ETA31 and ETA 32 was of the order of 40 m wider than at the commencement of monitoring in June 2004. Storm erosion in early March 2006 resulted in the temporary loss of this additional beach width, but by the end of May 2006 recovery in the range of 20 – 40 m was observed. From June to November 2006 the beach width oscillated by 20 m, with little net change in width occurring. From December 2006 to May 2007 the beach width continued to fluctuate throughout periods of two to four weeks, with an overall net increase in beach width of the order of 20 m observable.

During the period June to November 2007, the beach width at transects ETA31 and ETA32 experienced the most rapid period of erosion since the monitoring program began in June 2004. The erosion of the beach was the result of a series of four high energy storms in a period of three months, with the beach decreasing in width by approximately 35 m during this period.

The mid-southern transects (ETA31, and ETA32) showed further beach erosion during the monitoring period December 2007 to May 2008, as a result of the large storm events experienced during December and January. Following these storms, this section of the beach was the narrowest it has been observed during the four years of monitoring completed at that time, with beach widths of only 40 m to 60 m seaward of the boulder wall. The beach recovered slightly during February and March 2008, and then remained relatively stable throughout April and May, with beach widths at the end of May 2008 similar to those observed four years earlier in June 2004 when monitoring began. Beach widths during the current five month monitoring period June to October 2008 were relatively stable at transects ETA31 and ETA32. Only relatively minor (10 m) fluctuations in beach width were observed, and there was little net change in width.

7.1.3 Central – Northern Embayment

From June 2004 to March 2005 the more northern transects ETA33, ETA34, ETA35 and ETA36 (Figure 7.3) located between and to the immediate north of the 11th and 21st Street groynes all exhibited fluctuations in beach width in response to the varying wave energy during this time, with no clearly identifiable trends emerging. At ETA33 and ETA34, located between the 11th and 21st Street groynes, a marginal trend of decreasing beach width was recorded, with the beach width decreasing to around 50 – 60 m. Commencing in March at the more southern ETA33 and ETA34 transects and a month later at the more northern ETA35, a distinct trend of beach widening was observed, with the beach width by mid September 2005 increased by 30 – 40 m. This widening was attributed to the continued northward movement of sand placed within the nearshore zone of more southern transects some six months previously. At the most northern transect ETA36 located to the north of the 21st street groyne, the beach width through the period June 2004 to September 2005 continued to react in response to the varying incident wave energy, with no net accretion or erosion trend in evidence.

A general trend of net erosion was observed from September 2005 to February 2006 at the more southern transects ETA33 and ETA34, and then distinctive and rapid storm erosion in early March 2006. Varying degrees of beach recovery were monitored through to the end of November 2006. At the more northern ETA36 and ETA35 transects, the beach was around 10 m narrower than the conditions that prevailed 2.5 years earlier in June 2004. At ETA34 located midway between the two groyne structures and ETA33 located immediately north of the 11th Street groyne, by the end of November 2006 the beach width conditions had returned to very similar conditions to those that were monitored 2.5 years earlier in June 2004.

From November 2006 to May 2007, all of the northern transects responded to fluctuations in wave energy, with a net overall beach widening of approximately 20 m occurring. The rate of accretion was the most significant during April and May 2007. During the following six month period, June to November 2007, steady increases in beach width were observed to continue through June and July, followed by 30 m to 35 m of storm erosion during August and September, with the intensity of the erosion decreasing along the far northern section of the embayment. During the final months of this period, the beach maintained a relatively stable width across the northern transects.

During the period December 2007 to May 2008, the northern section of the beach at transects ETA33 to ETA36 suffered further erosion during the storm events of December and January, followed by recovery during the period March to May. Shortly following the December and January storm events, the beach width along the northern section of the Palm Beach embayment was the narrowest that has been recorded during the four year total monitoring campaign completed at the time. The recovery of the beach during the later months of April and May 2008 saw the beach regain significant width, with beach width almost completely recovering from the storm events experienced during August/September 2007 and again in December 2007/January 2008.

From June to October 2008, the beach at the far northern transects ETA34 to ETA36 peaked in width during the initial two months of June and July, steadily decreased in width during August and September, before stabilising during October. At the completion of this period of monitoring, the beach at the northern transects was again typically in a more eroded state than had been observed during the previous four and a half years.

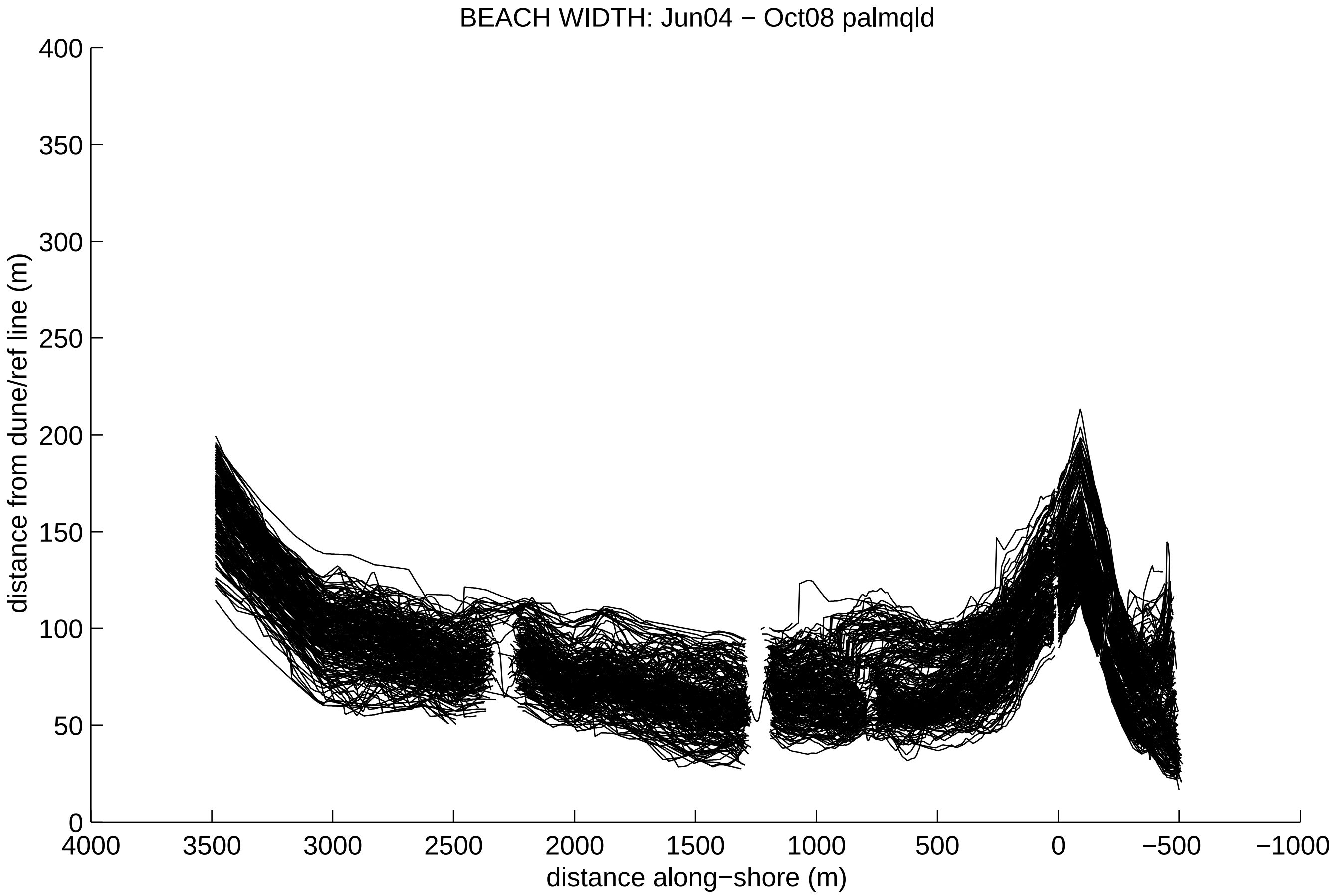
7.2 On-Line Beach Width Analysis

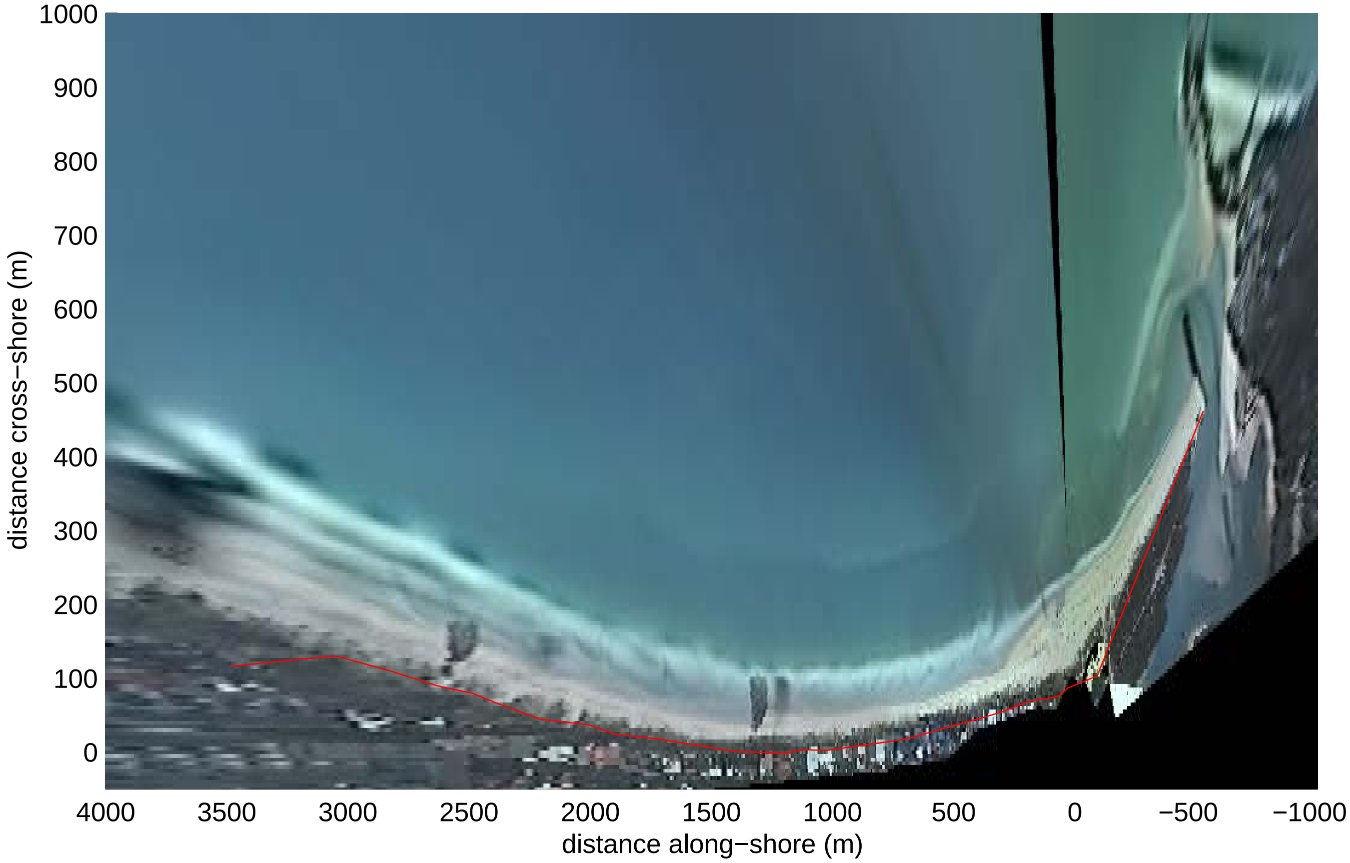
For the sake of completeness, Figures 7.4 and 7.5 are included here that show the same data presented in Figures 7.2 and 7.3, but in the on-line graphical format ('Beach Width Analysis') that are updated each week, and are available for public viewing (and download) via the monitoring project web site (refer Section 4). The top and bottom panels in these figures are equivalent to the two panels in Figures 7.2 and 7.3, with the additional feature that a selection of shorelines are also shown. As well as the same trends identified and discussed above, an interesting additional feature that is more clear in this alternative representation of the data, is the convergence toward a more uniform width alongshore for much of the Palm Beach embayment. Only at the far southern end of the embayment where ongoing nourishment of the beach is undertaken annually, does the beach width diverge from the remainder of the embayment. At the commencement of the monitoring program in June 2004 the width of the storm buffer seaward of the boulder wall varied by up to 150 m. As shown in Figures 7.4 and 7.5, by June 2005 the beach width at the ETA transect lines had converged toward a more uniform range of around 100 ± 20 m at all of the eight ETA transects. However, during the storm of March 2006, a period of slightly higher wave climate in late 2006 to early 2007, and the storm of December 2007 and January 2008, the beach width at the far southern transect ETA 29 has maintained a reasonable buffer, while all transects further north along the beach have steadily eroded. This highlights the localised effectiveness of the dredge spoil used to nourish this far southern stretch of the Palm Beach embayment.

7.3 Summary

Prior to March 2006, the dominant beach changes observed within the Palm Beach embayment were directly attributable to the nearshore nourishment and beachface sand placement campaigns completed in 2004 and 2005. At the southern sand spit area (ETA29) the beach had eroded due to the alongshore and cross-shore re-distribution of sand originally placed along the beachface. In contrast, in the southern-central region (ETA31 to ETA32) the landward movement of sand placed within the nearshore had resulted in a net widening and straightening of the beach. Between the 11^{th} and 21^{st} Street groynes (ETA33 to ETA35) the delayed widening of the beach has been observed, as a portion of the nearshore nourishment volume moved northward along the Palm Beach embayment. Only in the northern region of the Palm Beach embayment (ETA36) have significant impacts from the nourishment campaign not been observed.

The major storm event that occurred in March 2006 caused significant erosion of the beach along much of the Palm Beach embayment. A general trend of beach recovery was observed through to November 2006, with the addition of dredged material from the Currumbin Creek supporting beach recovery. Following completion of the 2006 nourishment campaign in November, the beach continued to accrete through until July 2007, with net widening observed at most transects. A series of storms in August and September 2007 resulted in erosion of the beach north of the ARGUS station, but resulted in little net change in beach width along the southern sand spit. The southern sand spit was again nourished during October and November 2007 with sand dredged from the Currumbin Creek entrance, resulting in a significant increase in beach width along this section of the embayment. Storm events experienced during December 2007 and January 2008 caused significant further erosion along the entire beach, which was followed by beach recovery during lower energy wave conditions experienced during February and March 2008. The ongoing periods of lower wave energy continued through the five months of the current monitoring period from June to October 2008, with bursts of higher wave energy occurring on occasions. This resulted in relatively stable beach width conditions, with comparably less change in beach width observed than in previous six month monitoring periods.





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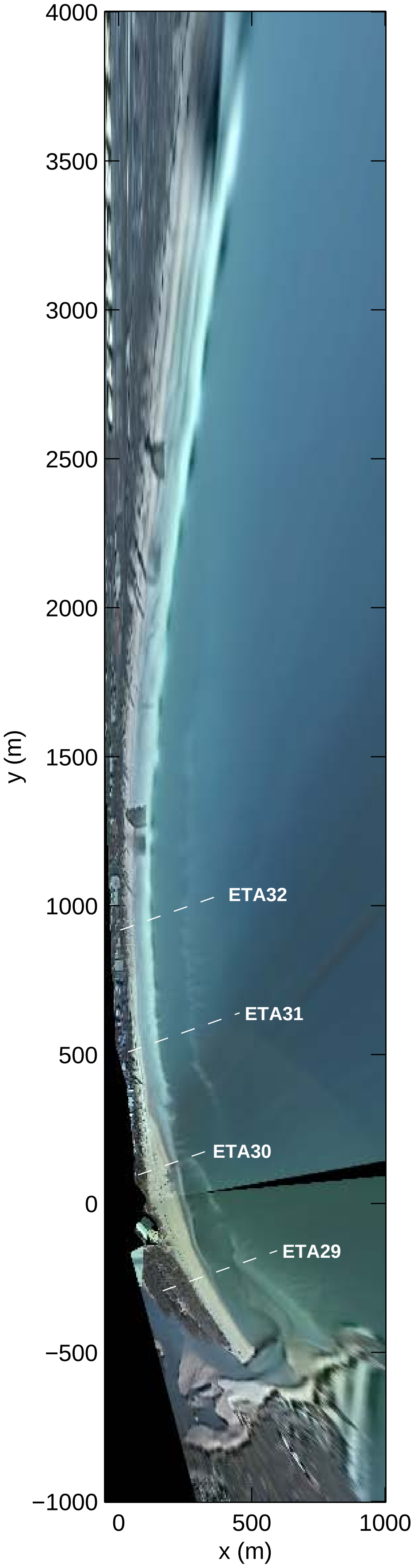
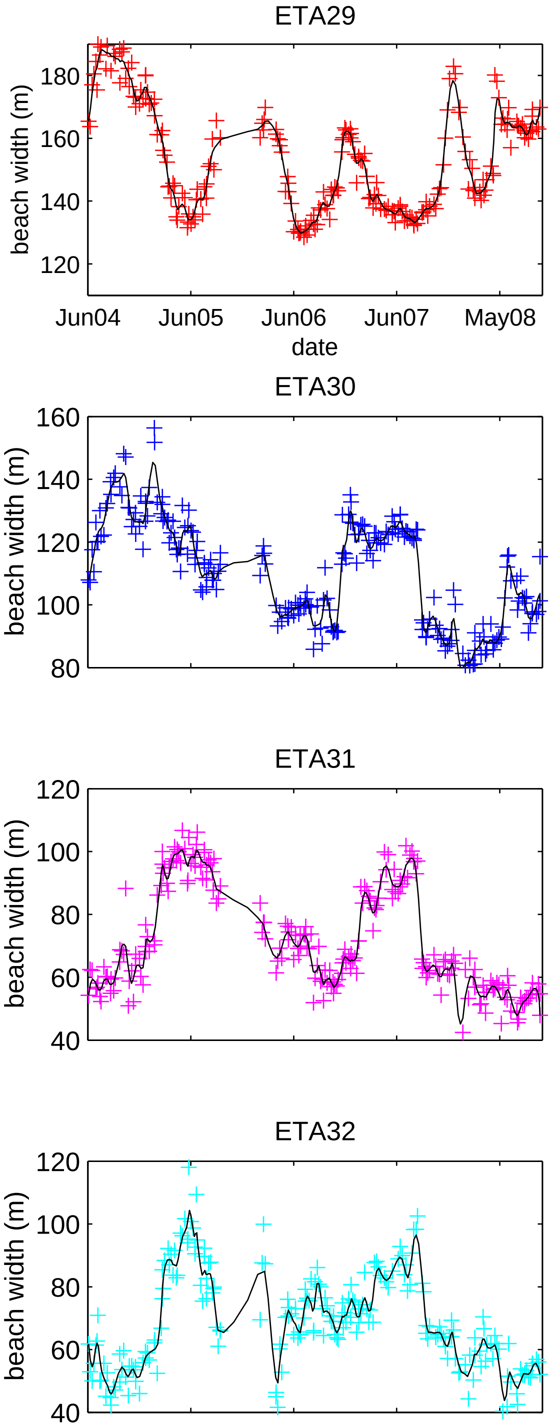
Report No.2008/32

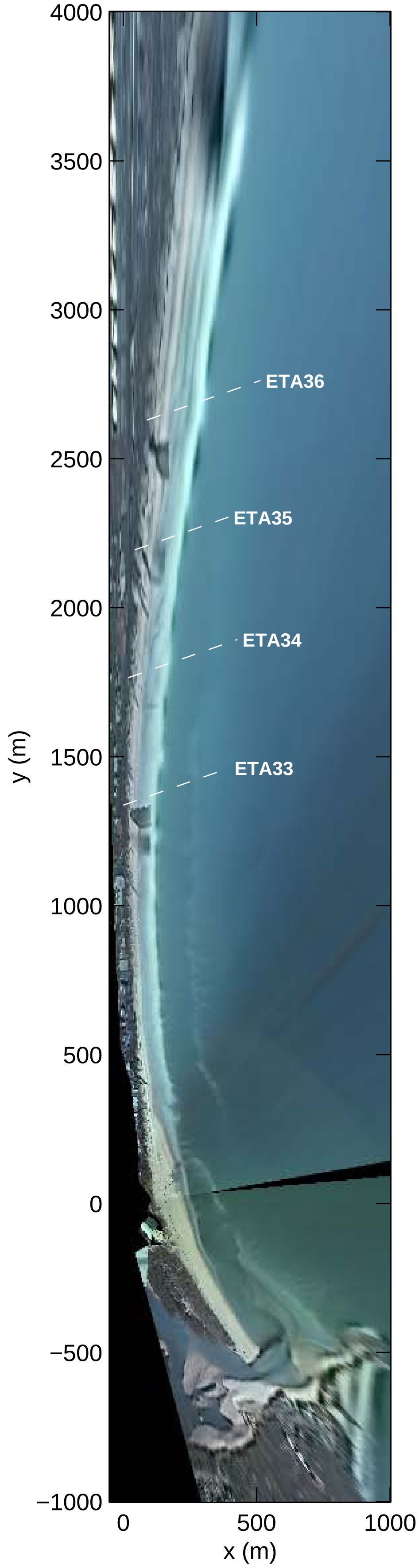
WEEKLY BEACH WIDTH:
JUNE 2004−OCTOBER 2008

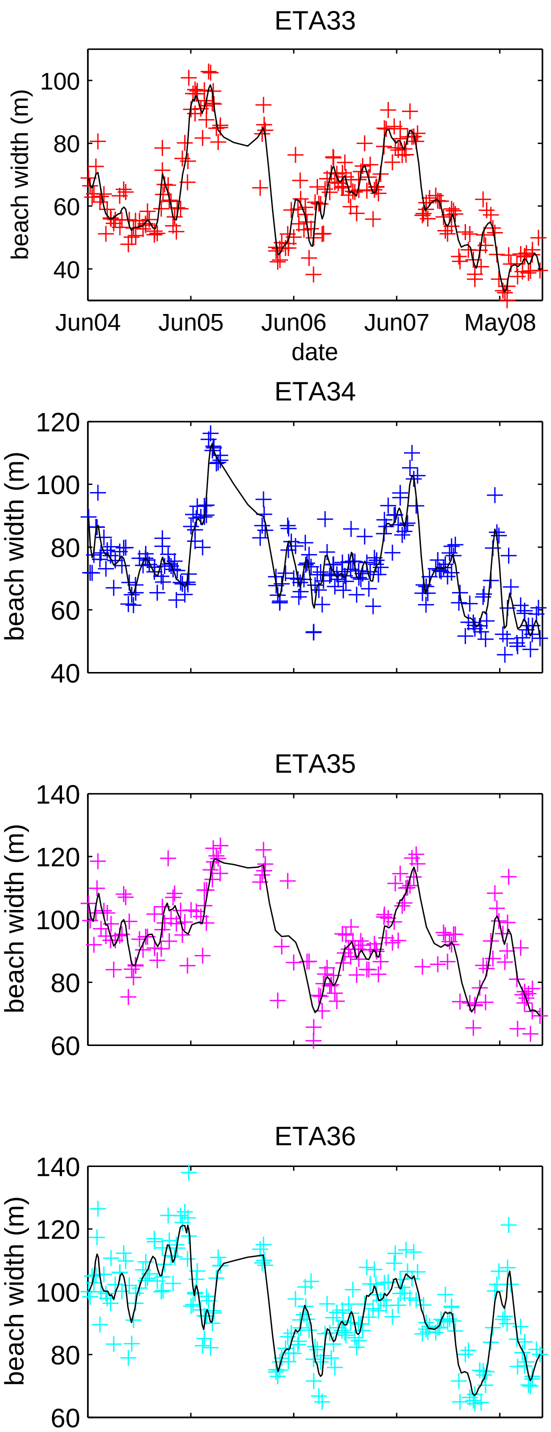
Figure
7.1



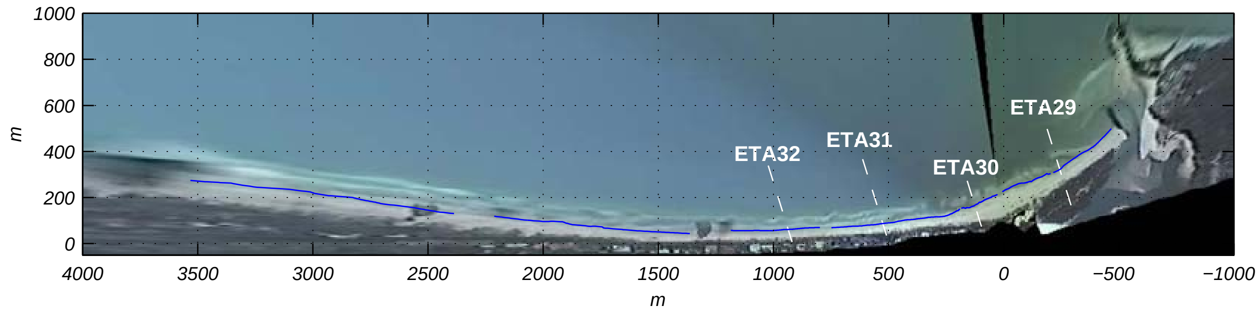


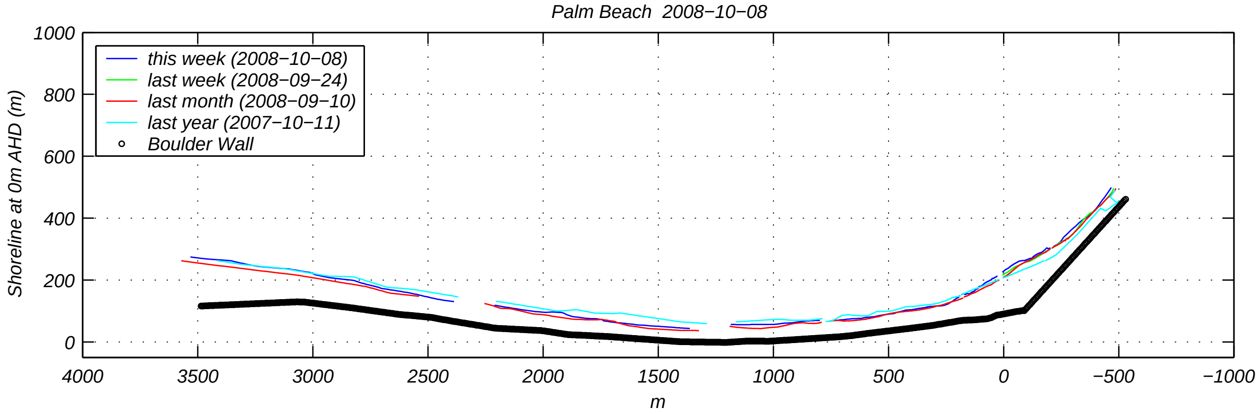
WRL Report No.2008/32	TIME−SERIES OF BEACH WIDTH (SOUTH): JUNE 2004−OCTOBER 2008	Figure 7.2

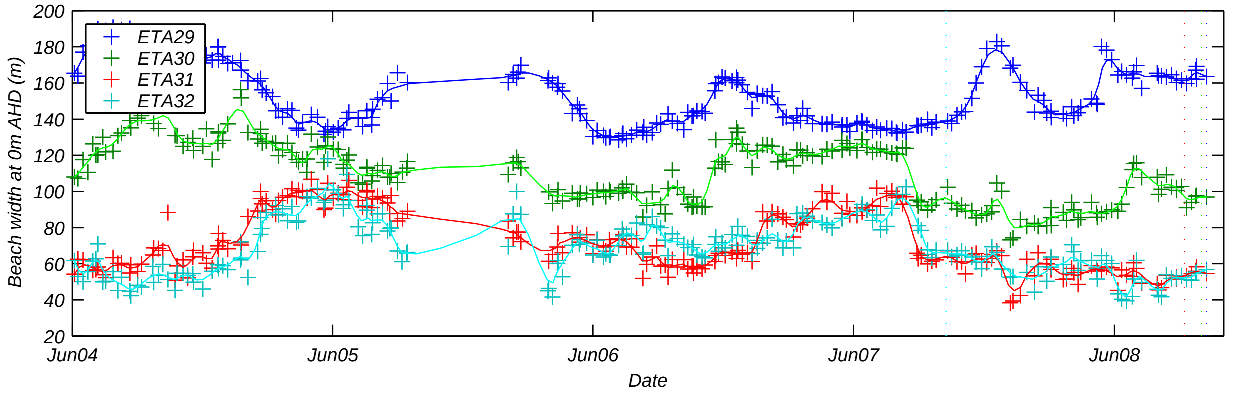


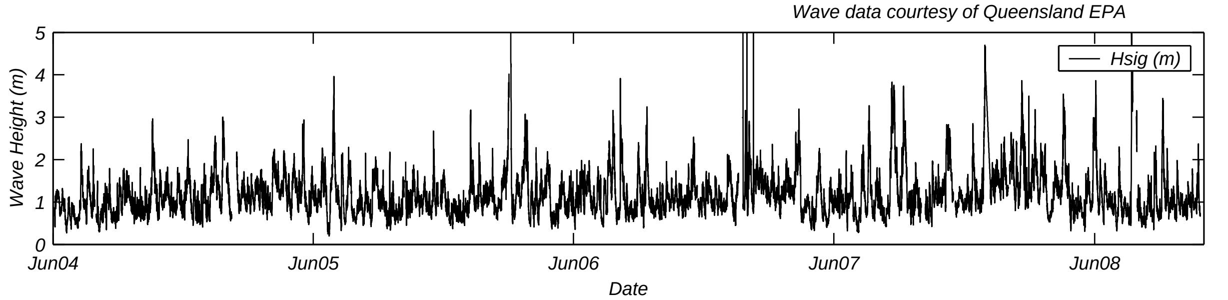


WRL Report No.2008/32	TIME−SERIES OF BEACH WIDTH(NORTH): JUNE 2004−OCTOBER 2008	Figure 7.3









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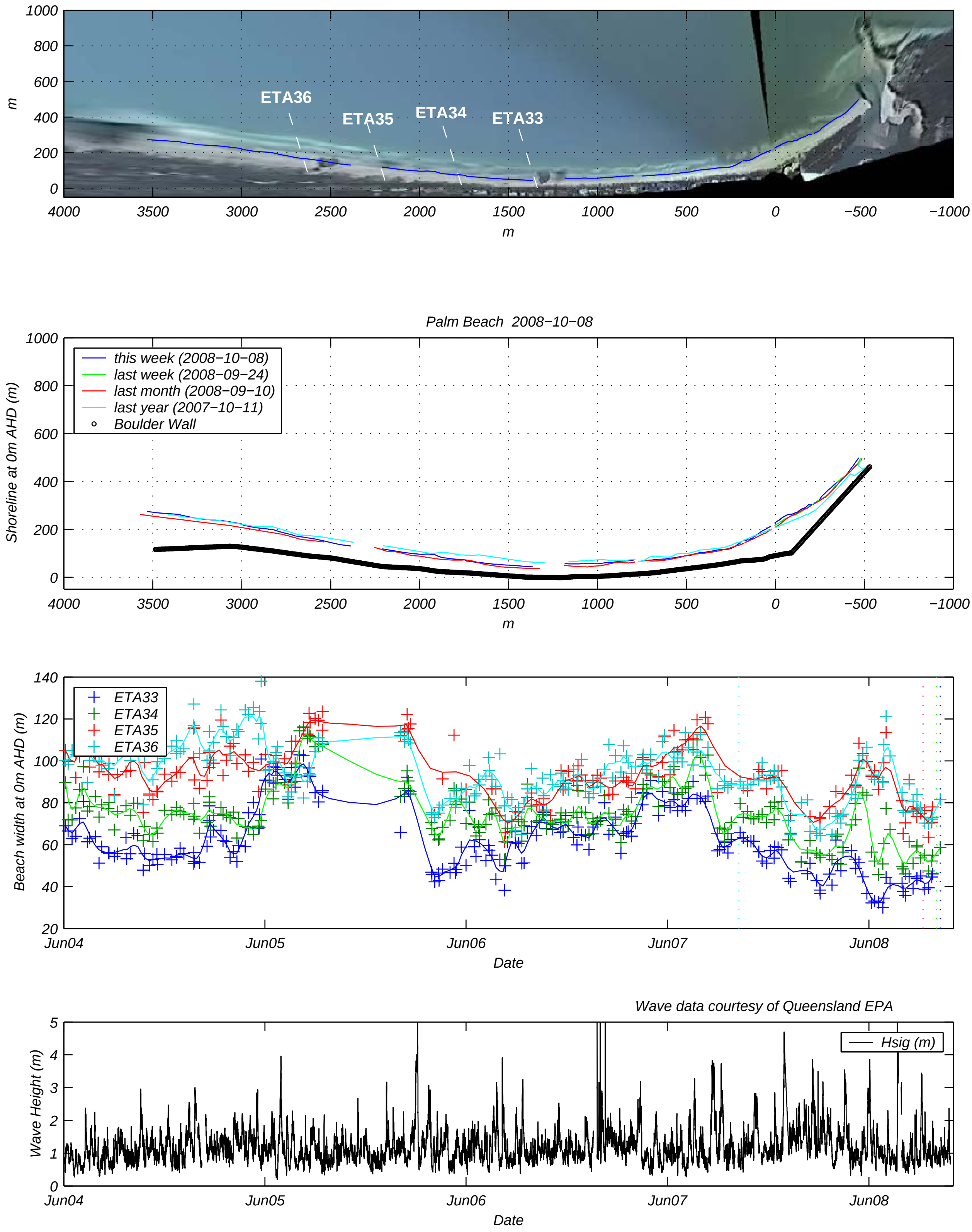
WRL Report No.2008/32	ON−LINE BEACH WIDTH ANALYSIS TO OCTOBER 2008(SOUTH)	Figure 7.4



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WRL Report No.2008/32	ON−LINE BEACH WIDTH ANALYSIS TO OCTOBER 2008(NORTH)	Figure 7.5

8. ANALYSIS OF EROSION-ACCRETION TRENDS

Coinciding with the implementation of the ARGUS-based beach monitoring program at Palm Beach in mid 2004, an image analysis technique was implemented enabling patterns of beachface slope erosion and accretion to be identified and quantified. On a monthly basis, hourly images throughout a single spring tide are analysed and a 3-D bathymetry of the beachface extending from the low tide waterline to the high tide waterline is derived. These data are further analysed to assess regions of beachface erosion and deposition within the Palm Beach embayment.

8.1 Methodology

A detailed description of the analysis techniques used to derive three-dimensional beachface bathymetry from two-dimensional image analysis was provided in Turner (2004). In summary, throughout a single spring tide cycle, the shoreline mapping technique is applied to locate the waterline in successive hourly images. The elevation corresponding to the detected waterlines is calculated on the basis of concurrent tide and wave information, which is incorporated in a model that combines the effects of wave setup and swash, at both incident and infragravity frequencies. As illustrated in Figure 8.1, if this process is repeated at all points alongshore throughout a complete spring-tide cycle, a three-dimensional bathymetry of the beachface - between the high tide and low tide waterlines - is derived. The beachface is the most dynamic region of sediment movement within the coastal system, and sand changes observed in this area are indicative of the total profile.

8.2 Monthly Beachface Bathymetric Mapping

Beachface bathymetries derived at approximately monthly intervals along the Palm Beach embayment are shown in Figure 8.2 (28th June and 31st July 2008), Figure 8.3 (27th August and 24th September 2008) and Figure 8.4 (21st October 2008).

Analysis of intertidal beachface maps in previous monitoring reports has identified a persistent feature of the Palm Beach embayment that is not easily discernable from the raw images or shoreline analysis. This feature is a distinct flattening of the beach gradient northward along the beachfront. This observation is consistent with the increasing exposure of the beach to predominantly south-easterly waves. The flattening of the beach gradient with increasing distance north of Currumbin is attributed to the modal beach state transitioning from more reflective (steeper), lower-intermediate morphology in the south, to increasingly dissipative (flatter), higher energy intermediate beach states towards the north.

Early in the current monitoring period (June 2008) the beachface could be seen to have two distinct beachface morphological compartments, with the first extending south and the second extending north of the 11th Street groyne. From directly adjacent the Currumbin creek entrance channel where the beachface was steep, the beachface became flatter in cross shore gradient with increasing distance to the north. The beachface was wide and flat on the southern side of the 11th Street groyne, where sand had accreted as a result of the northward migration of sand along the beach in response to the more southerly winter wave direction. In the second morphological compartment, immediately on the north side of the 11th Street groyne the beach was significantly more eroded, and also steep in cross shore gradient. Again, with further distance north, the beachface became flatter in cross shore gradient, with the beachface at the far north of the analysis area clearly wider and flatter than further south.

The beachface was significantly straighter in alignment by the end of July 2008 (Figure 8.2 bottom panel), as a result of storm waves which impacted the beach for a short period of time. Over most sections of the mapped area, the beachface can be seen to have eroded slightly, with the main exception being the already eroded area on the north side of the 21st Street Groyne. Lower wave conditions experienced in August resulted in very little observable change in beachface appearance (Figure 8.3 top panel), with the most notable change being a slight steepening of the beachface along the northern stretches.

Between August and September 2008 (Figure 8.3 bottom panel) there was again very little notable change in beachface bathymetry. The section of beach just north of the ARGUS station was observed to migrate slightly landward, while further north the beachface again became slightly flatter with sand developing at the toe of the beachface in terrace type formations.

The beachface map produced for October 2008 (Figure 8.4) shows a range of relatively discreet alterations in beachface bathymetry that occurred during the previous month. Directly in front of the ARGUS station and at the extreme southern end of the embayment, the beach was seen to migrate landward with accretion of sand to the beachface. This resulted in the beachface also becoming flatter in cross shore gradient at these locations. There was a slight steepening of the cross shore beachface gradient along the middle regions of the embayment. In contrast, the far northern stretch of the beach was observed to erode at the toe, creating a steeper beach profile than typical for this section of the beach.

8.3 Monthly Erosion-Accretion Trends

By further processing of the monthly bathymetries shown in Figures 8.2 - 8.4, a quantitative measure of the net change in sand volumes across the beachface (between the elevations of -0.5 and +0.7 m AHD) throughout the Palm Beach embayment can be obtained. Figure 8.5a shows the results of these calculations to determine the net change in bed elevation between May – June 2008, June – July 2008, and July – August 2008, and Figure 8.5b for August – September 2008, and September – October 2008.

The top panel of Figure 8.5a shows that from May – June 2008 there were localised regions of both erosion and accretion, with the most extensive change in beachface volumes occurring along the southern sand spit. The beachface gained up to 1 m in vertical elevation along the section of beach south of the ARGUS station, while further north other notable changes included modest erosion on the north side of the 11th Street groyne and modest accretion north of the 21st Street groyne. Averaged along the entire measured section of the Palm Beach embayment the net change in sand volume within the mapped beachface was **+23,994 m^3** of accretion, which equates to **+7.2 m^3 per m of shoreline** when averaged over the length of the beach (between -0.5 and +0.7 m AHD).

From June to July 2008 (Figure 8.5a, middle panel), the beach suffered a modest level of erosion over most sections, with the most extensive erosion occurring along the southern sand spit and just north of the 21st Street groyne. In these regions the beachface lost up to 1 m in vertical elevation between June and July, while at other sections of the beach there was negligible change in beachface volume. In total, between 28th of June and 31st of July 2008 there was a predicted net erosion of **-28,622 m^3** across the length of the embayment, equating to **-8.6 m^3 per m of shoreline** (between -0.5 and 0.7 m AHD).

Between July and August 2008 (Figure 8.5a bottom panel) there was little net change in intertidal beachface volumes experienced, with some regions of the beach experiencing minor erosion while others accreted slightly. In general, there was less than 0.2 m change in vertical elevation experienced at any location along the embayment during this one month period. From July to August there was a net beachface erosion over the entire embayment of **-4,475 m^3**, equating to **-1.4 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

From August to September 2008 (Figure 8.5b top panel), the beach again experienced only minor erosion/accretion changes, with the general trend being very minor accretion. A localised stretch of beach just north of the ARGUS station experienced the most notable change in beachface volumes, dropping by up to 1 m in vertical elevation over a stretch of beach approximately 100 – 200 m long. Overall there was accretion of **+13,489 m^3**, equating to **+4.1 m^3 per m of shoreline** over the intertidal beachface (-0.5 m to +0.7 m AHD).

During the final month of the current monitoring period between September and October 2008 (Figure 8.5b bottom panel), the change in beachface volumes was a reversal of that experienced during the previous month. Generally there was very minor erosion experienced along most sections of the embayment, with the only exceptions being the stretches of beach just north of the ARGUS station and adjacent the Currumbin Creek training wall. In total the net beachface erosion over the entire embayment was **-7,895 m^3**, equating to **-2.4 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

8.4 Net Erosion-Accretion Trends: June – October 2008

The net change in beachface bathymetry calculated for the previous and present monitoring periods are summarised in Figure 8.6a-e. The upper panel of Figure 8.6a is for the six month period June –November 2004, while the lower panel of Figure 8.6a is for the six month period December 2004 – May 2005. Figure 8.6b shows the net change in beachface bathymetry for the period of June 2005 – September 2005 (at which time the cameras were temporarily removed for roof repairs), and February to May 2006. The net change in beachface bathymetry for the period June to November 2006 is shown in the upper panel of Figure 8.6c, while the lower panel of Figure 8.6c shows the net change during the period December 2006 to May 2007. The net change in beachface bathymetry observed during the period May to November 2007 is shown in the upper panel of Figure 8.6d, while the net change for the period November 2007 to May 2008 is shown in the lower panel. The net change experienced during the present five month monitoring period from mid May to mid October 2008 is shown in Figure 8.6e.

During June to November 2004 (Figure 8.5a, upper panel) the region of beach that extends southward from midway between 11th Street groyne and Currumbin Spit experienced a period of distinct beach accretion, centred around two areas: the first in the lee of the southern offshore sand dump boxes area, and the second where sand was placed from the dredging of the lower Currumbin Estuary during July – September 2004. Northward of this region a general trend of net beach erosion was observed. Lowering of the beachface profile by 0.2 m to 0.6 m was measured along the majority of the embayment.

In contrast, during December 2004 to May 2005 the southern sand spit eroded, whereas the region of beach extending from in front of the Royal Palm building (0 m alongshore) to around the 11th Street groyne exhibited a period of major beachface accretion. During this time the positive benefits of the 2004 nearshore nourishment campaign had emerged and were very clearly evident during this monitoring period.

The monitoring period June – September 2005 was dominated by the re-distribution along the Palm Beach embayment of the nearshore nourishment placed in the latter part of 2004. The northward movement of the surfeit of sand away from the region immediately inshore of the nourishment area (500 – 1000 m alongshore) resulted in the retreat of the southern half of the embayment, countered by accretion along the northern half as sand moved alongshore. At the extreme southern end along the sand spit adjacent to the Currumbin estuary, the beach accreted, in response to the beachface placement of sand dredged from the estuary entrance. During this four month period the Palm Beach embayment experienced an embayment-scale rotation, as a new equilibrium shoreline alignment developed to accommodate the approximately 250,000 cubic metres of sand had been placed within the nearshore at that time.

The monitoring period December 2005 – May 2006 (Figure 8.6b) was dominated by the storm erosion event that occurred in early March 2006, with substantial erosion of the beach resulting, and only modest recovery by May 2006. By May 2006 around 20% of the total sand volume that had been removed from the beachface during the storm three months earlier had returned to the beach. Net vertical erosion of the beachface by 1 m or more was characteristic of the entire embayment through to May 2006. Only in one very localised area immediately up-drift of the 11th Street groyne had this net erosion trend reversed by the end of May.

Modest accretion continued within the central and northern regions of the Palm Beach embayment during the monitoring period June – November 2006 (Figure 8.6c top panel). Toward the southern end the persistence of transverse bar-rip morphology resulted in a complex pattern of localised erosion-accretion ‘cells’ alongshore. At the extreme southern end of the embayment a distinctive trend of net beach accretion was observed, largely due to the beachface placement of sand in this region as a part of sand removal operations undertaken in October-November within the entrance to the adjacent Currumbin Creek (refer section 2.3).

During the period December 2006 to May 2007, the beachface across the northern sections of the embayment fluctuated between periods of erosion and accretion, with little net change in mapped beachface bathymetry. It can be seen from Figure 8.6c that the beachface along this section of the beach effectively steepened throughout the six month period, with minor erosion on the seaward edge of the beachface and minor accretion across the landward edge. South of the beach monitoring cameras, significant erosion occurred, with the beachface lowering by up to 1 m in vertical elevation along the Currumbin Spit. The trend averaged across the entire embayment throughout this period was minor accretion.

Significant net erosion occurred along the entire stretch of the embayment north of the ARGUS camera station during the period May to November 2007. During this time a series of four separate storm events with high energy wave conditions impacted the Gold Coast beaches. The most significant section of erosion was for the 1500 m stretch to the north of the Royal Palm building, where in excess of 1 m in vertical beachface elevation was lost as a result of the storm events. At the extreme southern end of the embayment a localised trend of net beach accretion was observed, again largely due to the placement of sand in this region as a part of sand removal operations undertaken in October-November within the entrance to the adjacent Currumbin Creek (refer section 2.3).

Between December 2007 and May 2008, net erosion again occurred along the Palm Beach embayment. While most of this period was characterised by stable and slightly accretionary beach conditions, the storm events experienced during December 2007 and January 2008 dictated the net sediment transport determined for the intertidal beachface. Localised sections of the beach suffering the most notable net erosion were along the southern Currumbin Spit, on the south side of the 11th Street groyne, and to the north of the 21st Street groyne. In all of these locations, the intertidal beachface lost up to 1 m in vertical elevation, and the position of mean sea level migrated some 10 to 20 m landward.

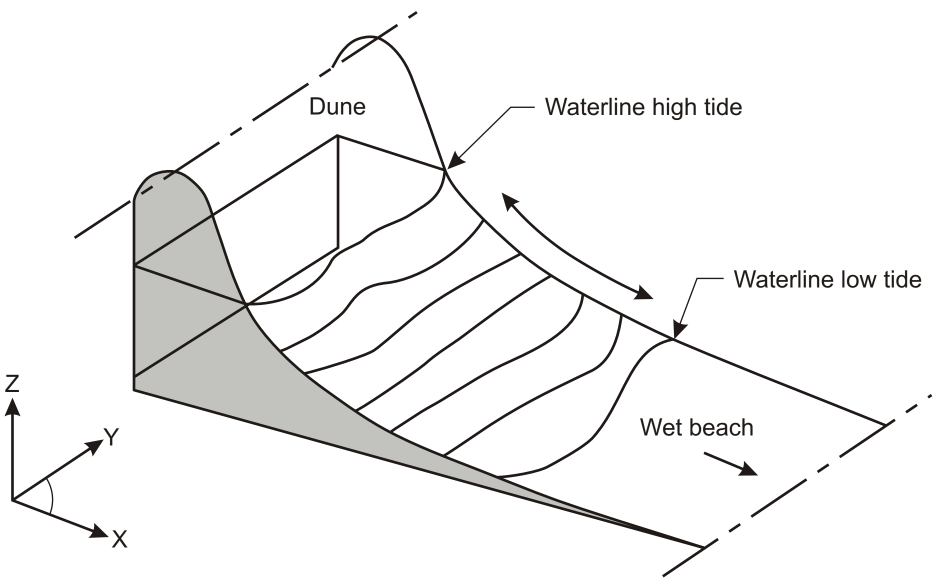
During the current monitoring period two large and distinct regional variations in beachface erosion/accretion occurred. Firstly, the region of beach extending from in front of the ARGUS station south along the Currumbin spit experienced modest net accretion, with the beachface gaining in excess of 1 m in vertical elevation. In contrast, the stretch of beach between the 11th Street and 21st Street groynes suffered erosion of up to 1 m in vertical beachface elevation. Between the ARGUS station and the 11th Street groyne minor erosion occurred, while north of the 21st Street groyne minor accretion was evident.

8.5 Total Erosion-Accretion Trends: June 2004 – October 2008

Figure 8.7 shows the total net change in beachface bathymetry for the four and a half year monitoring period June 2004 to October 2008. It has been observed in previous monitoring reports, that the net erosion and accretion trends can typically be separated into four compartments along the length of the Palm Beach embayment. South of the monitoring cameras significant long term net erosion is typically evident, while the section of beach between the Royal Palm building and the 11th Street groyne has generally been a location of accretion. Over the stretch of beach between the 11th Street and 21st Street groynes there has typically been minor net erosion, while north of the 21st Street groyne there has been more modest net erosion observed at the end of previous monitoring periods.

The changes in beachface bathymetry that have occurred between May and October 2008 have made these typical long term observations less obvious. The erosion/accretion map shown in Figure 8.7 for the period June 2004 to October 2008 shows that there has been only a minor net erosion over the stretch of beach south of the 11th Street groyne, while the remainder of the embayment further to the north has experienced more significant net erosion. While the northern end of the embayment is typically exposed to higher energy wave conditions, this also identifies the long term benefit on erosion reduction achieved with the placement of Currumbin Creek dredge spoil onto the southern stretch of the embayment.

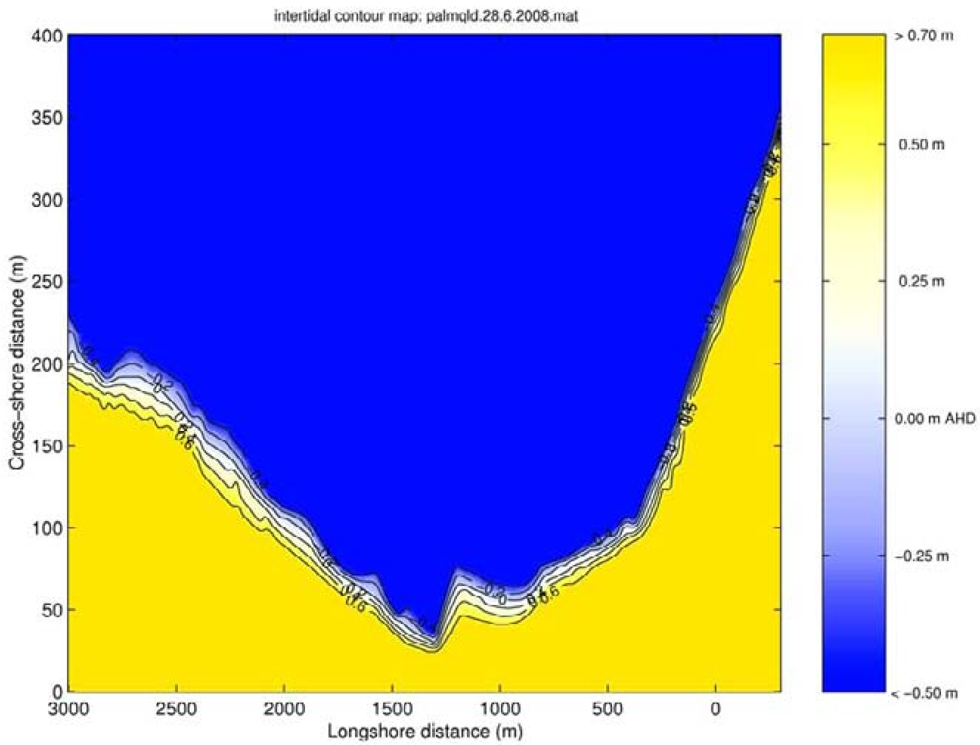
Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **-54,584 m^3** of sand has been eroded along the ~3.5 km of beachfront included in this monitoring program, equating to an alongshore-average of around **-16.5 m^3** within the intertidal profile, for every 1 m alongshore.



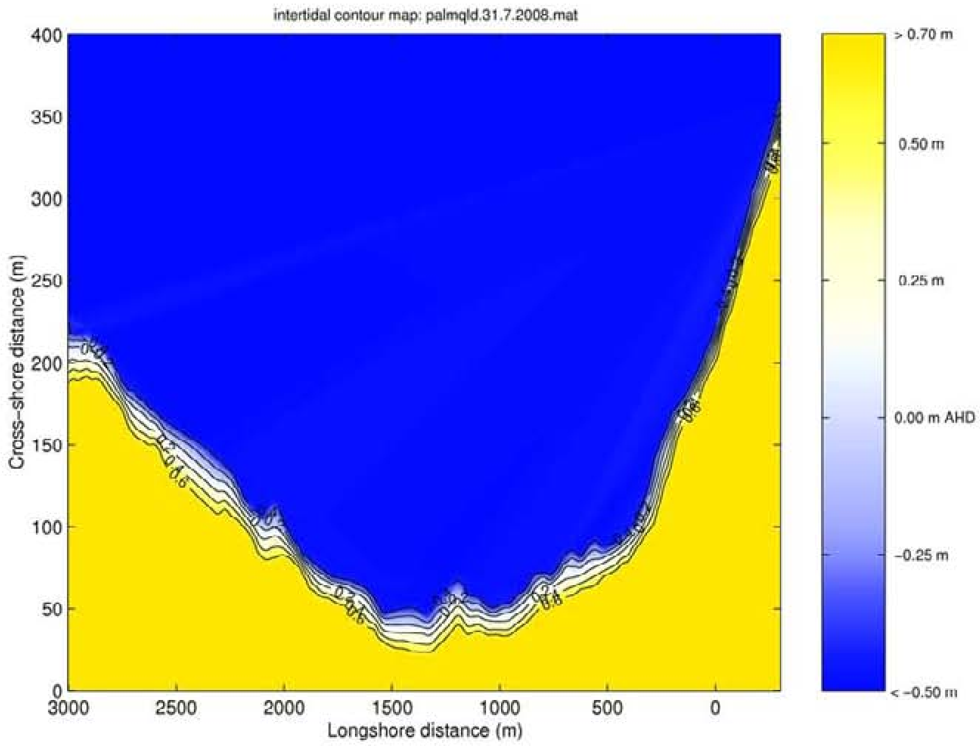
DEFINITION SKETCH
INTERTIDAL BATHYMETRY FROM HOURLY WATERLINES

Figure
8.1

JUNE 2008

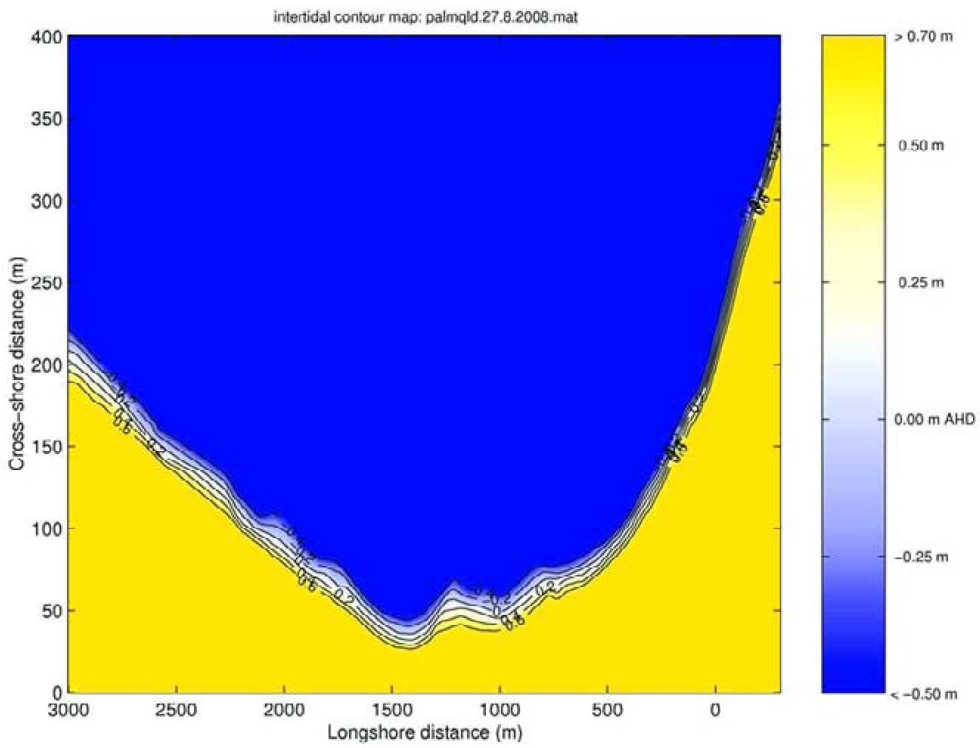


JULY 2008

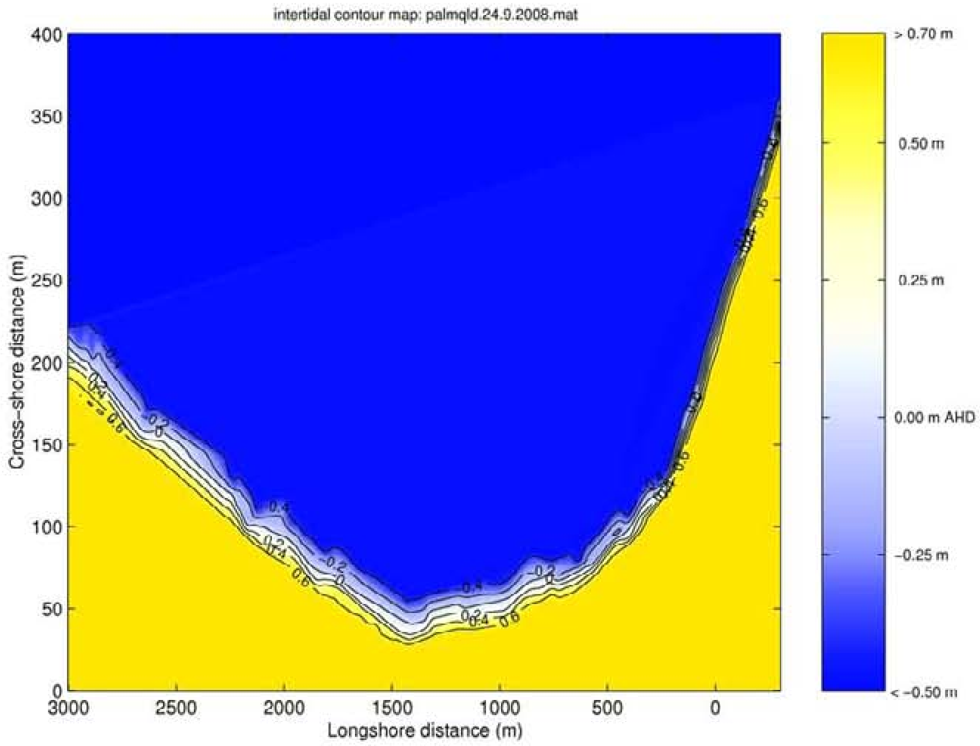


WRL Report No. 2008/32	BEACHFACE MAPPING - JUNE, JULY 2008	Figure 8.2 06037-8-2.cdr

AUGUST 2008

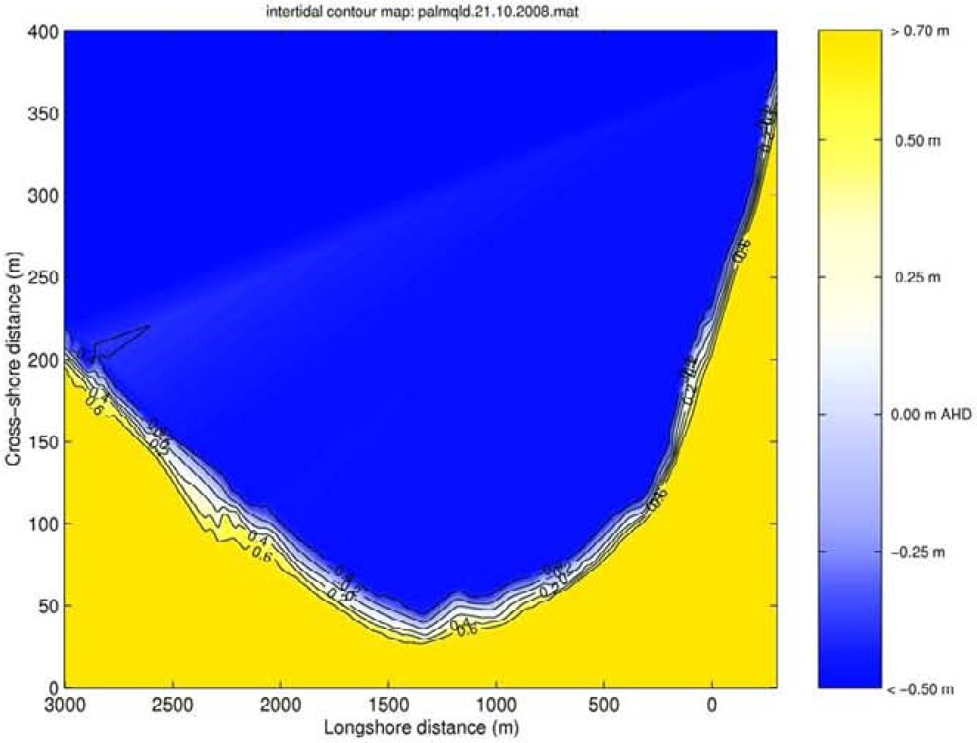


SEPTEMBER 2008



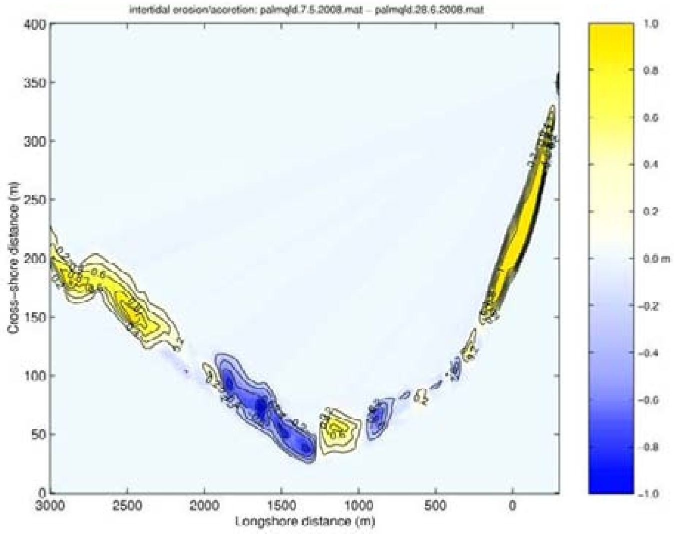
WRL Report No. 2008/32	BEACHFACE MAPPING - AUGUST, SEPTEMBER 2008	Figure 8.3 06037-8-3.cdr

OCTOBER 2008

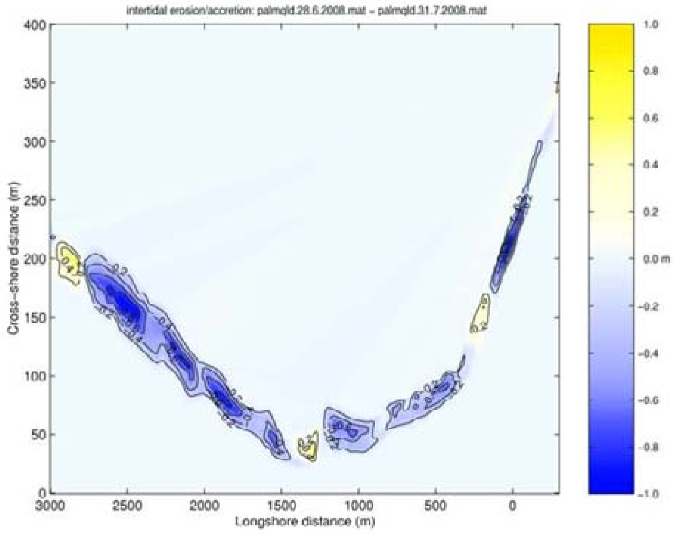


WRL Report No. 2008/32	BEACHFACE MAPPING - OCTOBER 2008	Figure 8.4 06037-8-4.cdr

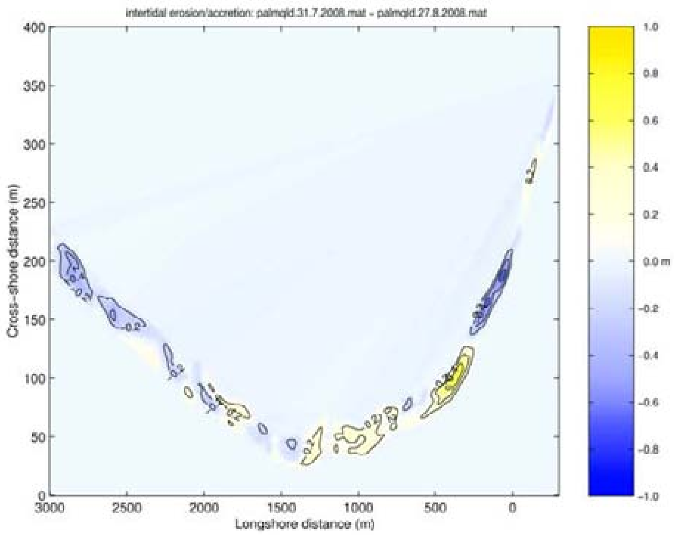
MAY - JUNE 2008



JUNE - JULY 2008

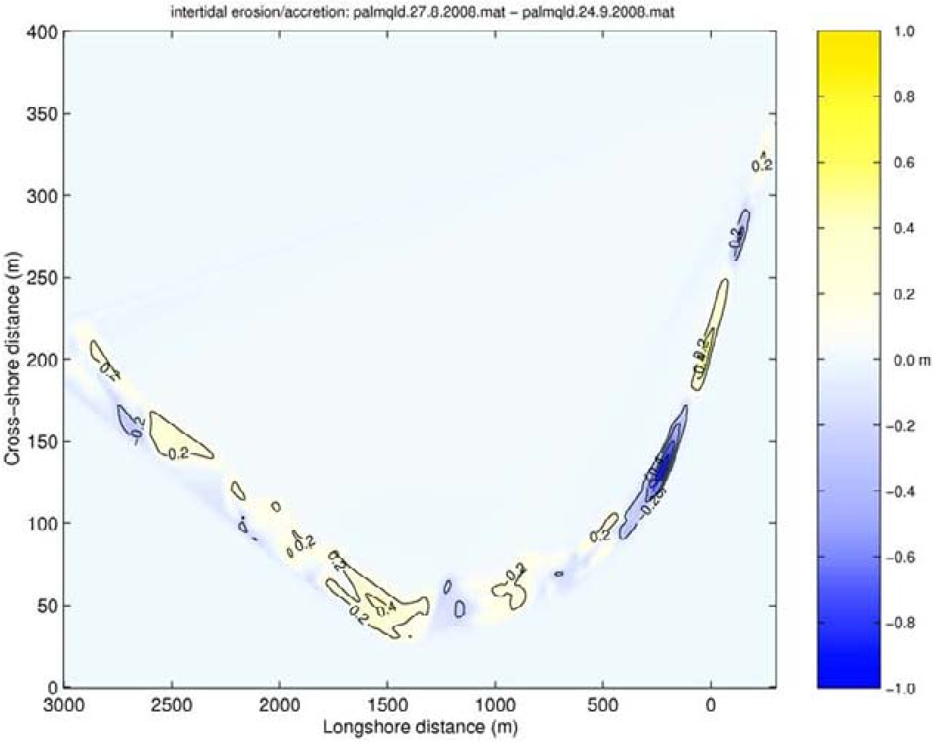


JULY - AUGUST 2008

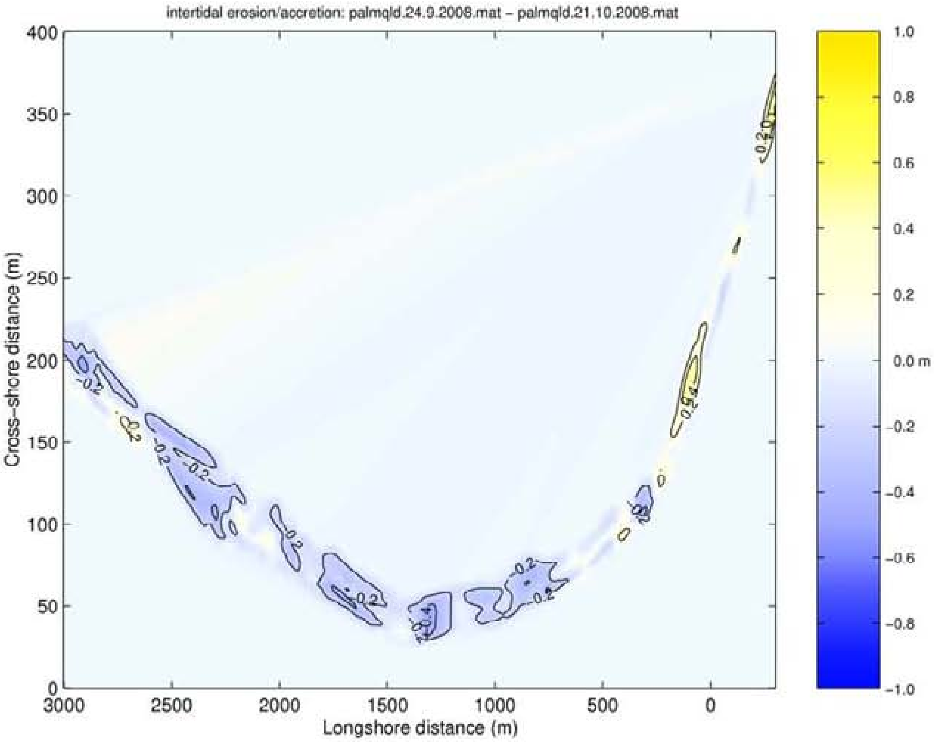


WRL Report No. 2008/32	MONTHLY EROSION/ACCRETION: MAY - AUGUST 2008	Figure 8.5a 06037-8-5a.cdr

AUGUST - SEPTEMBER 2008

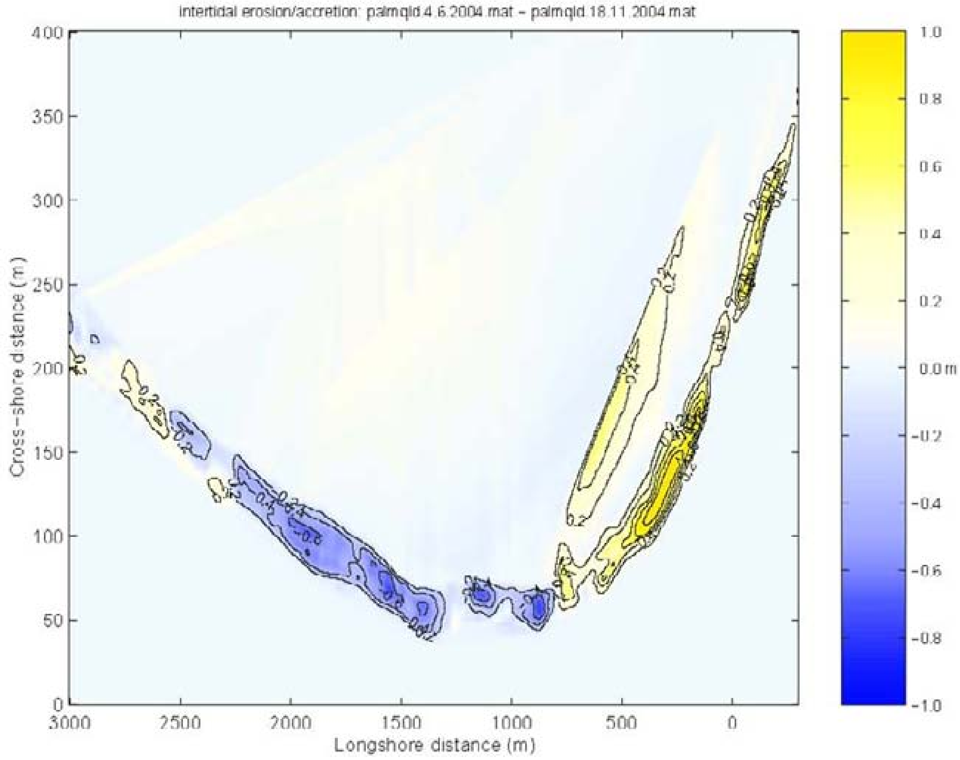


SEPTEMBER - OCTOBER 2008

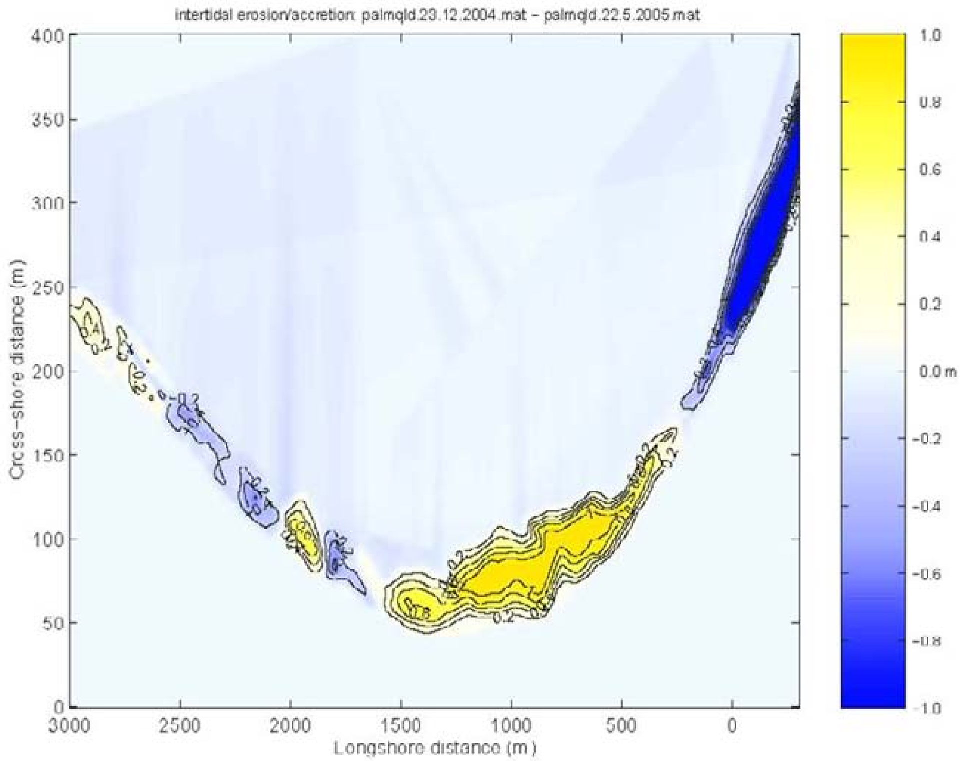


WRL Report No. 2008/32	MONTHLY EROSION/ACCRETION: AUGUST - OCTOBER 2008	Figure 8.5b 06037-8-5b.cdr

NET CHANGE: JUNE - NOVEMBER 2004

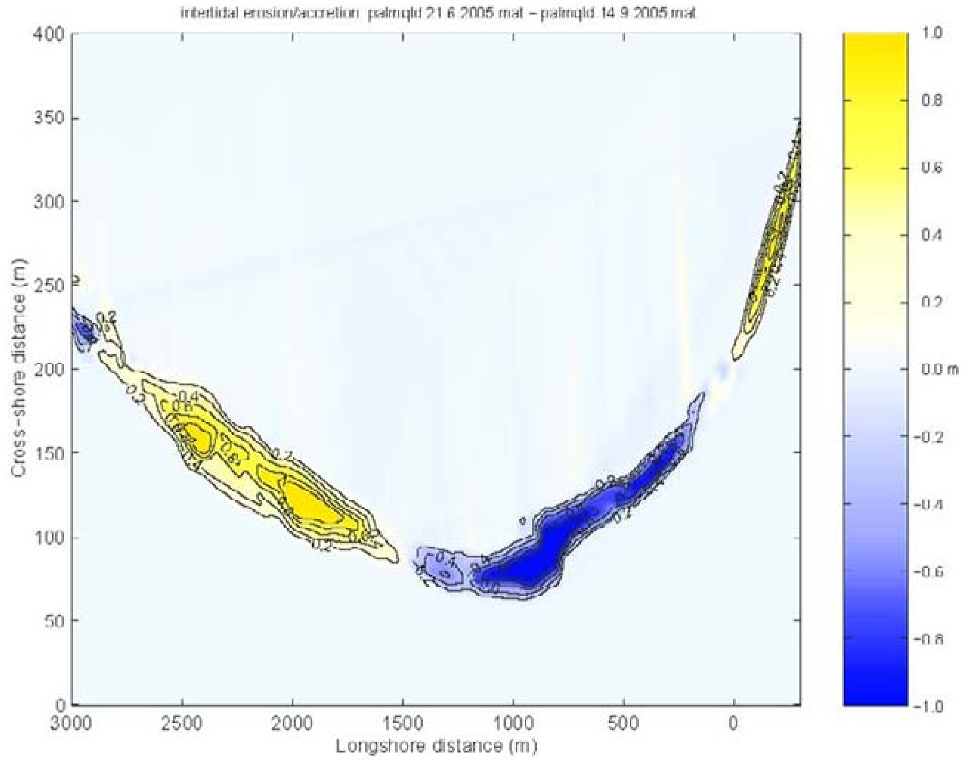


NET CHANGE: DECEMBER 2004 - MAY 2005

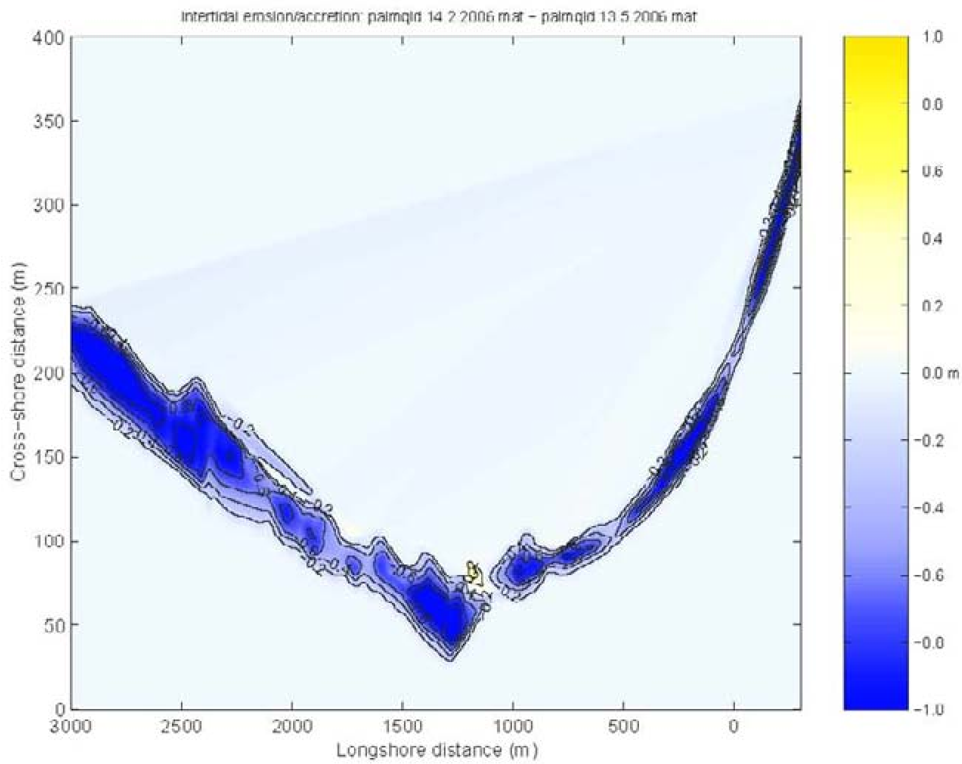


WRL Report No. 2008/32	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6a 06037-8-6a.cdr

NET CHANGE: JUNE - SEPTEMBER 2005

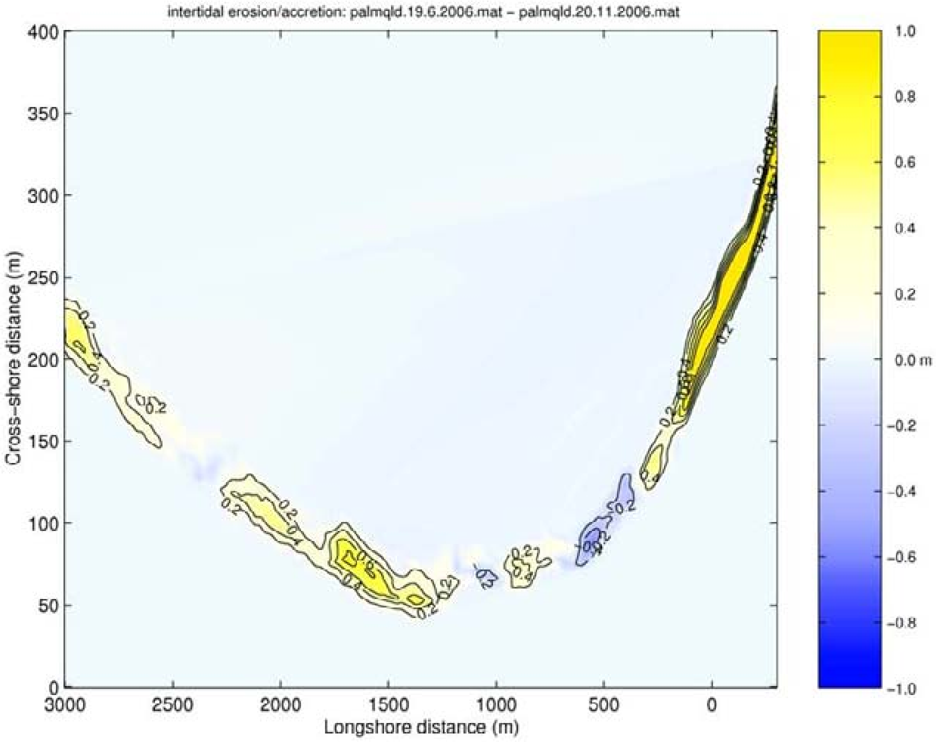


NET CHANGE: FEBRUARY - MAY 2006

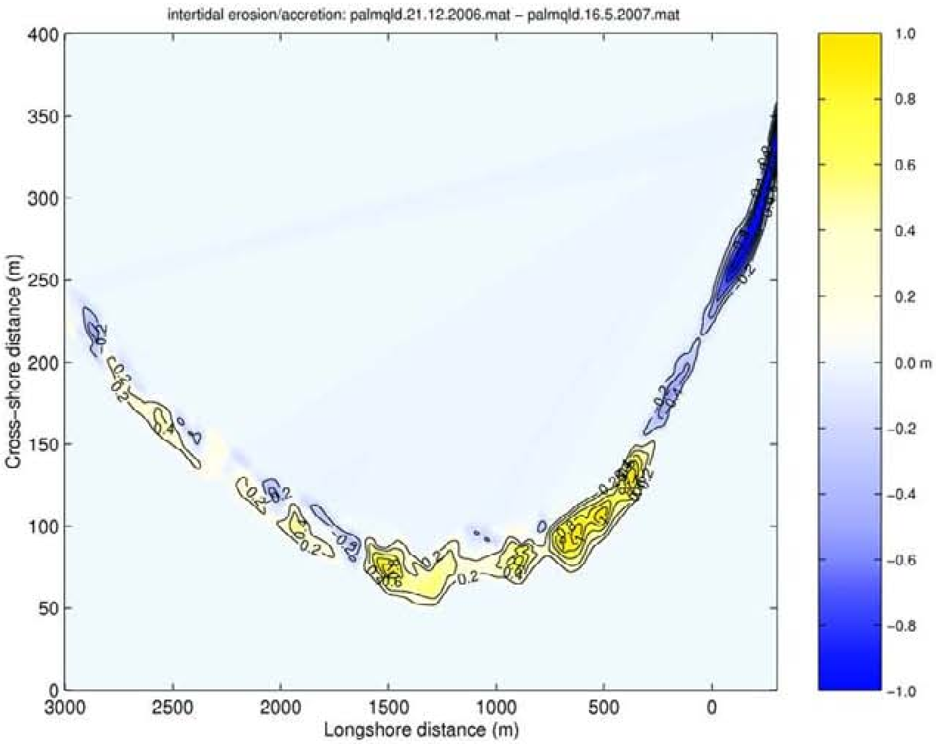


WRL Report No. 2008/32	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6b 06037-8-6b.cdr

NET CHANGE: JUNE - NOVEMBER 2006

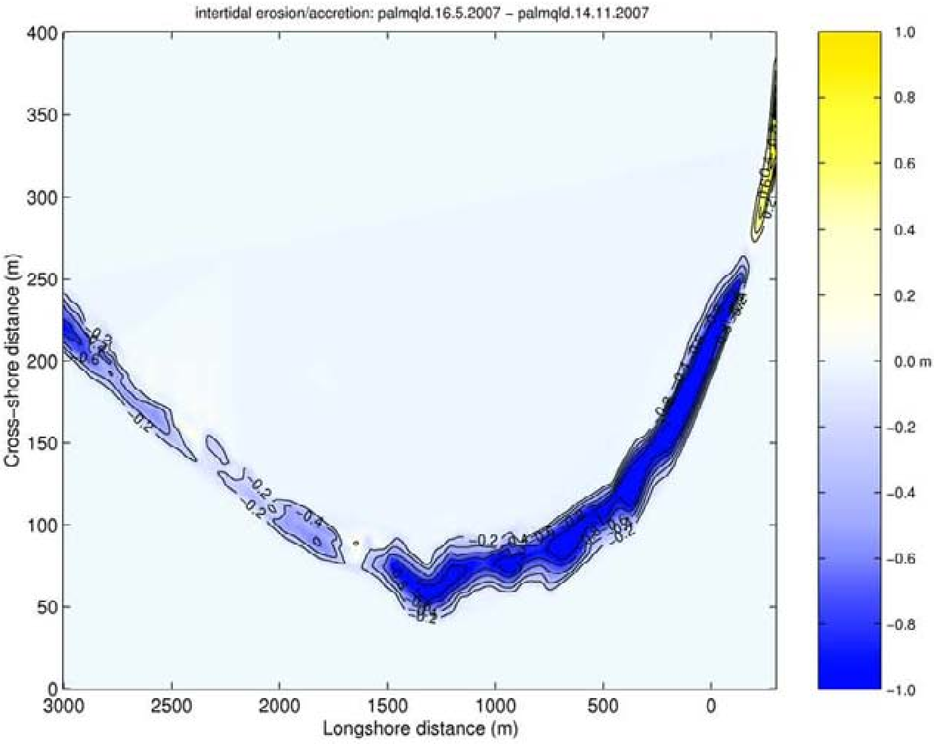


NET CHANGE: DECEMBER 2006 - MAY 2007

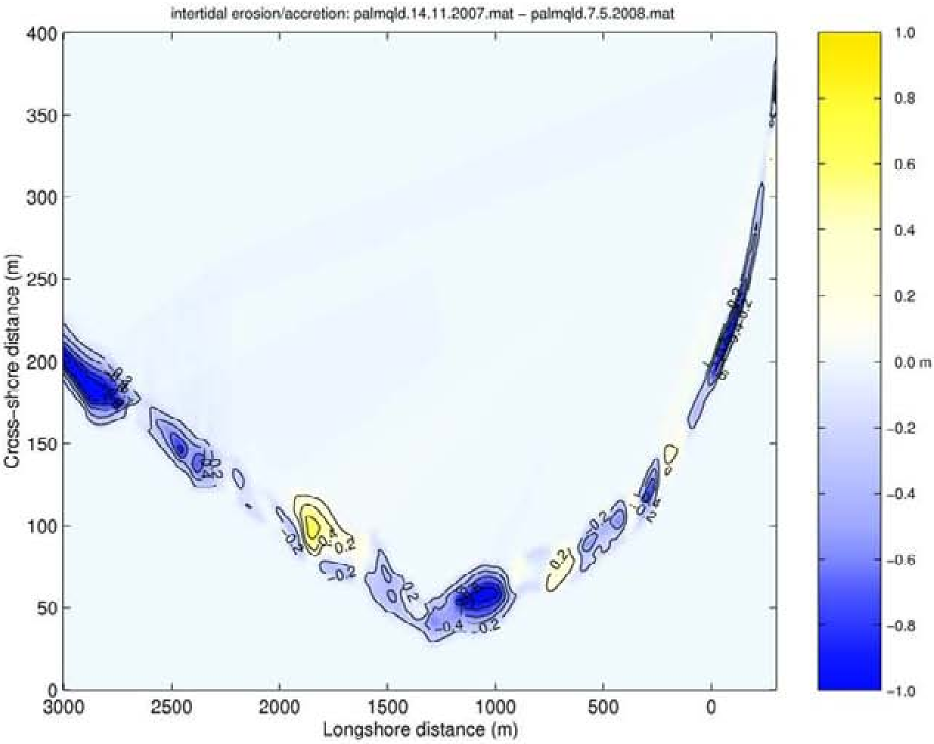


WRL Report No. 2008/32	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6c 06037-8-6c.cdr

NET CHANGE: MAY - NOVEMBER 2007

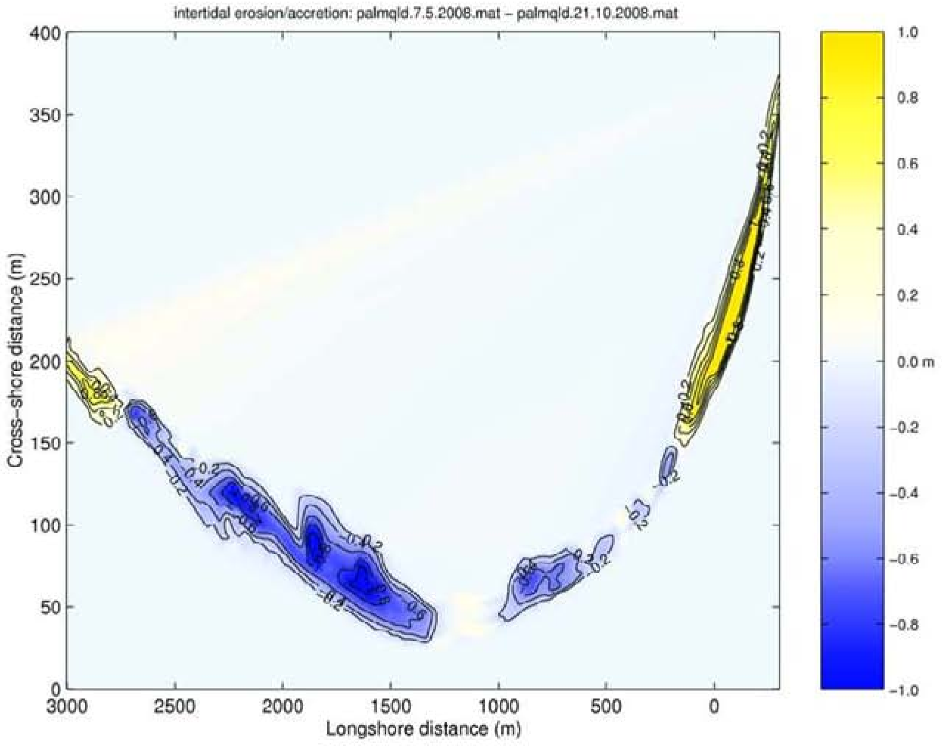


NET CHANGE: NOVEMBER 2007 - MAY 2008



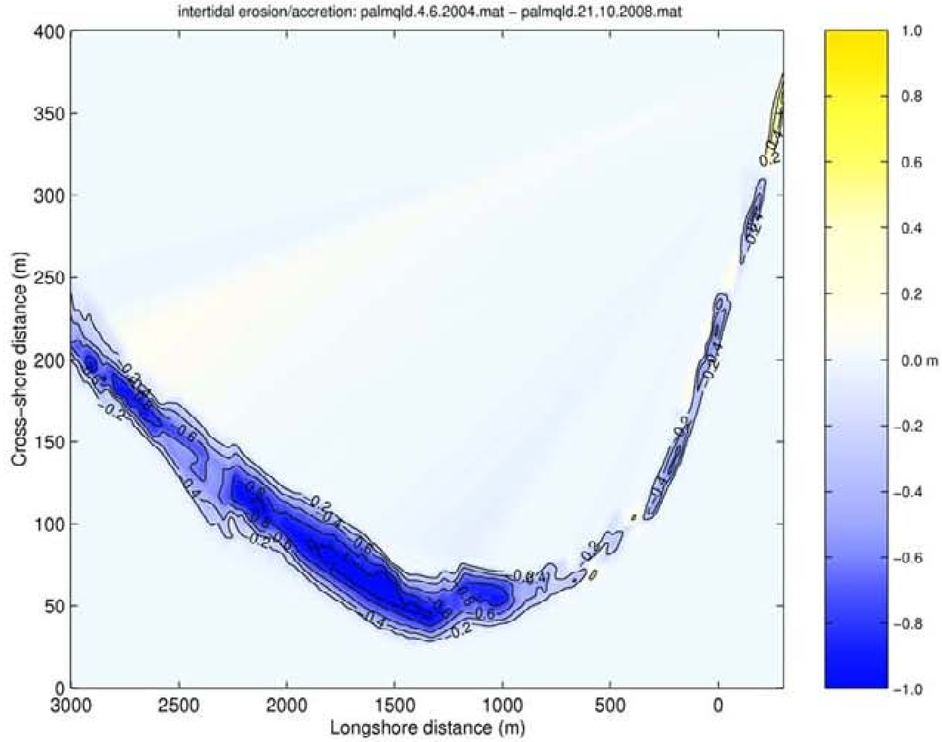
WRL Report No. 2008/32	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6d 06037-8-6d.cdr

NET CHANGE: MAY - OCTOBER 2008



WRL Report No. 2008/32	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6e 06037-8-6e.cdr

TOTAL NET CHANGE: JUNE 2004 - OCTOBER 2008



WRL Report No. 2008/32	TOTAL NET EROSION/ACCRETION TO OCTOBER 2008	Figure 8.7 06037-8-7.cdr

9. SUMMARY AND CONCLUSIONS

The present monitoring period June to October 2008 is the ninth in the series of regular six-month monitoring reports to be produced for Palm Beach. The end of this monitoring period marks almost four and a half years of continuous analysis of the Palm Beach embayment.

9.1 Qualitative Visual Assessment

An alongshore wave energy gradient generally exists at Palm Beach, due to the increased exposure at the northern end of the embayment to the predominately south-easterly swells. The effect of this gradient on the beach and nearshore zone is typically more noticeable following periods of high wave energy, with the beach appearing more uniform across its length after periods of low wave energy.

Beach and nearshore conditions during the current five month monitoring period of June – October 2008 were dictated by typically lower energy wave conditions. The storm events experienced in early June and late July resulted in minor erosion of the beach, however, the ongoing low wave energy experienced from August to October saw low tide terrace features develop at the beachface, increasing the beach width.

A qualitative visual assessment of the net trends in beach adjustment during this period can be seen by contrasting images of the beach obtained at the start and end of this five-month monitoring period. A visual assessment of resulting beach changes from May to October 2008 (Figure 5.2 and Figure 5.3) shows that during the present monitoring period along the southern section of the embayment, the beach increased in width very slightly, primarily as a result of the additional sand stored in the low tide terrace features. Immediately adjacent to the Currumbin Creek training wall, the fillet of sand that was present at the start of June can be seen to have eroded by the end of the current monitoring period. Looking north along the Palm Beach embayment (Figure 5.3), the beach can be seen to have increased in width very slightly between the ARGUS station and the 11th Street groyne. More modest accretion occurred on the north side of the 11th Street groyne, while immediately adjacent the 21st Street groyne on both the southern and northern sides, the beach changed very little in width. More notable accretion appears to have occurred along the far northern stretches of the Palm Beach embayment during the present monitoring period.

Extending this qualitative visual assessment of images to include the entire four and a half year monitoring period, (Figures 5.4 and 5.5) from June 2004 to November 2004, along the southern beach the surfeit of sand that was observed within the intertidal and nearshore zones in June 2004, appeared to have moved onshore by November, resulting in modest beach widening and a general straightening of the beach alignment in this southern region. Towards the north, from June to November 2004 the southern end of this region appeared to have generally widened. In contrast, towards the middle and northern end of the embayment, the shoreline appeared much more irregular and scalloped, with a discernable trend of a generally narrower beach.

From December 2004 to May 2005 the southern beach receded again, and from visual assessment was clearly narrower than the initial beach conditions observed 12 months earlier in June 2004. In contrast, towards the north a general trend of beach widening was observed, with the beach reverting to a more uniform alignment than was observed to develop during the preceding six month period.

During June to December 2005 a general trend of beach widening was apparent at the far southern end of the Palm Beach embayment, while in the region in the immediate vicinity of the Royal Palm building little net change in beach width is discernable. The region immediately south of the 11th Street groyne decreased in width, while the region between the 11th and 21st Street groynes increased in beach width. By December 2005 the southern beach was similar to the commencement of the monitoring program in June 2004, while along the central and northern regions of embayment the impacts of the nearshore nourishment campaign were clearly discernable, with the beach especially to the south and between the 11th and 21st Street groynes exhibiting a substantially wider beach and more uniform alignment alongshore.

During the period December 2005 to May 2006 a distinctive trend of beach narrowing was apparent at the far southern end of the Palm Beach embayment in the region of the Currumbin Spit. Immediately south of the 11th Street groyne the beach had increased in width, while the region between the 11th and 21st Street groynes and to the north exhibited a general trend of beach retreat. The beach conditions that prevailed at the end of May 2006 along the southern Palm Beach embayment were similar to the eroded conditions observed 12 months earlier in May 2005. Along the northern beach the conditions in May 2006 were intermediate to the accreted beach that was observed in May 2005, and the eroded beach observed six months prior to that time in December 2004.

During the period between May and November 2006, a general trend of beach widening occurred across the far southern end of the Palm Beach embayment, while a more modest trend of increasing beach width was observed in the immediate vicinity of the Royal Palm building. Minor recession occurred across the region immediately south of the 11th Street groyne, while the region immediately to the north slightly widened. In the vicinity of the 21st Street groyne and further north along the Palm Beach embayment, little net change in the beach was observed.

From November 2006 to May 2007 notable beach recession occurred across the far southern end of the beach in the region of the Currumbin Spit, reducing further to the north in the immediate vicinity of the Royal Palm building. Looking northward along the Palm Beach embayment, there was significant accretion on the southern side of the 11th Street groyne, as well as in the vicinity of the 21st Street groyne and further to the north. The similarity in appearance of the beach and nearshore zone looking both south and north, between the images taken at the end of May 2005 and May 2006, was worth noting.

From June to November 2007, the southern section of beach in the region of the Currumbin Spit widened significantly, which was primarily the result of nourishment of this section of the beach during October and November. The effect of the nourishment on beach width decreases rapidly in a northward direction, with the beach actually decreasing in width in the vicinity of the Royal Palm building during the same period. Across the northern section of the Palm Beach embayment, the majority of the beach experienced a trend of erosion between June and November 2007, with the sections of beach adjacent the 11th Street groyne experiencing the most extensive narrowing, and erosion further north around the 21st Street groyne less pronounced.

During the period between November 2007 and May 2008 the beach to the south of the Royal Palm building can be seen to slightly narrow. Further north, significant net erosion occurred in the vicinity of the 11th Street groyne and also to the north of the 21st Street groyne. The effect of the higher energy waves experienced from December 2007 to February 2008 were evident at the end of this six month monitoring period, with the surfzone somewhat flatter and wider in May 2008 compared to November 2007.

Between May and October 2008 the beach generally widened slightly along the southern stretches, in particular the location seaward of the Royal Palm building, however, there was slight erosion at the far southern end of the beach, immediately adjacent the Currumbin Creek entrance training wall. There was only very minor net changes in beach width along the northern stretches of beach, however, significant quantities of sand could be seen to have developed with the growth of low tide terrace features.

9.2 Shoreline Variability and Weekly Beach Width Analysis at GCCC Survey Lines ETA29 – ETA36

Based upon the quantitative analysis of the available weekly shoreline positions during the monitoring period 01/06/08 – 31/10/08, it can be seen from Figure 6.2 that the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 25 m (relative to the alignment of the back-beach boulder wall) on the northern side of the 11th Street groyne, to around 170 m at the Location of the ARGUS station on the Royal Palm building. The envelope of beach width changes along the entire embayment was in the range of 15 - 50 m during this period.

The mean beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 35 – 85 m along much of the Palm Beach embayment. With the alignment of the boulder wall changing orientation and dipping landward at the southern sand spit, the measured beach width is observed to increase accordingly, reaching 150 m in front of the site of the cameras (i.e., distance = 0 m alongshore in Figure 6.3). In the far north the maximum beach width was approximately 30 m wider than the mean width, while the minimum width was only 10 m – 15 m narrower than the mean shoreline position. South of the 11th Street groyne, the variation between maximum and minimum beach width was observed to be less than the northern half of the embayment, with both maximum and minimum widths approximately 10 m wider and narrower respectively, than the mean shoreline position. The standard deviation of shoreline position was typically 10 m – 15 m for the section of beach north of the 21st Street groyne. Between the 21st Street and 11th Street groynes, the standard deviation was observed to decrease with further distance south along the beach, and ranged from approximately 12 m at the 21st street groyne to 5 m at the 11th Street groyne. The standard deviation of shoreline position was more variable along the southern sections of beach, with the highest standard deviation of slightly less than 20 m recorded immediately adjacent the Currumbin Creek training wall.

The variation in shoreline position measured at Gold Coast City Council's southern transect ETA29, located across the southern sand spit, was seen to change very little in width during the current five month monitoring period. In the later months of September and October the beach increased slightly in width by approximately 10 m. The transects north of the Royal Palm building (ETA30, ETA31, and ETA32) all showed similar behaviour in terms of beach width throughout the current monitoring period. At these sections, the beach was observed to increase in width during June, and then remain relatively stable throughout the remaining four months. At the completion of the current monitoring period, the beach at transects ETA30, ETA31, and ETA32 was approximately 10 m wider than at the start of the monitoring period five months earlier. Further north along the embayment, the beach width at transect ETA33 behaved similar to the transects further south, increasing in width during June/July, and then remaining reasonably stable throughout the remaining months. At transects ETA34 to ETA36 the beach width peaked in July then steadily decreased during August and September, before stabilising for the final month of the current monitoring period. At the completion of the current monitoring period, the beach at the northern transects had eroded by 10 m to 30 m when compared to beach width five months earlier.

When the weekly shoreline data for the period June to October 2008 was re-analysed to assess beach width changes relative to the mean shoreline position for the preceding six month period (Figure 6.6), the analysis showed that the beach was generally narrower between the Royal Palm building and the 21st Street Groyne. North of the 21st Street groyne the beach was wider during the current monitoring period than the mean shoreline position from six months earlier, with the maximum beach width between June and October 2008 being almost 40 m greater. The area immediately in front and slightly south of the Royal Palm building was also wider during the current monitoring period than six months earlier. However, at the far southern end of the Currumbin Spit, the beach was generally narrower during the current monitoring period, partially due to the sand fillet that had been established against the Currumbin Creek training wall during the previous monitoring period.

In summary, the current five month monitoring period resulted in relatively minor changes in beach width compared to previous monitoring periods. Moderate storm conditions were experienced on several occasions during the months of June and July, while the remaining three months provided ongoing low energy wave conditions. During the current five month monitoring period, generally, there were slight increases in beach width observed for most locations over the southern part of the embayment, while beach width over the northern part of the embayment was seen to slightly decrease.

9.3 Erosion/Accretion Trends

Beachface bathymetries derived at monthly intervals along the Palm Beach embayment (Figures 8.2 - 8.4) continue to show a persistent feature of the Palm Beach embayment that there is a distinct flattening of the beach gradient northward along the beachfront. This observation is consistent with the increasing exposure of the beach to predominantly south-easterly waves. The flattening of the beach gradient with increasing distance north of Currumbin is attributed to the modal beach state transitioning from more reflective (steeper), lower-energy intermediate morphology in the south, to increasingly dissipative (flatter), higher energy intermediate beach states towards the north.

Early in the current monitoring period (June 2008) the beachface could be seen to have two distinct beachface morphological compartments, with the first extending south and the second extending north of the 11th Street groyne. From directly adjacent the Currumbin creek entrance channel where the beachface was steep, the beachface became flatter in cross shore gradient with increasing distance to the north. In the second morphological compartment, immediately on the north side of the 11th Street groyne the beach was significantly more eroded, and also steep in cross shore gradient. With further distance north, the beachface again became flatter in cross shore gradient, and at the far north of the analysis area was clearly wider and flatter than further south.

The beachface was significantly straighter in alignment by the end of July 2008 (Figure 8.2 bottom panel), as a result of storm waves which impacted the beach for a short period of time. Over most sections of the mapped area, the beachface can be seen to have eroded slightly, with the main exception being the already eroded area on the north side of the 21st Street groyne. Lower wave conditions experienced in August resulted in very little observable change in beachface appearance (Figure 8.3 top panel), with the most notable change being a slight steepening of the beachface along the northern stretches. Between August and September 2008 (Figure 8.3 bottom panel) there was again very little notable change in beachface bathymetry. The section of beach just north of the ARGUS station was observed to migrate slightly landward, while further north the beachface again became slightly flatter with sand developing at the toe of the beachface in terrace type formations. The beachface map produced for October 2008 (Figure 8.4) showed a range of relatively discreet alterations in beachface bathymetry that occurred during the previous month. Directly in front of the ARGUS station and at the extreme southern end of the embayment, the beach was seen to migrate landward with accretion of sand to the beachface. There was a slight steepening of the cross shore beachface gradient along the middle regions of the embayment. In contrast, the far northern stretch of the beach was observed to erode at the toe, creating a steeper beach profile than typical for this section of the beach.

The top panel of Figure 8.5a shows that from May – June 2008 there were localised regions of both erosion and accretion, with the most extensive change in beachface volumes occurring along the southern sand spit. The beachface gained up to 1 m in vertical elevation along the section of beach south of the ARGUS station, while further north other notable changes included modest erosion on the north side of the 11th Street groyne and modest accretion north of the 21st Street groyne. Averaged along the entire measured section of the Palm Beach embayment the net change in sand volume within the mapped beachface was **+23,994 m^3** of accretion, which equates to **+7.2 m^3 per m of shoreline** when averaged over the length of the beach (between -0.5 and +0.7 m AHD). From June to

July 2008 (Figure 8.5a, middle panel), the beach suffered a modest level of erosion over most sections, with the most extensive erosion occurring along the southern sand spit and just north of the 21st Street groyne. In these regions the beachface lost up to 1 m in vertical elevation between June and July, while at other sections of the beach there was negligible change in beachface volume. In total there was a predicted net erosion of **-28,622 m^3** across the length of the embayment, equating to **-8.6 m^3 per m of shoreline** (between -0.5 and 0.7 m AHD).

Between July and August 2008 (Figure 8.5a bottom panel) there was little net change in intertidal beachface volumes experienced, with some regions of the beach experiencing minor erosion while others accreted slightly. During this month there was a net beachface erosion over the entire embayment of **-4,475 m^3**, equating to **-1.4 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD). From August to September 2008 (Figure 8.5b top panel), the beach again experienced only minor erosion/accretion changes, with the general trend being very minor accretion. A localised stretch of beach just north of the ARGUS station experienced the most notable change in beachface volumes, dropping by up to 1 m in vertical elevation over a stretch of beach approximately 100 – 200 m long. Overall there was accretion of **+13,489 m^3**, equating to **+4.1 m^3 per m of shoreline** over the intertidal beachface (-0.5 m to +0.7 m AHD).

During the final month of the current monitoring period between September and October 2008 (Figure 8.5b bottom panel), the change in beachface volumes was a reversal of that experienced during the previous month. Generally there was very minor erosion experienced along most sections of the embayment, with the only exceptions being the stretches of beach just north of the ARGUS station and adjacent the Currumbin Creek training wall. In total the net beachface erosion over the entire embayment was **-7,895 m^3**, equating to **-2.4 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD).

It has been observed in previous monitoring reports, that the long term erosion and accretion trends can typically be separated into four compartments along the length of the Palm Beach embayment. South of the monitoring cameras significant long term net erosion is typically evident, while the section of beach between the Royal Palm building and the 11th Street groyne has generally been a location of accretion. Over the stretch of beach between the 11th Street and 21st Street groynes there has typically been minor net erosion, while north of the 21st Street groyne there has been more modest net erosion observed at the end of previous monitoring periods.

The changes in beachface bathymetry that have occurred between May and October 2008 have made these typical long term observations less obvious. The erosion/accretion map shown in Figure 8.7 for the period June 2004 to October 2008 shows that there has been only a minor net erosion over the stretch of beach south of the 11th Street groyne, while the remainder of the embayment further to the north has experienced more significant net erosion. While the northern end of the embayment is typically exposed to higher energy wave conditions, this also identifies the long term benefit on erosion reduction achieved with the placement of Currumbin Creek dredge spoil onto the southern stretch of the embayment.

Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **-54,584 m^3** of sand has been eroded along the ~3.5 km of beachfront included in this monitoring program, equating to an alongshore-average of around **-16.5 m^3** within the intertidal profile, for every 1 m alongshore.

10. ACKNOWLEDGEMENTS

This project was commissioned and funded by the Gold Coast City Council.

The Body Corporate of Royal Palm are thanked for permitting the ARGUS system to reside on the roof of the building. Also, we thank the building managers for their support during installation and routine maintenance visits to the site.

The Queensland Department of Environment is acknowledged for the ongoing provision of deepwater wave data from the Gold Coast and Brisbane Waverider buoys.

Doug Anderson of WRL continues to manage the wave and tide data processing, computer operations for remote communications, image storage, off-line image archiving and web serving at WRL. Luis Mallen Lopez of WRL completed the weekly analysis and updating of monitoring program information via the project web site.

Finally, Professor Rob Holman of Oregon State University and the growing world-wide team of ARGUS users are acknowledged for continuing system development. These research efforts are providing practical tools for coastal monitoring and management.

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APPENDIX A

WEEK-TO-A-PAGE: JUNE – OCTOBER 2008

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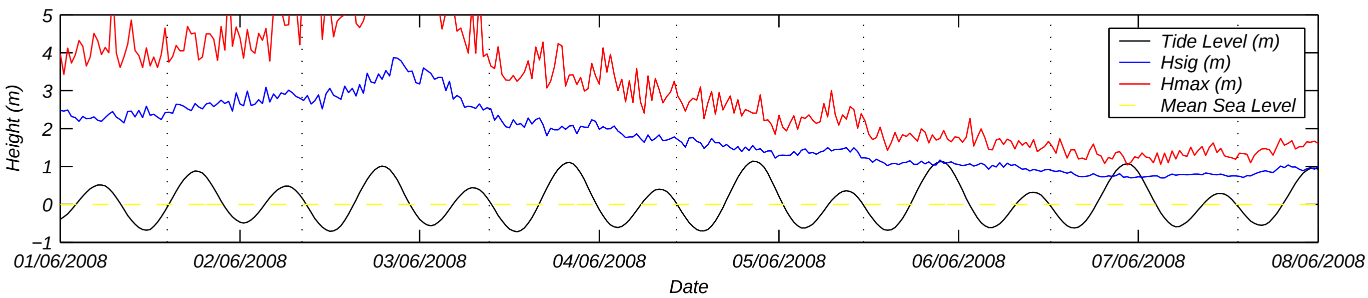

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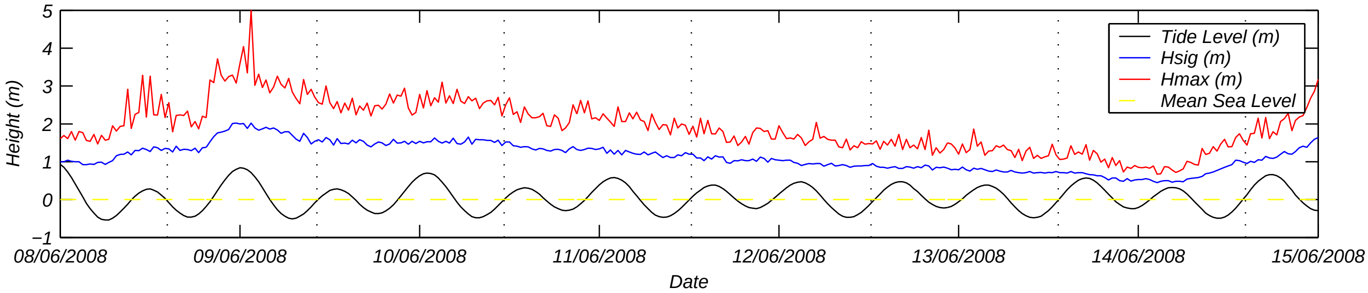

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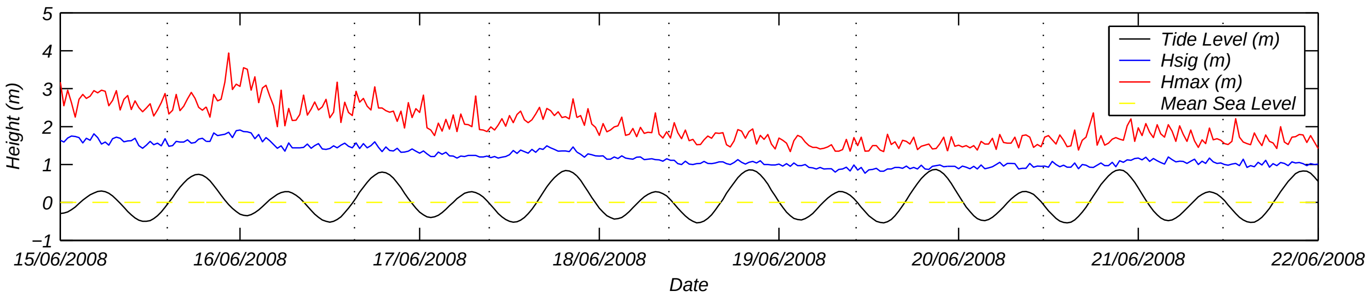

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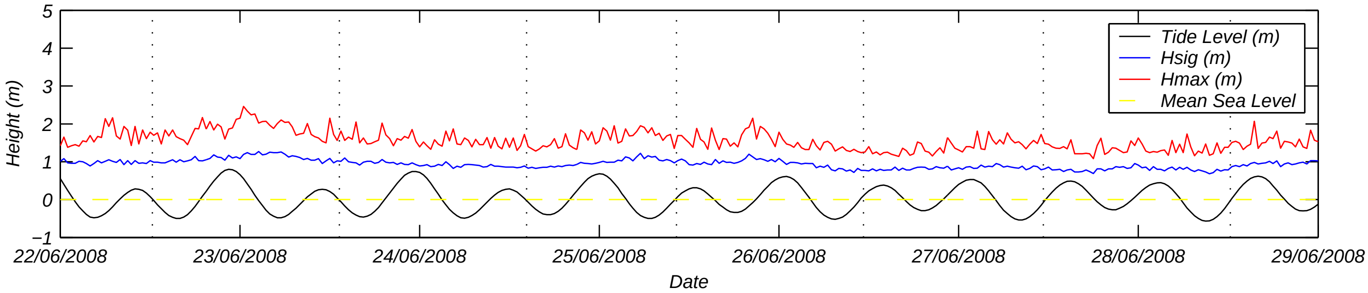

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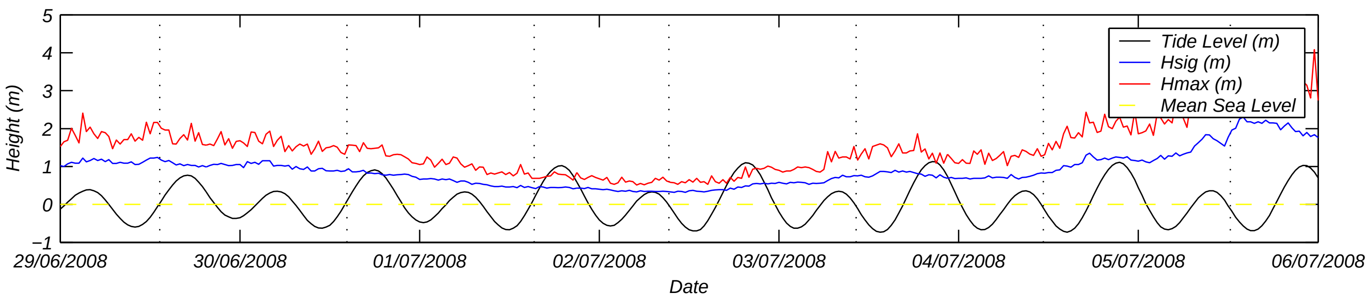

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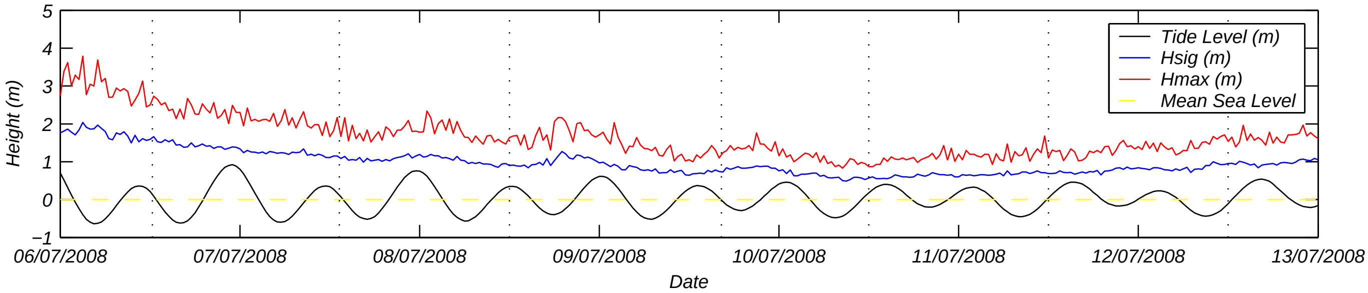

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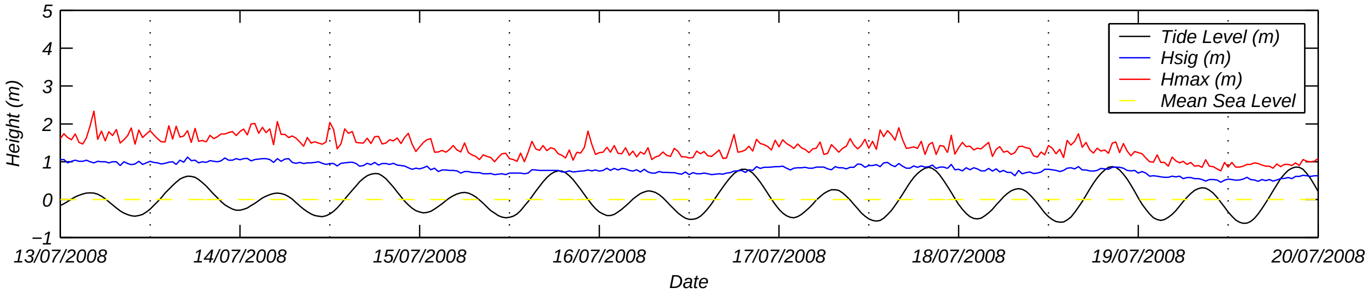

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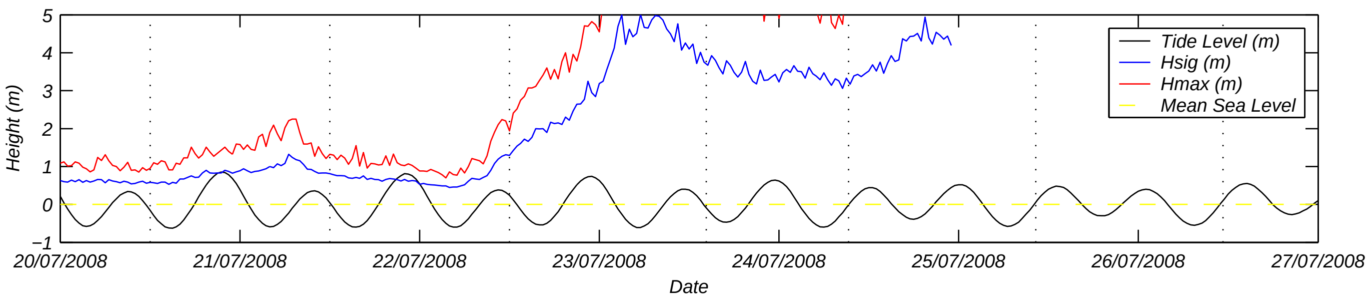

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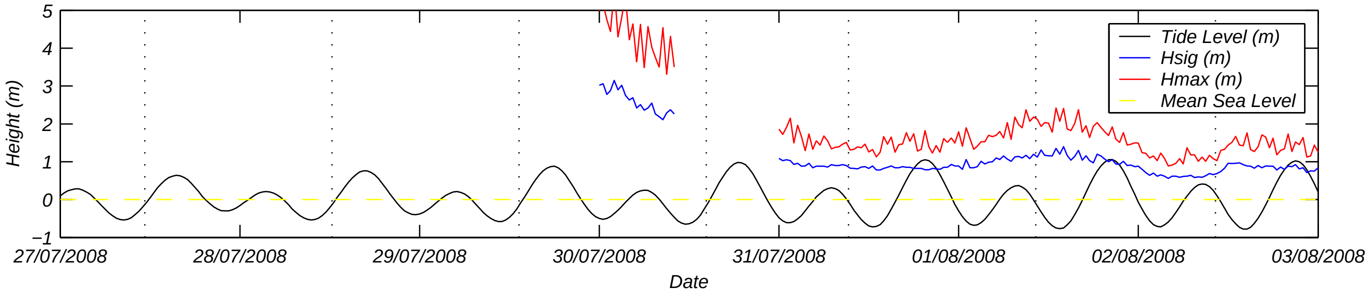

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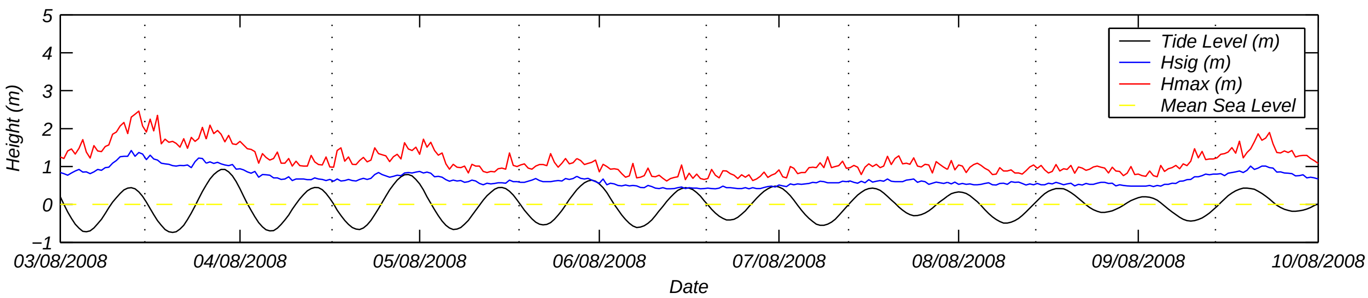

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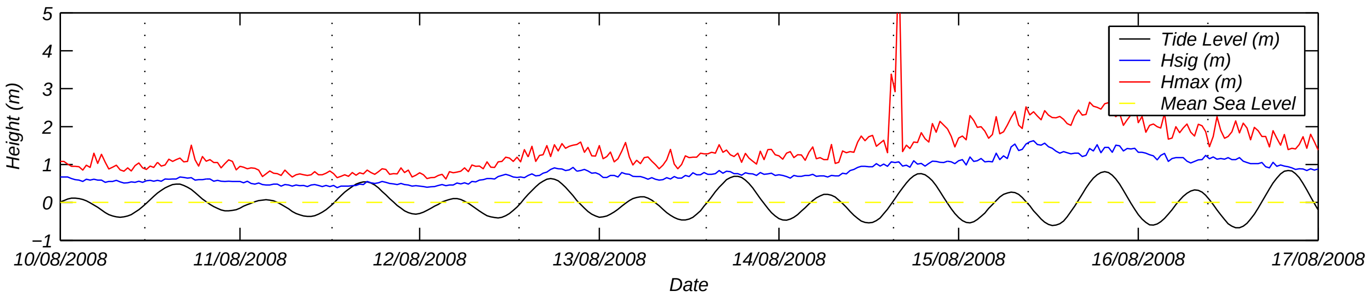

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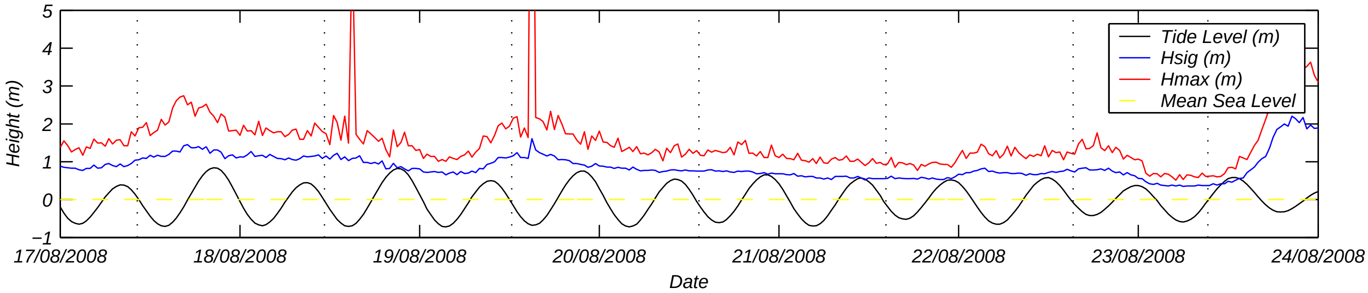

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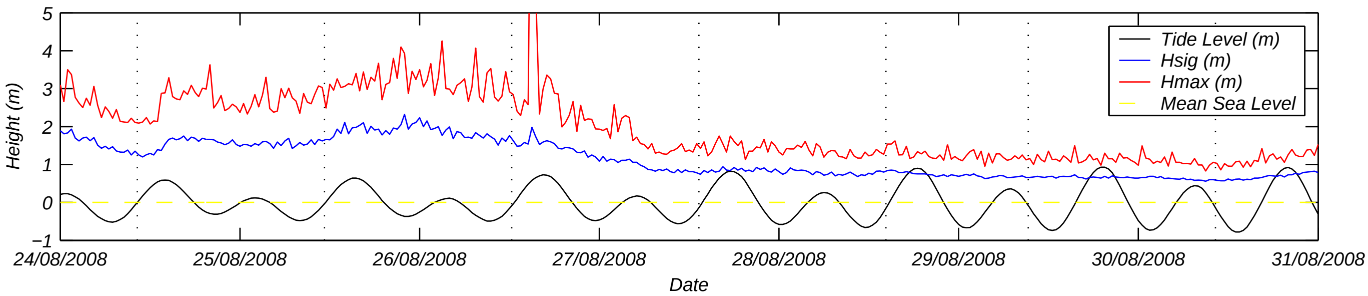

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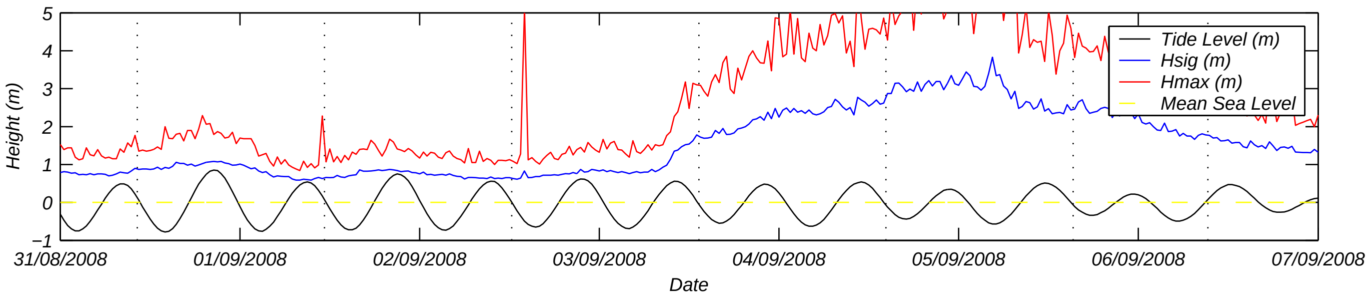

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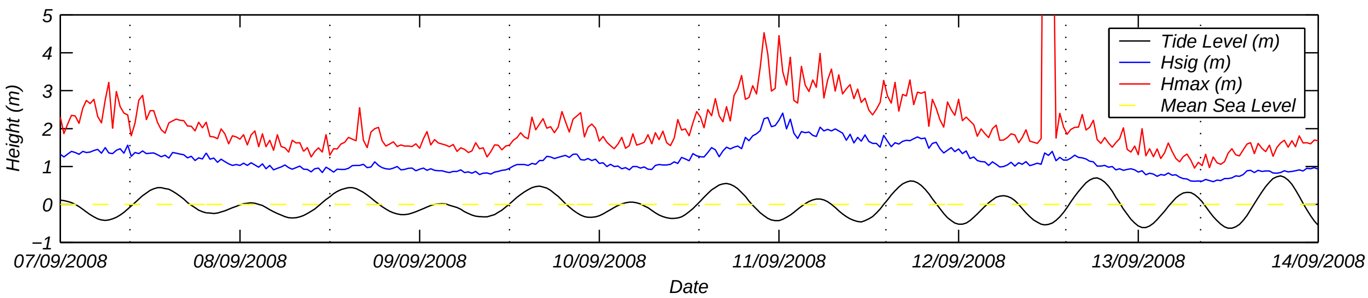

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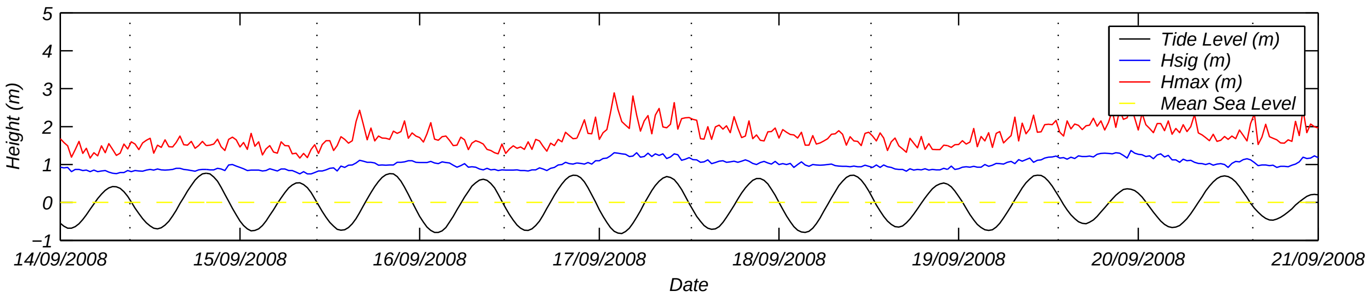

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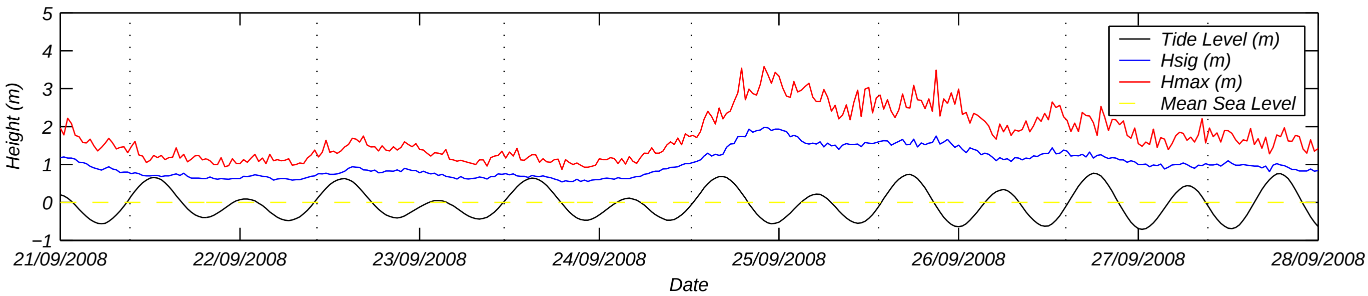

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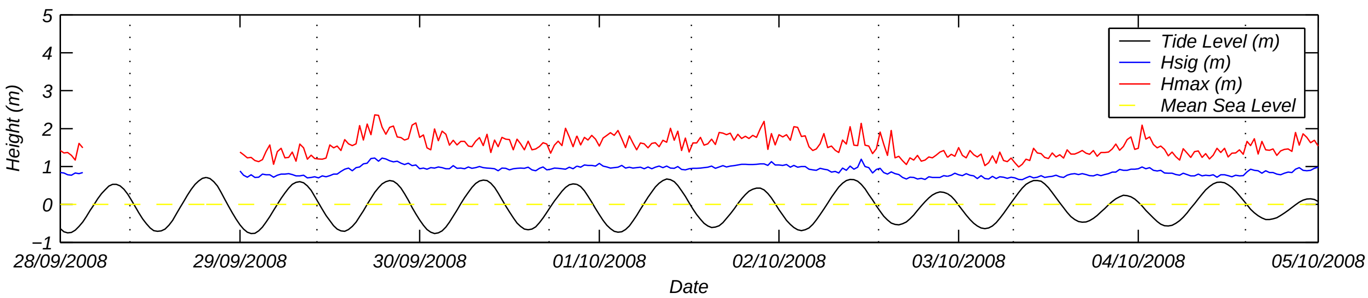

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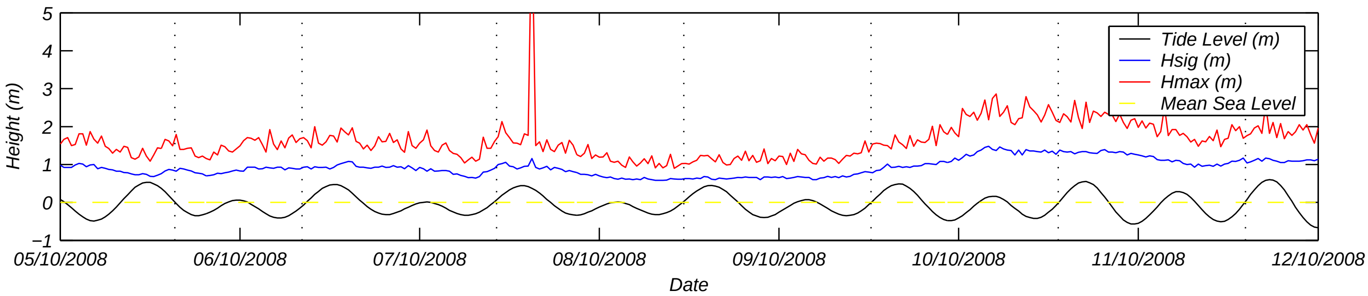

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Report No.2008/32

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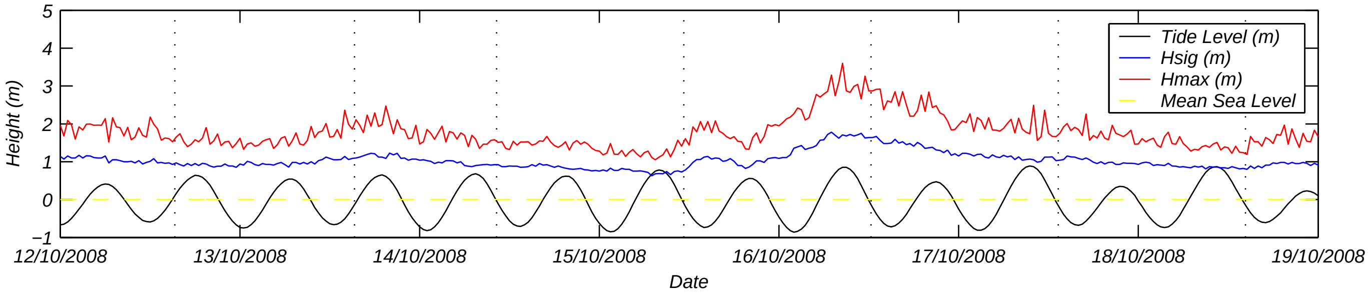

WRL Report No.2008/32	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL PALM BEACH, QUEENSLAND 12/10/2008 − 18/10/2008	Figure A20

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20/10/2008 08:17

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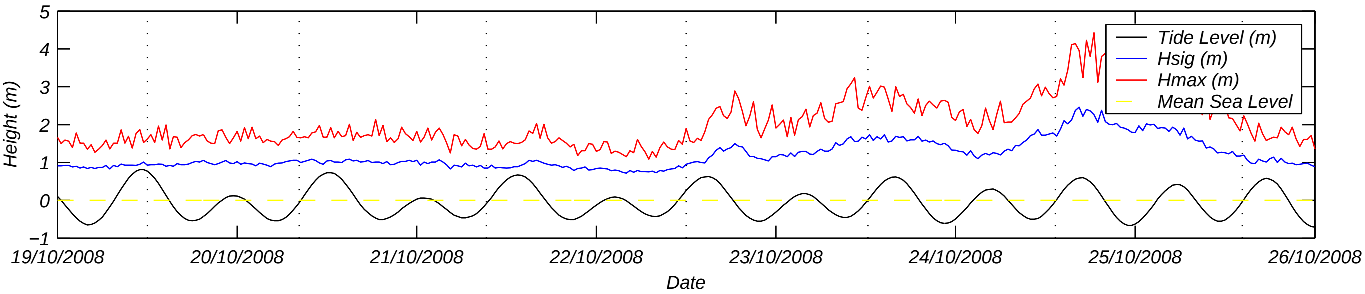

WRL Report No.2008/32	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL PALM BEACH, QUEENSLAND 19/10/2008 − 25/10/2008	Figure A21

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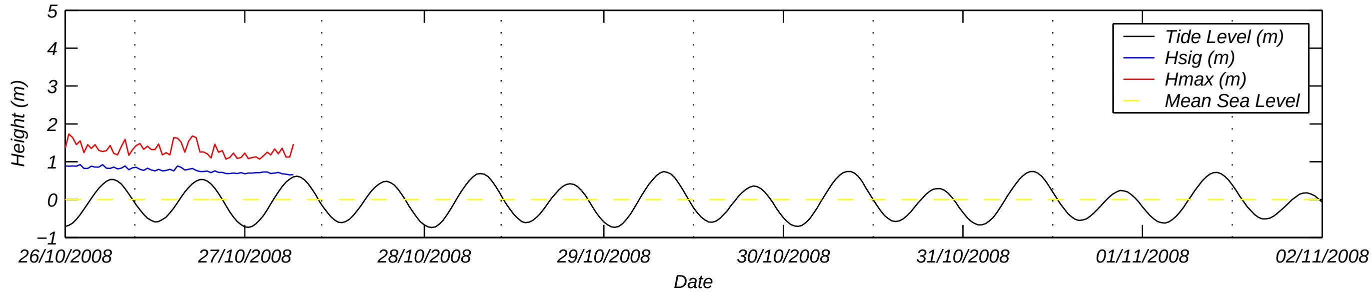
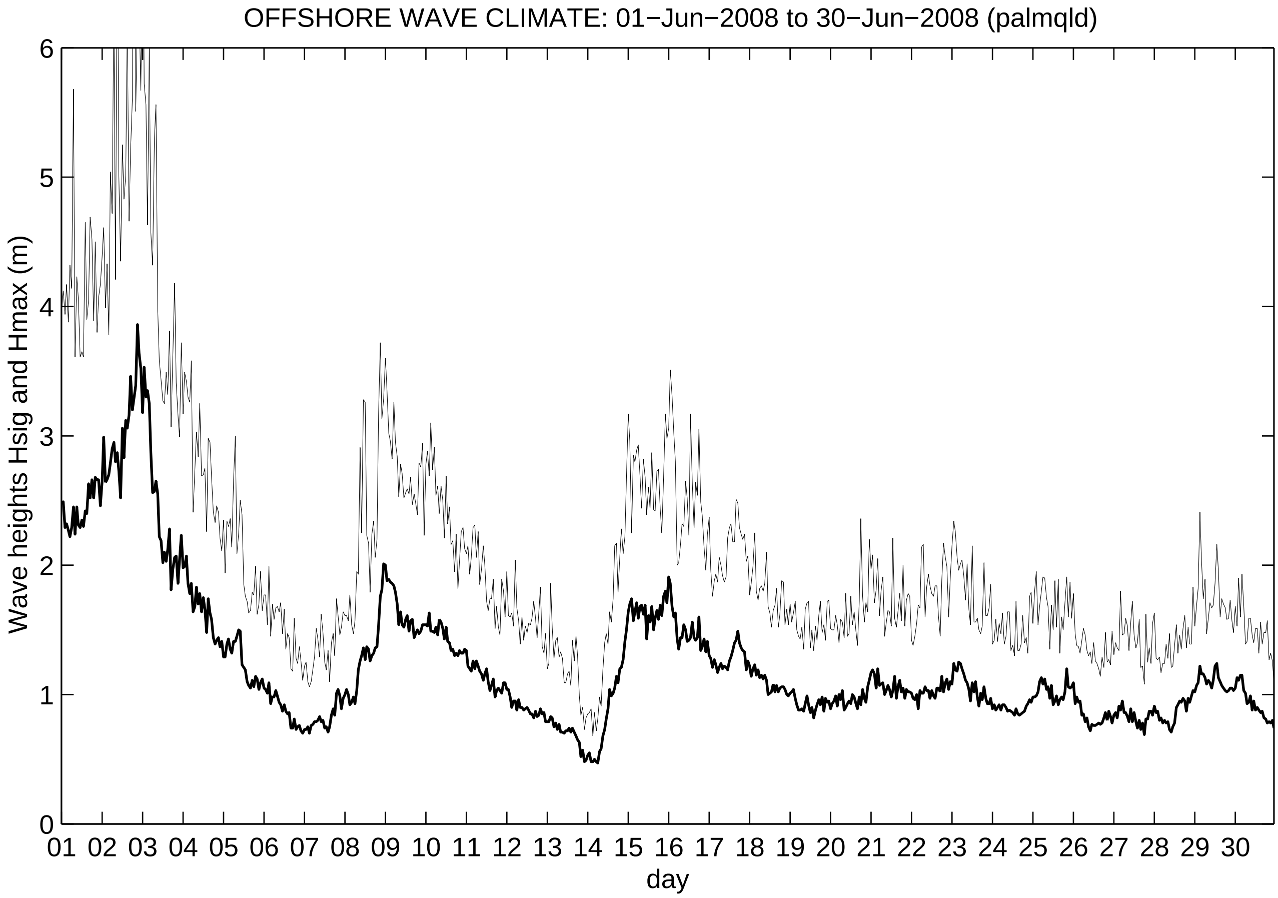
01/11/2008 12:00

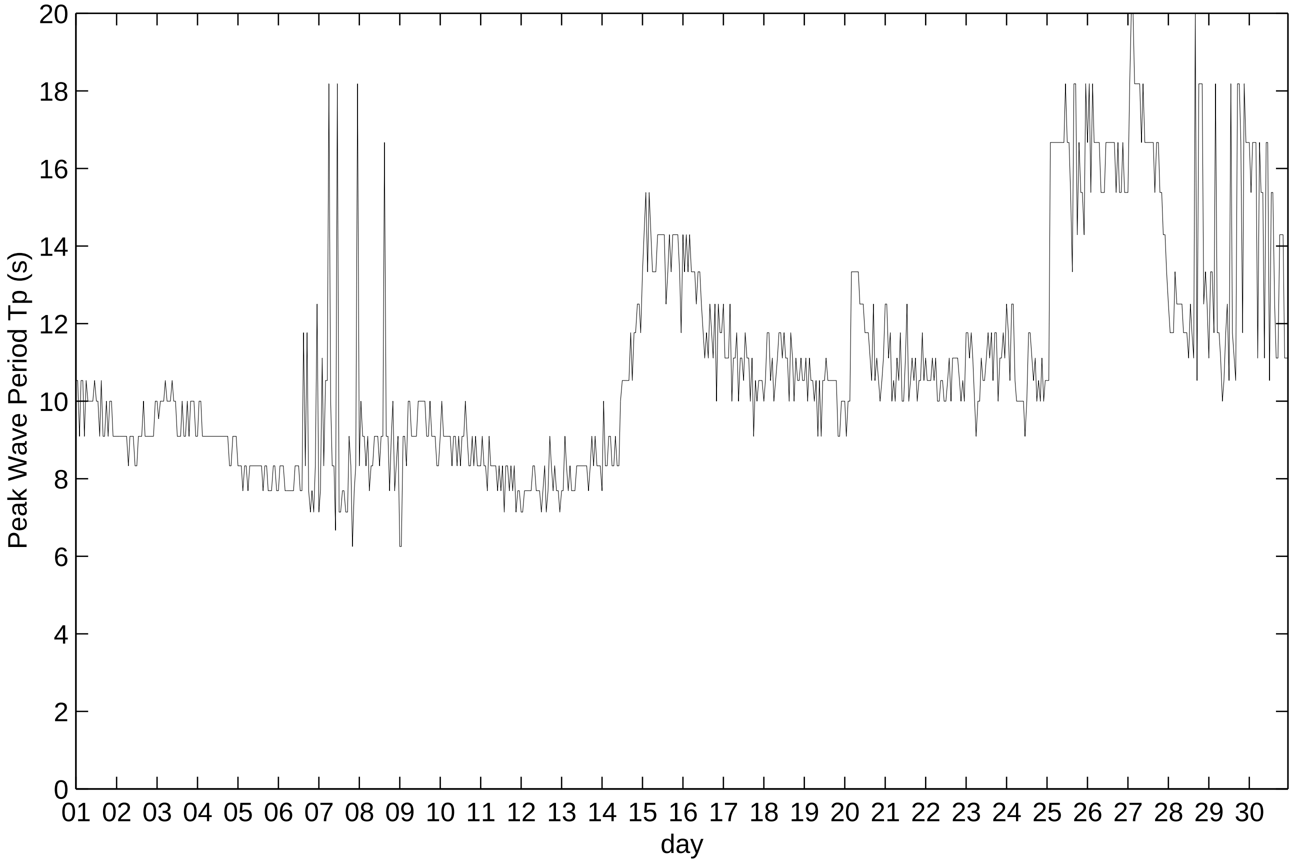


WRL Report No.2008/32	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL PALM BEACH, QUEENSLAND 26/10/2008 − 01/11/2008	Figure A22

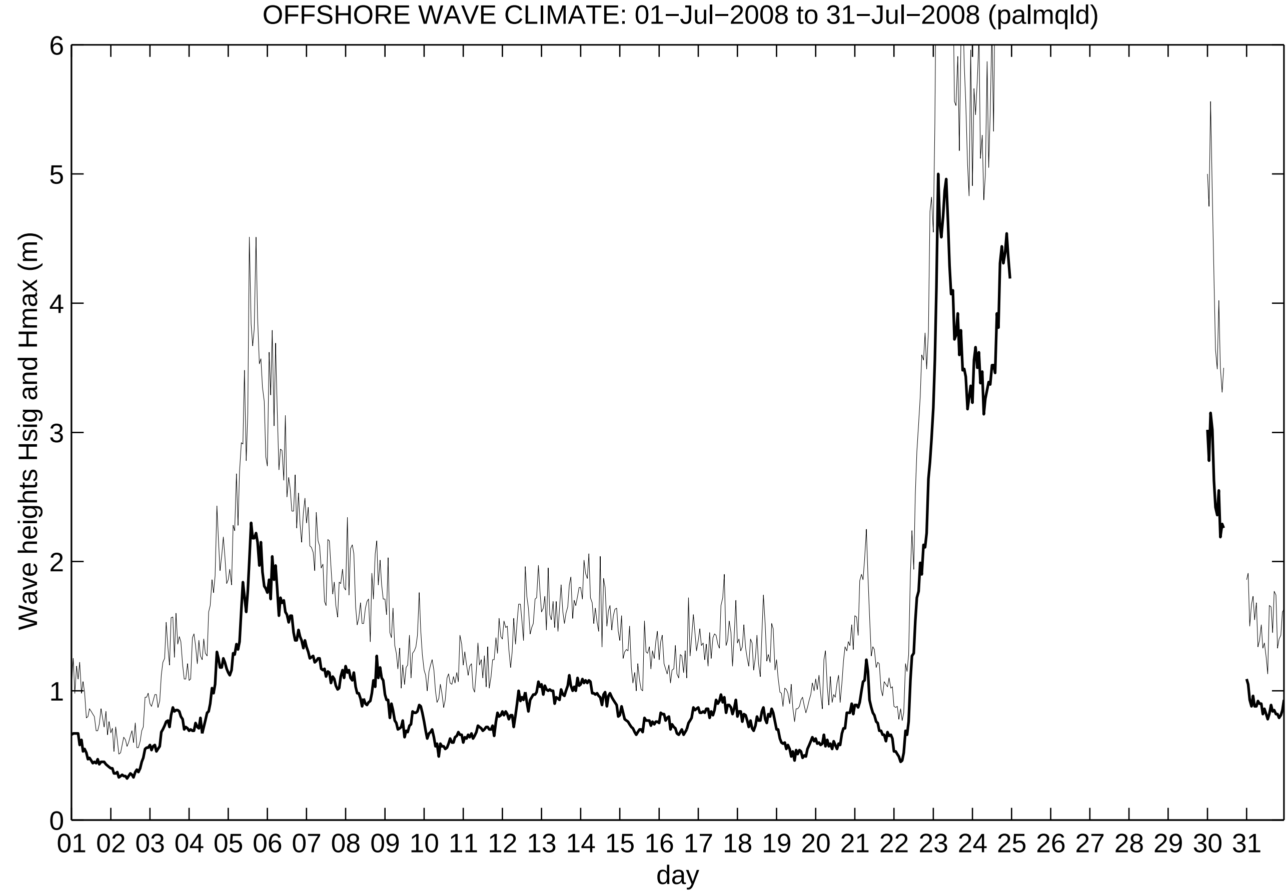
APPENDIX B

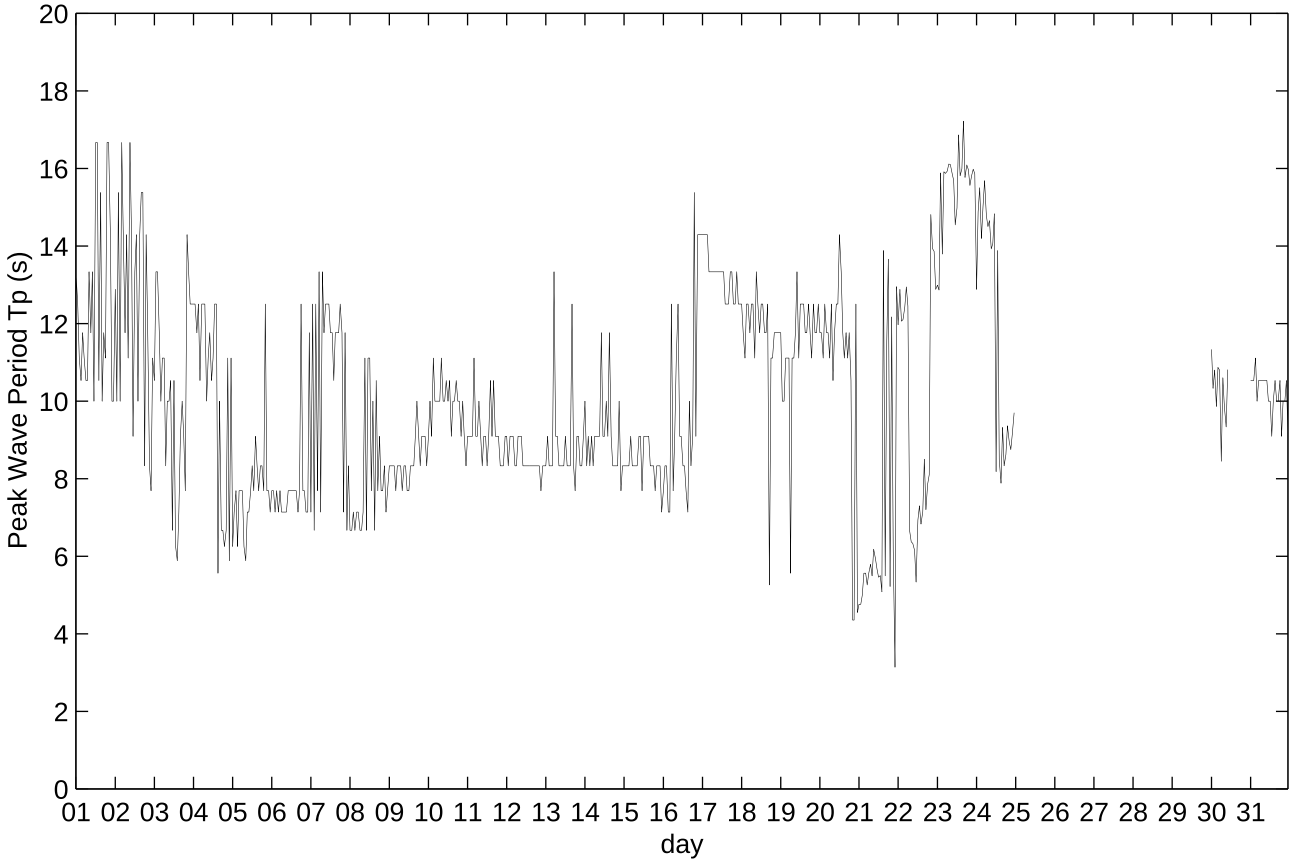
MONTHLY WAVE CLIMATE SUMMARIES: JUNE – OCTOBER 2008





WRL Report No.2008/32	MONTHLY WAVE SUMMARY JUNE 2008	Figure B1





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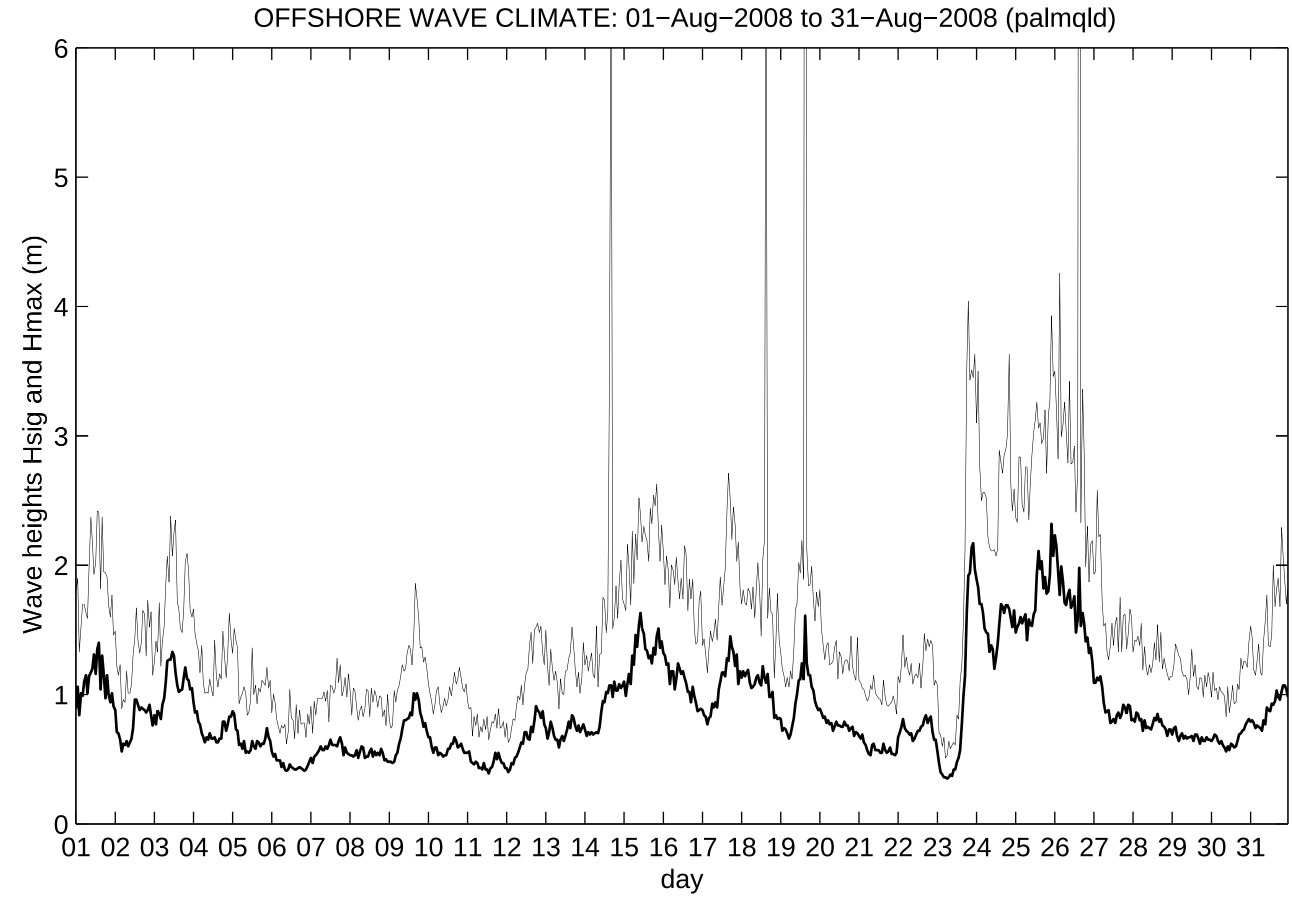
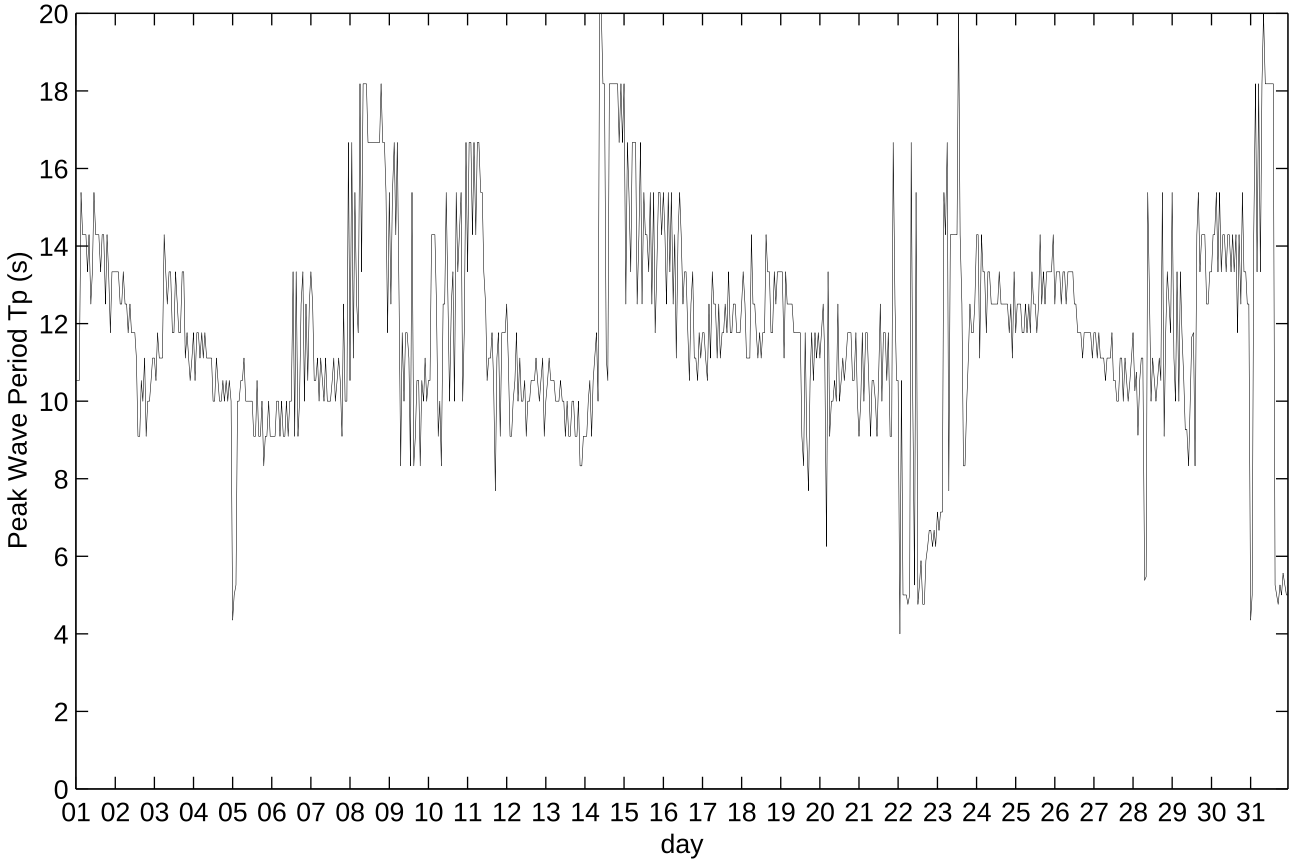
Report No.2008/32

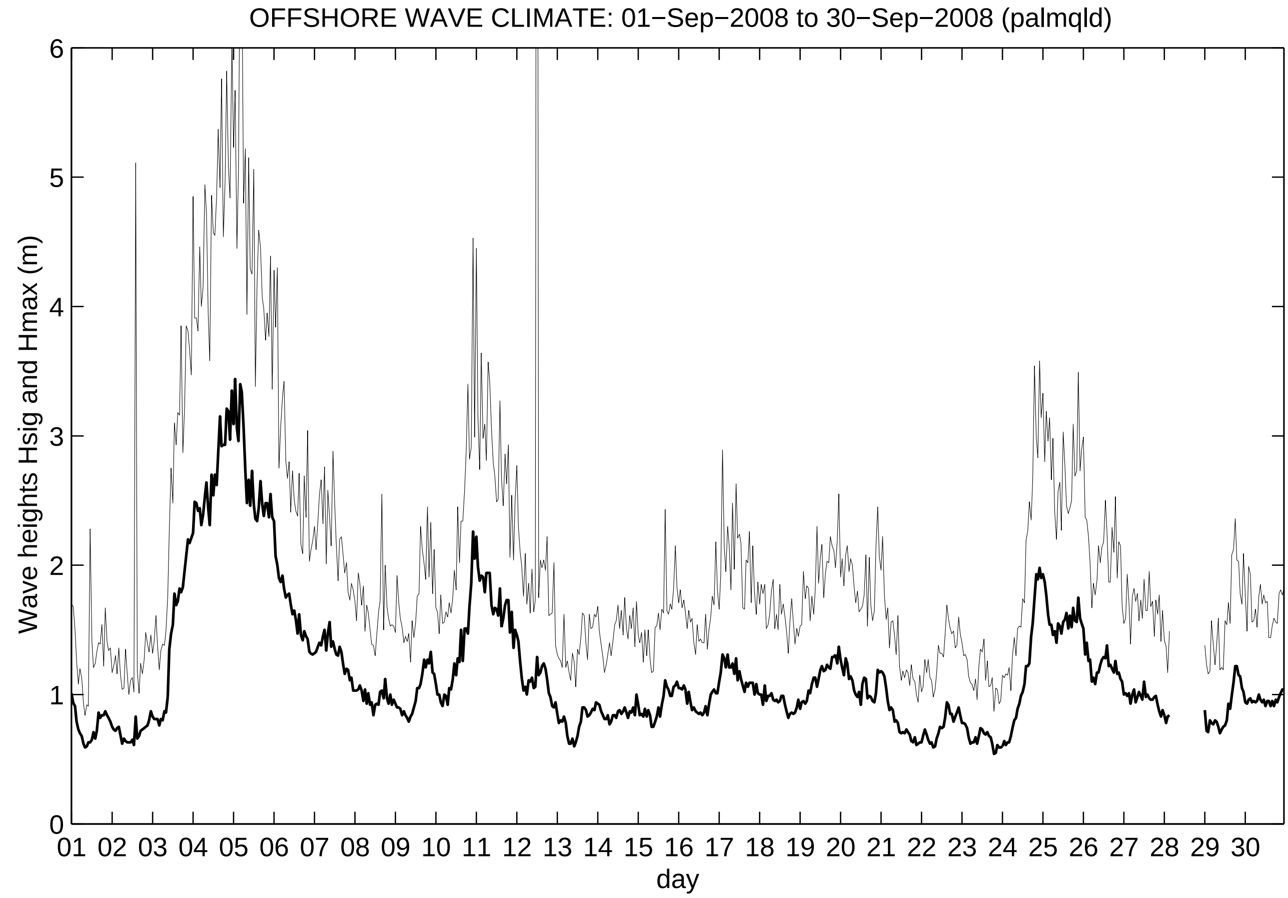
MONTHLY WAVE SUMMARY
JULY 2008

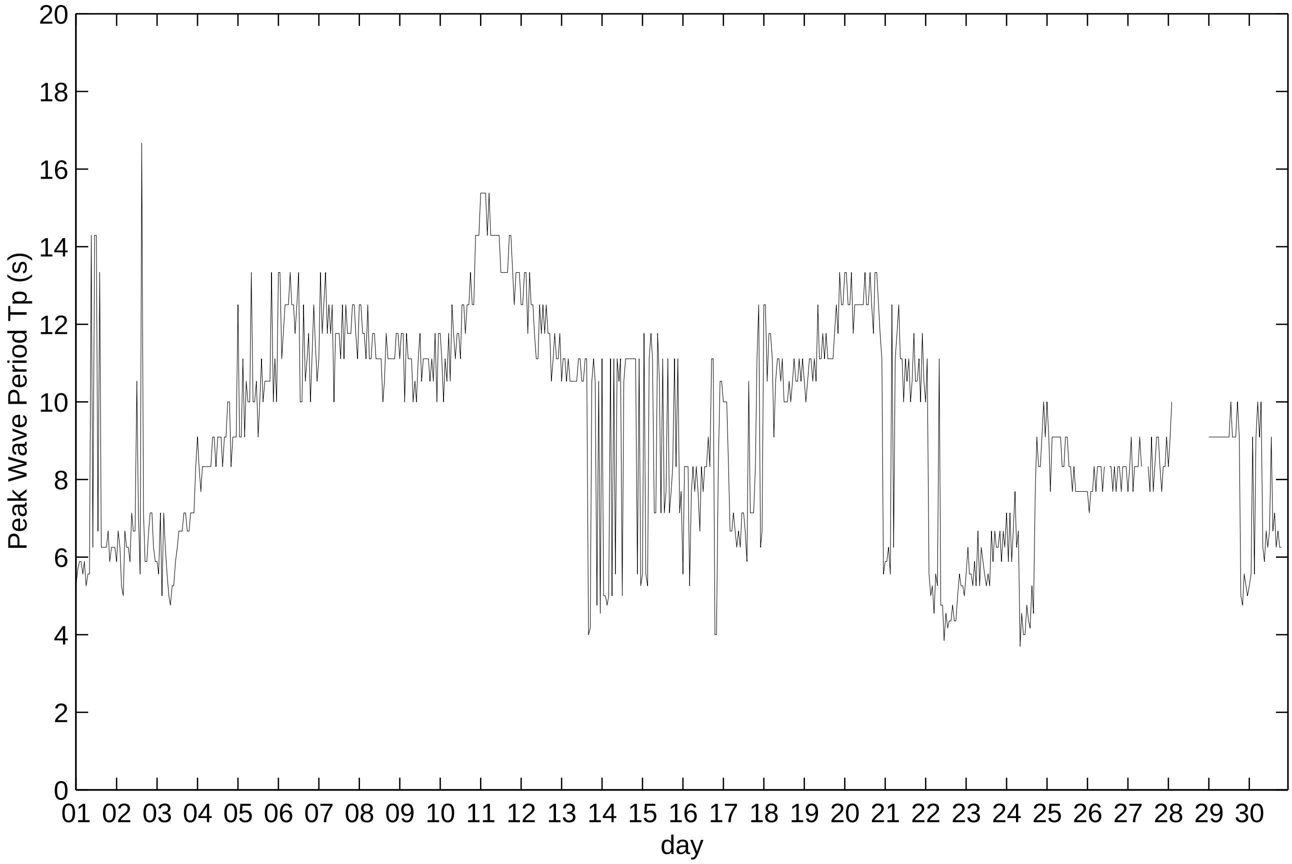
Figure
B2





WRL Report No.2008/32	MONTHLY WAVE SUMMARY AUGUST 2008	Figure B3





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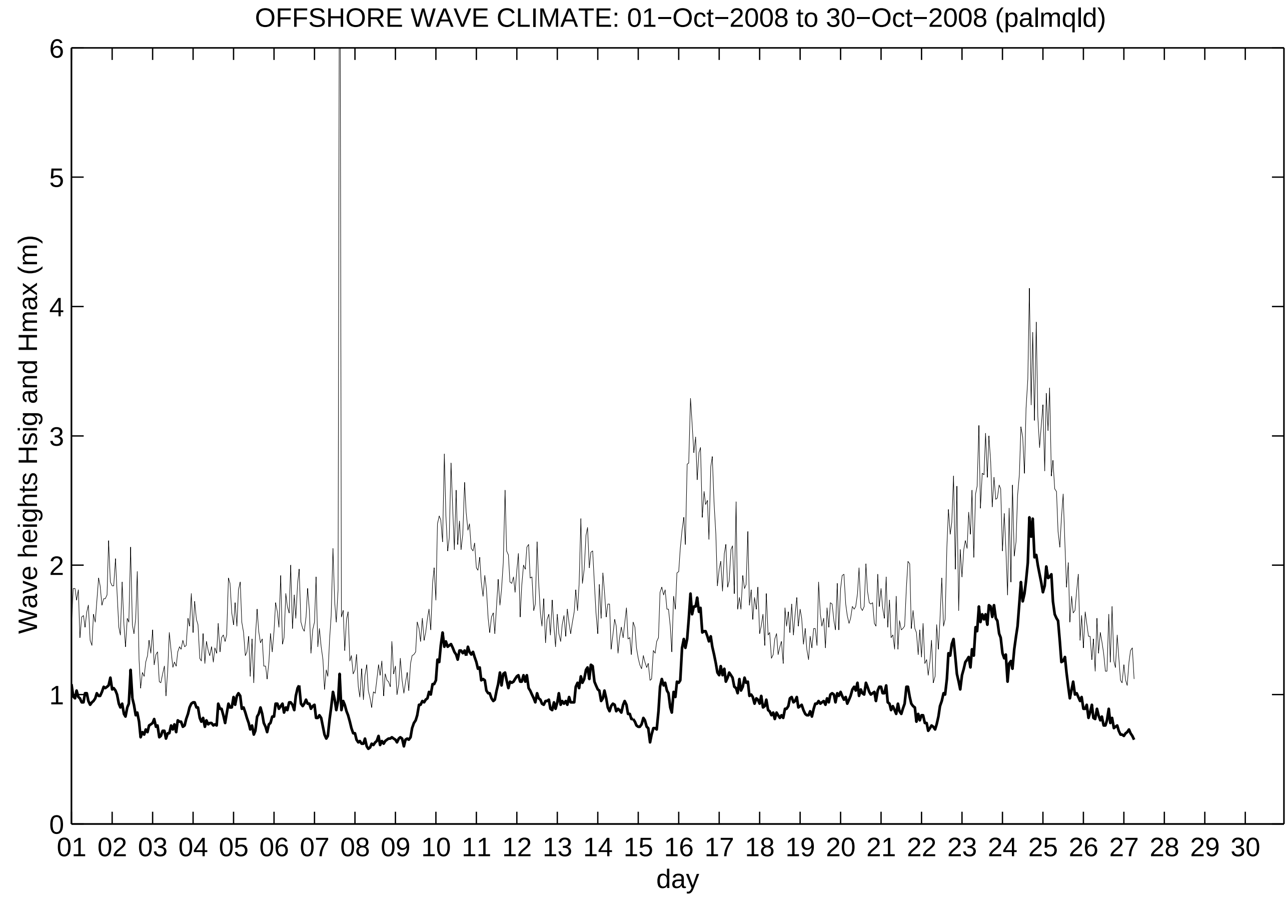
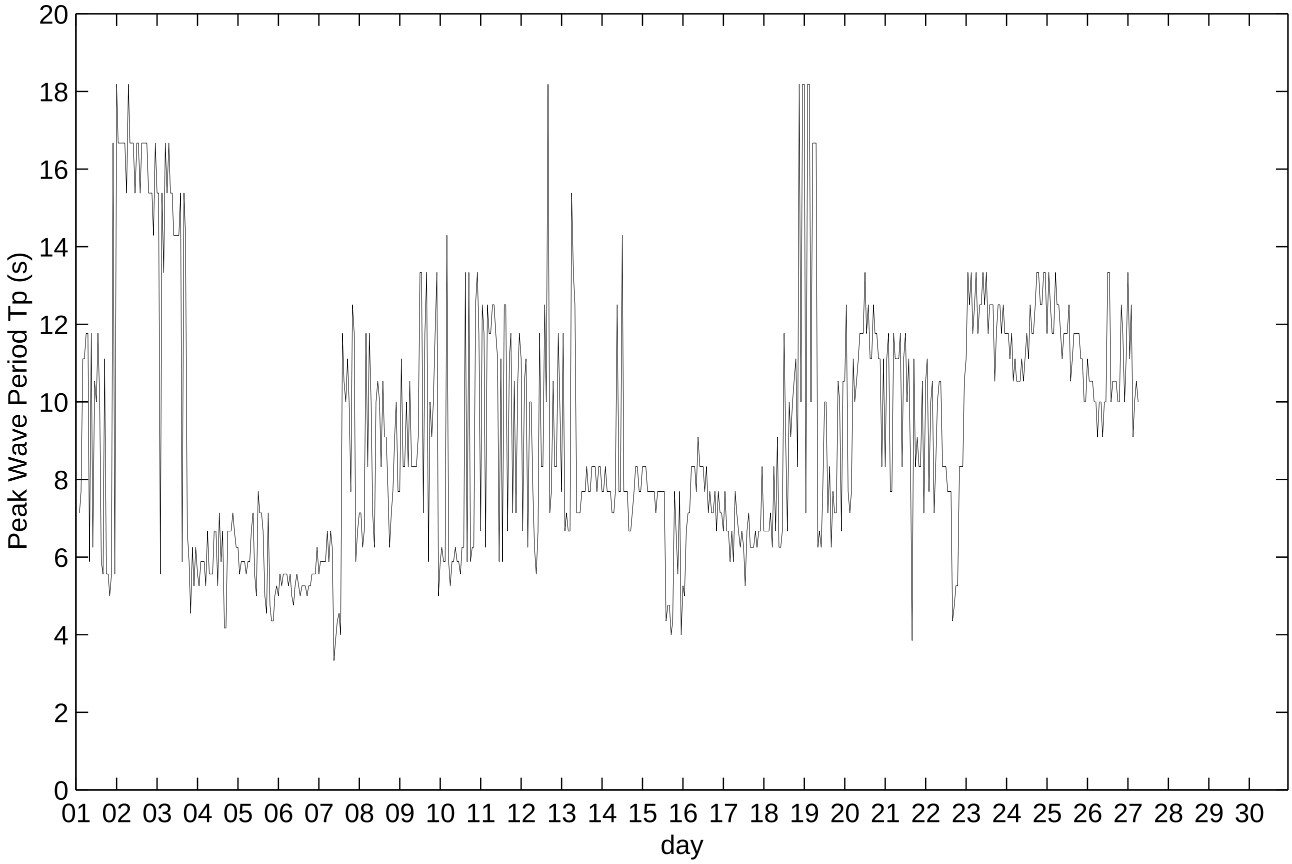
Report No.2008/32

MONTHLY WAVE SUMMARY
SEPTEMBER 2008

Figure
B4





WRL Report No.2008/32	MONTHLY WAVE SUMMARY OCTOBER 2008	Figure B5