Analysis of shoreline variability and erosion/accretion trends: December 2006 - May 2007: report 6 - Palm Beach coastal imaging system

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ANALYSIS OF SHORELINE VARIABILITY AND EROSION/ACCRETION TRENDS: DECEMBER 2006 - MAY 2007

REPORT 6
PALM BEACH COASTAL IMAGING SYSTEM

by

M J Blacka, D J Anderson and I L Turner

Technical Report 2007/21
July 2007

THE UNIVERSITY OF NEW SOUTH WALES
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
WATER RESEARCH LABORATORY

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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 sixth 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 growing 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 a growing number of 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).

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 sixth report is to present the results of shoreline change analysis and erosion/accretion trend analysis for the six-month monitoring period December 2006 to May 2007, and to assess the net changes that have occurred within the Palm Beach embayment since the commencement of the monitoring program 36 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.

Since March 2006 the Palm Beach ARGUS station has remained fully operational, with routine maintenance including cleaning of the camera housings being undertaken in mid March 2007.

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. 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 six 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 36 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 sixth six-monthly monitoring period at 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

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". The upper panel shows the volume of sand placed per month. There has been no beach nourishment undertaken during the current monitoring period, December 2006 to May 2007.

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.

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. During the current monitoring period December 2006 to May 2007, no dredging of Currumbin Creek has occurred, and as such there has been no subsequent nourishment of Palm 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

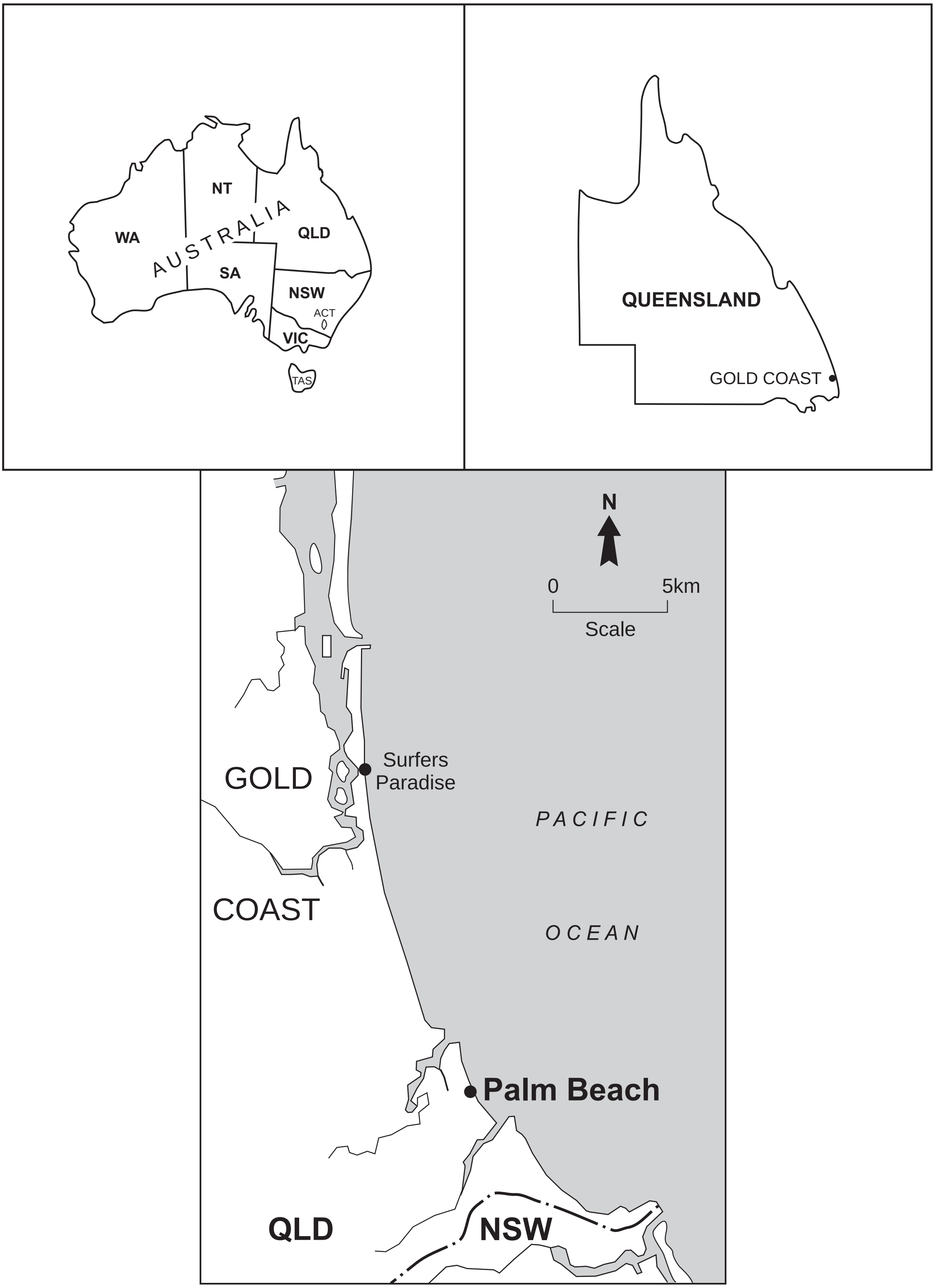
From April to June 2005 an additional **26,493 m^3** of sand was placed at a single discharge point, shown in Figure 2.4 (lower panel). Daily delivery rates varied between approximately 200 m^3 and 1100 m^3 per day, with the engineering works being completed between 6 am and 6 pm.

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.

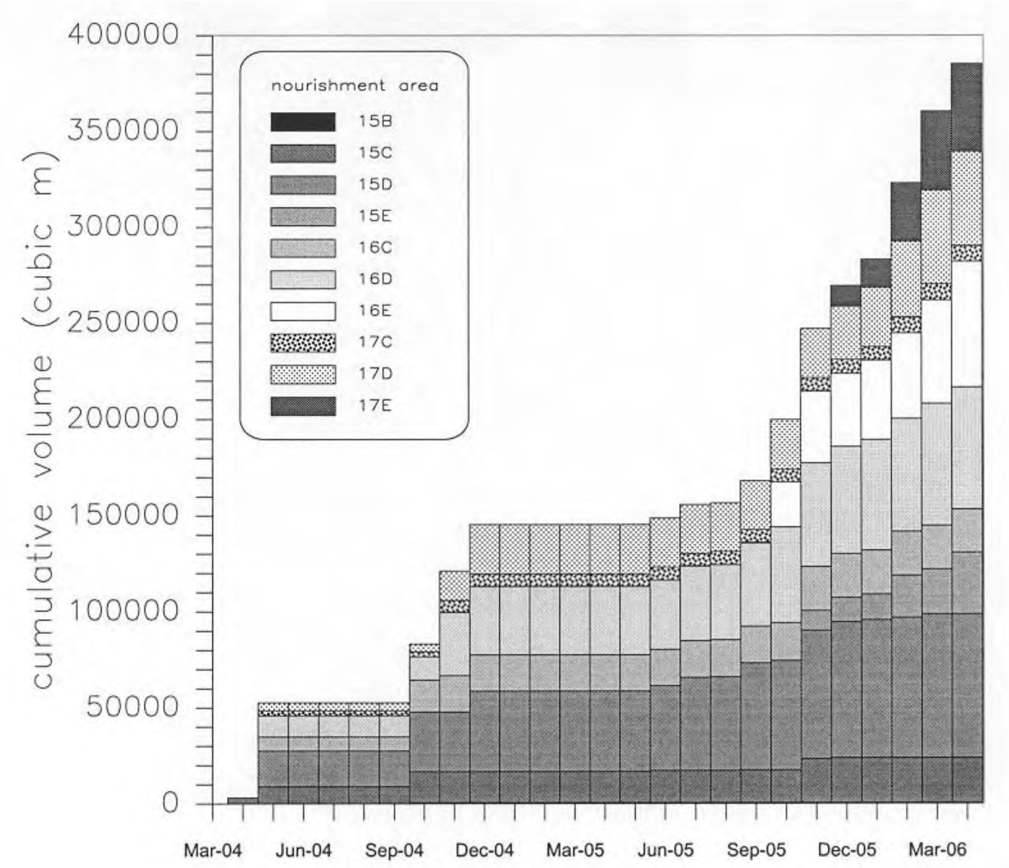


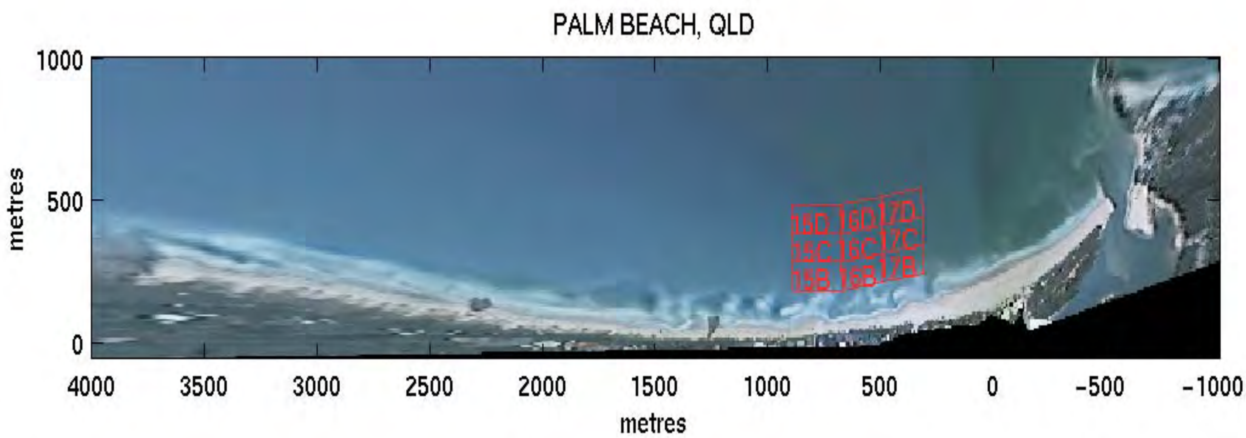
WRL Report No. 2007/21	LOCALITY	Figure 2.1 02114-2-1.cdr

Palm Beach Embayment,
Southern Portion

Palm Beach Embayment
viewed from North

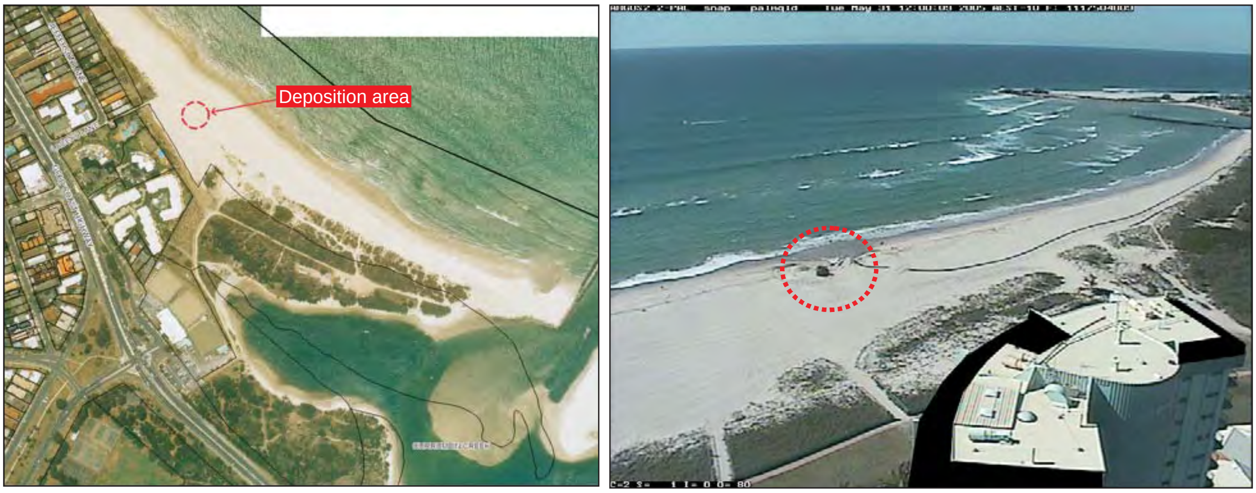
WRL Report No. 2007/21	PALM BEACH, GOLD COAST, QUEENSLAND	Figure 2.2 02114-2-2.cdr





WRL Report No. 2007/21	NEARSHORE NOURISHMENT DEPOSITION AREAS AND VOLUMES	Figure 2.3 02114-2-3.cdr

SAND PLACEMENT - 2004



SAND PLACEMENT - 2005

WRL Report No. 2007/21	PLACEMENT OF CURRUMBIN CREEK DREDGE MATERIAL	Figure 2.4 02114-2-4.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 recent 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 fifteen 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 in May 2007 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 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 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).

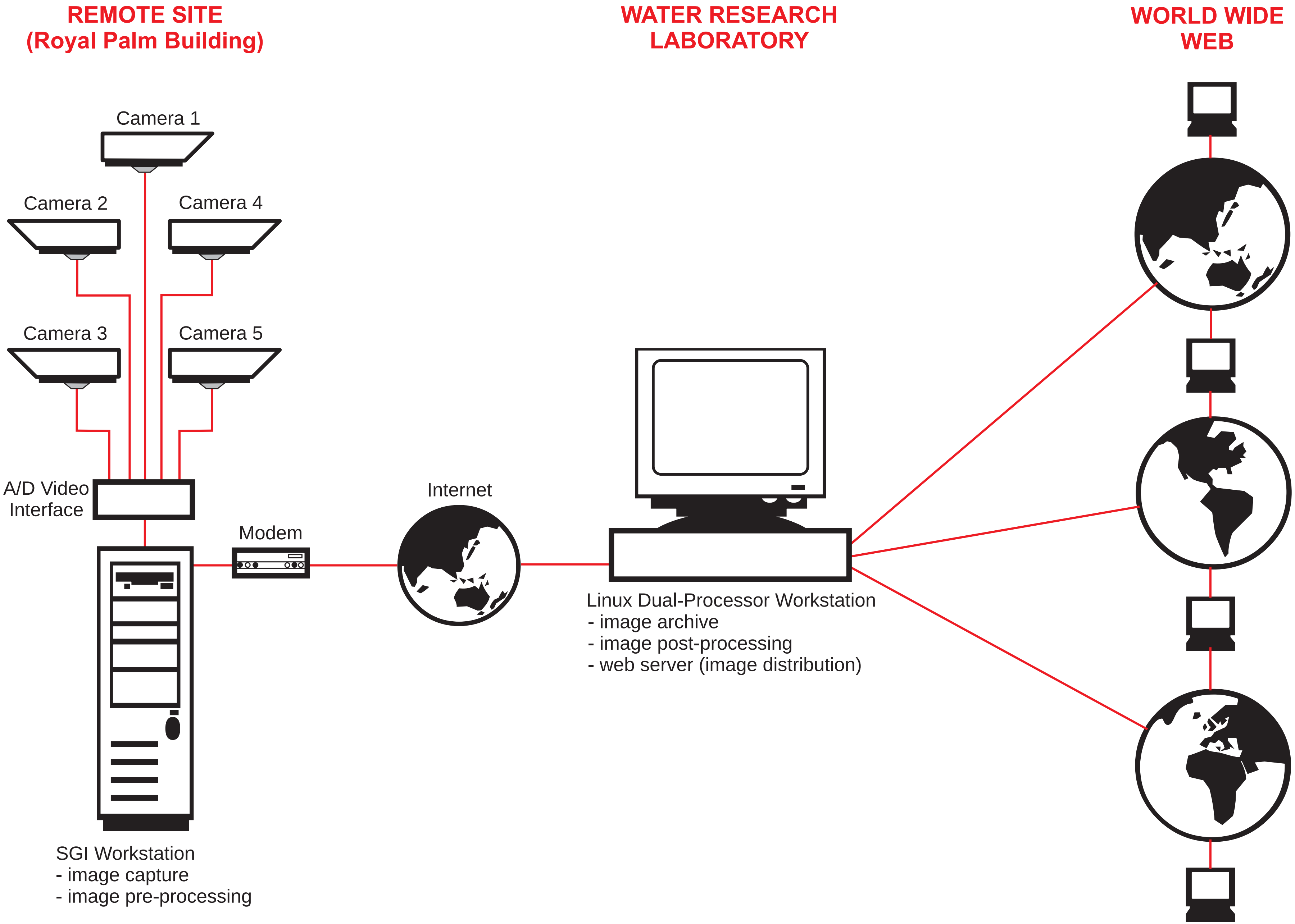
The filtered histogram is used to define a line to distinguish between Hue Saturation information used for colour discrimination (Figure 3.6a), or Value information in the case of luminance-based discrimination (Figure 3.6b). For both discriminators, the line defined in this manner crosses the saddle 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.



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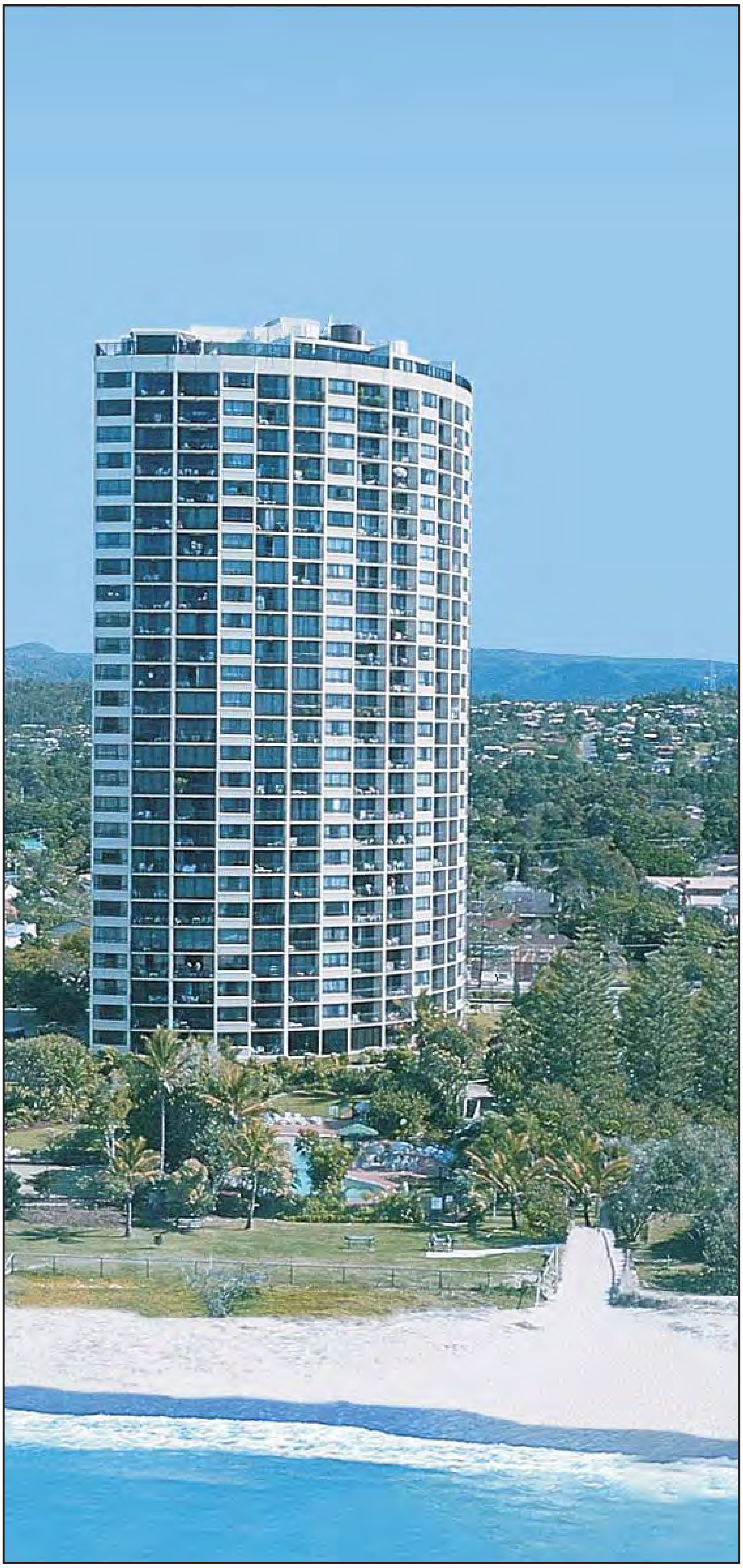
SCHEMATIC OF AN ARGUS COASTAL IMAGING SYSTEM

Figure
3.1

02114-3-1.cdr



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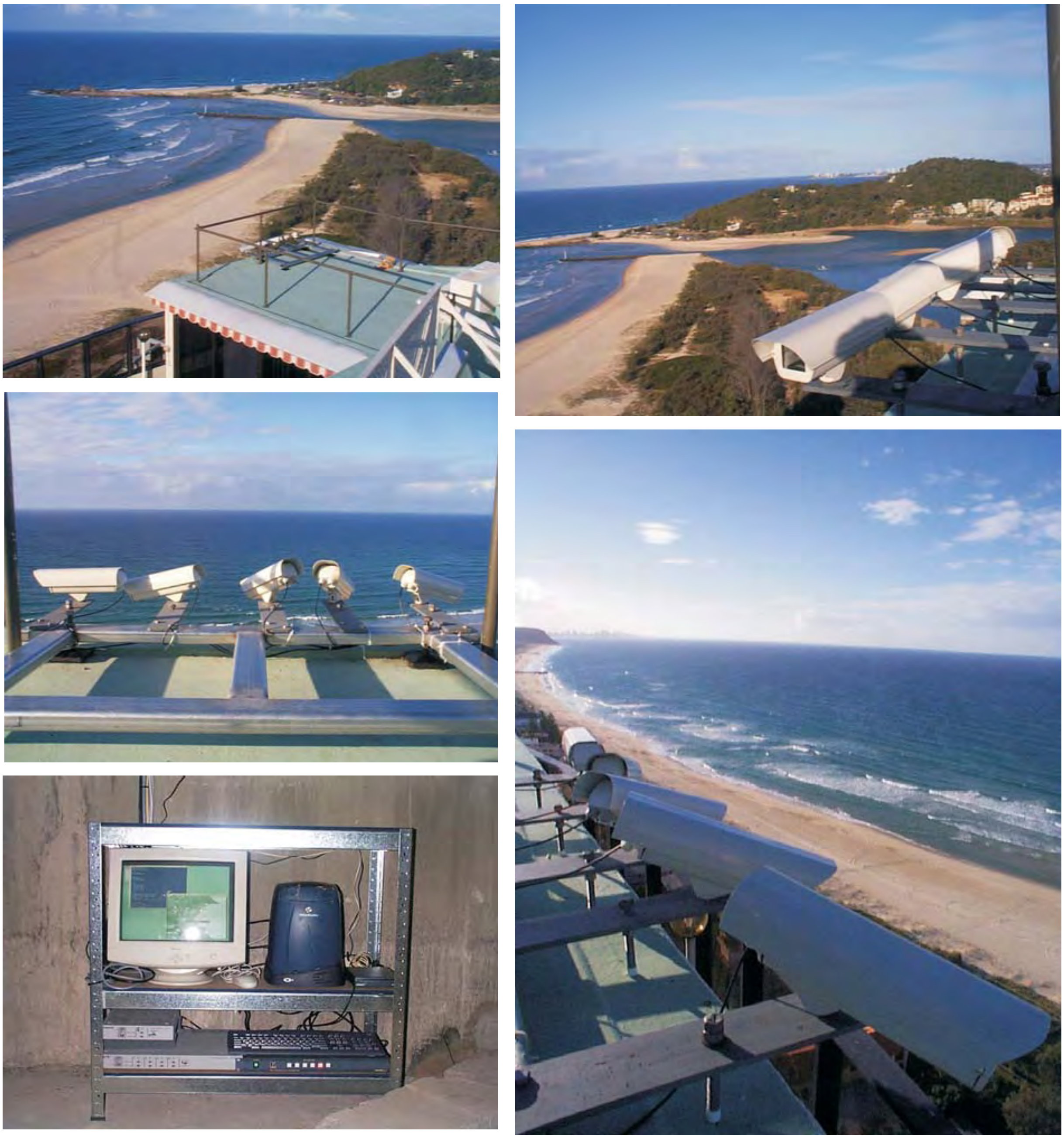
LOCATION OF COASTAL IMAGING SYSTEM
ROYAL PALM BUILDING

Figure
3.2

02114-3-2.cdr



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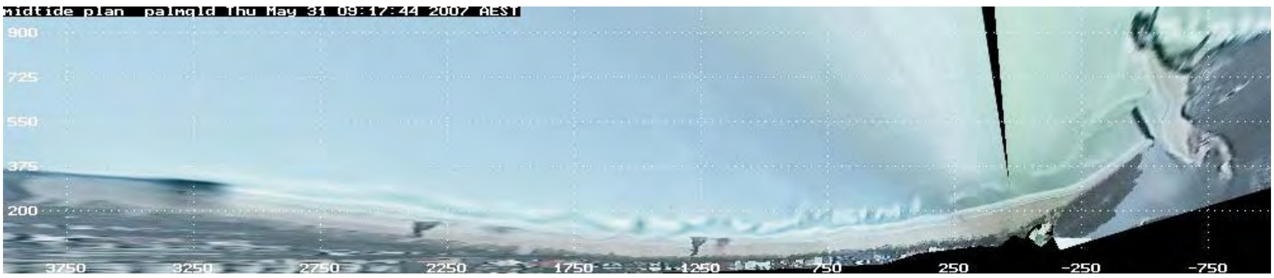
CAMERAS MOUNTED AT AN ELEVATION
OF APPROXIMATELY 80m

Figure
3.3

02114-3-3.cdr

WRL Report No. 2007/21	SNAP-SHOT, TIME-EXPOSURE AND VARIANCE IMAGE TYPES (MAY 2007)	Figure 3.4 02114-3-4.cdr



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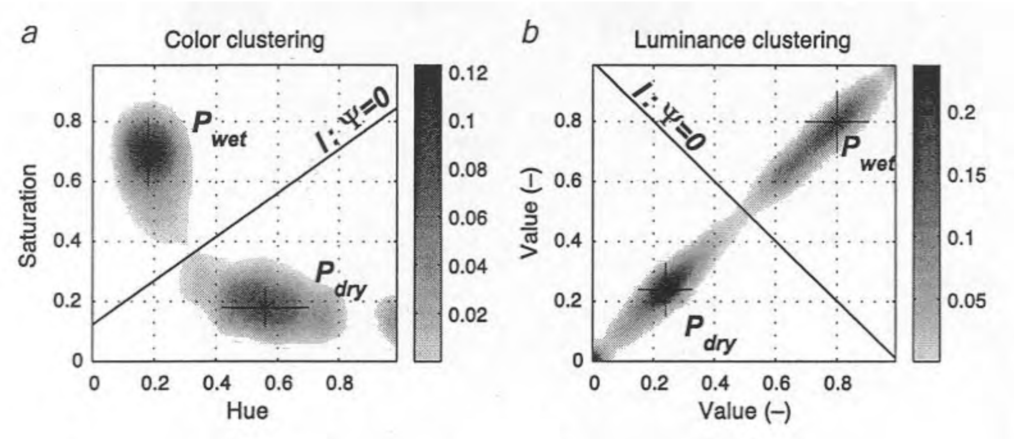
PAN AND PLAN VIEW IMAGES:
FIVE-CAMERA MERGE/RECTIFICATION (MAY 2007)

Figure

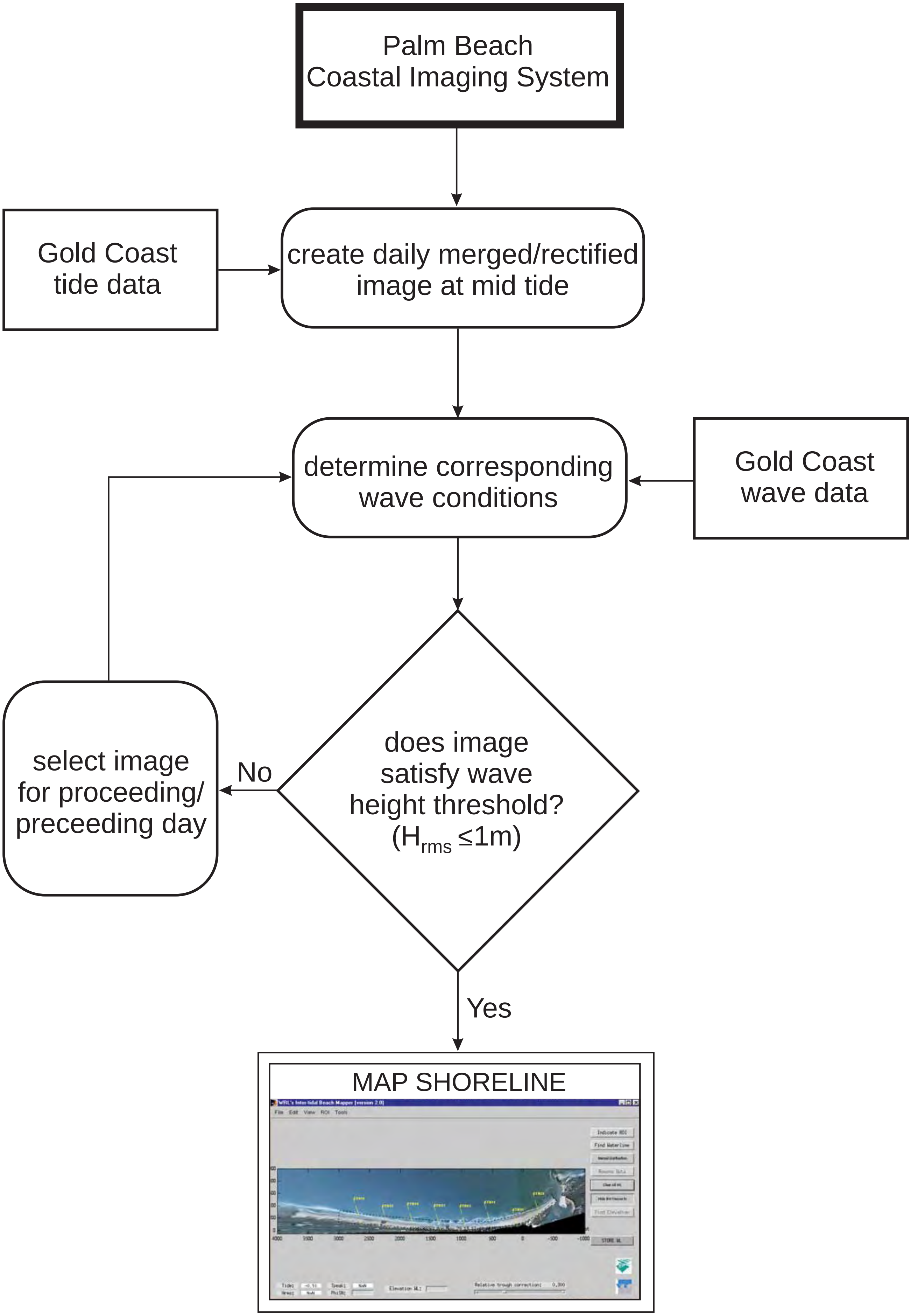
3.5

02114-3-5.cdr



Source: Aarninkhof (2003)

WRL Report No. 2007/21	IDENTIFICATION OF 'SHORELINE' FEATURE FROM COLOUR IMAGES	Figure 3.6 02114-3-6.cdr



STANDARDISED SHORELINE MAPPING PROCEDURE

Figure
3.7

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, almost **270,000 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.

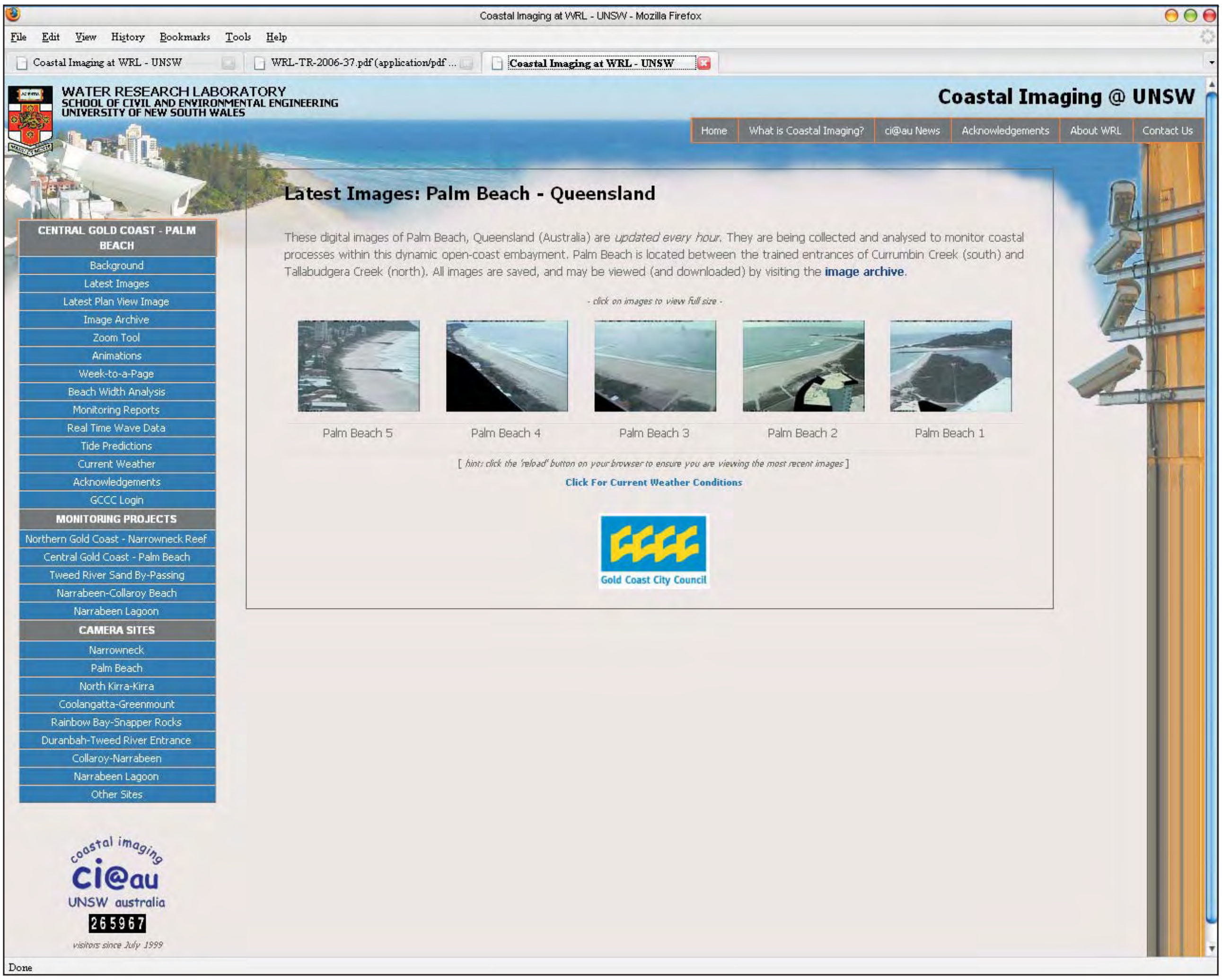
4.3 On-Line 'Beach Analysis System'

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.

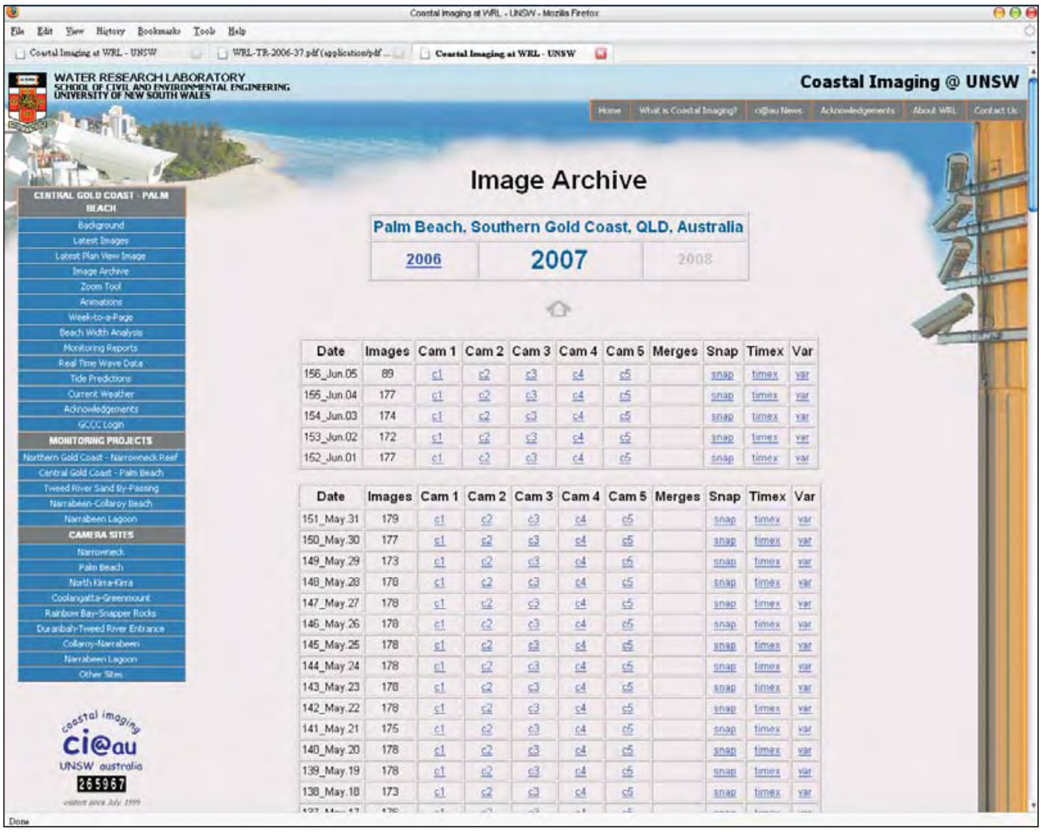
A description of the capabilities of this system was detailed in Anderson *et al.* (2003). To summarise, the features available at the project web site include the ability to view the latest mid-tide plan images; access to a zoom tool feature that enables zooming-in and panning through the current oblique 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.

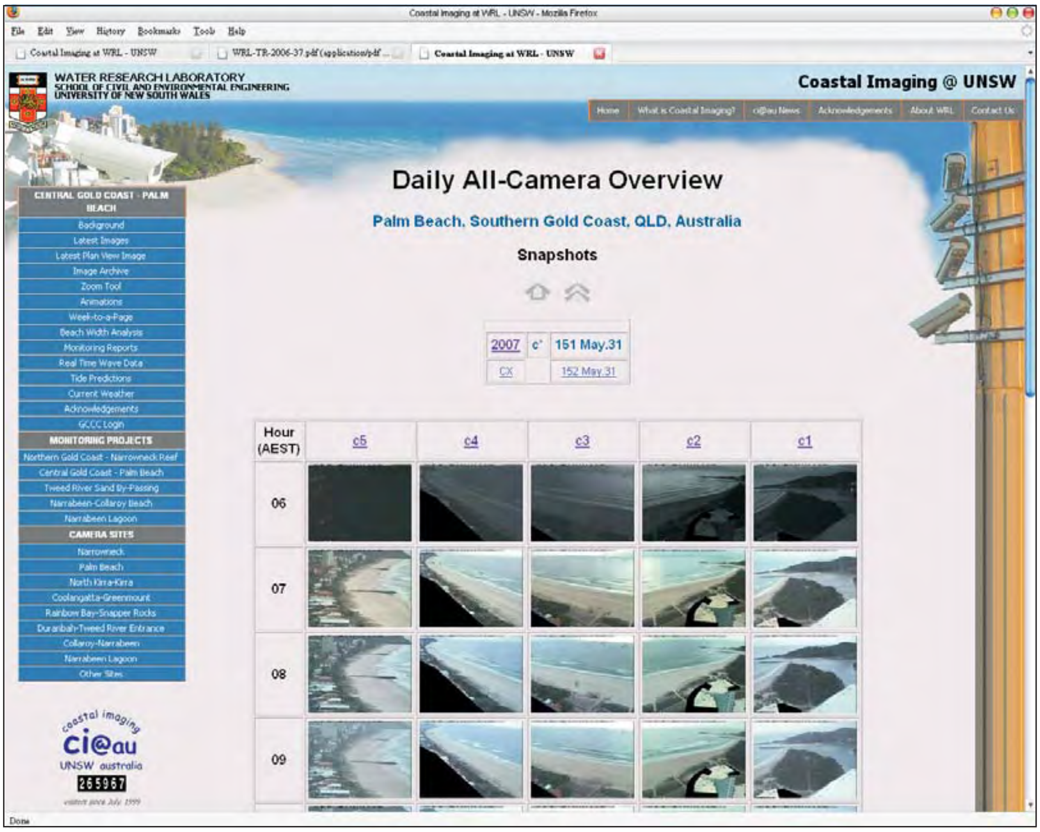
An example of the first of these products called 'week-to-a-page' is illustrated in Figure 4.3. Every Monday morning, this figure is generated and made available for viewing (and download, if required) via the project web site. The figure is pre-formatted to fit on a standard A4 page, to assist reporting. 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. 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.



WRL Report No. 2007/21	COASTAL IMAGING WEB SITE - HOME PAGE	Figure 4.1 02114-4-1.cdr





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COASTAL IMAGING SYSTEM WEB SITE - IMAGE ARCHIVE

Figure
4.2

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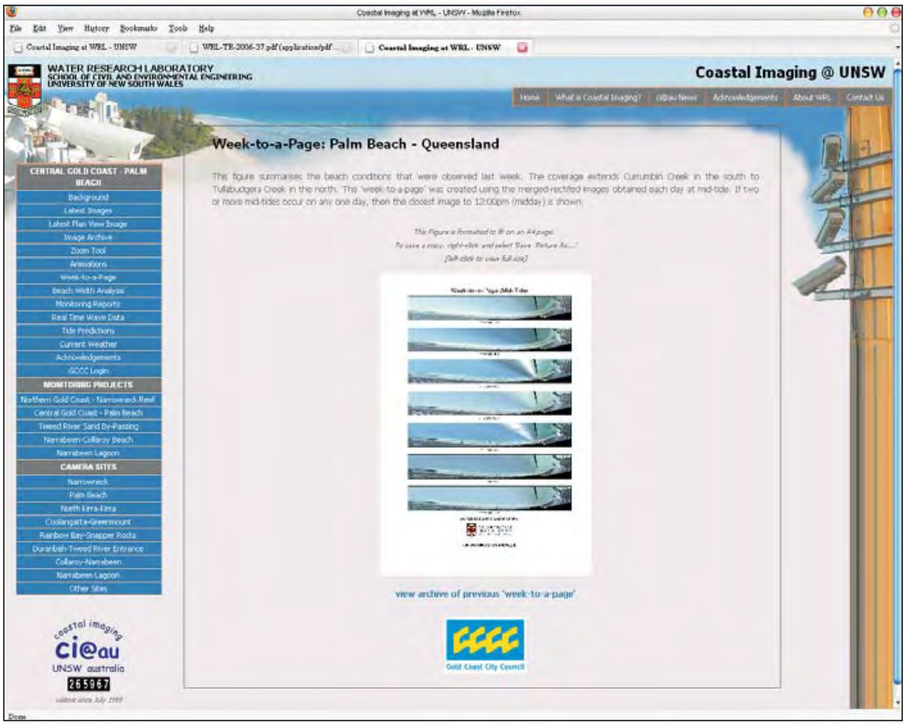
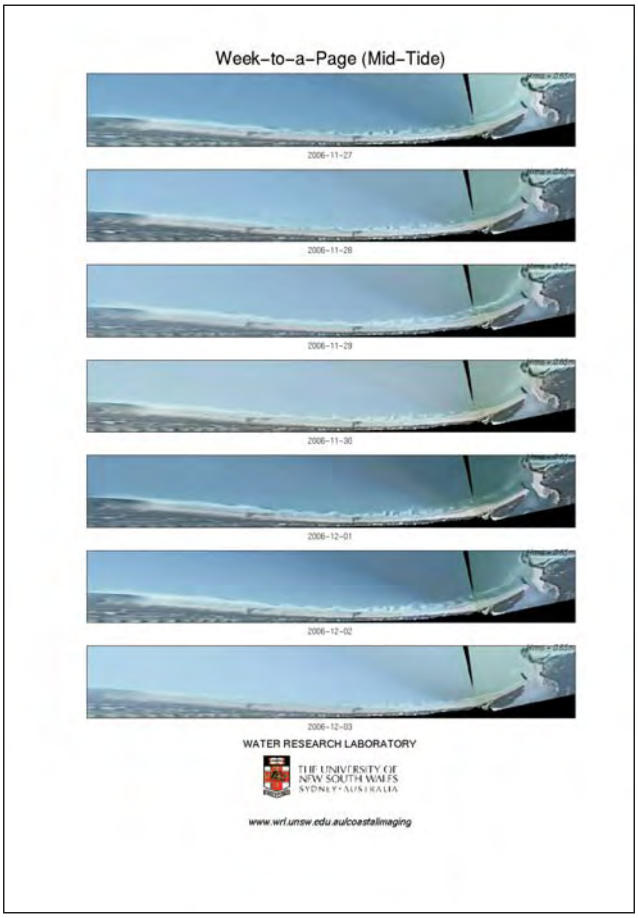
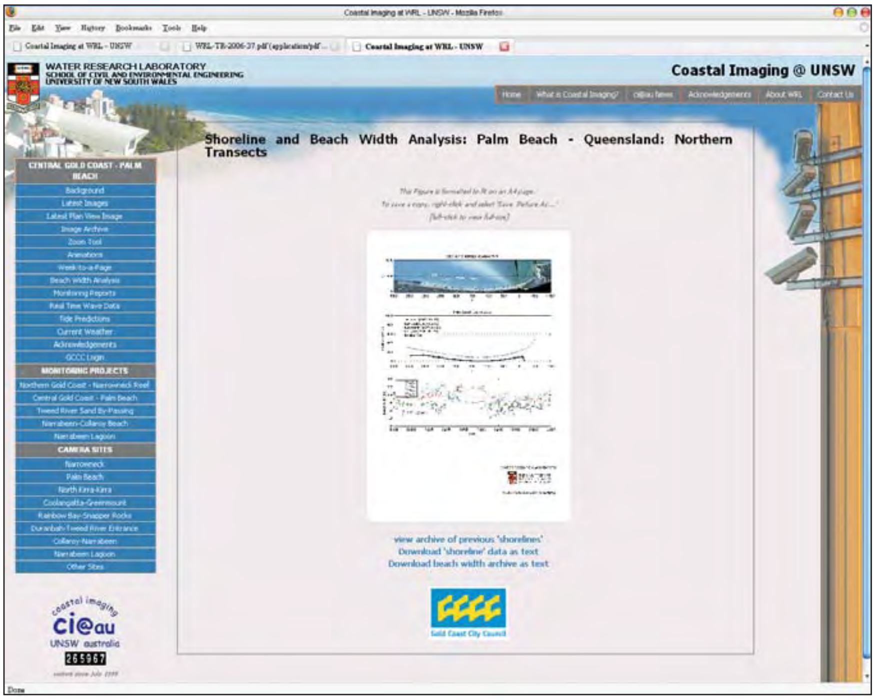
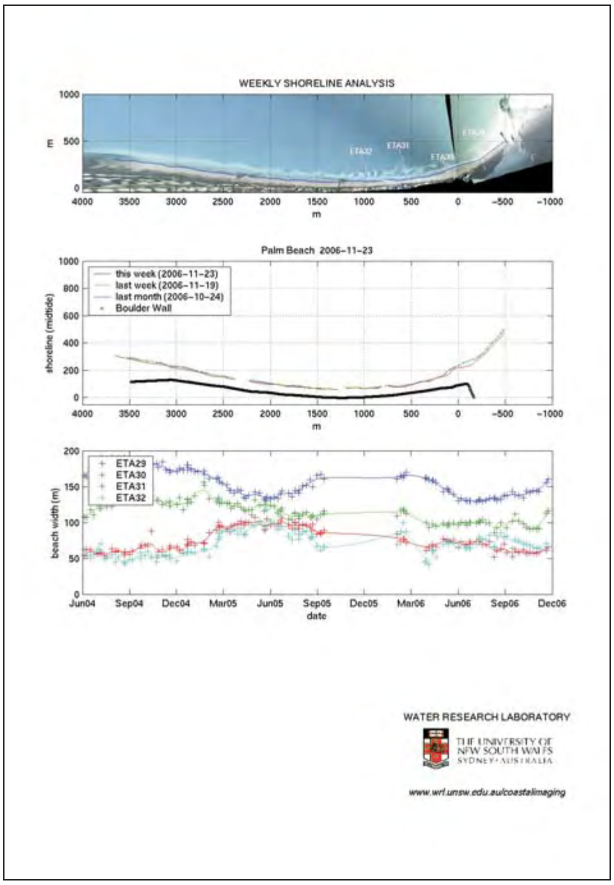




ON-LINE BEACH ANALYSIS SYSTEM
‘WEEK-TO-A-PAGE’

Figure
4.3





WRL Report No. 2007/21	ON-LINE BEACH ANALYSIS SYSTEM 'BEACH WIDTH ANALYSIS'	Figure 4.4 02114-4-4.cdr

5. MORPHODYNAMIC DESCRIPTION OF PALM BEACH: DECEMBER 2006 – MAY 2007

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 December 2006 to May 2007. 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 is also used at the Surfers Paradise site, and will continue to be used in future reports to enable inter-comparison as the monitoring programs continue.

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 December 2006 to May 2007 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 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.

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 December 2006

At the end of the previous monitoring period (June – November 2006), the entire Palm Beach embayment had responded to lower ongoing energy throughout late October and November, and was in an intermediate TBR/RBB state. Throughout most of December the significant wave height remained at about 1 m, peaking to 1.5 m on occasions.

The beach morphology remained essentially stable throughout December. The most notable morphological features were evident across the southern section of the beach, from the Currumbin Creek training wall to the 11th Street groyne. An offshore sand shoal extended from the mouth of the Currumbin Creek, north for approximately 500 m, with wave breaking evident across the shoal at times. By the end of December the shoal was less uniform, with undulations and transverse features developing. The section of beach extending approximately 1000 m south of the 11th Street groyne was generally the most active throughout December, with highly irregular morphology evident through the surf zone. Beachface undulations along with transverse sections of bar and migrating rip currents, typical of the TBR beach state, dominated this section of beach.

5.2.2 January 2007

At times during January, the wave energy was higher than the preceding months, with significant wave height often in the range of 1.5 m – 2 m, peaking at up to 3 m during the onset of a storm at the end of the month. Elevated storm wave heights first occurred on the 28th, and continued in pulses through the first week of February. The wave conditions observed were still markedly lower than during the storms of March 2006, which saw erosion across most of the Gold Coast beaches.

The highly featured TBR beach state at the end of December quickly migrated to a higher energy state during the first week of January, during a period of higher wave energy. On the 3rd of January, an almost uninterrupted bar can be seen to have formed along the entire beach length. The northern half of the beach showed typical characteristics of the RBB/LBT beach states, while south of the 11th Street groyne, the beach was more typical of the RBB state, with rip currents and rhythmic longshore bar observable.

Following the initial higher wave energy during the first ten days of January, the significant wave height was observed to drop off quickly, remaining in the range of 0.5 m to 0.75 m for several days. During this time of low wave energy, the bar that had developed became inactive, with a generally featureless surfzone observable until the 18th. Under moderate wave conditions from the 18th until the end of January, the bar that had developed earlier in the month again became active, with the beach again appearing in a TBR/RBB state along its entire length.

The onset of storm waves through the last four days of January resulted in the initiation of narrowing of the southern section of beach (just north of the Currumbin Creek entrance training wall). The effect of the storm waves on the surfzone is not directly evident in the mid-tide plan images captured for these days, due to the irregular pulsing nature of the elevated wave conditions (see Appendix B, Figure B2).

5.2.3 February 2007

The 2 m – 3 m significant wave height storm conditions continued from the end of January into the first week of February. The prevailing wave conditions throughout the remainder of February were typically 1.5 m – 2 m significant wave height.

The higher wave energy conditions during the first few weeks of February resulted in the beach migrating from a lower energy intermediate state, to an upper energy state more typical of LBT conditions. This is particularly evident in the plan images from the 12th through to the 15th, where an almost continuous detached longshore bar stretched the entire length of the beach.

A series of interesting morphological changes are evident during the period from the 17th through until the 22nd, particularly across the middle sections of the beach. On the 17th, crescentic features in the offshore detached bar began to form, which are typically evident of the RBB state. Throughout the next five days, these features grew in intensity, and transverse sections of bar progressively formed. By the 22nd, clear sections of transverse nearshore bars, separated by rip channels, dominated the surfzone across the mid section of the beach. Throughout the remainder of February, the middle section of the beach was characteristic of a TBR state, while the northern and southern stretches of beach were typically dominated by an active detached longshore bar.

5.2.4 March 2007

Wave energy throughout the month of March was consistent, peaking for only a short period of one to two days around the 7th and 8th, with a significant wave height of approximately 2 m from a more southerly direction. Generally the predominant wave conditions were 8 to 10 second period, 1 to 1.5 m significant wave height.

The morphology which developed at the end of February, with complex TBR conditions along the middle stretch of the beach, and a longshore bar at the southern and northern sections of the beach, persisted throughout the entire month of March. The effect of changing predominant wave conditions more from the south was evident at several times during the month. An example of this is from the 27th to the 30th, when the nearshore morphology was observed to adjust to the southerly wave direction, with obvious transverse rip currents carrying material offshore and to the north, at regular intervals along the beach.

5.2.5 April 2007

Prevailing low wave conditions through the first two weeks of April saw the northern section of Palm Beach migrate from an offshore bar to a more typical TBR state, similar in appearance to the mid section of the beach. Clear irregularities and transverse sections in the surfzone bathymetry were present by the middle of the month, across this northern beach section. While a clear and active offshore bar remained across the southern section of the beach during this time, transverse rip currents were also observed to cut through this bar at several places along the beach, by the middle of the month. Wave breaking across a shallow sandy shoal was clearly evident at the mouth of the Currumbin Creek, with this shoal extending offshore of the creek entrance training wall, and initiating the longshore bar over the southern section of the beach. It appears from the daily plan view images, that the northern littoral drift of sand is in fact being fed from the south by this offshore shoal, and effectively starving the southern section of beach (across the sand spit to the training wall) of sand. This is perhaps evidenced by the obvious decrease in beach width throughout the first half of this monitoring period at the southern end, even though there has been no major storm wave conditions.

The last half of April was dominated by very low wave conditions, with significant wave heights typically less than 1 m. The resulting morphological changes closely followed the Wright and Short (1983) beach state model, with the entire beach migrating into a lower energy TBR state, and then with the formation of shore connected bars at several places along the beach, as the low wave energy prevailed.

5.2.6 May 2007

While the predominant wave conditions throughout May were again low significant wave height of less than 1 m, there was a period of one week from the 8^{th} to the 15^{th} where the wave height exceeded 1.5 to 2 m. During this period of higher wave energy, the surfzone morphology adjusted, such that by the 15^{th} a clear detached longshore bar was again present along the entire length of the beach. This longshore bar remained clearly evident until the 19^{th}, when a series of transverse rips formed within the middle section of the beach.

Throughout the final 10 days of this monitoring period, low wave conditions again saw the beach state shift and adapt to the lower energy conditions, as occurred at the end of April. The detached bar became irregular, being cut by many transverse rips, and steadily migrating closer to the shore, particularly across the centre stretch of the beach.

5.3 Visual Assessment of Beach Width Changes (December 2006 – May 2007)

Beach and nearshore conditions during the period December 2006 to May 2007 were characterised by relatively consistent moderate wave conditions. No significant storm events were observed in terms of beach morphology, with beach width changes occurring at relatively steady rates throughout the monitoring period. 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 six-month monitoring period.

Figure 5.2 shows the snap images obtained at mid-tide from Camera 2 (south) in December 2006 and May 2007 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) in the region of the Currumbin Spit, significant narrowing of the beach has occurred. The amount of beach narrowing steadily decreases in a northward direction, but is still relatively apparent even as far north as the immediate vicinity of the Royal Palm building.

Looking north along the Palm Beach embayment (Figure 5.3), from December 2006 to May 2007, significant accretion has occurred in the region immediately south of the 11th Street groyne, while there has been very little observable change in beach width on the north side of the groyne. In the vicinity of the 21st Street groyne and further north, significant accretion has also occurred, with noticeable beach widening during the present six-month monitoring period.

5.4 Visual Assessment of Total Beach Width Changes (June 2004 – May 2007)

The net beach changes to date since the commencement of monitoring at Palm Beach three years ago in early June 2004 are seen in Figure 5.4. In this figure, 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 – May 2007.

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. Toward the north, from June to November the southern end of this region appears to have generally widened. In contrast, toward 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.

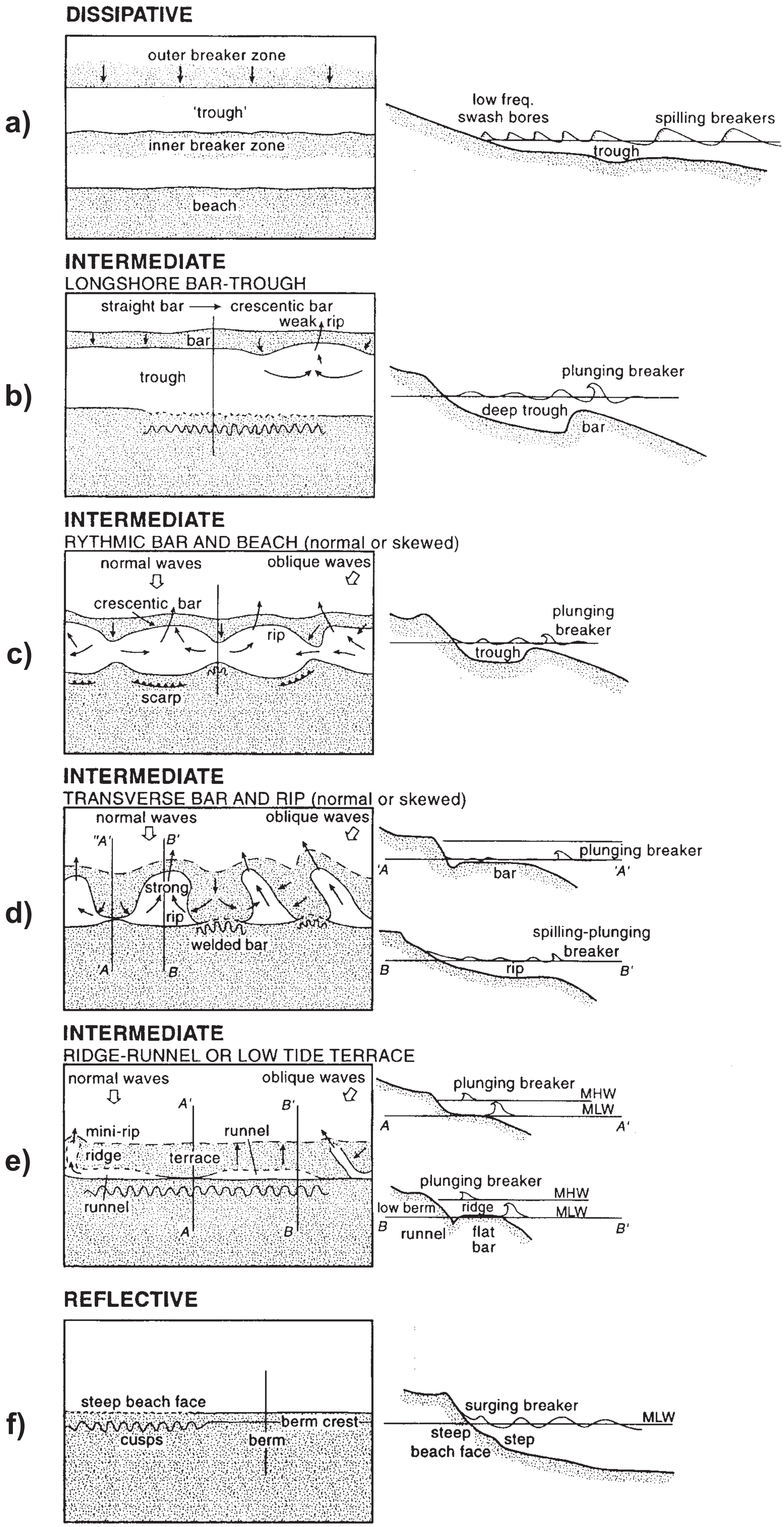
During the period December 2005 to May 2006 a distinctive trend of beach narrowing was apparent at the far southern end of the Palm Beach embayment in the region of the Currumbin Spit. Immediately south of the 11th Street groyne the beach had increased in width, while the region between the 11th and 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.

During the present six month monitoring period, notable beach recession has 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 is evident. Looking northward along the Palm Beach embayment, the beach appears to have 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. 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 2007, is worth noting.

From the images shown in Figure 5.4, 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 steadily accretes and is typically much wider at the end of November. 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.

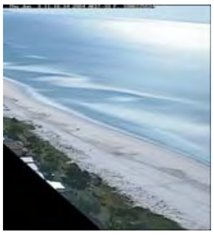
A more quantitative assessment of the response of Palm Beach for the period December 2006 to May 2007 is detailed in the following Section 6.



WRL Report No. 2007/21	MORPHODYNAMIC BEACH STATE MODEL (after WRIGHT and SHORT, 1983)	Figure 5.1 02114-5-1.cdr

WRL Report No. 2007/21	SNAP IMAGES FROM CAMERA 2 (SOUTH): DECEMBER 2006 AND MAY 2007	Figure 5.2 02114-5-2.cdr

WRL Report No. 2007/21	SNAP IMAGES FROM CAMERA 5 (NORTH): DECEMBER 2006 AND MAY 2007	Figure 5.3 02114-5-3.cdr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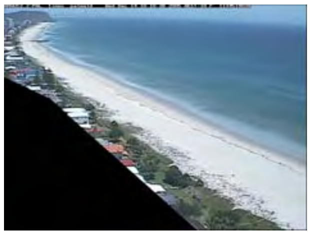
December 2004


May 2005


December 2005


May 2006


December 2006


May 2007


June 2004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May 2005


December 2005


May 2006


December 2006


May 2007

WRL Report No. 2007/21	SIX-MONTHLY BEACH CHANGES CAMERA 2 (SOUTH) AND CAMERA 4 (NORTH): JUNE 2004 - MAY 2007	Figure 5.4 02114-5-4.cdr

6. QUANTITATIVE ANALYSIS OF SHORELINE CHANGES: DECEMBER 2006 – MAY 2007

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 current (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 01/12/06 to 31/05/07 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: 31st May 2007). 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 six 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 01/12/06 – 31/05/07, it can be seen from Figure 6.2 that the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 50 m (relative to the alignment of the back-beach boulder wall) approximately midway between the Royal Palm building and the 11th Street groyne, to around 180 m at the extreme northern end of the embayment adjacent to Tallebudgera Creek. At the southern end of the boulder wall, adjacent to Currumbin Creek, the reference boulder wall alignment dips landward, resulting in over 250 m of beach between the wall and shoreline. The envelope of beach width changes along the entire embayment was in the range of 20 - 40 m during this period.

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

The alongshore variability of the measured shoreline positions during the monitoring period 01/12/06 – 31/05/07 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 on to a merged/rectified timex image of the northern Gold Coast (image date: 31st May, 2007).

Referring to Figure 6.3, the median beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 60 – 80 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 125 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) reveals a relatively uniform trend along the northern half of the embayment, with the beach width varying by of the order of ±25 m from the mean shoreline position. The variation in beach width along the southern half of the embayment (south of the 11th Street groyne) was irregular, with the beach width varying by ±5 m from the mean shoreline position in some locations, but up to ±40 m at other locations.

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 01/12/06 - 31/05/07. Relatively low standard deviation of weekly shorelines was in the range of 5 - 10 m, which is indicative of a relatively stable beach throughout the present 6-month monitoring period. As noted above, the area south of the 11th Street groyne was sensitive to shoreline change, having the embayment's highest and lowest sections of shoreline variation. The surfzone of this section of beach was typically dominated by transverse nearshore bars and rips throughout the current monitoring period, resulting in the high variation in beach width along this section of the beach. The region in front of the cameras and further south also exhibited a higher degree of variability, due to the steady shoreline recession along Currumbin Spit south to Currumbin Creek.

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 December 2006 to May 2007 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: 31/05/2007).

6.3.1 Southern Transects (ETA29 – ETA32)

At the southern-most transect ETA29 located across the southern Sand Spit, a steady decreasing beach width trend was apparent throughout the entire monitoring period from December to May, with the beach decreasing in width by just over 20 m during this period. The transect just north of the Royal Palm building (ETA30) accreted rapidly in December, and then decreased in width again during January. The beach width at this location then remained relatively stable throughout the remainder of the monitoring period, with very little net change in beach width from December 2006 to May 2007. The transects further to the north (ETA31 and ETA32) both showed beach widening during the current monitoring period, with the greatest increase in net beach width of approximately 30 m occurring at transect ETA31 between December 2006 and May 2007.

6.3.2 Central and Northern Transects (ETA33 – ETA36)

The weekly analysis of shoreline position at the central and northern transects ETA33 to ETA36 are shown in Figure 6.5. The beach width at the central transects ETA33 and ETA34 fluctuated between minor erosion and accretion from December through to March, but have both been widening at a relatively uniform rate through until the end of May 2007. The net increase in beach width across these transects during the current six month monitoring program has been of the order of 20 m. Transect ETA35, just on the southern side of the 21st Street groyne, has experienced only minor fluctuations in beach width between December 2006 and May 2007, with negligible net change. The beach also fluctuated in width throughout December and January at transect ETA 36 in the far north, but then steadily accreted throughout February, March, and into April. A minor net increase of 5 to 10 m in beach width occurred at this transect throughout the six month monitoring period.

In summary, the dominant observation during the present monitoring period across the mid and northern transects, was fluctuating beach widths from December until February, followed by steady increase in width in the range of 5 – 20 m until the end of May 2007. However, across the southern transects, there was generally a narrowing of the beach, increasing in magnitude toward the south along Currumbin Spit, where the net decrease in beach width was over 20 m.

6.4 Weekly Shorelines (December 2006 – May 2007 Relative to Mean Shoreline Position of Previous Monitoring Period (June - November 2006)

To summarise, Figure 6.6 presents the analysis of all available weekly beach widths for the period December 2006 to May 2007, relative to the mean shoreline alignment calculated for the prior six month period June to November 2006. 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 June - November 2006 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 entire mapped section of the Palm Beach embayment experienced a minor trend of beach widening. Generally the increase in beach width was relatively uniform across the entire embayment. In the centre of the beach compartment between the 11th Street and 21st Street groynes, the beach widening was minimal, with the maximum beach width during the current monitoring period approximately 15 m wider than the mean shoreline position from the previous six month monitoring period. At the southern end of the embayment, between the Royal Palm building and the 11th Street groyne the widening was the most evident, with the maximum beach width observed between December 2006 and May 2007 some 40 m wider than the mean beach width from the period June to December 2006.

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. While the entire mapped section of the embayment experienced an underlying trend of accretion in the range of 15 – 40 m, the southern Currumbin Spit experienced erosion throughout the current monitoring period. This section of the beach extends beyond the mapped region shown in Figure 6.6, but the extent of erosion can be seen by contrasting the first and last week-to-a-page mid-tide plan images of the beach, included in Appendix A. It can be estimated from these images that the net change in beach width along Currumbin Spit was of the order of 20 m.

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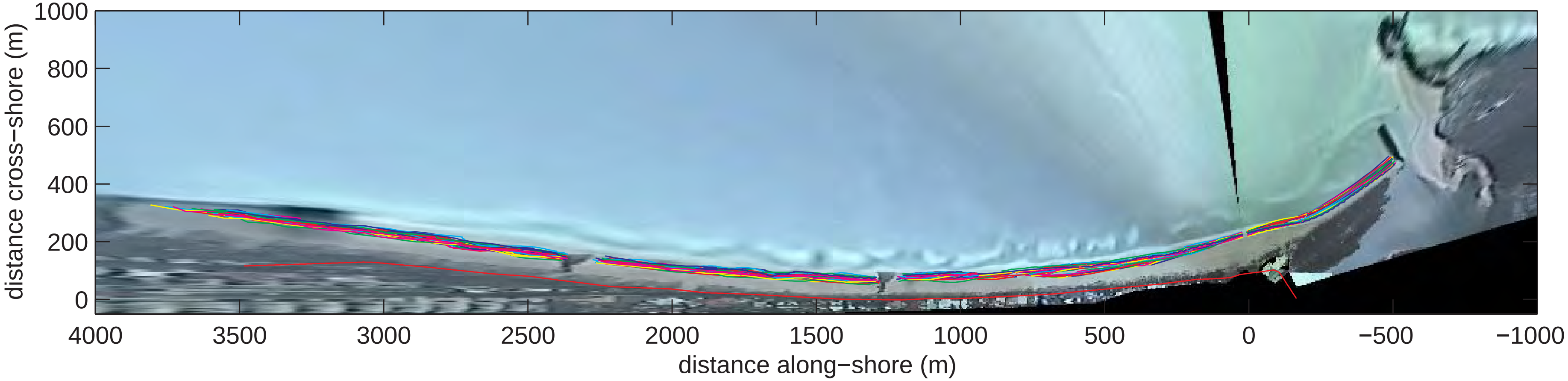
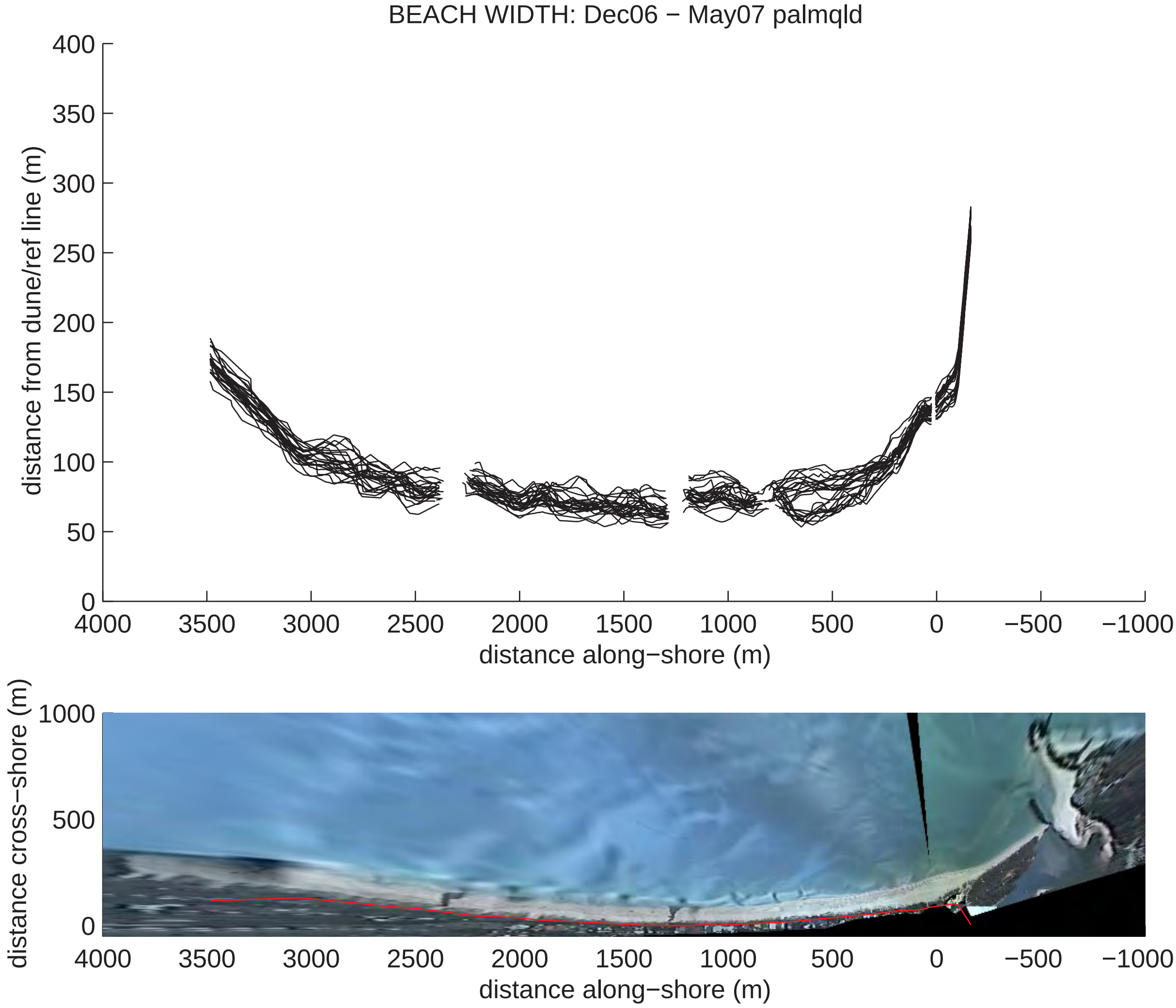
WEEKLY SHORELINES:
DECEMBER 2006 - MAY 2007

Figure
6.1

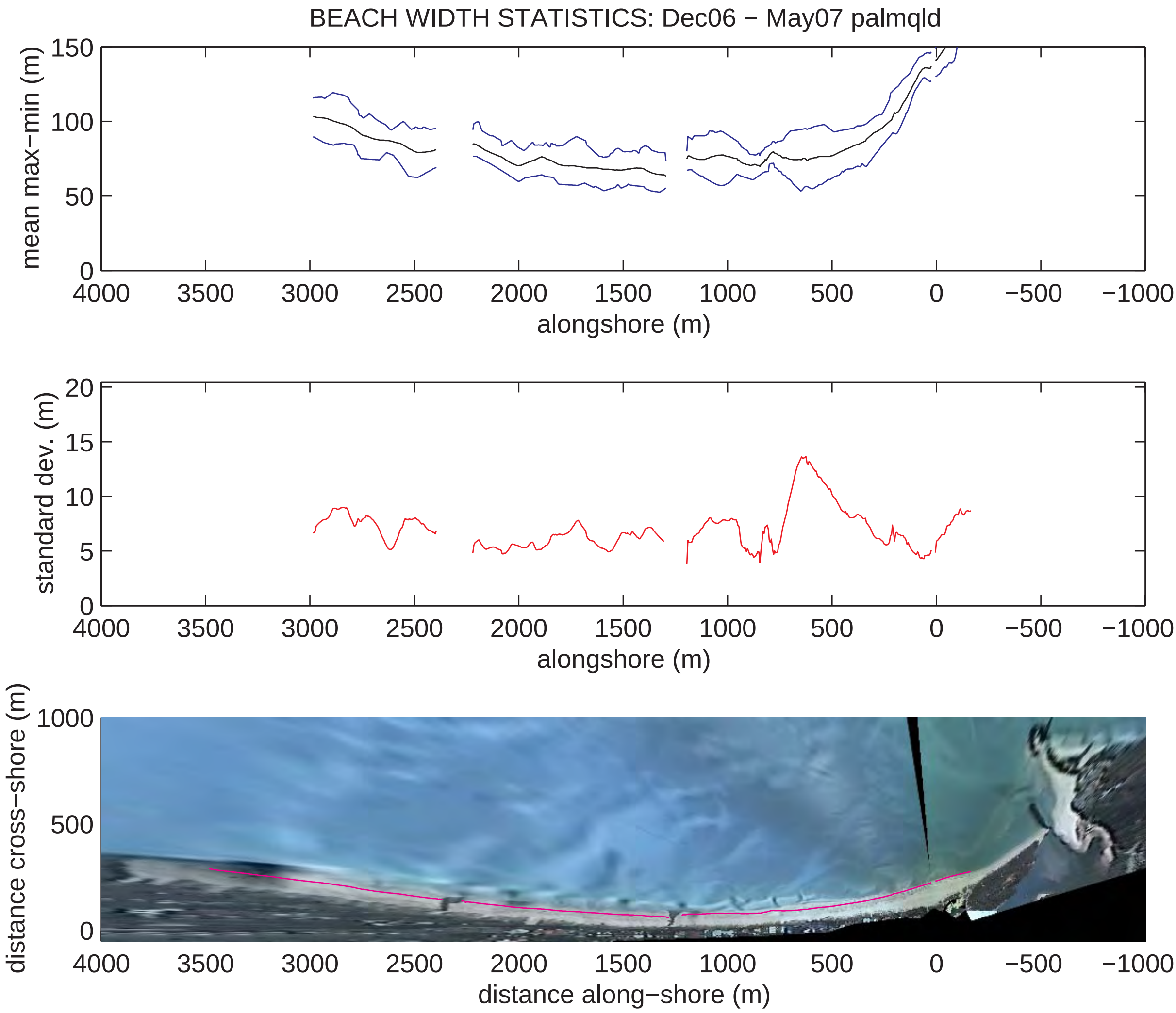
02114-6-1.cdr

WEEKLY SHORELINES: Dec2006 − May2007 palmqld

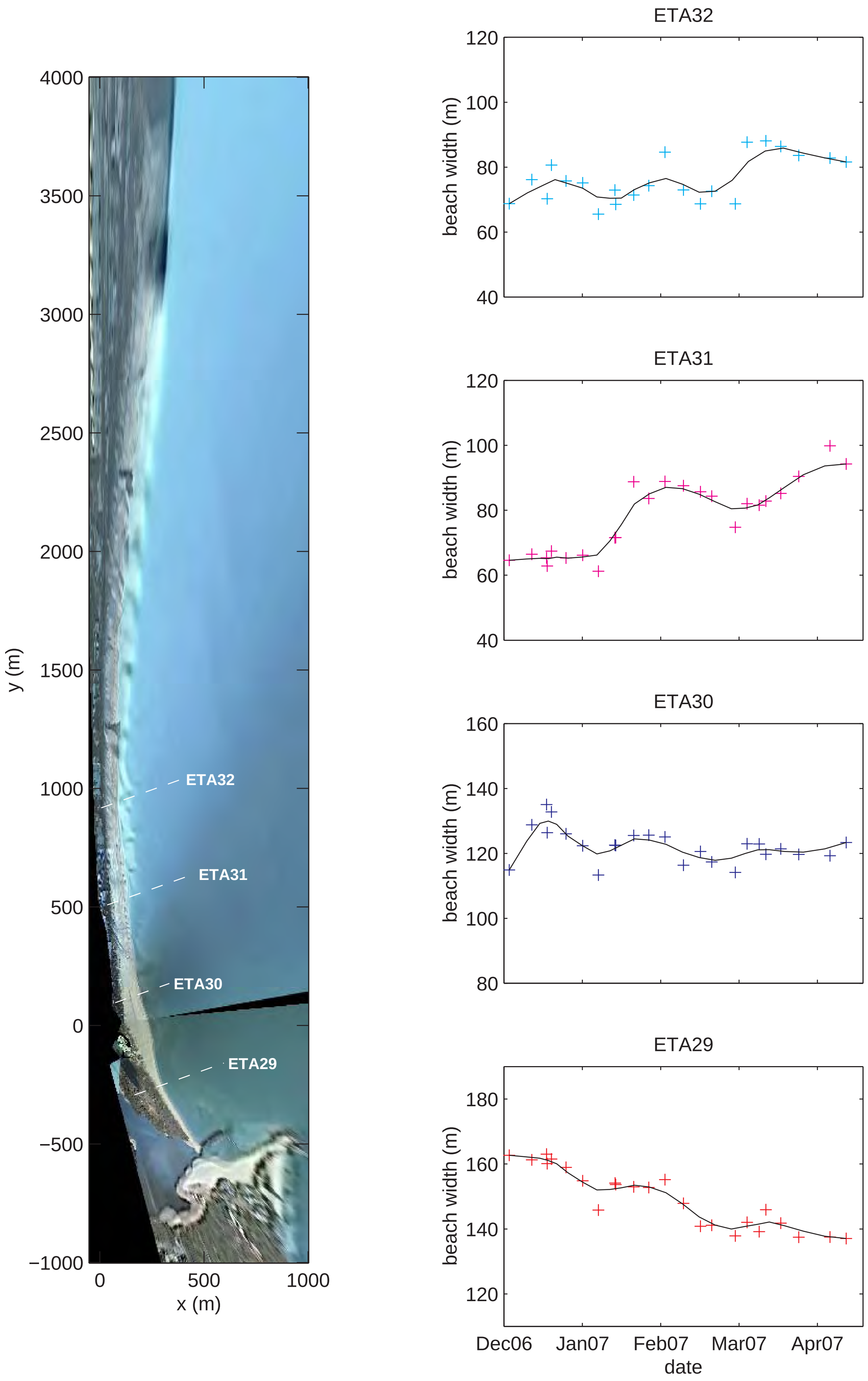




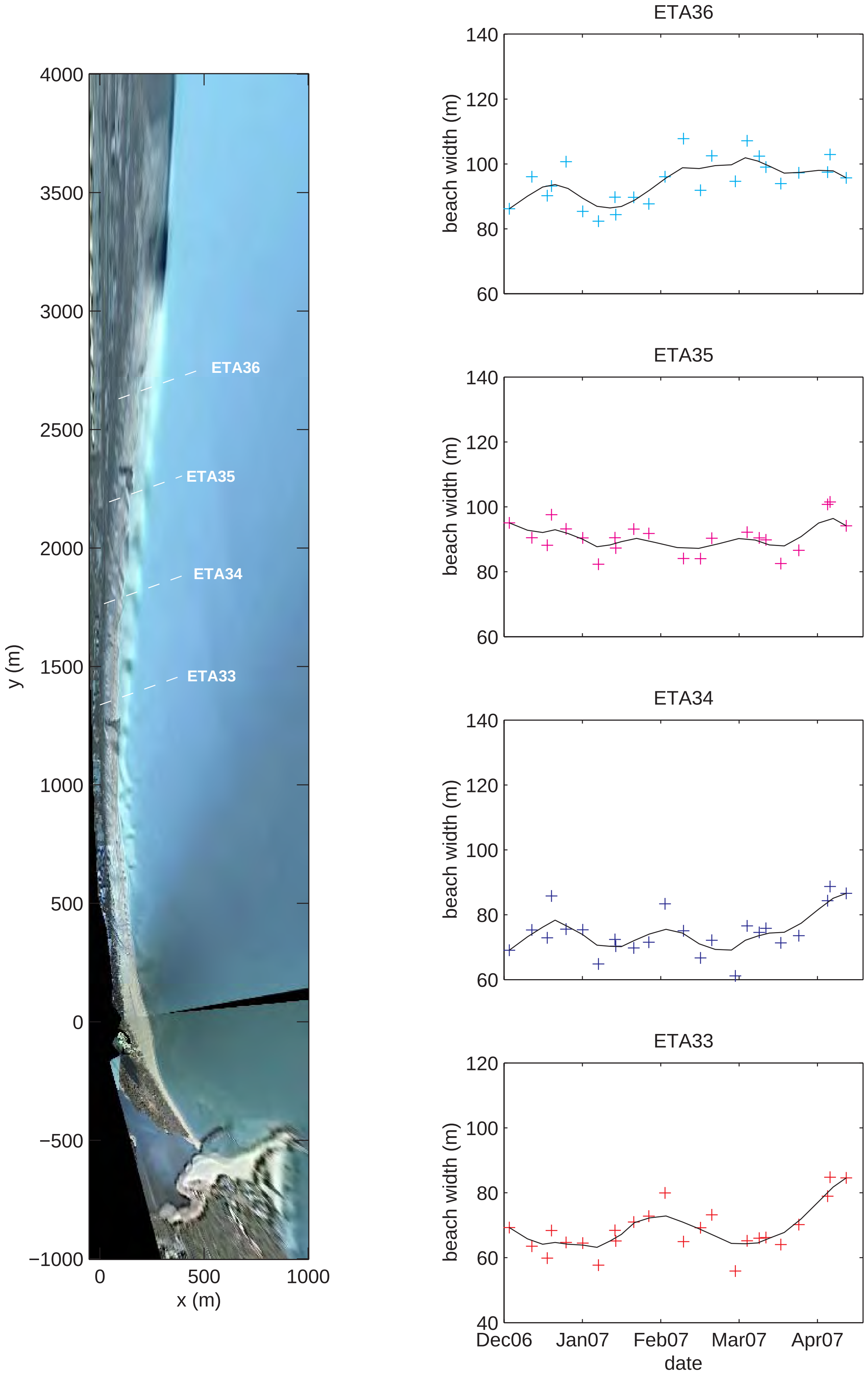
WRL Report No. 2007/21	WEEKLY BEACH WIDTH: DECEMBER 2006 - MAY 2007	Figure 6.2 02114-6-2.cdr



WRL Report No. 2007/21	STATISTICAL SUMMARY OF BEACH WIDTH CHANGES: DECEMBER 2006 - MAY 2007	Figure 6.3 02114-6-3.cdr



WRL Report No. 2007/21	TIME-SERIES OF BEACH WIDTH (SOUTH): DECEMBER 2006 - MAY 2007	Figure 6.4 02114-6-4.cdr



WRL

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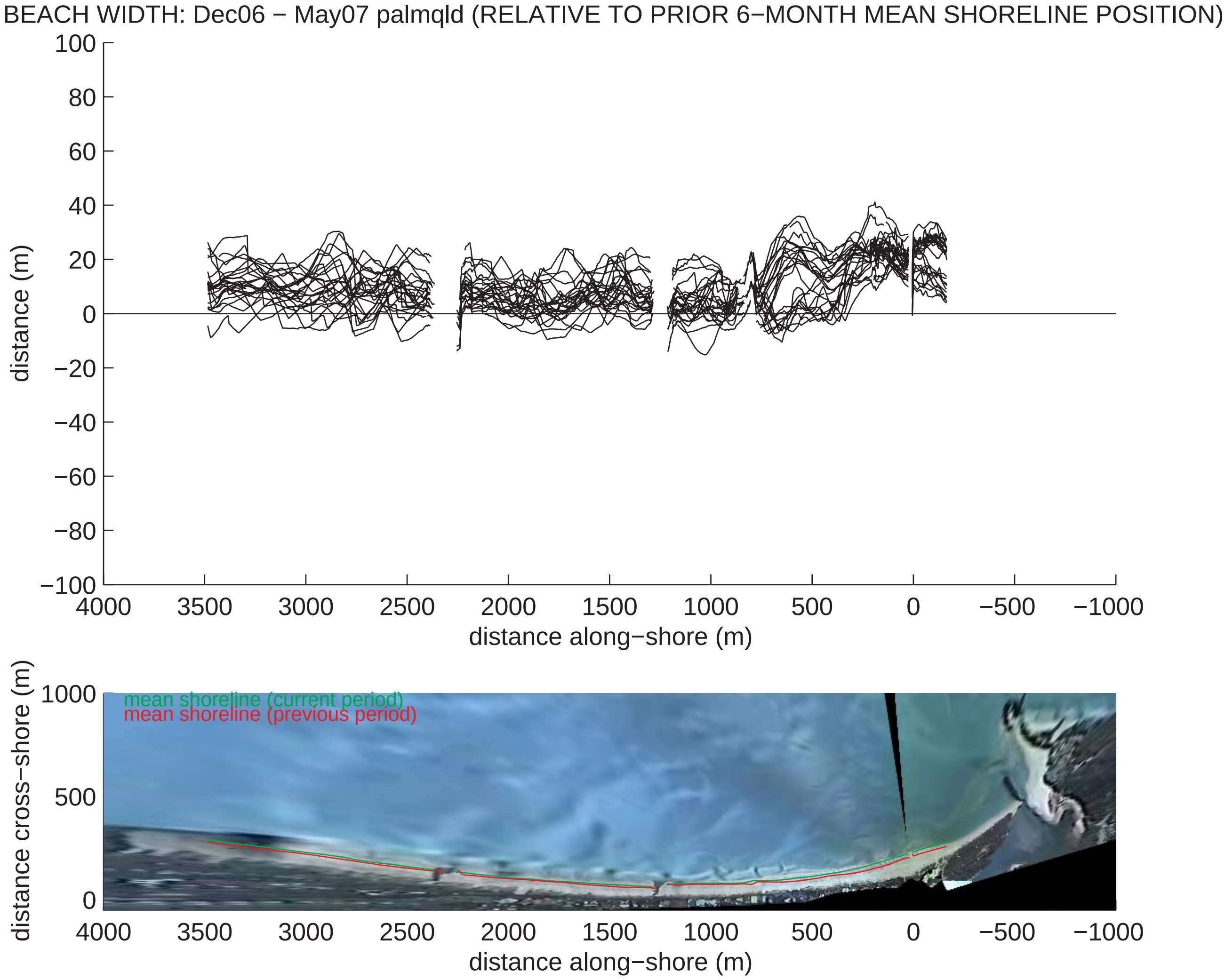
TIME-SERIES OF BEACH WIDTH (NORTH):
DECEMBER 2006 - MAY 2007

Figure

6.5

02114-6-5.cdr



WRL Report No. 2007/21	WEEKLY BEACH WIDTH DECEMBER 2006 - MAY 2007 RELATIVE TO PRIOR SIX-MONTH MEAN SHORELINE POSITION	Figure 6.6 02114-6-6.cdr

7. QUANTITATIVE ANALYSIS OF TOTAL SHORELINE CHANGES: JUNE 2004 – MAY 2007

The completion of a total of 3 years (36 months) of monitoring at Palm Beach provides the opportunity to summarise and analyse longer-term shoreline changes observed to date. As the monitoring program continues in the future, this analysis will extend accordingly, providing potential insight to possible seasonal and/or longer-term trends that may emerge.

7.1 Weekly Shorelines and Shoreline Variability: June 2004 – May 2007

All weekly beach widths (relative to the alignment of the back-beach boulder wall) for the 156 week period June 2004 to May 2007 are shown in Figure 7.1. As per previous figures, a merged/rectified image is shown in the lower panel for reference (image date: 31st May 2007). 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.

The variations in shoreline position measured at the eight ETA survey transects for the entire period June 2004 to May 2007 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: 31st May 2007).

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 current monitoring period from December 2006 to May 2007, the beach width at the southern sand spit steadily decreased, with a net change in beach 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.

Fluctuations of the beach width at ETA30 (Figure 7.2) were similarly 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 decline 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 declined 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.

7.1.2 Nearshore Nourishment Area

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.

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 ETA 36 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 through the last two months of the current monitoring period.

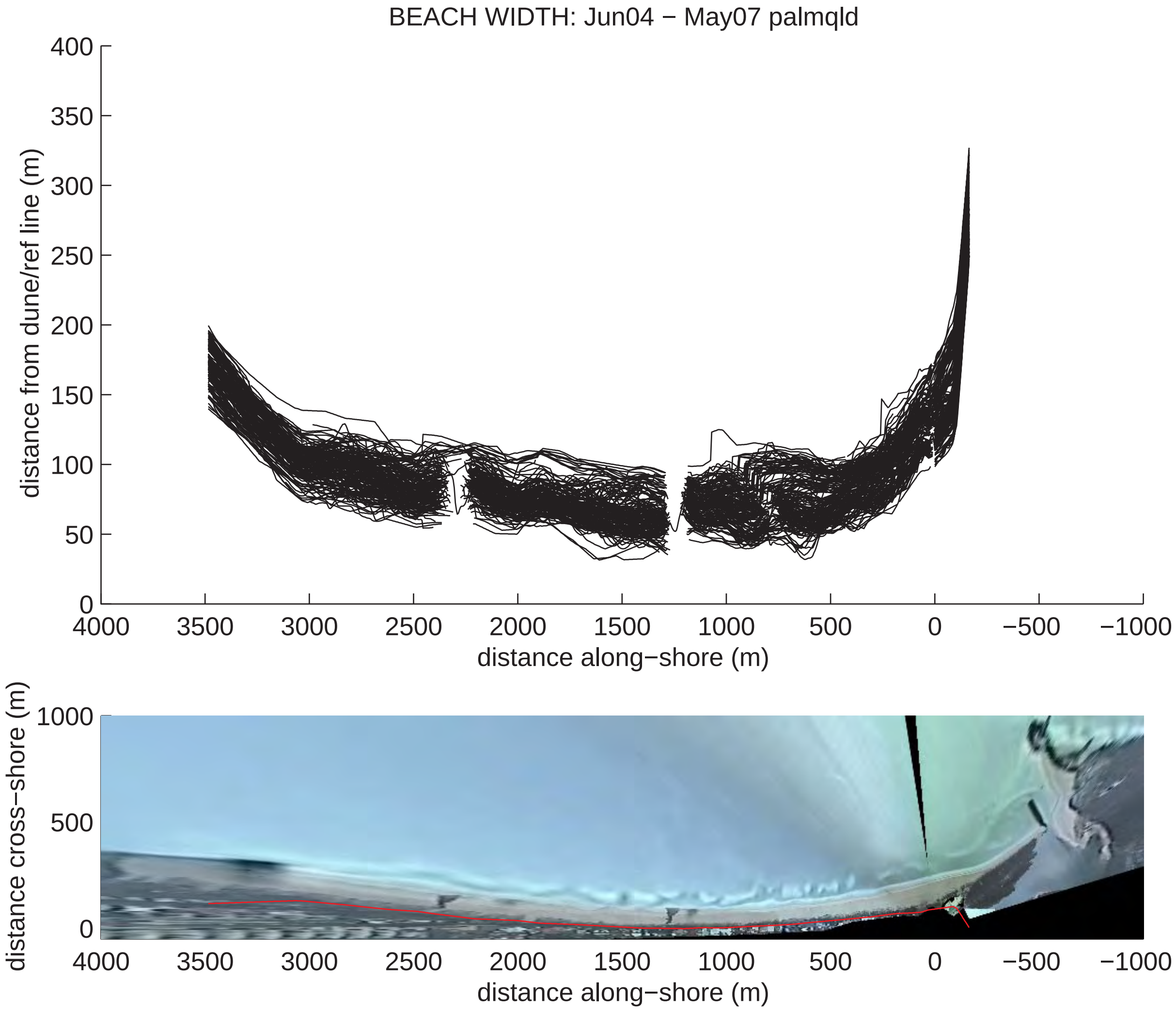
7.2 On-Line Beach Width Analysis

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. 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, following the storm of March 2006 and a period of slightly higher wave climate in late 2006 to early 2007, divergence of beach width alongshore was again apparent. From January 2007 until the end of the current monitoring period in May 2007, the ETA transect lines again show reasonably rapid convergence toward a uniform storm buffer, with a continuous beach width of 100 ± 20 m at all of the eight ETA transects.

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 receded 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 11th and 21st 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. Since nourishment of the beach ceased in November 2006, the beach has continued to accrete, with net widening observed at most transects. Generally the beach is wider now than at the initiation of the monitoring period three years ago, with the net increase in beach width throughout the last three years ranging from 5 m to greater than 20 m at some transects. Only on the southern sand spit has the beach become narrower throughout the six months from December 2006 to May 2007, with a decrease in beach width of approximately 30 m observed at transect ETA29. While the beach width recorded at transect ETA29 at the end of November 2006 was similar to that at the start of the monitoring period in June 2004, it is now some 30 m narrower due to the erosion which occurred during the last six months.



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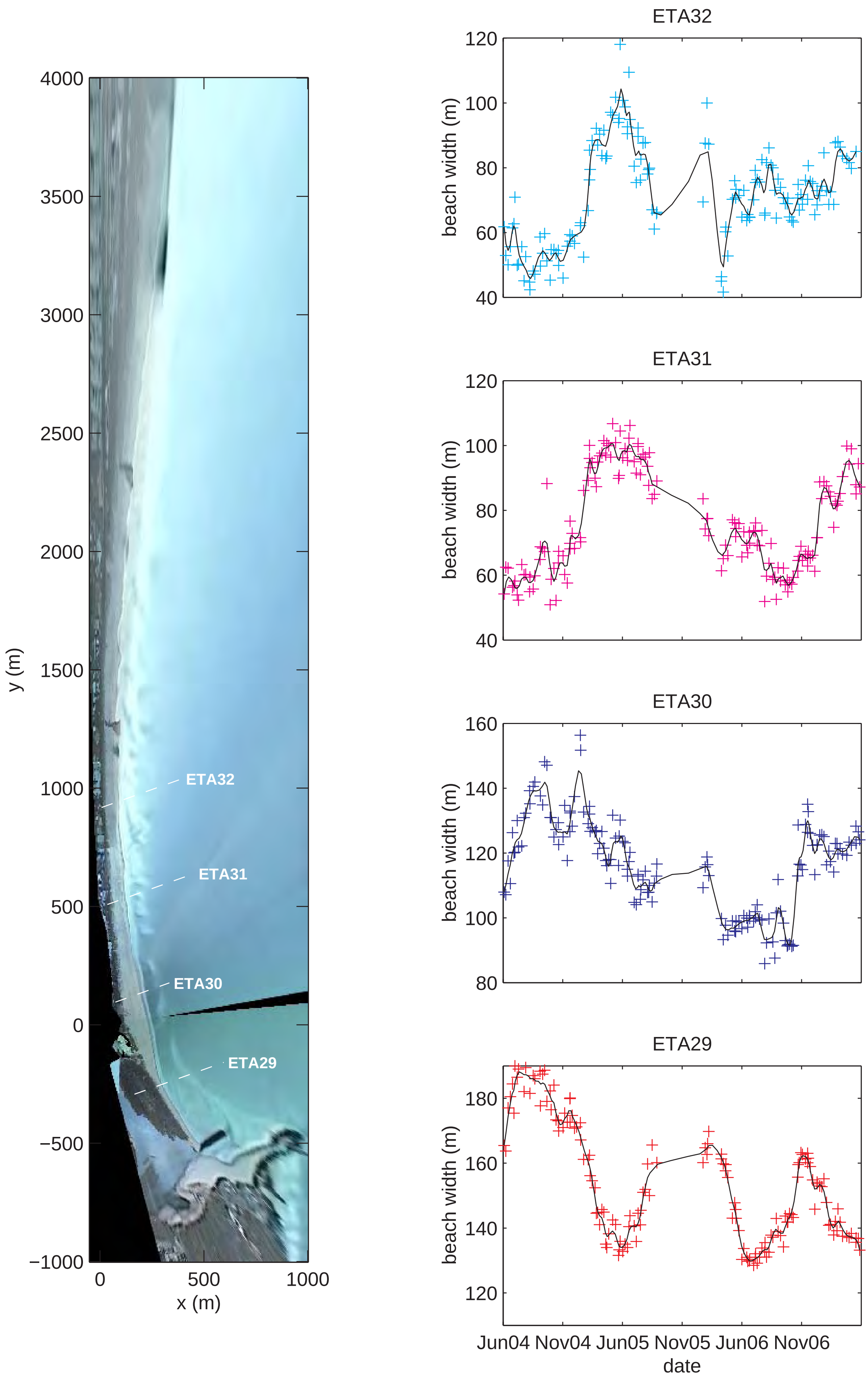
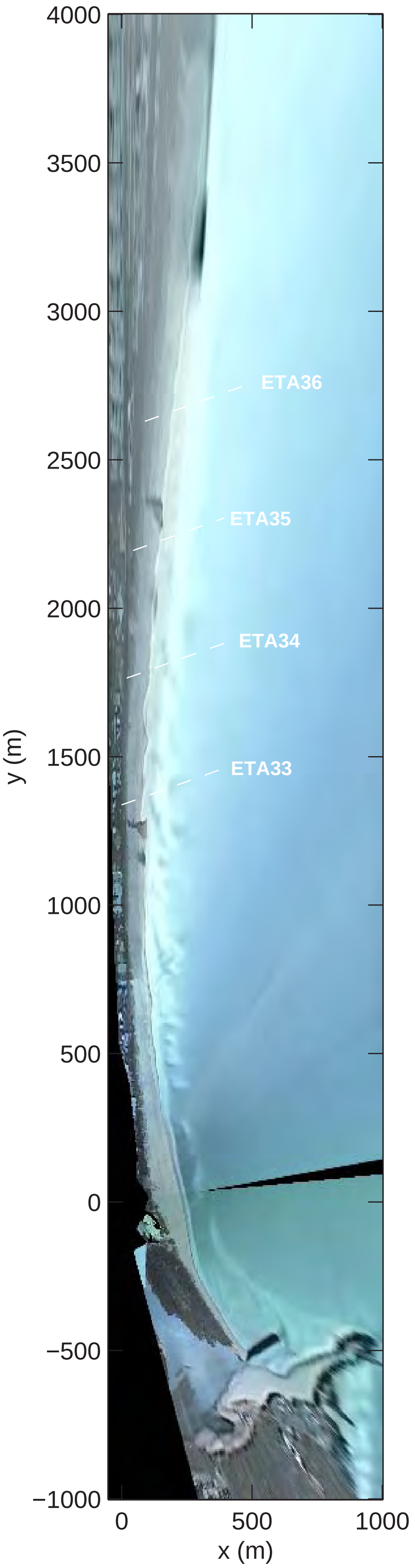
WEEKLY BEACH WIDTH:
JUNE 2004 - MAY 2007

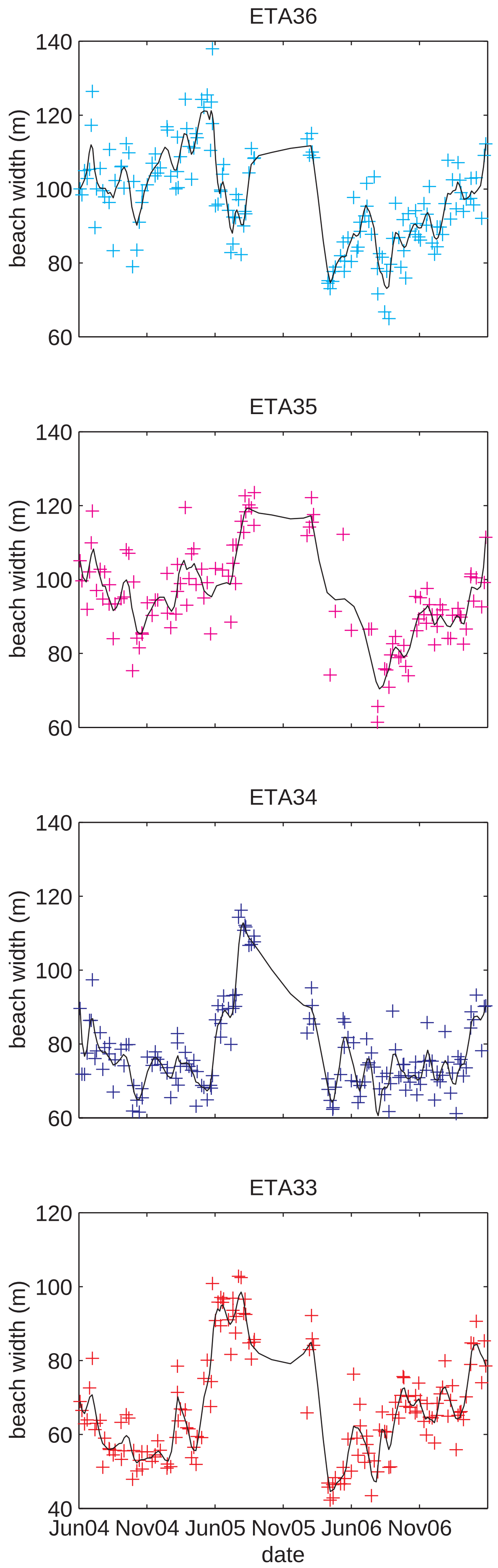
Figure
7.1

02114-7-1.cdr



WRL Report No. 2007/21	TIME-SERIES OF BEACH WIDTH (SOUTH): JUNE 2004 - MAY 2007	Figure 7.2 02114-7-2.cdr





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Report No. 2007/21

TIME-SERIES OF BEACH WIDTH (NORTH):
JUNE 2004 - MAY 2007

Figure
7.3

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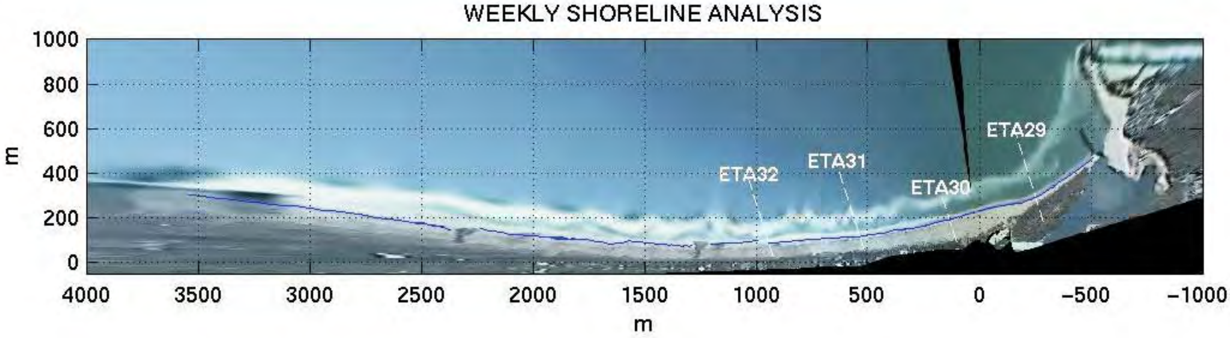

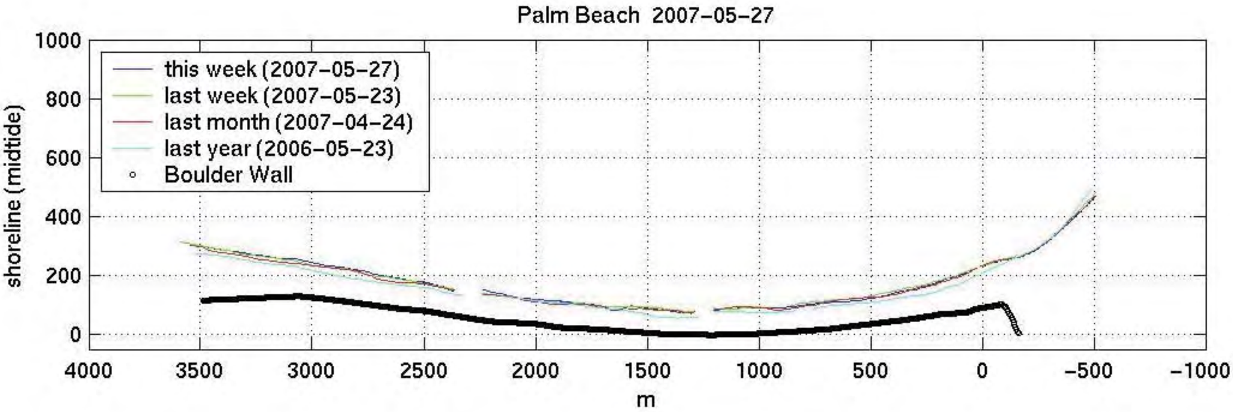

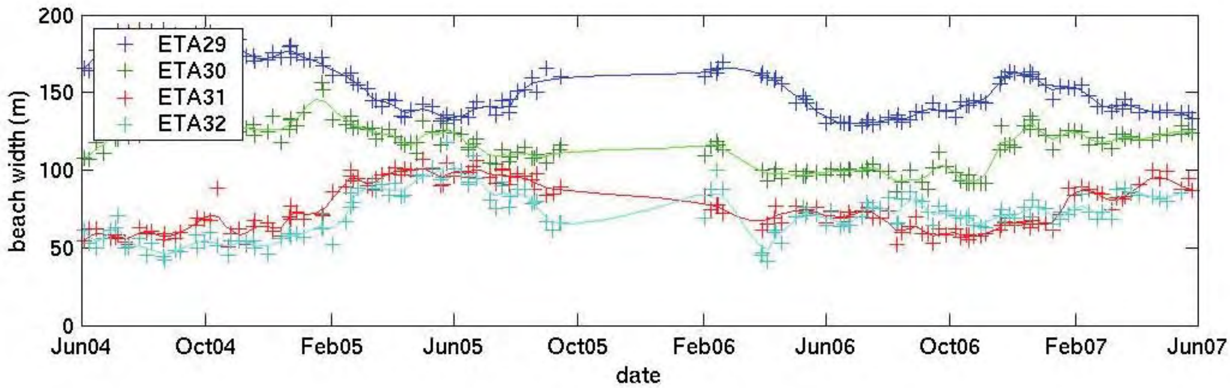

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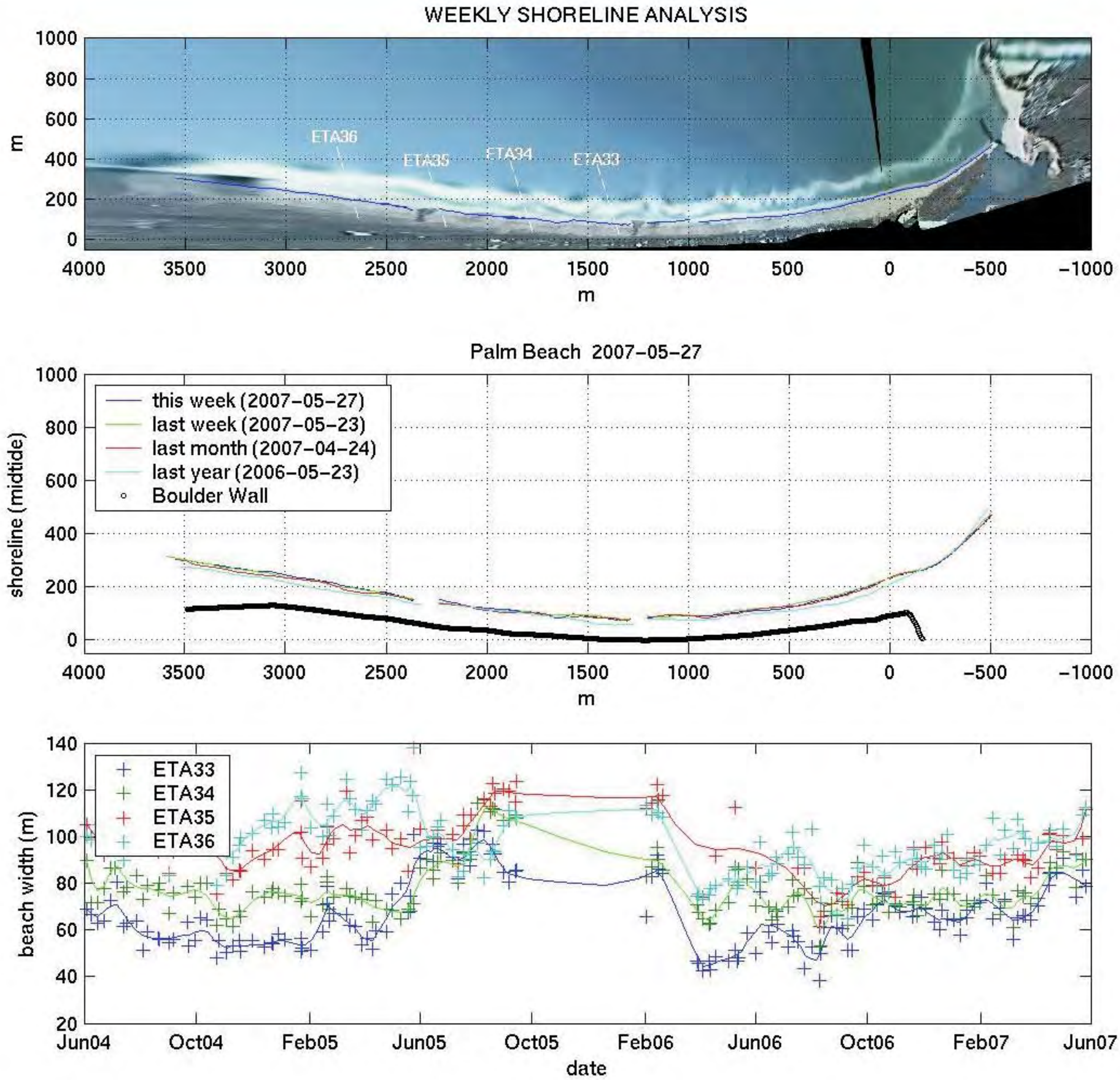
WRL Report No. 2007/21	ON-LINE BEACH WIDTH ANALYSIS TO MAY 2007 (SOUTH)	Figure 7.4 02114-7-4.cdr



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WRL Report No. 2007/21	ON-LINE BEACH WIDTH ANALYSIS TO MAY 2007 (NORTH)	Figure 7.5 02114-7-5.cdr

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 (21 December 2006 and 17 January 2007), Figure 8.3 (7 February 2007 and 19 March 2007) and Figure 8.4 (17 April 2007 and 16 May 2007).

Analysis of interdidal beachface maps in previous monitoring reports has identified a persistent feature of the Palm Beach embayment that is not 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.

In contrasting the beachface map images recorded early in the current monitoring period (December 2006 and January 2007) with those recorded several months later (April and May 2007), it can be seen that the northward decrease in beachface slope declined throughout the monitoring period. This is consistent with the beach state model, as the beach has moved toward a lower energy state with the ongoing period of lower wave energy from March through to May 2007.

Also readily apparent in the beachface maps recorded during the current monitoring period, is the effect of nearshore rips and transverse bars on the intertidal beachface. As discussed in Section 5, large regions of the Palm Beach embayment spent most of the time between December 2006 and May 2007, in a TBR beach state. The rip currents are relatively easy to identify in the week-to-a-page plan images of the beach in Appendix A. The effects on wave breaking of the nearshore bars and rip currents in the surf zone are translated to the morphology of the intertidal beachface. The contoured section of the beachface shown in Figures 8.2 to 8.4 can be seen to be very irregular at times, with large crescentic features present. The erosion and accretion processes occurring in the surf zone generate these beachface features during periods of the tidal cycle where the water level is higher.

It may in fact be possible to make predictions regarding the beach state from the intertidal beachface map images. Considering for example the beachface map for December 2006 (Figure 8.2 top panel). The beachface can be seen to be steep but regular at the southern end of the embayment, typical of a more reflective beach state. The central beach compartment has a slightly shallower gradient, but is highly irregular in planform with extensive crescentic features, typical of a more intermediate beach state. Across the northern section of the embayment the beach is significantly more uniform in planform and has a much flatter gradient, typical of a higher energy more dissipative beach state.

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 December 2006 - January 2007, January - February 2007 and February - March 2007, and Figure 8.5b for March – April 2007 and April – May 2007.

The top panel of Figure 8.5a shows that from December 2006 to January 2007 minor changes in sand volume across the beachface occurred. Generally there was a slight trend of erosion across the embayment, with a typical drop in vertical beachface elevation of approximately 0.2 m. The minor exception to the overall erosive trend was a small pocket of accretion approximately 500 m north of the Royal Palm building, where the beachface accreted by up to 0.8 m in elevation. Averaged along the entire measured section of the Palm Beach embayment the net change sand volume within the mapped beachface was a minor **+1,443 m^3** of accretion, which translates to **+0.4 m^3 per m of shoreline** when averaged over the length of the beach (between -0.5 and +0.7 m AHD).

From January to February 2007 (Figure 8.5a, middle panel), there was a slight trend of beach accretion over most sections of the embayment. North of the 11th Street groyne, the 0.2 m drop in beach face elevation from December to January was reversed between January and February. The zone of accretion that occurred between December and January approximately 500 m north of the Royal Palm building continued to accrete, with an additional 0.8 m of vertical beachface elevation being recorded in this zone. This pocket of accretion also increased in plan area toward the north, extending from approximately 500 m north of the Royal Palm building, north to the 11th Street groyne. The southern section of the embayment was seen to slightly erode between January and February. Overall there was a net accretion of **+7,374** m^3 across the length of the embayment, equating to **+2.2 m^3 per m of shoreline**.

Between February and March (Figure 8.5a, lower panel) relatively uniform erosion of the beachface occurred across the entire embayment. The stretch of beach south of the Royal Palm building again showed the worst erosion, with the beachface lowering by more than 0.5 m in vertical elevation at this location. The net beachface erosion over the entire embayment was **-11,969 m^3**, equating to **-3.6 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD). From March to April (Figure 8.5b, top panel) the beachface underwent the most significant change observed throughout the current monitoring period, with **+33,987 m^3** of sand accreting across the embayment. Averaged over the entire length of the embayment this equates to accretion of **+10.3 m^3 per m of shoreline**. Despite the significant accretionary trend, the beachface to the south of the Royal Palm building still eroded between March and February, lowering further in vertical elevation by up to 0.4 m.

In the final month of the current monitoring period, April to May (Figure 8.5b middle panel), the beachface was again eroded across the entire embayment, with **-22,470 m^3** of material being removed. This equates to an average erosion of **-6.8 m^3 per m of shoreline**.

8.4 Net Erosion-Accretion Trends

The net change in beachface bathymetry calculated for the previous and present monitoring periods are summarised in Figure 8.6a-c. 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 previous monitoring 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 current monitoring period December 2006 to May 2007.

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.

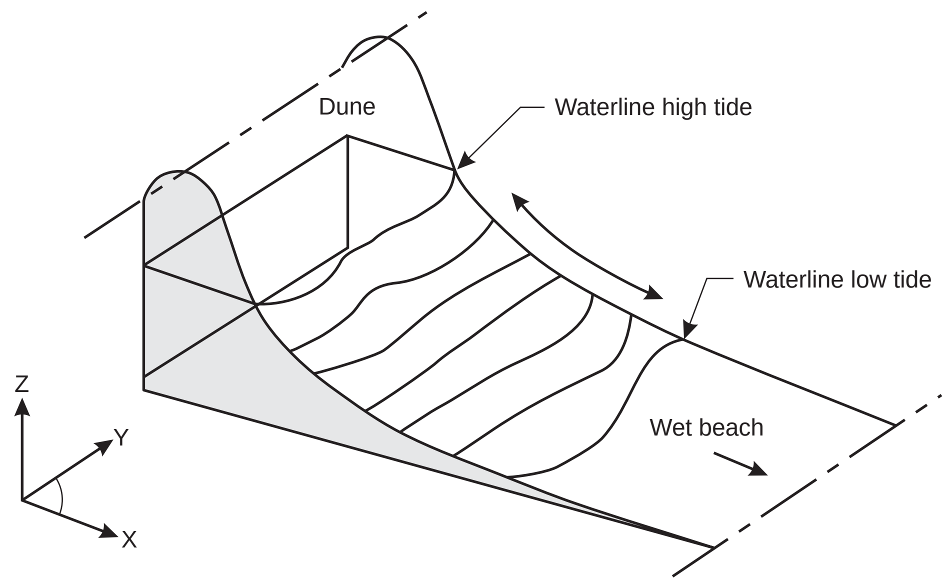
Modest accretion continued within the central and northern regions of the Palm Beach embayment during the monitoring period June – November 2006 (Figure 8.6c top panel). Toward the southern end the persistence of complex transverse bar-rip morphology resulted in a complex pattern of localised erosion-accretion '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 current monitoring 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 the current monitoring period was minor accretion.

8.5 Total Erosion-Accretion Trends: June 2004 - May 2007

Figure 8.7 shows the total net change in beachface bathymetry for the three year monitoring period June 2004 to May 2007. It appears from this figure that the net erosion and accretion trends can be separated into four compartments along the length of the embayment. South of the monitoring cameras significant net erosion has occurred, with the mapped beachface dropping by up to 1 m in vertical elevation. The section of beach between the Royal Palm building and the midpoint between the 11th Street and 21st Street groynes, has significantly accreted during the three year period. The section of beach to the south of the 21st Street groyne has had a minor erosion trend, while to the north of the groyne there has been slight overall accretion.

Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **+33407 m^3** of sand was gained along the ~3.5 km of beachfront included in this monitoring program, equating to an alongshore-average of around **+10.1 m^3** within the intertidal profile, for every 1 m alongshore.



WRL

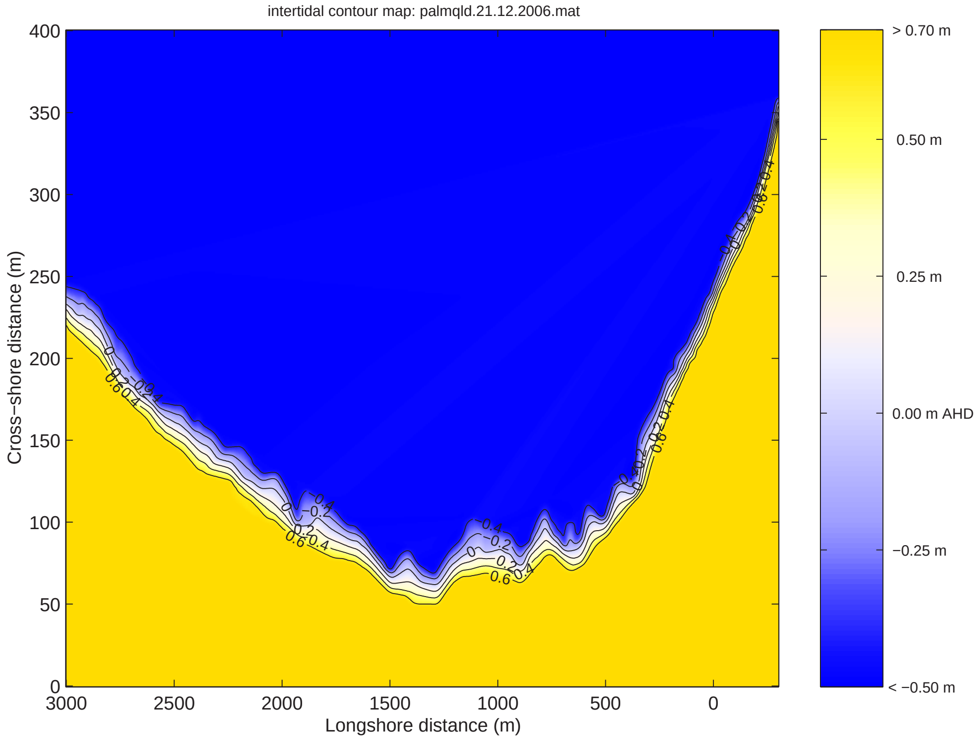
Report No. 2007/21

DEFINITION SKETCH
INTERTIDAL BATHYMETRY FROM HOURLY WATERLINES

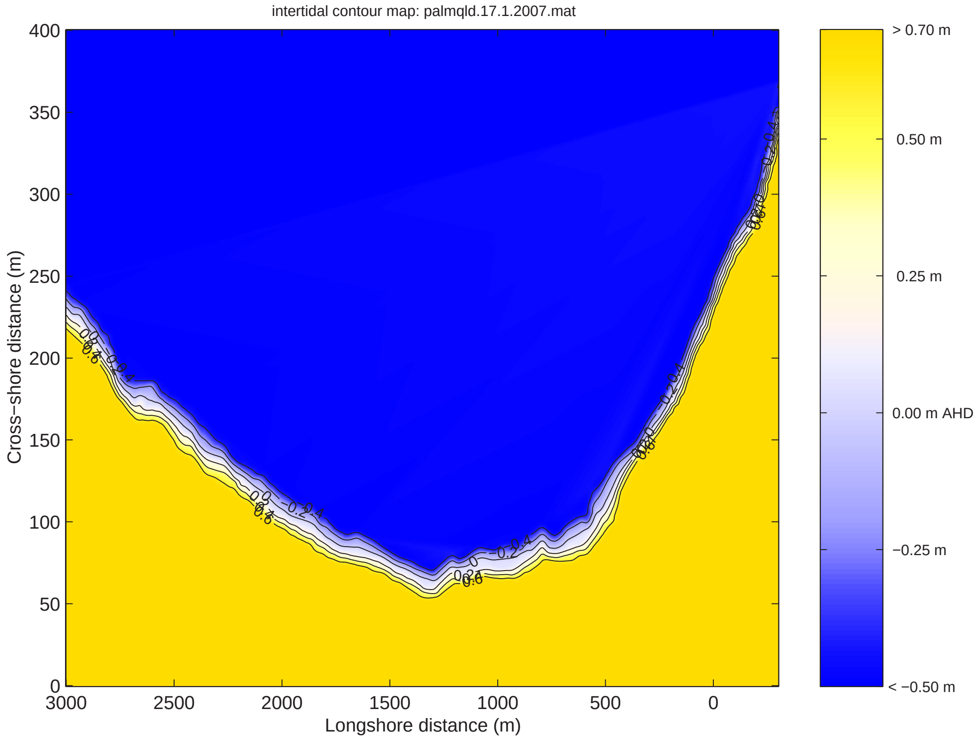
Figure
8.1

02114-8-1.cdr

DECEMBER 2006



JANUARY 2007



WRL

Report No. 2007/21

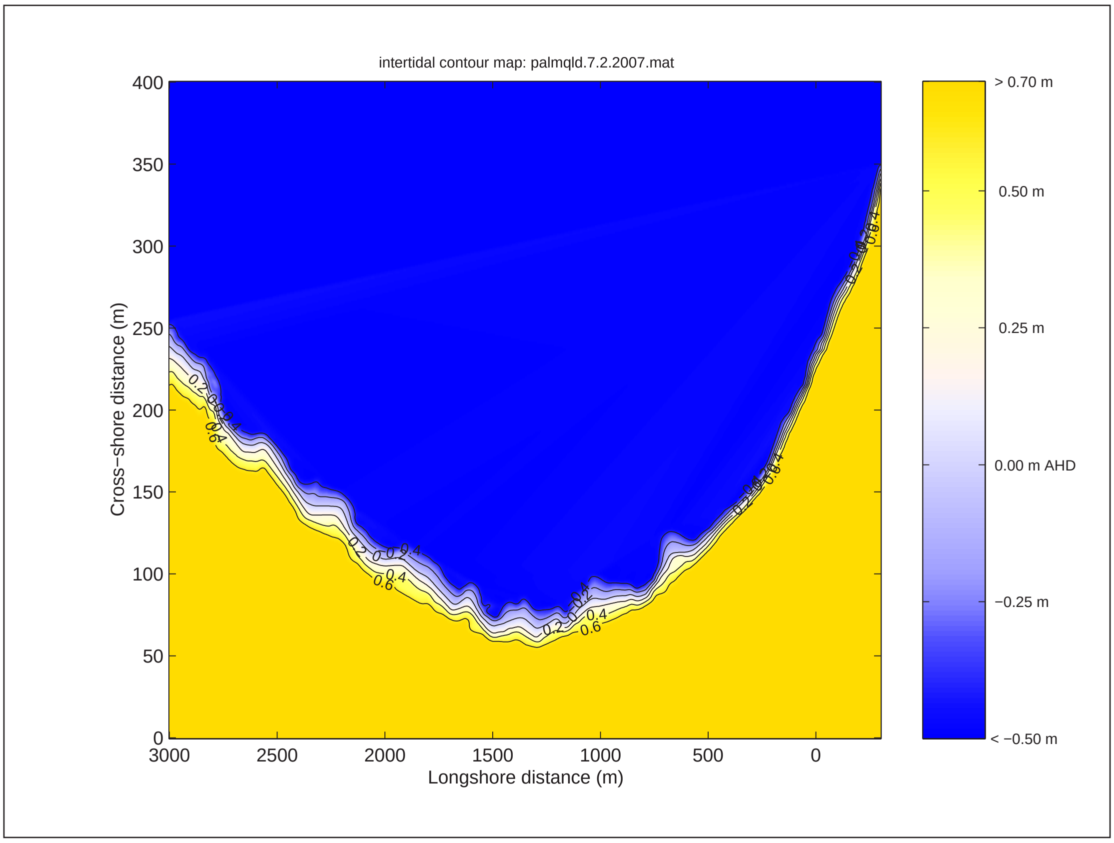
BEACHFACE MAPPING - DECEMBER 2006, JANUARY 2007

Figure

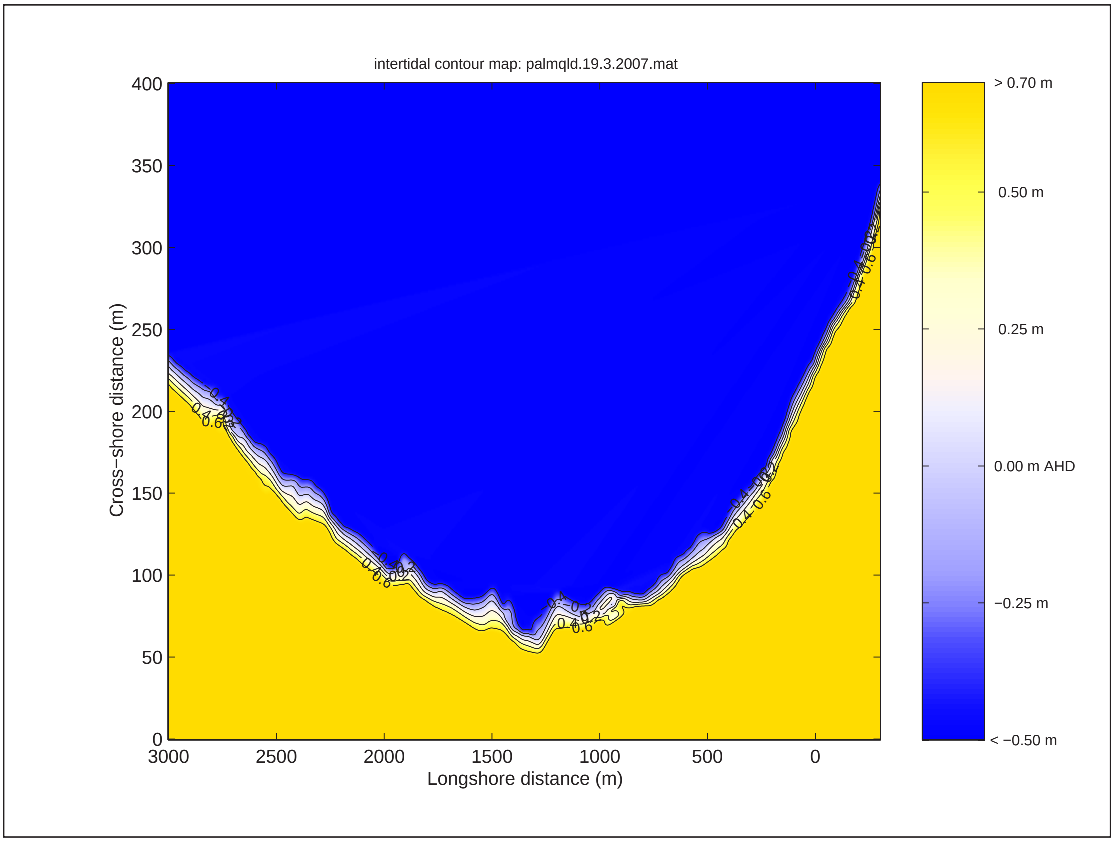
8.2

02114-8-2.cdr

FEBRUARY 2007

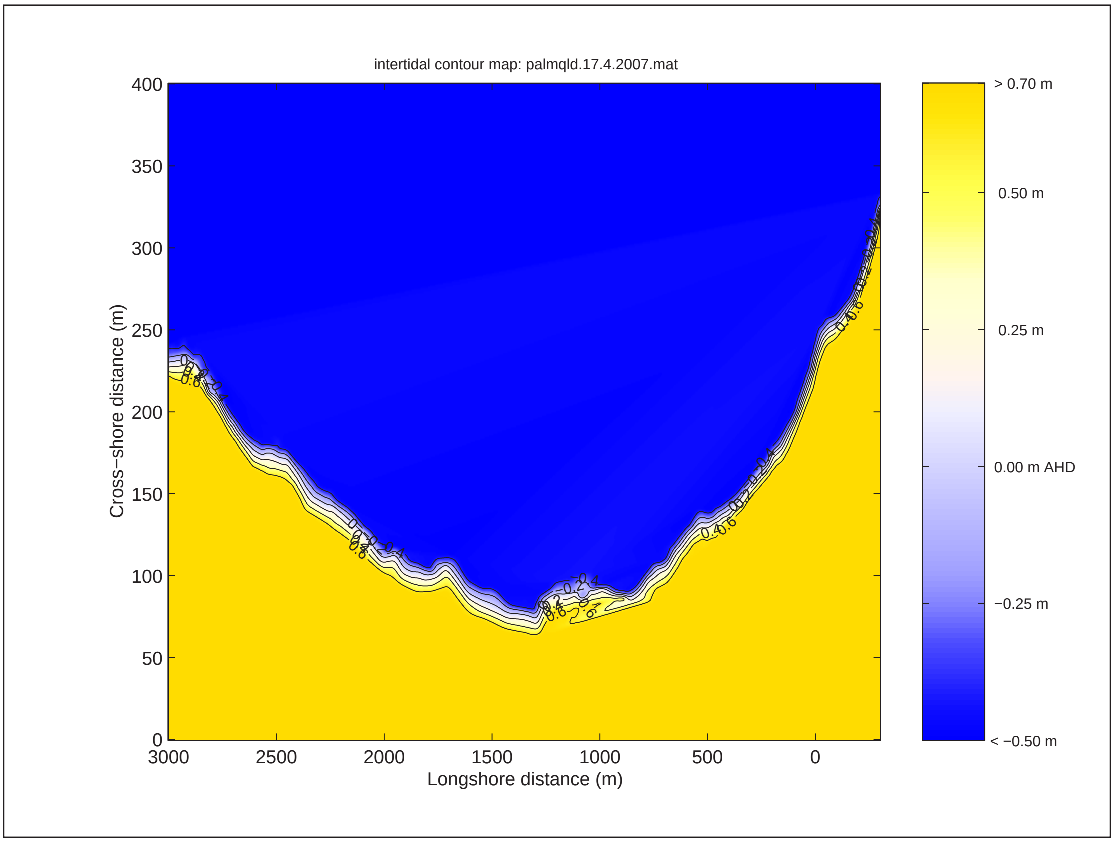


MARCH 2007

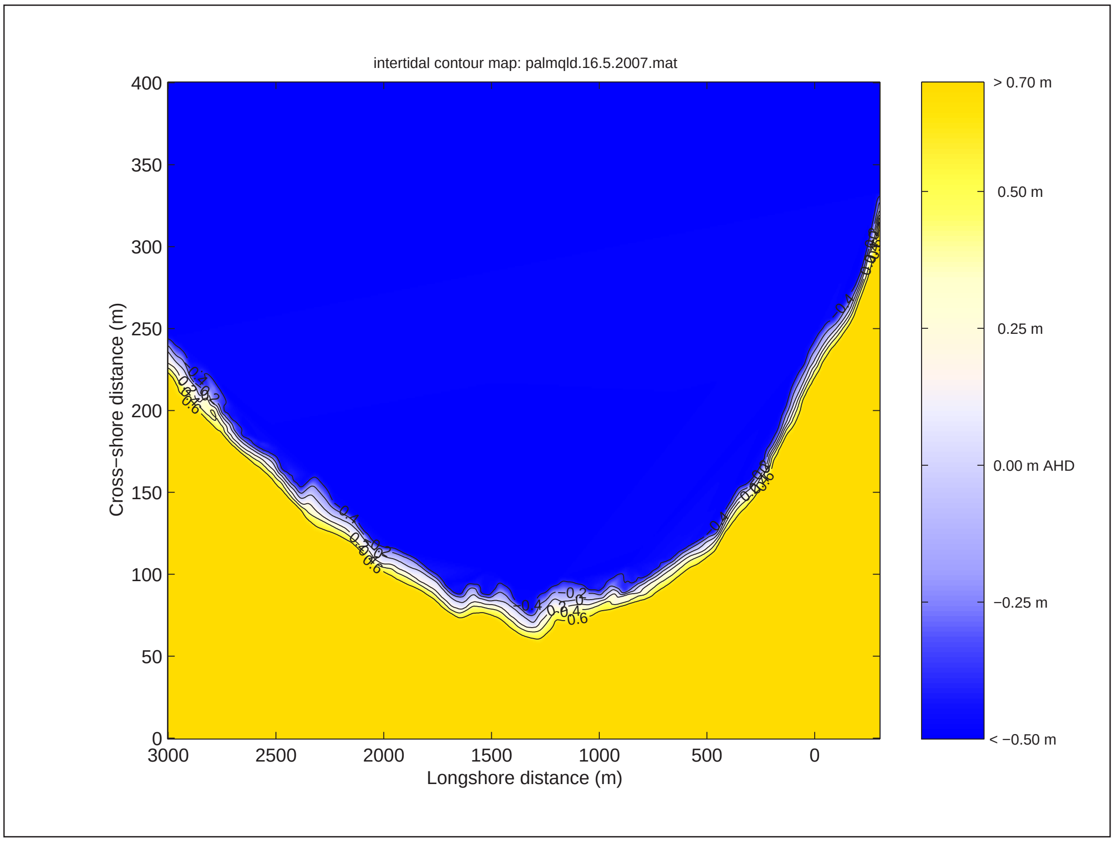


WRL Report No. 2007/21	BEACHFACE MAPPING - FEBRUARY, MARCH 2007	Figure 8.3 02114-8-3.cdr

APRIL 2007



MAY 2007



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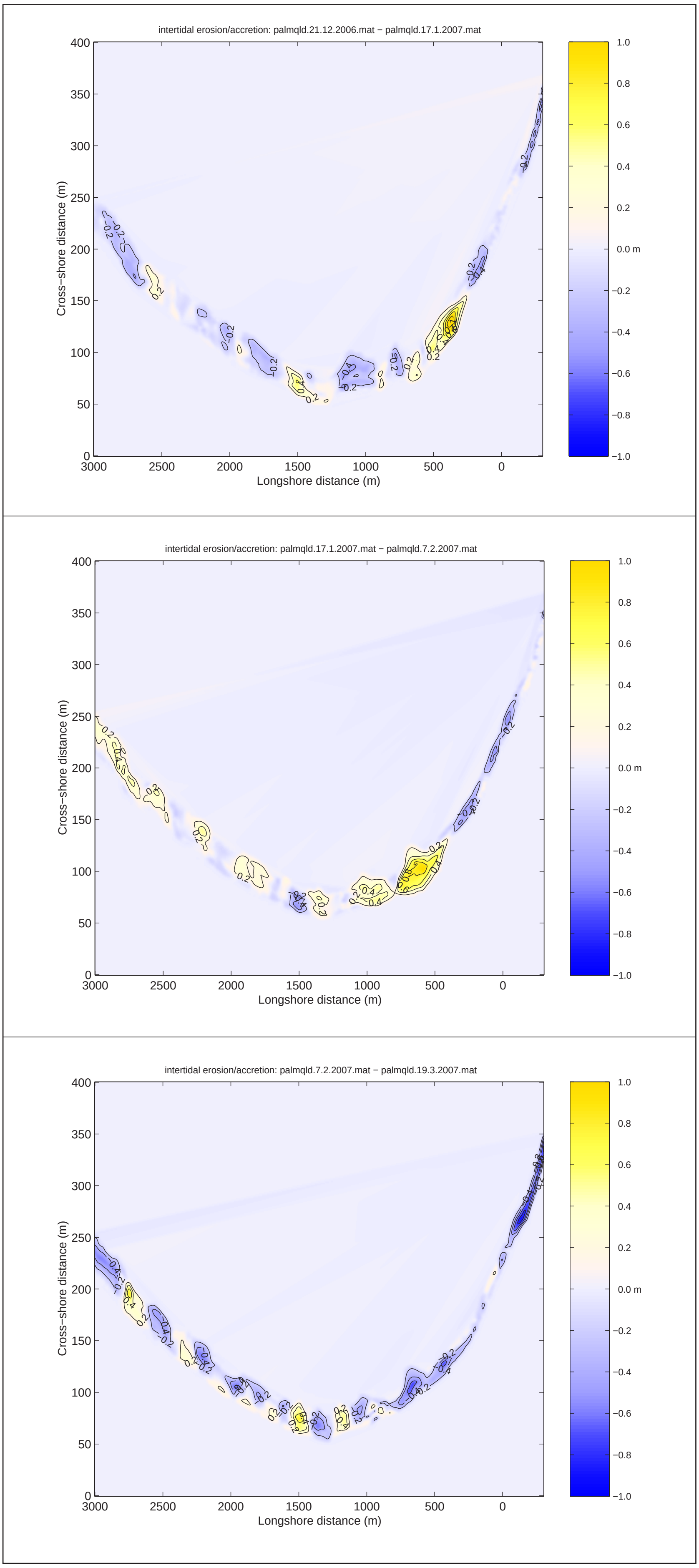
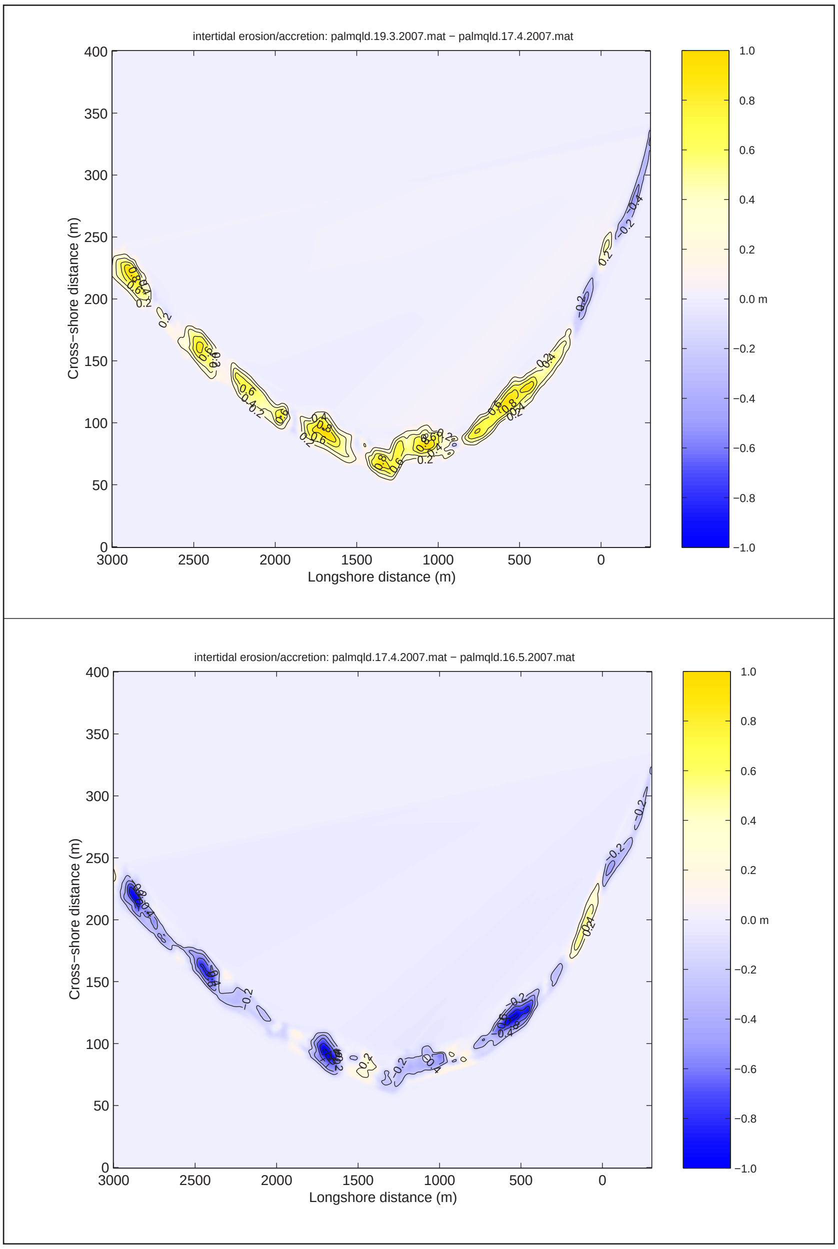


WRL Report No. 2007/21	MONTHLY EROSION/ACCRETION: DECEMBER 2006 - FEBRUARY 2007	Figure 8.5a 02114-8-5a.cdr



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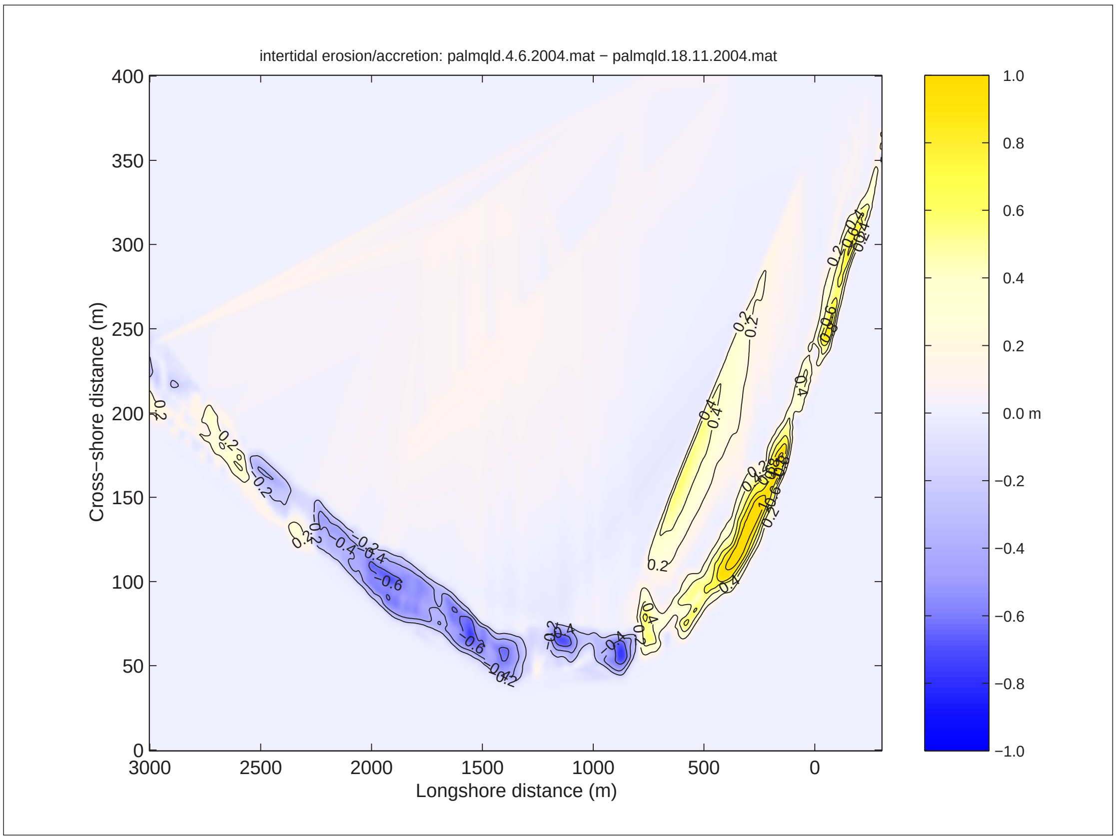
Report No. 2007/21

MONTHLY EROSION/ACCRETION:
MARCH - MAY 2007

Figure
8.5b

02114-8-5b.cdr

NET CHANGE: JUNE - NOVEMBER 2004



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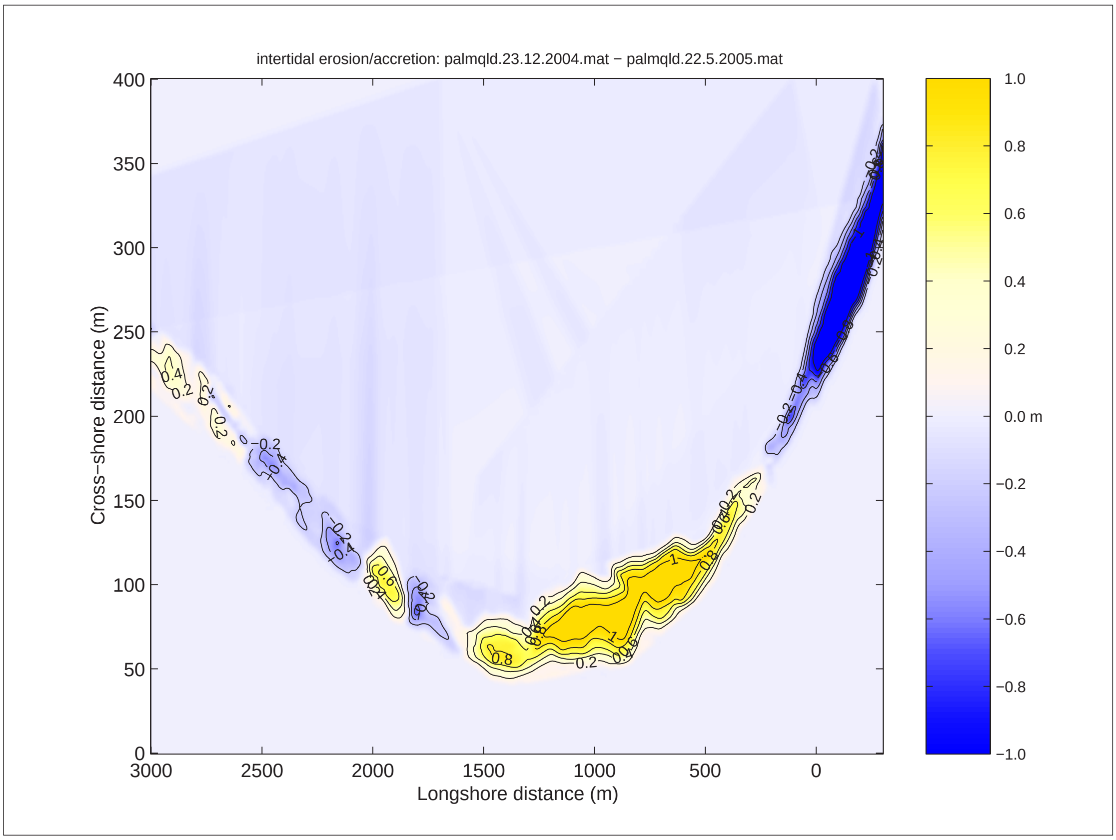

WRL Report No. 2007/21	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6a 02114-8-6a.cdr

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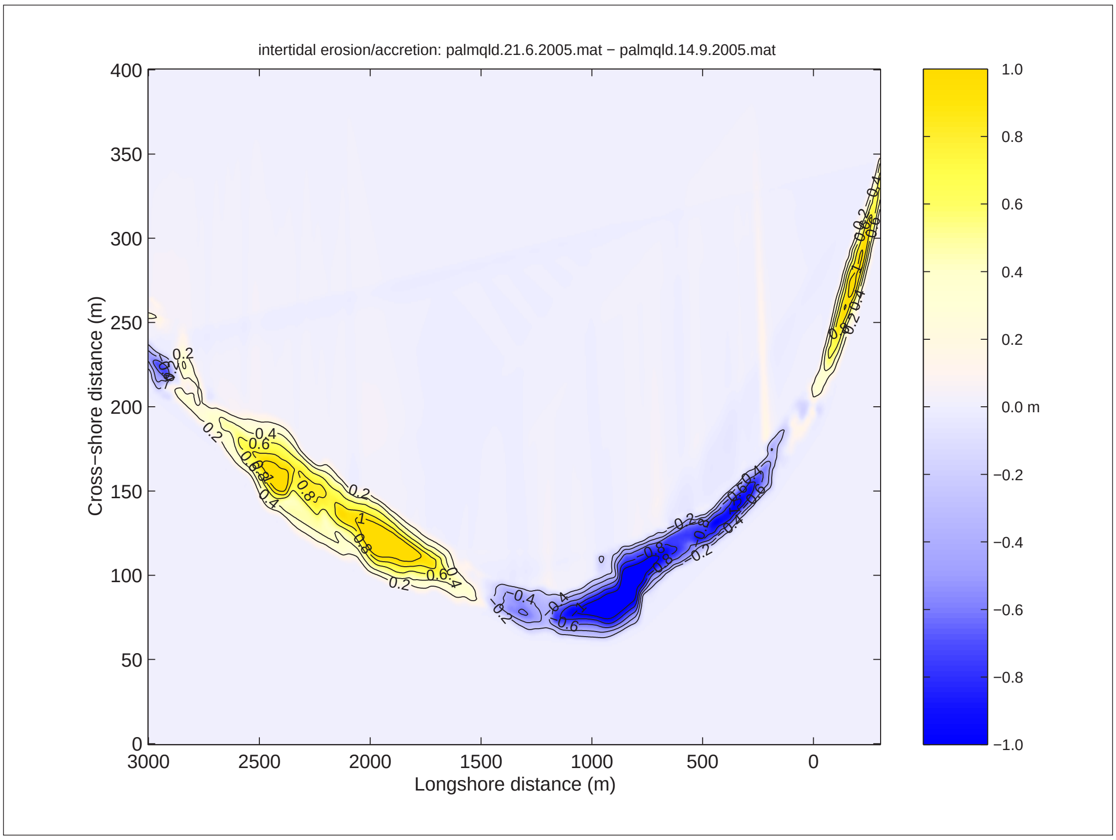
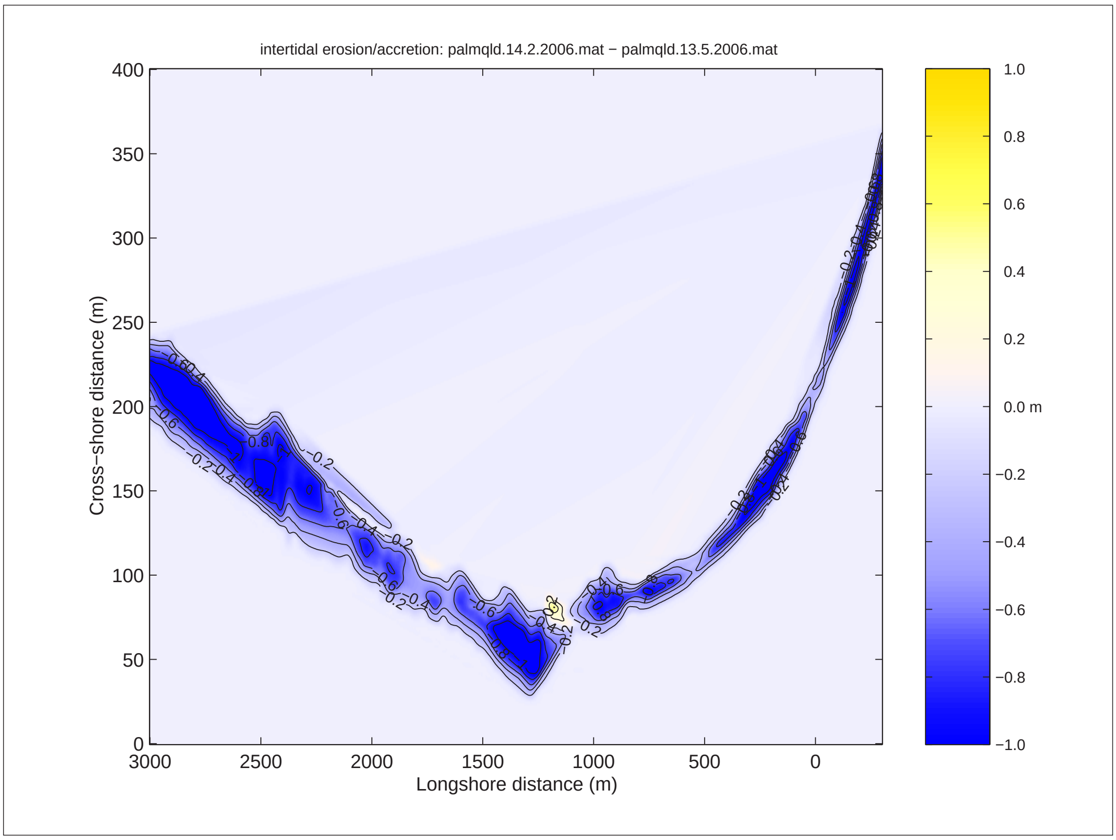
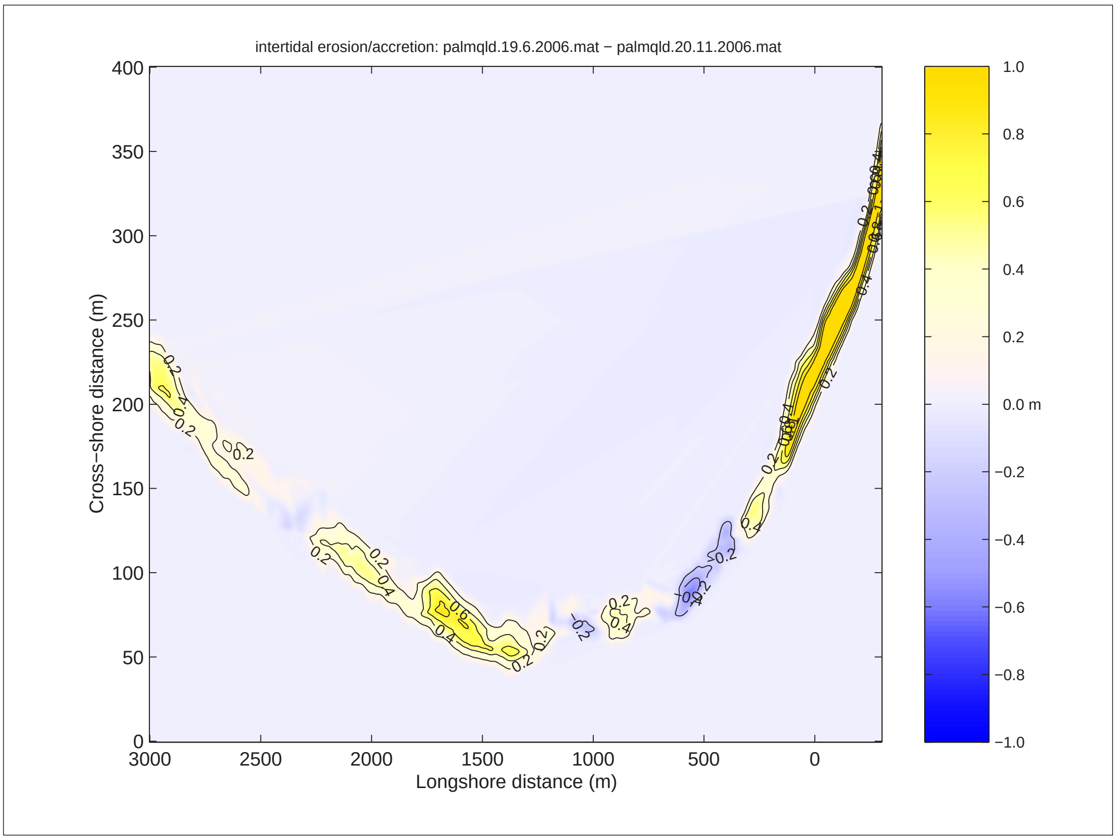


NET CHANGE: FEBRUARY - MAY 2006

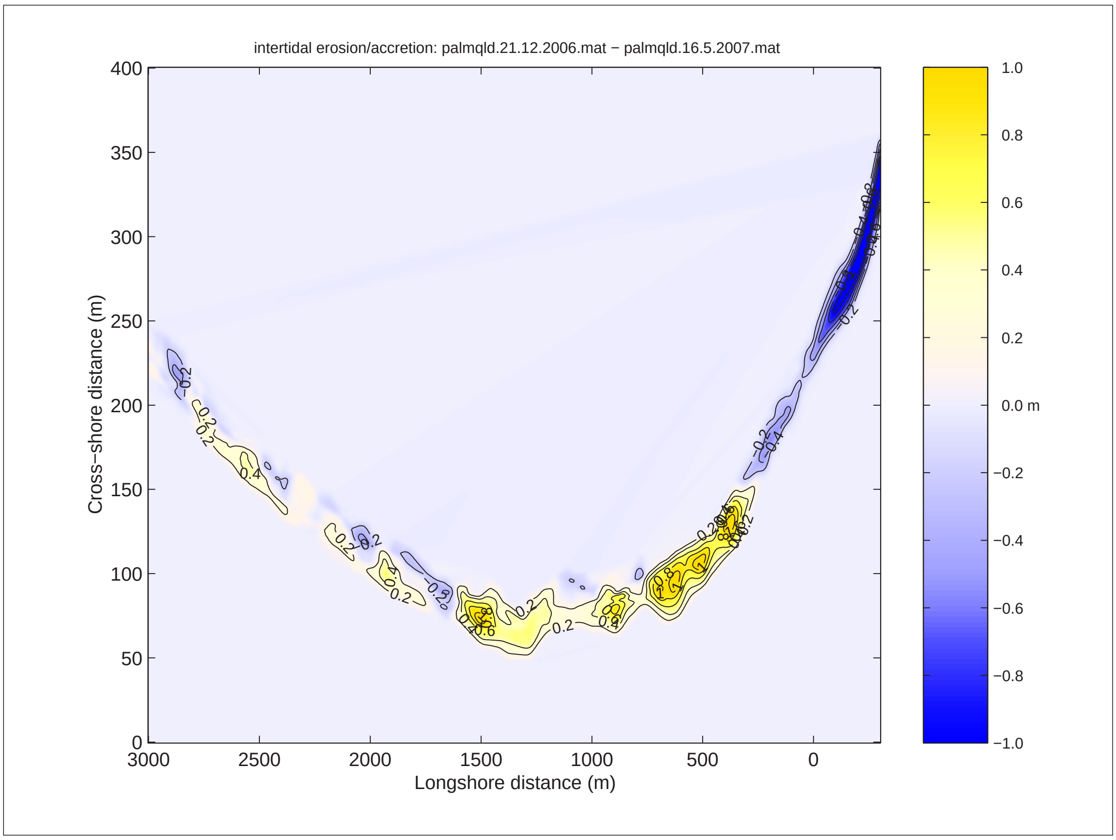


WRL Report No. 2007/21	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6b 02114-8-6b.cdr

NET CHANGE: JUNE - NOVEMBER 2006

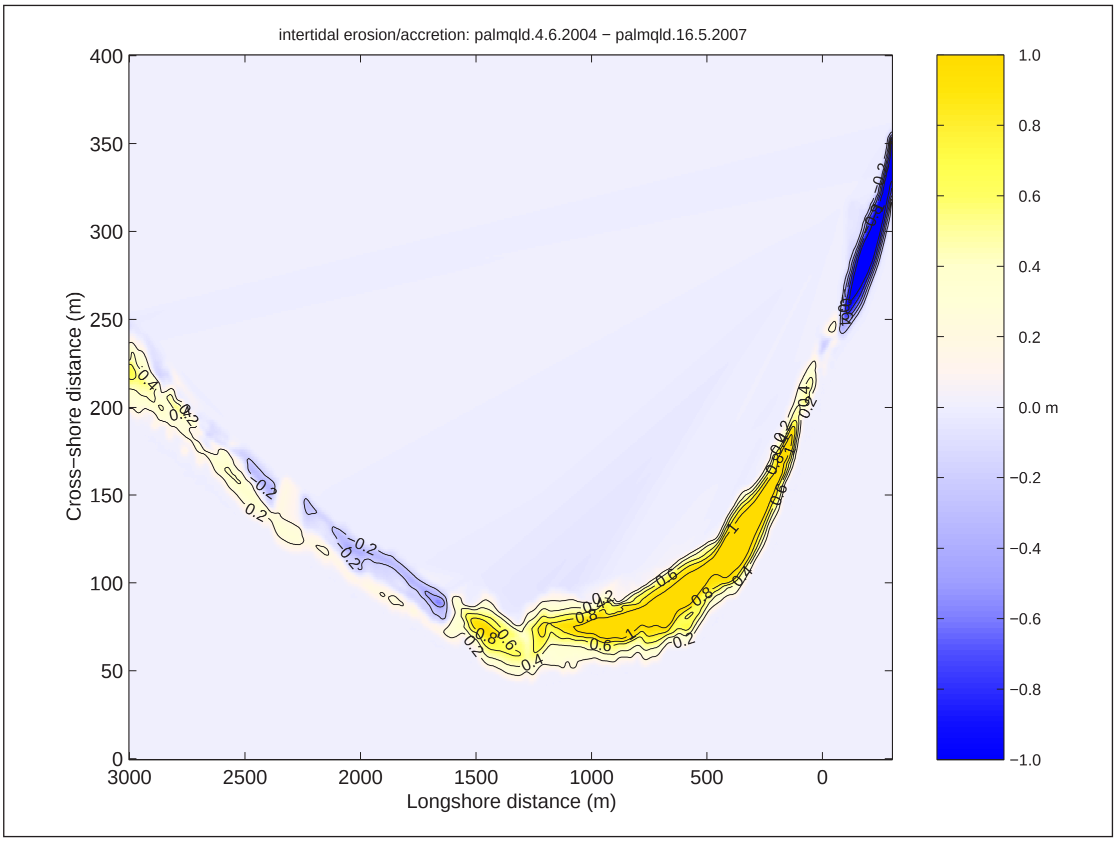


NET CHANGE: DECEMBER 2006 - MAY 2007



WRL Report No. 2007/21	EROSION/ACCRETION PER SIX-MONTH MONITORING PERIOD	Figure 8.6c 02114-8-6c.cdr

TOTAL NET CHANGE: JUNE 2004 - MAY 2007



WRL

Report No. 2007/21

TOTAL NET EROSION/ACCRETION TO MAY 2007

Figure
8.7

02114-8-7.cdr

9. SUMMARY AND CONCLUSIONS

The present monitoring period December 2006 to May 2007 is the sixth in the series of regular six-month monitoring reports to be produced for Palm Beach. The end of this monitoring period marks three years of continuous analysis of the Palm Beach embayment.

With the end of the most recent period of beach nourishment in November 2006 coinciding with the end of the previous monitoring period, this report provides a first look at how the beach has responded during the ensuing six months.

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 period December 2006 to May 2007 were characterised by relatively continuous moderate wave conditions. No significant storm events were observed in terms of beach morphology, with beach width changes occurring at relatively steady rates throughout the monitoring period. 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 six-month monitoring period. A visual assessment of resulting beach changes during December 2006 to May 2007 (Figure 5.2 and Figure 5.3) shows that during the present six month monitoring period, notable beach recession has occurred across the far southern end of the beach in the region of the Currumbin Spit, while in the immediate vicinity of the Royal Palm building only minor narrowing of the beach is evident. Looking northward along the Palm Beach embayment, the beach appears to have 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.

Extending this qualitative visual assessment of images to include the entire 3 year monitoring period, (Figure 5.4) 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, appeared to have moved onshore by November, resulting in modest beach widening and a general straightening of the beach alignment in this southern region. Toward the north, from June to November 2004 the southern end of this region appeared to have generally widened. In contrast, toward 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, 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.

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.

During the present six month monitoring period, notable beach recession has 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 has been 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, is worth noting.

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 present monitoring period 01/12/06 to 31/05/07, the beach along the Palm Beach oceanfront varied in width from a minimum of approximately 50 m (relative to the alignment of the back-beach boulder wall) approximately midway between the Royal Palm building and the 11th Street groyne, to around 180 m at the extreme northern end of the embayment. At the southern end of the boulder wall, adjacent to Currumbin Creek, the reference boulder wall alignment dips landward, resulting in over 250 m of beach between the wall and shoreline. Visually it can be seen from the plan images of this section of the beach that a considerable amount of narrowing has occurred at this southern end of the embayment during the current monitoring period. The envelope of beach width changes along the entire embayment was in the range of 20 - 40 m during this period.

The median beach width at mid-tide (relative to the alignment of the back-beach boulder wall) was of the order of 60 – 80 m along most of the Palm Beach embayment (Figure 6.3). Analysis of maximum and minimum beach width (upper panel, Figure 6.3) reveals a relatively uniform trend alongshore, with the beach width varying by of the order of ±25 m from the mean shoreline position. The exception to this uniform trend was the location just south of the 11th Street groyne, where the shoreline variability changed rapidly with distance along the beach. The standard deviation of weekly shorelines was in the range of 5 - 10 m, which is indicative of a relatively stable beach throughout the present 6-month monitoring period. The area south of the 11th Street groyne was the most sensitive to shoreline change, having the embayment's highest and lowest sections of shoreline variation. The surfzone of this section of beach was typically dominated by transverse nearshore bars and rips throughout the current monitoring period, resulting in the high variation in beach width. The region in front of the cameras and further south also exhibited a higher degree of variability, due to the steady shoreline recession along Currumbin Spit.

The variation in shoreline position measured at Gold Coast City Council's ETA transects 29 to 36 for the monitoring period November 2006 to May 2007 shows that the beach generally accreted, except along the southern Currumbin Spit. At the southern-most transect ETA29 located across the southern Sand Spit (Figure 6.4), a steady decreasing beach width trend was apparent throughout the entire monitoring period from December to May, with the beach decreasing in width by just over 20 m during this period. The transect just north of the Royal Palm building (ETA30) accreted rapidly in December, and then decreased in width again during January. The beach width at this location then remained relatively stable throughout the remainder of the monitoring period, with very little net change in beach width from December 2006 to May 2007. The transects further to the north (ETA31 and ETA32) both showed beach widening during the current monitoring period, with the greatest increase in net beach width of approximately 30 m occurring at transect ETA31.

At the central and northern transects ETA33 to ETA36 (Figure 6.5), the beach width fluctuated between minor erosion and accretion from December 2006 through to March 2007, but have all been widening at a relatively uniform rate through until the end of May. The net increase in beach width across these transects during the previous six months has been of the order of 20 m. Transect ETA35, just on the southern side of the 21st Street groyne, has experienced only minor fluctuations in beach width between December 2006 and May 2007, with negligible net change. The beach also fluctuated in width throughout December and January at transect ETA 36 in the far north, but then steadily accreted throughout February, March, and into April. A minor net increase of 5 to 10 m in beach width occurred at this transect throughout the six month monitoring period.

When the weekly shoreline data for the period November 2006 to May 2007 were 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, relative to the mean shoreline position for the preceding six month period, the entire mapped section of the Palm Beach embayment experienced a slight amount of beach widening. In the centre of the beach compartment between the 11th Street and 21st Street groynes, the beach widening was minimal, with the maximum beach width during the current monitoring period approximately 15 m wider than the mean shoreline position from the previous six month monitoring period. At the southern end of the embayment, between the Royal Palm building and the 11th Street groyne the widening was the most evident, with the maximum beach width observed between December 2006 and May 2007 some 40 m wider than the mean beach width from the period June to December 2006.

While the entire mapped section of the embayment experienced an underlying trend of accretion in the range of 15 – 40 m, the southern Currumbin Spit experienced erosion throughout the current monitoring period. This section of the beach extends beyond the mapped region shown in Figure 6.6, but the extent of erosion can be estimated to be of the order of 20 m, by contrasting the first and last week-to-a-page mid-tide plan images of the beach, included in Appendix A.

In summary, the dominant observation during the present monitoring period was a modest accretionary trend across most of the embayment, with increases in beach width of 5 – 20 m from December 2006 to May 2007. The stretch of beach along Currumbin Spit, however, suffered significant erosion, with the beach approximately 25 m narrower at the end of May in this area.

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-intermediate morphology in the south, to increasingly dissipative (flatter), higher energy intermediate beach states towards the north. In contrasting the beachface map images recorded early in the current monitoring period (December 2006 and January 2007) with those recorded several months later (April and May 2007), it can be seen that the intensity of the decrease in beach gradient toward the north decreased throughout the monitoring period. This is consistent with the beach state model, as the entire beach has moved toward a lower energy state with the ongoing period of lower wave energy from March through to May 2007.

Also readily apparent in the beachface maps recorded during the current monitoring period, is the effect of nearshore rips and transverse bars on the intertidal beachface. Large regions of the Palm Beach embayment spent most of the time between December 2006 and May

2007, in a TBR beach state. The effects on wave breaking of the nearshore bars and rip currents in the surf zone are translated to the morphology of the intertidal beachface. The contoured section of the beachface shown in Figures 8.2 to 8.4 can be seen to be very irregular at times, with large crescentic features present. The erosion and accretion processes occurring in the surf zone generate these beachface features during periods of the tidal cycle where the water level is higher.

From December 2006 to January 2007 (Figure 8.5a, top panel) almost negligible changes in sand volume across the beachface occurred. Generally there was a slight trend of erosion across the embayment, with a typical drop in vertical beachface elevation of approximately 0.2 m. The only contradiction to the overall erosive trend was a small pocket of accretion approximately 500 m north of the Royal Palm building, where the beachface accreted by up to 0.8 m in elevation. Along the measured section of the Palm Beach embayment, the net change sand volume within the mapped beachface was a minor **+1,443 m^3** of accretion, which translates to **+0.4 m^3 per m of shoreline** when averaged over the length of the beach (between -0.5 and +0.7 m AHD). From January to February 2007 (Figure 8.5a, middle panel), there was a slight trend of beach accretion over most sections of the embayment. The zone of accretion that occurred between December and January continued to accrete, with an additional 0.8 m of vertical beachface elevation being recorded in this zone. This pocket of accretion also increased in plan area toward the north, extending from approximately 500 m north of the Royal Palm building to the 11th Street groyne. The southern section of the embayment was seen to slightly erode between January and February. Overall there was a net accretion of **+7,374** m^3 across the length of the embayment, averaging to **+2.2 m^3 per m of shoreline**.

Between February and March (Figure 8.5a, lower panel) relatively uniform erosion of the beachface occurred across the entire embayment. The stretch of beach south of the Royal Palm building again showed the worst erosion, with the beachface lowering by more than 0.5 m in vertical elevation at this location. The net beachface erosion over the entire embayment was **-11,969 m^3**, equating to **-3.6 m^3 per m of shoreline** (between -0.5 and +0.7 m AHD). From March to April (Figure 8.5b, top panel) the beachface underwent the most significant change observed throughout the current monitoring period, with **+33,987 m^3** of sand accreting across the embayment. Averaged over the entire length of the embayment this equates to **+10.3 m^3 per m of shoreline**. Despite the significant accretionary trend, erosion of the beachface to the south of the Royal Palm building still occurred between March and February, lowering further in vertical elevation by up to 0.4 m. In the final month of the current monitoring period, April to May (Figure 8.5b middle panel), the beachface was again eroded across the entire embayment, with **-22,470**

m^3 of material being removed, equating to an average erosion of **-6.8 m^3 per m of shoreline**.

The final analysis of total net change in beachface bathymetry for the entire three year monitoring period June 2004 to May 2007 (Figure 8.7) shows that the net erosion and accretion trends can be separated into four compartments along the length of the embayment. South of the monitoring cameras significant net erosion has occurred, with the mapped beachface lowering by up to 1 m in vertical elevation. The section of beach between the Royal Palm building and the midpoint between the 11th Street and 21st Street groynes, has significantly accreted during the three year period. The section of beach to the south of the 21st Street groyne has had a minor erosion trend, while to the north of the groyne there has been slight overall accretion.

Within the intertidal beach (-0.5 and +0.7 m AHD) a total net volume of approximately **+33,407 m^3** of sand was gained along the ~3.5 km of beachfront included in this three year monitoring program, equating to an alongshore-average of around **+10.1 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. Ian Cunningham of WRL was responsible for 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: December 2006 - May 2007

Week–to–a–Page (Mid–Tide)

20/11/2006 11:17

21/11/2006 11:17

22/11/2006 12:17

23/11/2006 13:17

24/11/2006 13:17

25/11/2006 14:17

26/11/2006 15:17

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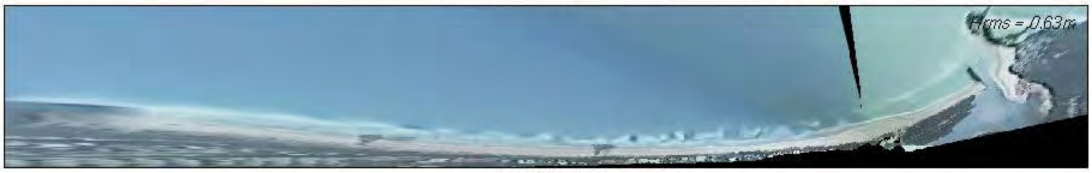
WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 20/11/2006 - 26/11/2006	Figure A1 02114-A01.cdr

Week-to-a-Page (Mid-Tide)



27/11/2006 09:17

28/11/2006 10:17

29/11/2006 11:17

30/11/2006 12:17

01/12/2006 13:17

02/12/2006 15:17

03/12/2006 09:17

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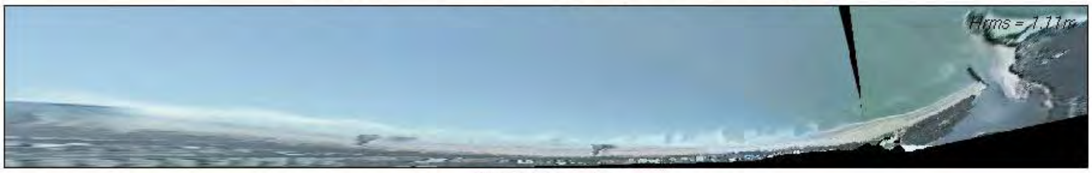
WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 27/11/2006 - 03/12/2006	Figure A2 02114-A02.cdr

Week-to-a-Page (Mid-Tide)



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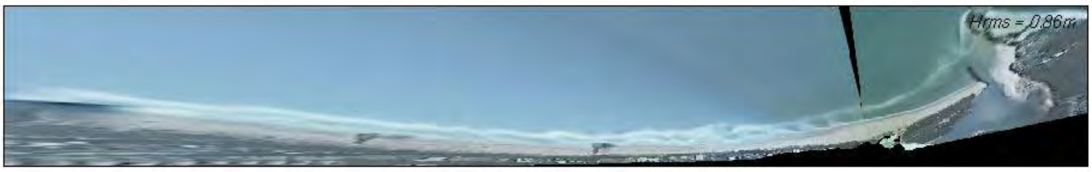

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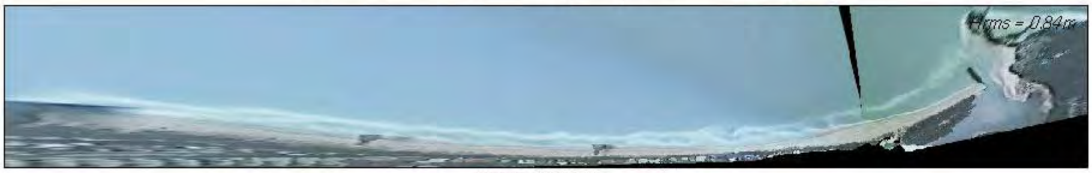
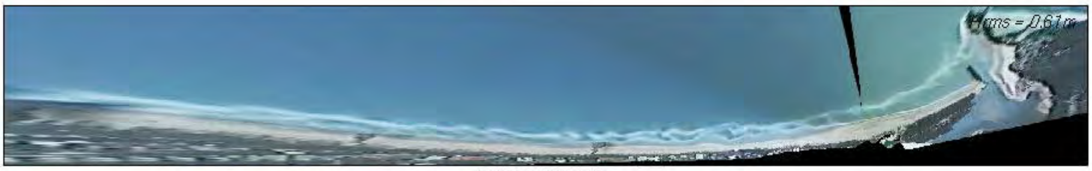
WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 04/12/2006 - 10/12/2006	Figure A3
		02114-A03.cdr

Week–to–a–Page (Mid–Tide)



11/12/2006 09:17



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17/12/2006 09:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 11/12/2006 - 17/12/2006	Figure A4 02114-A04.cdr

Week-to-a-Page (Mid-Tide)

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19/12/2006 10:17

20/12/2006 11:17

21/12/2006 12:17

22/12/2006 12:17

23/12/2006 13:17

24/12/2006 14:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 18/12/2006 - 24/12/2006	Figure A5
		02114-A05.cdr

Week-to-a-Page (Mid-Tide)

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26/12/2006 08:17

27/12/2006 09:17

28/12/2006 10:17

29/12/2006 12:17

30/12/2006 14:17

31/12/2006 09:17

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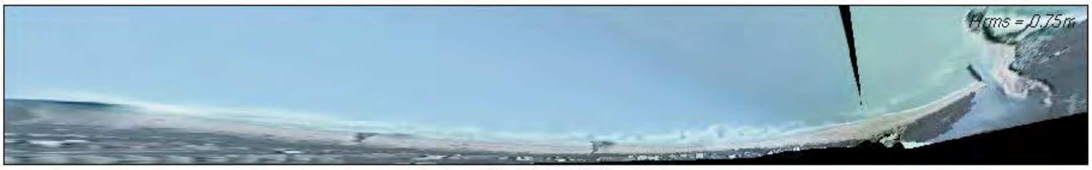
Week-to-a-Page (Mid-Tide)

01/01/2007 10:17



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05/01/2007 13:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 01/01/2007 - 07/01/2007	Figure A7 02114-A07.cdr

Week-to-a-Page (Mid-Tide)

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09/01/2007 15:17

10/01/2007 09:17

11/01/2007 09:17

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13/01/2007 12:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 08/01/2007 - 14/01/2007	Figure A8
		02114-A08.cdr

Week–to–a–Page (Mid–Tide)

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21/01/2007 13:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 15/01/2007 - 21/01/2007	Figure A9
		02114-A09.cdr

Week-to-a-Page (Mid-Tide)

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23/01/2007 14:17

24/01/2007 15:17

25/01/2007 09:17

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27/01/2007 12:17

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Week-to-a-Page (Mid-Tide)

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01/02/2007 11:17

02/02/2007 12:17

03/02/2007 12:17

04/02/2007 13:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 29/01/2007 - 04/02/2007	Figure A11 02114-A11.cdr

Week-to-a-Page (Mid-Tide)

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06/02/2007 13:17

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08/02/2007 14:17

09/02/2007 14:17

10/02/2007 10:17

11/02/2007 12:17

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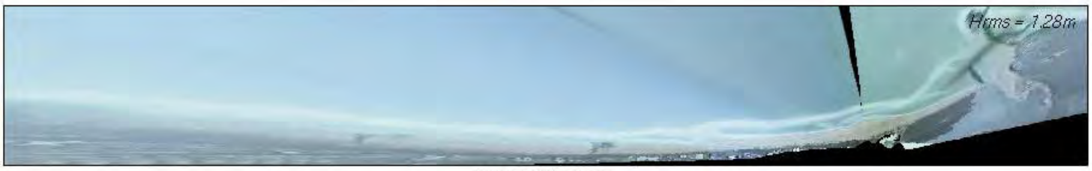
WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 05/02/2007 - 11/02/2007	Figure A12 02114-A12.cdr

Week-to-a-Page (Mid-Tide)

12/02/2007 14:17



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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 12/02/2007 - 18/02/2007	Figure A13 02114-A13.cdr

Week-to-a-Page (Mid-Tide)

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23/02/2007 09:17

24/02/2007 11:17

25/02/2007 13:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 19/02/2007 - 25/02/2007	Figure A14 02114-A14.cdr

Week-to-a-Page (Mid-Tide)

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27/02/2007 09:17

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03/03/2007 11:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 26/02/2007 - 04/03/2007	Figure A15 02114-A15.cdr

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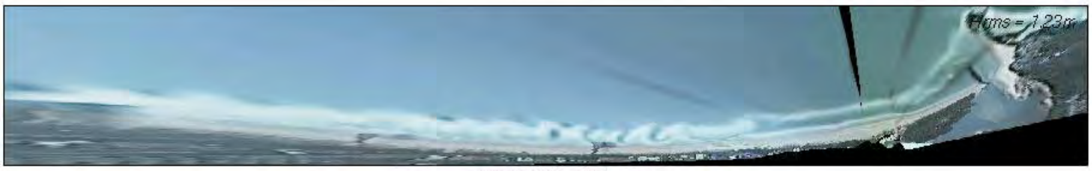

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 05/03/2007 - 11/03/2007	Figure A16 02114-A16.cdr

Week-to-a-Page (Mid-Tide)

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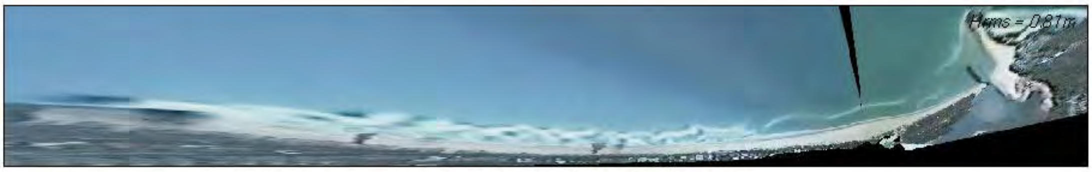

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 12/03/2007 - 18/03/2007	Figure A17
		02114-A17.cdr

Week-to-a-Page (Mid-Tide)

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 19/03/2007 - 25/03/2007	Figure A18 02114-A18.cdr

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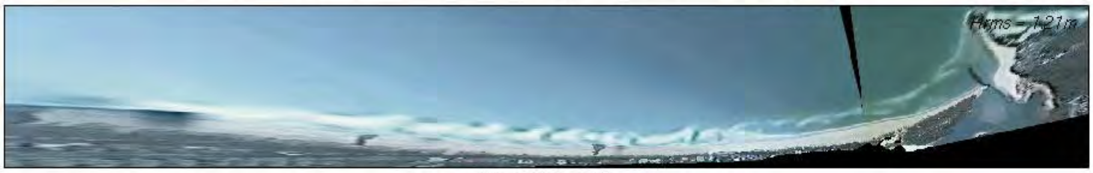

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 26/03/2007 - 01/04/2007	Figure A19 02114-A19.cdr

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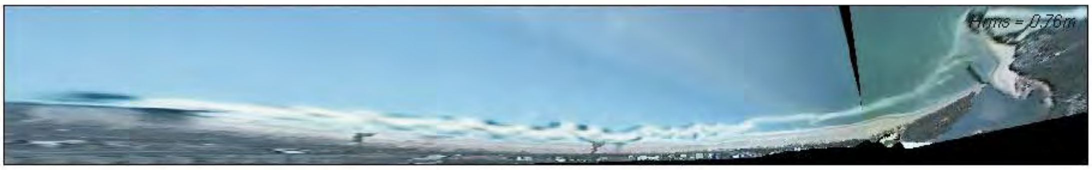

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 02/04/2007 - 08/04/2007	Figure A20 02114-A20.cdr

Week–to–a–Page (Mid–Tide)

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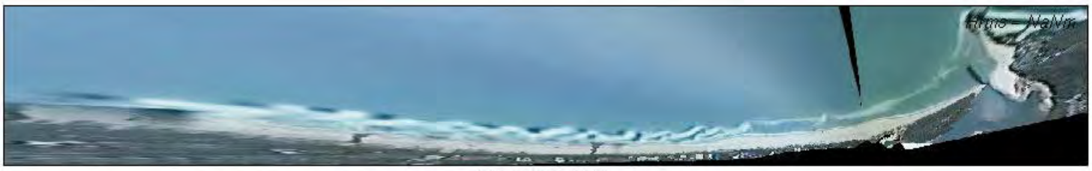

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 09/04/2007 - 15/04/2007	Figure A21 02114-A21.cdr

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Week-to-a-Page (Mid-Tide)

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 23/04/2007 - 29/04/2007	Figure A23 02114-A23.cdr

Week-to-a-Page (Mid-Tide)

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05/05/2007 11:17

06/05/2007 12:17

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 30/04/2007 - 06/05/2007	Figure A24 02114-A24.cdr

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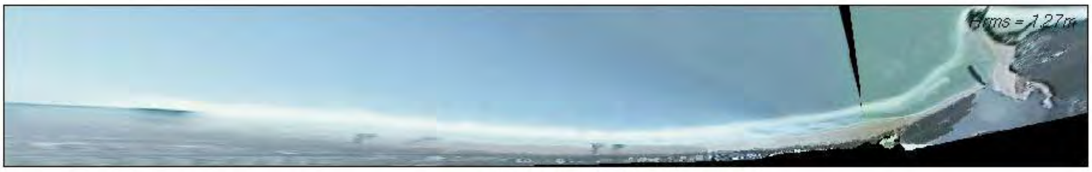

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13/05/2007 14:17

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Week-to-a-Page (Mid-Tide)

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Week-to-a-Page (Mid-Tide)

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WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 21/05/2007 - 27/05/2007	Figure A27 02114-A27.cdr

Week-to-a-Page (Mid-Tide)

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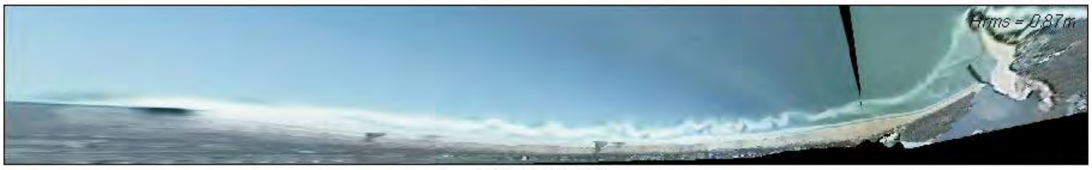

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03/06/2007 11:17

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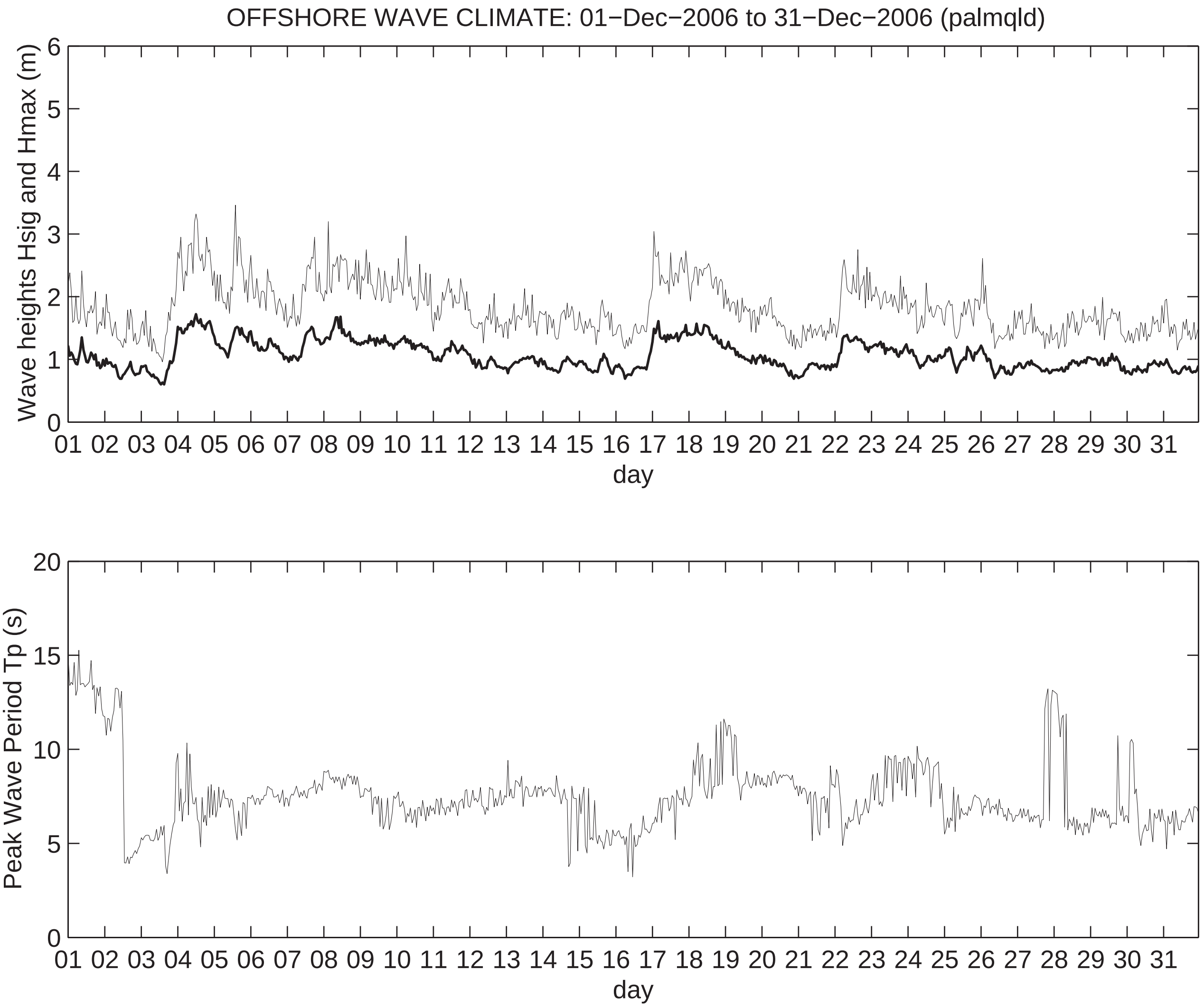
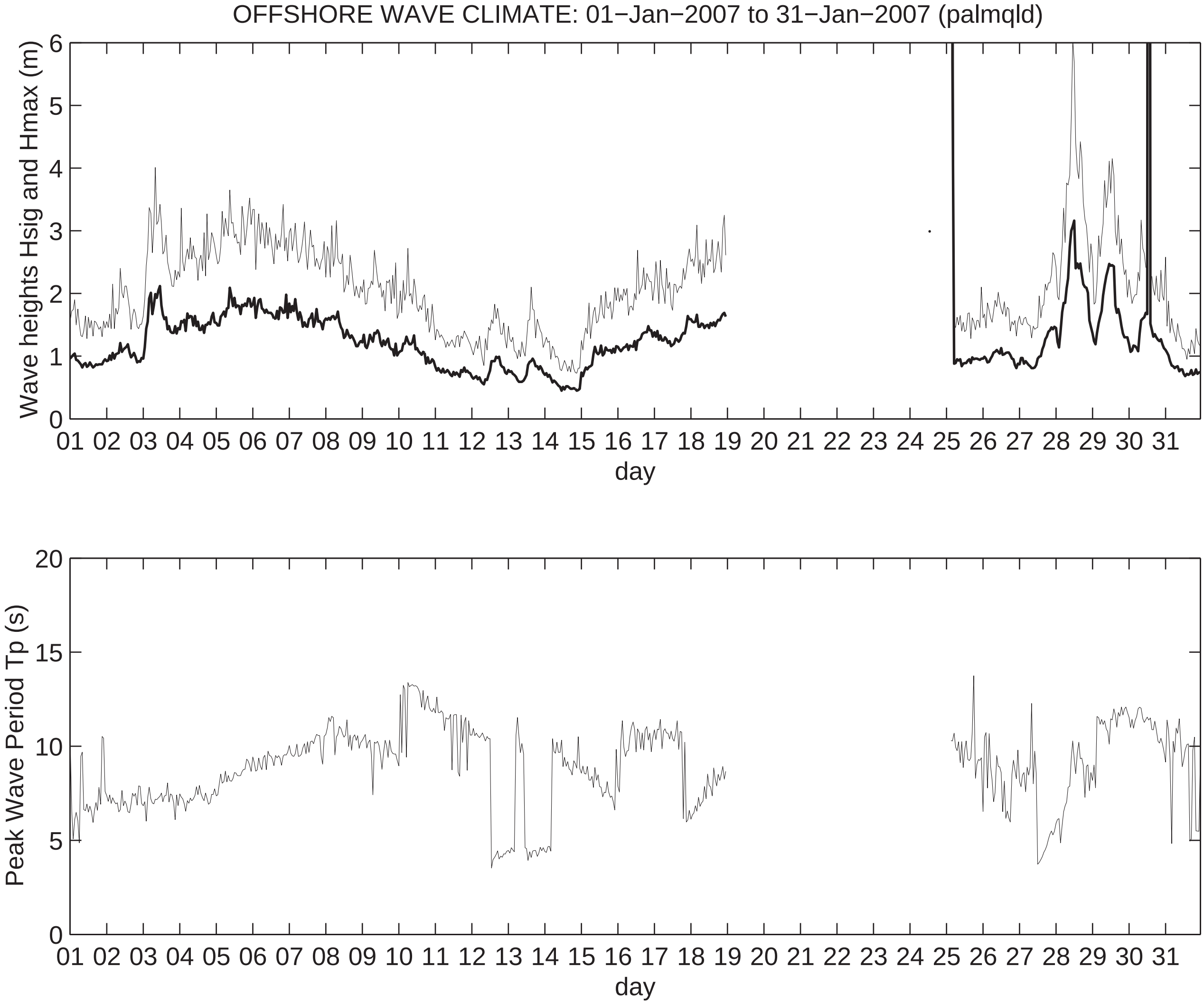
WRL Report No. 2007/21	DAILY MID-TIDE IMAGES 28/05/2007 - 03/06/2007	Figure A28 02114-A28.cdr

Appendix B

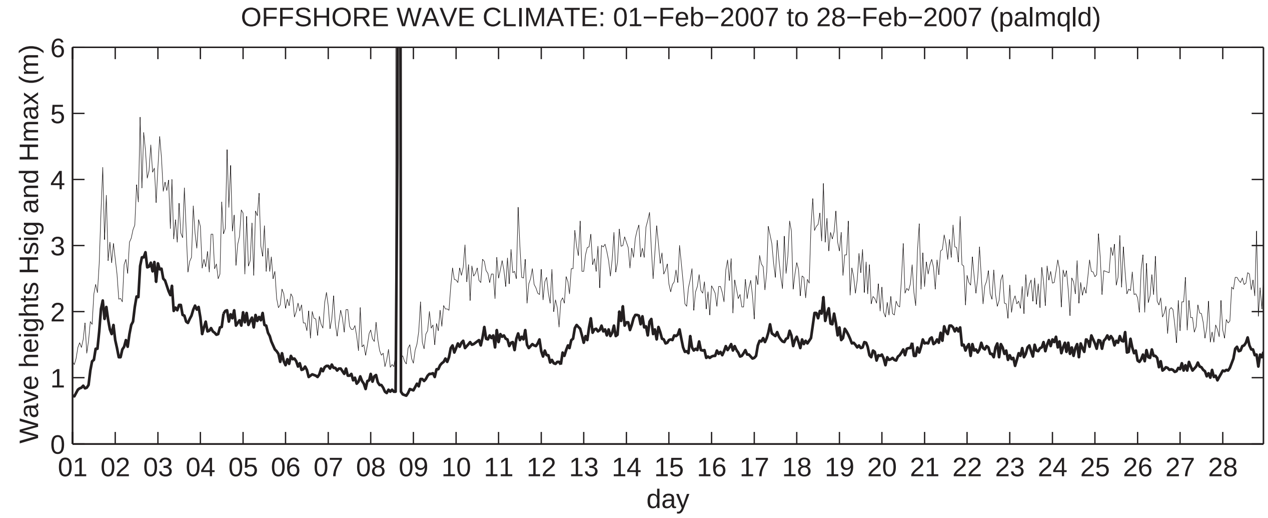
Monthly Wave Climate Summaries: December 2006 - May 2007

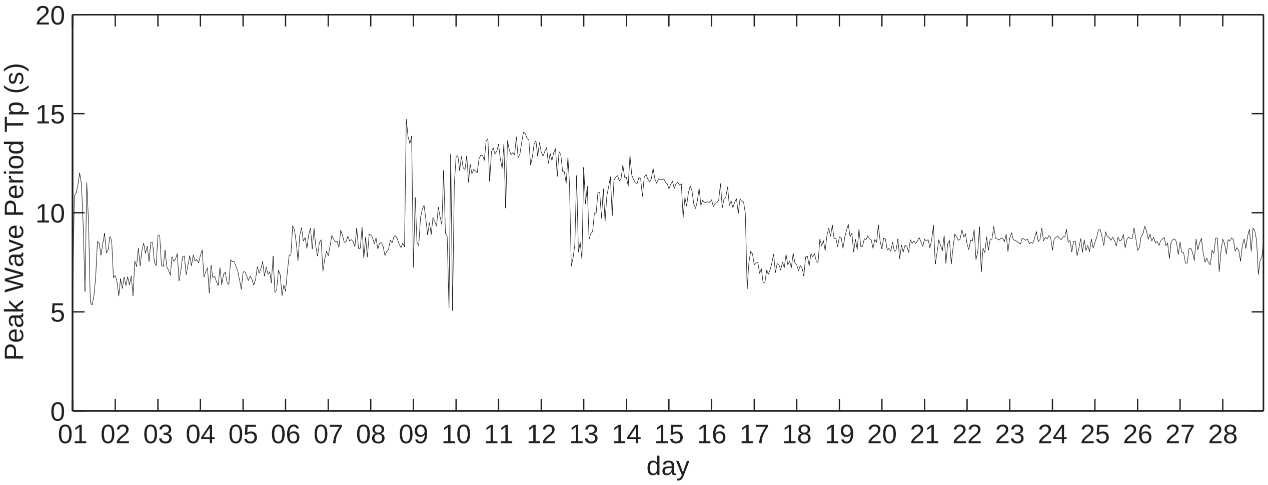


WRL Report No. 2007/21	MONTHLY WAVE SUMMARY DECEMBER 2006	Figure B1 02114-B01.cdr

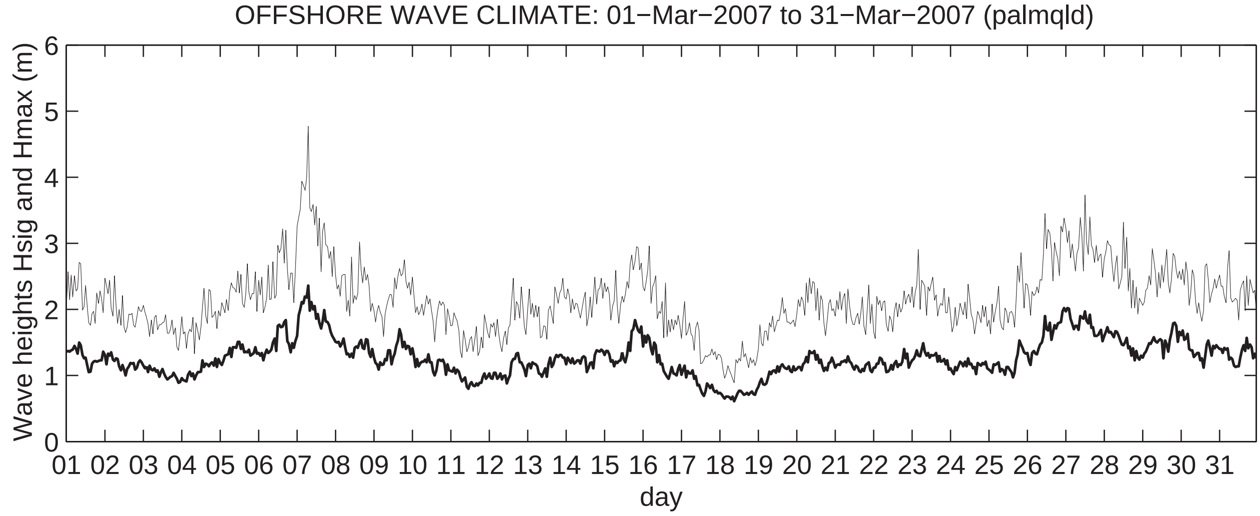


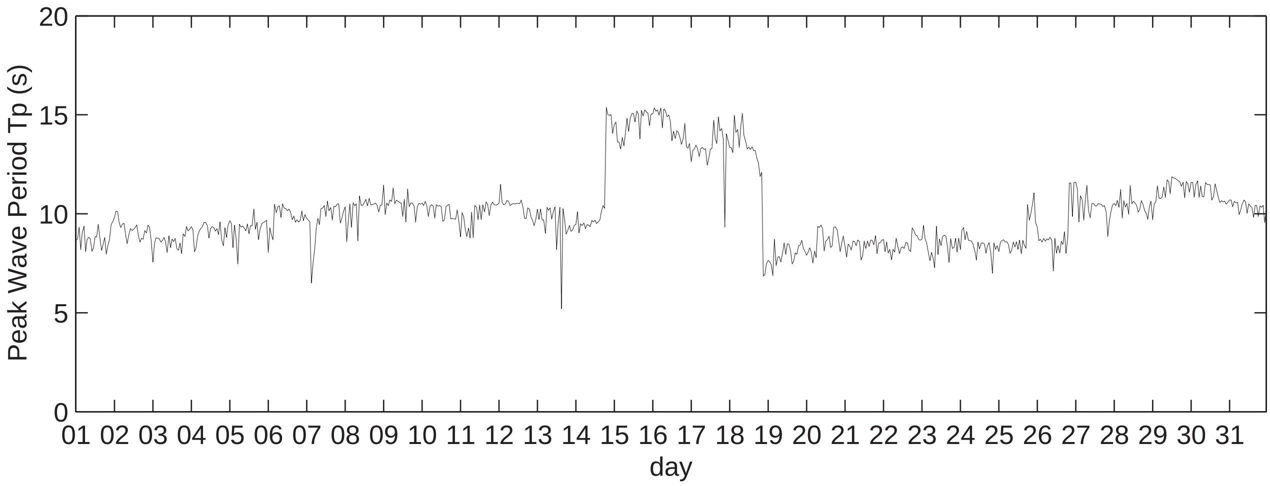
WRL Report No. 2007/21	MONTHLY WAVE SUMMARY JANUARY 2007	Figure B2 02114-B02.cdr



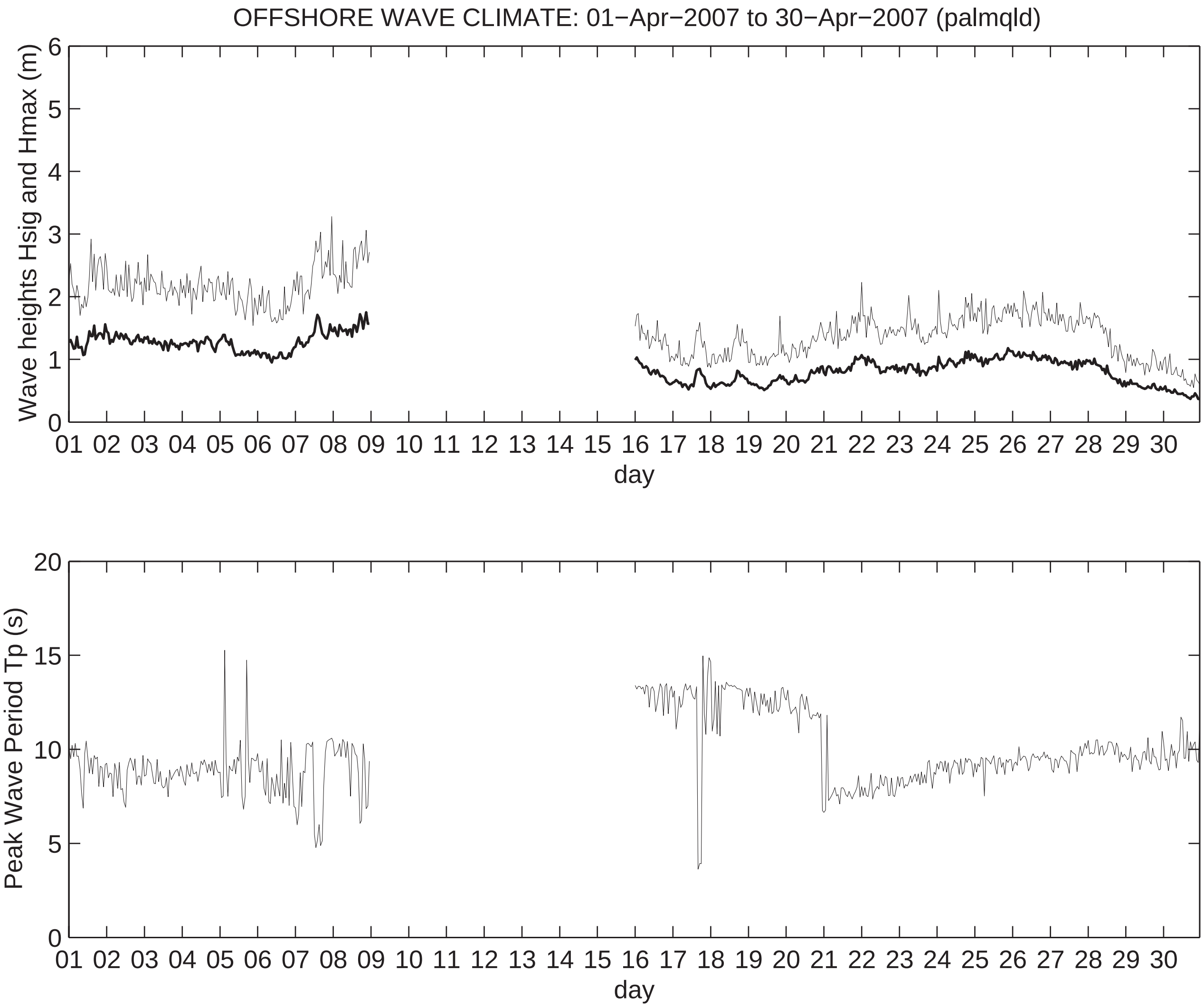


WRL Report No. 2007/21	MONTHLY WAVE SUMMARY FEBRUARY 2007	Figure B3 02114-B03.cdr

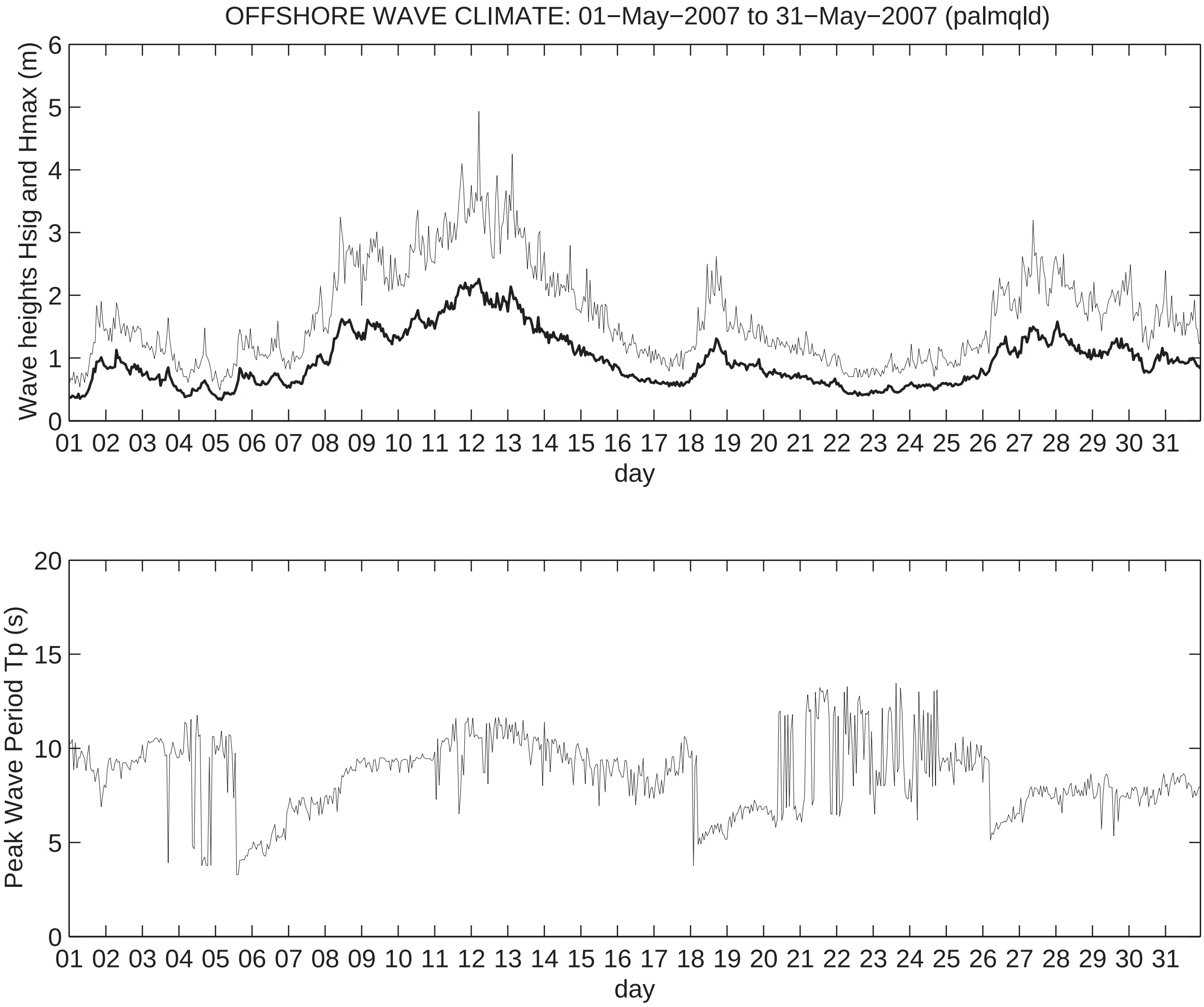




WRL Report No. 2007/21	MONTHLY WAVE SUMMARY MARCH 2007	Figure B4 02114-B04.cdr



WRL Report No. 2007/21	MONTHLY WAVE SUMMARY APRIL 2007	Figure B5 02114-B05.cdr



WRL Report No. 2007/21	MONTHLY WAVE SUMMARY MAY 2007	Figure B6 02114-B06.cdr