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ANALYSIS OF SHORELINE VARIABILITY, SEASONALITY AND EROSION /ACCRETION TRENDS: AUGUST 2007 - JANUARY 2008

REPORT 17
NORTHERN GOLD COAST COASTAL IMAGING SYSTEM

by

M J Blacka, D J Anderson and L Mallen Lopez

Technical Report 2008/06
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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
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1. INTRODUCTION

This report was prepared by Water Research Laboratory (WRL) for Gold Coast City Council. It is the 17th in a series of six-monthly reports, that describe, quantify and analyse the regional-scale coastline changes that have occurred following the implementation of the Northern Gold Coast Beach Protection Strategy (NGCBPS).

1.1 General

In July of 1999, an ARGUS coastal imaging system was installed at the northern Gold Coast. This leading-edge technology was selected by Gold Coast City Council to provide quantitative, continuous and long-term monitoring of coastline changes. It is this ability to provide quantitative information that distinguishes the ARGUS coastal imaging system from conventional 'webcam' technology.

The northern Gold Coast was the first of eight sites in Australia that currently utilise coastal imaging technology and techniques to monitor regional-scale coastal response to proposed, current or completed major coastal engineering works. It is fitting that the first installation in Australia should have occurred in conjunction with the implementation of the innovative NGCBPS coastal management project.

The coastal imaging system installed at the northern Gold Coast became fully operational on 1st August 1999. This timing coincided with the commencement of construction of the Gold Coast Reef. Beach nourishment commenced in February 1999, approximately six months prior to the installation of the coastal imaging system. The NGCBPS Beach nourishment program was completed in June 2000. During January – April 2005, dredging of the Broadwater resulted in a smaller quantity of sand being placed along the Surfers Paradise beachfront. The primary phase of reef construction concluded in December 2000. A second phase of reef construction with the addition of 15 geocontainers to the crest of the reef was completed at the end of 2001, and in November 2002 a further 10 bags were placed. The placement of the additional geocontainers in 2001 and again in 2002 was used to trim the crest level, and to fill the larger void spaces more generally across the reef structure. A further 15 bags were placed during January, July and August 2004, to continue this trimming and maintenance program of the reef structure.

The analysis of beach changes during the preceding six-monthly monitoring periods are detailed in a growing volume of reports:

- WRL Report 00/12: August 1999 to February 2000 (Turner and Leyden, 2000a)
- WRL Report 00/33: March to July 2000 (Turner and Leyden, 2000b)
- WRL Report 01/06: August 2000 to January 2001 (Turner and Adamantidis, 2001)
- WRL Report 01/35: February to July 2001 (Turner, 2001)
- WRL Report 02/08: August 2001 to January 2001 (Turner, 2002a)
- WRL Report 2002/31: February to July 2002 (Turner, 2002b)
- WRL Report 2003/05: August 2002 to January 2003 (Turner, 2003a)
- WRL Report 2003/36: February to July 2003 (Turner, 2003b)
- WRL Report 2004/05: August 2003 to January 2004 (Turner, 2004a)
- WRL Report 2004/25: February 2004 to July 2004 (Turner, 2004b)
- WRL Report 2005/04: August 2004 to January 2005 (Turner, 2005a)
- WRL Report 2005/25: February 2005 to July 2005 (Turner, 2005b)
- WRL Report 2006/01: August 2005 to January 2006 (Turner, 2006a)
- WRL Report 2006/25: February 2006 to July 2006 (Turner, 2006b)
- WRL Report 2007/08: August 2006 to January 2007 (Blacka *et al.* 2007a)
- WRL Report 2007/34: February 2007 to July 2007 (Blacka *et al.* 2007b)

Electronic copies of all these reports are available for public viewing and download in pdf format at:

→ www.wrl.unsw.edu.au/coastalimaging/public/goldcst (monitoring reports).

The purpose of this 17th report is to present an analysis of shoreline variability, seasonality and erosion-accretion trends for the monitoring period August 2007 to January 2008, and to assess the net changes that have occurred to northern Gold Coast beaches since the commencement of the monitoring program eight and a half years ago in August 1999.

1.2 Maintenance and Upgrade History

Three years following the installation of the original camera and computer equipment at the northern Gold Coast in July 1999, in October 2002 a major systems hardware and software upgrade was completed (refer Turner, 2002a for details). Since that time the stability of the system and the connectivity between the remote station and the server at WRL has exceeded expectations. Short-lived interruptions (<2 hours) to the power supply at both the remote site and server caused a limited number of automatic system reboots during this period. A UPS backup power supply was installed to the server computer at WRL in March 2003, which has further reduced the requirement for system reboots due to interruptions to the mains power supply.

To bring the northern Gold Coast monitoring project in line with similar projects at other major coastal management and coastal engineering sites in both Australia and overseas, in February 2003 a refined methodology was implemented to map and quantify weekly shoreline variability and change. The software tool called 'WRL Intertidal Beach Mapper' (or 'WIBM') was implemented. Further details are provided in Section 3.7. Coinciding with this upgrade, a new on-line beach monitoring system was progressively implemented during February-March 2003. This system now provides 'real-time' access to the results of the video-based beach monitoring program at the northern Gold Coast via the world-wide-web, and is designed in part to replace the reliance upon (retrospective) six-monthly reporting. Further details of these 'real-time' monitoring capabilities are provided in Section 4.3.

Routine maintenance of computer and camera equipment at the northern Gold Coast site was undertaken in January 2004, including a minor upgrade to the automated image capture software (refer Turner, 2004a). More extensive maintenance of the system was undertaken in November 2004, including the replacement of three of the four cameras installed at the northern Gold Coast ARGUS station. These cameras were beginning to show signs of reduced picture quality due to continuous exposure to the elements. Following extensive testing, in December 2004 a new 'remote reboot' device was also installed at the site, that facilitates a reboot of the system via the telephone line, even when communications between the remote and local computer systems have failed. It has been observed that this event occurs several times per year, generally associated with power surges and/or momentary power failures at the remote computer site.

In February 2005 the fourth camera (not replaced in November 2004) developed a power supply fault, and after a period of testing, a new camera was installed in mid March. Routine maintenance of cameras, camera housings and the computer system was completed in December 2005. Early in 2006 camera 1 (southern camera) failed, and subsequently the camera was replaced on the 16th of March. Later in 2006, a range of new cameras were purchased, and the southern camera was again replaced on 23rd October with one of the new cameras. While the camera had still been operational at that time, the recorded images were showing a green colour tinge compared to images from the other cameras at the site.

In February 2007 WRL staff completed routine maintenance of the ARGUS station, and surveyed new ground control points (GCPs) for the southern camera. Shortly after this time, the computer system at the station became unstable, and subsequently a replacement system was tested and deployed on 14th of March. The new computer system failed several days after installation, and was repaired by WRL staff at the end of March 2007. The system again failed in April at which point a fault in the remote power management hardware was identified and repaired, restoring functionality of the system. At the end of May it became apparent that communications to the site had been lost, with the phone line having been disconnected. Throughout June and July the system continued to collect and store images locally on the station computer, but was unable to transfer the images to WRL for upload to the World Wide Web. At the end of July 2007 communications to the site were again established with the reconnection of the phone line by GCCC, and the images that had been recorded throughout June and July transferred to the WRL server and uploaded to the World Wide Web.

The northern Gold Coast ARGUS station went offline on 4th August 2007 due to ISP problems, with image collection not re-established until 14th August. During this period, nine days of images were not captured by the station. Further intermittent problems were experienced with the station late in August, before a maintenance visit by WRL staff in the first week of September. During this visit, problems with an electrical power supply to the station and video hardware were identified. The faulty video hardware was replaced, and a heavy duty power filter and surge protector installed to reduce the risk of further damage due to power supply problems. A spare replacement computer system was stored at the site to reduce downtime during future station malfunctions.

The ARGUS server located at WRL suffered catastrophic failure on 18th October 2007, and was subsequently replaced by the 24th October. All data that had been stored on the failed server was restored using backup copies. Image data continued to be collected during this period, except for the day of the 18th. The northern Gold Coast ARGUS station again went offline on the 15th November, with image collection restored the following day.

1.3 Report Outline

Following this introduction, Section 2 of this report provides a brief overview of the Northern Gold Coast Beach Protection Strategy.

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 Northern Gold Coast Coastal Imaging System entitled *System Description and Analysis of Shoreline Change: August 1999 – February 2000* (Turner and Leyden, 2000a).

The web site used to promote and distribute the images collected by the monitoring program is introduced in Section 4. Description includes the web-based image archive that provides unrestricted access to all images, weekly-updated quantitative analysis of current coastline conditions, as well as links to local information such as current weather conditions and wave measurements.

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 period covered by this report, August 2007 – January 2008.

The quantitative analysis of shoreline variability for the six month period August 2007 to January 2008 is detailed in Section 6. This is followed in Section 7 by the corresponding analysis for the total eight and a half year monitoring period, August 1999 – January 2008, as well as the analysis of cyclic-seasonal versus longer-term erosion-accretion trends observed during this period.

An assessment of shoreline variability and seasonal-cyclic versus net erosion-accretion trends at the reef site at Narrowneck is provided in Section 8. Section 9 contains more detailed analysis of quantitative beachface erosion-accretion trends during the present monitoring period. Section 10 briefly discusses the now ubiquitous occurrence of wave breaking at the reef when wave heights exceed approximately 1 m, following the placement of additional geocontainers across the crest of the reef in 2001, 2002, and most recently in 2004. Section 11 summarises the major findings of this 17^{th} six-monthly monitoring period at the northern Gold Coast.

2. BACKGROUND

2.1 Northern Gold Coast Beach Protection Strategy

The Northern Gold Coast Beach Protection Strategy (ICM, 1997; Boak *et al.*, 2000) proposed a long-term, sustainable plan to maintain and enhance the beaches at Surfers Paradise, Gold Coast Queensland, Australia (Figure 2.1). Tourism is the Gold Coast's largest industry, however, the tourist economy is at risk of significant downturn in the event of major storm beach erosion.

Gold Coast beaches are dynamic, and coastal erosion has been an ongoing challenge for coastal managers since development began last century. Early and more recent coastal protection measures have included the construction of timber walls in the 1920s and 1930s, progressive construction of a continuous boulder wall along the entire northern Gold Coast beachfront, construction of the Gold Coast Seaway and sand by-passing system in the mid-1980s, and periodic beach nourishment since the 1970s.

The Northern Gold Coast Beach Protection Strategy (NGCBPS) aims to decrease the risk of economic loss following storm events, by increasing the volume of sand within the storm buffer seaward of the existing oceanfront boulder wall. The NGCBPS has the dual objectives of increasing the sand volume within the dunal buffer and improving surf quality through the implementation of sand nourishment and the construction of an artificial reef (McGrath *et al.*, 2000).

The NGCBPS is specifically concerned with the 1.75 km of beach between Main Beach and Cavill Avenue at Surfers Paradise (refer Figure 2.1). The reef is located at Narrowneck. This section of coastline is part of the Gold Coast coastal compartment between the Gold Coast Seaway 5 km to the north and Burleigh Heads 20 km to the south. The Master Plan for the engineering works now completed at the northern Gold Coast is summarised in Figure 2.2.

2.2 Reef Construction

Construction of the artificial reef at Narrowneck commenced in August 1999, with the major phase of reef building concluded in mid-December 2000. In late 2001, a second phase of construction was completed to raise the crest level of the structure by the placement of a further 15 geocontainers. In November 2002 a further 10 geocontainers were placed at the site to raise the crest level of the northern reef, and to more generally fill larger void areas across the reef structure.

During 2004 a further 15 bags were placed to trim the crest of the reef, and to partially close the central channel between the northern and southern halves of the reef. One bag was placed in January 2004, a further 5 bags in July, and 9 bags in August of the same year.

The novel shape of the reef was designed following field investigations and extensive numerical model simulations to determine the optimum reef layout (Black, 1998; Black *et al.,* 1998). The final reef design was further tested by a physical model study (Turner *et al.*, 1998a). Reef construction commenced in August 1999, and to date around 430 sand-filled geocontainers (up to 350 tonnes) have been used to construct the reef. The reef design consists of two primary layers of stacked geocontainer units. Figure 2.3 shows the progress of reef construction up to and including the most recent phase of geocontainer placement.

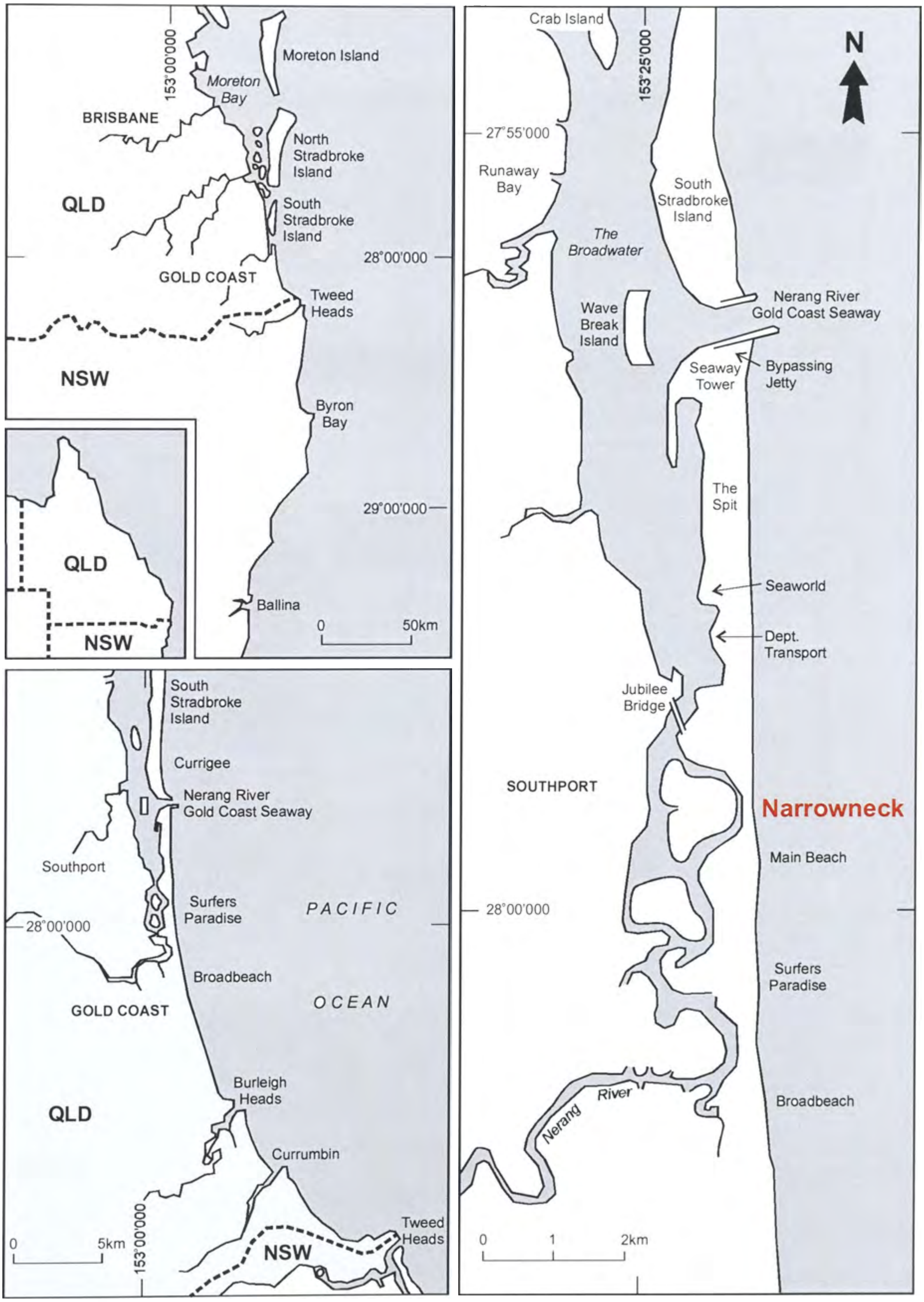
2.3 Sand Nourishment

Nourishment of the northern Gold Coast beaches commenced in February 1999, six months prior to reef construction. Cumulative nourishment volumes for the 17 month nourishment period February 1999 to June 2000 are shown in Figure 2.4, at which time this major phase of beach nourishment within the 4,500 m study area was completed.

In summary, during this period approximately 1,170,000 m^3 of sand was placed on the beach and nearshore at the northern Gold Coast. The locations of the six sand nourishment deposition areas are indicated in Figure 2.5. For reference, the location of the reef construction site at Narrowneck is shown in this figure. A small volume of additional sand (~ 37,000 m^3) was also deposited approximately 300 m north of deposition area A1 in June 2000, denoted deposition area A1a in Figure 2.4.

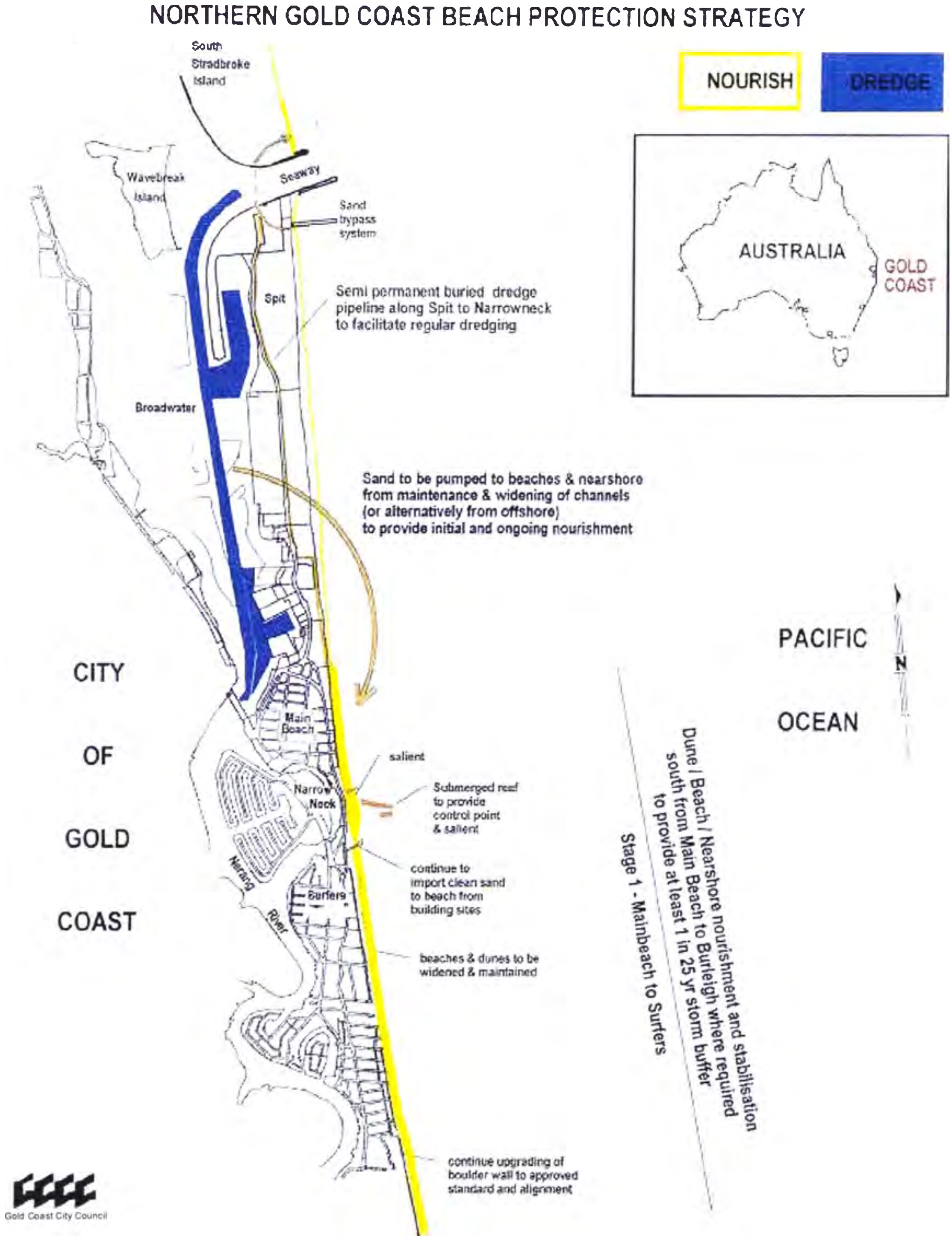
Due to dredging operations in the Broadwater, in January 2005 around 27,000 m^3 of sand was placed in the vicinity of deposition area A5. From February to April 2005 another 32,000 m^3 of sand was placed within this region. From February to July 2007, 6,400 m^3 of sand, sourced from excavations undertaken at development sites, has been deposited on the beaches of the northern Gold Coast.

During the current monitoring period August 2007 to January 2008, minor nourishment of the beach has taken place at Higman Street, with 9,790 m^3 of sand being placed between 16^{th} November and 28^{th} November 2007.

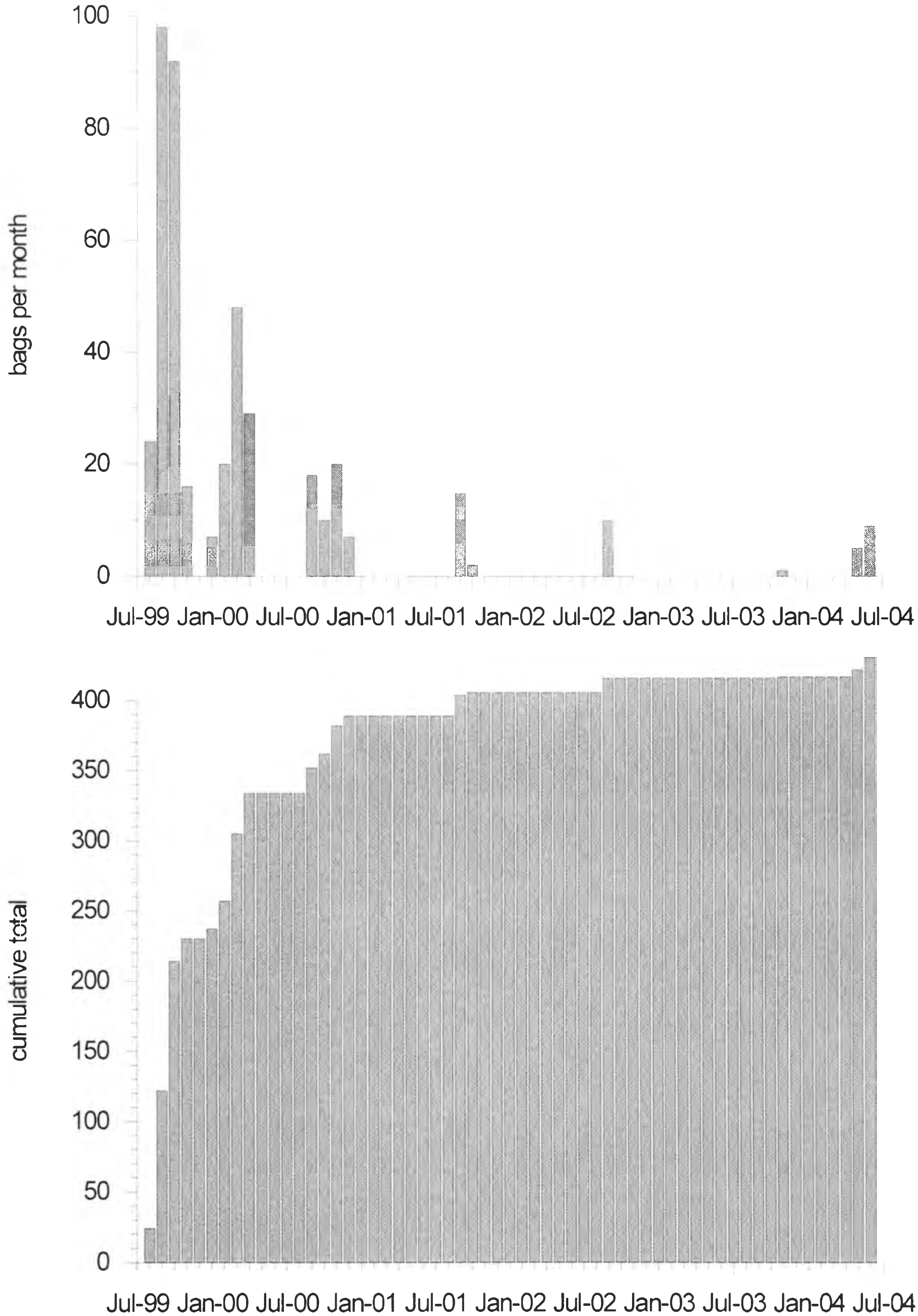


WRL Report No. 2008/06	LOCALITY	Figure 2.1

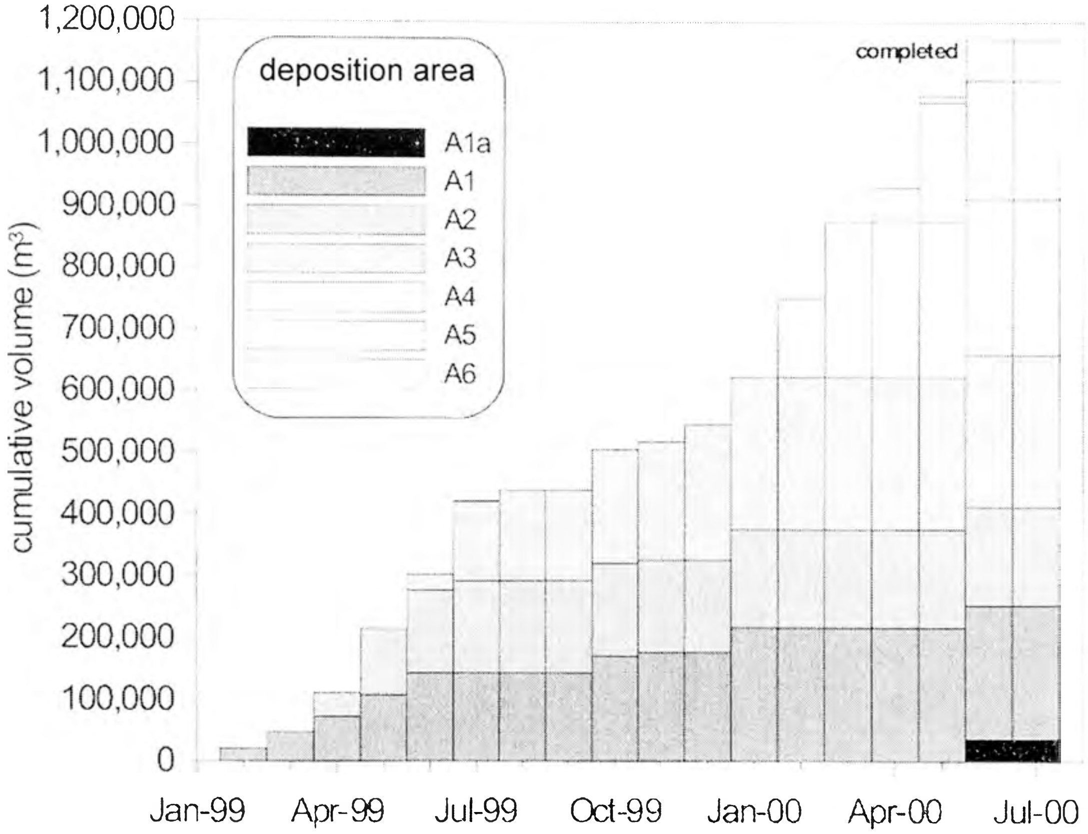
06037-2-1.cdr



Source: McGrath et al. (2000)

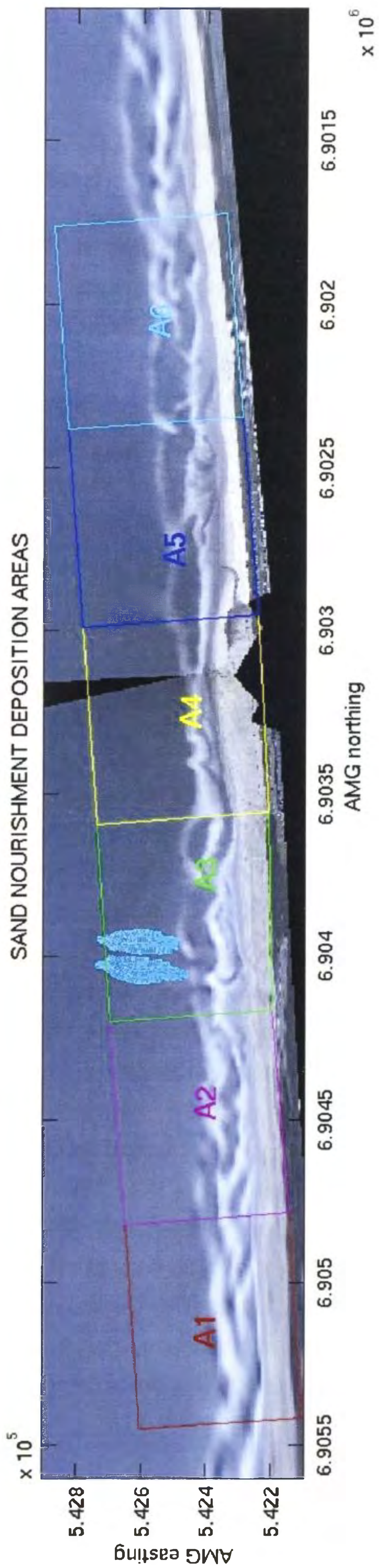


WRL Report No. 2008/06	REEF CONSTRUCTION	Figure 2.3 06037-2-3.cdr



WRL Report No. 2008/06	SAND NOURISHMENT (NGCBPS)	Figure 2.4

06037-2-4.cdr



WRL Report No. 2008/06	SAND NOURISHMENT DEPOSITION AREAS	Figure 2.5 06037-2-5.cdr

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

Comprehensive descriptions of the northern Gold Coast coastal imaging system, image types and imaging processing techniques were detailed in the first NGCBPS coastal imaging report *System Description and Analysis of Shoreline Change: August 1999 – February 2000* (Turner and Leyden, 2000a). 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. Also included is a description of the image analysis technique (called WRL Intertidal Beach Mapper or 'WIBM') that was implemented in mid 2003 to bring the northern Gold Coast monitoring project in line with similar projects at other major coastal management and coastal engineering sites in both Australia and overseas.

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. Also of course, pictures are only obtained when the airplane is in the air and visibility is satisfactory, often resulting in a limited number of suitable pictures per year (at most), with no information about the behaviour of the beach between flights.

In contrast, with the development of digital imaging and analysis techniques, one or more automated cameras can be installed at a remote site and, via a telephone or internet connection, be programmed to collect and transfer to the laboratory a time-series of images. These images, taken at regular intervals every hour of the day for periods of 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 documented and available for more detailed analysis as required.

3.2 The Difference between Coastal Imaging and a 'Webcam'

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 Webcams 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. For detailed description and illustration of the methods used to calibrate the lens and cameras installed at the northern Gold Coast, the reader is referred to Turner and Leyden (2000a).

3.3 The ARGUS Coastal Imaging System

The ARGUS coastal imaging system has developed out of almost two decades of ongoing research effort originating from 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 the northern Gold Coast 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 analog I/O card that enables all images to be captured, stored and distributed in standard jpeg digital image file format.

At WRL a 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 the northern Gold Coast 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 the Northern Gold Coast

The ARGUS coastal imaging system was installed at the northern Gold Coast in late July 1999. The system is located at an elevation of approximately 100 m above mean sea level, within a roof services area of the Focus Building (Figure 3.2). The Focus Building is located approximately 60 m landward of the dune line, approximately 900 m to the south of Narrowneck.

The cameras are mounted externally to the building, and are protected within weatherproof housings (Figure 3.3). The SGI workstation is housed within an air-conditioning 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, or by site visit from WRL staff or contracted technical officers. Occasional cleaning of the camera lenses is also required during the site visits.

3.5 Image Types

The ARGUS coastal imaging system installed at the northern Gold Coast 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 on 31st January 2008 is shown in Figure 3.4 (upper panel).

3.5.2 Time-Exposure 'timex' Images

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

A lot of quantitative information can be obtained from these images. Time exposures of the shore break and nearshore wave field have the effect of averaging out the natural variations of breaking waves, to reveal smooth areas of white, which has been shown to provide an excellent indicator of the shoreline and nearshore bars. In this manner, a quantitative 'map' of the underlying beach morphology can be obtained. An example of a timex image 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 changing water surface (bright) is readily identifiable against the beach (dark). 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 the northern Gold Coast 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. In earlier monitoring reports the daily daytimex images provided the basis for the qualitative description of the morphodynamic trends and changes that characterised each six-monthly monitoring period. With the implementation in mid 2003 of the enhanced ‘real-time’ online beach monitoring system at the northern Gold Coast, (refer Section 4.3), the ‘week-to-a-page’ product replaced this use of the daytimex images. However, daytimex images continue to be created, and are available for viewing and download at the project web site via the online image archive.

3.6 Basic Image Processing – Merge, Rectification and Reference to Real-World Coordinate System

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. This is achieved through the solution of the camera model parameters (refer Turner and Leyden, 2000a) to extract three-dimensional real-world position from two-dimensional 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. This merged and rectified image created from four oblique images is analogous to a montage of distortion-corrected photographs taken from an airplane flying directly overhead the northern Gold Coast. 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 the Gold Coast is 5 m; that is, a single pixel represents an area 5 m × 5 m.

The final step in the routine processing of images at the northern Gold Coast is the referencing of merged/rectified images to a convenient map reference system. As the coordinates of the cameras are known, this final step is relatively easy to achieve. In Figure 3.6 an example of a merged and rectified image is shown, referenced to Australian Map Grid (AMG) eastings and northings. The referencing of images to real-world coordinates permits the combination of image information with other cadastral information; in Figure 3.6 a merged and rectified timex image is overlaid by an engineering design drawing showing the layout of the geotextile bags comprising the bottom layer of the Gold Coast reef. As illustrated in the upper panel of this figure, specific regions of interest within an image can be enlarged to examine in greater detail that region of the beach or nearshore. As also shown in Figure 3.6, this enables the geo-referenced images to be overlaid by other cadastral information (e.g. reef layout).

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.

In earlier reports, a shoreline mapping technique developed specifically for the Gold Coast site was employed, that fully utilised the RGB (Red-Green-Blue) colour information that was newly available at the northern Gold Coast site (prior to 1999, ARGUS stations typically collected grey-scale images only). A comprehensive description of this colour-based shoreline detection technique can be found in Turner and Leyden (2000a), and a summary of the method is contained in all previous reports.

Since that time, the use of full colour information has been adopted more generally by the international ARGUS-user community, which has led to considerable improvements to the range of shoreline detection and mapping techniques that are now more generally available. To ensure that the current and future monitoring program at the northern Gold Coast is in line with these international developments, during 2003 the 'standardised' shoreline mapping methodology (called 'Pixel Intensity Clustering' or 'PIC') that is being used at a number of sites around the world was implemented within the northern Gold Coast image database. For a detailed description of the analysis and image database re-processing that was performed prior to the implementation of this enhanced methodology, the reader is referred to Turner (2003b).

3.7.1 Overview of the 'PIC' shoreline identification technique

Comprehensive description of the PIC shoreline identification technique is provided in Aarninkhof (2003), Aarninkhof and Roelvink (1999) and Aarninkhof *et al.* (2003). Briefly, 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 3.7).

The filtered histogram is used to define a line to distinguish between Hue Saturation information used for colour discrimination (Figure 3.7a), or Value information in the case of luminance-based discrimination (Figure 3.7b). 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 3.7). The areas of dry and wet pixels are then mapped, and the boundary between the two regions defines the resulting shoreline feature of interest.

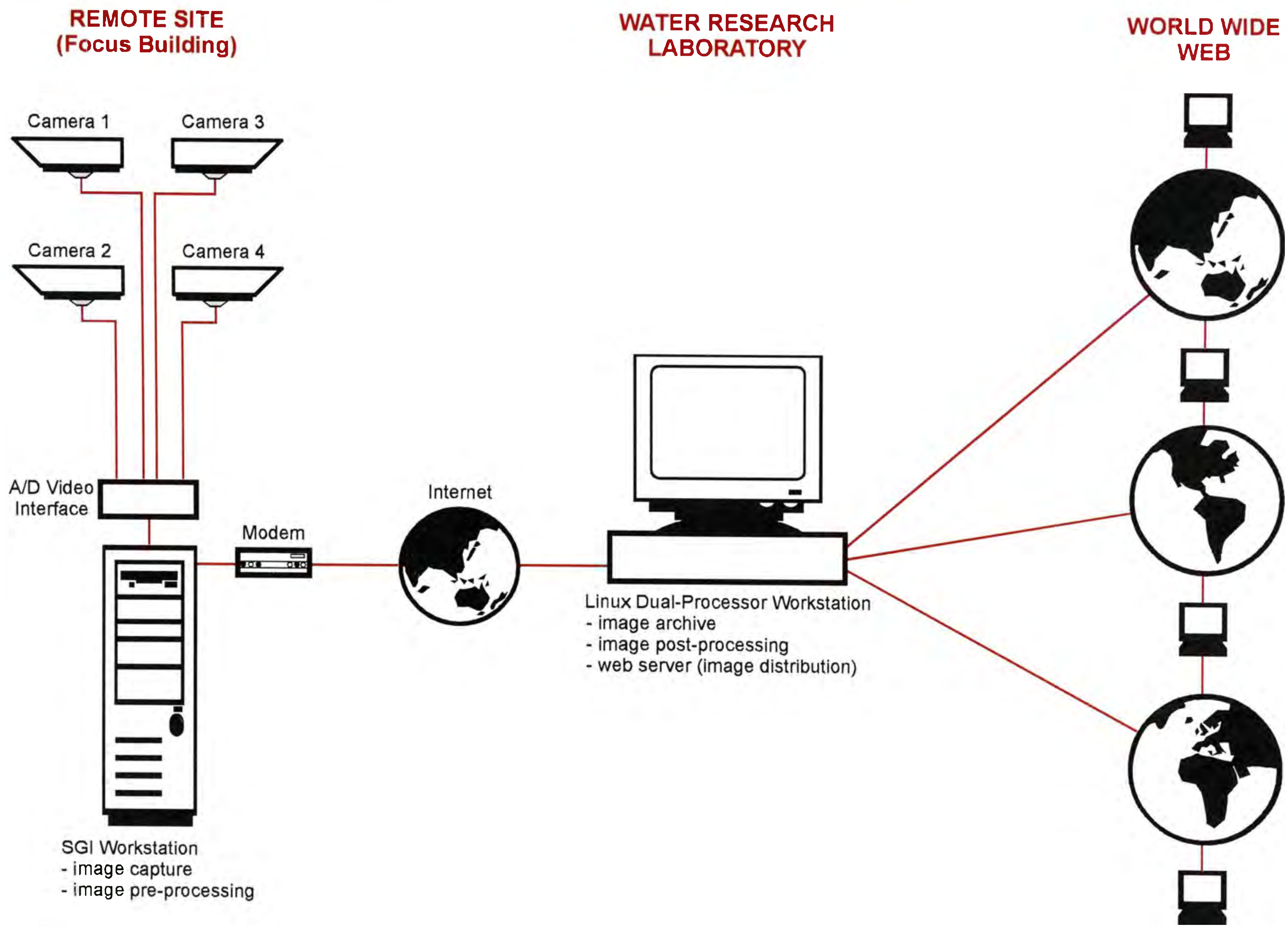
3.8 Standardised Procedure for Shoreline Mapping

The procedure used to map the shoreline at the northern Gold Coast is summarised in Figure 3.8. At weekly (nominal seven day) intervals, predicted tide information is used to determine the hourly timex images that correspond to mid-tide (0m AHD). 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 images are checked to confirm that the wave height satisfies the low-pass criteria $H_{rms} \leq 1.0$m (ie. $H_s \leq \sim 1.4$ m). This wave height criteria is used for all shoreline mapping as, above this wave height, wave runup at the beachface increases and the width of the swash zone widens, introducing a degree of uncertainty in the cross-shore position of the waterline. If the Root Mean Square wave height is less than 1.0m, then the shoreline is mapped. Prior to November 2004 a single merged-rectified image of the entire study area was analysed, but since that time the four (higher resolution) individual oblique images are analysed separately, camera geometries are applied to convert between image and real-world coordinates, and finally the resulting shoreline segments are merged along the length of the study area. The current use of individual-oblique versus merged-rectified images for shoreline mapping enables the full resolution of the individual raw images to be better exploited.

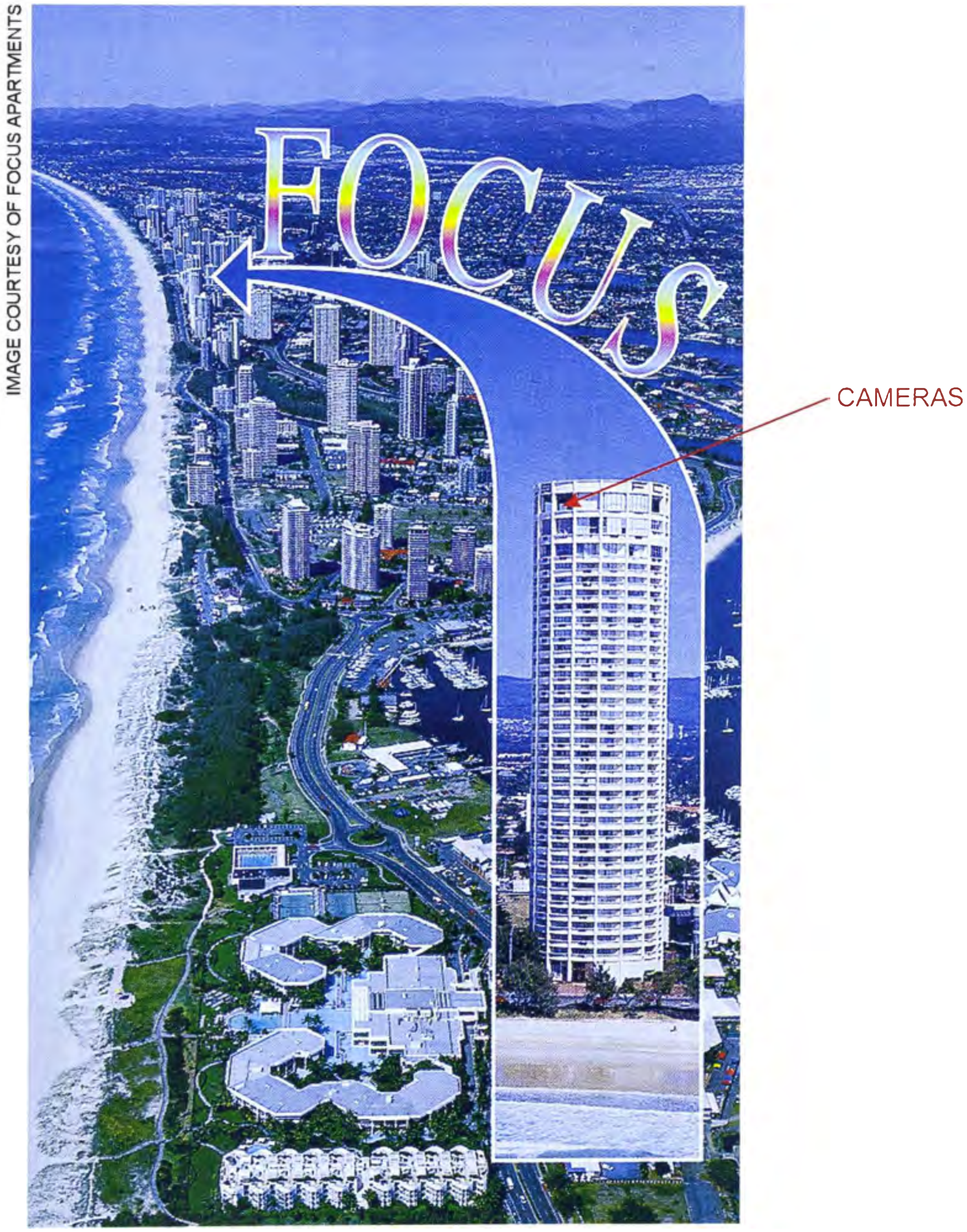
If the wave height exceeds the H_{rms} = 1.0 m threshold, then the mid-tide images for the preceding day are checked. If these images still does not satisfy the wave height criteria, then the following day's images are checked. This process is repeated for up to ± 3 days from the original target weekly image, to locate mid-tide images for which the 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 images to be processed has been identified, the PIC method is applied and the shoreline feature is mapped. Beach width is then calculated relative to a dune reference line. By repeating this procedure every seven days, a growing data base 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 Sections 6 to 9 of this report.

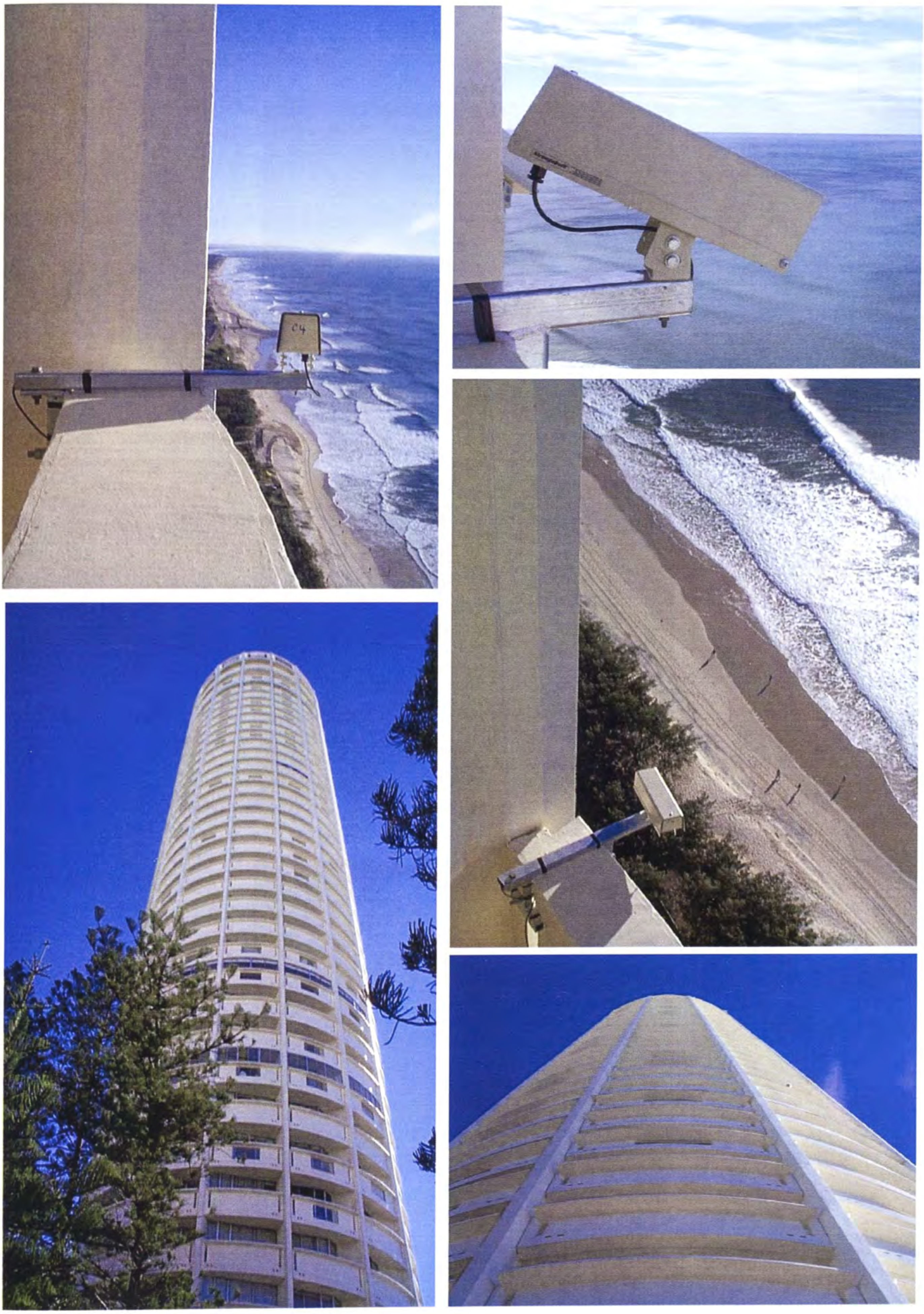


WRL Report No. 2008/06	SCHEMATIC OF AN ARGUS COASTAL IMAGING SYSTEM	Figure 3.1

05037-3-1.cdr



WRL Report No. 2008/06	LOCATION OF ARGUS COASTAL IMAGING SYSTEM AT THE GOLD COAST	Figure 3.2 06037-3-2.cdr



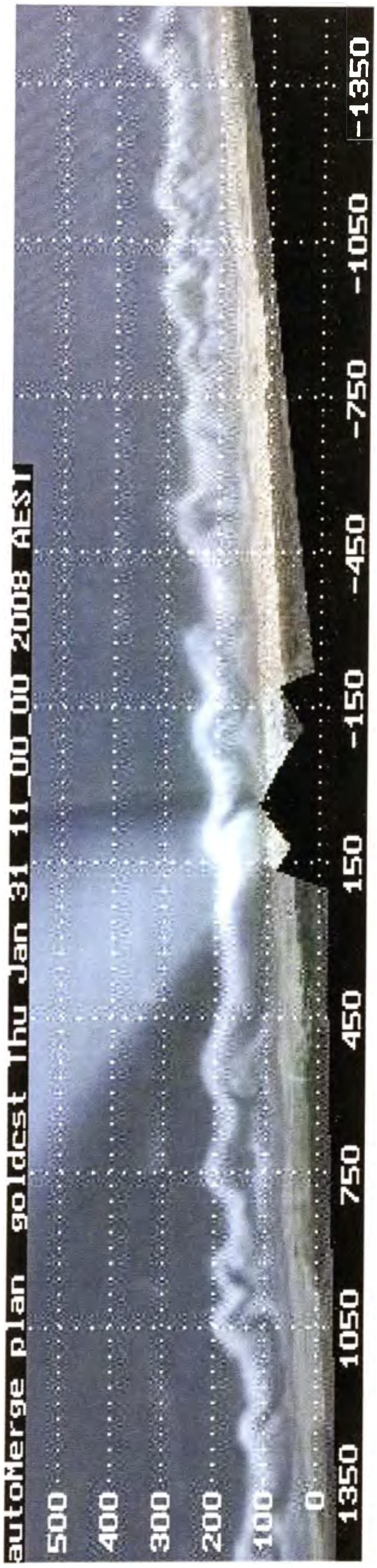
WRL Report No. 2008/06	CAMERAS MOUNTED AT AN ELEVATION OF APPROXIMATELY 100m	Figure 3.3 08037-3-3.cdr

snap

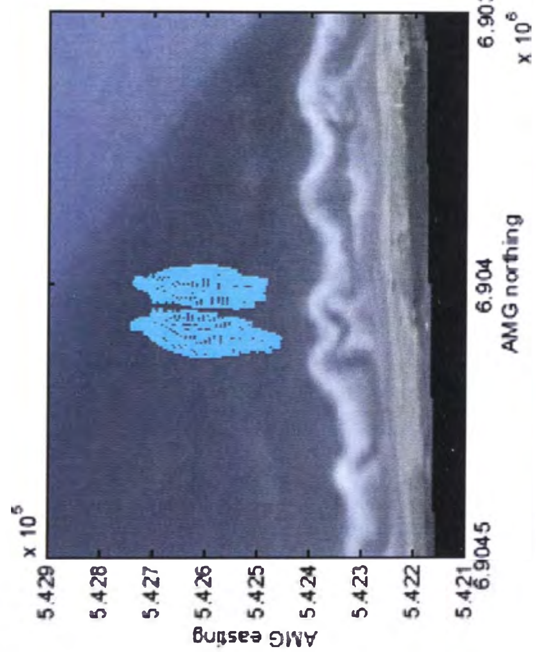
timex

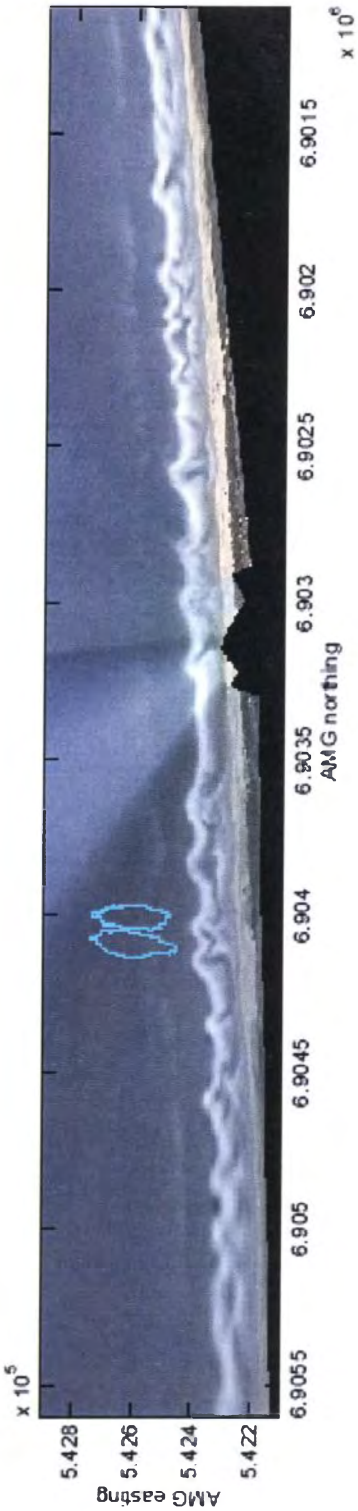
var

WRL Report No. 2008/06	SNAP-SHOT, TIME-EXPOSURE AND VARIANCE IMAGE TYPES (31/01/08)	Figure 3.4

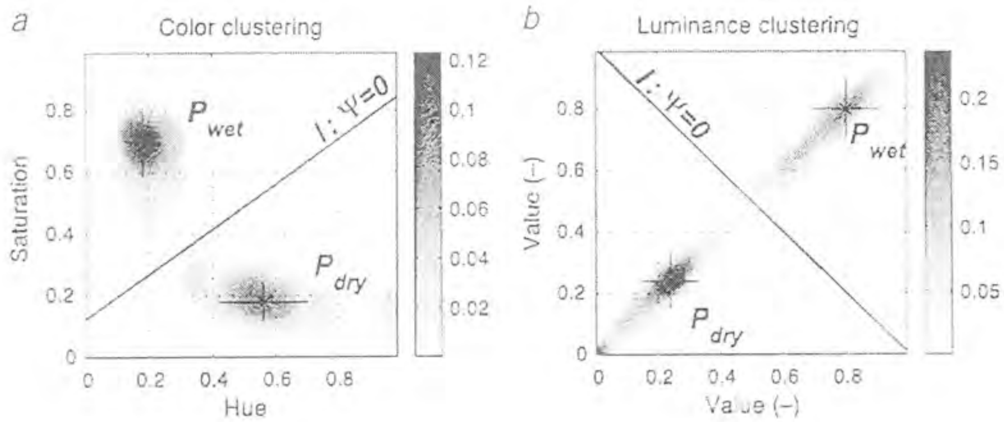


WRL Report No. 2008/06	PLAN VIEW IMAGE 4 CAMERA MERGE/RECTIFICATION (31/01/08)	Figure 3.5

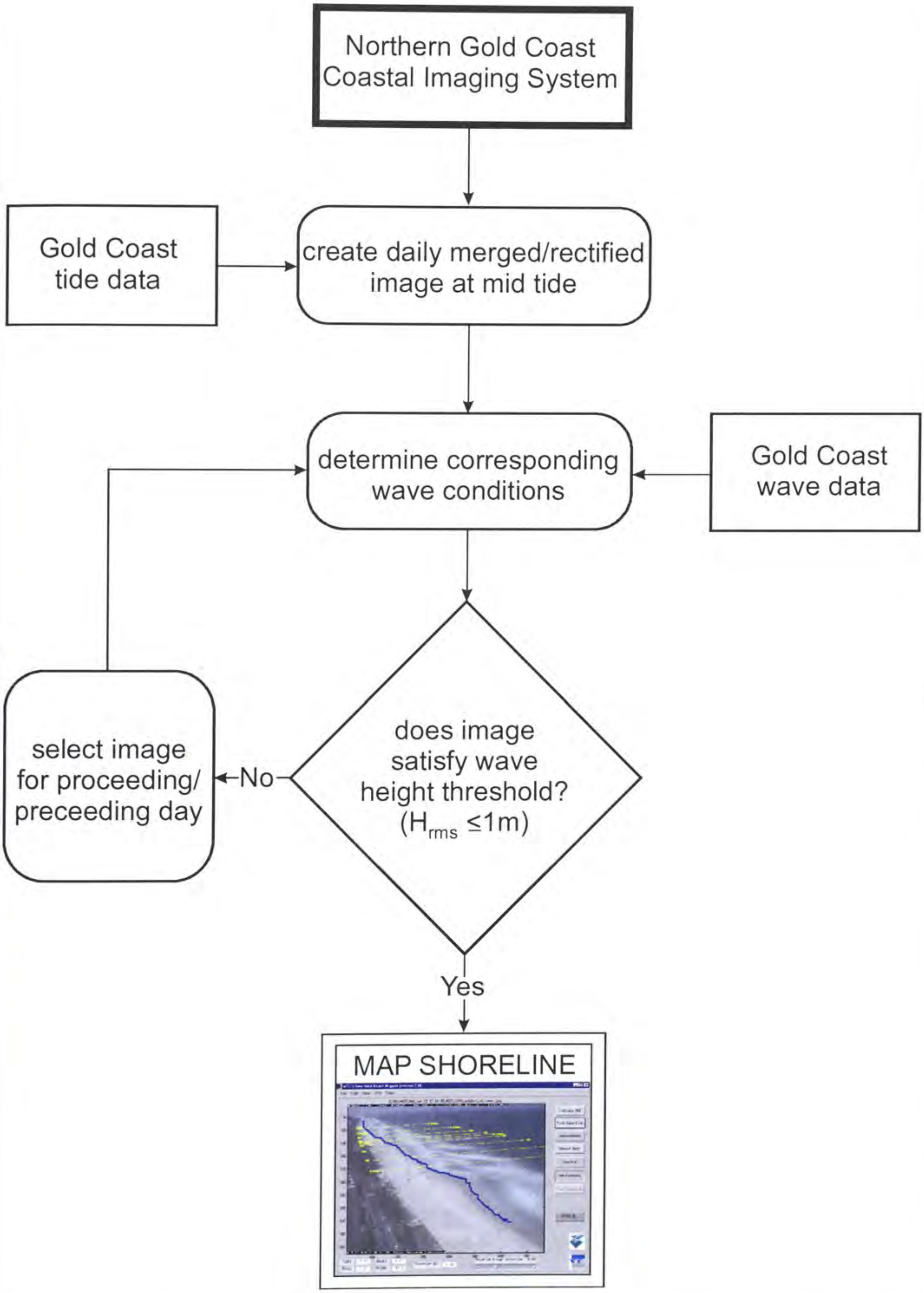




WRL Report No. 2008/06	PLAN VIEW IMAGE REFERENCED TO 'REAL WORLD' AMG COORDINATE SYSTEM	Figure 3.6



Source: Aarninkhof (2003)



WRL

Report No. 2008/06

STANDARDISED SHORELINE MAPPING PROCEDURE

Figure 3.8

4. COASTAL IMAGING WEB SITE

4.1 Coastal Imaging Home Page

To promote the dissemination of information about the northern Gold Coast coastal monitoring project, to provide a convenient means to distribute images as they are collected, and to enable '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 address:

→ http://www.wrl.unsw.edu.au/coastalimaging/public/goldcst

The northern Gold Coast 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 at the northern Gold Coast. 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 NGCBPS web site maintained by International Coastal Management, the waverider buoy site run by the Queensland Department of Environment, local weather conditions provided by the Bureau of Meteorology, 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, more than 311,200 hits to 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 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.

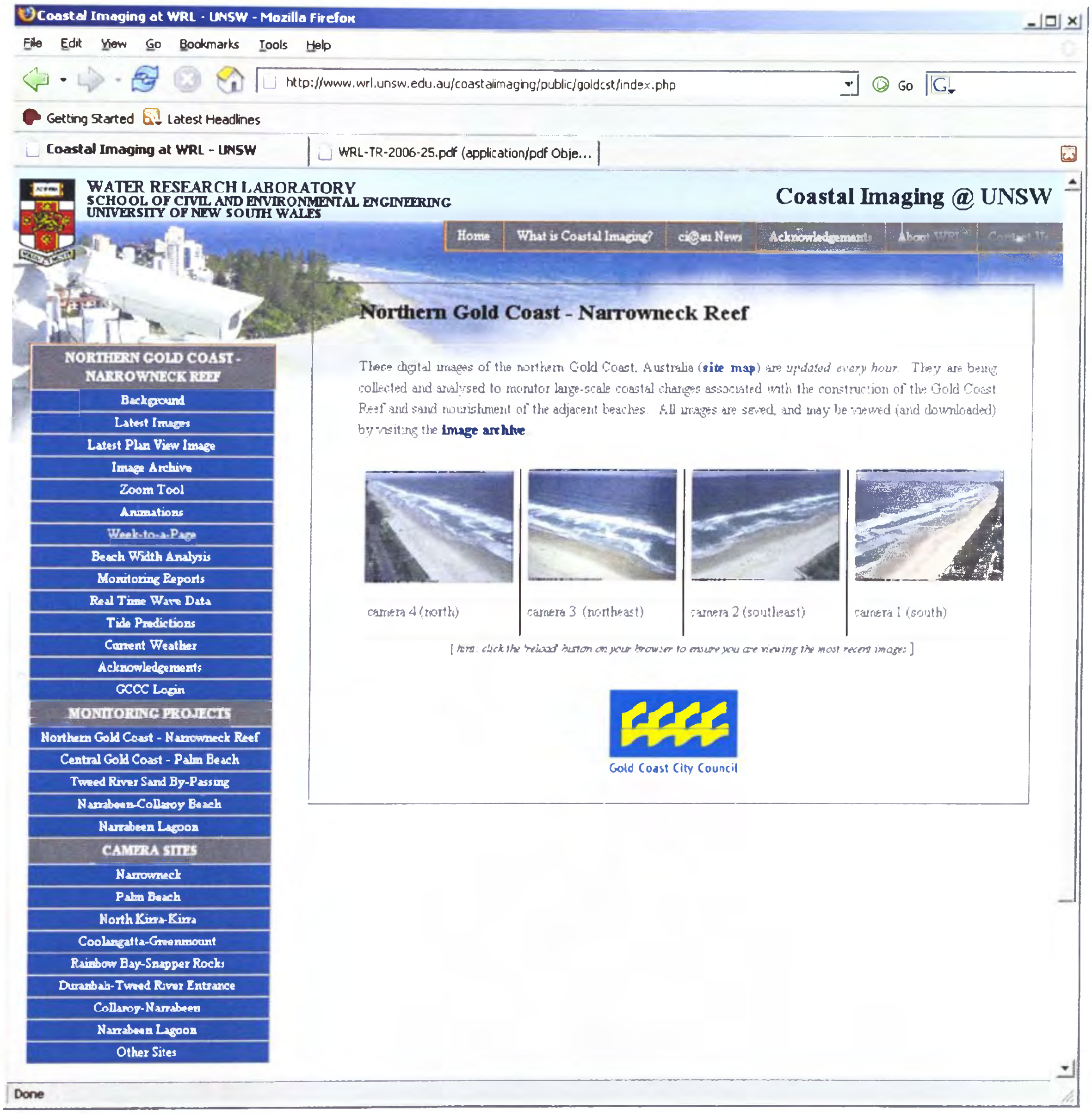
4.3 On-Line 'Beach Analysis System'

Since 2003, on-line access to 'real time' beach monitoring analysis and information (similar to that provided every six months in these NGCBPS reports) has been made available at the northern Gold Coast 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 Council and the interested general public on a routine basis, via the world wide web.

A detailed description of the capabilities of this system is available 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.

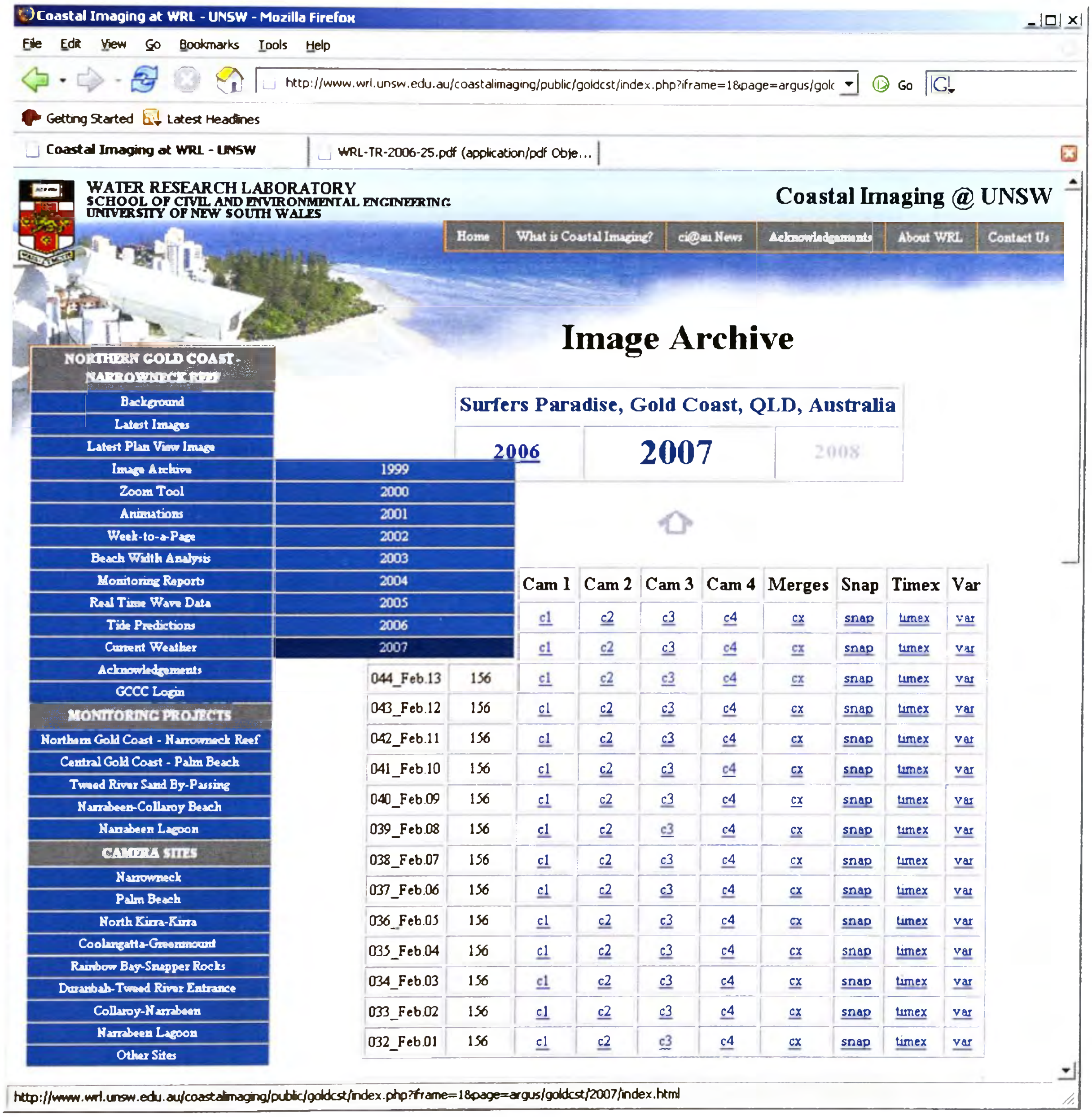
An example of the first of these products called 'week-to-a-page' is illustrated in Figure 4.3. Every Monday morning, this figure is generated and made available for viewing (and download if required) via the project web site. The figure is pre-formatted to fit on a standard A4 page, to assist reporting. This figure compiles daily mean sea level plan view images of the entire northern Gold Coast study site for that week, into a compact one-page summary. A recent addition to the 'week-to-a-page' summary product is a plot showing the tide and wave statistics for the week, allowing the impacts of changes in wave climate to the beach morphodynamics to be more easily assessed. 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-defmed monitoring transects; and beach width trends throughout the history of the monitoring project.



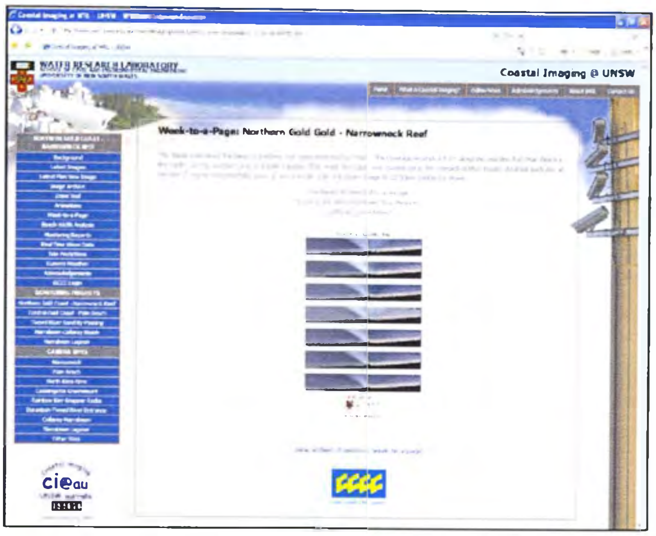
COASTAL IMAGING WEB SITE - HOME PAGE

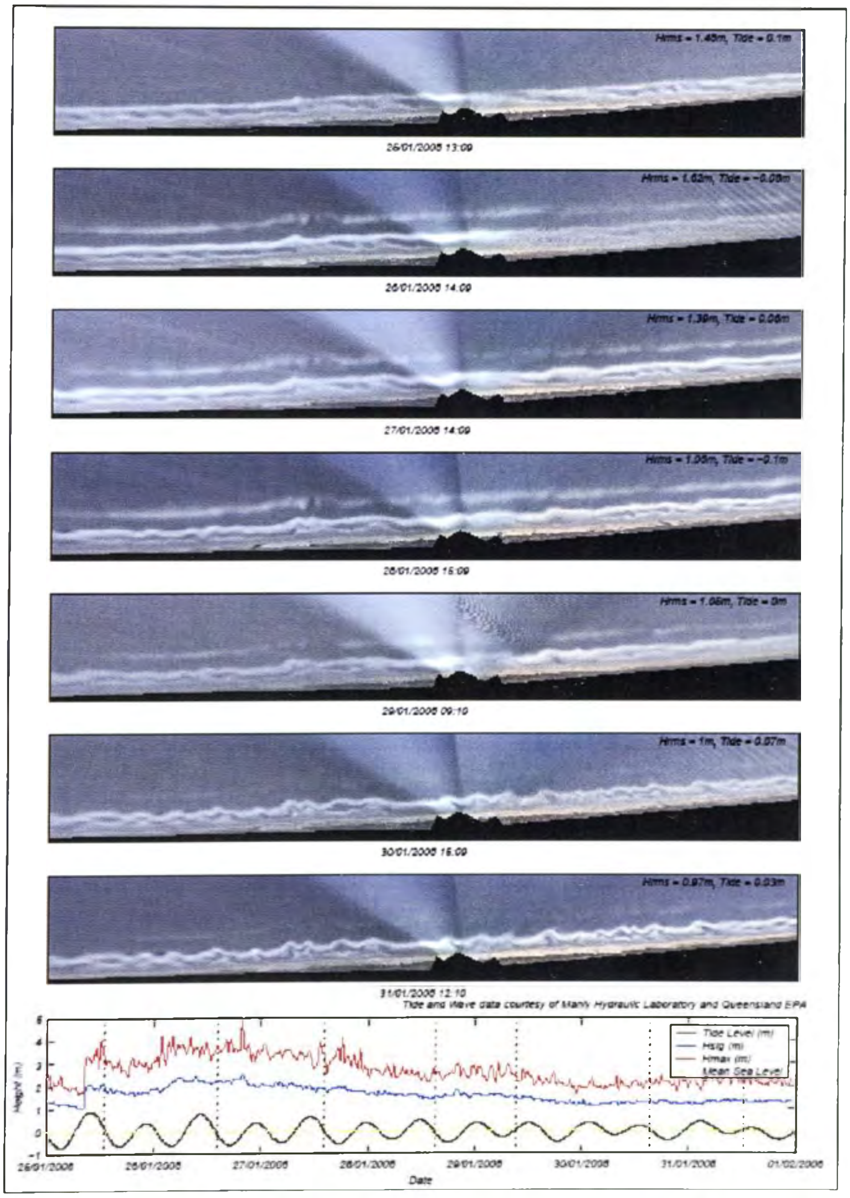
Figure 4.1



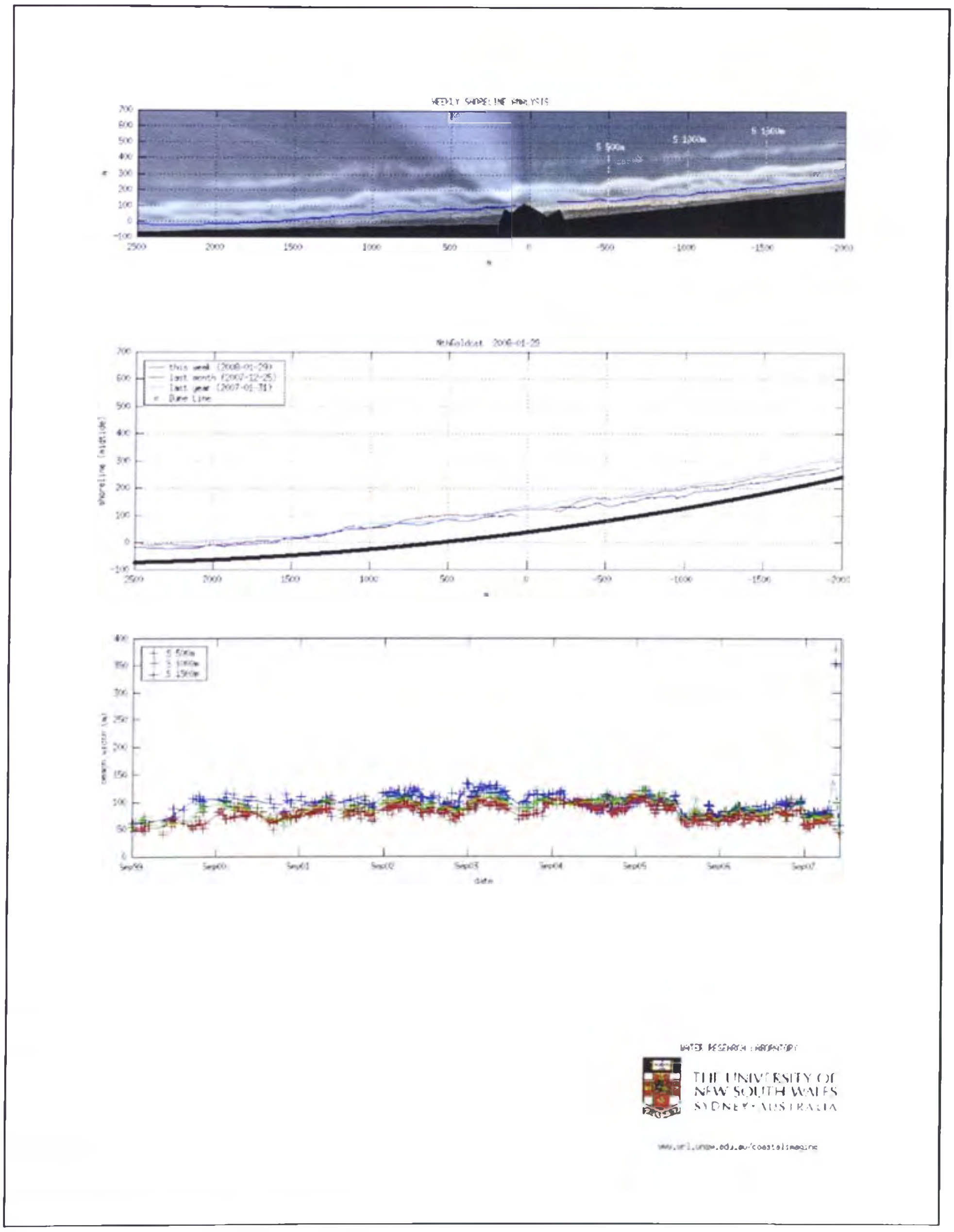
COASTAL IMAGING SYSTEM WEB SITE - IMAGE ARCHIVE

Figure 4.2





WRL Report No. 2008/06	ON-LINE BEACH ANALYSIS SYSTEM - 'WEEK-TO-A-PAGE'	Figure 4.3



WRL Report No. 2008/06	ON-LINE BEACH ANALYSIS SYSTEM - 'BEACH WIDTH ANALYSIS'	Figure 4.4 06037-4-4.cdr

5. MORPHODYNAMIC DESCRIPTION OF THE GOLD COAST BEACHES: AUGUST 2007 – JANUARY 2008

From the daily images obtained by the ARGUS coastal imaging station atop the Focus building, it is self-evident that the beaches of the northern Gold Coast are 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 and beach nourishment. As in previous reports, this section is included to provide a qualitative description of the observed beach changes during the present six-month monitoring period August 2007 to January 2008. The 'week-to-a-page' summary figures that are updated every week and made publicly available for inspection and download via the project web site, are used in this section to illustrate the observed beach changes. The objective is not to describe every characteristic of the northern Gold Coast beaches during this period, but rather the aim is to 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 was used in all previous NGCBPS coastal imaging reports, and will continue to be used in future reports to enable inter-comparison as the monitoring program continues.

5.1 A Morphodynamic Classification of Beaches

Despite the seemingly endless range of changes observed at any sandy coastline, 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 planform 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 week-to-a-page figures for the period August 2007 to January 2008 are presented in Appendix A. Each of these figures shows a week (seven days) of sequential mid-tide plan images, with the date of each indicated. All images are obtained at approximately the same stage of the tide (mean sea level), to enable the direct comparison between different days and weeks. The region shown in these figures extends 4,500 m alongshore, from approximately 1,500 m north of the reef site at Narrowneck, to 3,000 m south of the reef along the Surfers Paradise Esplanade.

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. While generally both buoys will measure similar wave conditions, the Gold Coast buoy measures wave heights after wave shoaling and refraction has occurred, as it is located in significantly shallower water.

5.2.1 August 2007

Following the two storm events experienced in mid and late July, the surfzone appeared relatively uniform and two-dimensional along the entire monitored section of beach at the start of August. The morphology of the beach was typical of a LBT system, with waves breaking across the outer shore parallel bar, then reforming through the nearshore gutter, before finally breaking on the beachface. Low energy wave conditions were experienced throughout the first half of the month, with the significant wave height dropping from 1.5 m during the first week down to 1 m during the second week. On the 19th August the significant wave height increased quickly to 2 m with the onset of a storm, and continued to increase steadily throughout the following two days, peaking at over 3 m. The significant wave height remained at approximately 3 m to 3.5 m until the 25th, before steadily declining to 1 m by the end of the month.

During the mild wave conditions experienced at the start of August, the detached offshore bar became relatively inactive. By the middle of the month the longshore bar can be seen to have become less consistent along the beach, with undulations in the bar clearly evident on the 16th and 17th. The onset of the higher energy wave conditions on the 19th saw wave breaking across the detached bar intensify, as the surfzone morphology again shifted toward a LBT state. While some protection for the beachface was provided by the offshore bar, erosion still occurred during the last week of August. Wave breaking over the Narrowneck reef was clearly evident during these larger wave conditions. The lull in wave energy at the end of August saw the detached offshore bar again become inactive, while a series of cross shore rips and troughs developed through the nearshore surfzone.

5.2.2 September 2007

Higher wave conditions were again experienced during the first half of September, with the significant wave height increasing to 2 m on the 5th, and peaking in excess of 3 m on the 7th. During this time a wide double bar system was established (see image collected on 11th September), with strong wave breaking evident across the outer detached longshore bar, as well as a wide nearshore surfzone. Between the two bars as well as between the inner bar and beachface there were clear longshore troughs.

The significant wave height dropped to approximately 1 m from the 12th to the 24th September, during which time a series of transverse rips through the nearshore bar again dominated the surfzone. The surfzone increased in width, and the rips migrated to a more longshore direction during the slight increase in wave energy from the 24th to the 26th, before becoming almost non existent at the end of the month.

5.2.3 October 2007

The month of October saw relatively mild wave conditions for the northern Gold Coast beaches, with the significant wave height typically of the order of 1 m, peaking to 2 m on occasions. Throughout the first and second weeks of October the surfzone was very narrow, with the beach responding to the low wave energy, and shifting toward a TBR state. The mid tide images captured during this period clearly show the complex cross shore rip and bar formations typical of lower energy intermediate beach states.

Slight increases in wave height on the 13th, 14th, and 17th October resulted in very mild wave breaking over the otherwise inactive offshore bar. Generally the lower ongoing wave energy throughout the last half of the month saw sand migrate towards the beachface, and the surfzone shift towards a very low energy state. By the end of the month the rips that were evident during the preceding days had reduced in intensity and frequency along the beach.

5.2.4 November 2007

The surfzone morphodynamics during the month of November were dominated by a one week period of higher wave energy from the 5th to the 12th, during which the significant wave height was typically 2 m to 2.5 m. Throughout the remainder of the month the significant wave height fluctuated between 0.8 m to 1.5 m.

The low energy surfzone morphology which developed during October continued for the first five days of November, with very minor wave breaking across a detached offshore bar, and a nearshore surfzone dictated by transverse rips. With the onset of higher wave energy conditions during the second week of November, the intensity of wave breaking across the outer detached offshore bar became more apparent as the beach shifted toward a higher energy intermediate state. The initial beach response showed characteristics of both RBB and TBR states, with the offshore bar having clear undulations along the beach and being separated from the beach by a relatively continuous longshore trough. Nearer to the beachface many intense rips developed and extended into the longshore trough.

With the milder wave conditions experienced throughout the last half of November, the offshore bar became irregular, as sand migrated toward the beach. At the end of the month the surfzone of the southern half of the beach had a very irregular but still detached longshore bar, separated from the beach by a longshore trough, and very few obvious rip currents in the nearshore zone. North of Narrowneck the offshore bar had migrated much closer to shore in some locations, such that the morphology of the entire surfzone was more typical of a TBR state, with no clear outer bar or longshore trough evident.

5.2.5 December 2007

Wave conditions were relatively mild for the first twelve days of December with the significant wave height ranging from 1 m to 1.5 m. Between the 12th and 16th of December the first of several storms impacted the Gold Coast, with significant wave height peaking at approximately 3 m, before again receding down to 1 m. Late in December a tropical low pressure system developed off the Queensland Whitsundays Coast. By the 2nd of January the low pressure system had intensified to a central pressure of 996 hPa and had migrated south, to be off the coast of Gladstone. The low pressure system was off the Sunshine Coast by the 4th of January, and continued to track south throughout the following days. The effect of the low pressure system was a rapid increase in wave height at the Gold Coast from the 28th to the 31st of December, with the significant wave height peaking at 5 m. The elevated wave heights continued in excess of 4 m before peaking again on the 4th of January at just over 5 m, then receding through until the 8th of January. The storm produced winds with gust speeds predicted to be 90 km/h as well as heavy rainfall.

During the first half of December the beach continued in an intermediate morphodynamic state with TBR conditions north of the ARGUS station, and RBB conditions further south. With the onset of slightly larger wave conditions on the 13th, there was little change to the surfzone morphology over the southern stretch of beach, while to the north, sand was shifted from the nearshore bar system to form a wider surf zone. During the lower wave energy conditions from the 16th to the 26th there was very little observable change to the surfzone morphology.

Leading up to the heavy storm conditions late in December, large tides impacted the Gold Coast beaches, resulting in minor scarping in localised areas. With the onset of the large storm waves on the 28th as a result of the developing low pressure system, the surfzone was seen to rapidly approach a higher energy state, increasing significantly in width.

5.2.6 January 2008

As discussed in Section 5.2.5, the deep tropical low pressure system which developed late in December and passed south down the coast during the first week of January produced large wave conditions with significant wave height ranging from 4 m to 5 m. These extreme wave heights dropped by the 8th of January, with the significant wave height fluctuating between 1 m and 2 m for the remainder of the month.

During the peak of the storm in early January images from cameras 2 and 3 became scrambled with images from another station. Images captured by the remainder of the cameras showed that the beach continued to migrate into a high energy dissipative state during the first week of January, becoming two dimensional over the entire mapped length. An extremely wide surf zone developed with a system of two detached longshore bars. Image data from all cameras was restored on the 11th of January, following the peak of the storm event.

Following the peak of the storm wave conditions, the outer detached longshore bar became inactive, while the inner longshore bar developed undulations, as sand again began to migrate back toward the beach. Images captured on the 11th of January show that the storm experienced during the preceding weeks had the effect of making the beach appear significantly more uniform along its length by generating relatively two-dimensional surfzone morphology. The 1 m to 2 m significant wave height conditions throughout the last half of December saw minor wave dissipation across the outer detached longshore bar, while the inner bar progressed into a lower energy state with many complex cross shore bars and rips developing as sand migrated back to the beachface.

5.3 Visual Assessment of Beach Width Changes (August 2007 – January 2008)

The morphology of the northern Gold Coast beaches from August to November was dictated be episodes of high wave energy which occurred at least once every month and lasted of the order of five days. During these times of higher wave energy, the significant wave height typically peaked at 2.5 to 3.5 m, and resulted in wave breaking across a detached offshore bar, with the beach showing characteristics typical of LBT or RBB beach states. Between the episodes of high wave energy, ambient wave conditions with significant wave height of 0.7 m to 1.5 m and peak spectral wave period of 8 to 10 seconds impacted the coastline, and the beaches responded with changes in nearshore morphology. Typically pockets of sand shifted into transverse bars, and many cross shore rips were seen along the beach, as the beach changed to a lower energy TBR state.

Late in December through to early January the effects of the tropical low pressure system impacted the Gold Coast beaches, with significant wave height peaking at 5 m, and remaining in excess of 4 m for six consecutive days. At the onset of these higher wave conditions, the beach rapidly migrated to a higher energy dissipative state, with a wide detached offshore bar as well as second detached bar nearer to shore. The nearshore bar formed through erosion of sand from the beachface, and resulted in a general flattening of the surfzone. The monthly bursts of higher wave energy from August to November, as well as the extreme storm event in December and January resulted in a net narrowing of the northern Gold Coast beaches during the present monitoring period.

A qualitative visual assessment of the net regional trends in beach adjustment during this period can be seen by contrasting images of the beach obtained at the start and end of the present six month monitoring period. Figure 5.2 shows the snap images obtained at mid-tide from Camera 1 (south) on 01/08/07 and 31/01/08, respectively. The corresponding snap images of the northern beaches obtained from Camera 4 are shown in Figure 5.3. Both south and north of the ARGUS station, extensive narrowing of the beach is evident from Figures 5.2 and 5.3. A wide flat surfzone and submerged bar can also be clearly seen in Figure 5.3 at the end of January 2008, as a result of the heavy storm conditions experienced throughout the previous month.

5.4 Visual Assessment of Total Beach Width Changes (August 1999 – January 2008)

The visible beach changes to date since the commencement of the NGCBPS coastal imaging monitoring program eight and a half years ago are seen in Figure 5.4 and Figure

5.5. In these figures mid-tide timex images of the beach to the south and north are shown at six-monthly intervals for the entire monitoring period August 1999 to January 2008.

During the first six months (August 1999 to January 2000) the on-going nourishment of the northern beach is visible, with no change to the southern beach as this area was yet to be nourished at that time. A dramatic change in the width of the beach occurred between January 2000 and August 2000, when nourishment of the entire stretch of coastline from Narrowneck to Cavill Avenue was completed, with the result that the mid-tide beach can be seen to have nearly doubled in width during this period.

During the next six months to January 2001 the beach alignment became more uniform alongshore, as the coastline re-adjusted to the new sand volume available within the beach system.

The following six-month period of February 2001 – July 2001 saw a general erosional trend along the northern Gold Coast beaches in response to a succession of storms. This contrasted to the following six months (August 2001 to January 2002) during which the beaches recovered, returning to a similar state as was seen 12 months previously in January 2001. As was first noted in a previous six-monthly report (Turner, 2002), a return to prior conditions following a period of storm erosion suggested that the beaches of the northern Gold Coast at that time were close to regaining a new equilibrium, post the extensive sand nourishment works completed in mid 2000.

From January 2002 – August 2002 the beaches of the northern Gold Coast were moderately depleted, with the beaches at the end of this period intermediate to the eroded state that prevailed in August 2001, and the most accreted state that was recorded at the end of January 2002. By January 2003 the beaches had returned to their more accreted state, similar to beach conditions observed 24 and 12 months previously in January 2001 and January 2002.

During February 2003 to August 2003, the beaches again experienced a period of modest erosion. Both to the north and south, the beach at the beginning of August 2003 appeared very similar to the conditions that prevailed 12 months previously in August 2002. Moderately depleted conditions prevailed, that were intermediate to the more accreted states observed in January 2002 and January 2003, and the more eroded state that prevailed two years previously in August 2001. From this now recurring pattern, it was concluded at that time (Turner, 2003b) that the beaches of the northern Gold Coast were fully adjusted to the sand nourishment that was placed three years previously, and the morphodynamic changes that were being observed were predominantly the result of seasonal variation in the frequency of storm events.

From August 2003 to January 2004 minimal storm wave activity was observed, and the beaches of the Northern Gold Coast generally accreted. During February 2004 to July 2004 large wave events occurred in March, and the beaches were observed to be cut back during that time. However, by the end of July 2004, both the northern and southern beaches had recovered. From August 2004 to January 2005, storms in October 2004 and again in January 2005 caused a general movement of sand offshore, with the visible width of the subaerial beach decreasing during this time, and the widening of the surf zone as the outer bar translated further seaward.

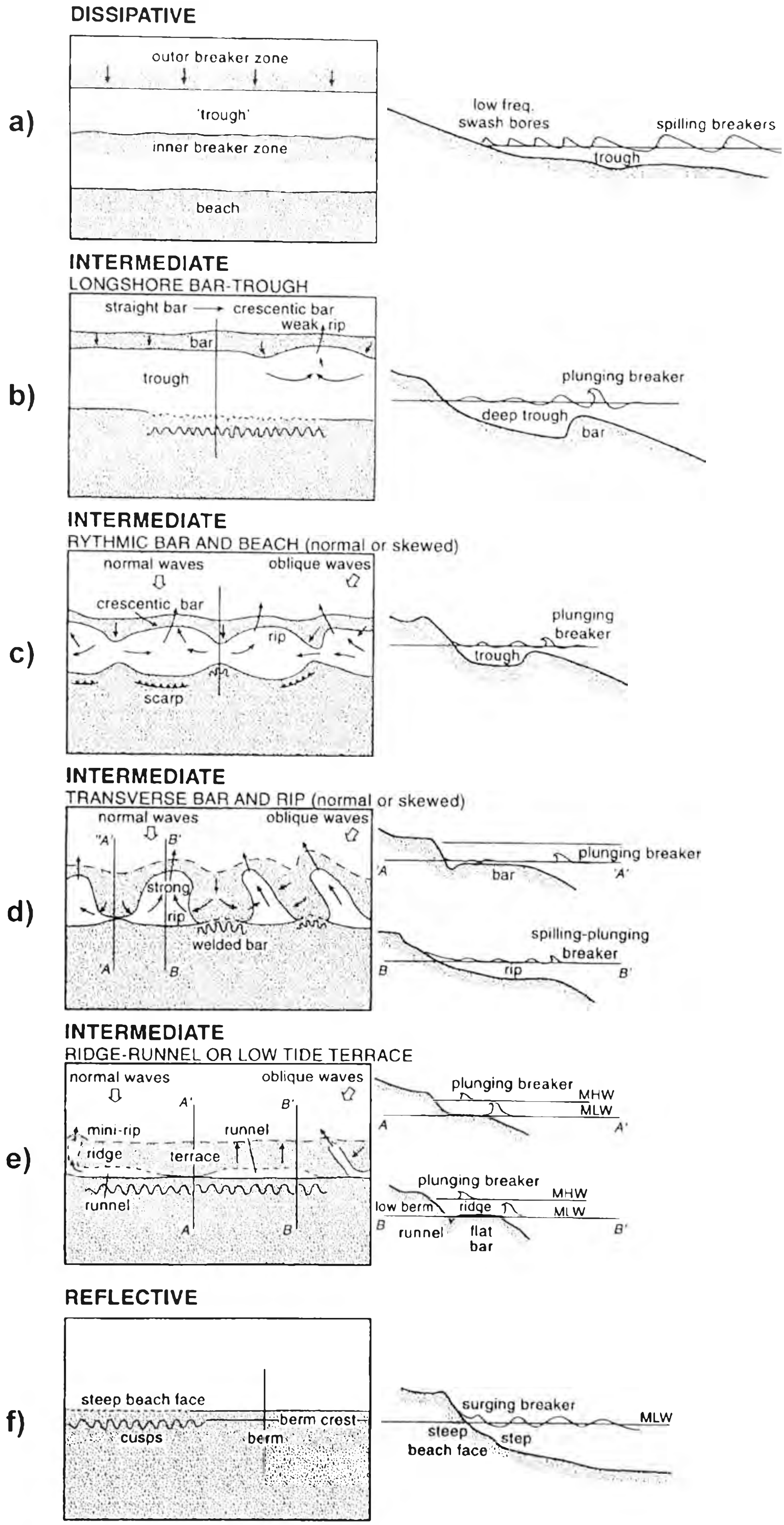
During February 2005 to July 2005 both the northern and southern beaches exhibited similar beach width and shoreline alignment, with the exception of the region in the immediate vicinity of Narrowneck, where a modest trend of net beach widening was discernable. From August 2005 to January 2006, along the southern beach no net change in the visible (subaerial) beach was discernable, with similar conditions also observed along the northern beach. The exception to this observation of similar conditions was along the northern beach north of Narrowneck, where a general straightening of the beach within this region was observed.

During the period from February 2006 to July 2006 a subtle trend of a narrower beach was observed to the south, with a more pronounced decrease in beach width to the north of Narrowneck. In contrast, in the vicinity of the reef site at Narrowneck the visible beach was similar at the beginning and end of this six month period. From August 2006 to January 2007, the wave climate was predominantly moderate to low, with very few storm wave occurrences. This resulted in a general widening in both the northern and southern beaches. The beach width and alignment at the end of January 2007 was comparable to that at the end of January 2006, with the beaches recovering from the higher energy period observed in the early parts of 2006.

In the monitoring period February to July 2007, there was very little net change in beach width both south and north of the ARGUS station. Generally there was slight accretion of the beach from February to May, followed by erosion caused by several long wave period swell events during June and July. The section of beach between the ARGUS station and the reef at Narrowneck appeared to widen between February and July 2007.

During the current monitoring period August 2007 to January 2008, the beach morphology was dictated by a series of smaller storm events from August to November, followed by a large storm event in late December and January. The ongoing effects of the smaller storms throughout the earlier months of the current monitoring period, as well as the rapid changes in beach morphology experienced during the December and January storm, resulted in a much narrower beach at the end of the current monitoring period.

A more quantitative assessment of the response of the northern Gold Coast beaches for the period August 2007 to January 2008 is detailed in Section 6.



WRL

Report No. 2008/06

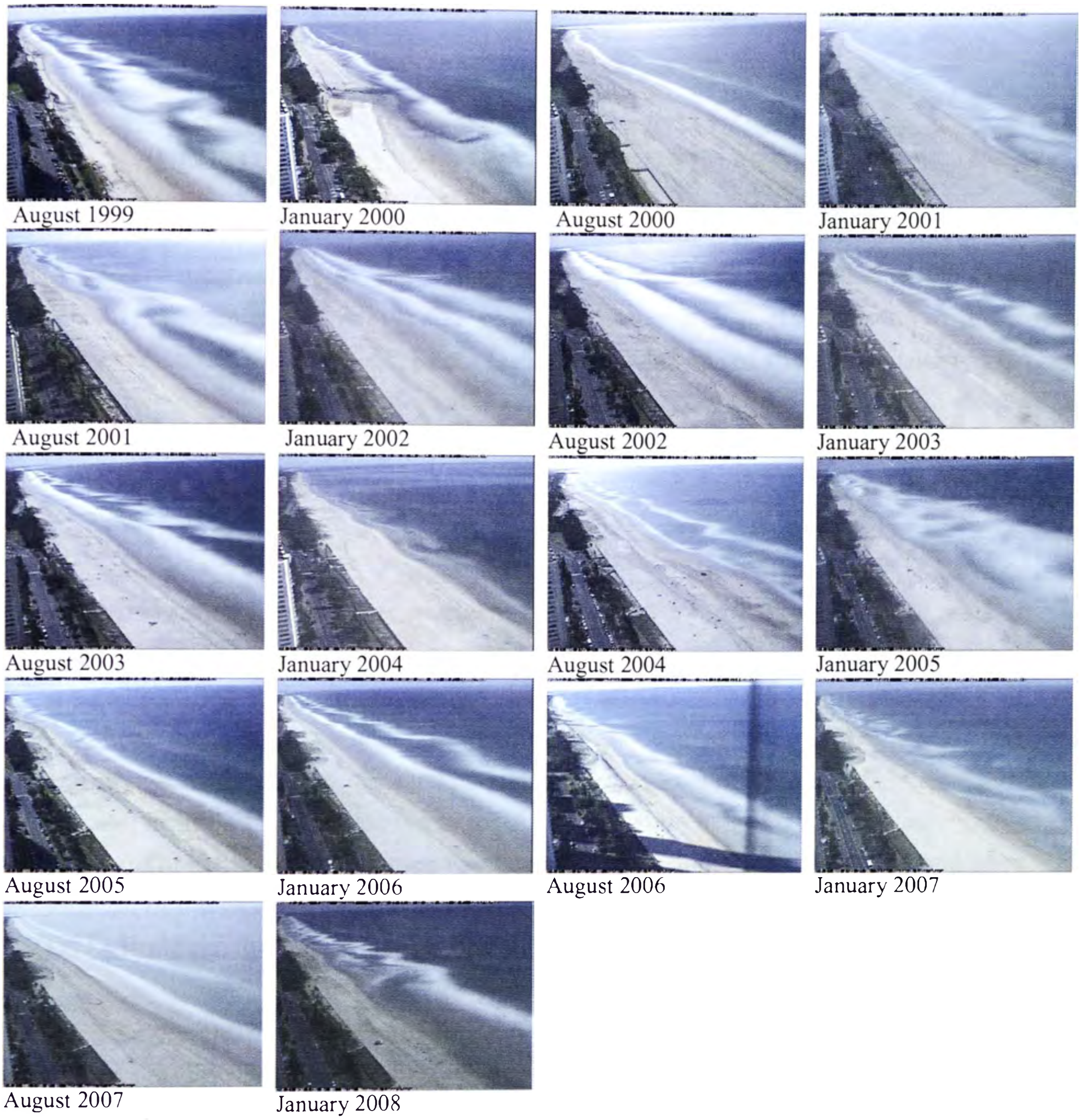
MORPHODYNAMIC BEACH STATE MODEL (after WRIGHT and SHORT, 1983)

Figure 5.1

WRL Report No. 2008/06	SNAP IMAGES FROM CAMERA 1 (SOUTH): 01/08/2007 AND 31/01/2008	Figure 5.2

WRL Report No. 2008/06	SNAP IMAGES FROM CAMERA 4 (NORTH): 01/08/2007 AND 31/01/2008	Figure 5.3

WRL Report No. 2008/06	SIX-MONTHLY BEACH CHANGES (CAMERA 1-SOUTH): AUGUST 1999 – JANUARY 2008	Figure 5.4



SIX-MONTHLY BEACH CHANGES (CAMERA 4-NORTH): AUGUST 1999-JANUARY 2008

Figure 5.5

6. QUANTITATIVE ANALYSIS OF SIX-MONTH SHORELINE CHANGES: AUGUST 2007 – JANUARY 2008

A primary function of the coastal imaging system installed at the northern Gold Coast is to quantify shoreline variability and changes during and post beach nourishment and construction of the Gold Coast Reef. Quantitative analysis of shoreline position and beach width provides an objective measure to assess the success of the NGCBPS in meeting the aims of enhanced beach amenity and the increased availability of an adequate storm buffer.

6.1 Weekly Shorelines

All weekly shorelines that are available for the period 01/08/07 to 31/01/08 are shown in Figure 6.1. For reference, these measured shorelines are overlaid onto a representative merged/rectified timex image (image date: 31/01/08). The image represents a 4,500 m length of the beach, extending approximately 3,000 m to the south of Narrowneck and approximately 1,500 m to the north. The Gold Coast Reef at Narrowneck is centred around x = 900 m in this image (relative to the ARGUS station centered at coordinate [0,0]). The landward dune reference line used to calculate beach width is also indicated (red line). The location of the cameras can be identified by the region of beach immediately in front of the Focus Building, that is outside (i.e. in front of, and below) the cameras' fields of view.

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 dune reference line. The distance of these shorelines from the dune reference line 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 Figure 6.1 is shown for reference.

Note that, due to sun glint off the surface of the ocean in cameras 2 and 3, the mapped shorelines between approximately -100 m and 500 m alongshore are regarded as lower accuracy, and are therefore excluded from the following discussion and analysis.

During the present monitoring period 01/08/07–31/01/08 it can be seen from Figure 6.2 that the beach along the 4,500 m study region varied in width (relative to the dune reference line) from approximately 40 m to 115 m. The envelope of beach width changes is most extensive south of the ARGUS station and north of Narrowneck, varying by 50 m to 60 m during this period.

It is important to note here that, although it may appear that the beach alignment widens in the centre of the 4,500 m study region, in fact this is not the case, but rather the wider beach in this central region is due to the curvature of the dune reference line used to calculate beach width. In reality, the position of this reference line is somewhat arbitrary, and was selected so as to generally indicate the seaward edge of the vegetated dune between the beach and The Esplanade.

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

The alongshore variability of the measured shoreline positions during the monitoring period 01/08/07 – 31/01/08 is further quantified in Figure 6.3. The upper panel of this figure shows a plot of the mean, maximum and minimum shoreline position at all locations alongshore. For reference, in the lower panel the mean shoreline position during this period is overlaid on to a merged/rectified timex image (image date: 31/01/2008) of the northern Gold Coast.

Referring to Figure 6.3, the median beach width at mid-tide (relative to the dune reference line) along the 4,500 m stretch of coastline during the period 01/08/07 – 31/01/08 was in the range of 65 – 95 m. As was discernible from Figure 6.2, relative to the dune reference line the mean beach width was greatest from approximately 500 m to 1000 m alongshore (to the north of the ARGUS station), with a width of approximately 95 m.

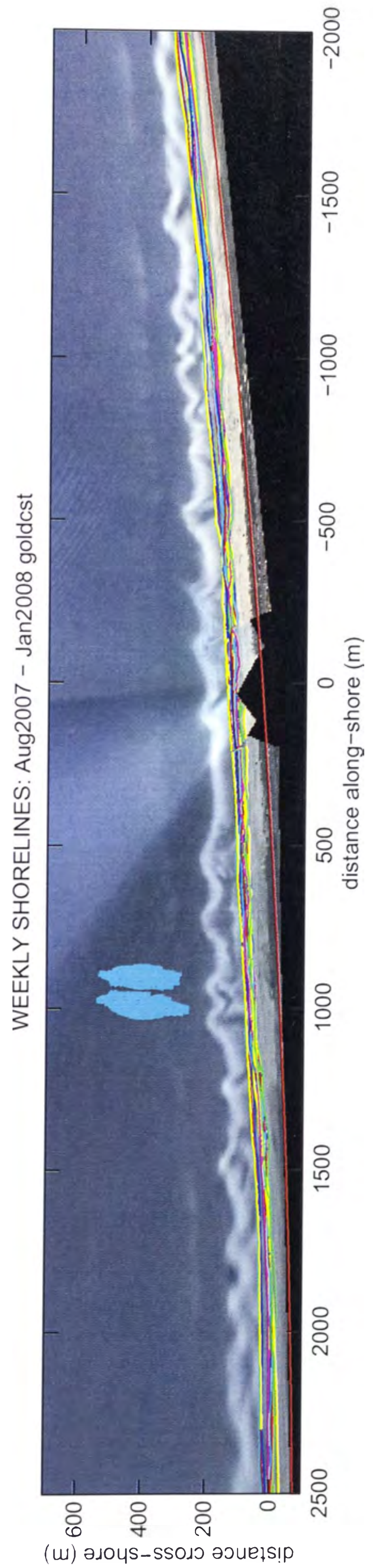
The analysis of maximum beach width (upper panel, Figure 6.3) reveals a relatively uniform maximum beach width of 30 m to 40 m wider than the median shoreline position, along the 4,500 m study area. However, minimum beach width was less uniform, with the beach being significantly wider in the lee of the Narrowneck reef, compared with stretches of beach further to the south and north. Both north and south of the Narrowneck reef, the minimum beach width generally deviated from the mean by approximately 25 m, while in the lee of the reef, the minimum beach width was only 10 m narrower than the median shoreline position.

The middle panel of Figure 6.3 shows the standard deviation of weekly shorelines from the mean shoreline position during the period 01/08/07 – 31/01/08. The standard deviation of weekly shorelines varied along the length of the beach, being relatively regular with high variability to the north of the Narrowneck reef and south of the ARGUS station, but a significantly lower standard deviation between the ARGUS station and Narrowneck. The minimum standard deviation was of the order of 7 m, while the maximum was approximately 15 m.

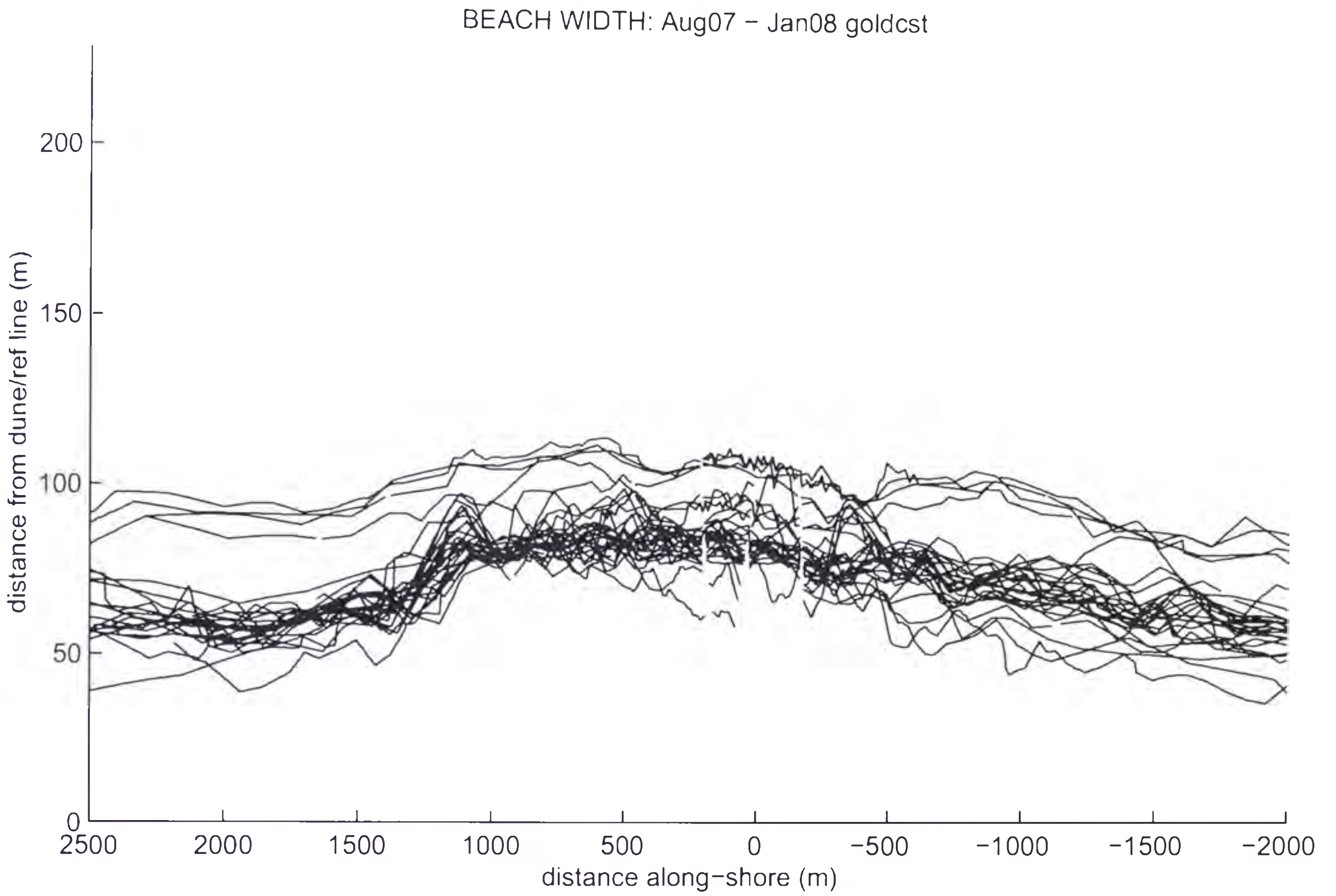
6.3 Weekly Shorelines (August 2007 – January 2008) Relative to Mean Shoreline Position of Previous Monitoring Period (February– July 2007)

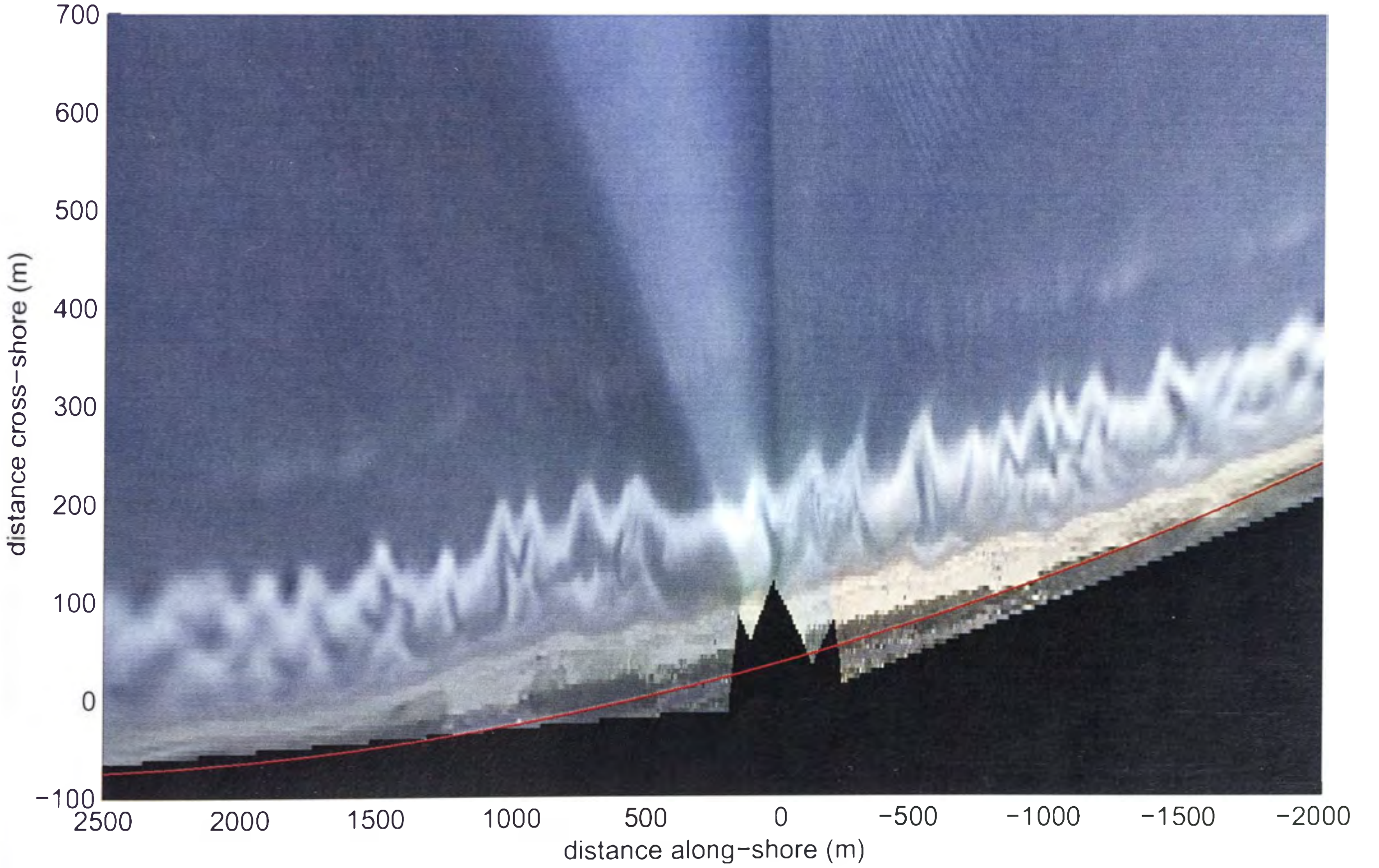
To remove the effect of the arbitrary dune reference line appearing to indicate a change in beach alignment in the centre of the 4,500 m study region, in Figure 6.4 weekly shorelines for the period 01/08/07–31/01/08 have been re-analysed and plotted relative to the mean shoreline position calculated for the previous six month monitoring period February – July 2007 (refer Blacka *et al.*, 2007b). In the upper panel the deviation of weekly shorelines from this earlier mean shoreline is plotted. In the lower panel the mean shoreline position for the previous monitoring period February – July 2007 is shown, along with the mean shoreline calculated for the present monitoring period.

Figure 6.4 top panel shows that during the present monitoring period the beaches of the northern Gold Coast were predominantly narrower than the previous monitoring period. The maximum beach width from August 2007 to January 2008 was approximately 20 m wider than the median beach width from the preceding six month monitoring period, however, the minimum beach width was approximately 40 m narrower. It can be seen from Figure 6.4 bottom panel that the median beach width was significantly wider during the previous monitoring period compared to the current monitoring period for the entire stretch of mapped beach.

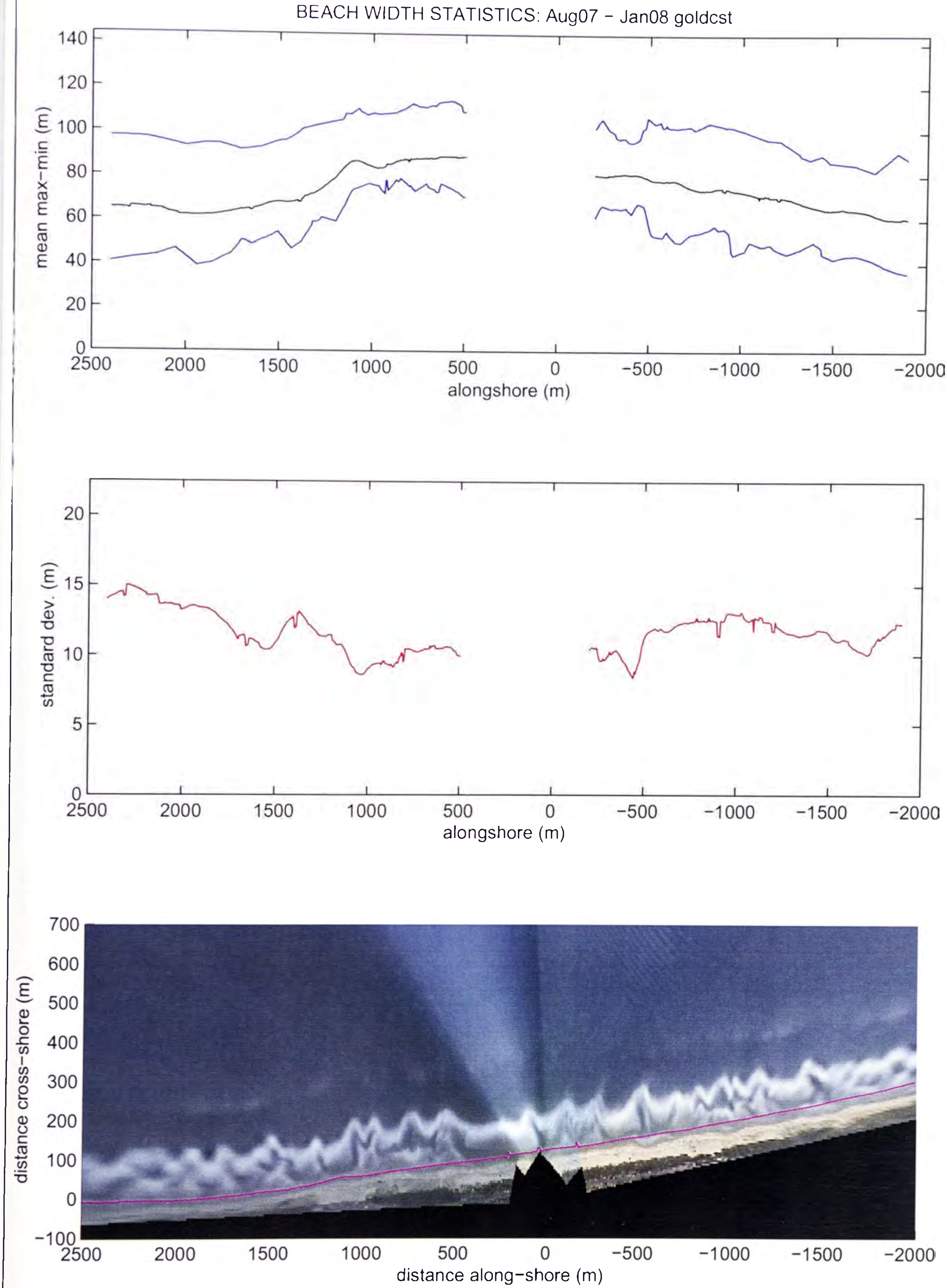


WRL Report No.2008/06	WEEKLY SHORELINES: AUGUST 2007 - JANUARY 2008	Figure 6.1

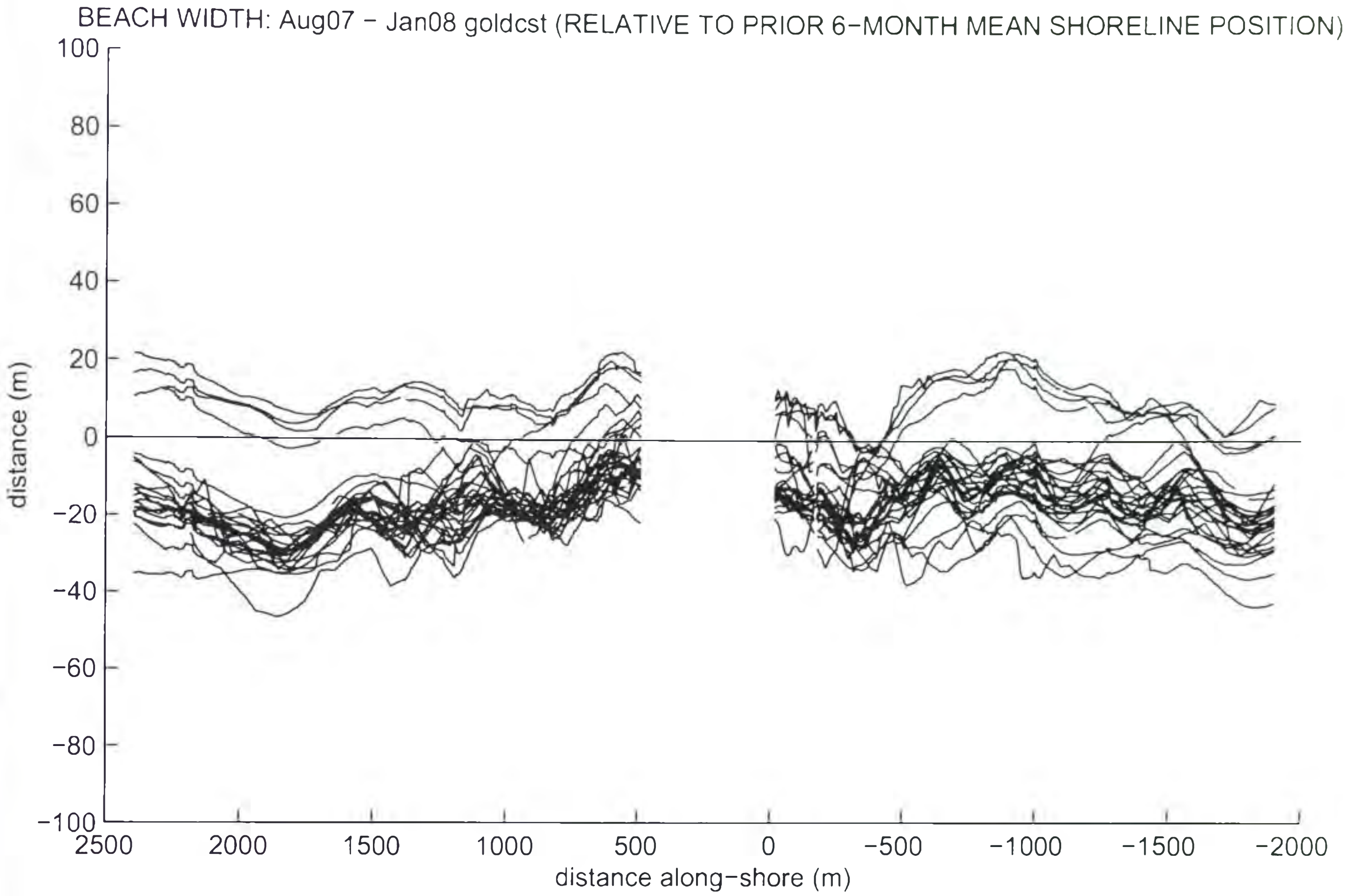


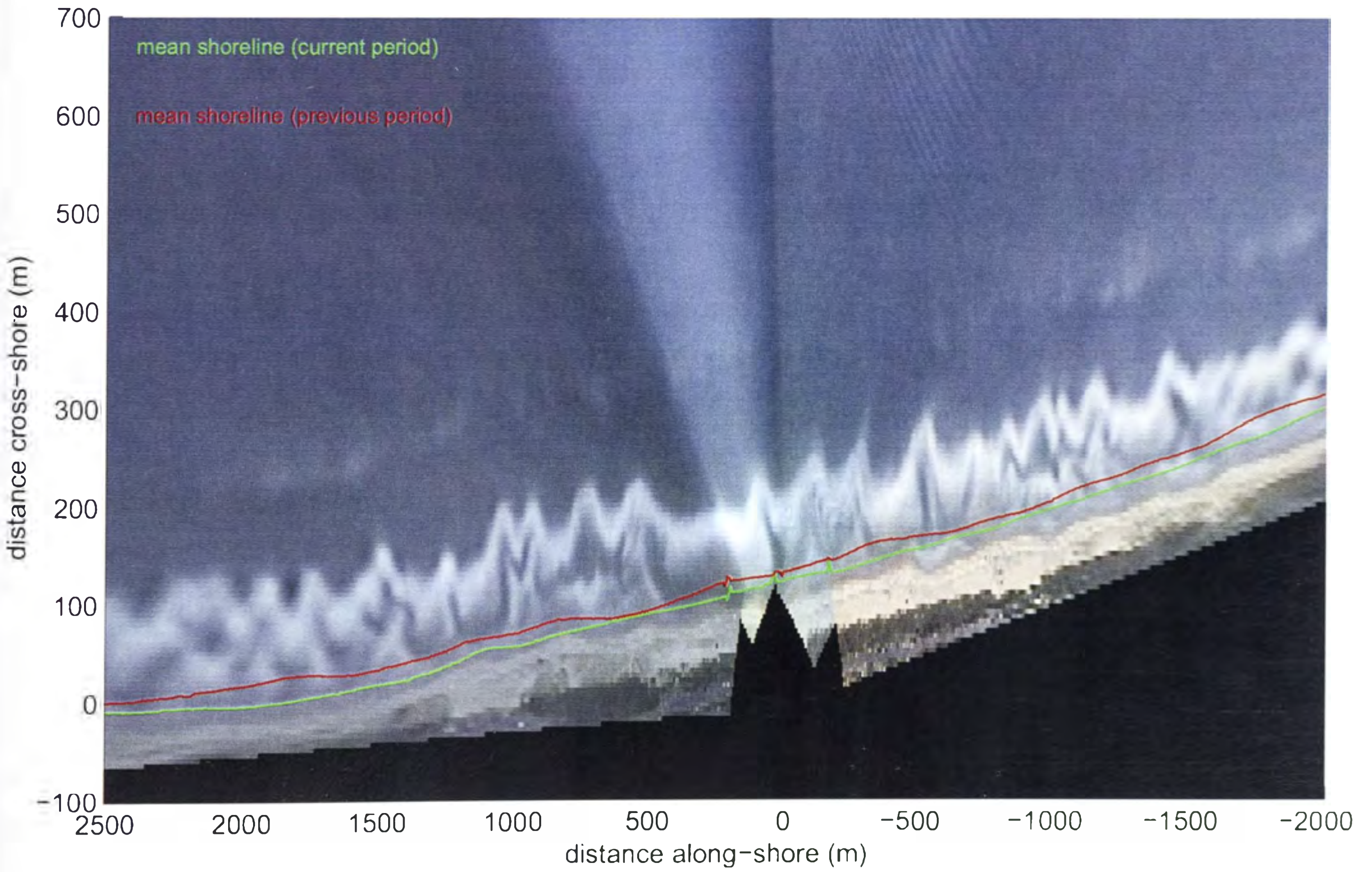


WRL Report No.2008/06	WEEKLY BEACH WIDTH: AUGUST 2007 – JANUARY 2008	Figure 6.2



WRL Report No.2008/06	STATISTICAL SUMMARY OF BEACH WIDTH CHANGES: AUGUST 2007 - JANUARY 2008	Figure 6.3





WRL Report No.2088/06	WEEKLY BEACH WIDTH CHANGES AUGUST 2007 - JANUARY 2008 RELATIVE TO PRIOR SIX-MONTH MEAN SHORELINE POSITION	Figure 6.4

7. QUANTITATIVE ANALYSIS OF SHORELINE VARIABILITY, SEASONALITY AND LONGER-TERM EROSION/ACCRETION TRENDS: AUGUST 1999 – JANUARY 2008

The completion of a total of eight and a half years of monitoring at the northern Gold Coast beaches provides the opportunity to summarise and analyse longer-term shoreline changes observed to date. With sand nourishment completed in mid 2000, and significant erosion-recovery of the beach observed during the twelve months that followed in 2001, since that time it is now apparent that the new equilibrium alignment of the northern Gold Coast coastline has developed, upon which cyclic-seasonal beach changes and longer-term erosion/accretion trends can be observed and quantified.

7.1 Weekly Shorelines and Shoreline Variability: August 1999 – January 2007

All weekly shorelines for the 440 week period August 1999 to January 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: 31 January 2008). Again, due to sun glint these data between –100 m and 500 m alongshore are less reliable, and are excluded from the following analysis and discussion. Over the entire 102 month monitoring period mid-tide beach width (relative to the dune reference line) along the full 4,500 m study region can be seen to have varied in the order of 100 m. Beach width changes of typically up to 50 m have been recorded at all positions alongshore, which highlights the highly dynamic nature of the beaches of the northern Gold Coast.

The variations in shoreline position measured at eight representative survey transects alongshore for the entire eight and a half year period August 1999–January 2008 are shown in Figures 7.2 and 7.3. Figure 7.2 plots the weekly shoreline position at transects spaced at regular 500 m intervals north of the camera location, and Figure 7.3 plots the weekly shoreline position at transects spaced at 500 m intervals south of the cameras. The alongshore position of each of these representative beach transects is shown in the accompanying merged/rectified image (image date: 31/01/2008).

A general trend of increasing beach width is apparent along both the northern and southern beaches during the initial 18 months of monitoring. The rapid growth of the beach at each of the nourishment areas (refer Figure 2.5) can be seen. As previously noted in preceding monitoring reports, the lag in beach response at each of these locations matches the progression southward of the beach nourishment program (see Figure 2.4). The effects of nourishment clearly dominate beach changes during the initial 18 month period.

During the period February – July 2001, a general erosion trend was evident. This six month period was characterised by a series of storms that resulted in the net recession of northern Gold Coast beaches. Examining this trend in more detail, Figures 7.2 and 7.3 show that the beaches eroded rapidly during the first months of 2001, followed by partial recovery, then eroded again towards the end of this six month period. The degree of recovery is variable, but at all locations alongshore, by the end of July 2001 the recovered beach width had again been lost.

This period of beach erosion was then followed during the 24 – 30 month period (August 2001 – January 2002) by a distinct trend of beach recovery at all locations. Most notably, by January 2002 Figures 7.2 and 7.3 show that the beach had recovered to the extent that beach widths were sufficiently regained to match the conditions that were measured 12 months previously in January 2001. At the central nourished regions of the beach it is concluded that the storms of early to mid 2001 resulted in the offshore movement of sediment, but that during the six month period that followed this, sand returned to the subaerial beach, rather than being lost from the beach system.

During the next six month monitoring period February 2002 to July 2002, in general a modest net erosional trend is seen in Figures 7.2 and 7.3. Erosion of the shoreline during February to April was then followed by a 1 – 2 month period of partial recovery, followed by stabilisation or minor erosion again up to the end of July. As a generalisation, the beach at the end of the 36 month period to July 2002 was intermediate between the initial (un-nourished) condition in August 1999, and the most accreted states as observed in January 2001 and January 2002.

From August 2002 to January 2003 the beach at all locations alongshore exhibited marked recovery, returning to and more typically exceeding (especially at the more southern transects) the accreted conditions that prevailed 12 and 24 months previously in January 2002 and January 2001. During the period February 2003 to July 2003 an erosional trend was again evident in Figures 7.2 and 7.3 for all transects alongshore. The beach receded, in response to the occurrence of a greater frequency of storm events during this time.

Net accretion at all locations alongshore was observed during the period August 2003 to January 2004. A very similar trend was measured at all locations. From August to December 2003 the beach accreted, this accretionary trend was interrupted once in late November when a brief period of higher wave activity caused the offshore bar to migrate seaward, and the inner bar to detach for a period of 1 – 2 weeks only from the shoreface. Following re-attachment of the inner bar, the beach continued to increase in width at all locations alongshore through to the beginning of January 2004, when two periods of higher waves caused the offshore movement of sand and detachment of the inner bar. From February 2004 to July 2004, two large storm events in March, followed by continued moderate wave activity in April, caused the beach at all locations to initially continue this erosion trend. However, by the end of July 2004 the beach had generally recovered to the conditions that prevailed at the end of January. The exception to this was in the region between Narrowneck and the cameras, where more limited recovery was observed.

This general accretionary trend initially continued during the period August 2004 to January 2005. However, due to a large storm wave event in the second half of October 2004, beach recession was then observed at all locations alongshore, being most pronounced in the north. Following a subsequent two month period of partial beach recovery, two more storms occurred in January 2005, resulting in further beach recession. In the northern region of the study area the beach had returned to the beach conditions that prevailed some 10 months prior following the major storms of March 2004. To the south, this cycle of accretion, erosion, partial recovery and subsequent erosion, was less pronounced.

From February 2005 to July 2005, the beaches of the northern Gold Coast initially accreted due to generally mild wave conditions, then receded again to the end of July 2005, following the occurrence of a series of moderate storm wave events. During the monitoring period of August 2005 to January 2006, the beaches oscillated around the same position, largely in response to the movement of the inner bar. As this feature initially became fully welded to the beachface, the beaches of the northern Gold Coast generally increased in width accordingly. As the mild wave conditions persisted through the second half of 2005, this resulted in the continued landward movement of a portion of the inner bar sand volume, resulting in a narrowing of the low tide terrace, and subsequent narrowing of the total beach width.

At the end of 2005, periods of slightly elevated wave energy caused the removal of this newly accreted sand from the beachface back to the low-tide terrace, causing re-widening of the beaches at this time. The partial separation of the inner bar from the beachface in response to a single storm wave event in January 2006 caused the beaches to narrow again. A major east coast low pressure weather system in early March 2006 caused the beaches of the northern Gold Coast to transition to a lower gradient and dissipative beach state, characterised by the removal of sand from the beachface and formation of a distinctive inner bar and outer storm bar system. A marked narrowing of the beach was observed at all locations alongshore. By May 2006 the inner bar had temporarily re-attached to the beachface to form a low tide terrace, but in June this detached again as the sand moved back into the inner surfzone, in response to a general increase in the incident wave energy. By the end of July 2006 the beach was continuing to recover from the significant erosion event of five months previous, as sand slowly moved back onshore.

During August and September of 2006, relatively consistent moderate wave conditions prevailed at the Gold Coast. During this time, the beach width fluctuated, and the double bar system established in March of 2006 was still evident for short durations during larger wave conditions. The beaches generally continued to increase in width throughout the last months of 2006, and by the end of the year, were almost completely recovered from the large east coast low pressure storm system which occurred in March. During this period, the beaches were predominantly in an intermediate state, fluctuating between RBB characteristics during moderate energy times, and transverse semi-attached bar systems during lower energy periods.

Ongoing moderate wave conditions with short duration periods of higher wave energy dominated the wave climate of the Northern Gold Coast beaches from January to March 2007. The higher wave energy events resulted in slight localised pockets of erosion of the beach during this time, however, the times of lower wave energy also saw sand accrete from the complex surfzone back to the beachface resulting in little net change in beach width both south and north of the ARGUS station. Lower wave conditions throughout late April and into May of 2007 forced the movement of sand from the surfzone to the beachface, forming a widening LTT. Long wave period storm events in June and again in July dictated the morphological changes during these months, again eroding material from the beachface as the beach shifted towards a higher energy intermediate state. This resulted in very little overall net change in beach width during the period February to July 2007.

Ongoing bursts of high wave energy every month between August and November 2008 resulted in the beaches generally being in an eroded state for most of the current monitoring period. A detached offshore bar was typically always present during these months, although at times of lower wave energy it became inactive. In the nearshore zone, sand was observed to migrate in response to fluctuating wave conditions, with complex transverse bars and rips typically present. Late in December 2007 and in January 2008 the Gold Coast was struck by high wave energy conditions for a period of one week. This resulted in the beaches shifting to a double bar dissipative state, with a relatively two-dimensional appearance. This storm event resulted in significant erosion of the northern Gold Coast beaches.

Referring to Figures 7.2 and 7.3, at the completion of eight and a half years of monitoring and around seven and a half years since the completion of the major phase of sand nourishment of northern Gold Coast beaches, at all southern monitoring sites the beaches experienced a net accretionary trend up to the beginning of 2006, that was interrupted in early March by the occurrence of high waves associated with the relatively slow passage of an east coast low pressure weather system. The beach had a trend of steady recovery at all southern monitoring sites following the March 2006 event, but the high energy wave conditions of the current monitoring period and the effects of another large low pressure system have again resulted in significant erosion of the beach. At the completion of the current monitoring period, the beach is again as narrow as it was at the beginning of the monitoring program eight and a half years ago.

In contrast, to the north, following the initial phase of beach widening in response to nourishment, Figure 7.2 indicates that a net erosional trend prevailed until the March 2006 event. Following the March 2006 event, the northern beaches also begun to recover, until the start of the current monitoring period. North of the Narrowneck reef, the beach suffered extensive erosion during the present monitoring period, and at the end of January 2008, is narrower than at any other stage during the eight and a half year monitoring period. Immediately in the lee and just south of the Narrowneck reef the effects of the ongoing high energy conditions and the December 2007 – January 2008 low pressure system, have been erosion at a reduced level compared to other sections of the beach. Further analysis and quantification of these longer-term trends is detailed in the following Section 7.2.

Since the implementation in 2003 of the web-based on-line 'Beach Analysis System' at the northern Gold Coast (refer Section 4.3), these shoreline and beach width data are now updated each week and available for public viewing at the project web site, extending back to the commencement of monitoring in August 1999. For completeness, the presentation of these same data in the on-line graphical format ('Beach Width Analysis') for the period to January 2008 is shown in Figures 7.4 and 7.5. The top and bottom panels in these figures are equivalent to the two panels in Figures 7.2 and 7.3, with the additional inclusion of selected shorelines to show the most recent shoreline movements. As has already been discussed, these summary Figures 7.4 and 7.5 show the same general accretion-erosion trends as summarised in report Figures 7.2 and 7.3.

7.2 Analysis of Cyclic-Seasonal versus Longer-Term Trends

It was noted in previous monitoring reports that for the period 2001 to mid 2004 a general cyclic pattern of beach variability had become evident. During this post-nourishment period, erosion was a characteristic of the first half of the calendar year, followed by accretion in the second half of the year. This cycle was interrupted during 2004, due to a large storm event that occurred in October 2004. This general cyclic trend matches the prevailing wave climate of the south east Queensland coast, whereby larger storm wave events are more frequent in the later summer and autumn months. Having observed this cyclic trend for a period of some three years, it was concluded in a prior monitoring report (Turner, 2004a) that the re-emergence of an annual erosion-recovery cycle is further indication that the beaches of the northern Gold Coast at that time had reached a dynamic state of equilibrium with the sand nourishment that was placed on the beach during 1999-2000.

The weekly shoreline data that continues to be obtained on a routine basis provides the opportunity to continue to assess and analyse the emergence of longer-term versus seasonal-cyclic trends at the northern Gold Coast. Of particular interest is to identify any underlying beach erosion or accretion, to assess whether this is uniform or variable within different areas of the study region, and to quantify the magnitude of any identified underlying trend(s), relative to the observed seasonal beach fluctuations. This information is of particular importance to the future planning for additional sand nourishment that may be required to maintain the acceptable beach conditions.

7.2.1 Auto-correlation Methodology

The auto-correlation method is used to identify and quantify the cyclic-seasonal regional-scale beach changes that have been monitored to date at the northern Gold Coast. Auto-correlation is a mathematical technique that seeks to identify repetitions of behaviour, in this case being the analysis of time-series of beach width, measured at discrete locations within the 4,500 m long study area. Repetitions, or cyclic behaviour, in data of this type can be found by computing a measure of the self-similarity of the sequence. That is, the sequence can be compared to itself at successive positions and the degree of similarity between the corresponding intervals computed. If every point (here the measured beach width on a specific day) is compared successively to every other point (i.e. all other weekly beach widths measured at that same location), the positions within the sequence of good correspondence will be detected, and also the degree of dissimilarity of other positions will be determined. The separation between two points is called the 'lag', which for the existing database of measured beach width at the northern Gold Coast corresponds to the weekly interval at which the shoreline is mapped.

In order to perform auto-correlation of any dataset, certain criteria must be met. The data sequence (i.e. weekly measures of the beach width) must be uniformly separated (in time), and the data must be stationary, or in other words exhibit no net increasing or decreasing trend through time. By careful pre-processing of the weekly shoreline data, it is this second criteria which can be exploited here to separate and compare seasonal-cyclic versus measured longer-term erosion-accretion trends at the northern Gold Coast.

7.2.2 Data Pre-processing

The dataset of shorelines obtained along the 4,500 m study area at the northern Gold Coast is obtained at nominal weekly intervals. Due to the maximum wave height criterion that is applied for the selection of images used for this analysis (see Section 3.8), the actual time interval (i.e. 'lag') between successive mapped shorelines may in reality vary between approximately 5 and 8 days. On a limited number of occasions, no shoreline is mapped for an entire weekly period. In order to perform auto-correlation analysis, the time-series of beach widths at each 5 m location alongshore within the 4,500 m study region was first interpolated at exact seven day intervals. The data prior to August 2000 was then removed, so that only the period post sand nourishment is included in the analysis.

In order that regional-scale variations can be identified, the alongshore-average shoreline position was then calculated for each week along three representative 500 m sections of the coastline. These comprised a northern section (centred at 2,000 m alongshore), a southern section (centred at –1,000 m alongshore) and at the site of the reef at Narrowneck (centred at 900 m alongshore). The resulting weekly time-series of alongshore-averaged beach width at the three representative sites was finally detrended (best-fit linear filter), to remove any non-stationarity prior to auto-correlation analysis.

7.2.3 Results

The results of auto-correlation analysis for the seven and a half year period August 2000 to January 2008 inclusive, to identify and quantify cyclic-seasonal versus longer-term erosion-accretion trends at the northern and southern sections, are summarised in Figures 7.6 and 7.7 respectively. The corresponding results in the vicinity of the reef are presented later in Section 8. The upper panel in these figures shows the interpolated 7-day time-series of alongshore-averaged beach width, the middle panel shows the corresponding detrended data, and the bottom panel shows the resulting auto-correlation function.

In both Figure 7.6 and 7.7 a strong annual cycle is evident during the first three years, but commencing with a storm in October 2004 (during what in preceding years was an accretionary period), this cyclic trend weakened. In prior monitoring reports it was observed that the further breaking down of this previously dominant seasonal-cyclic trend continued in 2005, as was evident by the diminishing auto-correlation function after January 2004 (3 years) for both northern and southern sites (bottom panels, Figures 7.6 and 7.7). In the first half of 2005 a net trend of accretion occurred along the northern beaches (Figure 7.6), during what in previous years has been a period of net erosion. Along southern beaches (Figure 7.7), no clear cyclic trend (as was observed in previous years) was evident.

The occurrence of significant beach erosion in March 2006 had had the effect of partially 'resetting' the cyclic erosion-accretion trends that dominated the northern Gold Coast during the years 2000 to 2003. Referring to both Figures 7.6 and 7.7, in 2006 this dominant cyclic behaviour re-emerged, characterised by erosion in the first half of the calendar year, followed by accretion throughout the second half of the year. Throughout the first quarter of 2007 the trend of erosion was evident, but significantly weaker than had been observed in the past, with this being followed by accretion in the second quarter of 2007.

During the current monitoring period, August 2007 to January 2008, strong erosion occurred along the northern Gold Coast beaches, during a period that has typically been dominated by accretion in the past. This identifies a continuing breakdown of the seasonal cyclic erosion/accretion trends at the Gold Coast.

In the upper panel of both these figures the best-fit linear trend to the full seven and a half years of post-nourishment data is also shown, and along with the detrended data in the middle panel, can be used to estimate the relative magnitude of the cyclic-seasonal beach changes, relative to longer-term beach erosion-accretion trends. Referring to the de-trended data first, at both the northern (Figure 7.6) and southern (Figure 7.7) sections, the beach width at these sites has typically varied cyclically and seasonally by +/- 20 m, indicating a range of approximately 40 m annual variability in beach width (although the larger erosion events of March 2006 and January 2008 exceeded these typical values) that can be attributed to the seasonal wave climate. In contrast, referring to the upper panel in both figures, the underlying trend at both sites is of a significantly lower magnitude.

The previous beach monitoring report (Blacka *et al.* 2007a) documented the effect of the March 2006 storm event, and the subsequent slow beach recovery, on the effect of the long term erosion/accretion trend. This single event, although short in duration, significantly increased the magnitude of the long term erosion trend determined from the then six year analysis. The further recovery of the beach throughout the first half of 2007 reduced the impact of the March 2006 event on the erosion/accretion trend analysis. From August 2000 to the end of January 2008, the long term trend over the northern section of beach has been determined to be erosion at a rate of -1.9 m per year. Over the southern section of the beach, there has also been a trend of net erosion, but at a slightly lower rate of only -1.5 m per year.

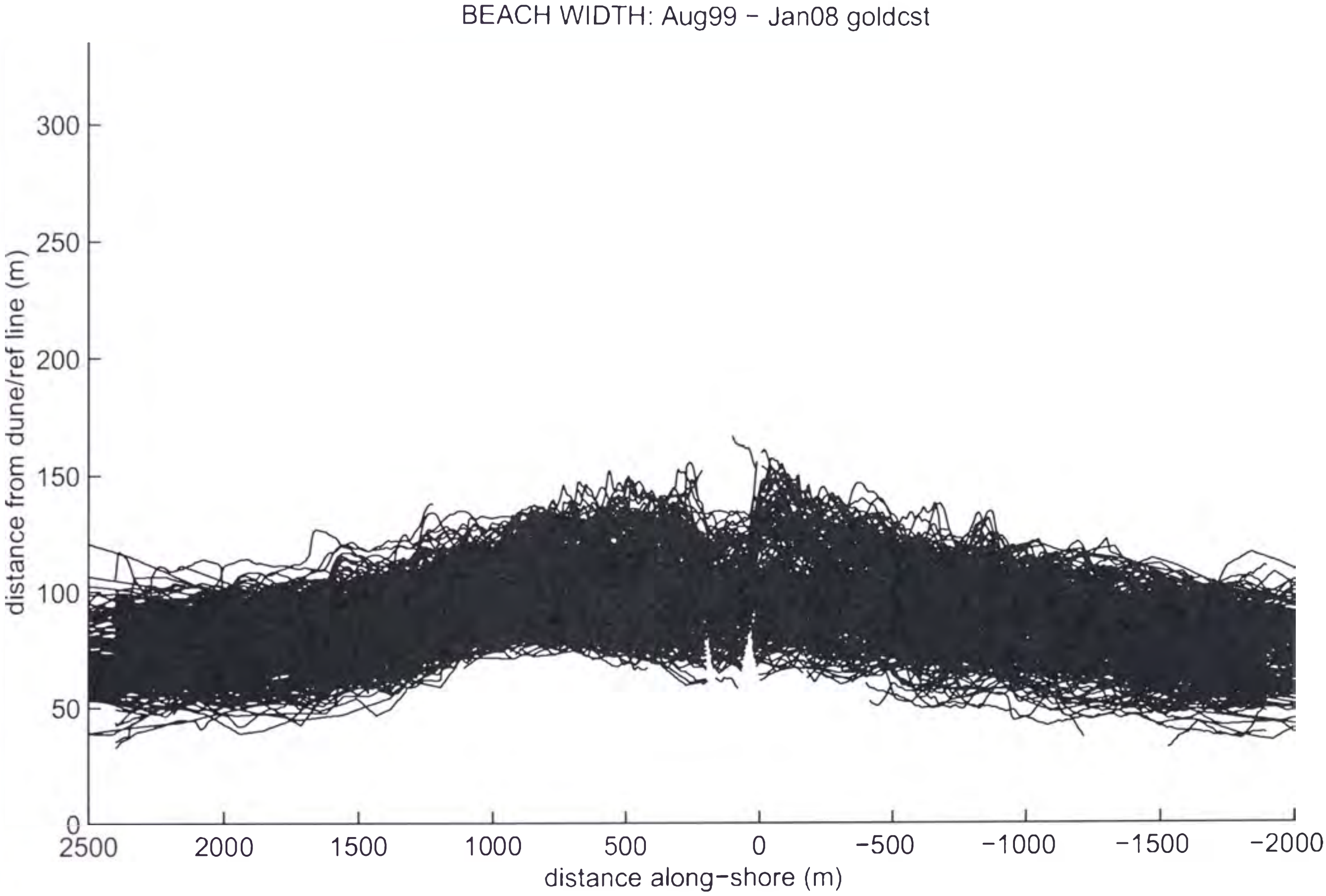
The analysis of cyclic-seasonal versus net erosion-accretion trends at the northern Gold Coast post sand nourishment (i.e. mid 2000) has been updated every six months monitoring period commencing in early in 2004. Table 7.1 summarises the six monthly results obtained to date. In the first six and a half years of analysis there had been a net accretionary trend persisting along the southern beaches within the 4,500 m study area, though a decrease in the rate of beach growth had emerged. For the past 12 months of monitoring, this trend has now been reversed to indicate long term erosion, at an increasing rate. Along the northern beaches a more constant erosion trend has been observed, with the current estimated erosion rate of -1.9 m per year being the highest rate of erosion predicted during the past seven and a half years.

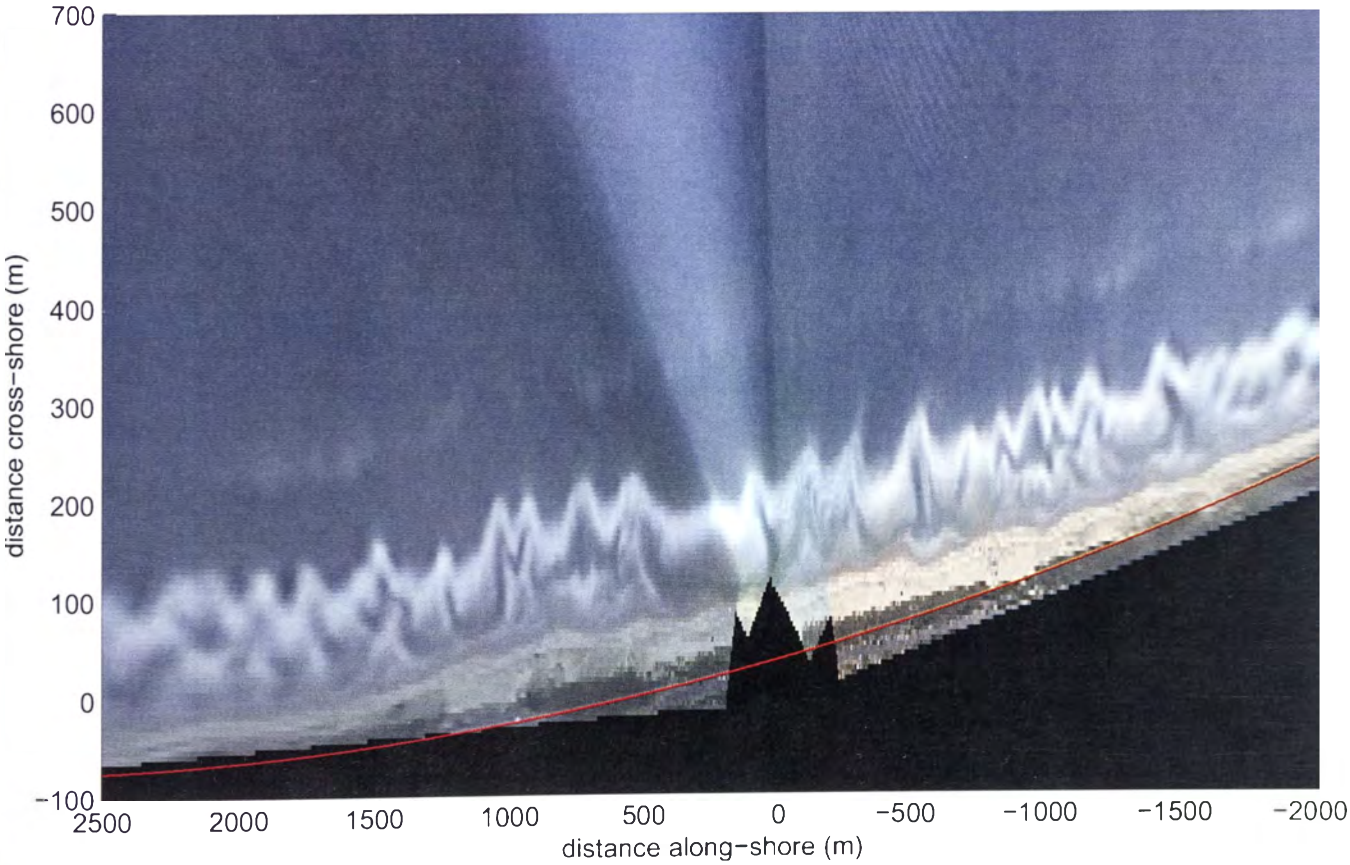
Table 7.1
Summary of Cyclic-Seasonal Variability versus Net Erosion-Accretion Trends

Post-nourishment monitoring period	Years	Cyclic-seasonal variability (m)	Net erosion-accretion trend (m per year)	
			North	South
August 2000 – January 2004	3.5	±20	+1.1	+7.4
August 2000 – July 2004	4	±20	-0.6	+5.2
August 2000 – January 2005	4.5	±20	-1.8	+3.1
August 2000 – July 2005	5	±20	-1.1	+3.8
August 2000 – January 2006	5.5	±20	-0.2	+4.2
August 2000 – July 2006	6	±20	-1.3	+1.8
August 2000 – January 2007	6.5	±10	-1.8	+0.2
August 2000 – July 2007	7	±30	-1.2	-0.4
August 2000 – January 2008	7.5	±30	-1.9	-1.5

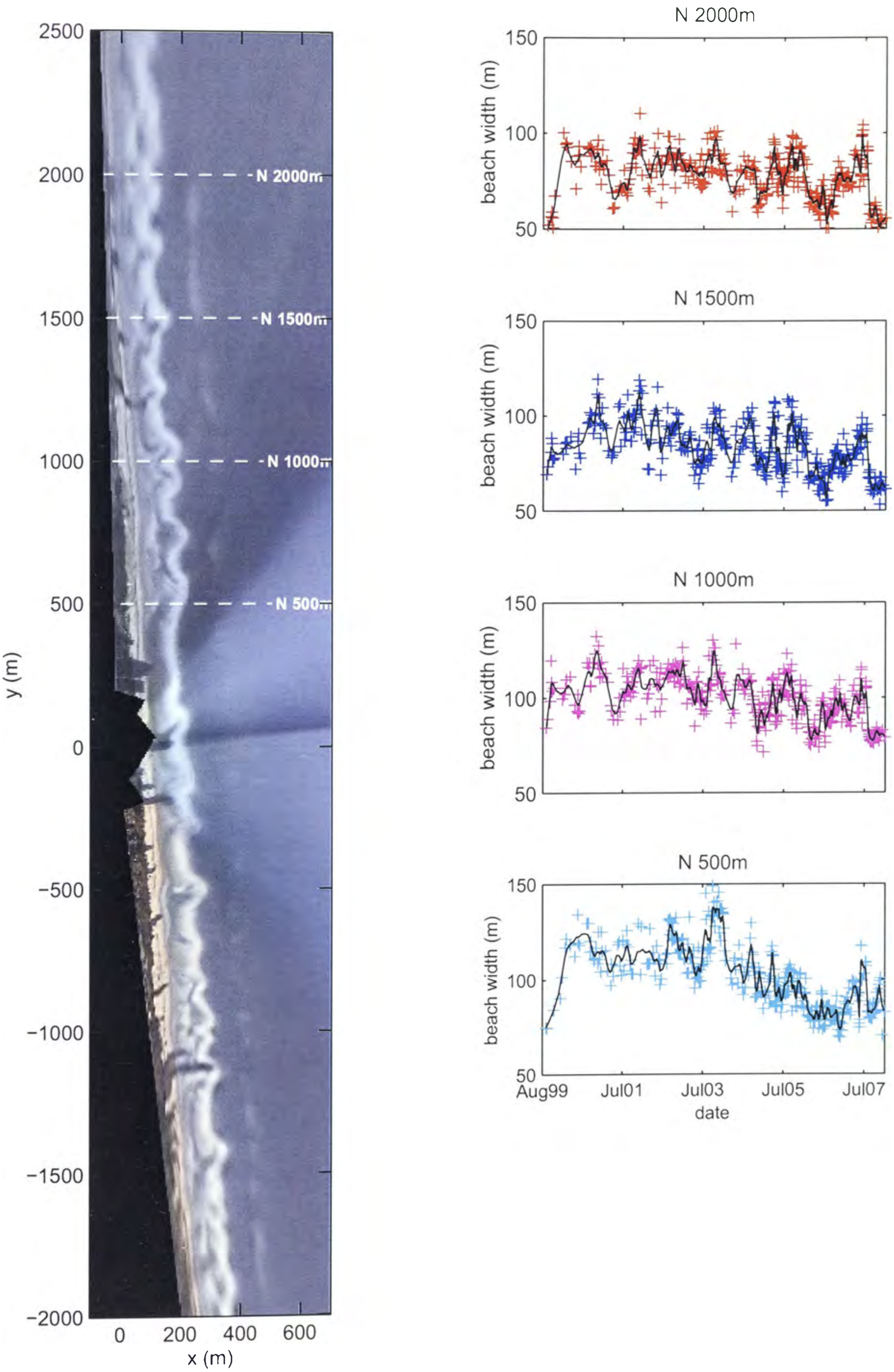
The seven and a half years of data upon which these longer-term trends are inferred is now sufficiently long to permit the results of this analysis to be used for future forecasting with a reasonable degree of confidence, and to draw two important conclusions regarding the regional-scale trends at the northern Gold Coast. The first conclusion refers to the long term erosion/accretion trends observed to date. There has typically been net minor beach accretion in the south, with the magnitude of the accretion reducing annually until January 2007, when in fact the beach began to show an overall erosive trend, which is now predicted to be of the order -11.25 m (-1.5 m/yr). The erosion/accretion trend for the northern sections of beach is predicted as relatively stable net erosion of the order of -14.25 m (-1.9 m/yr). The second conclusion which can be drawn from the analysis is that the cyclic annual variability of beach width due to the seasonally varying wave climate was an order of magnitude greater than the underlying beach width trends.

The underlying trend of long term erosion for the monitored section of the northern Gold Coast beaches will require future planning and ongoing management. However, it is shorter-term storm erosion rather than the underlying but much longer-term erosion trends, which at the present time are of primary importance to the ongoing planning and management of northern Gold Coast beaches.

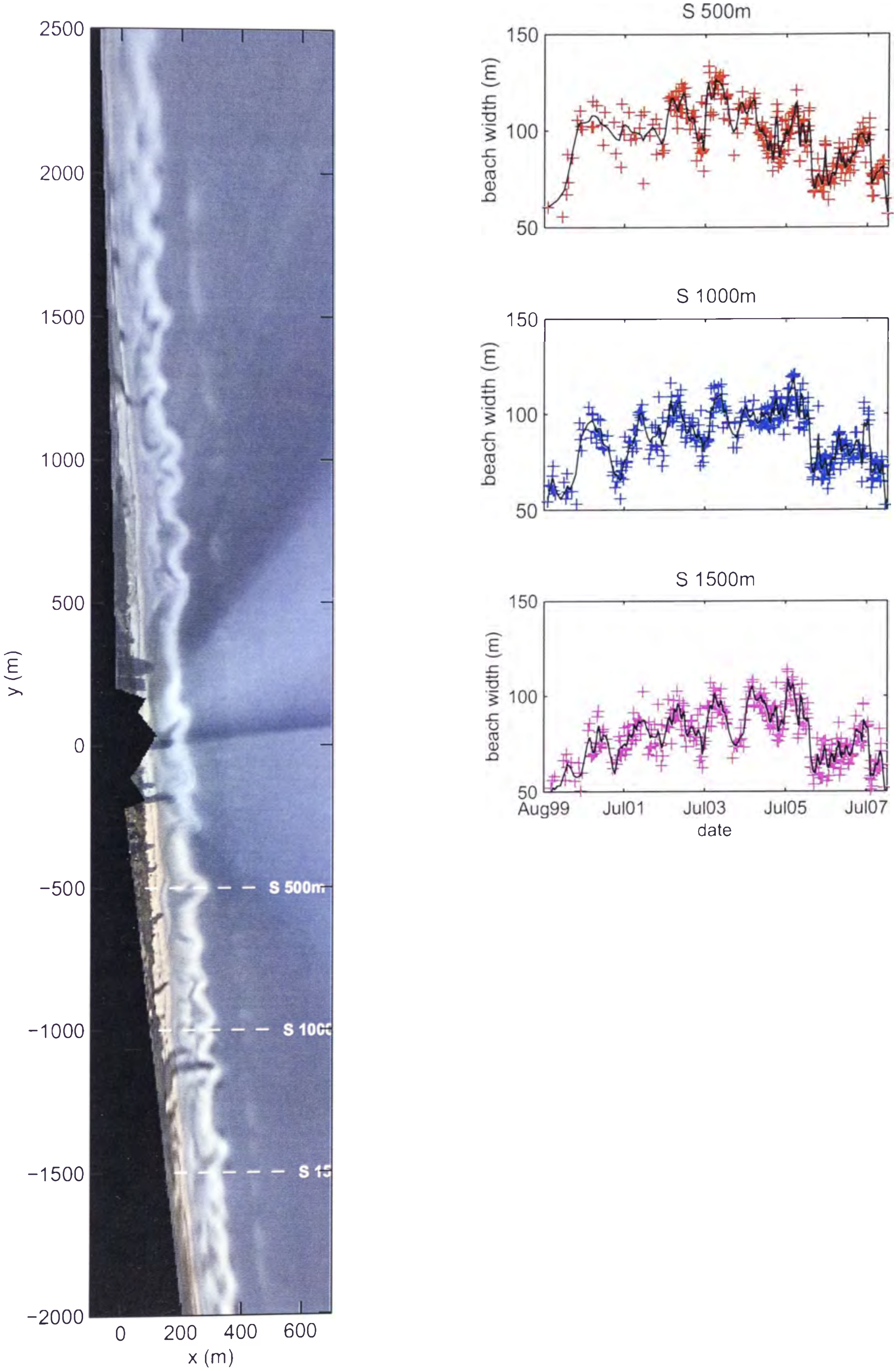




WRL Report No.2008/06	WEEKLY BEACH WIDYH: AUGUST 1999 - JANUARY 2008	Figure 7.1



WRL Report No.2008/06	TIME-SERIES OF BEACH WIDTH (NORTH): AUGUST 1999 – JANUARY 2008	Figure 7.2



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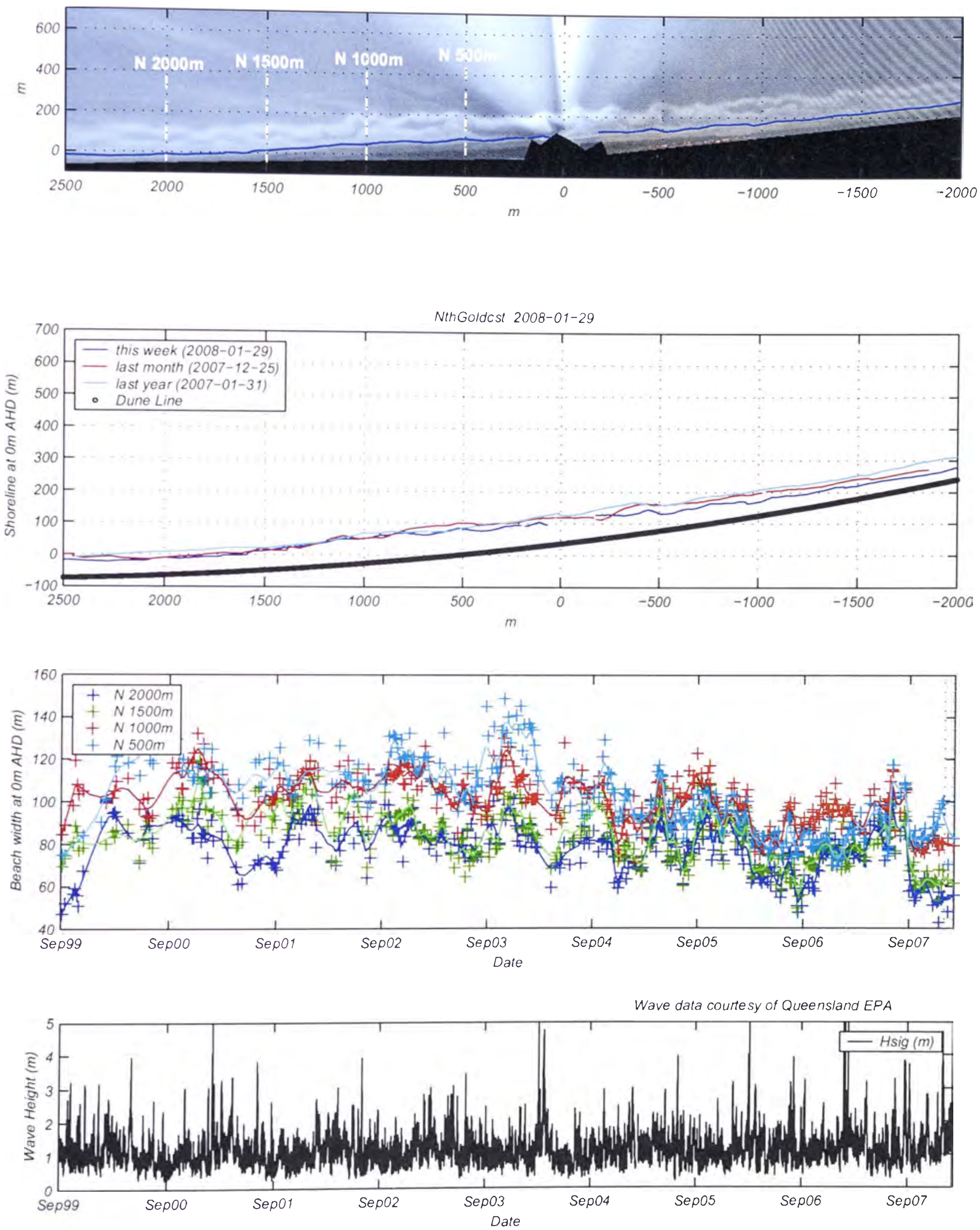
TIME-SERIES OF BEACH WIDTH (SOUTH):
AUGUST 1999 - JANUARY 2008

Figure 7.3



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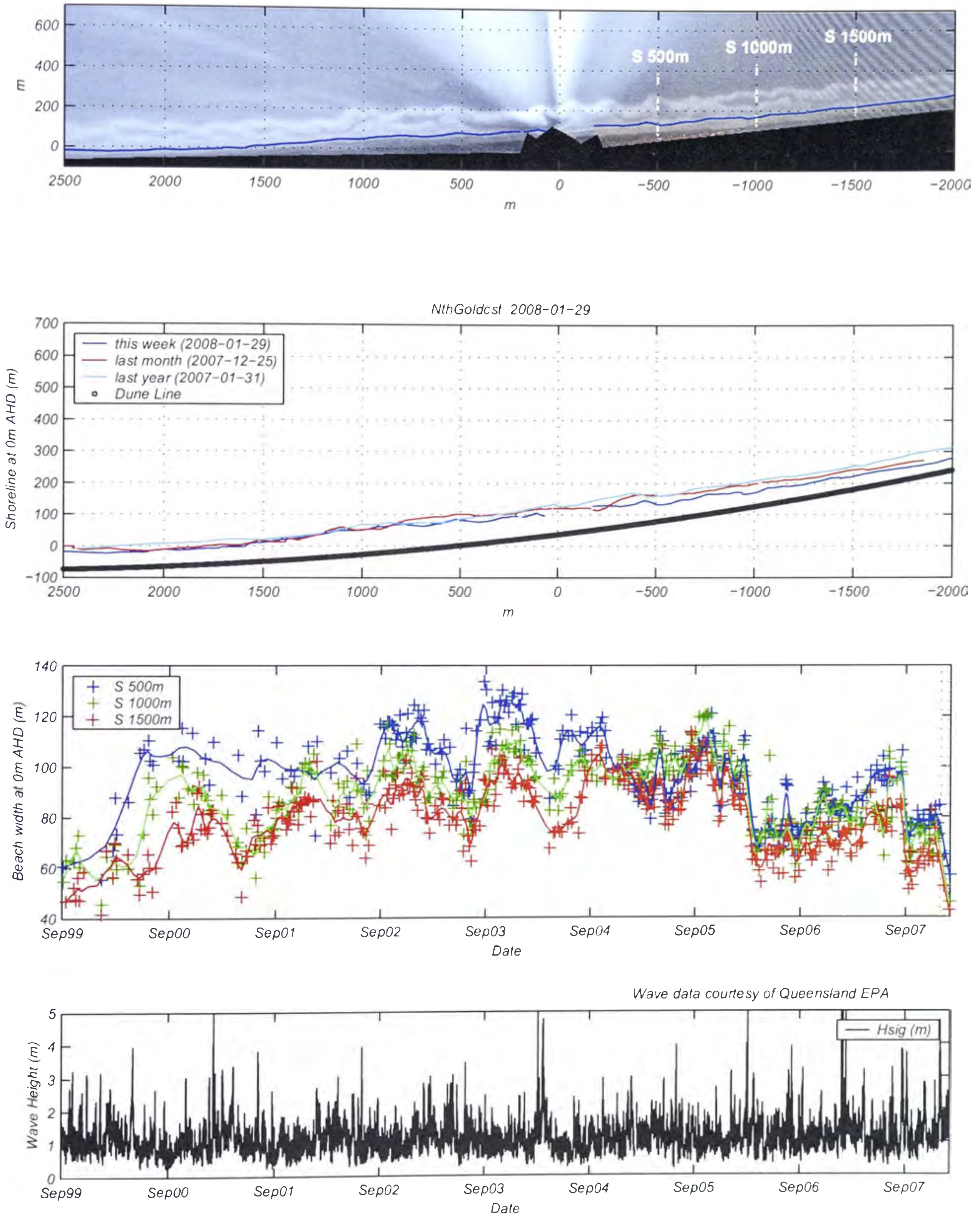
WRL Report No.2008/06	ON-LINE BEACH WIDTH ANALYSIS: JANUARY 2008 (NORTH)	Figure 7.4



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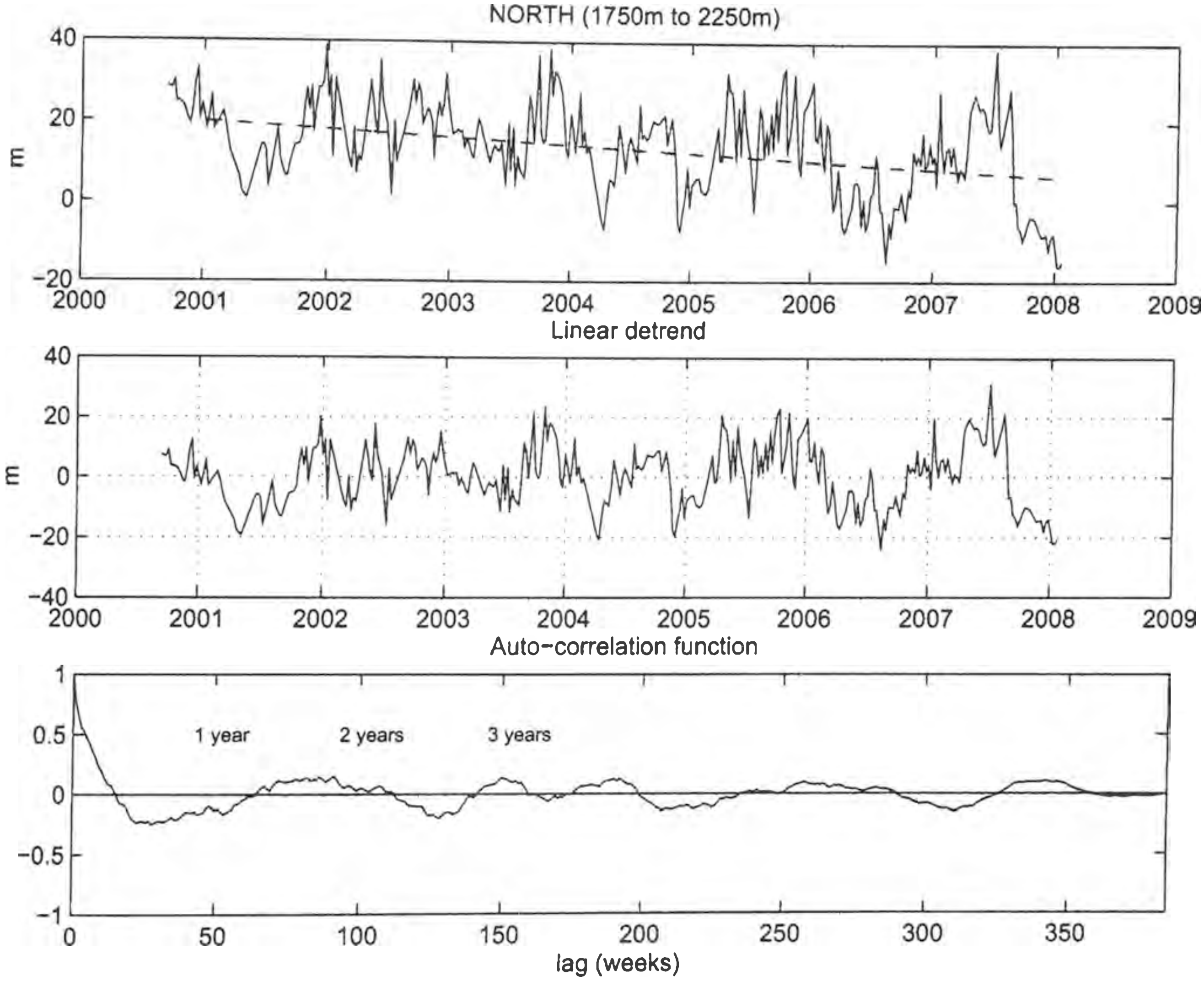
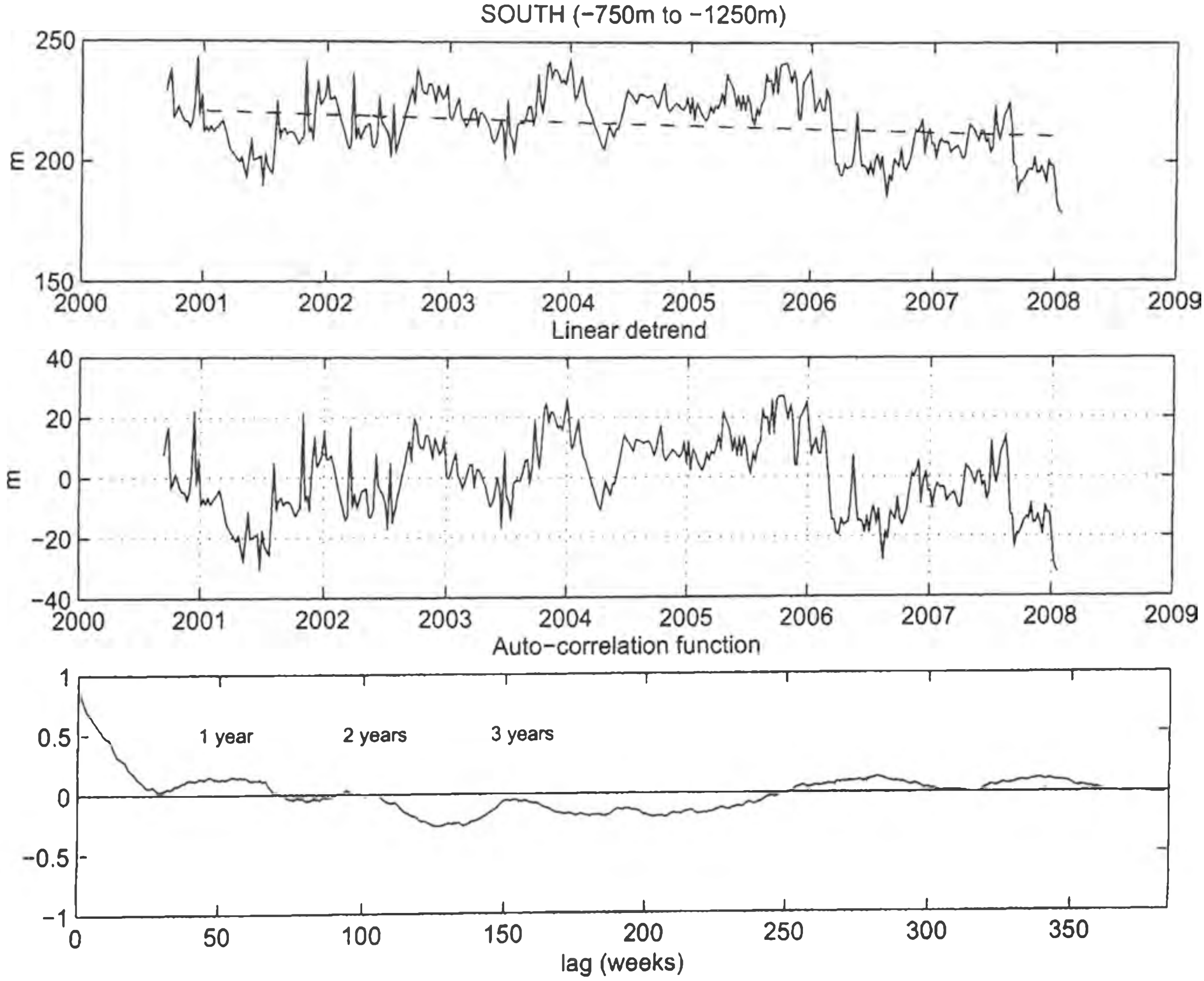
WRL Report No.2008/06	ON-LINE BEACH WIDTH ANALYSIS: JANUARY 2008 (SOUTH)	Figure 7.5



WRL Report No. 2008/06	CYCLIC SEASONAL VERSUS LONGER-TERM TRENDS NORTHERN STUDY SECTION	Figure 7.6 06037-7-6 cdr



SOUTH (−750m to −1250m)
250
m 200
150
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Linear detrend
40
20
m 0
−20
−40
Auto−correlation function
1
0.5
0
−0.5
−1
1 year
2 years
3 years
0
50
100
150
200
250
300
350
lag (weeks)

8. ASSESSMENT OF SHORELINE TRENDS IN THE LEE OF THE REEF

A primary objective of the Gold Coast Reef is to promote beach widening and stabilisation at Narrowneck by the development of a shoreline salient (ICM, 1997). The natural processes of wave dissipation, wave diffraction and wave refraction were predicted to result in a general widening of the beach, initially in the lee of the reef, then extending progressively southwards as the salient begins to act as a partially bypassing 'headland' (Black, 1998; Turner et al., 1998a). However, super-imposed on these anticipated changes at Narrowneck are the impacts of storms and re-adjustment of the beach following sand nourishment. It is therefore of interest to look more specifically at the shoreline trends within the region of beach in the immediate vicinity of Narrowneck.

8.1 Present Monitoring Period: August 2007 – January 2008

Figure 8.1 depicts a detailed view of a 1,000m long region of the beach, centred at Narrowneck at the site of the reef. The weekly shorelines for the period 01/08/07–31/01/08 are shown. The dune reference line (solid red line) and a schematic of the reef are also shown in this figure for reference.

A relatively uniform alongshore envelope of weekly shorelines at Narrowneck is apparent in this figure during the period August 2007 to January 2008. In Figure 8.2 the weekly beach widths (relative to the dune reference line) for the same period are plotted at an exaggerated cross-shore scale. Beach width can be seen to have varied by approximately 35 - 50 m alongshore, with the minimum variability being at a distance of 900 m north of the cameras. Figure 8.3 (upper panel) confirms that the maximum width shoreline varied from the mean in a generally uniform manner throughout Narrowneck, with the maximum beach width occurring approximately 550 m north of the cameras. The minimum width shoreline showed greater variability throughout the Narrowneck stretch compared to the median beach width, with the least eroded section of beach approximately in the lee of the Narrowneck reef, 900 m north of the ARGUS cameras. There was no significant observable trend in the standard deviation of weekly shorelines alongshore (Figure 8.3, middle panel) during the present monitoring period, with the region immediately behind the reef (900 m alongshore) and further south, showing a very minor reduction in shoreline variability, relative to the regions immediately north.

Figure 8.4 shows the weekly shorelines for the present monitoring period August 2007 to January 2008, relative to the mean shoreline position for the preceding monitoring period February – July 2007. The shoreline alignment at Narrowneck through the present monitoring period showed that the entire stretch of beach was generally narrower during the current monitoring period compared to the previous. The stretch of beach extending 500 m to the north of Narrowneck showed the greatest reduction in beach width during the current monitoring period compared to the median beach width of the previous monitoring period.

Fluctuations of the shoreline position during the present monitoring period August 2007 to January 2008, located at five cross-shore transects within the immediate vicinity of the reef, are shown in Figure 8.5. Four of the transects are located 150m and 300m north (R2 and R1) and south (R4 and R5) of the reef site respectively, while the fifth and central transect (R3) is aligned with the centre of the reef. Moving-average curve fitting was applied to these data to help clarify the general erosion/accretion patterns.

At all locations, the variation in beach width was similar throughout the current monitoring period, with only slight differences in trends between the northern, centre, and southern transects. The beach at transects R1 (300 m north of reef) and R2 (150 m north of reef) showed rapid reduction in beach width of the order of 25 m from August to September followed by steady beach recovery of approximately 10 m in width up to November. From November to January there was very little further change in beach width observed, even during the extreme storm event of late December/early January. At transect R3 (directly in the lee of the Narrrowneck reef) the beach also suffered an approximately 25 m reduction in beach width from August to September, but then remained reasonably static until December. During December and January a slight increase in beach width of 5 m to 10 m was observed at transect R3.

At the transects R4 (150 m south of reef) and R5 (300 m south of reef), beach width was eroded by approximately 50 m from August to September, which was followed by a period of very little change in width from September to November. The beach increased in width slightly into December, before again undergoing approximately 10 m of erosion in December and January.

8.2 Total Monitoring Period: August 1999 – January 2008

Figure 8.6 shows the changing shoreline position for the entire 102 month monitoring period August 1999 to January 2008 at the same five representative cross-shore transects in the immediate vicinity of Narrowneck. Again, the locations of the transects are shown in the panel on the left, and the onshore–offshore movement of the shoreline at each transect is shown in the five panels on the right.

8.2.1 Down-Drift of Reef

North of the reef construction site (located in deposition area A2 – refer Figure 2.5), the beach in the vicinity of Narrowneck can be seen to have widened by 20–25 m through the latter part of 1999, stabilised in the first months of 2000, and then evolved to a generally erosional state from April to August 2000. Accretion then occurred up to December 2000, followed by modest erosion again in January 2001. The net result by this time had been an increase in beach width of the order of 40–50 m. The beach then eroded though the first half of 2001, resulting in a net gain in beach width since the start of monitoring period of approximately 10 – 20 m. During the six month period August 2001 to January 2002 the beach recovered fully, regaining some 30 – 40 m beach width, of which some 20 – 30 m was removed again during February 2002 – July 2002. From August 2002 the beach again recovered some 40 – 50 m, then receded again during the period February 2003 to July 2003, followed again by a general trend of beach recovery during August 2003 to January 2004. From February 2004 to July 2004, a distinct erosion trend was measured, followed by recovery to the conditions that prevailed at the end of January 2004.

The period August 2004 to January 2005 was dominated by storm events in October and again in January 2005, resulting in a net erosion at Narrowneck. From February to July 2005 mild conditions through the first 3 months resulted in accretion and beach widening at Narrowneck, then the onset of a series of moderate storms through to July caused the partial removal of this accreted sand volume. The generally mild wave conditions that prevailed through August 2005 to January 2006 resulted in little net change to beach width during this time. In March 2006, a significant east coast low pressure system produced large wave conditions and resulted in rapid erosion of the beach by 20 to 30 m. Throughout the remainder of 2006 and into 2007, the beach fluctuated in width by approximately 5 - 10 m, steadily recovering from the March 2006 storm event. The beach width peaked in July 2007 at approximately 20 m greater than at the initiation of monitoring eight years earlier, before suffering approximately 25 m of erosion from August to September 2007. For the remainder of 2007 the beach down-drift of the reef accreted slightly, and at the completion of the current monitoring period in January 2008, is very similar in width to the beach eight and a half years earlier, at the initiation of the ARGUS monitoring program.

By the end of the present six month monitoring period the beach width immediately north of the Narrowneck reef (R1 and R2) was approximately the same as was recorded at the commencement of monitoring eight and a half years earlier in August 1999. It should be noted, however, that extensive sand nourishment was underway in this area prior to the commencement of the ARGUS monitoring program (refer Section 2.3). This stretch of beach has suffered significantly less erosion during the storms of December 2007/January 2008 than the beach further south and north of Narrowneck.

8.2.2 Lee and Up-drift of Reef

At the centre of the reef construction site and the two transects to the south (R3, R4 and R5 - all located in deposition area A3), beach widening of 50–60m was observed through to early 2000 in response to ongoing nourishment during this time. At the centre of the reef construction site and 150m south, this was followed by a period of erosion through to March then accretion to May, after which time a general accretionary trend persisted. At the transect 300m south the beach continued to increase in width at a generally steady rate through 2000. Again, the net result had been an increase in beach width of the order of 50 – 60 m. Storms in March, April and July 2001 resulted in recession of the shoreline, with the beach in mid 2001 approximately 30 m wider than at the commencement of the monitoring program.

Through August 2001 to January 2002 the beach in the lee of the reef and to the south recovered to the conditions of January 2001. During the period February 2002 to July 2002 the beach width decreased by 20 – 30 m, then recovered through to the end of 2002 and continue to accrete some 30 – 40 m, mirroring the shoreline erosion–accretion changes observed north of the reef. Through to July 2003 recession again occurred, followed by accretion to January 2004. As was observed to the north of the reef, a period of erosion followed by recovery was measured from February 2004 to July 2004, followed by further erosion through to January 2005. From February 2005 to July 2005 a similar pattern to that on the northern side of Narrowneck was observed: mild conditions through the first 3 months resulted in accretion and beach widening at Narrowneck, then the onset of a series of moderate storms through to July 2005 caused the partial removal of this accreted sand volume. As per the northern beach, through August 2005 to January 2006 the generally mild wave conditions resulted in little net change to beach width, until March 2006, when significant erosion occurred as a result of an east coast low pressure system.

From March 2006 to January 2007, the beach width fluctuated with a trend of slow accretion, but generally this was observed to be one of the most stable periods for beach width recorded throughout the previous 7.5 years. Beach width continued to fluctuate with little net change at transects R3 and R4 from February to April 2007, before undergoing rapid accretion of almost 20 m width followed by rapid erosion during June and July 2007.

The beach at transects R3, R4, and R5 suffered approximately 25 m of erosion from August to September 2007, followed by a period of minor but steady accretion up until November. During the December 2007 to January 2008 period the transects immediately updrift of the reef suffered erosion of approximately 10 m, while immediately in the lee of the reef there was little net change in beach width.

By the end of January 2008 the beach in the lee of the reef was similar to that at the commencement of monitoring eight and a half years ago, with this section of beach suffering little damage during the extreme storm of December 2007/January 2008. South of the reef at transects R4 and R5 the beach has remained in a relatively eroded state following storms of August and September 2007, but also suffered only minor loss of width during the December 2007/January 2008 storm. At the completion of the current monitoring period the beach is approximately 5 m to 10 m wider than at the initiation of monitoring eight and a half years earlier in August 1999.

Since the implementation of the new web-based 'Beach Analysis System', these weekly beach width data in the vicinity of the reef are now available on-line and updated each week. Again for the sake of completeness, these data in the on-line graphical format ('Beach Width Analysis') for the period to the end of January 2008 are shown in Figure 8.7, along with a selection of recent shorelines.

8.3 Analysis of Cyclic-Seasonal versus Longer-Term Trends

The results of auto-correlation analysis for the 500 m section of beach centred at the site of the reef are summarised in Figure 8.8. Refer to Section 7.2 for details of the methodology used to complete this analysis.

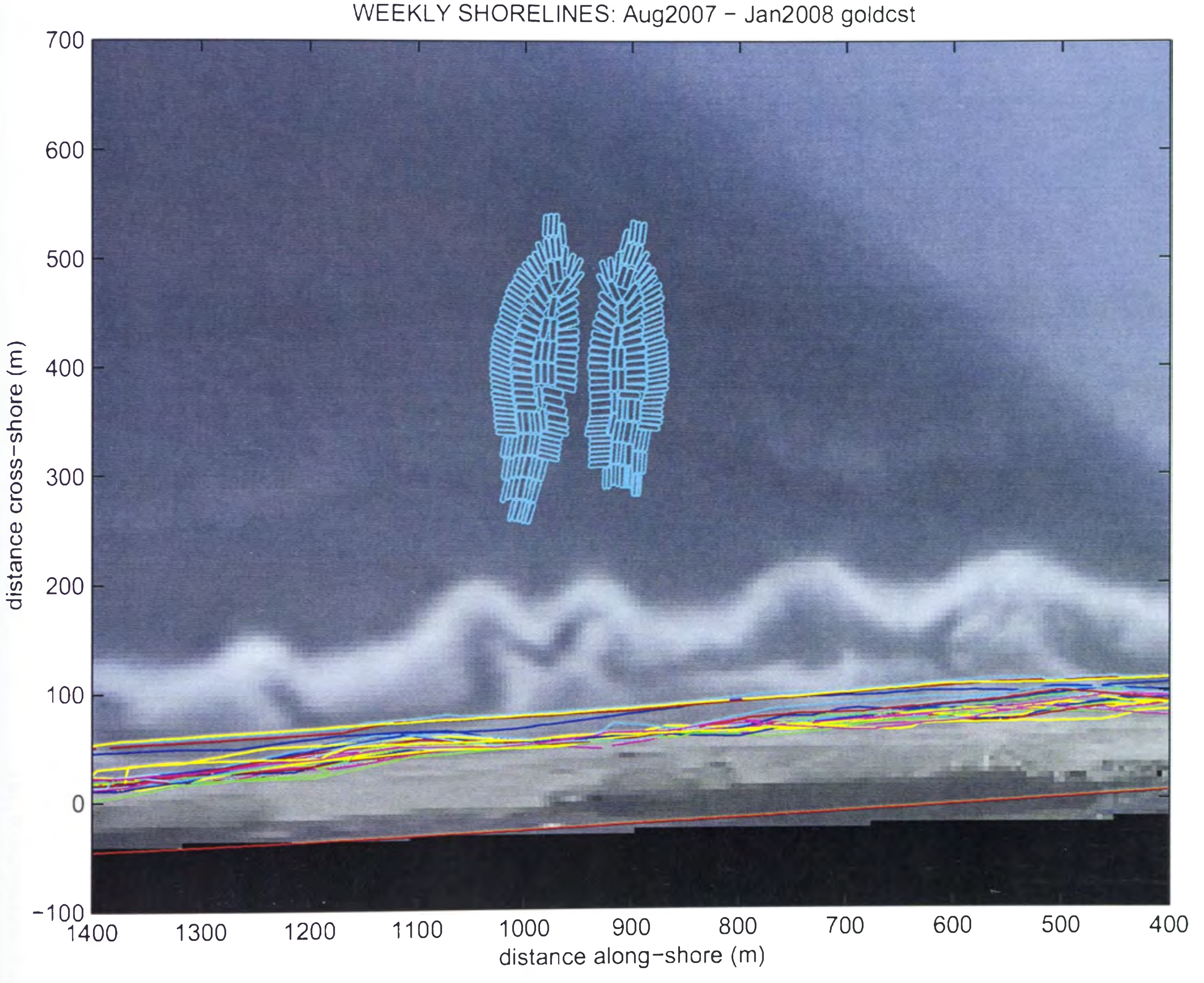
As per the northern and southern sections, the cyclic variation in beach width observed at Narrowneck (middle panel) for the seven and a half year period August 2000 to July 2007 is of the order of ± 20 m annually. It is interesting to note, however, that the east coast low and associated erosion in March 2006 and the erosion from the sub-tropical low in December 2007/January 2008 exceeded this typical seasonal beach width fluctuation across the northern and southern sections of beach, while at Narrowneck, this has not been the case. Again, the occurrence of significant beach erosion in early March 2006 had the effect of 're-setting' this dominant seasonal-cyclic trend for a short period, although the trend has again been less apparent throughout the second half of 2007. Referring to the best-fit linear trend to these data as shown in the upper panel of Figure 8.8, the underlying trend at this site for the seven year period to July 2007 is estimated to be of the order of -3.6 m per year (erosion).

The analysis of cyclic-seasonal versus net erosion-accretion trends at Narrowneck post sand nourishment (i.e. mid 2000) has been updated every six months monitoring period commencing in early in 2004. Table 8.1 summarises the six monthly results obtained to date. A modest net erosion trend has emerged at Narrowneck, with this trend now appearing to have stabilised compared to previous years.

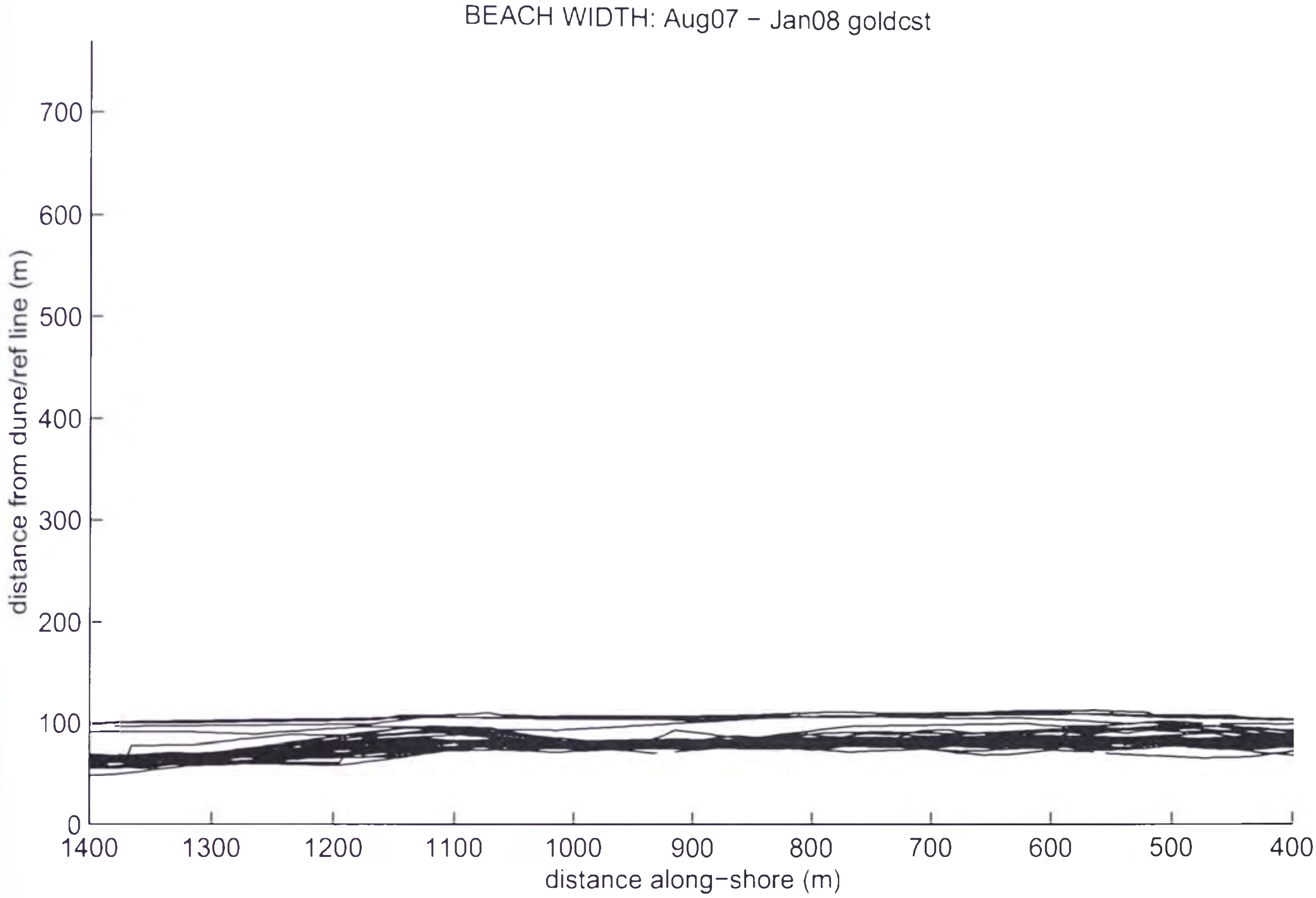
Table 8.1
Summary of Cyclic-Seasonal Variability versus Net Erosion-Accretion Trends (Narrowneck)

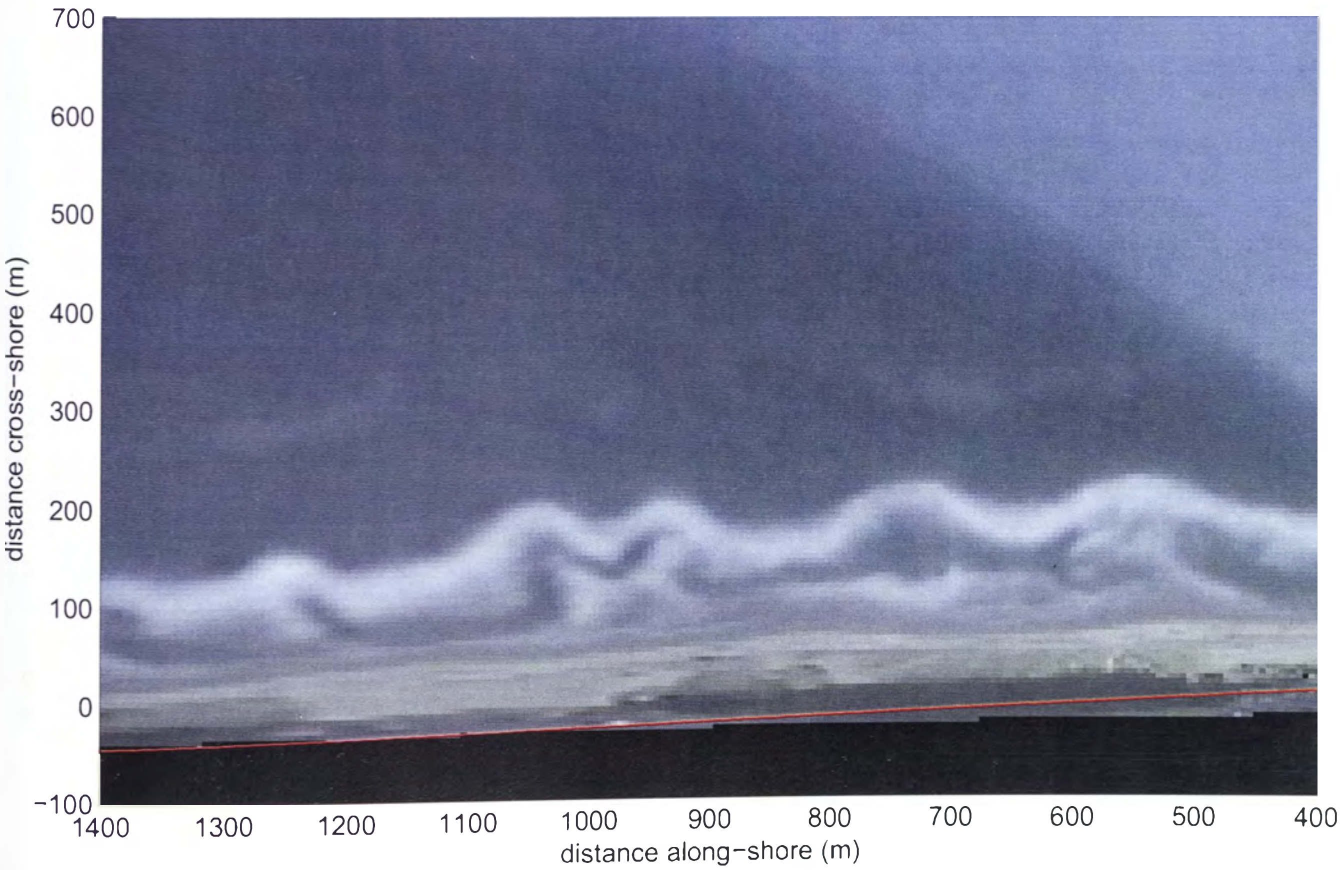
Post-nourishment monitoring period	Years	Cyclic-seasonal variability (m)	Net erosion-accretion trend (m per year) Narrowneck
August 2000 – January 2004	3.5	±20	+1.6
August 2000 – July 2004	4	±20	-0.6
August 2000 – January 2005	4.5	±20	-1.4
August 2000 – July 2005	5	±20	-2.8
August 2000 – January 2006	5.5	±20	-2.3
August 2000 – July 2006	6	±20	-3.5
August 2000 – January 2007	6.5	±10	-3.8
August 2000 – July 2007	7	±20	-3.3
August 2000 – January 2008	7.5	±20	-3.6

From the results presented in Table 8.1 it is concluded that at Narrowneck the underlying local beach width trend to date, since the completion of sand nourishment in mid 2000, has been modest net erosion of the order 27 m (-3.6 m/yr). More significant to the future management of this region, is the observation (as per the northern and southern beaches) that the cyclic annual variability of beach width at Narrowneck due to the seasonally varying wave climate and storm events, was an order of magnitude larger than the underlying slightly erosional beach width trend.

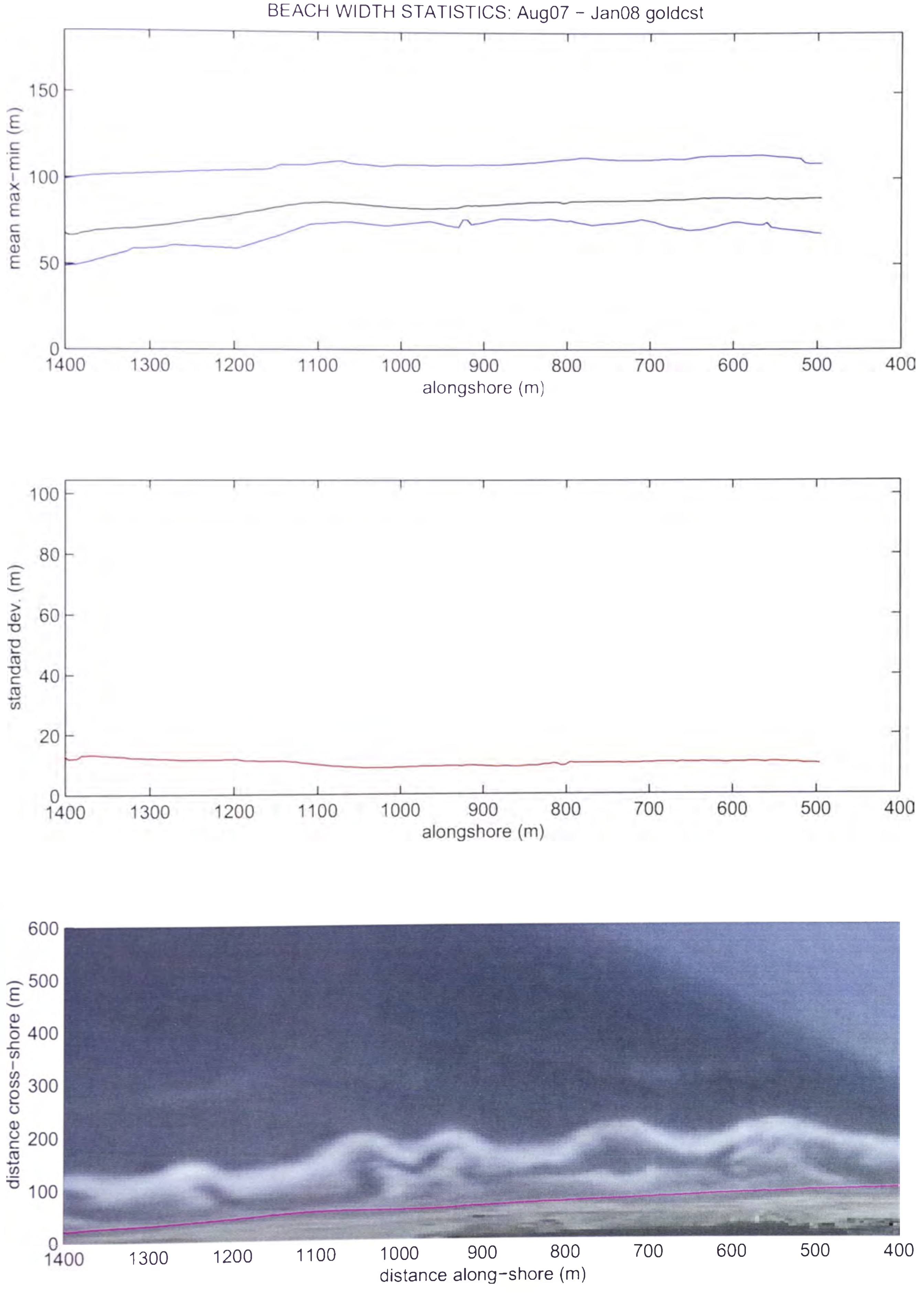


WRL Report No.2008/06	WEEKLY SHORELINES AT NARROWNECK: AUGUST 2007 - JANUARY 2008	Figure 8.1





WRL Report No.2008/06	BEACH WIDTH AT NARROWNECK: AUGUST 2007 - JANUARY 2008	Figure 8.2



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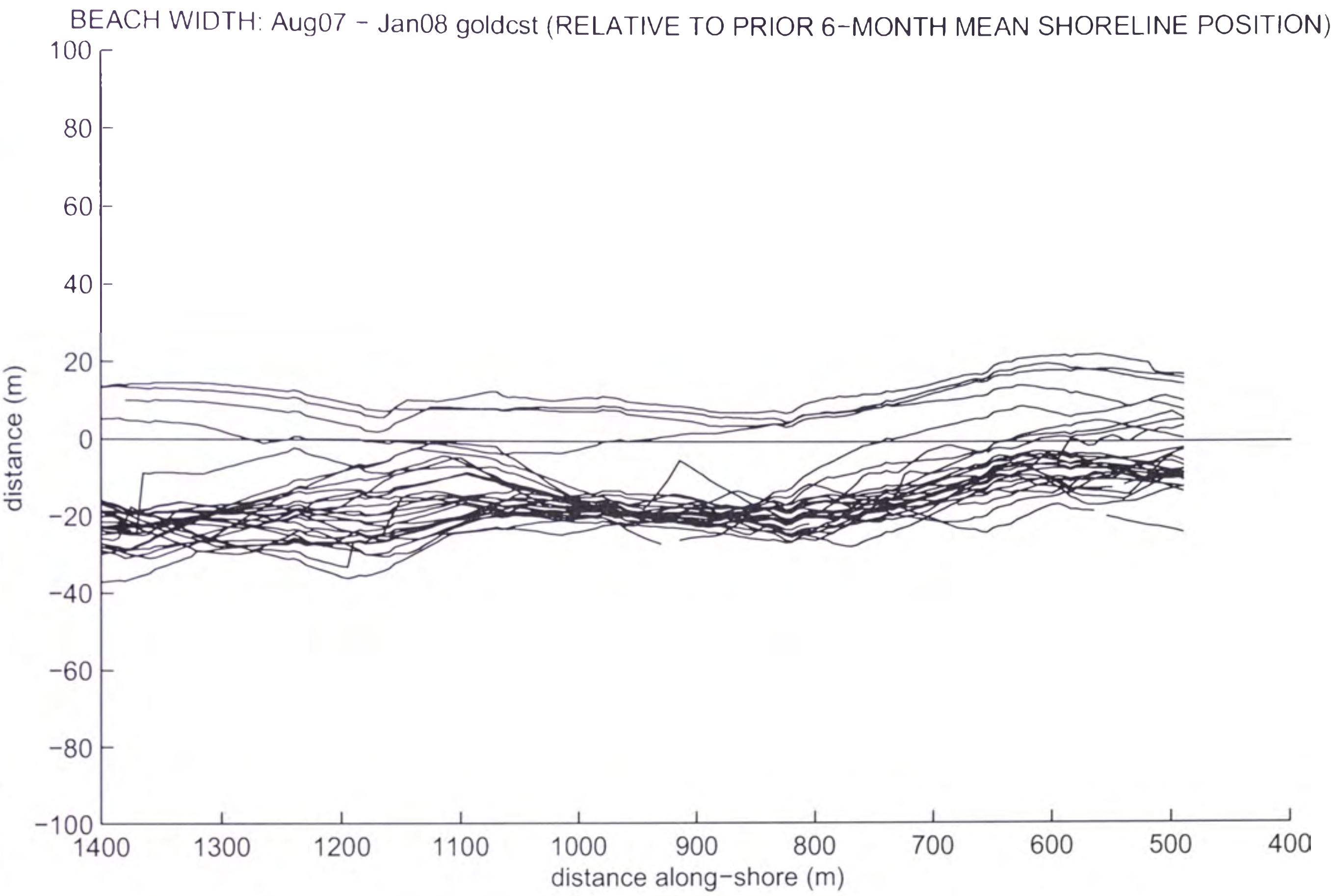
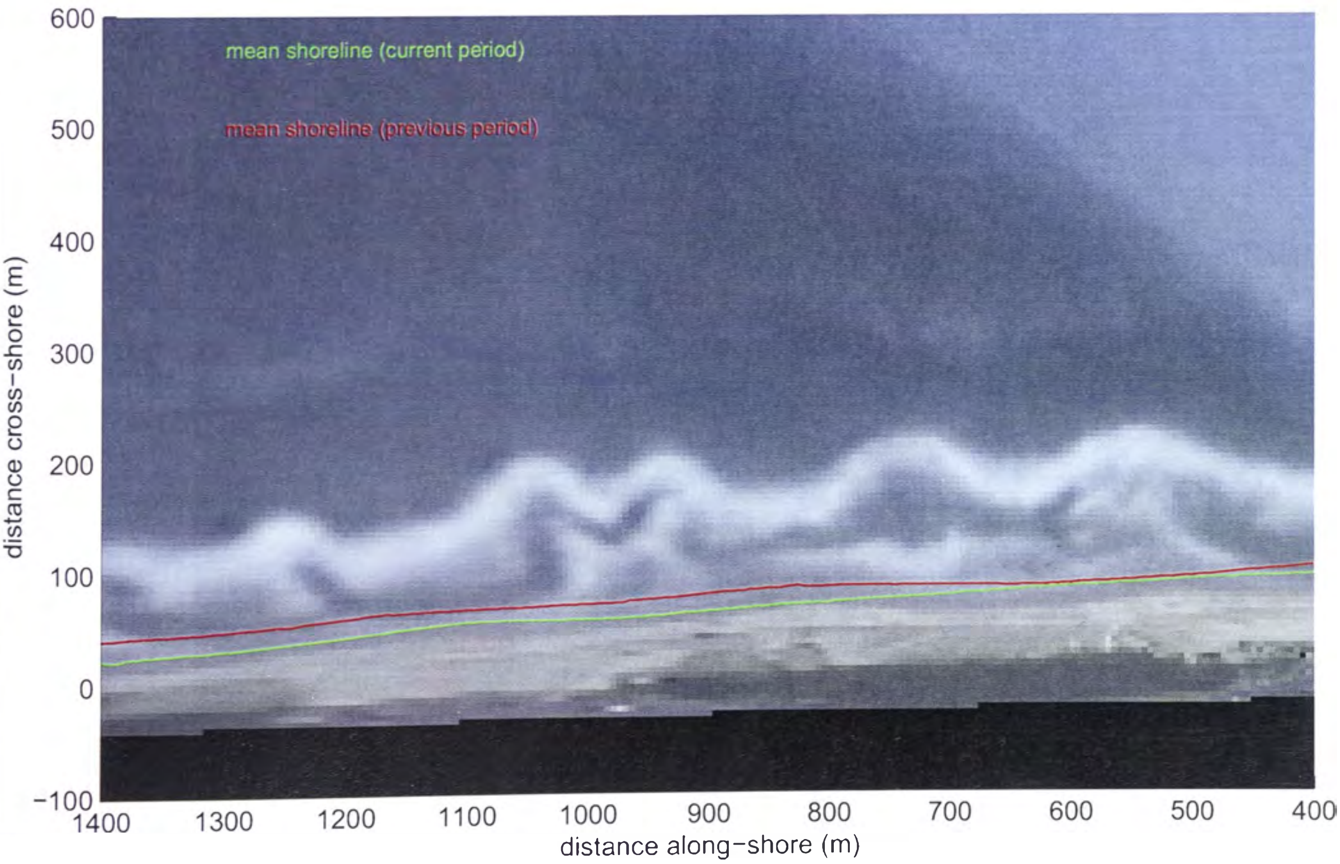
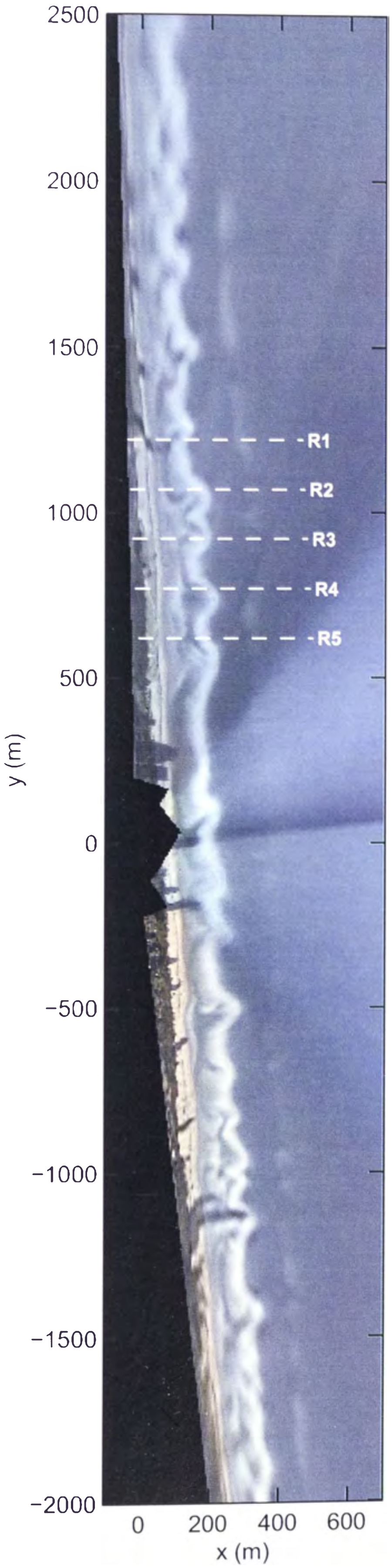
STATISTICAL SUMMARY OF BEACH WIDTH CHANGES AT NARROWNECK: AUGUST 2007 - JANUARY 2008

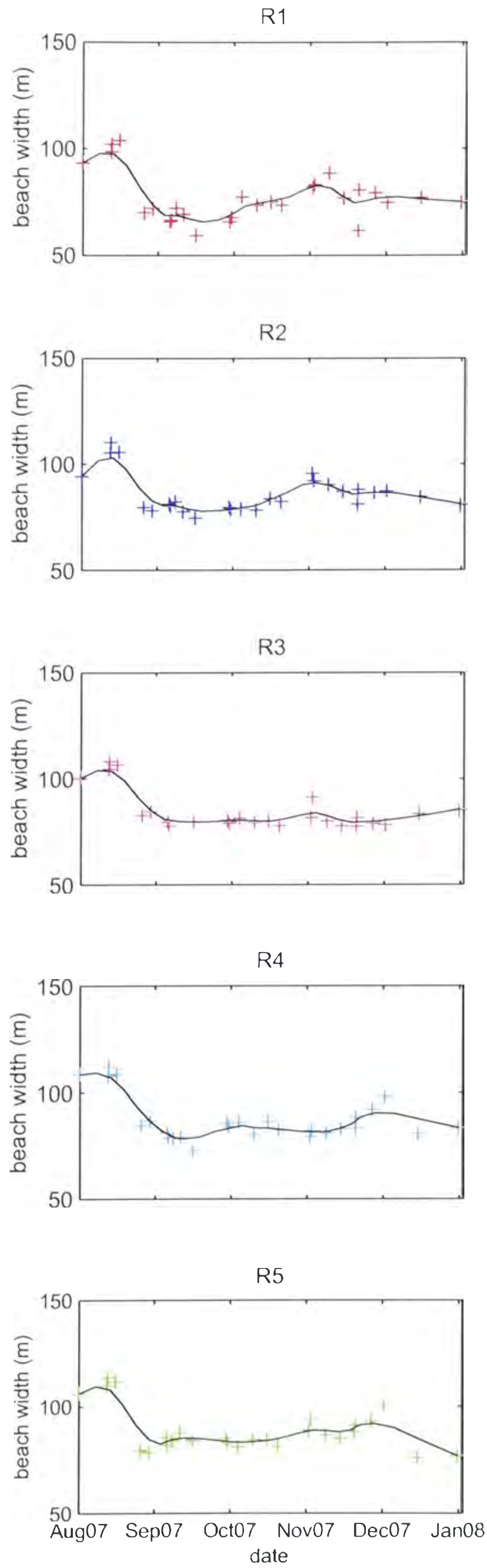
Figure 8.3



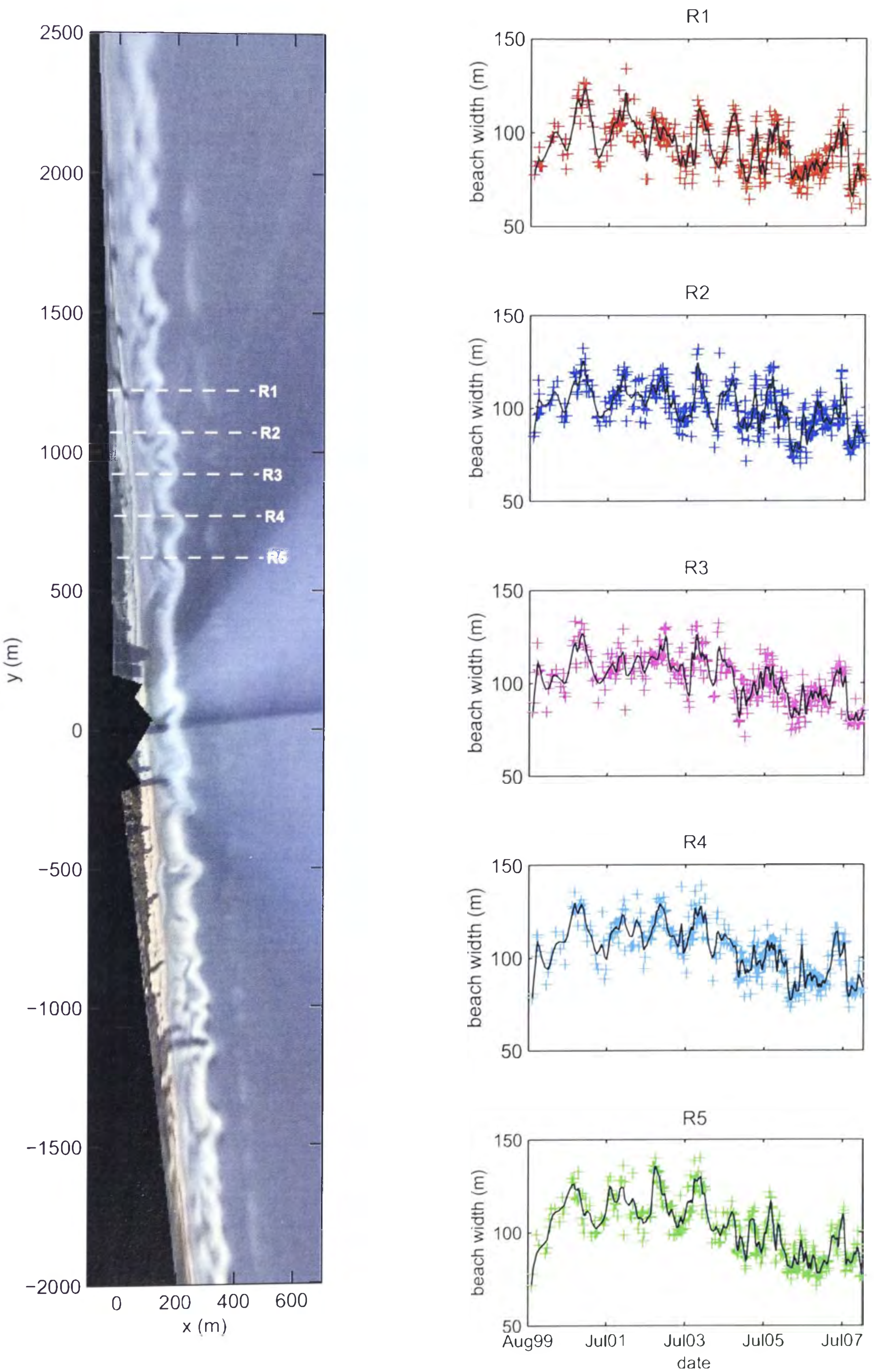


WRL Report No.2008/06	WEEKLY BEACH WIDTH CHANGES AT NARROWNECK AUGUST 2007 - JANUARY 2008 RELATIVE TO PRIOR SIX-MONTH MEAN SHORELINE POSITION	Figure 8.4

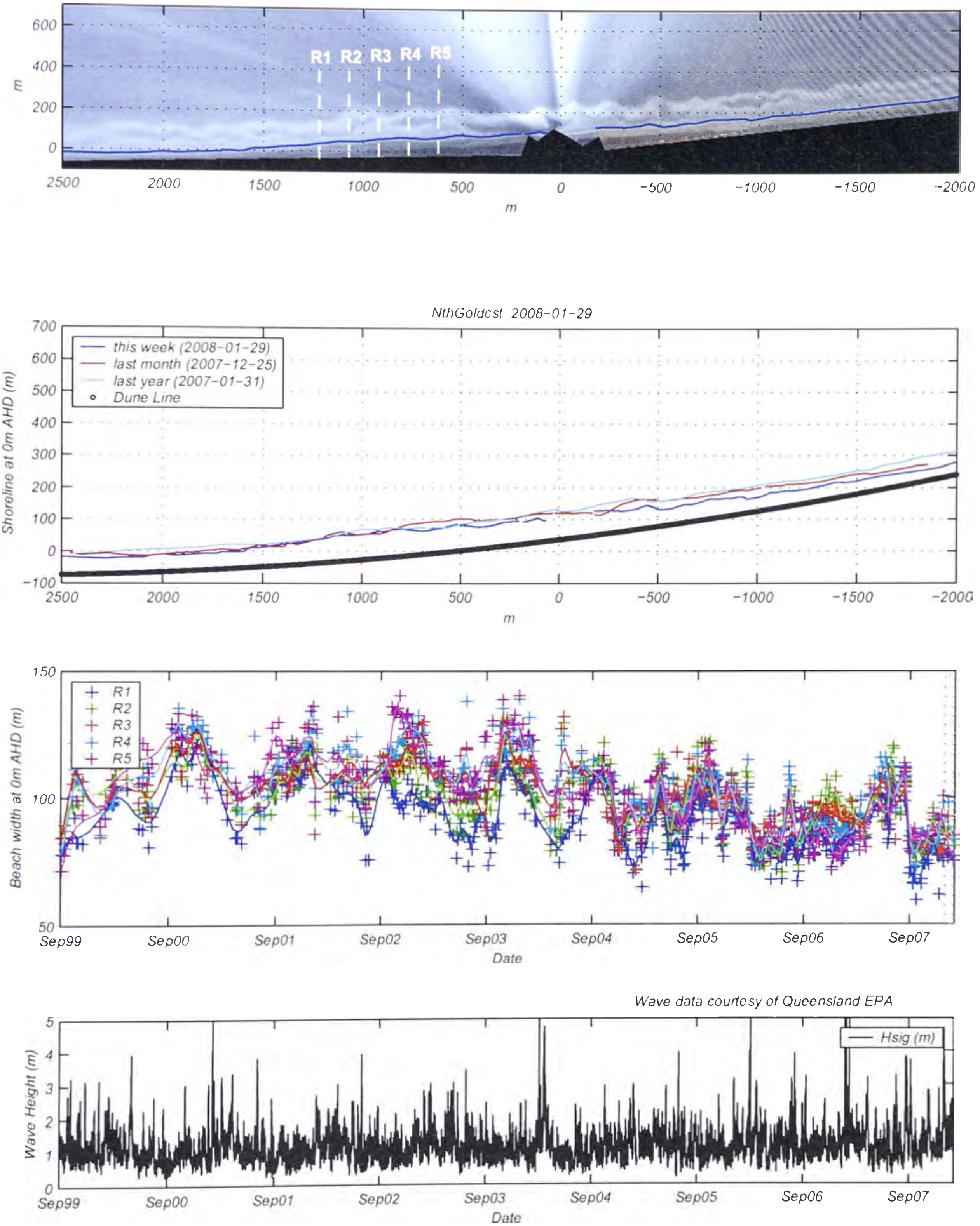




WRL Report No.2008/06	TIME-SERIES OF BEACH WIDTH AT NARROWNECK: AUGUST 2007 - JANUARY 2008	Figure 8.5



WRL Report No.2008/06	TIME-SERIES OF BEACH WIDTH AT NARROWNECK: AUGUST 1999 - JANUARY 2008	Figure 8.6



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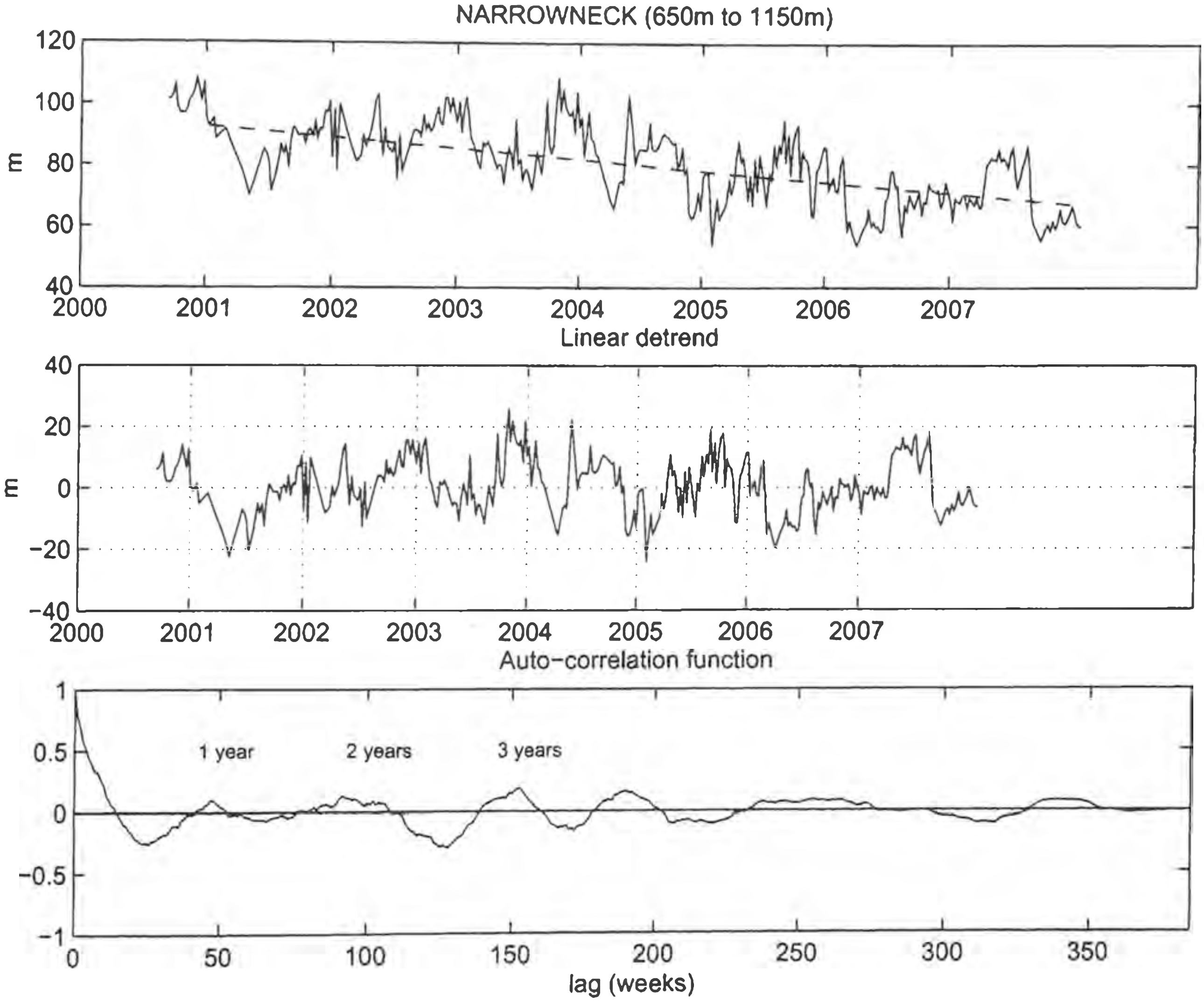
WRL Report No.2008/06	ON-LINE BEACH WIDTH ANALYSIS: JANUARY 2008 (REEF)	Figure 8.7



WRL Report No. 2008/06	CYCLIC SEASONAL VERSUS LONGER-TERM TRENDS NARROWNECK	Figure 8.8

9. ANALYSIS OF EROSION-ACCRETION TRENDS

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 then analysed to better assess regions of beachface erosion and deposition up-drift and down-drift of the artificial reef site at Narrowneck.

9.1 Methodology

A detailed description of the analysis techniques used to derive three-dimensional beachface bathymetry from two-dimensional image analysis was provided in Turner (2005a). 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 9.1, if this process is repeated at all points alongshore throughout a complete tide cycle, a three-dimensional bathymetry of the beachface, between the high tide and low tide waterlines, can be 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.

9.2 Monthly Beachface Bathymetric Mapping

Beachface bathymetry maps for 15th August and 15th September 2007 are shown in Figure 9.2, 12th October and 21st November 2007 in Figure 9.3, and 12th December 2007 and 13th January 2008 in Figure 9.4. In all these figures, the centre-line of the Gold Coast Reef structure at Narrowneck is located at the longshore coordinate x = 900 m, and the landward edge of the structure is located offshore at around y = 250 m.

The beachface mapped in August 2007 (Figure 9.2 top panel) showed that the beach had a relatively uniform and steep gradient, typical of a lower energy morphological state. From August to September (Figure 9.2 bottom panel) the beachface migrated significantly landward, by a distance of approximately 30 m in the north and 20 m in the south. This was the result of two storm events in late August and early September. The effect of the increased wave energy during this could also be seen by the significant flattening of the beachface gradient between August and September. From September to October 2007 (Figure 9.3 top panel) the slightly milder wave conditions saw the beachface steepen in the lee of the Narrowneck reef, and become somewhat irregular in alignment, particularly south of the reef.

The storm which occurred in early November resulted in further landward migration of the beachface by approximately 10 m to the north of Narrowneck, and again the beachface became more uniform in alignment to the south of the reef (see Figure 9.3 bottom panel). The impact of the reef on wave processes in its lee can be seen by the complex beachface alignment which developed during the November storm event. The milder wave conditions from mid November to early December (see Figure 9.4 top panel) again saw the beachface steepen in the lee of the reef, and become more irregular in alignment further south and north alongshore.

The impacts of the December 2007/January 2008 storm event on the beachface bathymetry can be seen by comparing the beachface bathymetry plots for December and January, shown in the top and bottom panels of Figure 9.4. The most significant observable changes occurred to the south of the Narownck reef, with the beachface migrating landward by approximately 40 m to 50 m. The alignment of the beachface became more two-dimensional as a result of this event, and the effect of an erosion scarp can be interpreted from the relatively steep beachface above approximately 0.2 m AHD.

Throughout the current six month monitoring period from August 2007 to January 2008, the most notable change that can be seen from the beachface bathymetric mapping, is that the shoreline (location of MSL) was observed to migrate some 40 m to 50 m landward over the entire mapped section of beach. The beachface at the completion of the current monitoring period showed a shallow gradient below MSL, backed by a steep eroded beachface above MSL.

9.3 Monthly Erosion-Accretion Trends

By further processing of the monthly bathymetries shown in Figures 9.2 to Figure 9.4, a quantitative measure of the net change in sand volumes across the beachface (between -0.5 and +0.7 m AHD) around Narrowneck can be obtained. Figure 9.5 shows the results of these calculations to determine the monthly net change in beachface elevation between July and October 2007, and Figure 9.6 summarises the monthly beachface changes between October 2007 and January 2008.

The top panel of Figure 9.5 shows the irregular patches of erosion and accretion that occurred between July and August 2007. The magnitude of changes in beachface volume was moderate during this period with a net erosion of -4,860 m^3 over the full 1000 m stretch of beach, equating to -4.8 m^3 per metre of shoreline. Between August and September (Figure 9.5 mid panel) the beach suffered significant erosion due to two large storm events. During this one month period in excess of 1 m in vertical beachface elevation was lost over a beach width of 20 m, along the entire mapped section of beach. The net erosion between August and September was approximately -33,000 m^3, which equates to -33.0 m^3 per m of shoreline, between the levels of -0.5 m AHD and +0.7 m AHD. Additional erosion is likely to have occurred above +0.7 m AHD but measurement of this is beyond the presently available techniques.

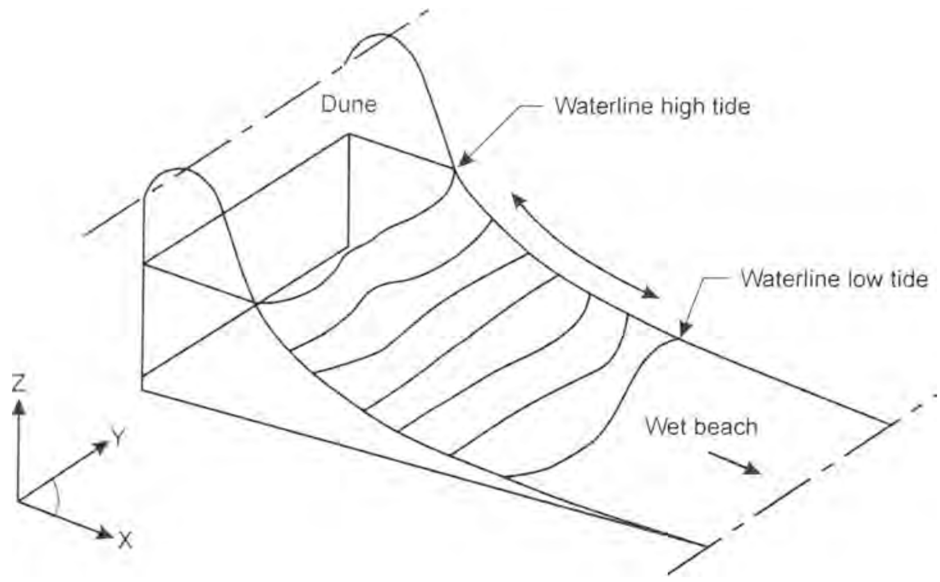
From September to October 2007 (Figure 9.5 bottom panel) the beach had very little net change, with minor accretion observed at most locations alongshore. The net accretion volume over the entire 1000 m length of beach was approximately 2,220 m^3, equating to 2.2 m^3 per m of shoreline between -0.5 m AHD and +0.7 m AHD. From October to November 2007 (Figure 9.6 top panel) patches of both erosion and accretion occurred at different locations alongshore, with the most significant being a large zone of accretion extending to the north of the Narrowneck reef. In this accretion zone the beachface gained up to 1 m in vertical elevation during the one month period, with a net accretion along the entire beach of approximately 5,040 m^3, equating to 5.0 m^3 of accretion per m of shoreline.

From November to December (Figure 9.6 mid panel), the zone of accretion north of Narrowneck which developed throughout the previous month was again eroded. Along the remainder of the beach only minor pockets of localised erosion and accretion were observed, with the net erosion over the entire 1000 m stretch of mapped beach of -1,100 m^3, equating to approximately -1.1 m^3 of erosion per m of shoreline, between -0.5 m AHD and +0.7 m AHD

Between December 2007 and January 2008, significant erosion of the beach again occurred as a result of extreme waves caused by an intense sub-tropical low pressure system passing the Queensland coast. The most extensive erosion was measured immediately to the north of the Narrowneck reef, and also further to the south of the reef, where in excess of 1 m in vertical beachface elevation was eroded. In the lee of the reef and the area immediately to the south of the reef also suffered erosion between December and January, but to a reduced extent, with a drop in vertical beachface elevation of approximately 0.6 m being observed. Analysis of the change in beachface topography between the elevations of -0.5 m AHD and +0.7 m AHD predicted a net erosion of approximately -16,600 m^3 over the 1000 m stretch of analysed beach, equating to -16.6 m^3 per m of shoreline. Significant erosion scarps observed on the Gold Coast beaches following the December/January storm event indicate that a significant quantity of sand in excess of that estimated by the ARGUS analysis was lost from the beachface above the level of +0.7 m AHD.

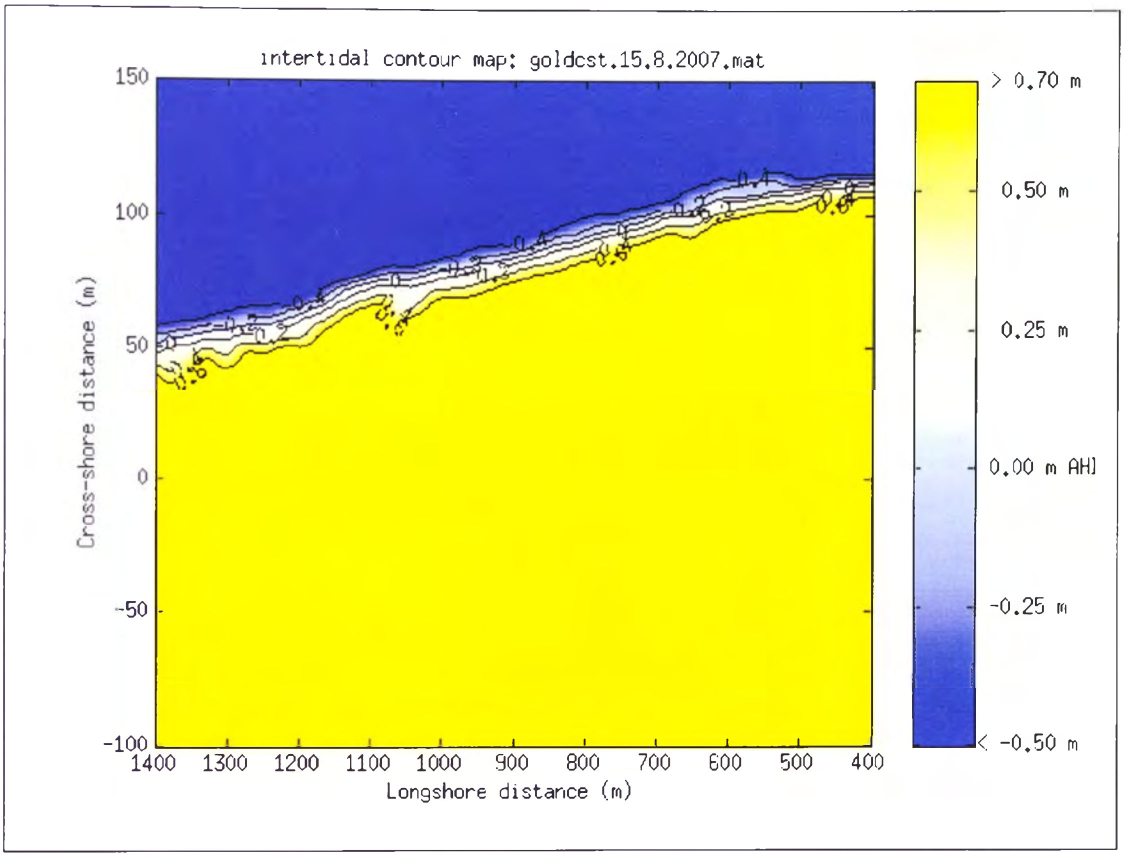
9.4 Net Erosion-Accretion Trends: August 2007 – January 2008

The net trend for the entire six-month period August 2007 to January 2008 was significant erosion across the entire 1 km stretch of beach. Referring to Figure 9.7, from 6th July 2007 to 13th January 2008, the 1000 m length of beach at Narrowneck eroded a net volume of approximately -48,600 m^3 between the elevations of -0.5 and +0.7 m AHD, equating to approximately -48.1 m^3 of erosion per metre of shoreline. It can be seen from Figure 9.7, that along the entire beach, the vertical beachface elevation was eroded by well in excess of 1 m over a beach width of 20 m to 30 m. The extensive erosion experienced throughout the current monitoring period was predominantly the result of three separate storm events which occurred in August, September and December/January.

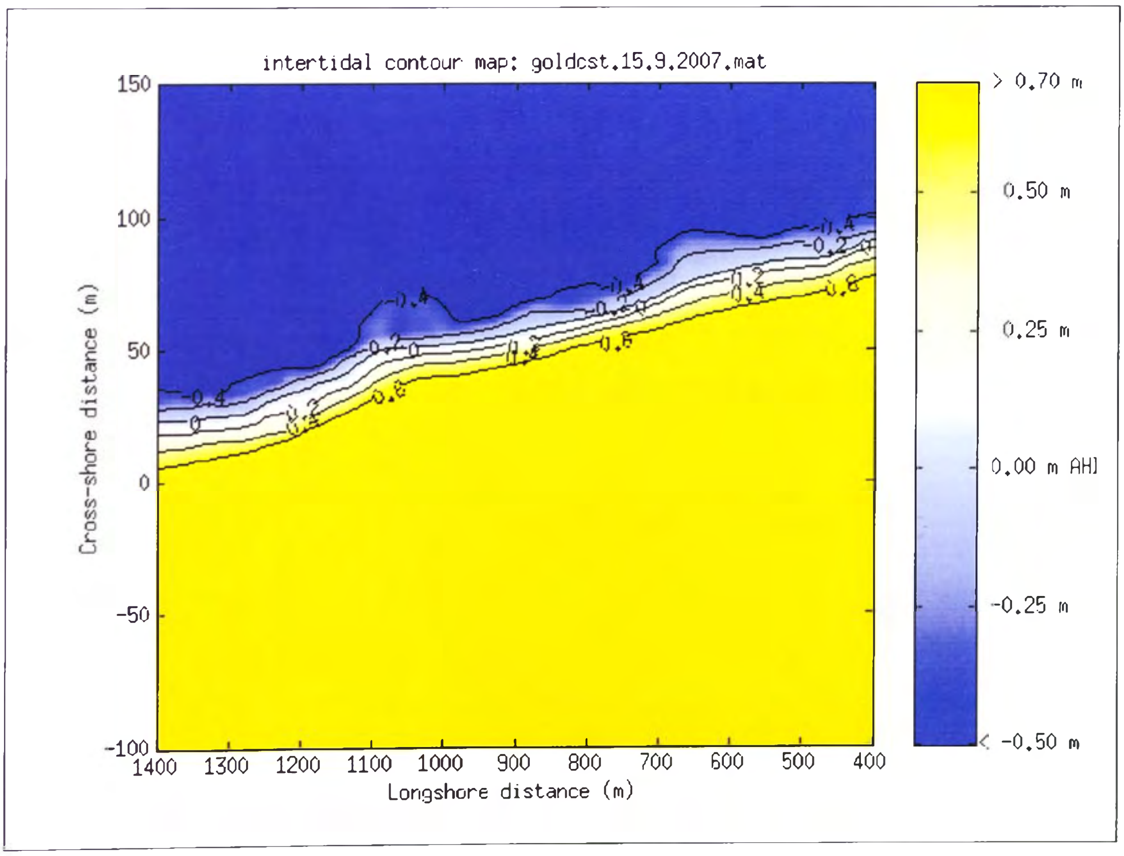


WRL Report No. 2008/06	DEFINITION SKETCH INTERTIDAL BATHYMETRY FROM HOURLY WATERLINES	Figure 9.1 06037-9-1.cdr

AUGUST 2007



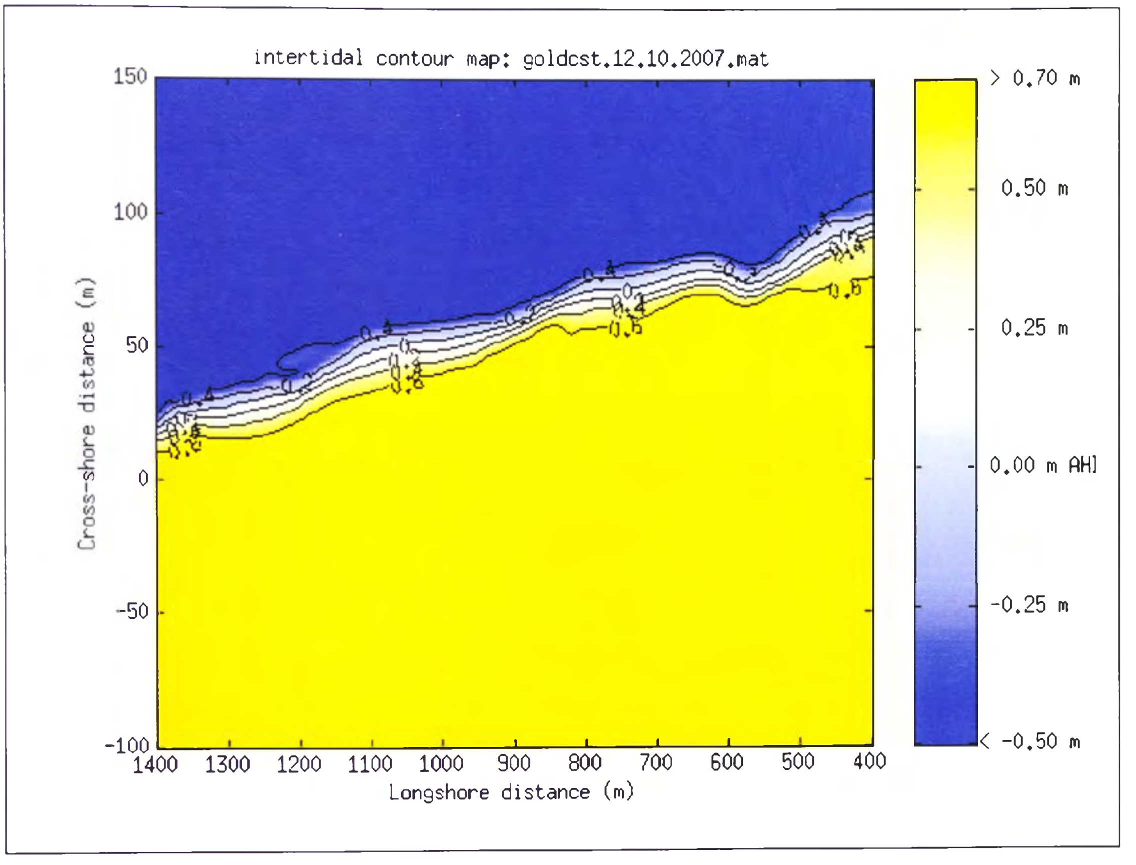
SEPTEMBER 2007



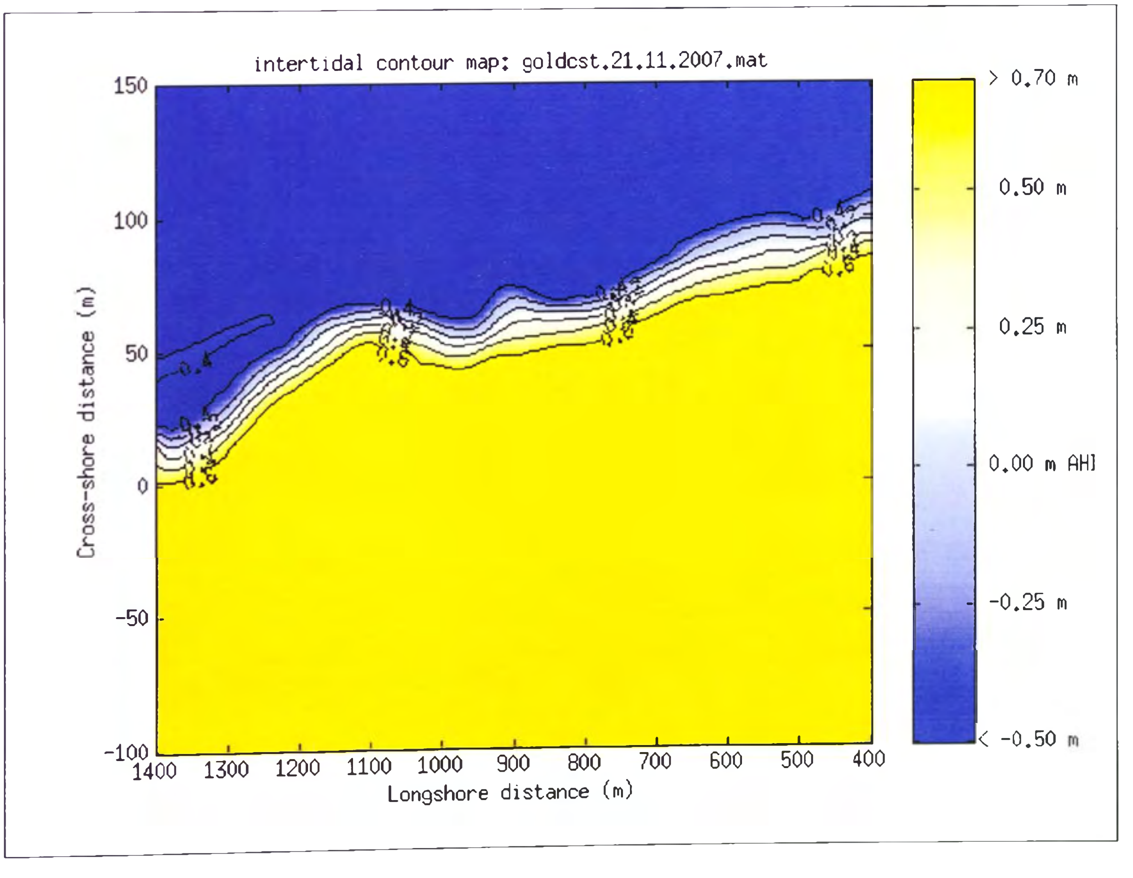
WRL Report No. 2008/06	BEACHFACE MAPPING AUGUST, SEPTEMBER 2007	Figure 9.2

06037-9-2.cdr

OCTOBER 2007

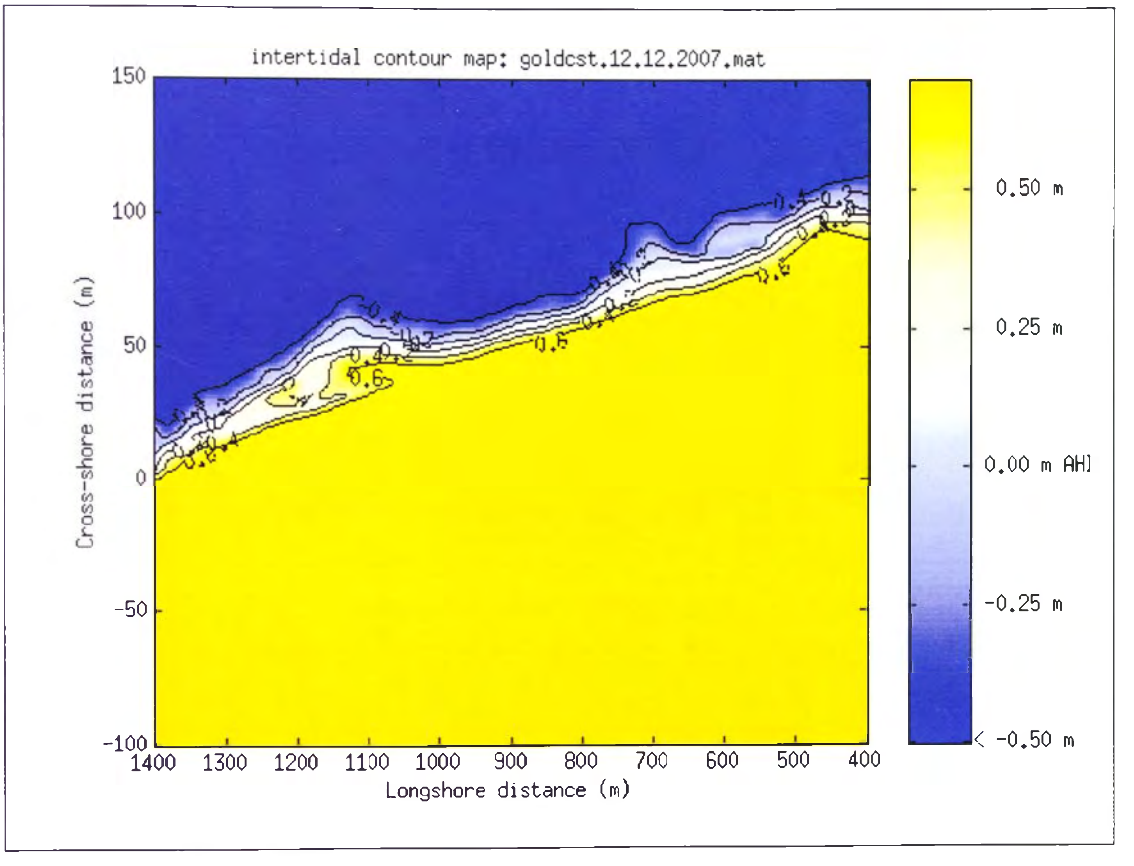


NOVEMBER 2007

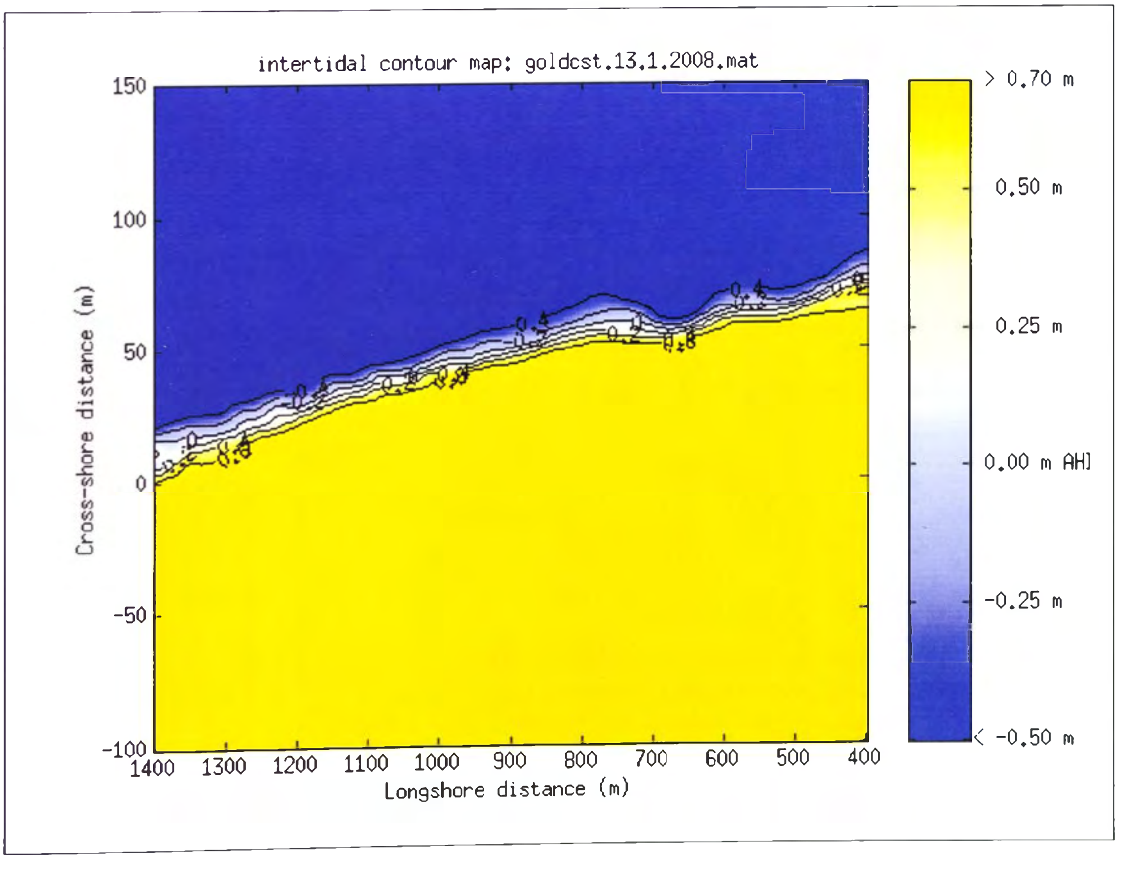


WRL Report No. 2008/06	BEACHFACE MAPPING OCTOBER, NOVEMBER 2007	Figure 9.3

DECEMBER 2007

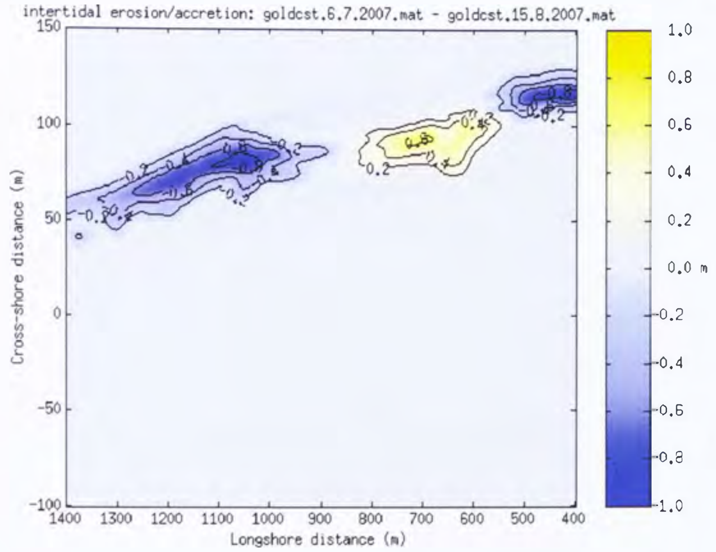


JANUARY 2008

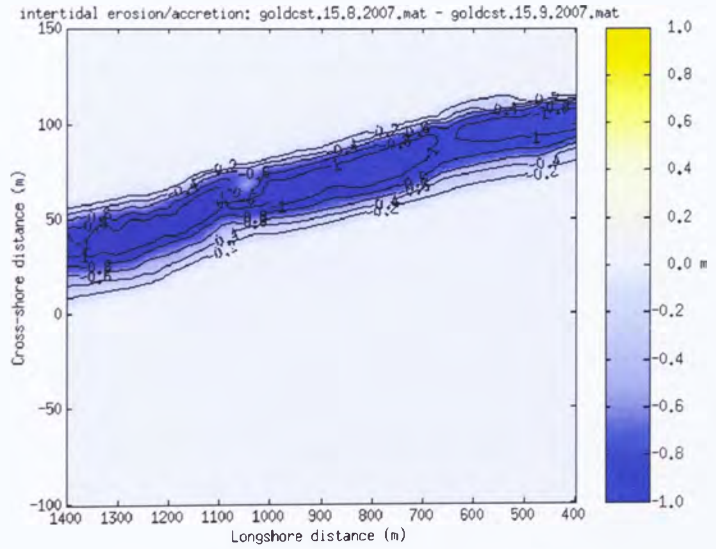


WRL Report No. 2008/06	BEACHFACE MAPPING DECEMBER 2007, JANUARY 2008	Figure 9.4

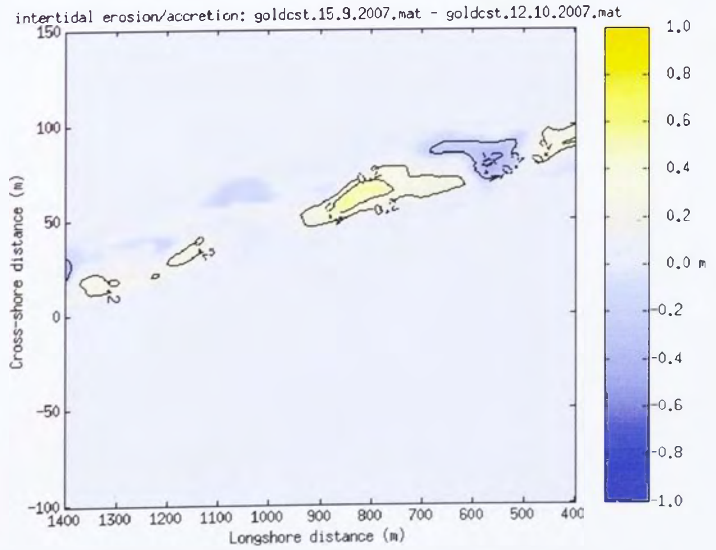
JULY - AUGUST 2007



AUGUST - SEPTEMBER 2007



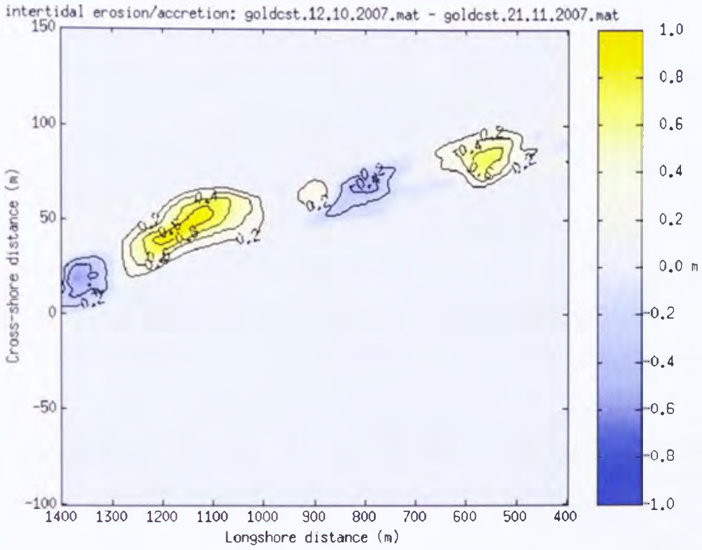
SEPTEMBER - OCTOBER 2007



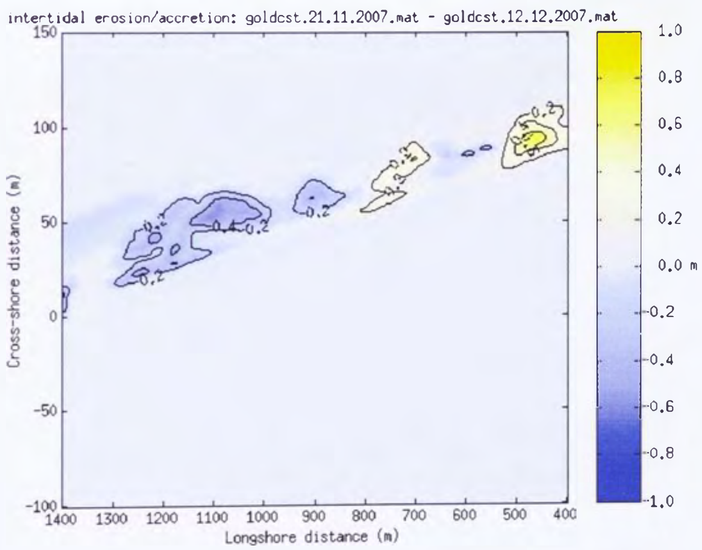
WRL Report No. 2008/06	MONTHLY EROSION/ACCRETION: JULY - OCTOBER 2007	Figure 9.5

06037 9-5.cdr

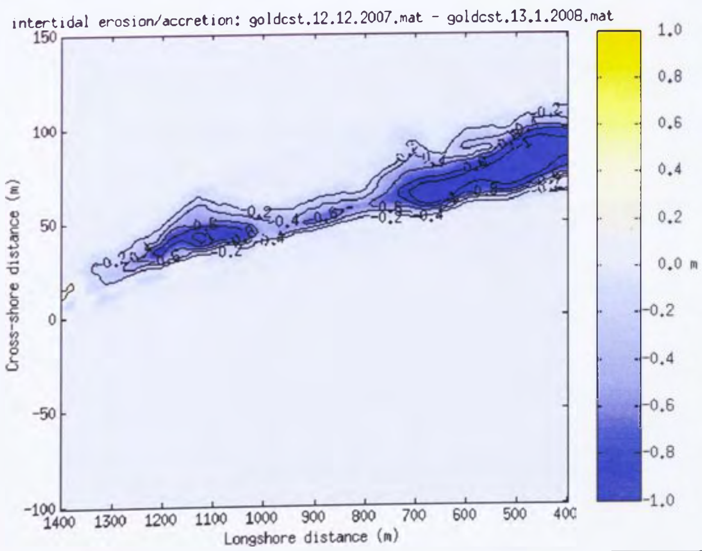
OCTOBER - NOVEMBER 2007



NOVEMBER - DECEMBER 2007



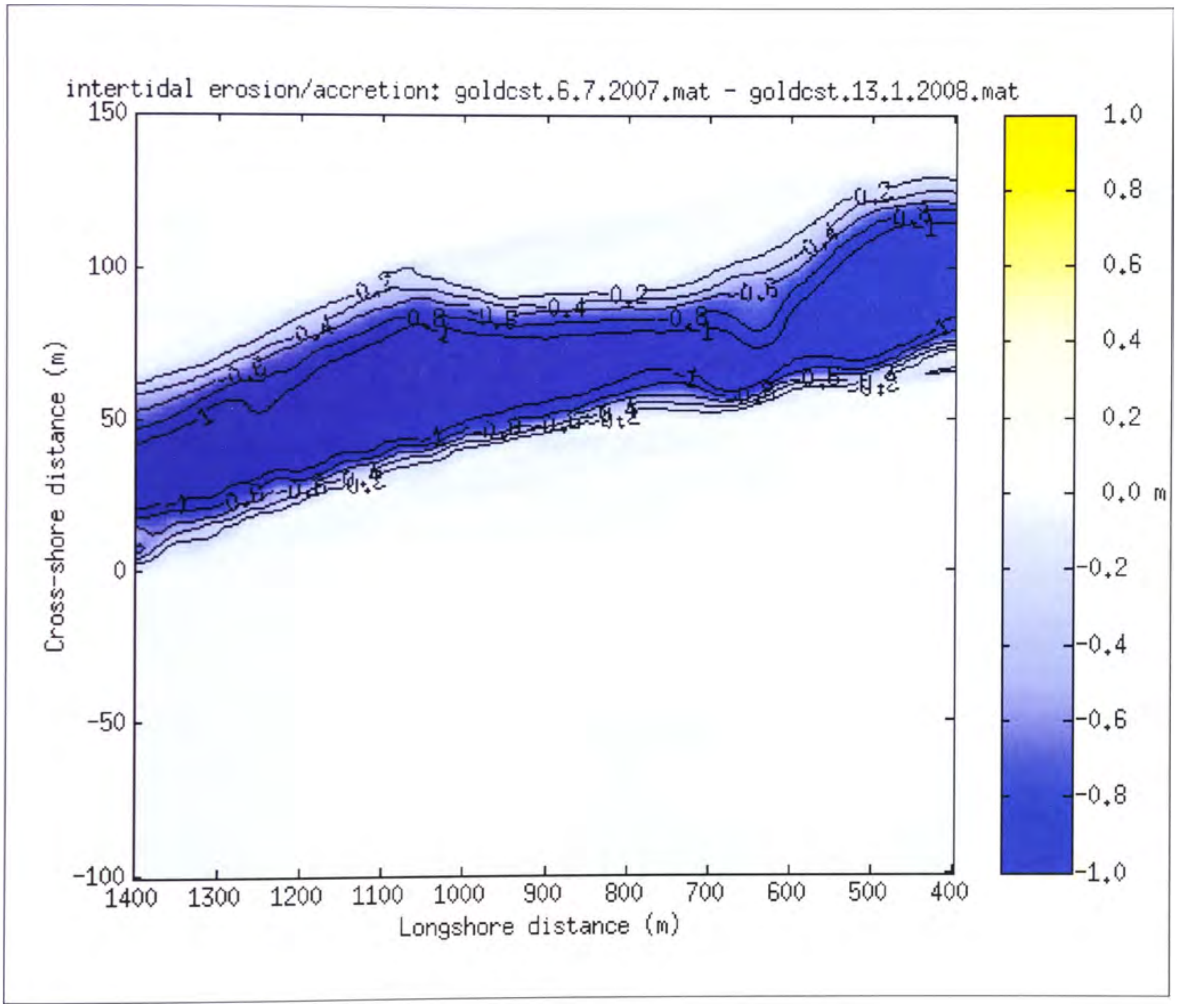
DECEMBER 2007 - JANUARY 2008



WRL Report No. 2008/06	MONTHLY EROSION/ACCRETION: OCTOBER 2007 - JANUARY 2008	Figure 9.6

06037-9-6.cdr

NET CHANGE: JULY 2007 - JANUARY 2008



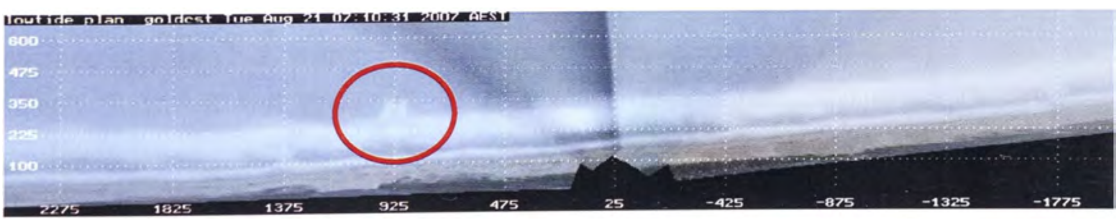
WRL Report No. 2008/06	NET EROSION/ACCRETION: JULY 2007 - JANUARY 2008	Figure 9.7 06037-9-7.cdr

10. ASSESSMENT OF WAVE BREAKING AT THE REEF

It was noted in Section 2.1 that the Gold Coast Reef was designed to serve two functions. The dual purpose of the structure is to: (1) act as a 'control point' at Narrowneck to promote beach widening and extend the design life of the sand nourishment, and (2) to improve the surfing conditions at Narrowneck (McGrath *et al.*, 2000).

The regional-scale focus of this monitoring program does not permit the use of the video system to assess the surf 'quality' (i.e. wave shape, peel angle, etc) at the reef. Current examples of an oblique (single camera) image and corresponding merged-rectified (four camera) image that clearly show wave breaking across the northern and southern halves of the reef, are shown in Figure 10.1 (image date 21st August 2007).

In earlier monitoring reports completed during the construction of the reef, the progressive increase in the occurrence of wave breaking was documented and quantified as additional geocontainers were added. Further geocontainers were placed on the reef crest in late 2001, November 2002 and again in January, July and August 2004 (refer Section 2.2). Since 2003, it has been observed that waves now break across the reef structure once the incident significant wave height exceeds approximately 1 m.



WRL Report No. 2008/06	VISIBLE WAVE BREAKING ON REEF (21 AUGUST 2007)	Figure 10.1

11. CONCLUSIONS

11.1 Overview

The present six month monitoring period to January 2008 marks seven and a half years since the completion of beach nourishment in mid 2000 at the northern Gold Coast, and seven years since the major phase of reef construction was completed in December 2000. A limited number of additional geocontainers were placed across the crest of the Gold Coast Reef in November – December 2001 (17 bags), November 2002 (10 bags) and January - August 2004 (15 bags). During the period January – April 2005 approximately 59,000 m^3 of additional sand dredged from the Broadwater was placed along the northern Gold Coast beachfront. Additional minor nourishment of approximately 6,400 m^3 of sand, sourced from excavations undertaken at local development sites, was placed during the period February to July 2007. During the current monitoring period August 2007 to January 2008, minor nourishment of the beach has taken place at Higman Street, with 9,790 m^3 of sand being placed between 16th November 2007 and 28th November 2007.

11.2 Beach Width

The morphology of the northern Gold Coast beaches from August to November 2007 was dictated be episodes of high wave energy which occurred at least once every month and lasted of the order of five days. During these times of higher wave energy, the significant wave height typically peaked at 2.5 to 3.5 m, and resulted in wave breaking across a detached offshore bar, with the beach showing characteristics typical of LBT or RBB beach states. Between the episodes of high wave energy, ambient wave conditions with significant wave height of 0.7 m to 1.5 m and peak spectral wave period of 8 to 10 seconds impacted the coastline, and the beaches responded with changes in nearshore morphology. Typically pockets of sand shifted into transverse bars, and many cross shore rips were seen along the beach, as the beach changed to a lower energy TBR state.

Late in December 2007 through to early January 2008 a deep tropical low pressure system impacted the Gold Coast beaches, with significant wave height peaking at 5 m, and remaining in excess of 4 m for six consecutive days. At the onset of these higher wave conditions, the beach migrated to a higher energy dissipative state, with a wide detached offshore bar as well as second detached bar nearer to shore. The nearshore bar formed through erosion of sand from the beachface, and resulted in a general flattening of the surfzone. The monthly bursts of higher wave energy from August to November, as well as the extreme storm event in December and January resulted in a net narrowing of the northern Gold Coast beaches during the present monitoring period.

A qualitative visual assessment of the net regional trends in beach adjustment during this period can be seen by contrasting images of the beach obtained at the start and end of the present six month monitoring period. Figure 5.2 shows the snap images obtained at mid-tide from Camera 1 (south) on 01/08/07 and 31/01/08, respectively. The corresponding snap images of the northern beaches obtained from Camera 4 are shown in Figure 5.3. Both south and north of the ARGUS station, extensive narrowing of the beach is evident from Figures 5.2 and 5.3. A wide flat surfzone and submerged bar can also be clearly seen in Figure 5.3 at the end of January 2008, as a result of the heavy storm conditions experienced throughout the previous month.

Extending this qualitative visual assessment of images to include the entire eight and a half year monitoring period (Figures 5.4 and 5.5), it is observed that during the first six months (August 1999 to January 2000) the on-going nourishment of the northern beach was visible, with no change to the southern beach as this area was yet to be nourished at that time. A dramatic change in the width of the beach occurred between January 2000 and August 2000, when nourishment of the entire stretch of coastline from Narrowneck to Cavill Avenue was completed, with the result that the mid-tide beach can be seen to have nearly doubled in width during this period. During the next six months to January 2001 the beach alignment became more uniform alongshore, as the coastline re-adjusted to the new sand volume available within the beach system. February 2001 to July 2001 saw a general erosional trend along the northern Gold Coast beaches, in response to a succession of storms. This contrasted to the following six months (August 2001 to January 2002) during which the beaches recovered, returning to a similar state as was seen 12 months previously in January 2001. A return to prior conditions following a period of storm erosion indicates that the beaches of the northern Gold Coast at that time were close to regaining a new equilibrium, post the extensive sand nourishment works completed in mid 2000.

From January 2002 to August 2002 the beach of the northern Gold Coast were moderately depleted, with the beach at the end of this period intermediate to the eroded state that prevailed in August 2001, and the most accreted state that was recorded at the end of January 2002. By January 2003 the beaches had returned to their more accreted state, similar to beach conditions observed 24 and 12 months previously in January 2001 and January 2002. During February 2003 to August 2003, the beaches again experienced a period of modest erosion. Both to the north and south, the beach at the beginning of August 2003 appeared very similar to the conditions that prevailed 12 months previously in August

2002. Moderately depleted conditions prevailed, that were intermediate to the more accreted states observed in January 2002 and January 2003, and the more eroded state that prevailed two years previously in August 2001. From August 2003 to January 2004 minimal storm wave activity was observed, and the beaches of the Northern Gold Coast generally accreted. During February 2004 to July 2004 large wave events occurred in March, and the beaches were observed to be cut back during that time. However, by the end of July 2004, both the northern and southern beaches had recovered. From August 2004 to January 2005, storms in October and again in January caused a general movement of sand offshore, with the visible width of the subaerial beach decreasing during this time, and the widening of the surf zone as the outer bar translated further seaward.

During February 2005 to July 2005 both the northern and southern beaches exhibited similar beach width and shoreline alignment, with the exception of the region in the immediate vicinity of Narrowneck, where a modest trend of net beach widening was discernable. From August 2005 to January 2006, along the southern beach no net change in the visible (subaerial) beach was discernable, with similar conditions also observed along the northern beach. The exception to this observation of similar conditions was along the northern beach north of Narrowneck, where a general straightening of the beach within this region was observed.

During the period from February 2006 to July 2006 a subtle trend of a narrower beach was observed to the south, with a more pronounced decrease in beach width to the north of Narrowneck. In contrast, in the vicinity of the reef site at Narrowneck the visible beach was similar at the beginning and end of this six month period. During the period from August 2006 to January 2007, the wave climate was predominantly moderate to low, with no storm wave occurrences, resulting in a general widening in both the northern and southern sections of the beach. The beach width and alignment at the end of January 2007 was comparable to that at the end of January 2006, with the beaches recovering from the higher energy period observed in the early period of 2006.

Ongoing moderate wave conditions with short duration bursts of higher wave energy dominated the wave climate of the Northern Gold Coast beaches throughout the first half of the monitoring period February to July 2007. Generally during the months of February and March there was little net change in beach width both south and north of the ARGUS station. Lower wave conditions throughout late April and into May of 2007 forced the movement of sand from the surfzone to the beachface, forming a widening LTT. This appeared to create a slightly wider beach at some locations for a short period of time. Long wave period storm events in June and again in July, however, dictated the morphological changes of the preceding four months, again eroding material from the beachface as the beach shifted towards a higher energy intermediate state. This resulted in very little overall net change in beach width during the monitoring period February to July 2007.

During the current monitoring period August 2007 to January 2008, the beach morphology was dictated by a series of smaller storm events from August to November, followed by a large storm event in late December and January. The ongoing effects of the smaller storms throughout the earlier months of the current monitoring period, as well as the rapid changes in beach morphology experienced during the December and January storm, resulted in a much narrower beach at the end of January 2008.

Based upon the quantitative analysis of weekly shorelines during the present monitoring period 01/08/07–31/01/08 it can be seen from Figure 6.2 that the beach along the 4,500m study region varied in width (relative to the dune reference line) from approximately 40m to 115m. The envelope of beach width changes is the most extensive south of the ARGUS station and north of Narrowneck, varying by 50 m to 60 m during this period.

Median beach width at mid-tide (relative to the dune reference line) along the 4,500m stretch of coastline during the period 01/08/07–31/01/08 was in the range of 65 – 95 m. As was discernible from Figure 6.2, relative to the dune reference line the mean beach width was greatest from approximately 500 m to 1000 m alongshore (to the north of the ARGUS station), with a width of approximately 95 m. The standard deviation of weekly shorelines varied along the length of the beach, being relatively regular with high variability to the north of the Narrowneck reef and south of the ARGUS station, but a significantly lower standard deviation between the ARGUS station and Narrowneck. The minimum standard deviation was of the order of 7 m, while the maximum was approximately 15 m.

The weekly shoreline data for the current monitoring period was re-analysed to assess beach width changes relative to the mean shoreline position for the preceding six month period (Figure 6.4). The analysis showed that during the present monitoring period, the beaches of the northern Gold Coast were predominantly narrower than the previous monitoring period. The maximum beach width from August 2007 to January 2008 was approximately 20 m wider than the median beach width from the preceding six month monitoring period, however, the minimum beach width was approximately 40 m narrower.

Over the entire 102 month monitoring period mid-tide beach width (relative to the dune reference line) along the full 4,500 m study region can be seen to have varied in the order of 100m. Beach width changes of typically up to 50m have been recorded at all positions alongshore. A general trend of increasing beach width was apparent during the initial 18 months of monitoring, clearly indicating the dominant effect of nourishment during this period. In contrast, during the period 18 – 24 months, a general erosion trend occurred. The monitoring period February – July 2001 was characterised by a series of storms that resulted in the net recession of northern Gold Coast beaches. From August 2001 to January 2002 a distinct trend of beach recovery at all locations alongshore was observed. By January 2002 the beach had recovered to the extent that beach widths were sufficiently regained to match the conditions that were measured 12 months previously in January 2001. From February 2002 to July 2002 a modest net erosional trend was recorded, which again reversed though to January 2003, at which time the beach at all locations alongshore exhibited marked recovery, returning to the accreted conditions that prevailed 12 and 24 months previously in January 2002 and January 2001. During February 2003 to July 2003 an erosion trend was again evident. The beach receded, in response to the occurrence of the greater frequency of storm events during this time.

Net accretion at all locations alongshore was observed during the period August 2003 to December 2003, followed by the commencement of erosion in January 2004, in response to two periods of higher waves (> 2m significant wave height). From February 2004 to July 2004, two large storm events in March, followed by continued moderate wave activity in April, caused the beach at all locations to initially continue this erosion trend. However, by the end of July 2004 the beach had generally recovered to the conditions that prevailed at the end of January. The exception to this was in the region between Narrowneck and the cameras, where more limited recovery was observed. From August 2004 to January 2005 this general accretionary trend initially continued. However, due to the large storm wave event in the second half of October 2004 beach recession was then observed at all locations alongshore. A two month period of beach recovery followed, when beach width temporarily increased, but was again removed by two storms in January 2005.

From February 2005 to July 2005, the beaches of the northern Gold Coast initially accreted due to generally mild wave conditions, then receded again to the end of July 2005, following the occurrence of a series of moderate storm wave events. During August 2005 to January 2006, the beaches oscillated around the same position, largely in response to the movement of the inner bar. As this feature initially became fully welded to the beachface, the beaches of the northern Gold coast generally increased in width accordingly. But as the mild wave conditions persisted through the second half of 2005, this resulted in the continued landward movement of a portion of the inner bar sand volume, resulting in a narrowing of the low tide terrace, and subsequent narrowing of the total beach width. At the end of 2005, periods of slightly elevated wave energy caused the removal of this newly accreted sand from the beachface back to the low-tide terrace, causing re-widening of the beaches at this time. The partial separation of the inner bar from the beachface in response to a single storm wave event in January 2006 caused the beaches to narrow again. A major east coast low pressure weather system in early March 2006 caused the beaches of the northern Gold Coast to transition to a lower gradient and dissipative beach state, characterised by the removal of sand from the beachface and formation of a distinctive inner bar and outer storm bar system. A marked narrowing of the beach was observed at all locations alongshore. By May 2006 the inner bar had temporarily re-attached to the beachface to form a low tide terrace, but in June this detached again as the sand moved back into the inner surfzone, in response to a general increase in the incident wave energy. By the end of July 2006 the beach was continuing to recover from the significant erosion event of five months previously, as sand slowly moved back onshore.

During August and September of 2006, relatively consistent moderate wave conditions prevailed at the Gold Coast. During this time, the beach width fluctuated, and the double bar system established in March of 2006 was still evident for short durations during larger wave conditions. The beaches generally continued to increase in width throughout the last months of 2006, and by the end of the year, were almost completely recovered from the large east coast low pressure storm system which occurred in March. During this period, the beaches were predominantly in an intermediate state, fluctuating between RBB characteristics during moderate energy times, and transverse semi-attached bar systems during lower energy periods. Ongoing moderate wave conditions with short duration bursts of higher wave energy dominated the wave climate of the Northern Gold Coast beaches from January to March 2007. The higher wave energy events resulted in slight localised pockets of erosion of the beach during this time, however, the times of lower wave energy also saw sand accrete from the complex surfzone back to the beachface. Lower wave conditions throughout late April and into May of 2007 forced the movement of sand from the surfzone to the beachface, forming a widening LTT. This appeared to create a slightly wider beach at some locations for a short period of time. Long wave period storm events in June and again in July dictated the morphological changes during these months, again eroding material from the beachface as the beach shifted towards a higher energy intermediate state.

Bursts of high wave energy every month between August and November 2008 resulted in the beaches generally being in an eroded state for most of the current monitoring period. A detached offshore bar was typically always present during these months, although at times of lower wave energy it became inactive. In the nearshore zone, sand was observed to migrate in response to fluctuating wave conditions, with complex transverse bars and rips typically present. Late in December 2007 and in January 2008 the Gold Coast was struck by high wave energy conditions for a period of one week. This resulted in the beaches shifting to a double bar dissipative state, with a relatively two-dimensional appearance. This storm event resulted in significant erosion of the northern Gold Coast beaches.

At the completion of eight and a half years of monitoring and around seven and a half years since the completion of the major phase of sand nourishment of northern Gold Coast beaches, at all southern monitoring sites the beaches experienced a net accretionary trend up to the beginning of 2006, that was interrupted in early March by the occurrence of high waves associated with the relatively slow passage of an east coast low pressure weather system. The beach had a trend of steady recovery at all southern monitoring sites following the March 2006 event, but the high energy wave conditions of the current monitoring period and the effects of another large low pressure system have again resulted in significant erosion of the beach. At the completion of the current monitoring period, the beach is again as narrow as it was at the beginning of the monitoring program eight and a half years ago.

In contrast, to the north, following the initial phase of beach widening in response to nourishment, Figure 7.2 indicates that a net erosional trend prevailed until the March 2006 event. Following the March 2006 event, the northern beaches also begun to recover, until the start of the current monitoring period. North of the Narrowneck reef, the beach suffered extensive erosion during the present monitoring period, and at the end of January 2008, is narrower than at any other stage during the eight and a half year monitoring period. Immediately in the lee and just south of the Narrowneck reef the effects of the ongoing high energy conditions and the December 2007 – January 2008 low pressure system, have been erosion at a reduced level compared to other sections of the beach.

11.3 Cyclic-Seasonal versus Longer-term Erosion-Accretion Trends

It was noted in previous monitoring reports that for the period 2001 to mid 2004 a general cyclic pattern of beach variability had become evident. During this post-nourishment period, erosion was a characteristic of the first half of the calendar year, followed by accretion in the second half of the year. This general cyclic trend matches the prevailing wave climate of the south-east Queensland coast, whereby larger storm wave events are more frequent in the later summer and autumn months. This cycle was interrupted during 2004 due to a large storm event that occurred in October 2004, and the further breaking down of this previously dominant seasonal-cyclic trend was noted in to the first half of 2005.

The occurrence of significant beach erosion in March 2006 had had the effect of partially 'resetting' the cyclic erosion-accretion trends that dominated the northern Gold Coast during the years 2000 to 2003. Referring to both Figures 7.6 and 7.7, in 2006 this dominant cyclic behaviour re-emerged, characterised by erosion in the first half of the calendar year, followed by accretion throughout the last half of the year. Throughout the first quarter of 2007 the trend of erosion was evident, but significantly weaker than had been observed in the past, with this being followed by accretion in the second quarter of 2007. During the current monitoring period, August 2007 to January 2008, strong erosion occurred along the northern Gold Coast beaches, during a period that has typically been dominated by accretion in the past. This identifies a continuing breakdown of the seasonal cyclic erosion/accretion trends at the Gold Coast.

Application of the statistical auto-correlation method provides objective confirmation that the cyclic behaviour of beach changes at the northern Gold Coast has decreased since mid 2004. In the northern (Figure 7.6) and southern (Figure 7.7) sections of the 4,500 m study region, the beach width at these sites previously varied cyclically by up to +/- 20 m, indicating a range of approximately 40 m annual variability in beach width (although March 2006 and December 2007/January2008 exceeded this) that could be attributed to the seasonal wave climate. In contrast, referring to the upper panel in these figures, the underlying trend at these three sites is of a significantly lower magnitude.

Post-nourishment monitoring period	Years	Cyclic-seasonal variability (m)	Net erosion-accretion trend (m per year)	
			North	South
August 2000 – January 2004	3.5	±20	+1.1	+7.4
August 2000 – July 2004	4	±20	-0.6	+5.2
August 2000 – January 2005	4.5	±20	-1.8	+3.1
August 2000 – July 2005	5	±20	-1.1	+3.8
August 2000 – January 2006	5.5	±20	-0.2	+4.2
August 2000 – July 2006	6	±20	-1.3	+1.8
August 2000 – January 2007	6.5	±10	-1.8	+0.2
August 2000 – July 2007	7	±30	-1.2	-0.4
August 2000 – January 2008	7.5	±30	-1.9	-1.5

The table above summarises the six monthly results obtained to date. In the first six and a half years of analysis there had been a net accretionary trend persisting along the southern beaches within the 4,500 m study area, though a decrease in the rate of beach growth had emerged. For the past 12 months of monitoring, this trend has now been reversed to indicate long term erosion, at an increasing rate. Along the northern beaches a more constant erosion trend has been observed, with the current predicted erosion rate of -1.9 m per year being the highest rate of erosion predicted during the past seven and a half years.

The seven and a half years of data upon which these longer-term trends are inferred is now sufficiently long to permit the results of this analysis to be used for future forecasting with a reasonable degree of confidence, and to draw two important conclusions regarding the regional-scale trends at the northern Gold Coast. The first conclusion refers to the long term erosion/accretion trends observed to date. There has typically been net minor beach accretion in the south, with the magnitude of the accretion reducing annually until January 2007, when in fact the beach began to show an overall erosive trend, which is now predicted to be of the order -11.25 m (-1.5 m/yr). The erosion/accretion trend for the northern sections of beach is predicted as relatively stable net erosion of the order of -14.25 m (-1.9 m/yr). The second conclusion which can be drawn from the analysis is that the cyclic annual variability of beach width due to the seasonally varying wave climate was an order of magnitude greater than the underlying beach width trends.

The underlying trend of long term erosion for the monitored section of the northern Gold Coast beaches will require future planning and ongoing management. However, it is shorter-term storm erosion rather than the underlying but much longer-term erosion trends, which at the present time are of primary importance to the ongoing planning and management of northern Gold Coast beaches.

11.4 Shoreline Trends in the Vicinity of the Reef Structure

As per the northern and southern sections, the cyclic variation in beach width observed at Narrowneck (middle panel) for the seven and a half year period August 2000 to July 2007 is of the order of ± 20 m annually. It is interesting to note however, that the east coast low and associated erosion in March 2006 and the erosion from the sub-tropical low in December 2007/January 2008 exceeded this typical seasonal beach width fluctuation across the northern and southern sections of beach, while at Narrowneck, this has not been the case. Again, the occurrence of significant beach erosion in early March 2006 had the effect of 're-setting' this dominant seasonal-cyclic trend for a short period, although the trend has again been less apparent throughout the last half of 2007. Referring to the best-fit linear trend to these data as shown in the upper panel of Figure 8.8, the underlying trend at this site for the seven and a half year period to January 2008 is estimated to be of the order of -3.6 m per year (erosion).

The table below summaries the six monthly seasonal-cyclic versus longer-term erosion-accretion trends observed at Narrowneck.

Post-nourishment monitoring period	Years	Cyclic-seasonal variability (m)	Net erosion-accretion trend (m per year) Narrowneck
August 2000 – January 2004	3.5	±20	+1.6
August 2000 – July 2004	4	±20	-0.6
August 2000 – January 2005	4.5	±20	-1.4
August 2000 – July 2005	5	±20	-2.8
August 2000 – January 2006	5.5	±20	-2.3
August 2000 – July 2006	6	±20	-3.5
August 2000 – January 2007	6.5	±10	-3.8
August 2000 – July 2007	7	±20	-3.3
August 2000 – January 2008	7.5	±20	-3.6

From the results presented in Table 8.1 it is concluded that at Narrowneck the underlying local beach width trend to date, since the completion of sand nourishment in mid 2000, has been modest net erosion of the order 27 m (-3.6 m/yr). More significant to the future management of this region, is the observation (as per the northern and southern beaches) that the cyclic annual variability of beach width at Narrowneck due to the seasonally varying wave climate and storm events, was an order of magnitude larger than the underlying slightly erosional beach width trend.

11.5 Erosion-Accretion Trends in the Vicinity of the Reef Structure

Irregular patches of erosion and accretion occurred between July and August 2007 in the vicinity of the Narrowneck Reef. The magnitude of changes in beachface volume was moderate during this period with a net erosion of -4,860 m^3 over the full 1000 m stretch of beach, equating to -4.8 m^3 per metre of shoreline. Between August and September (Figure 9.5 mid panel) the beach suffered significant erosion due to two large storm events. During this one month period in excess of 1 m in vertical beachface elevation was lost over a beach width of 20 m, along the entire mapped section of beach. The net erosion between August and September was approximately -33,000 m^3, which equates to -33.0 m^3 per m of shoreline, between the levels of -0.5 m AHD and +0.7 m AHD.

From September to October 2007 (Figure 9.5 bottom panel) the beach had very little net change, with minor accretion observed at most locations alongshore. The net accretion volume over the entire 1000 m length of beach was approximately 2,220 m^3, equating to 2.2 m^3 per m of shoreline between -0.5 m AHD and +0.7 m AHD. From October to November 2007 (Figure 9.6 top panel) patches of both erosion and accretion occurred at different locations alongshore, with the most significant being a large zone of accretion extending to the north of the Narrowneck reef. In this accretion zone the beachface gained up to 1 m in vertical elevation during the one month period, with a net accretion along the entire beach of approximately 5,040 m^3, equating to 5.0 m^3 of accretion per m of shoreline.

From November to December (Figure 9.6 mid panel), the zone of accretion north of Narrowneck which developed throughout the previous month was again eroded. Along the remainder of the beach only minor pockets of localised erosion and accretion were observed, with the net erosion over the entire 1000 m stretch of mapped beach of -1,100 m^3, equating to approximately -1.1 m^3 of erosion per m of shoreline, between -0.5 m AHD and +0.7 m AHD.

Between December 2007 and January 2008, significant erosion of the beach again occurred as a result of extreme waves caused by an intense sub-tropical low pressure system passing the Queensland coast. The most extensive erosion was measured immediately to the north of the Narrowneck reef, and also further to the south of the reef, where in excess of 1 m in vertical beachface elevation was eroded. In the lee of the reef and the area immediately to the south of the reef also suffered erosion between December and January, but to a reduced extent, with a drop in vertical beachface elevation of approximately 0.6 m being observed. Analysis of the change in beachface topography between the elevations of -0.5 m AHD and +0.7 m AHD predicted a net erosion of approximately -16,600 m^3 over the 1000 m stretch of analysed beach, equating to -16.6 m^3 per m of shoreline. Significant erosion scarps observed on the Gold Coast beaches following the December/January storm event indicate that a significant quantity of sand in excess of that estimated by the ARGUS analysis was lost from the beachface above the level of +0.7 m AHD, but quantification of this is not possible with the present analysis system.

The net trend for the entire six-month period August 2007 to January 2008 was significant erosion across the entire 1 km stretch of beach. Referring to Figure 9.7, from 6th July 2007 to 13th January 2008, the 1000 m length of beach at Narrowneck eroded a net volume of approximately -48,600 m^3 between the elevations of -0.5 and +0.7 m AHD, equating to approximately -48.1 m^3 of erosion per metre of shoreline. It can be seen from Figure 9.7, that along the entire beach, the vertical beachface elevation was eroded by well in excess of

1 m over a beach width of 20 m to 30 m. The extensive erosion experienced throughout the current monitoring period was predominantly the result of three separate storm events which occurred in August, September, and December/January.

11.6 Wave Breaking at Reef

Wave breaking on the reef at Narrowneck continues to be commonly visible in images obtained by the coastal imaging system (Figure 10.1). In previous monitoring reports completed during the initial construction phase of the reef, the progressive increase in the occurrence of wave breaking was documented and quantified as additional geocontainers were added. Further geocontainers were placed on the reef crest in late 2001 and again in November 2002 (refer Section 2.2). Since that time it has been observed that waves break across the reef structure once the incident significant wave height exceeds around 1 m.

It is concluded that the reef continues to achieve the objective of enhancing potential surfing opportunities at Narrowneck.

12. ACKNOWLEDGEMENTS

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The owners of the Focus Apartments are thanked for continuing to permit the ARGUS system to reside within the roof of the Focus Building. Also we thank the building manager and caretaker for their support during routine maintenance visits to the site.

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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. Since June 2002 Doug has undertaken the day-to-day management of the Gold Coast ARGUS system. Luis Mallen Lopez of WRL completes the weekly analysis and updating of monitoring program information via the project web site, and provides assistance during the writing of the six monthly monitoring reports. Dr Ian Turner continues to provide guidance for the coastal imaging operations at WRL, and reviews the six monthly monitoring reports prior to publishing.

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 assisting to provide the continued development of practical tools for coastal monitoring and management.

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Appendix A

Week-to-a-Page: August 2007 - January 2008

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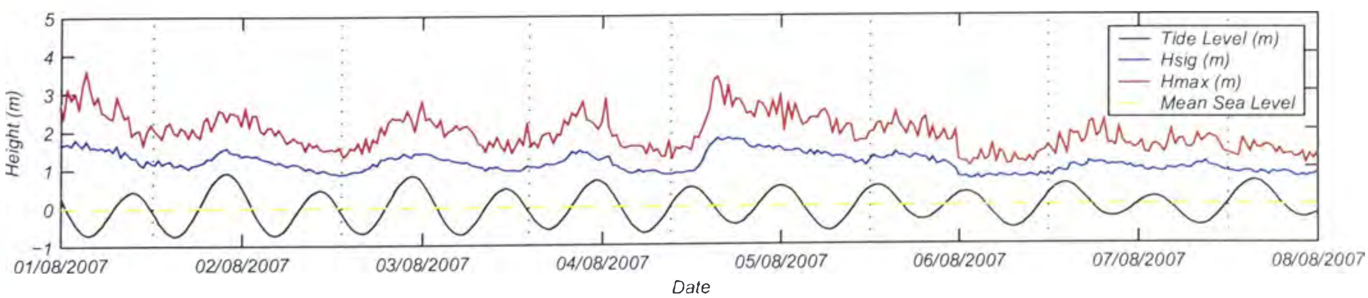

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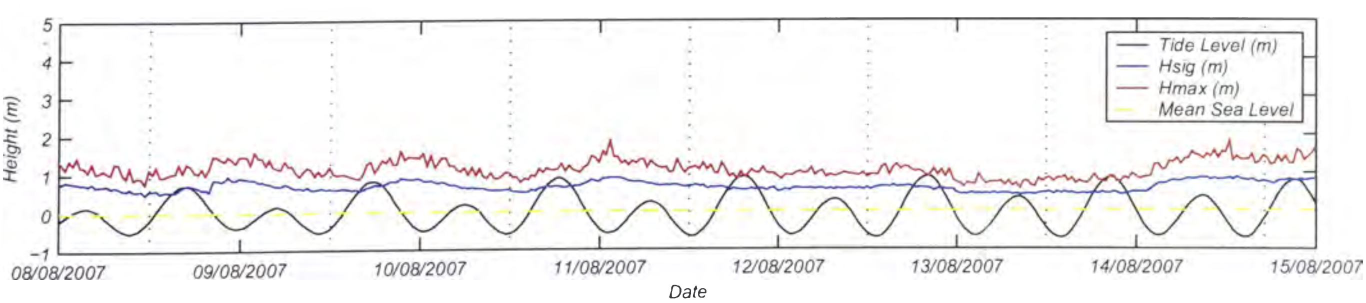

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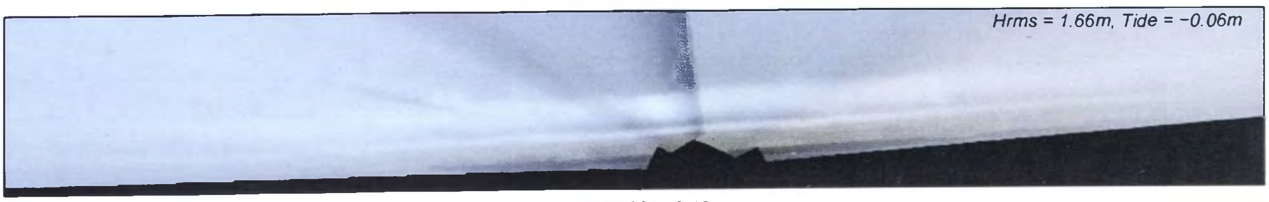

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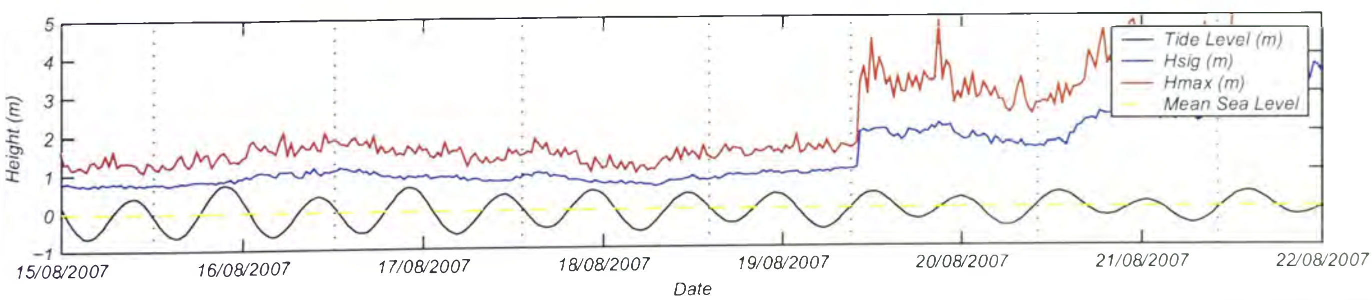

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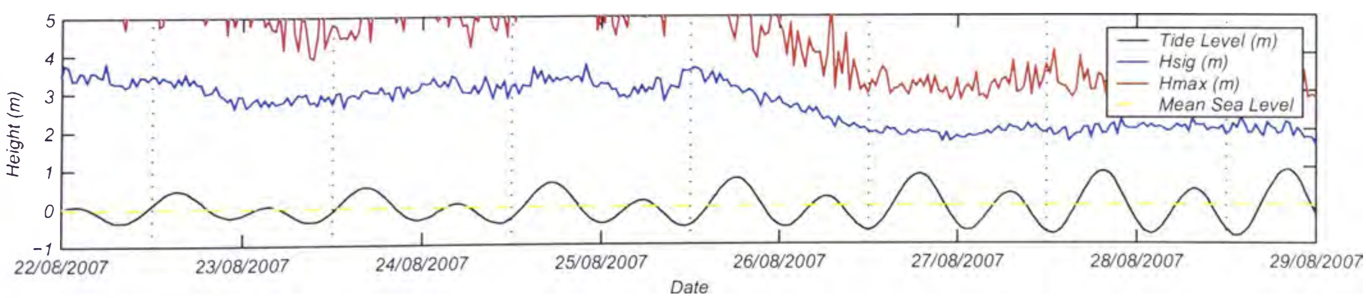

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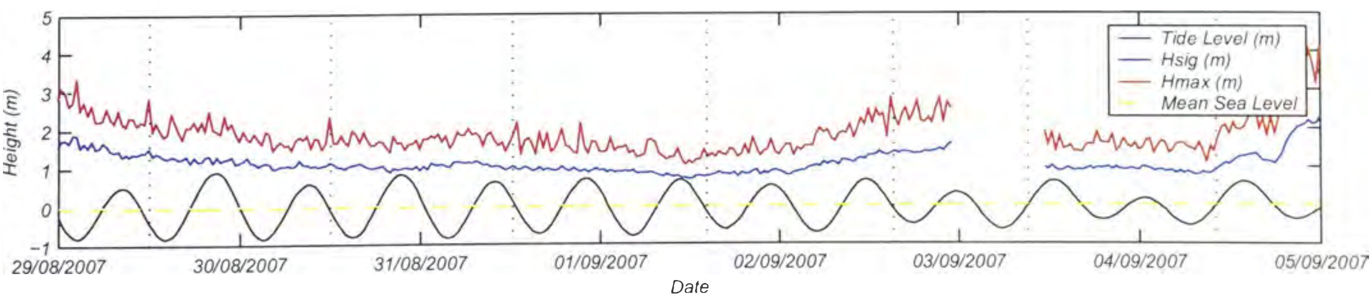

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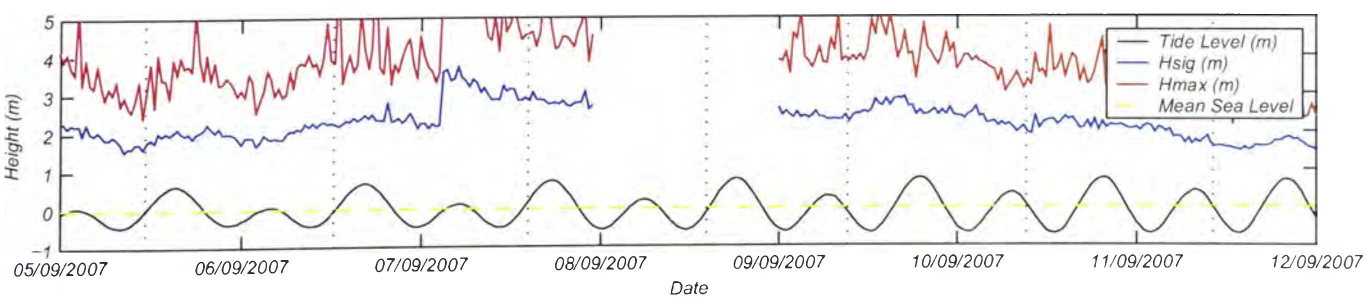

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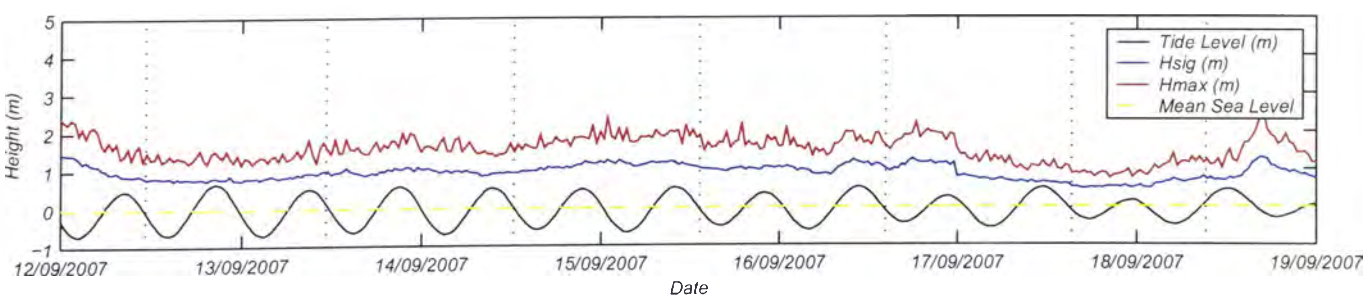

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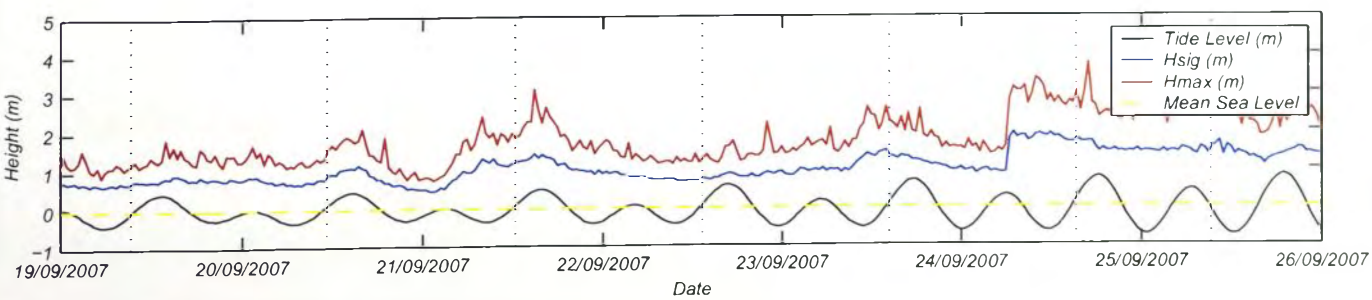

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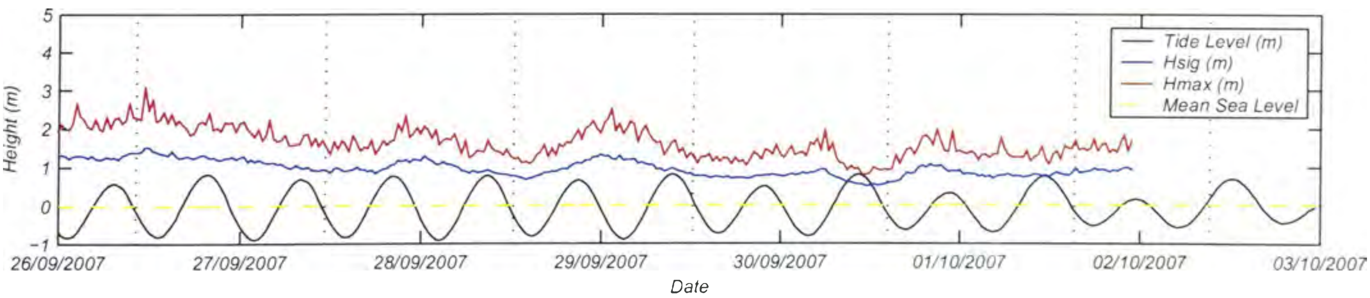

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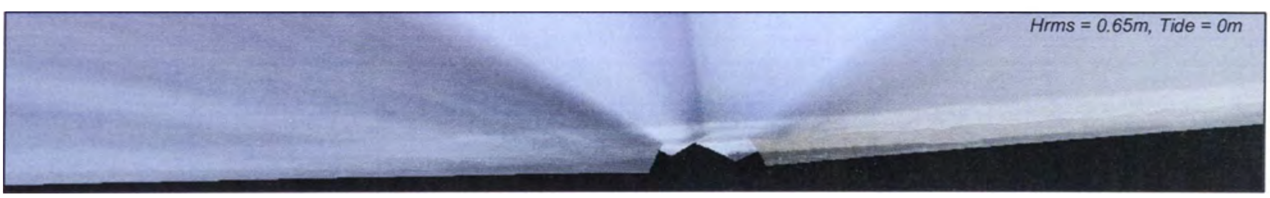

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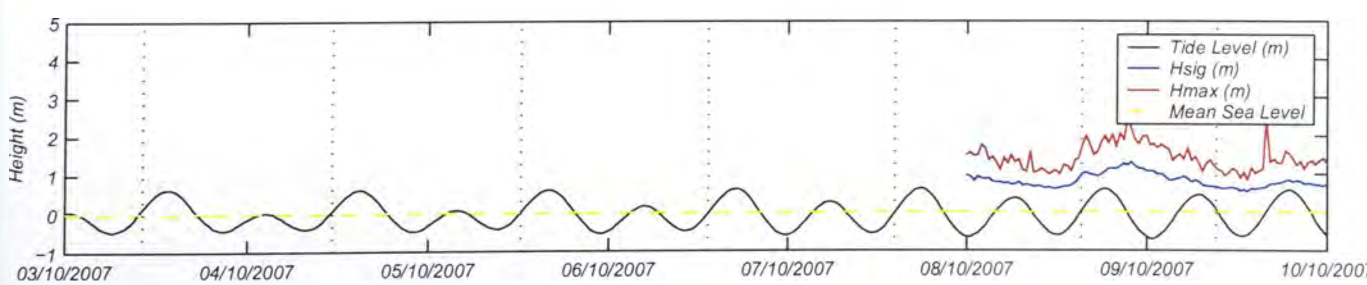

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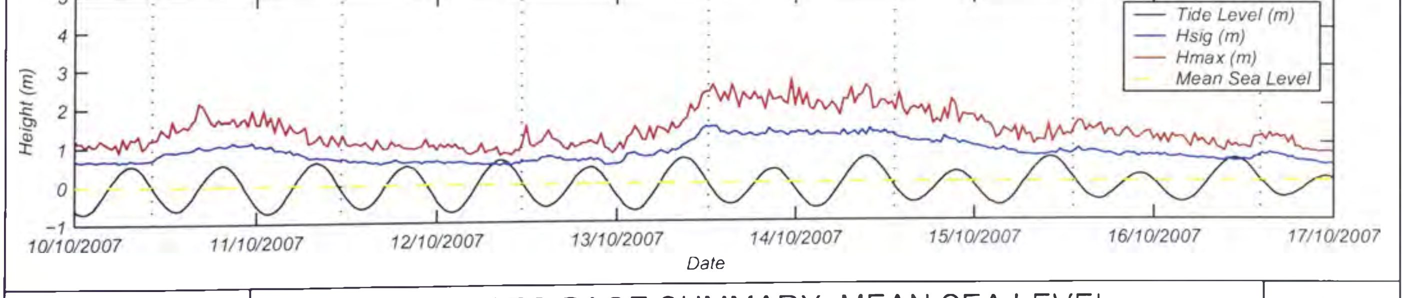

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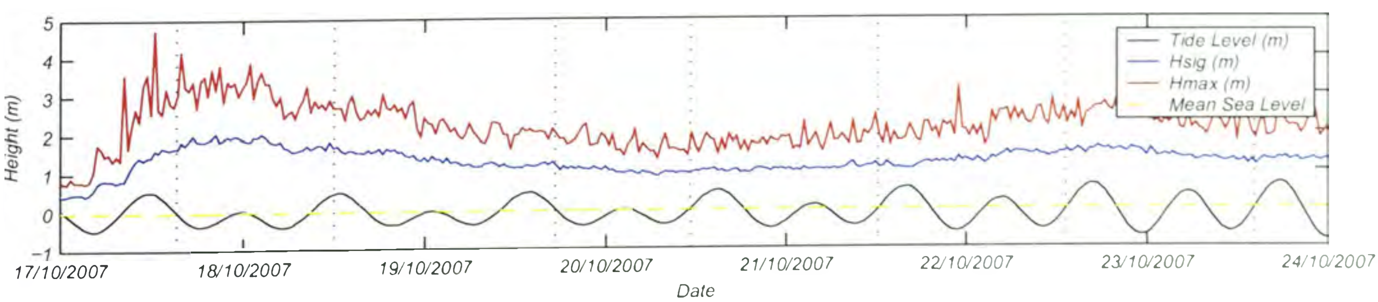

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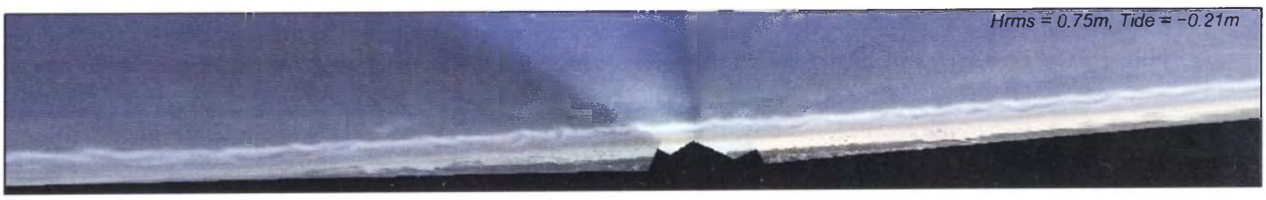

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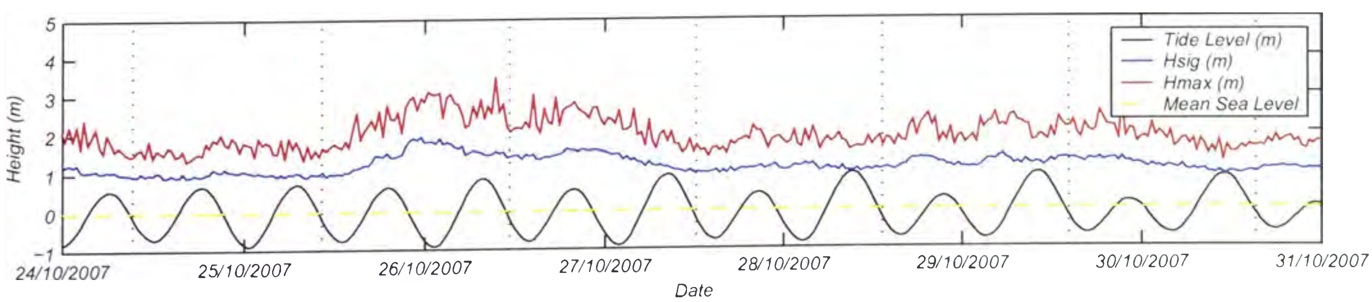

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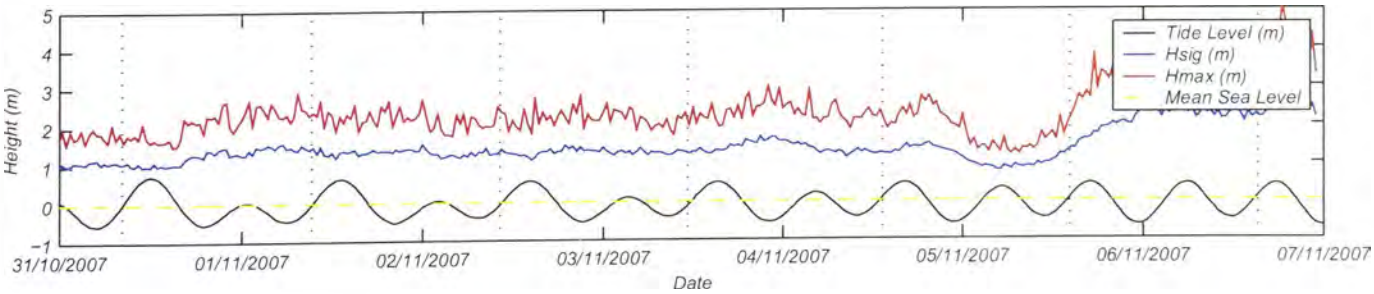

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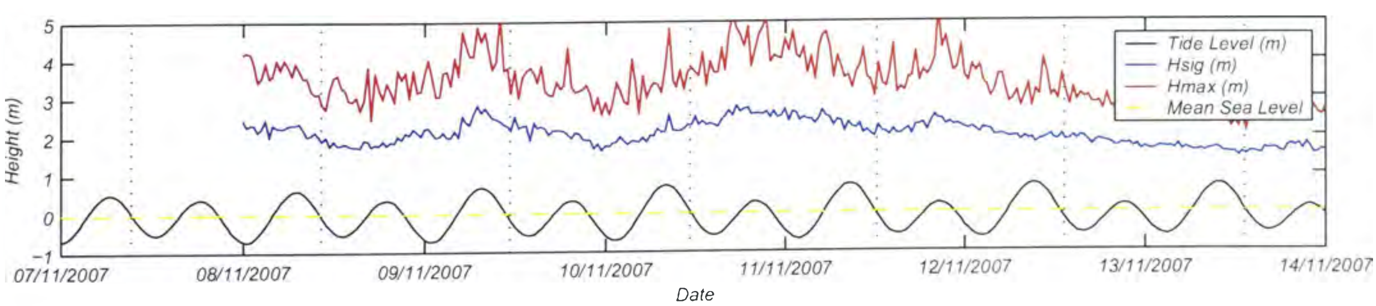

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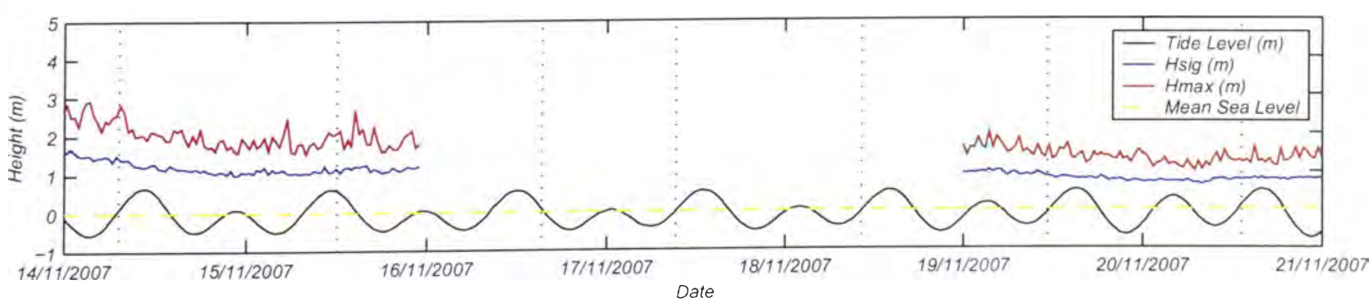


WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 14/11/2007 – 21/11/2007	Figure A16

21/11/2007 14:15

22/11/2007 15:15

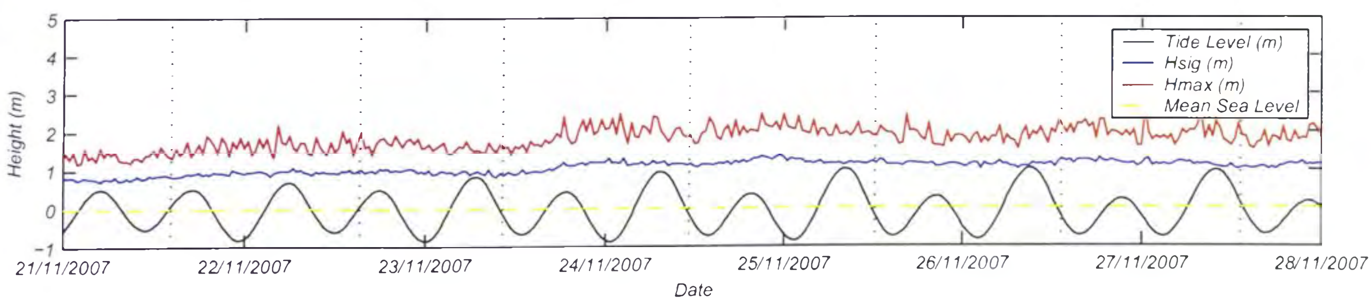
23/11/2007 10:15

24/11/2007 11:15

25/11/2007 12:15

26/11/2007 13:15

27/11/2007 13:15



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 21/11/2007 – 28/11/2007	Figure A17

28/11/2007 14:15

29/11/2007 15:15

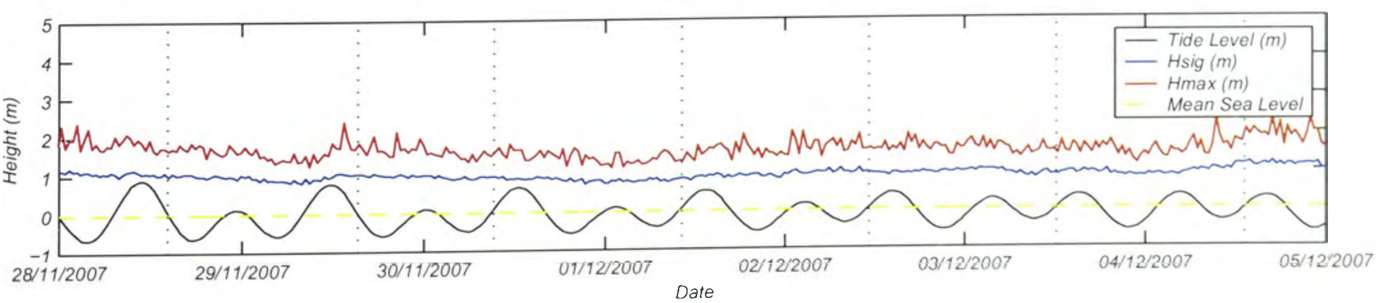
30/11/2007 09:15

01/12/2007 10:15

02/12/2007 11:15

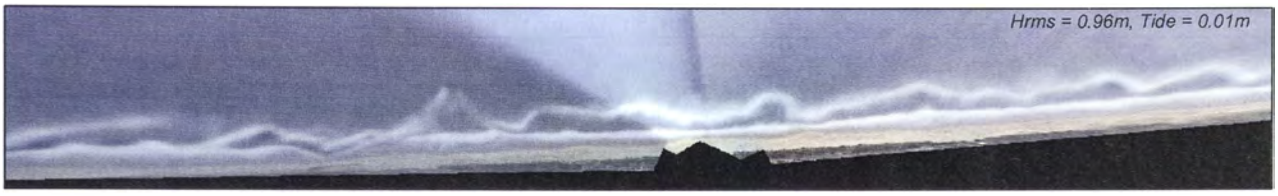
03/12/2007 12:15

04/12/2007 13:15



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 28/11/2007 - 05/12/2007	Figure A18

05/12/2007 14:15



06/12/2007 09:15

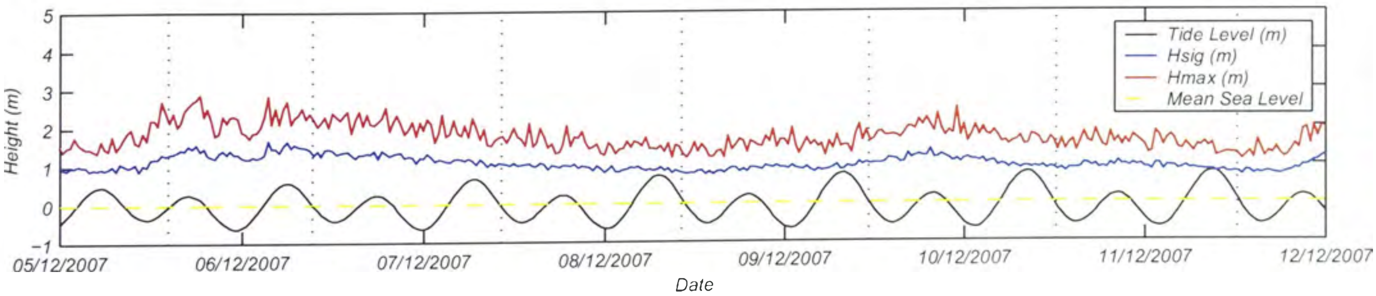
07/12/2007 10:15

08/12/2007 10:15

09/12/2007 11:15

10/12/2007 12:15

11/12/2007 12:15



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 05/12/2007 − 12/12/2007	Figure A19

12/12/2007 13:15

13/12/2007 14:15

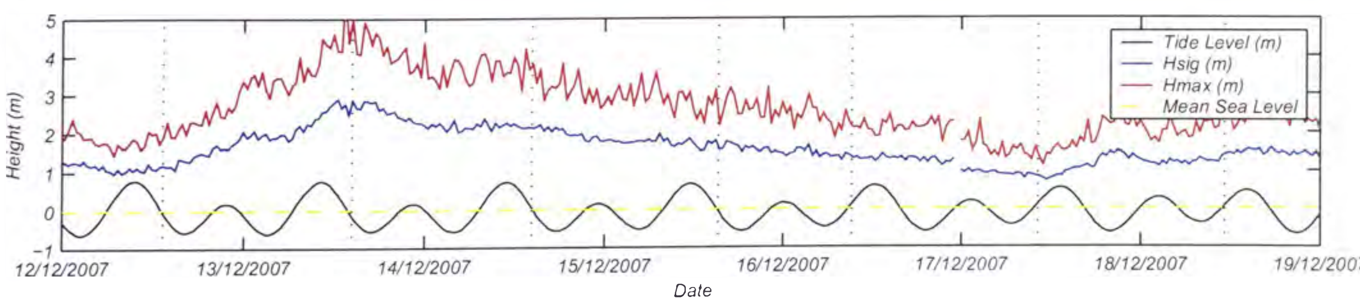
14/12/2007 14:15

15/12/2007 15:15

16/12/2007 09:15

17/12/2007 10:15

18/12/2007 11:15



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 12/12/2007 − 19/12/2007	Figure A20

19/12/2007 12:15

20/12/2007 14:15

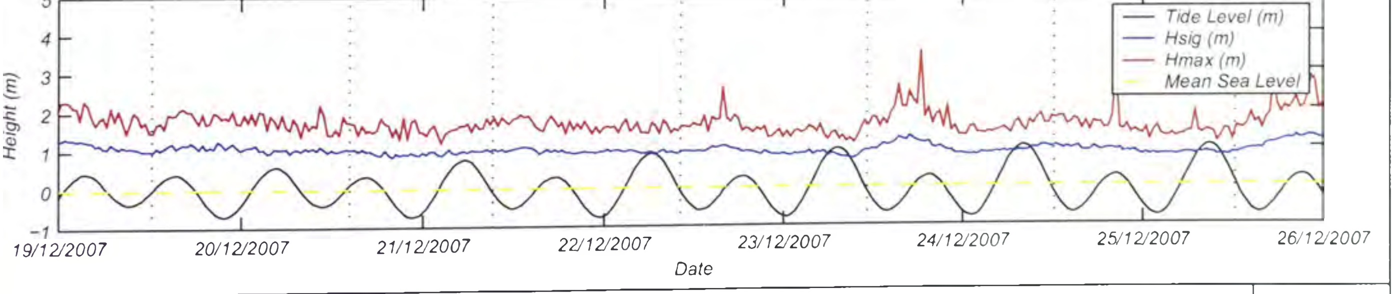
21/12/2007 09:15

22/12/2007 10:15

23/12/2007 11:15

24/12/2007 12:15

25/12/2007 12:15



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 19/12/2007 − 26/12/2007	Figure A21

26/12/2007 13:15

27/12/2007 14:15

28/12/2007 14:15

29/12/2007 08:15

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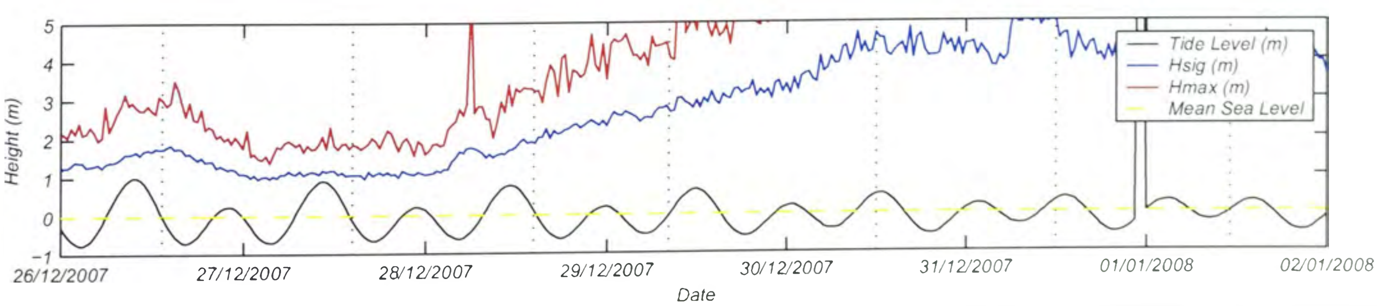
30/12/2007 12:00

image not available

31/12/2007 12:00

01/01/2008 11:10



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 26/12/2007 − 02/01/2008	Figure A22

02/01/2008 12:10

03/01/2008 14:10

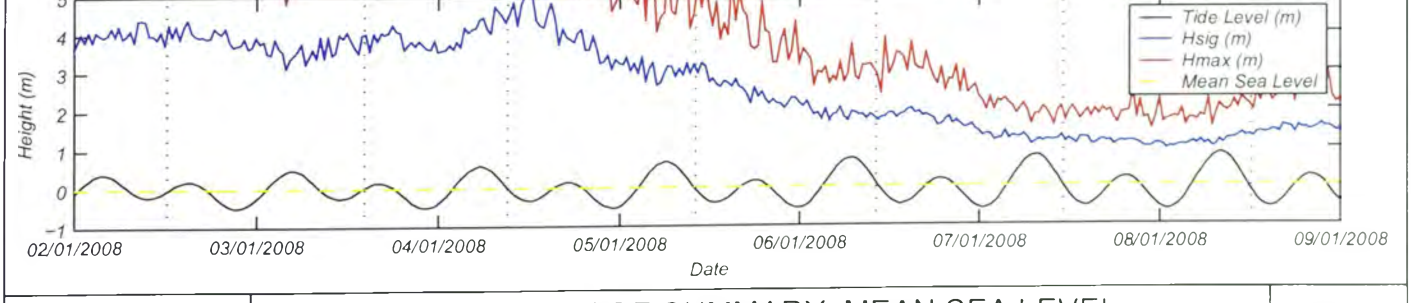
04/01/2008 09:10

05/01/2008 10:10

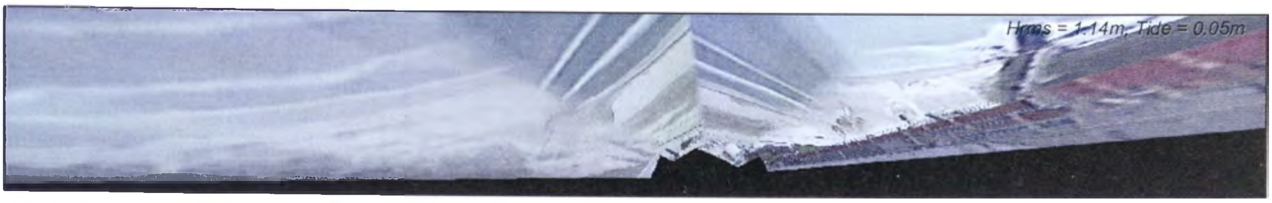
06/01/2008 10:10

07/01/2008 11:10

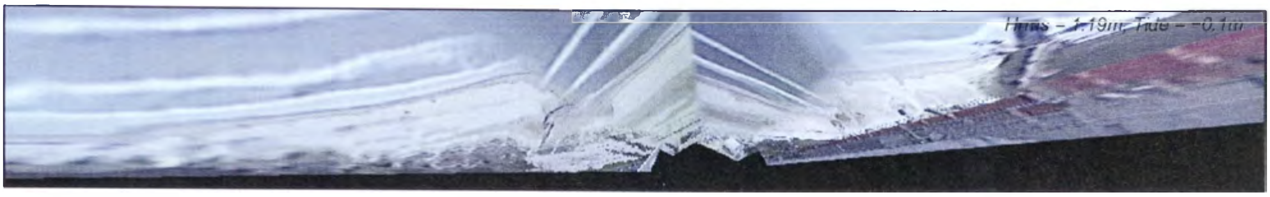
08/01/2008 12:10



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 02/01/2008 - 09/01/2008	Figure A23



09/01/2008 12:10



10/01/2008 13:10

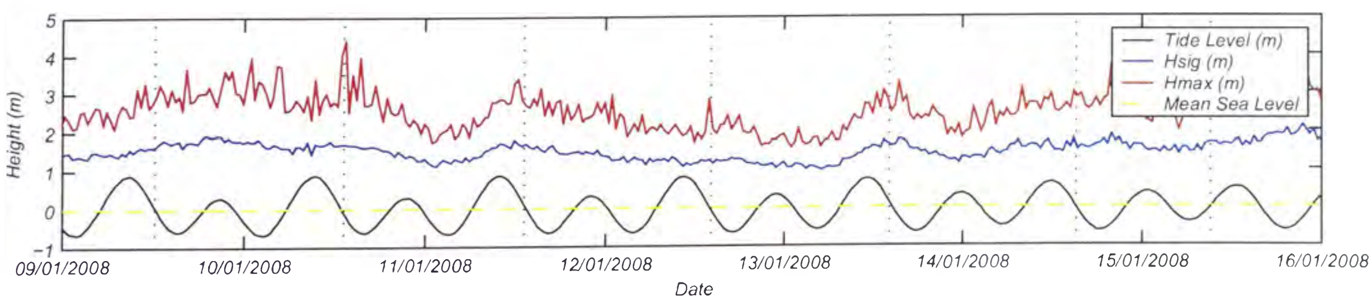
11/01/2008 13:10

12/01/2008 14:10

13/01/2008 14:09

14/01/2008 15:09

15/01/2008 09:10



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 09/01/2008 - 16/01/2008	Figure A24

16/01/2008 10:10

17/01/2008 12:09

18/01/2008 14:09

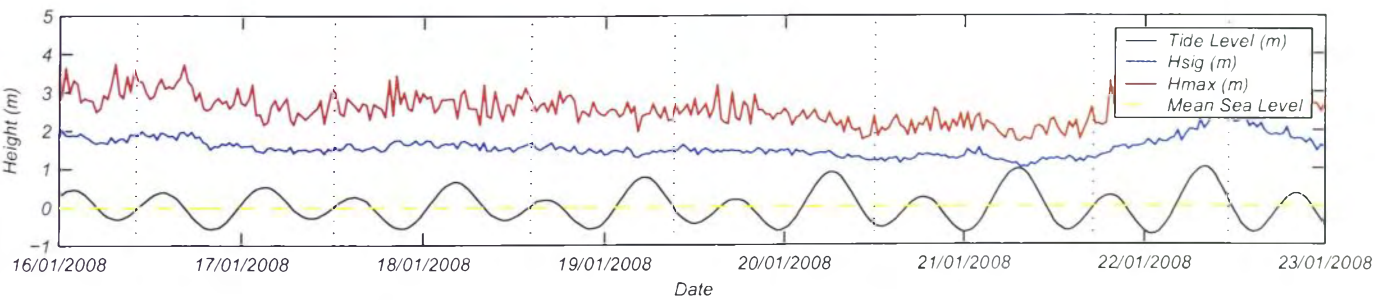
19/01/2008 09:09

image not available

20/01/2008 12:00

21/01/2008 17:09

22/01/2008 11:09



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 16/01/2008 - 23/01/2008	Figure A25

23/01/2008 12:09

24/01/2008 13:09

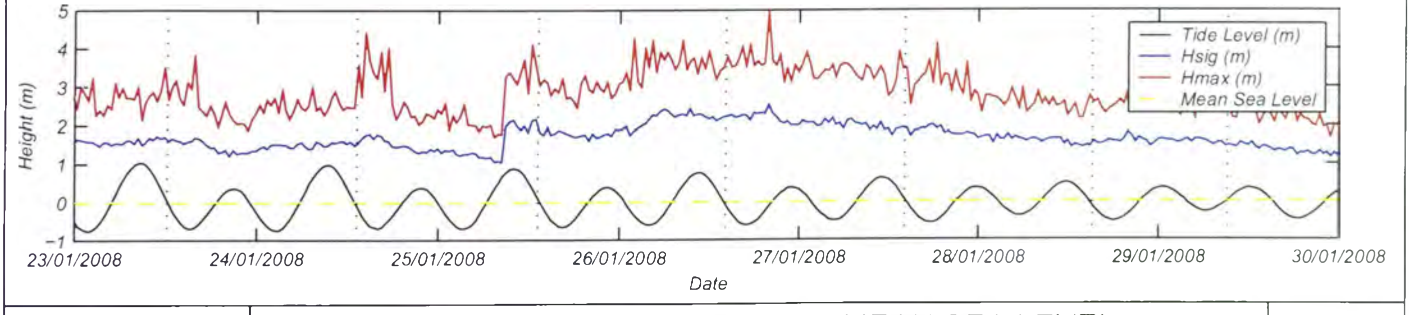
25/01/2008 13:09

26/01/2008 14:09

27/01/2008 14:09

28/01/2008 15:09

29/01/2008 09:10



WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 23/01/2008 − 30/01/2008	Figure A26

30/01/2008 15:09

31/01/2008 12:10

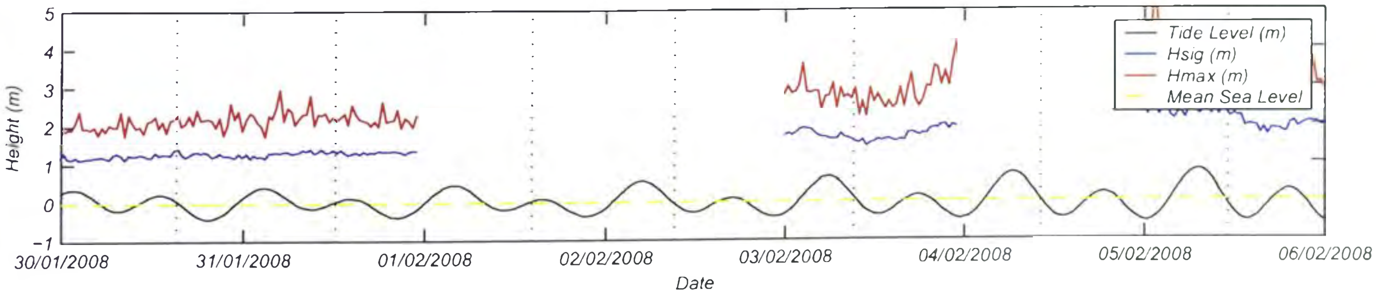
01/02/2008 14:09

02/02/2008 09:09

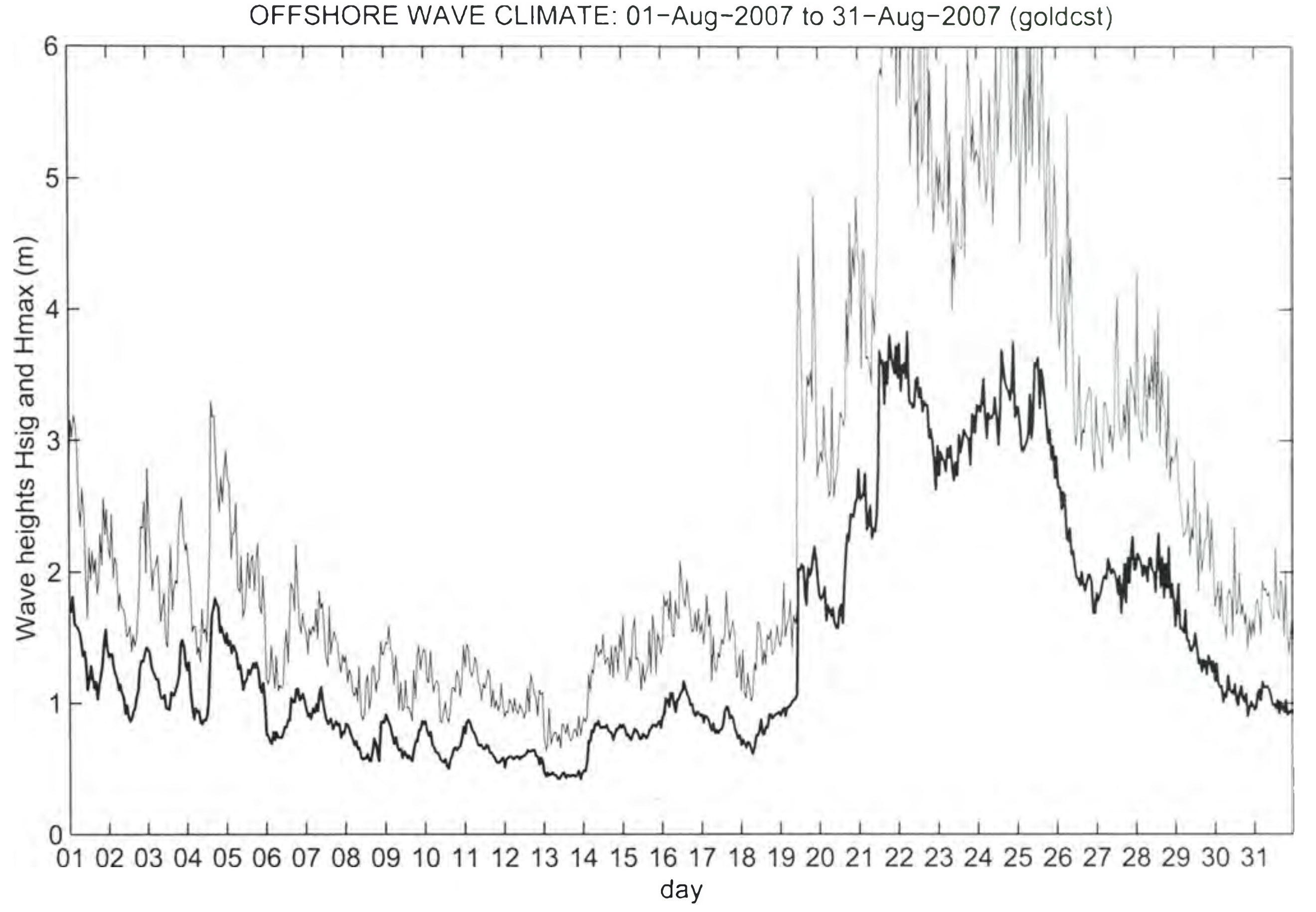
03/02/2008 09:09

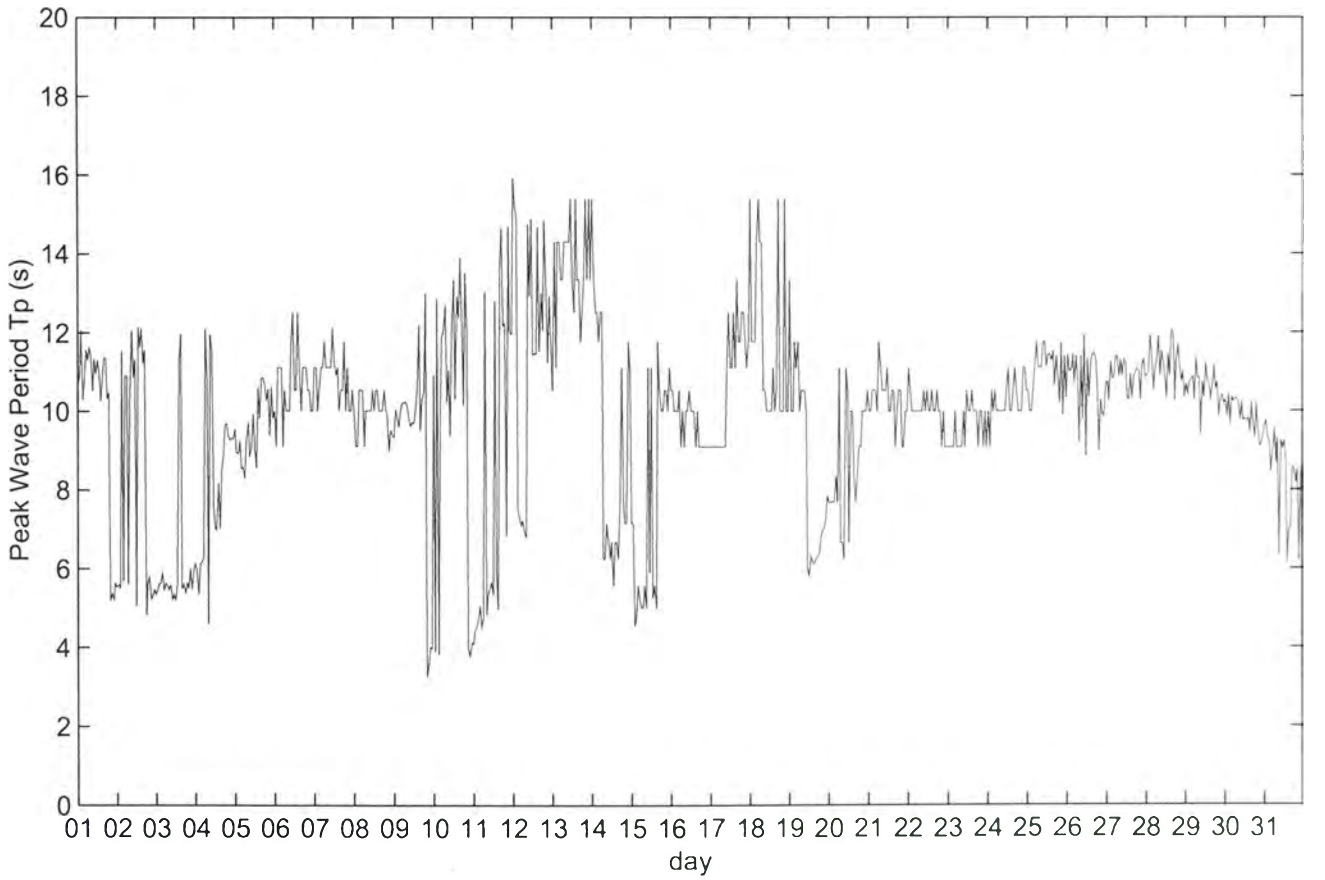
04/02/2008 10:10

05/02/2008 11:09

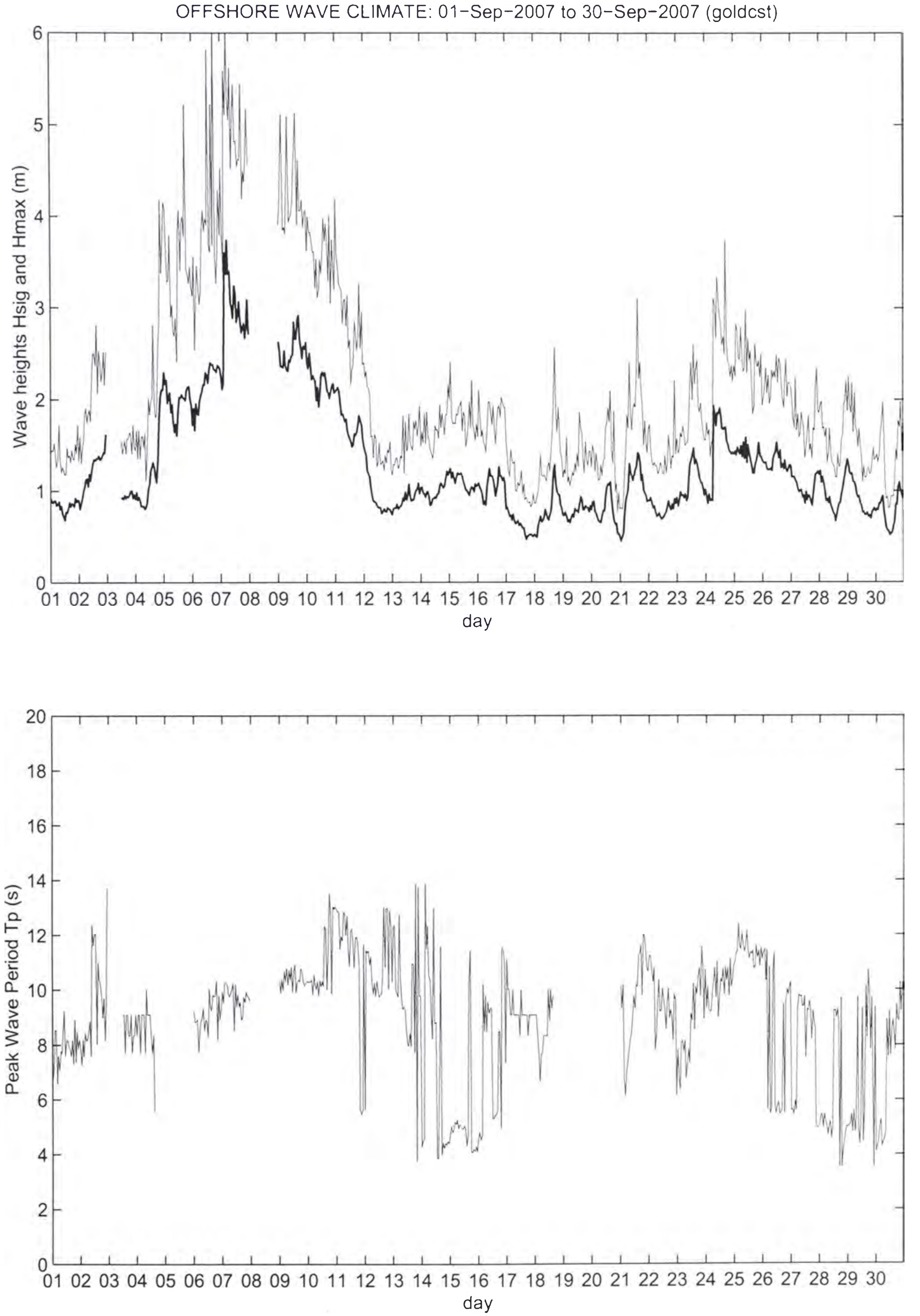


WRL Report No.2008/06	WEEK TO PAGE SUMMARY: MEAN SEA LEVEL GOLD COAST, QUEENSLAND, AUSTRALIA 30/01/2008 − 06/02/2008	Figure A27



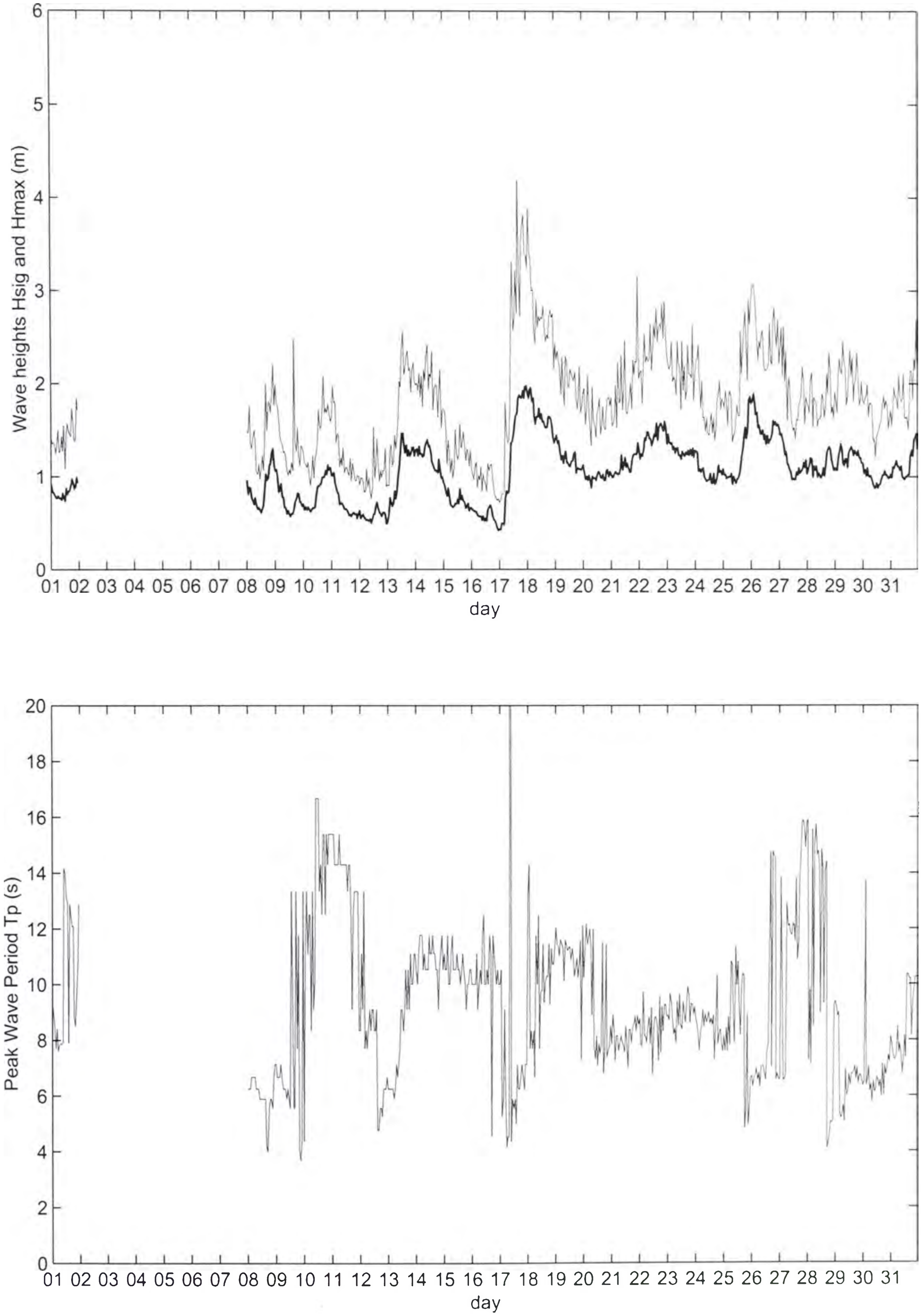


WRL Report No.2008/06	MONTHLY WAVE SUMMARY AUGUST 2007	Figure B1

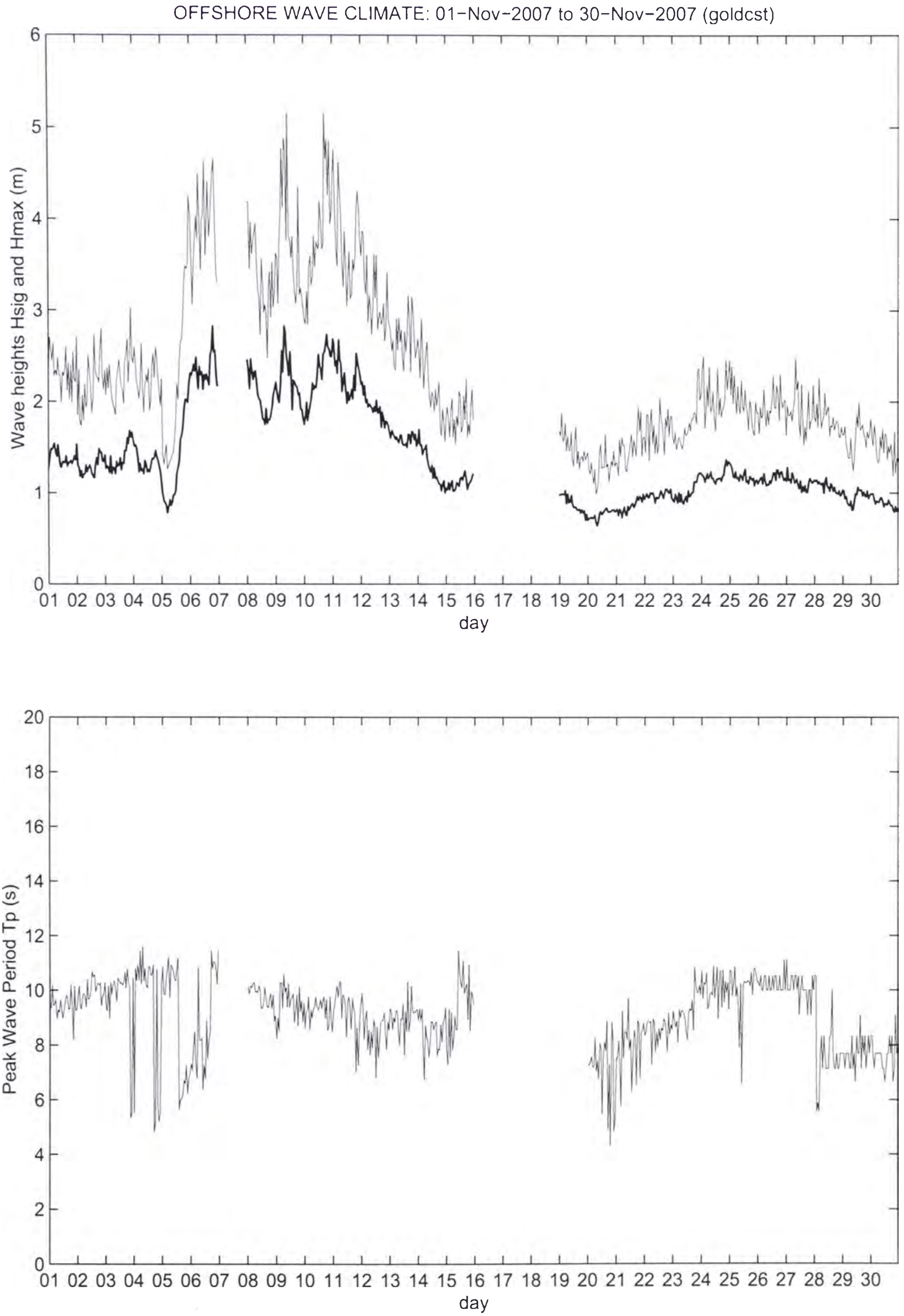


WRL Report No.2008/06	MONTHLY WAVE SUMMARY SEPTEMBER 2007	Figure B2

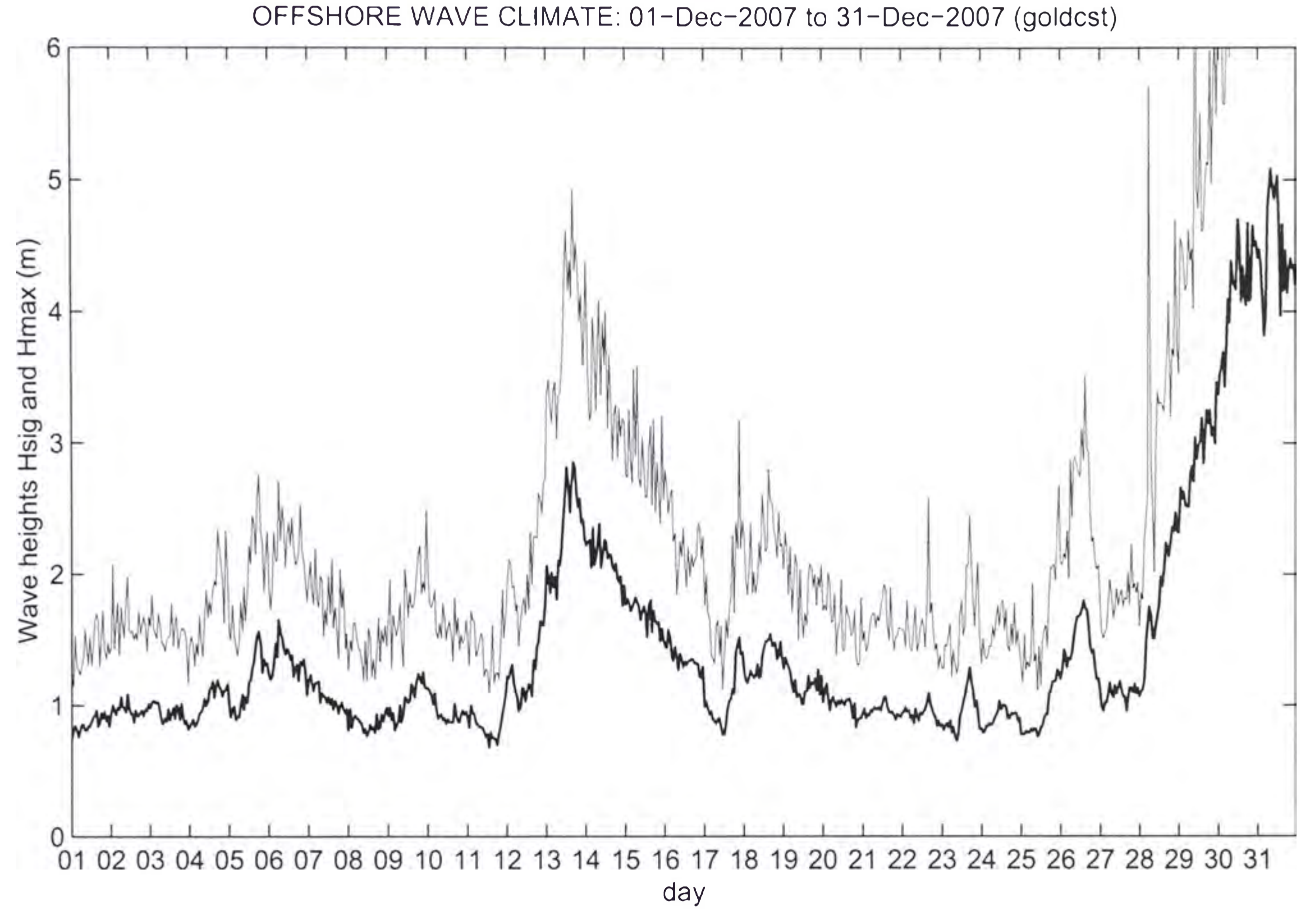
OFFSHORE WAVE CLIMATE: 01-Oct-2007 to 31-Oct-2007 (goldcst)

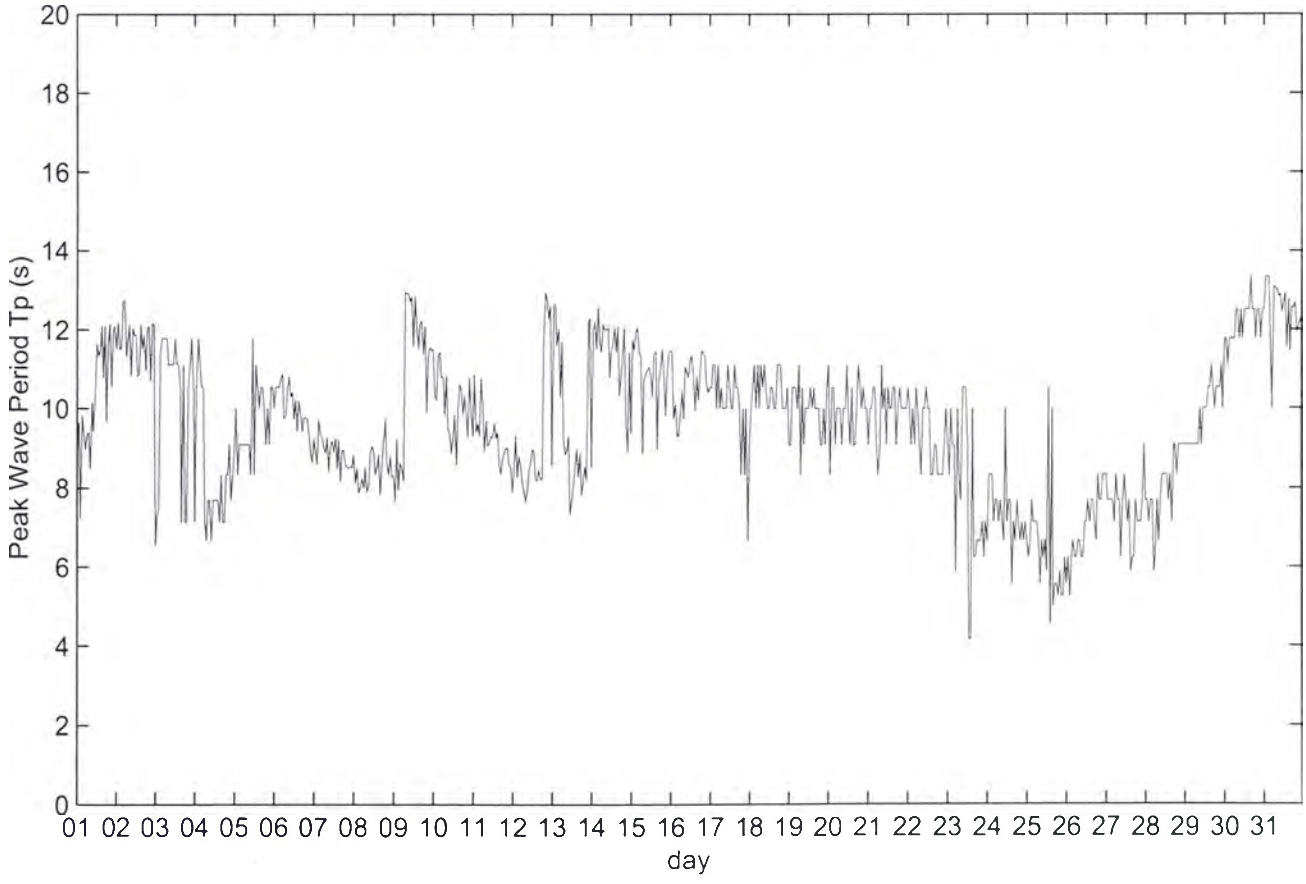


WRL Report No.2008/06	MONTHLY WAVE SUMMARY OCTOBER 2007	Figure B3

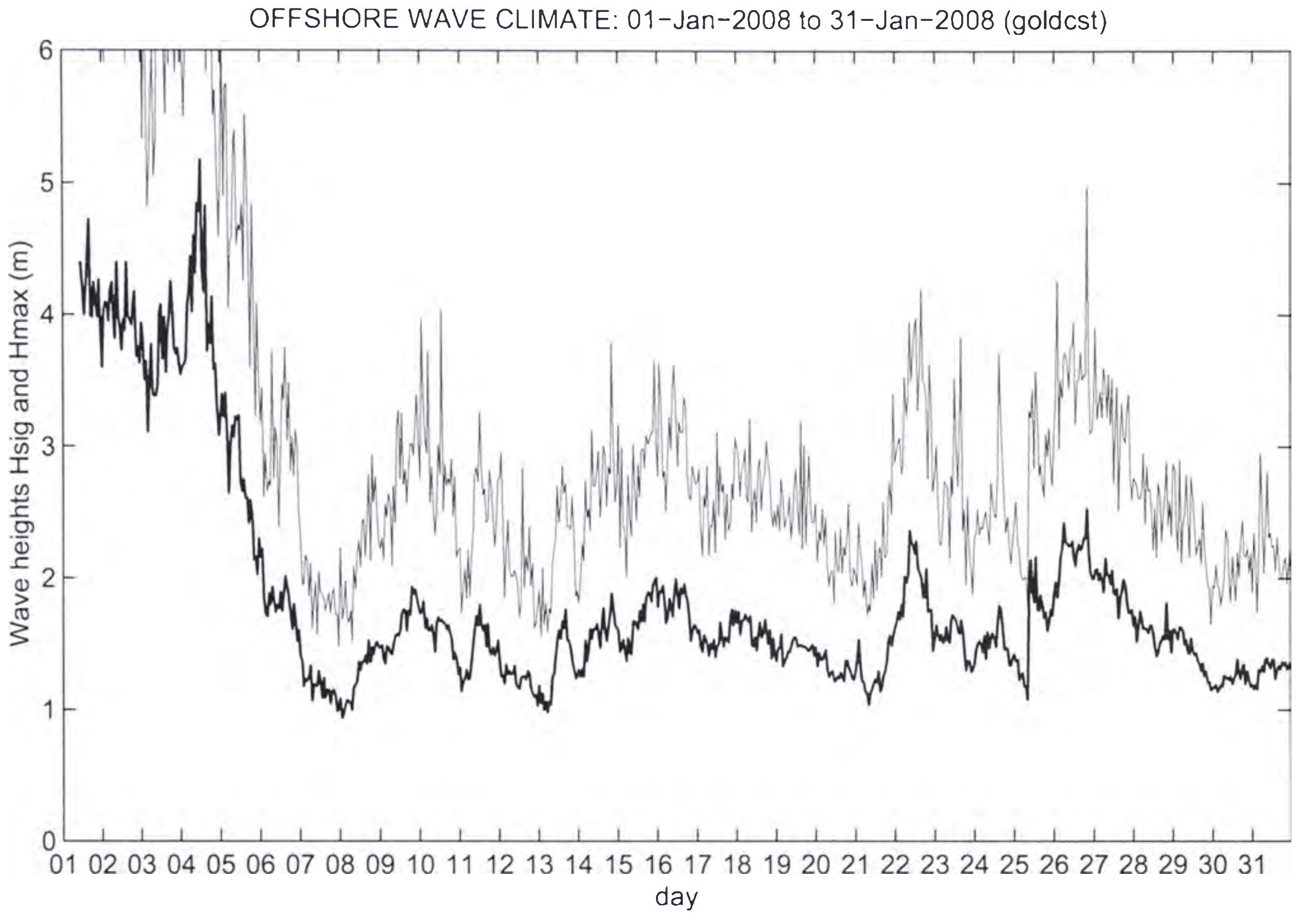


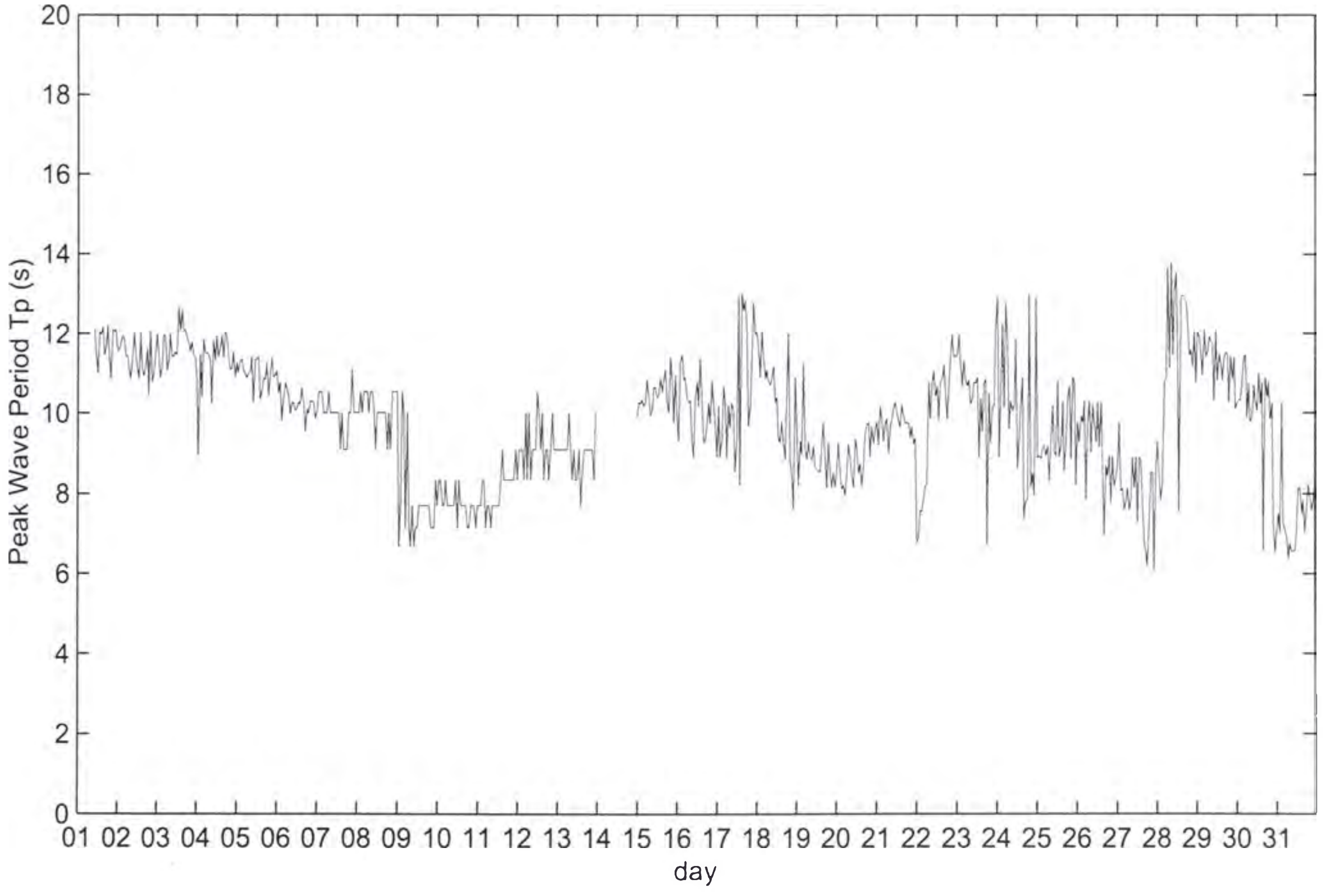
WRL Report No.2008/06	MONTHLY WAVE SUMMARY NOVEMBER 2007	Figure B4





WRL Report No.2008/06	MONTHLY WAVE SUMMARY DECEMBER 2007	Figure B5





WRL Report No.2008/06	MONTHLY WAVE SUMMARY	Figure B6