

# Analysis of shoreline variability, seasonality and erosion/accretion trends: February - July 2008 report 18, northern Gold Coast coastal imaging system

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THE UNIVERSITY OF NEW SOUTH WALES

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**ANALYSIS OF SHORELINE VARIABILITY, SEASONALITY AND  
EROSION /ACCRETION TRENDS:  
FEBRUARY - JULY 2008**

**REPORT 18  
NORTHERN GOLD COAST COASTAL IMAGING SYSTEM**

by

M J Blacka, D J Anderson and L Mallen Lopez

Technical Report 2008/27  
November 2008  
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THE UNIVERSITY OF NEW SOUTH WALES  
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING  
WATER RESEARCH LABORATORY

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Report 18: Northern Gold Coast Coastal Imaging System

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## **1. INTRODUCTION**

This report was prepared by Water Research Laboratory (WRL) for Gold Coast City Council. It is the 18<sup>th</sup> 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 adopted 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 1<sup>st</sup> 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)
- WRL Report 2008/06: August 2007 to January 2008 (Blacka *et al.* 2008).

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](http://www.wrl.unsw.edu.au/coastalimaging/public/goldcst) (monitoring reports).

The purpose of this 18<sup>th</sup> report is to present an analysis of shoreline variability, seasonality and erosion-accretion trends for the monitoring period February to July 2008, and to assess the net changes that have occurred to northern Gold Coast beaches since the commencement of the monitoring program nine 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 16<sup>th</sup> of March. Later in 2006, a range of new cameras were purchased, and the southern camera was again replaced on 23<sup>rd</sup> 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 14<sup>th</sup> 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 4<sup>th</sup> August 2007 due to ISP problems, with image collection not re-established until 14<sup>th</sup> 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 18<sup>th</sup> October 2007, and was subsequently replaced by the 24<sup>th</sup> 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 18<sup>th</sup>. The northern Gold Coast ARGUS station again went offline on the 15<sup>th</sup> November, with image collection restored the following day.

Spare parts were re-stocked on 10<sup>th</sup> and 11<sup>th</sup> January 2008, the hard drive was replaced and the cameras were cleaned.

### **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, February to July 2008. The quantitative analysis of shoreline variability for the six month period February to July 2008 is detailed in Section 6. This is followed in Section 7 by the corresponding analysis for the total nine year monitoring period, August 1999 – July 2008, as well as the analysis of cyclic-seasonal and 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 18<sup>th</sup> 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.

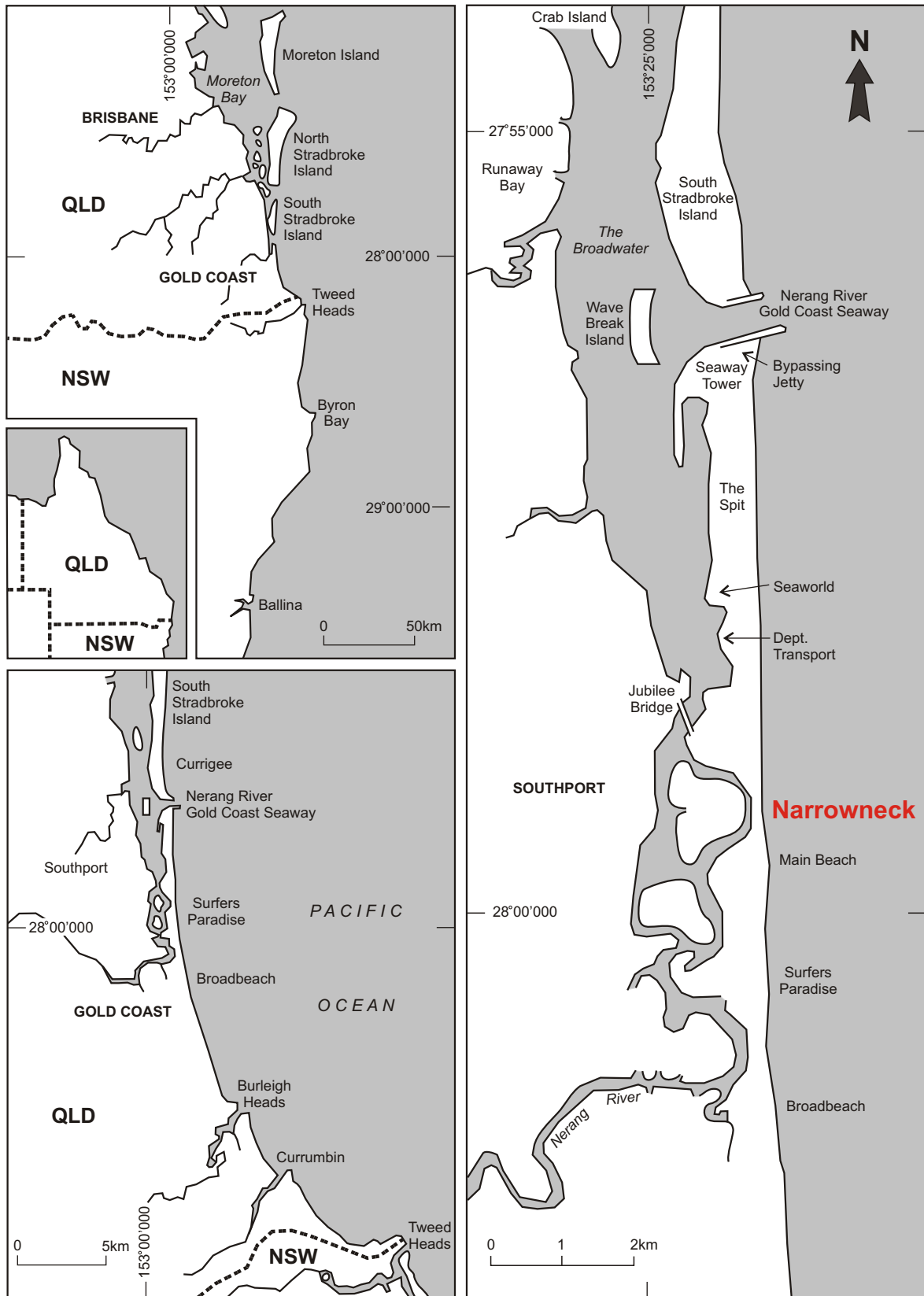
The novel shape of the reef was designed following field investigations and extensive numerical model simulations to determine the optimum reef layout (Black, 1998; Black *et al.*, 1998). The final reef design was further tested by a physical model study (Turner *et al.*, 1998a). Reef construction commenced 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

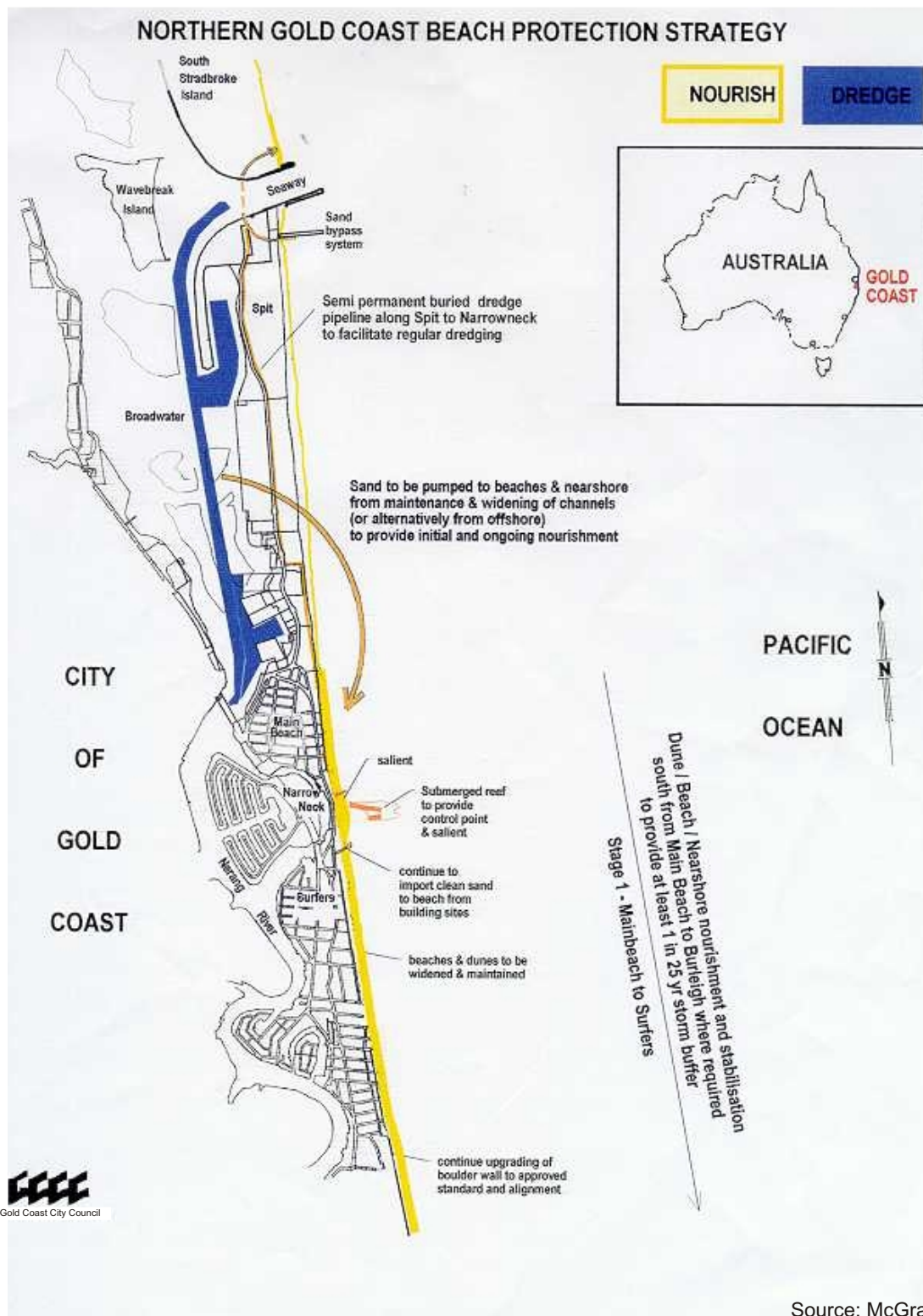
Nourishment of the northern Gold Coast beaches commenced in February 1999, six months prior to reef construction. Cumulative nourishment volumes for the 17 month nourishment period February 1999 to June 2000 are shown in [Figure 2.4](#), at which time this major phase of beach nourishment within the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

In summary, during this period (February 1999 to June 2000) approximately 1,170,000 m<sup>3</sup> 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 (~ 37,000m<sup>3</sup>) was also deposited approximately 300m north of deposition area A1 in June 2000, denoted deposition area A1a in [Figure 2.4](#).

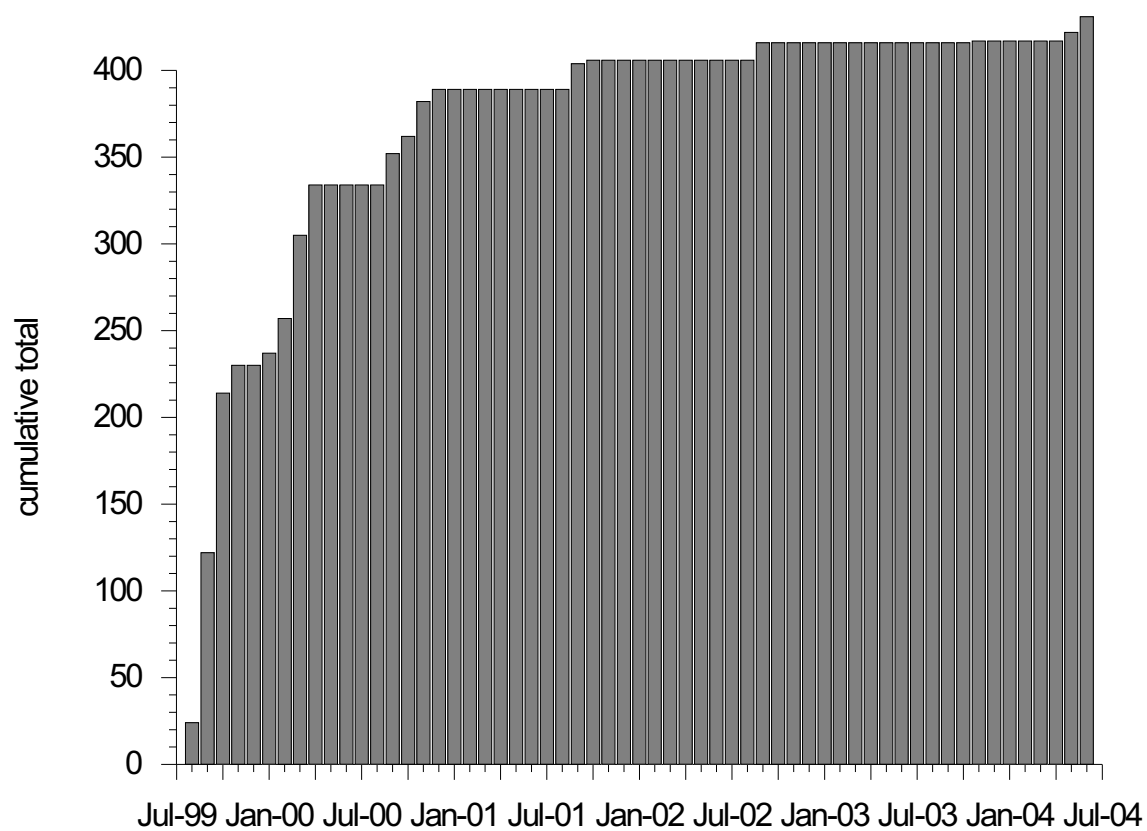
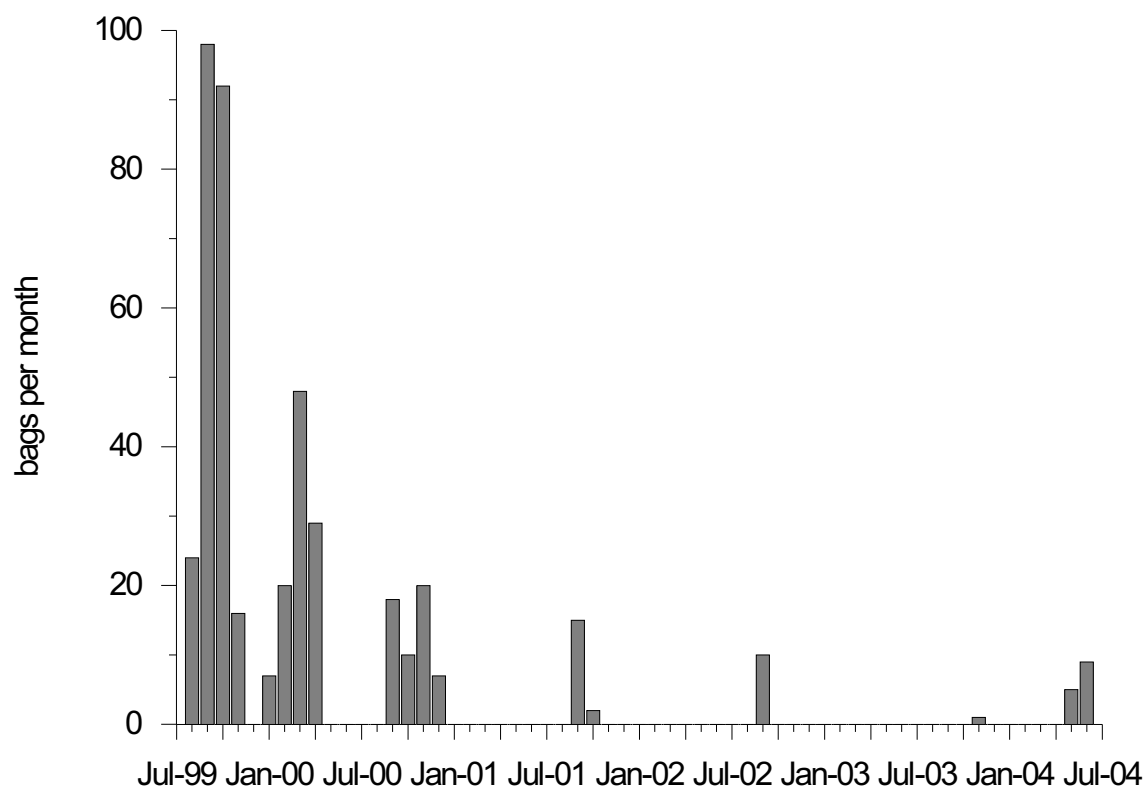
Due to dredging operations in the Broadwater, in January 2005 around 27,000 m<sup>3</sup> of sand was placed in the vicinity of deposition area A5. From February to April 2005 another 32,000 m<sup>3</sup> of sand was placed within this region. From February to July 2007, 6,400 m<sup>3</sup> of sand, sourced from excavations undertaken at development sites, was deposited on the beaches of the northern Gold Coast, followed by a further 9,790 m<sup>3</sup> placed on the beach at Higman Street between 16<sup>th</sup> and 28<sup>th</sup> November 2007. Between 18<sup>th</sup> December 2007 and March 2008, approximately 80,000m<sup>3</sup> of sand was placed at Margaret Avenue, Broadbeach. This was outside of the study area covered in this report, but is still a part of the same longshore sediment transport system.

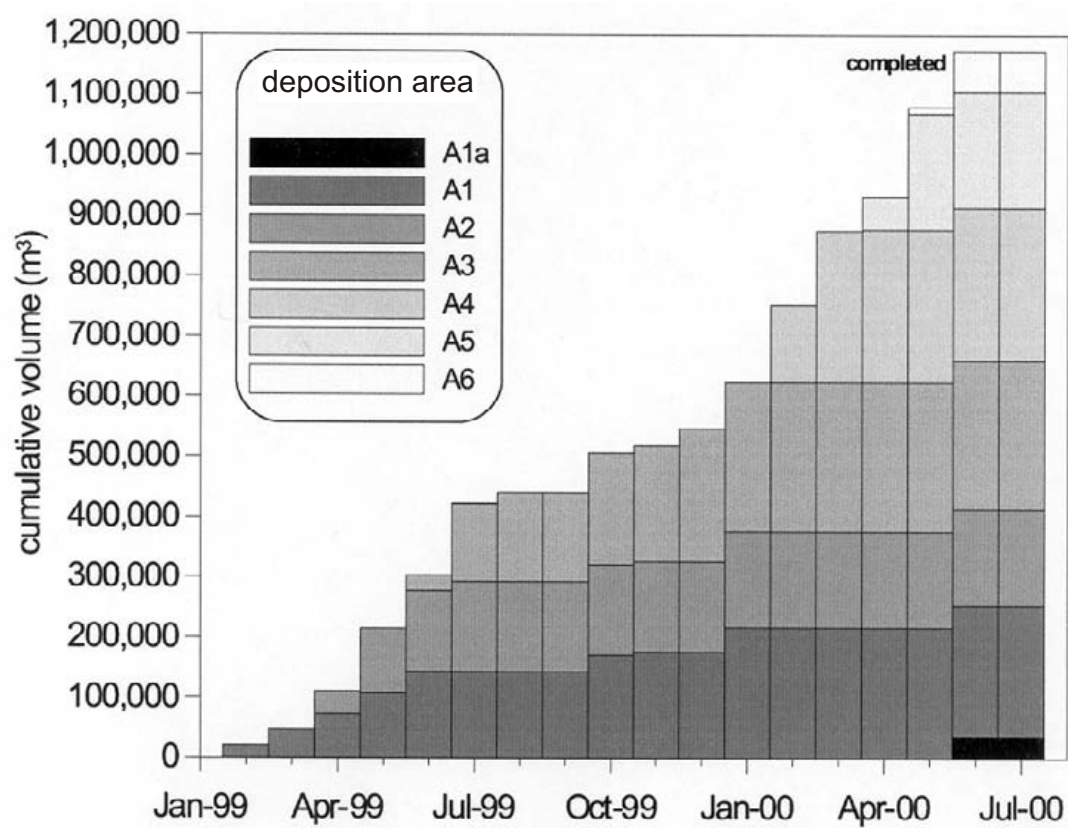


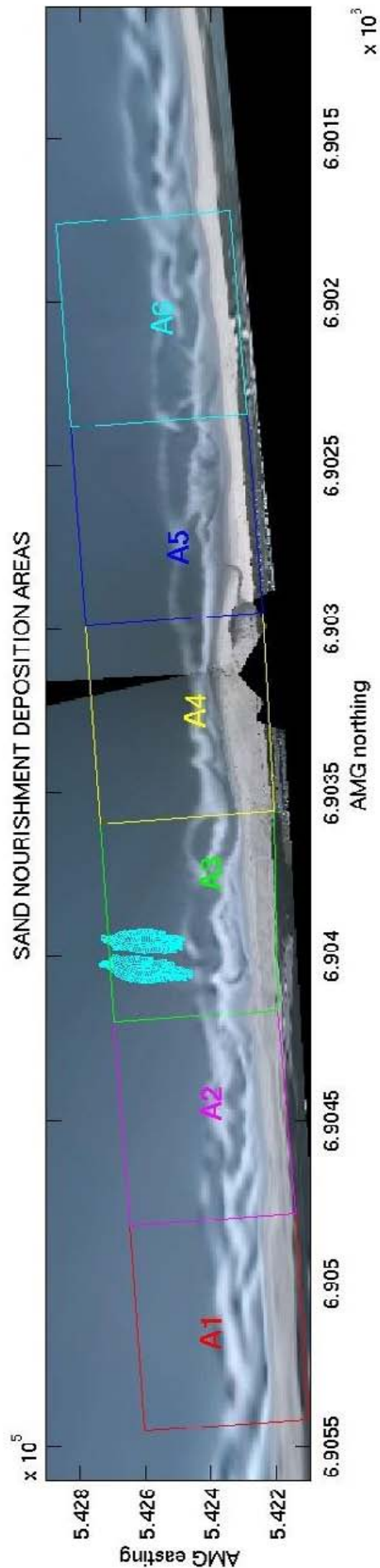




Source: McGrath et al. (2000)







### **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 100m above mean sea level, within a roof services area of the Focus Building ([Figure 3.2](#)). The Focus Building is located approximately 60m landward of the dune line, approximately 900m 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 240V 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 31<sup>st</sup> July 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  $P_{\text{dry}}$  and  $P_{\text{wet}}$ , 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  $\Psi$  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 ( $H_{\text{rms}}$ ) 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  $H_{\text{rms}} \leq 1.0\text{m}$  (ie.  $H_s \leq \sim 1.4\text{ m}$ ). 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  $H_{\text{rms}} = 1.0$  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  $\pm 3$  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.

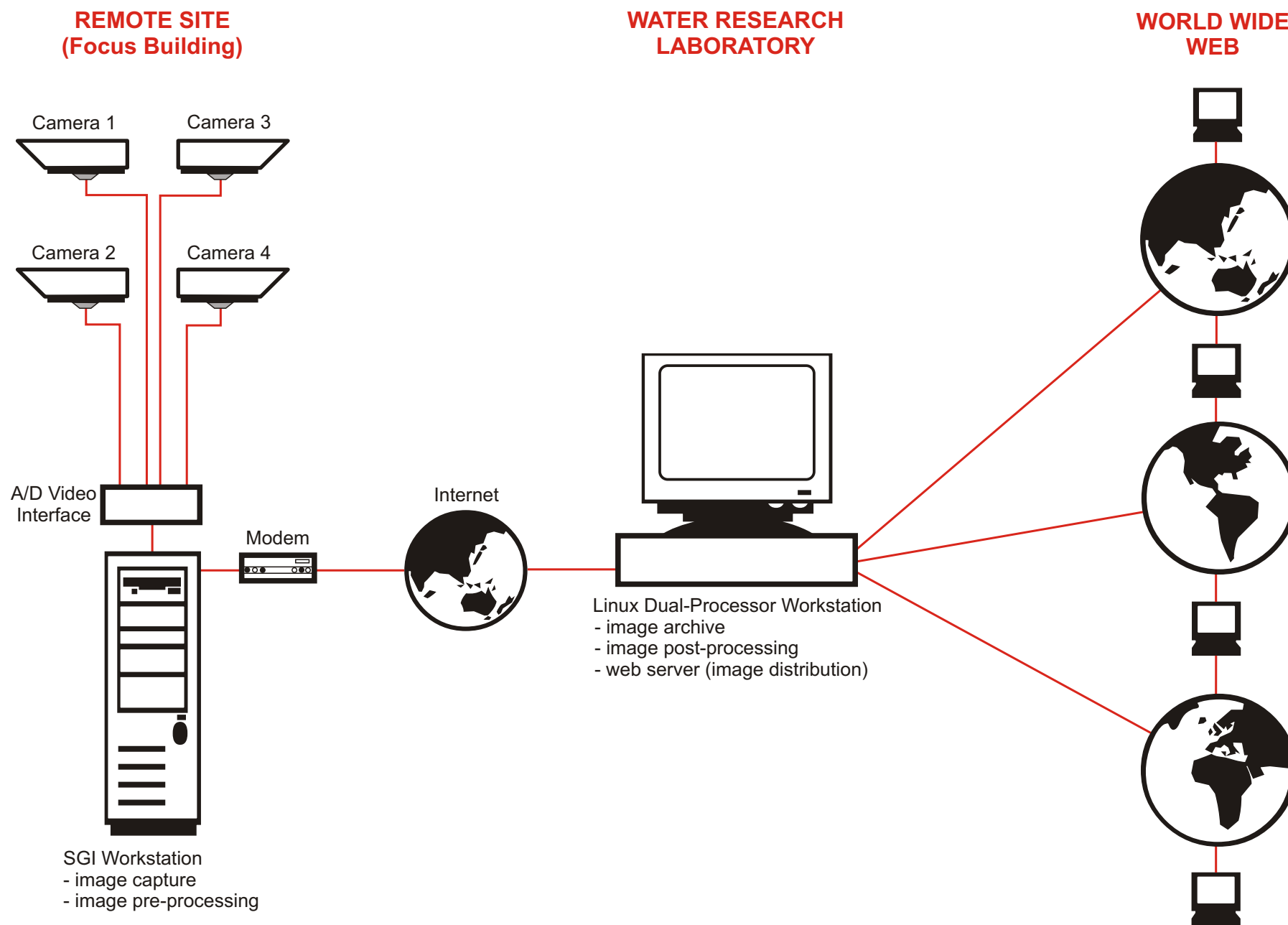
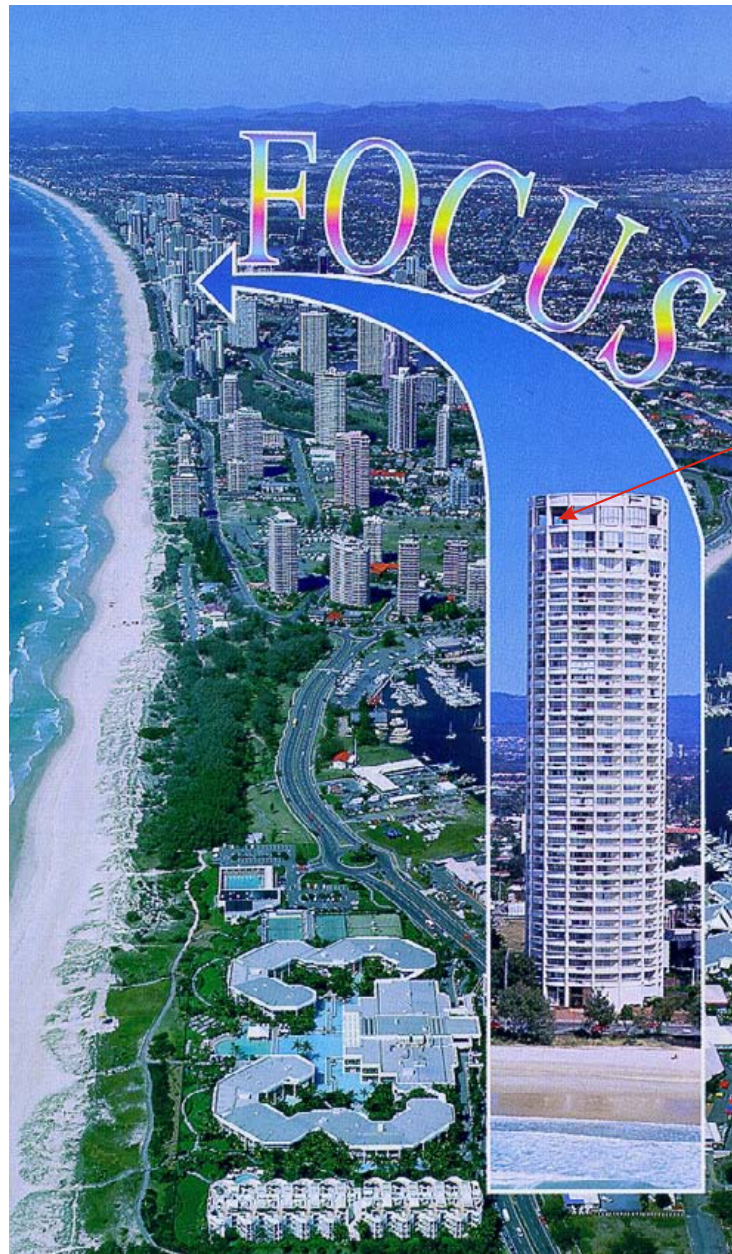


IMAGE COURTESY OF FOCUS APARTMENTS



CAMERAS





<p>WRL</p> <p>Report No. 2008/27</p>	<p>CAMERAS MOUNTED AT AN ELEVATION OF APPROXIMATELY 100m</p>	<p>Figure 3.3</p> <p>06037-3-3.cdr</p>
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snap

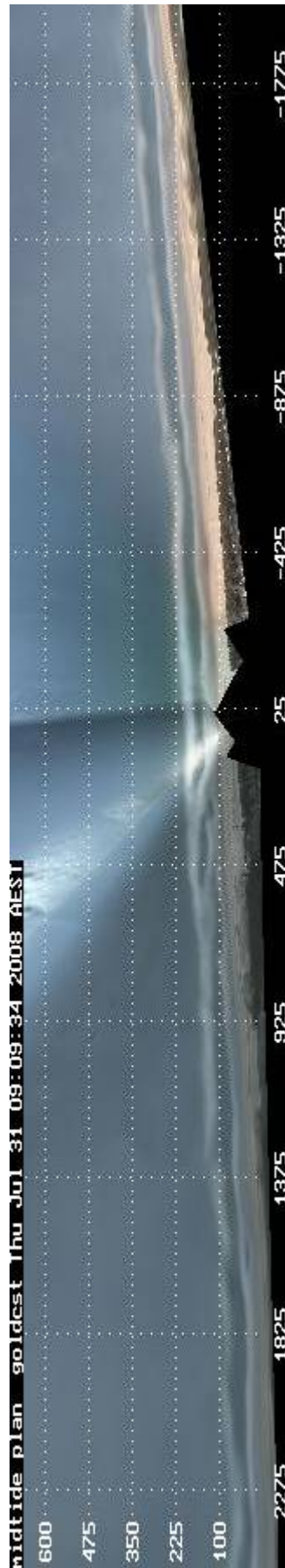


timex

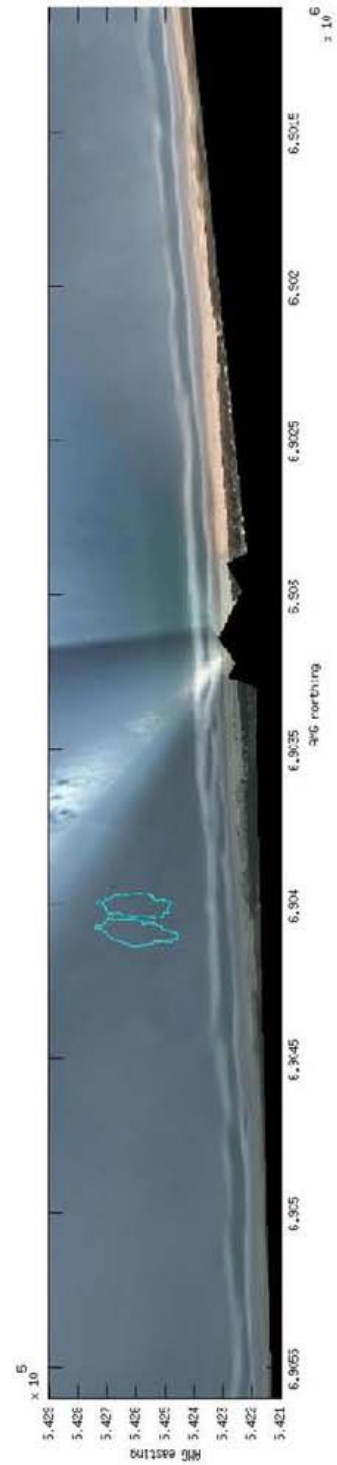
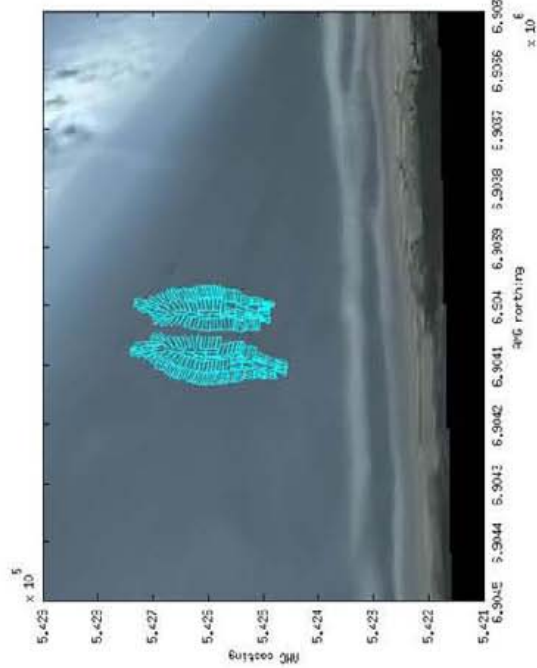


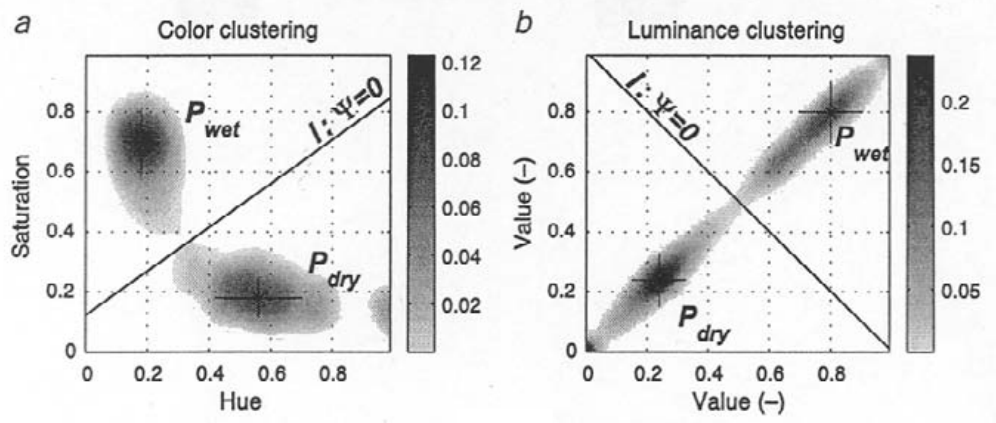
var



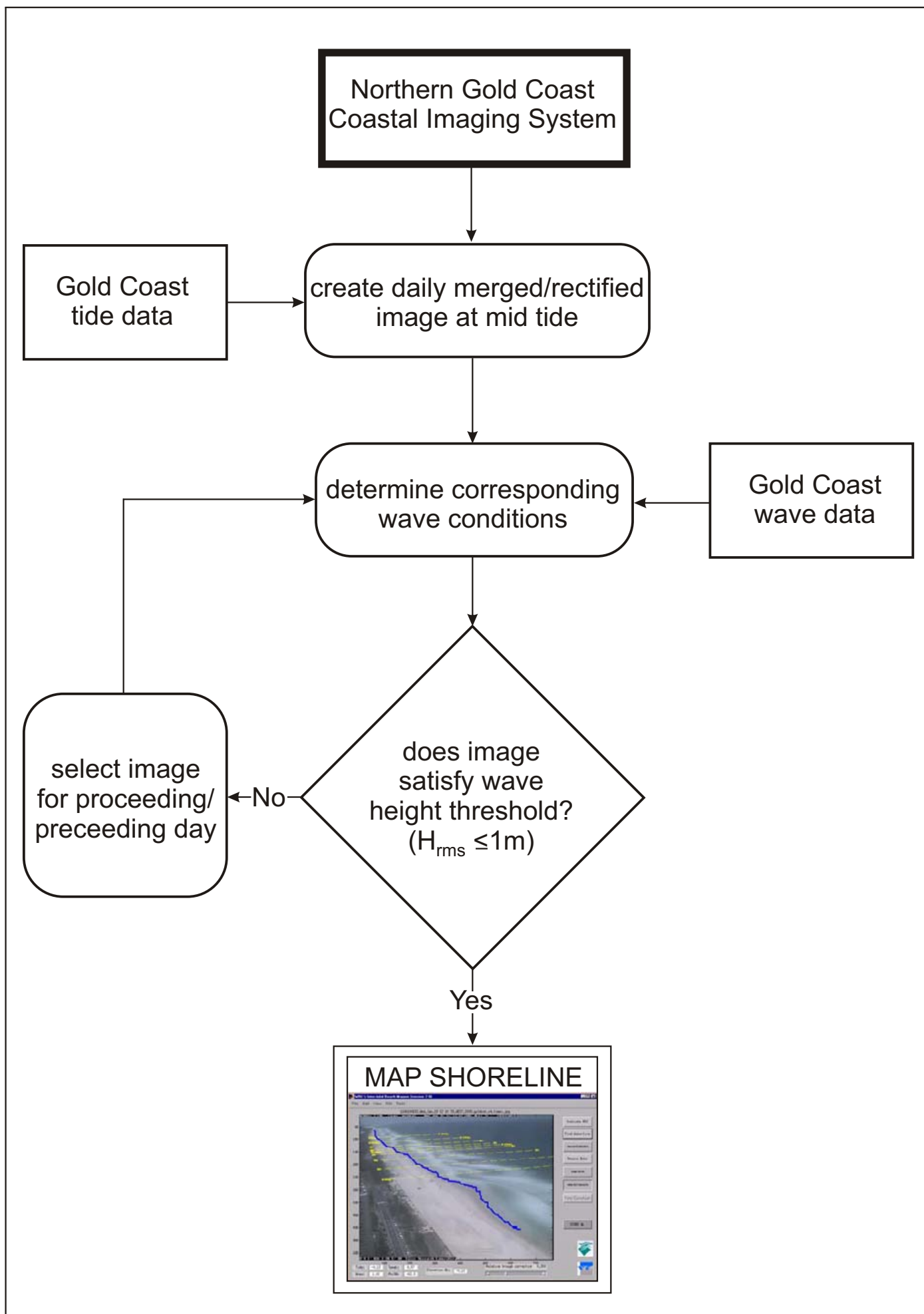








Source: Aarninkhof (2003)



## **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 343,800 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’

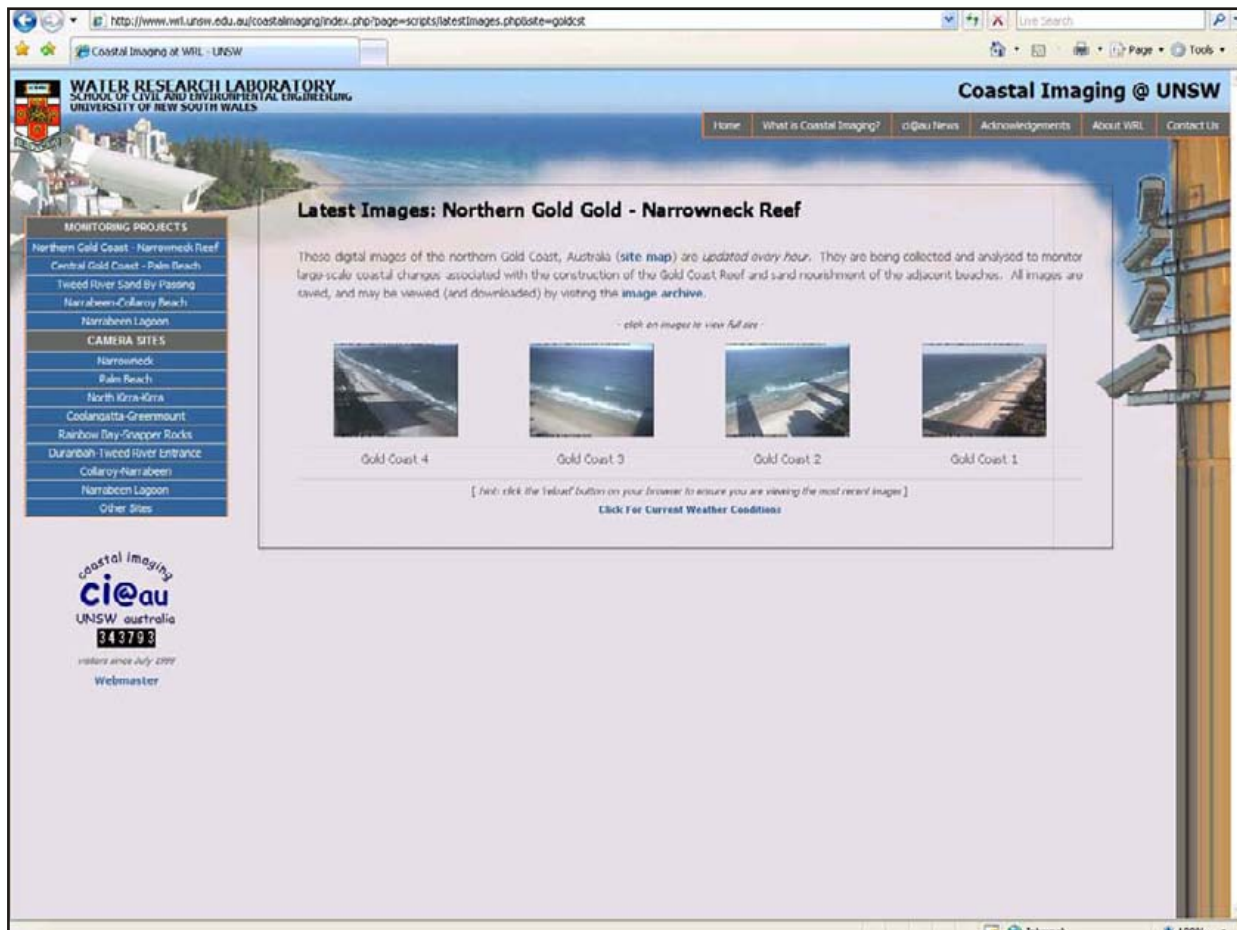
Since 2003, on-line access to ‘real time’ beach monitoring analysis and information (similar to that provided every six months in these NGCBPS reports) has been made available at the northern Gold Coast coastal imaging web site. This capability results from the on-going research and development effort 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.

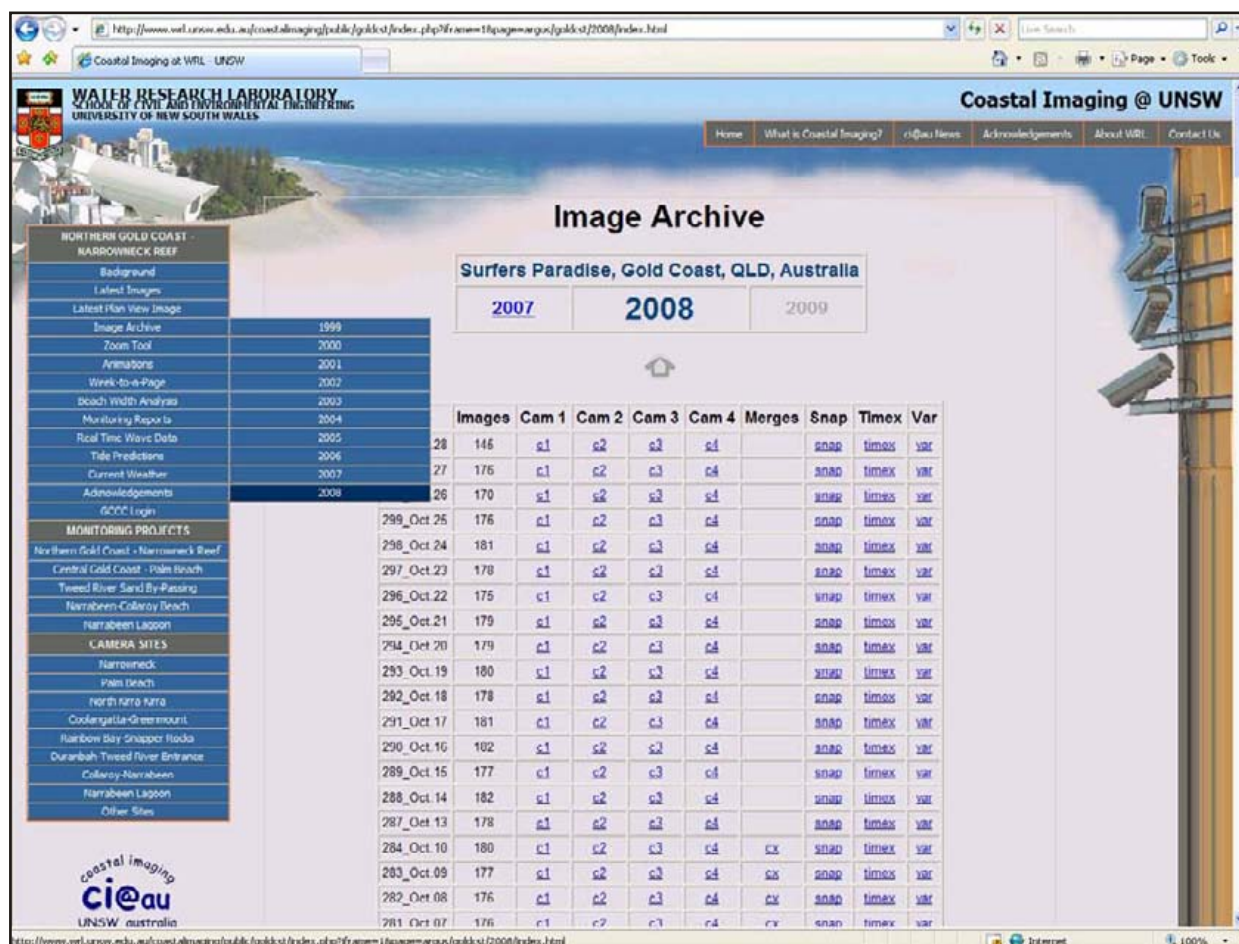
A detailed description of the capabilities of this system is available in Anderson *et al.* (2003). To summarise, the features available at the project web site include the ability to view the latest mid-tide plan images; access to a zoom tool feature that enables zooming in and panning through the current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

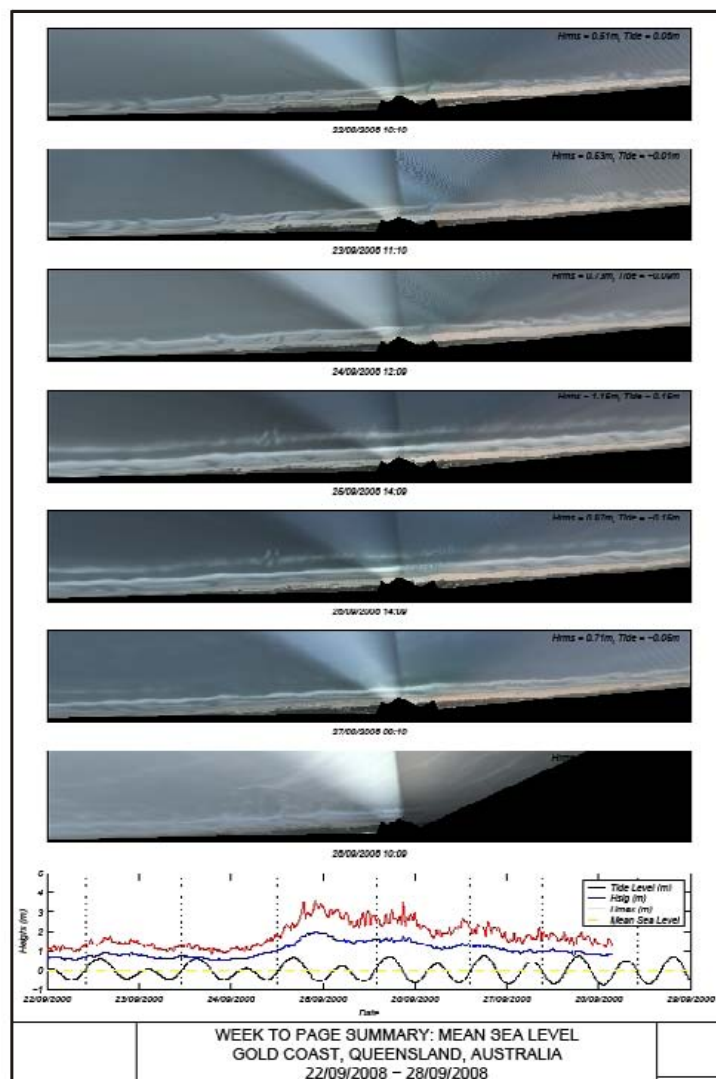
An example of the first of these products called ‘week-to-a-page’ is illustrated in [Figure 4.3](#). Every Monday morning, this figure is generated and made available for viewing (and download if required) via the project web site. The figure is pre-formatted to fit on a standard A4 page, to assist reporting. 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. This product provides coastal managers a means of quickly and efficiently interpreting the daily changes in beach morphology and shoreline position, without continual recourse to the hourly images. An archive of these weekly figures is also maintained and available on-line.

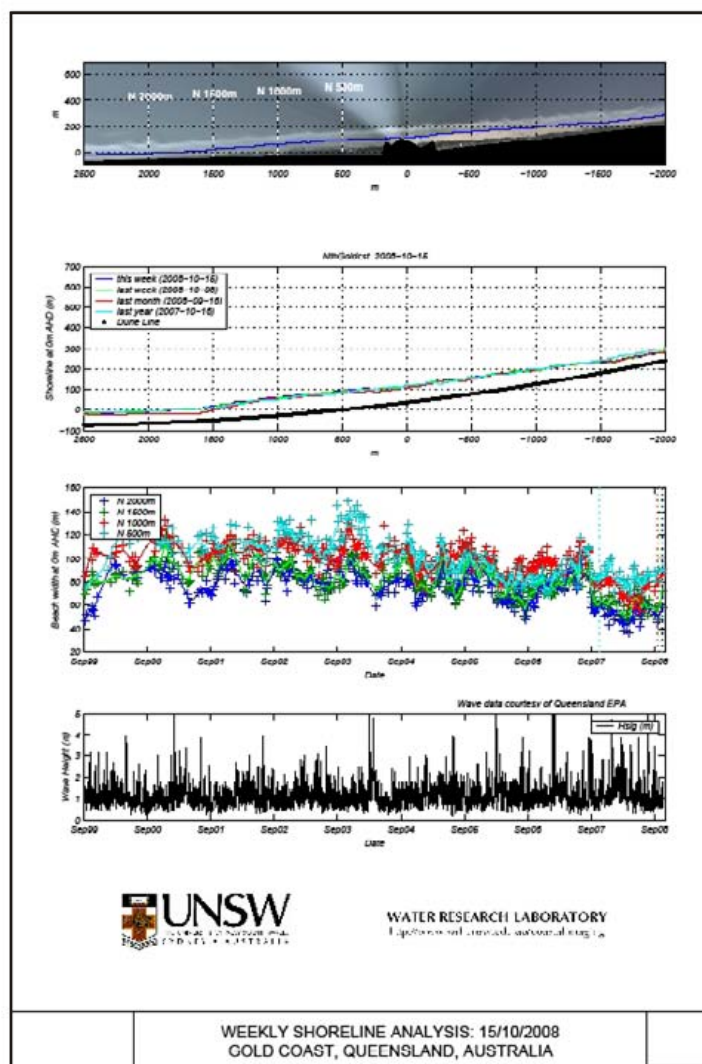
The second product that is also updated each Monday morning and made available via the project web site is ‘Beach-Width-Analysis’ ([Figure 4.4](#)). This figure in graphical format summarises quantitative information of the mean shoreline position for that week; shoreline variability by comparing the current shoreline position with previous weeks and months; beach width along pre-defined monitoring transects; and beach width trends throughout the history of the monitoring project.











## **5. MORPHODYNAMIC DESCRIPTION OF THE GOLD COAST BEACHES: FEBRUARY – JULY 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 February to July 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.

### **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 February to July 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 4,500m alongshore, from approximately 1,500m north of the reef site at Narrowneck, to 3,000m 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 February 2008*

Following the large storm events experienced at the Gold Coast during late December 2007 and early January 2008, the beach was in a relatively high energy state at the start of the current monitoring period in February 2008. Wave breaking over a detached longshore bar was evident over the entire mapped stretch of beach, while a complex inner nearshore surfzone of rips and transverse bars was also present. Significant wave heights of 1 m to 2 m dictated the morphology of the beach up until the 18<sup>th</sup>, when a slight increase in wave height was experienced. The significant wave height peaked at approximately 4 m on the 20<sup>th</sup> before decreasing to 1 m from the 25<sup>th</sup> to the end of the month.

During the first week of February little change to the inner surf zone was evident, with the persistence of irregular bars cut by transverse rips along the entire beach length. The outer detached longshore bar also became irregular as the lower energy wave conditions progressed throughout the week. During the second week of the month, the wave energy continued to reduce, with breaking across the outer bar intermittent and not evident at times. A series of undulations developed in the nearshore surfzone, with a corresponding series of undulations developing on the beachface. This feature was particularly evident along the beach to the south of the ARGUS station.

With the onset of higher energy wave conditions experienced from the 18<sup>th</sup> to the 21<sup>st</sup>, the previously dormant detached longshore bar again became active, with a wide high energy LBT surf zone morphology again present. The lull in wave energy during the last week of

February saw the longshore bar again become dormant, while sand migrating in the nearshore surfzone produced morphology typical of a TBR beach state.

### *5.2.2 March 2008*

The significant wave height was relatively consistent at just over 1 m during the first four days of March 2008. During this time, the low energy intermediate morphology continued, with intermittent wave breaking across the offshore bar, while sand migrated towards the beachface in the nearshore surfzone. The beachface became somewhat irregular in alignment during this period, as nearshore bars and rips continued to generate undulations along the beach.

Higher than average wave conditions were experienced from the 5<sup>th</sup> to the 27<sup>th</sup> of March, with the significant wave height fluctuating between 1 m and 2.5 m. During this period of higher wave energy, wave breaking across the detached longshore bar was again apparent. The inner surfzone was separated from the outer bar by a clear longshore trough, with closely spaced cross shore rip currents cutting through the inner surfzone. By the 20<sup>th</sup> of March, the morphology along the entire mapped section of beach showed characteristics that were very typical of a RBB state, corresponding to the higher/intermediate energy conditions.

During the last four days of March 2008, the significant wave height was seen to reduce to approximately 0.75 m. The undular detached bar became inactive, with wave breaking only occurring across the complex nearshore morphology that had developed during the preceding three weeks. Well defined transverse bars and cross shore rip currents were present during this period, and the shoreline could be seen to again increase in irregularity.

### *5.2.3 April 2008*

The significant wave height steadily increased from 0.75 m to 1.5 m during the first week of April 2008, and then remained relatively constant until the 18<sup>th</sup>. A burst of higher wave energy impacted the coast from the 18<sup>th</sup> to the 21<sup>st</sup>, before decreasing to 0.5 m during the following week. Throughout the final two days of April, the significant wave height increased to be 1.5 m at the end of the month.

Images for the first week of April were not available due to system problems, with the first available image being for the 7<sup>th</sup> of April. Wave breaking across an undular detached bar was clearly evident along the beach at this time, with the beach again appearing in a higher



energy intermediate RBB state. The relatively consistent wave conditions resulted in little observable change in nearshore morphology through until the 18<sup>th</sup>, with the onset of a burst of higher energy wave conditions. During the three day period until the 20<sup>th</sup>, the surfzone increased in width, with a double bar system typical of a LBT state forming for a short period of time. Wave breaking was clearly visible across a detached offshore bar, separated from the inner surfzone by a longshore trough. Sand previously stored in nearshore transverse bars straightened in alignment, and also formed a detached nearshore bar.

With the decreasing wave conditions experienced throughout the last week of April 2008, a complex and rapidly evolving nearshore morphology was observed along the Northern Gold Coast beaches. The clear longshore trough between the outer and inner longshore bars steadily closed, as sand migrated across the double bar system. Active transverse bars and rips also shifted sand across the inner surfzone, resulting in changes to the longshore beachface alignment.

#### *5.2.4 May 2008*

Lower energy wave conditions with a significant wave height of 0.5 m to 1 m persisted throughout the first three weeks of May 2008. Slightly larger wave conditions with a significant wave height of 1 m to 2 m occurred from the 20<sup>th</sup> to the 30<sup>th</sup>, before increasing rapidly to 3 m on the 31<sup>st</sup>.

The ongoing lower energy wave conditions experienced throughout most of May continued to result in a surfzone that appeared highly complex. Along the southern stretches of the beach, sand migrated from the nearshore surfzone to the beachface, resulting in a series of low tide terrace formations adjacent the beachface. Sand that had previously been located in an offshore detached bar formed a series of transverse bars spanning from the inner surfzone into deeper water. Over the northern stretches of beach, a wider surfzone was present, which was more typical of TBR morphological conditions, as opposed to LTT.

The transverse bars that had formed in the outer surfzone from the previous longshore bar system, became more apparent, (due to the increased wave breaking ) as the wave energy increased from the 20<sup>th</sup> May. At this time a widened beach was evident to the south of the ARGUS station, while an undulating and irregular beach alignment was visible to the north. The migration of surfzone morphology from a TBR system to a higher energy system where the morphology was dominated by a detached bar, was clearly evident along the far northern stretches of the beach from the 23<sup>rd</sup> to the 29<sup>th</sup> of May. Sand was also eroded from the low tide terrace formations that had previously formed to the south of the ARGUS

station during this time. The rapid increase in wave height at the end of May was clearly evident in the recorded images from the 30<sup>th</sup> and 31<sup>st</sup>, where the surfzone can be seen to be wide and highly energetic.

#### 5.2.5 June 2008

Wave conditions continued to increase during the first three days of June, peaking on the 3<sup>rd</sup> with a significant wave height of just under 4 m, before again decreasing to 1 m by the 7<sup>th</sup>. During this period sand continued to erode from the nearshore surfzone with the development of the detached offshore bar. During the decreasing wave conditions throughout the later half of the first week, wave breaking over a complex series of transverse nearshore bars was present.

The significant wave height fluctuated throughout the following two week period between the 7<sup>th</sup> and 21<sup>st</sup> of June, peaking at 2 m on the 9<sup>th</sup> and 15<sup>th</sup>. During this period, a narrower surfzone was present, with wave breaking on the outer bar only present during the times of larger wave height. The typical surfzone morphology consisted of an irregular nearshore bar, separated from the beachface by a very narrow longshore channel, and with regularly spaced transverse rip currents.

The last 10 days of June saw relatively consistent wave conditions with a significant wave height of 1 m, but a long spectral peak wave period of 14 seconds to 16 seconds. The nearshore morphology was more inactive during this period, than any other time during the current six month monitoring period. Sand shifted from the nearshore bar to the beachface as the beach responded to the lower energy conditions, shifting to a lower energy intermediate morphological state.

#### 5.2.6 July 2008

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

The beach morphology remained relatively consistent during the first week of July, with the lower energy conditions experienced from the 9<sup>th</sup> to the 13<sup>th</sup> resulting in the development of closely spaced transverse rip currents along the entire mapped section of beach. The conditions shown on the 12<sup>th</sup> of July were a good example of a TBR morphological beach state. By the 17<sup>th</sup>, the number of rips had significantly decreased, and were less prominent along the northern stretches of beach. Between the cross shore rips, the beach alignment was very straight, with the undulations that had developed in earlier months no longer present.

With the onset of large wave conditions on the 22<sup>nd</sup>, the beach responded immediately, having a much wider and two dimensional surfzone by the 23<sup>rd</sup> and from the 23<sup>rd</sup> to the 26<sup>th</sup>, the high energy wave conditions continued to result in wave breaking across a detached offshore bar, along with the formation of a secondary nearshore bar system. The morphological state of the beach during this period was more typical of a higher energy LBT system.

At the completion of the current monitoring period at the end of July 2008, the wave conditions had again decreased, leaving the beaches of the Northern Gold Coast in a lower energy state, but appearing very two dimensional due to the preceding storm experienced late in July.

### **5.3 Visual Assessment of Beach Width Changes (February – July 2008)**

The morphology of the northern Gold Coast beaches from February to July 2008 was dictated by ongoing moderate wave conditions, with the significant wave height typically in the range of 1 m to 2 m. A nearshore surfzone typical of a TBR morphological state was typically present, with complex bar and rip formations observable over the entire beach length.

Bursts of higher wave energy were experienced during each of the six months of the current monitoring period, during which significant wave heights typically reached 3 m to 4 m. While some of these occasions lasted for only a few days, during the more persistent bursts of higher wave energy, the beach was observed to shift to a higher energy LBT morphological state. The surfzone during these periods was typically wide and two dimensional, with intense wave breaking across a detached offshore bar, as well as the migration of sand from the beachface to form an inner longshore bar.

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 31/01/08 and 31/07/08, 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, it is evident from [Figures 5.2](#) and [5.3](#) that there has been little net change in beach width from the start to the end of the current monitoring period. The surfzone can be seen to be wider and more energetic at the start of the current monitoring period than at the end, predominantly due to the large storms experienced 3 weeks before the start of the monitoring period.

#### **5.4 Visual Assessment of Total Beach Width Changes (August 1999 – July 2008)**

The visible beach changes to date since the commencement of the NGCBPS coastal imaging monitoring program nine 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 July 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

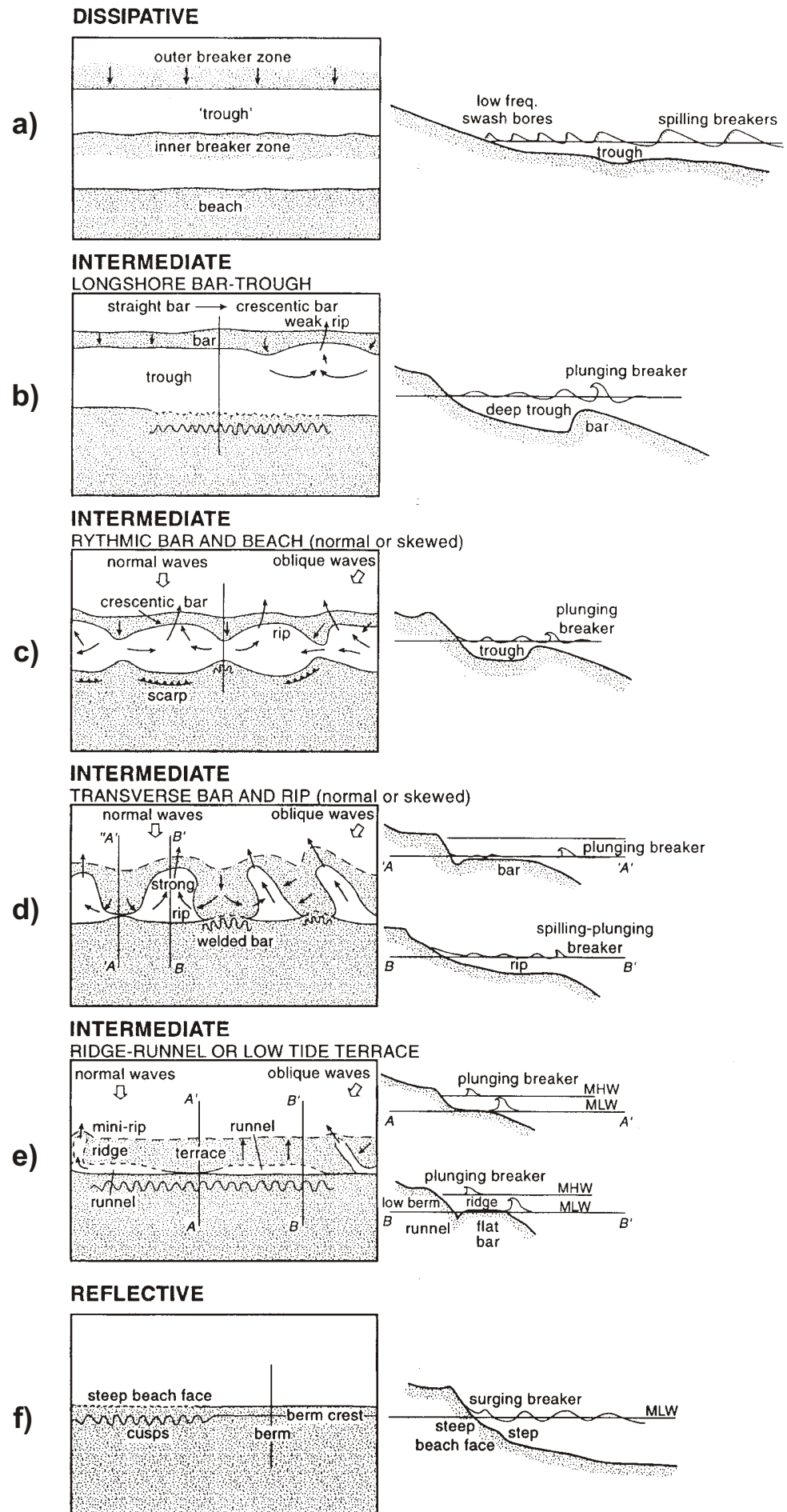
Narrowneck. In contrast, in the vicinity of the reef site at Narrowneck the visible beach was similar at the beginning and end of this six month period. From August 2006 to January 2007, the wave climate was predominantly moderate to low, with very few storm wave occurrences. This resulted in a general 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.

From 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 2007 and January 2008. The ongoing effects of the smaller storms throughout the earlier months of August to November, 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.

Ongoing moderate wave conditions, separated by periods of higher and lower wave energy, resulted in little net change in observable beach width during the current monitoring period, February to July 2008. Typically, the nearshore surfzone was in a complex TBR morphological state, with occasional shifts to a wider and more energetic LBT state. On several occasions of lower energy wave conditions, localised sections of the beach accreted through the formation of terrace or undulation features at the beachface.

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











August 1999



January 2000



August 2000



January 2001



August 2001



January 2002



August 2002



January 2003



August 2003



January 2004



August 2004



January 2005



August 2005



January 2006



August 2006



January 2007



August 2007



January 2008



August 2008



August 1999



January 2000



August 2000



January 2001



August 2001



January 2002



August 2002



January 2003



August 2003



January 2004



August 2004



January 2005



August 2005



January 2006



August 2006



January 2007



August 2007



January 2008



August 2008

## **6. QUANTITATIVE ANALYSIS OF SIX-MONTH SHORELINE CHANGES: FEBRUARY – JULY 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 01/02/08 to 31/07/08 are shown in [Figure 6.1](#). For reference, these measured shorelines are overlaid onto a representative merged/rectified timex image (image date: 31/07/08). 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 01/02/08–31/07/08 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 25 m to 100 m. The envelope of beach width changes is the most extensive south of the ARGUS station and north of Narrowneck, varying by 40 m to 50 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 01/02/08–31/07/08 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: 31/07/2008) of the northern Gold Coast.

Referring to [Figure 6.3](#), the mean beach width at mid-tide (relative to the dune reference line) along the 2,000 m stretch of coastline north of the ARGUS station during the period 01/02/08–31/07/08 was in the range of 65 – 80 m. South of the ARGUS station, the beach width was more uniform alongshore and in the range of 40 – 65 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 80 m.

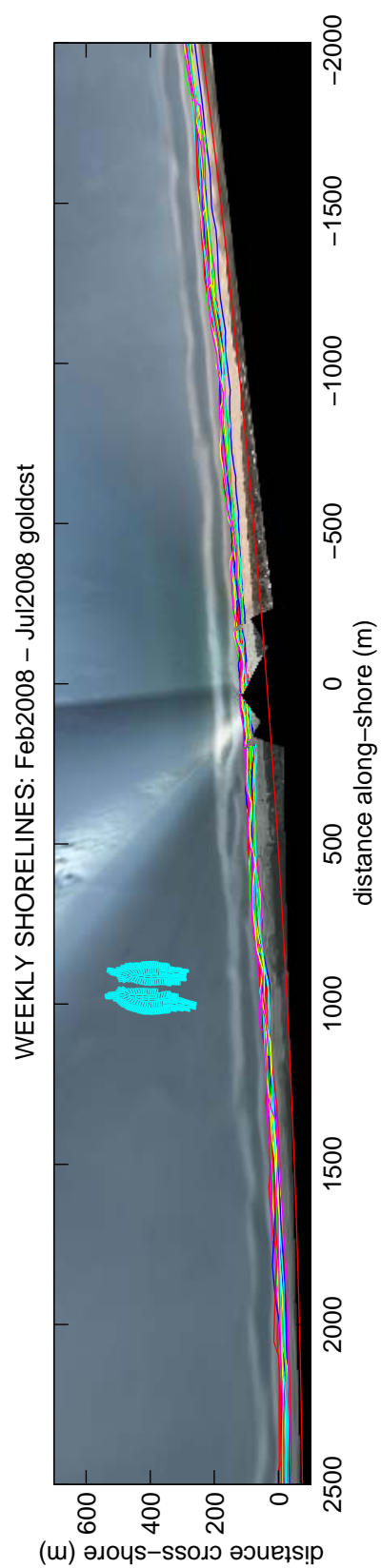
The analysis of maximum beach width (upper panel, [Figure 6.3](#)) reveals a relatively uniform maximum beach width of 5 m to 15 m wider than the mean shoreline position, along the 4,500 m study area. However, minimum beach width was less uniform, with the beach being significantly wider in the lee of the Narrowneck reef, compared with stretches of beach further to the south and north. South of the ARGUS station and north of the Narrowneck reef, the minimum beach width was typically 10 – 20 m narrower than the mean beach width. In the vicinity of the reef, the minimum beach width was typically only 5 m narrower than the mean beach width.

The middle panel of [Figure 6.3](#) shows the standard deviation of weekly shorelines from the mean shoreline position during the period 01/02/08–31/07/08. The standard deviation of weekly shorelines was the most extreme to the north of Narrowneck, peaking at the far northern end of the monitored section of beach at approximately 17 m. To the south of Narrowneck, the standard deviation in weekly shoreline position was reasonably variable alongshore, and typically ranged from 0 m up to 10 m.

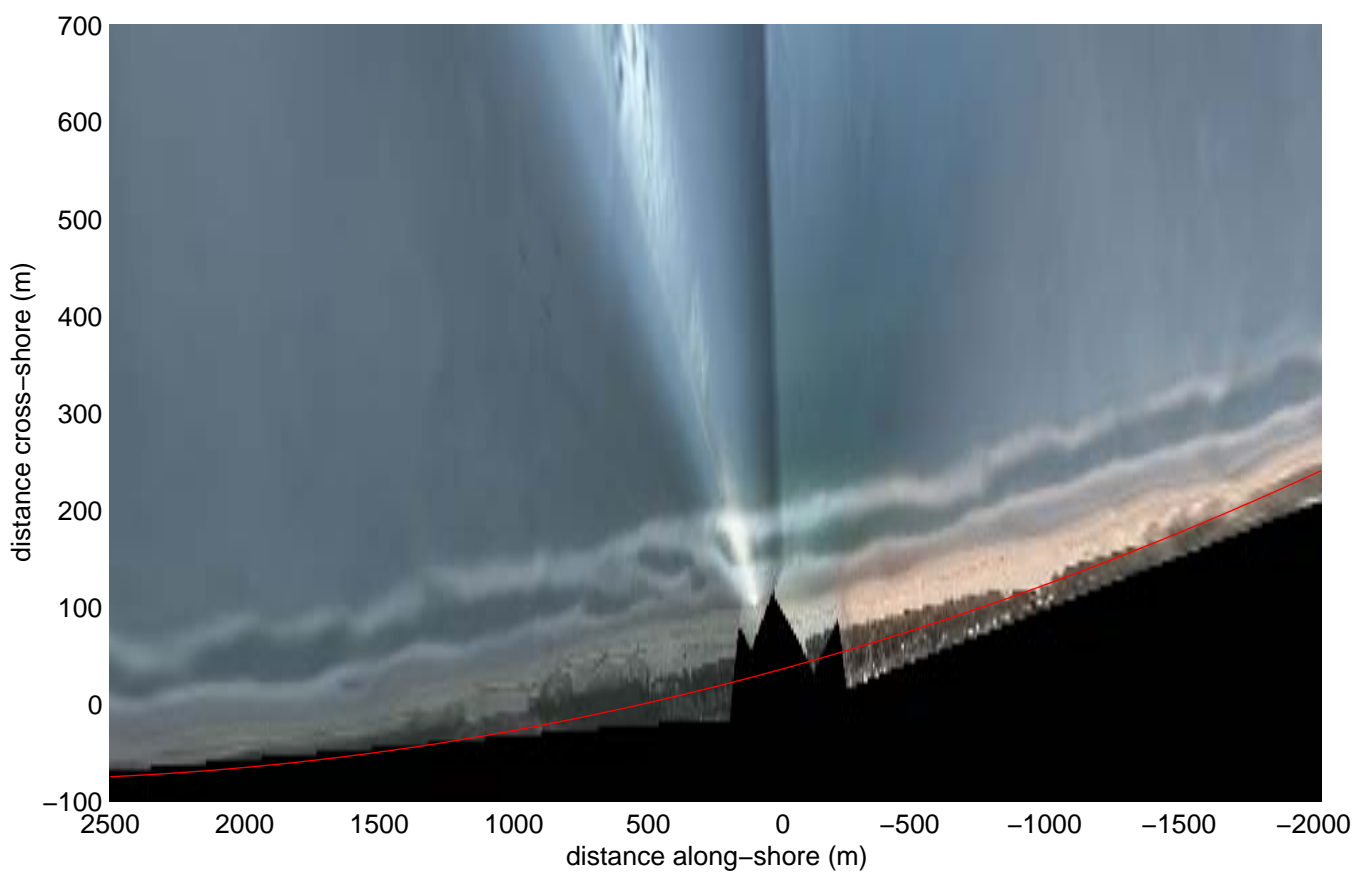
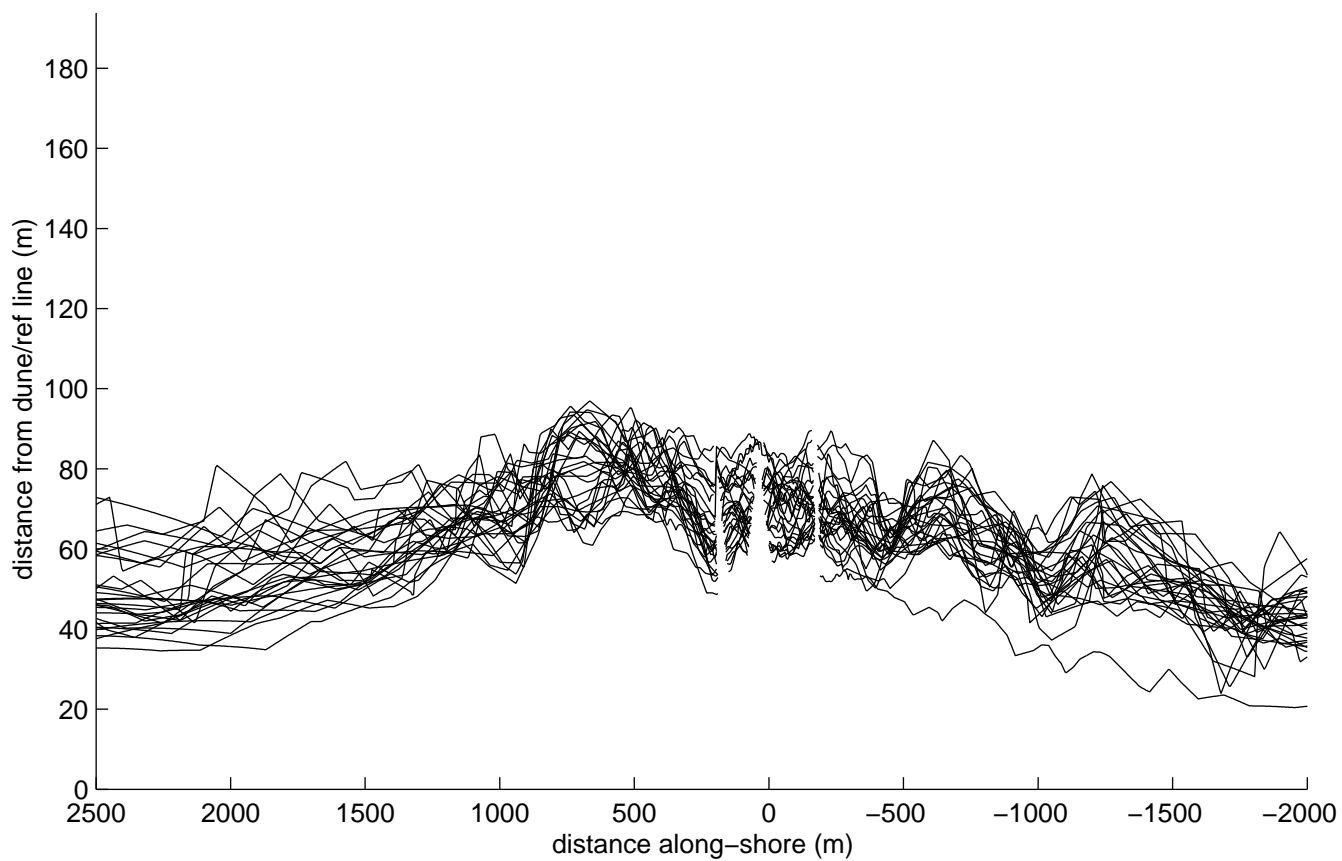
### **6.3 Weekly Shorelines (February – July 2008) Relative to Mean Shoreline Position of Previous Monitoring Period (August 2007 – January 2008)**

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 01/02/08–31/07/08 have been re-analysed and plotted relative to the mean shoreline position calculated for the previous six month monitoring period August 2007 – January 2008 (refer Blacka *et al.*, 2008). 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 August 2007 – January 2008 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 February – July 2008 varied approximately from 10 m wider to 10 m narrower than the mean beach width from the preceding six month monitoring period, for the region to the south of Narrowneck. North of Narrowneck, the maximum beach width was typically 5 – 20 m wider during the current monitoring period, than the mean shoreline position of the previous monitoring period. The minimum beach width during the current monitoring period of February to July 2008, was typically 30 – 40 m narrower than the mean beach width observed during the previous monitoring period August 2007 – January 2008. It can be seen from [Figure 6.4](#) bottom panel that the mean beach width was slightly wider during the previous monitoring period compared to the current monitoring period for the entire stretch of mapped beach.

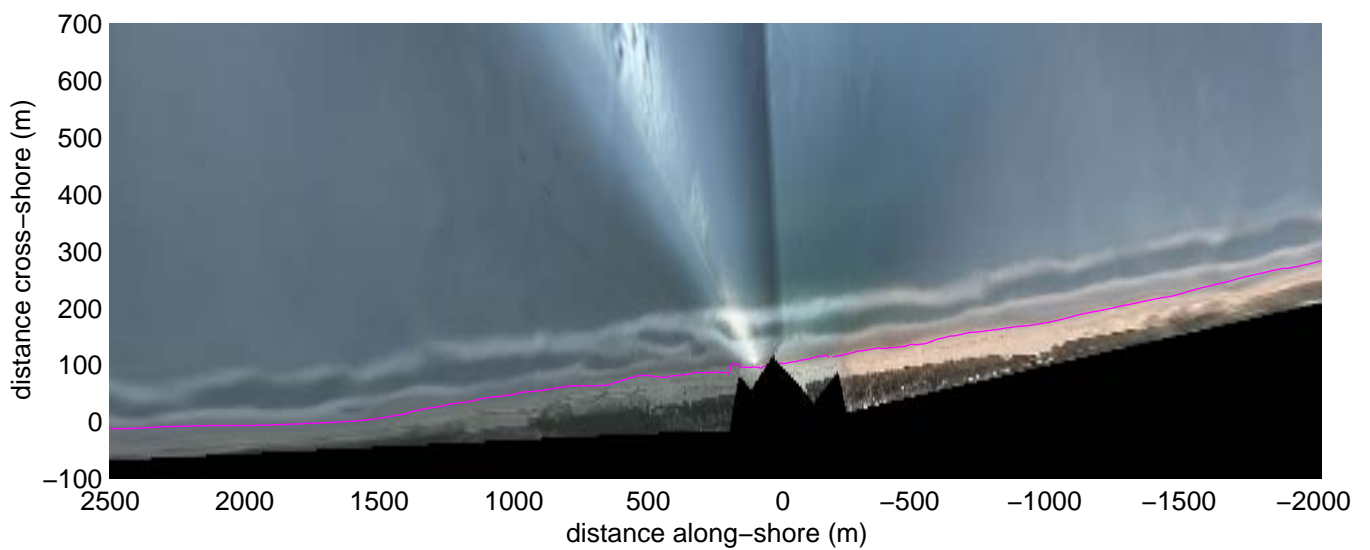
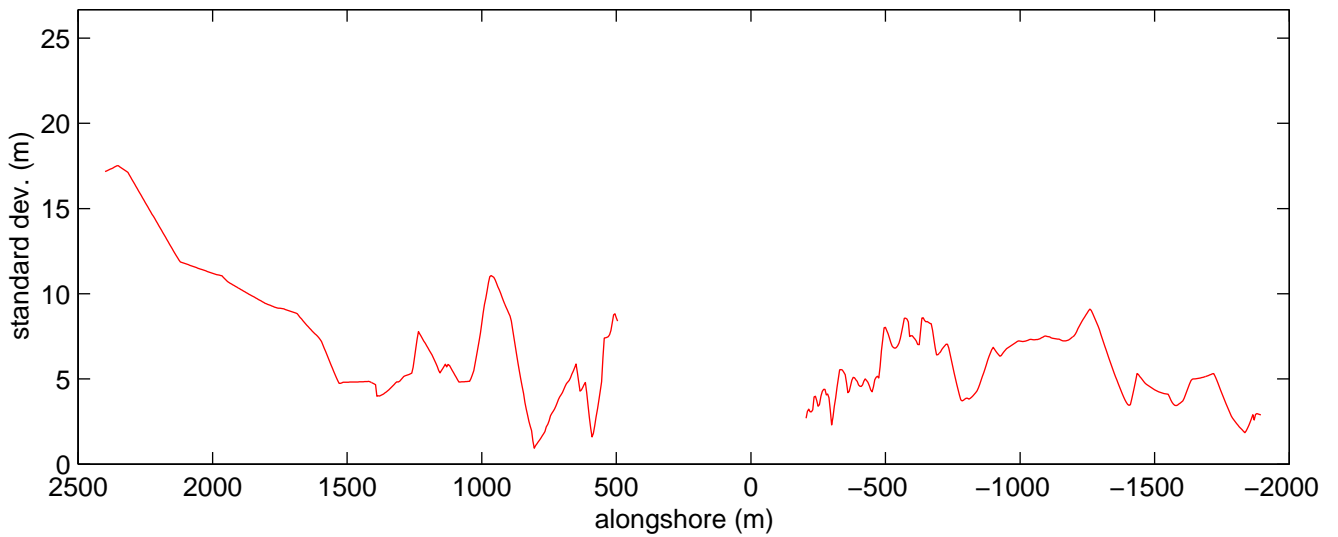
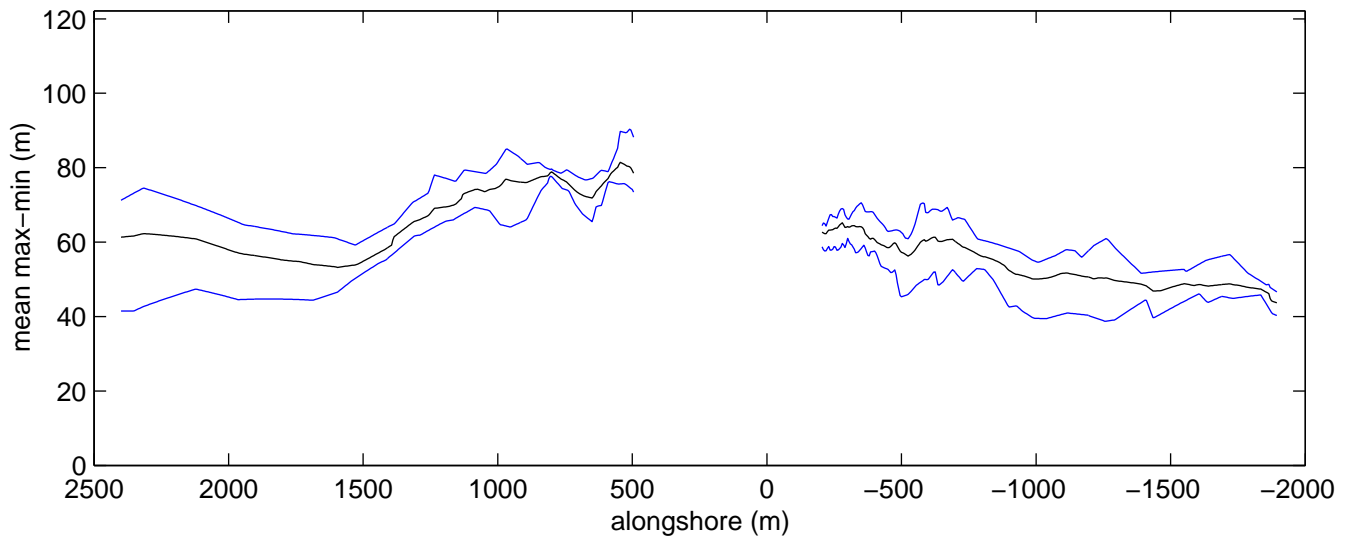


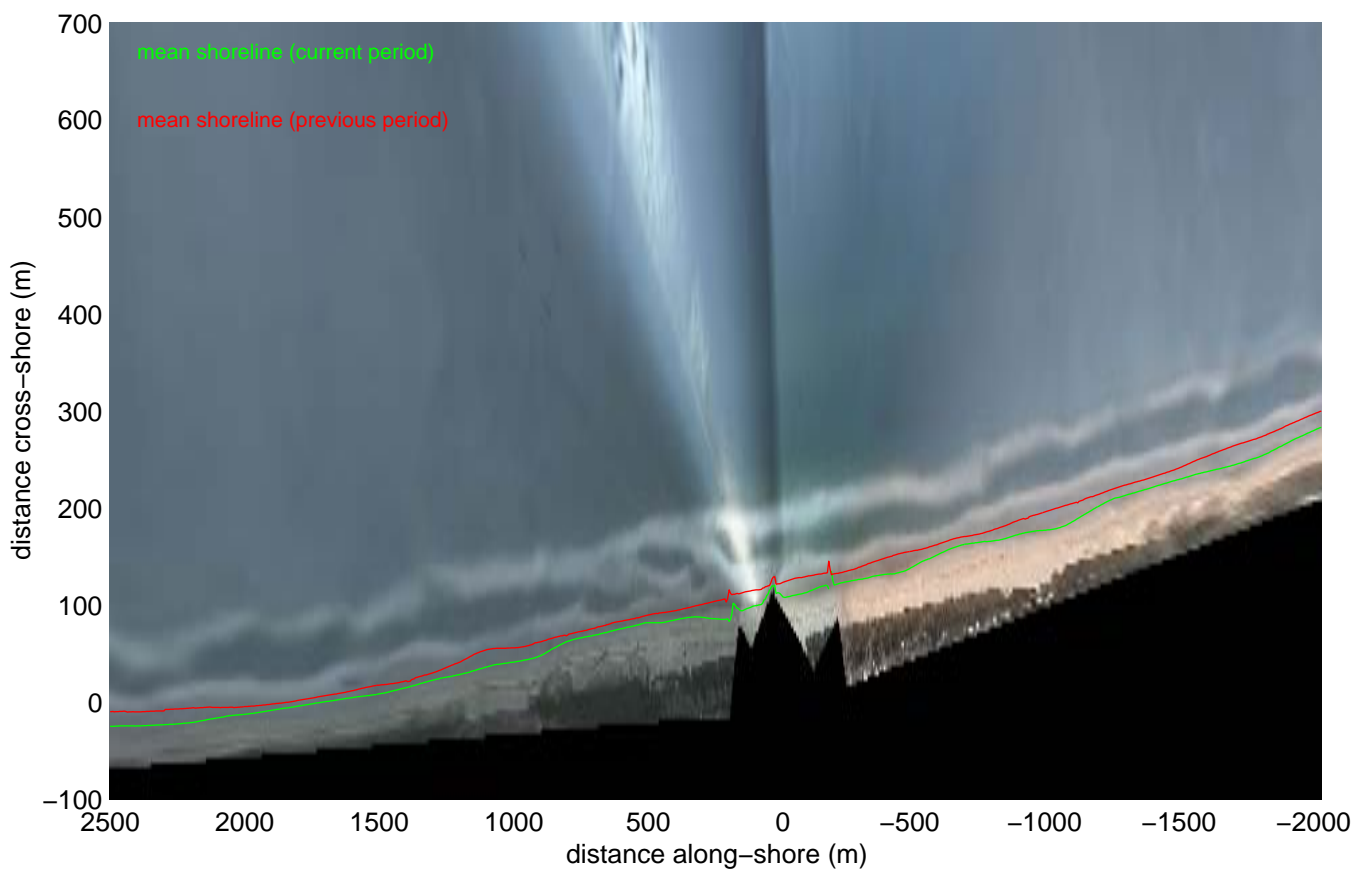
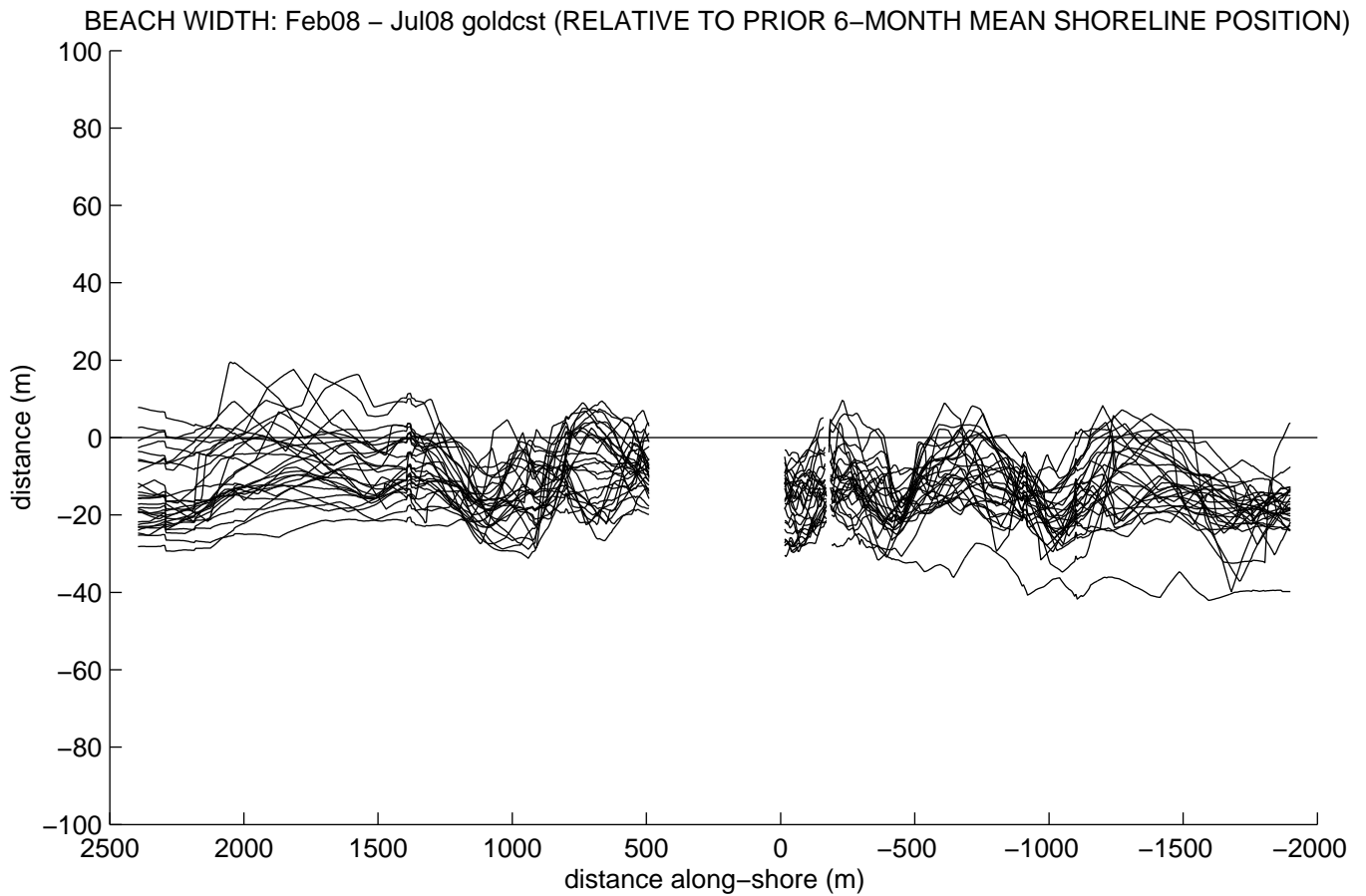
# BEACH WIDTH: Feb08 – Jul08 goldcst





BEACH WIDTH STATISTICS: Feb08 – Jul08 goldcst





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

The completion of a total of nine 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 – July 2008**

All weekly shorelines for the 468 week period August 1999 to July 2008 are shown in [Figure 7.1](#). As per previous figures, a merged/rectified image is shown in the lower panel for reference (image date: 31 July 2008). Again, due to sun glint the data between –100 m and 500 m alongshore is less reliable, and is excluded from the following analysis and discussion. Over the entire 108 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 60m 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 seven representative survey transects alongshore for the entire nine year period August 1999–July 2008 are shown in [Figures 7.2](#) and [7.3](#). [Figure 7.2](#) plots the weekly shoreline position at transects spaced at regular 500m intervals north of the camera location, and [Figure 7.3](#) plots the weekly shoreline position at transects spaced at 500m 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: 31/07/2008).

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 2007 resulted in the beaches generally being in an eroded state for most of the period from August 2007 to January 2008. 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 energy wave 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.

Ongoing moderate wave conditions, separated by periods of higher and lower wave energy, resulted in little net change in observable beach width during the current monitoring period, February to July 2008. Typically, the nearshore surfzone was in a complex TBR morphological state, with occasional shifts to a wider and more energetic LBT state. On several occasions of lower energy wave conditions, localised sections of the beach accreted through the formation of terrace or undulation features at the beachface. The beach width at the four northern and three southern monitoring transects can be seen to be very similar to that observed nine years ago prior to the extensive nourishment program.

Referring to [Figures 7.2](#) and [7.3](#), at the completion of nine years of monitoring and around eight 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 occurrence of higher than average wave conditions during the period August 2007 to July 2008 and the effects of several large low pressure systems resulted in the beach being maintained in an eroded state. At the completion of the current monitoring period, the beach is again as narrow as it was at the beginning of the monitoring program nine 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 has prevailed throughout the entire nine year monitoring period. Following the March 2006 event, the northern beaches steadily recovered, until August 2007. North of the Narrowneck reef, the beach suffered extensive erosion during the period August 2007 to January 2008, and throughout the current monitoring period, the beaches have maintained an eroded state due to ongoing larger than average wave conditions. The beach to the north of Narrowneck is narrower at the completion of the current monitoring period than what it was nine years ago prior to the extensive nourishment program. 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](#)), the shoreline and beach width data is 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 July 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 collected to date 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 eight year period August 2000 to July 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 (4.5 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 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 identifying a continuing breakdown of the seasonal cyclic erosion/accretion trends at the Gold Coast. The current monitoring period of February to July 2008 showed fluctuations in beach width along both the northern and southern stretches of beach, with a weaker trend of accretion than has been observed at this time of year previously.

In the upper panel of both these figures the best-fit linear trend to the full eight 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  $\pm 20$  m, indicating a range of approximately 40 m annual variability in beach width. Since 2007, both wider and narrower fluctuations of beach width have been recorded that have exceeded the typical window of observed beach widths. This highlights the periods of more extreme ongoing higher and lower wave energy experienced during the last 1.5 year period. In contrast to the relatively high seasonal cyclic variations, referring to the upper panel in both figures, the underlying trend at both sites is of a significantly lower magnitude.

The previous beach monitoring reports (Blacka *et al.* 2007a and 2008) documented the effect of the March 2006 and January 2008 storm events. These isolated events, and the inability of the beach to fully recover, have perhaps exaggerated the long term erosive trend for the northern Gold Coast beaches. From August 2000 to the end of July 2008, the long term trend over both the northern and southern sections of beach has been determined to be erosion at a rate of -2.8 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 month 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 18 months of monitoring, this trend has now been reversed to indicate long term erosion, at an increasing rate, with the current estimate of -2.8 m per year. Along the northern beaches a more constant (but still accelerating) erosion trend has been observed, with the current estimated erosion rate of -2.8 m per year being the highest rate of erosion predicted during the past eight years.

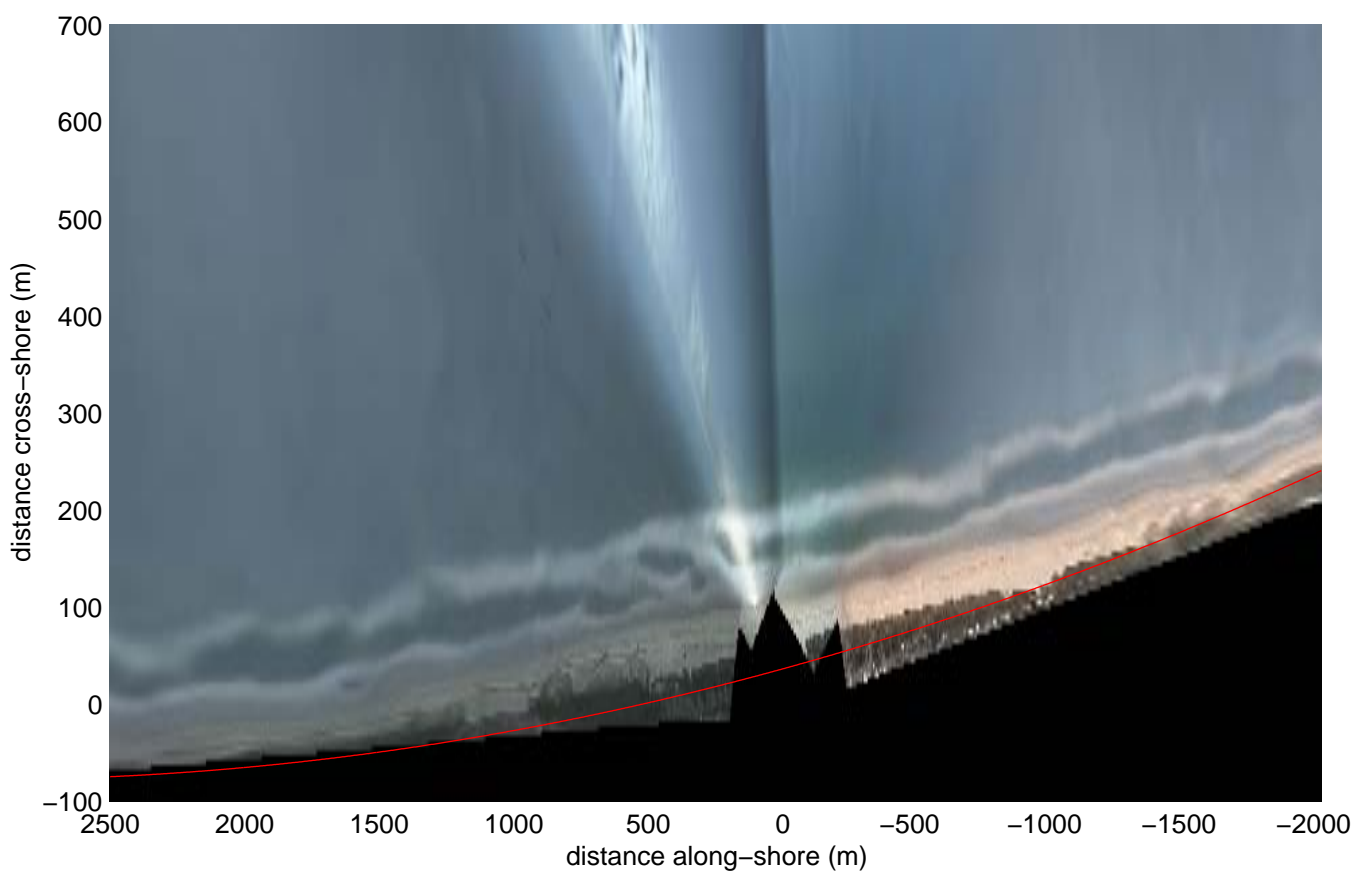
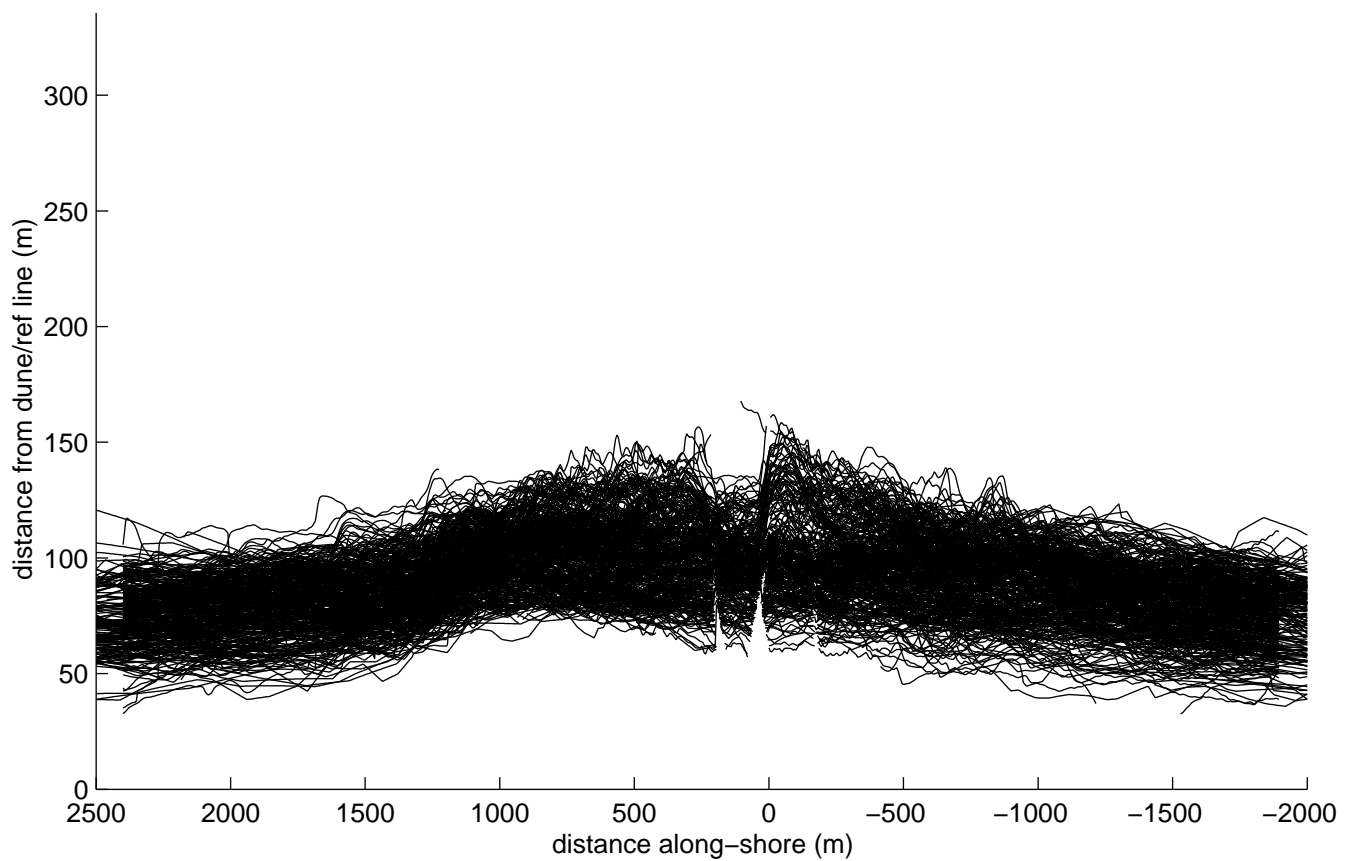
**Table 7.1**  
**Summary of Cyclic-Seasonal Variability versus Net Erosion-Accretion Trends**

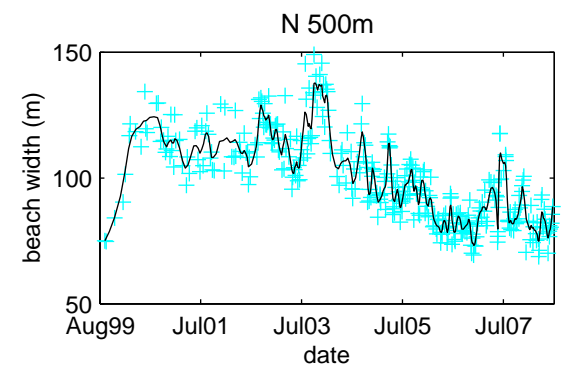
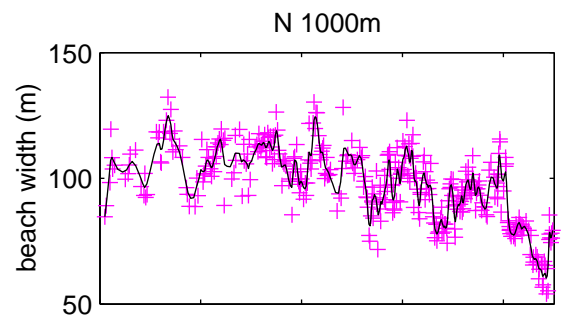
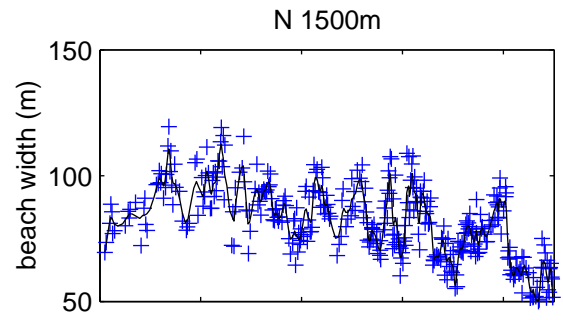
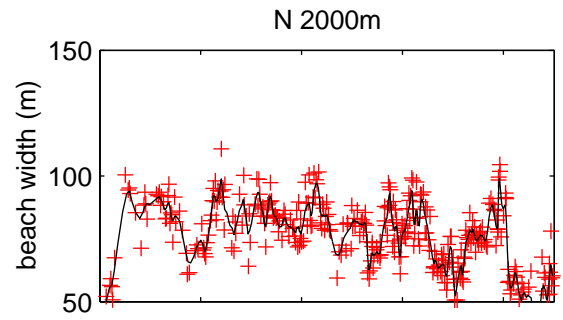
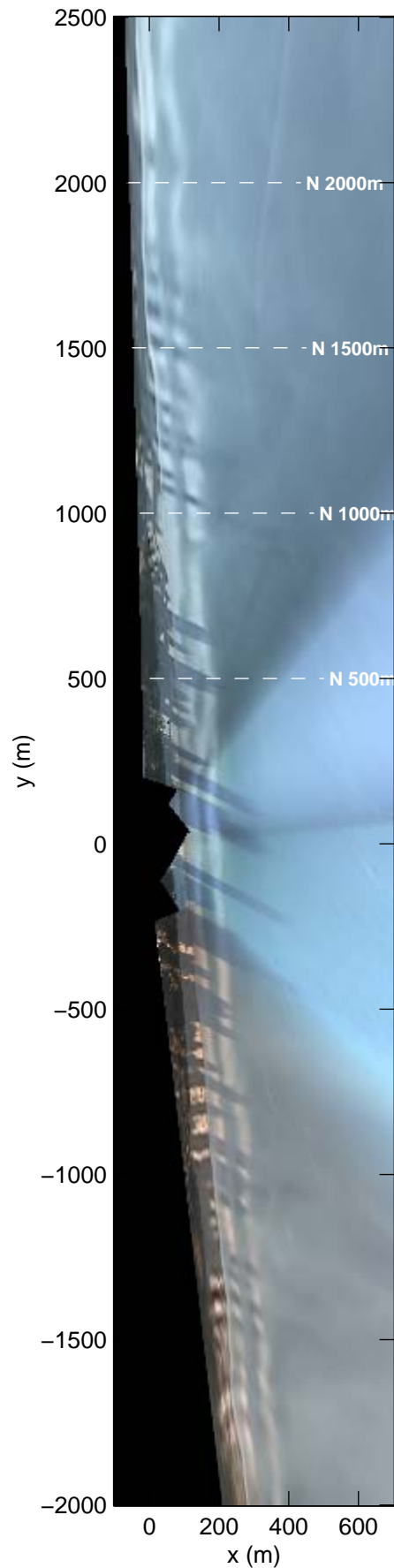
Post-nourishment monitoring period	Years	Cyclic-seasonal variability (m)	Net erosion-accretion trend (m per year)	
			North	South
August 2000 – January 2004	3.5	±20	+1.1	+7.4
August 2000 – July 2004	4	±20	-0.6	+5.2
August 2000 – January 2005	4.5	±20	-1.8	+3.1
August 2000 – July 2005	5	±20	-1.1	+3.8
August 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
August 2000 – July 2008	8	±30	-2.8	-2.8

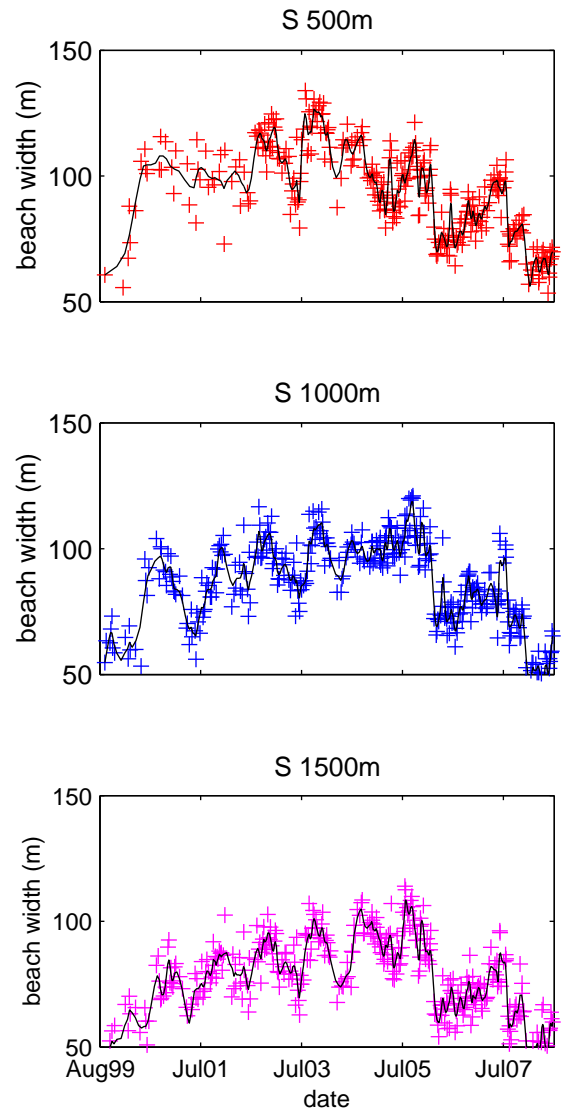
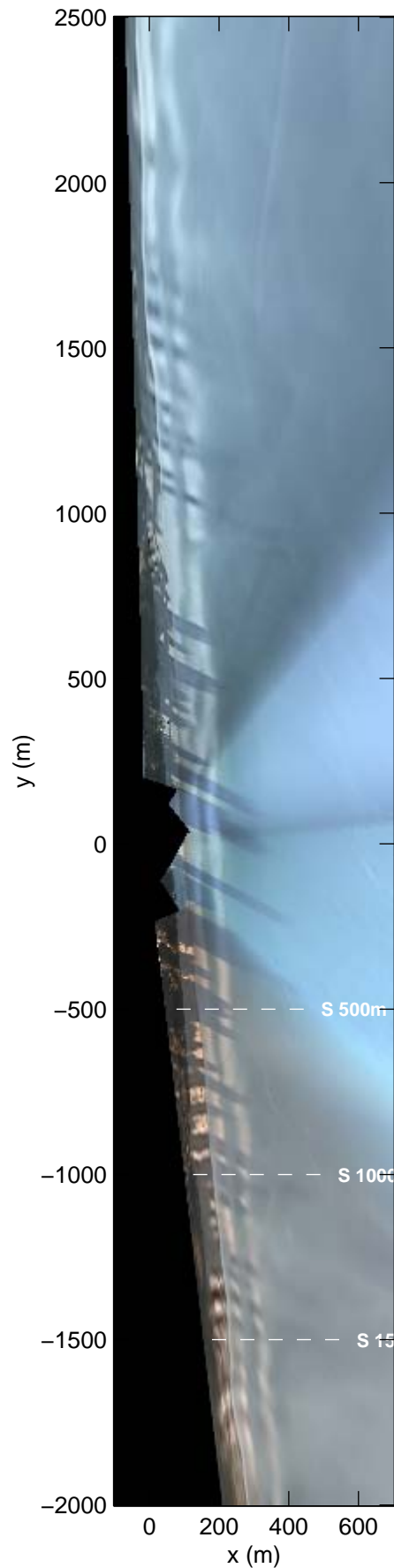
The eight years of data upon which these longer-term trends are inferred is now sufficiently long to permit the results of this analysis to be used for future forecasting with a reasonable degree of confidence, and to draw two important conclusions regarding the regional-scale trends at the northern Gold Coast. The first conclusion refers to the long term erosion/accretion trends observed to date. While there was initially a net minor beach accretion trend in the south, it is becoming increasingly likely that the long term trend is that of erosion, which is now predicted to be of the order -2.8 m per year (-22.4 m recession over eight years). The long term trend for the northern sections of beach also appears to be accelerating net erosion, also of the order of -2.8 m per year (-22.4 m recession over eight years). 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 annual beach width change.

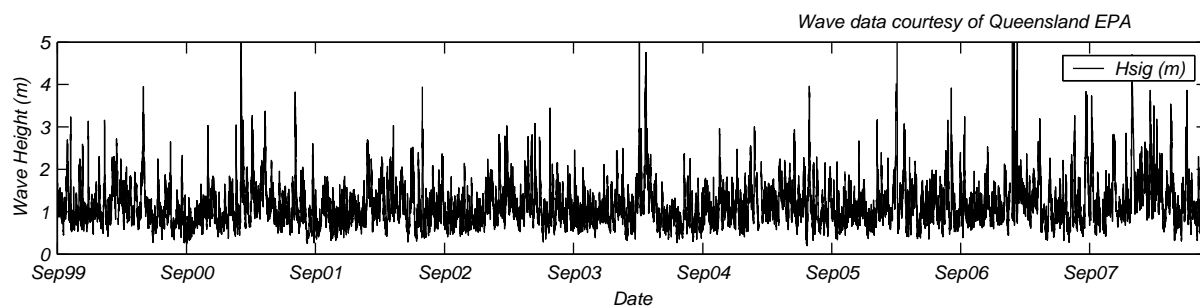
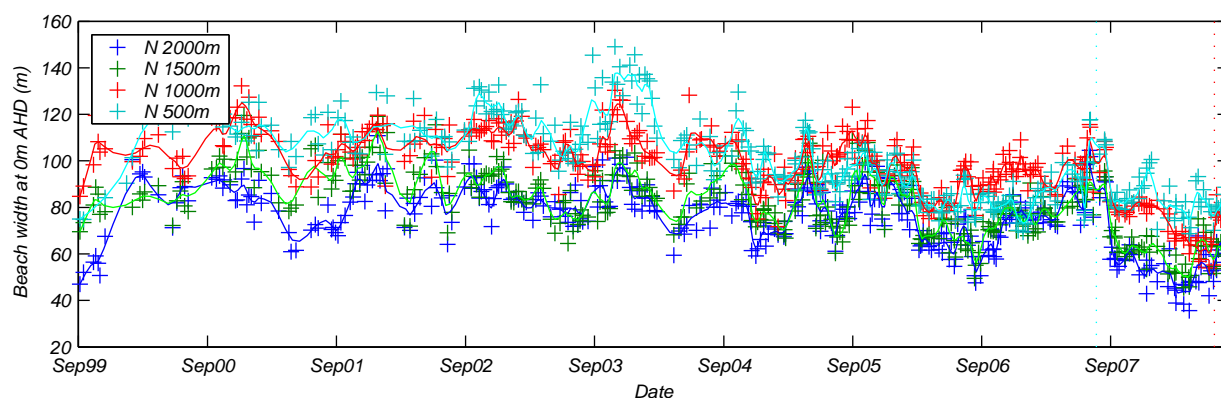
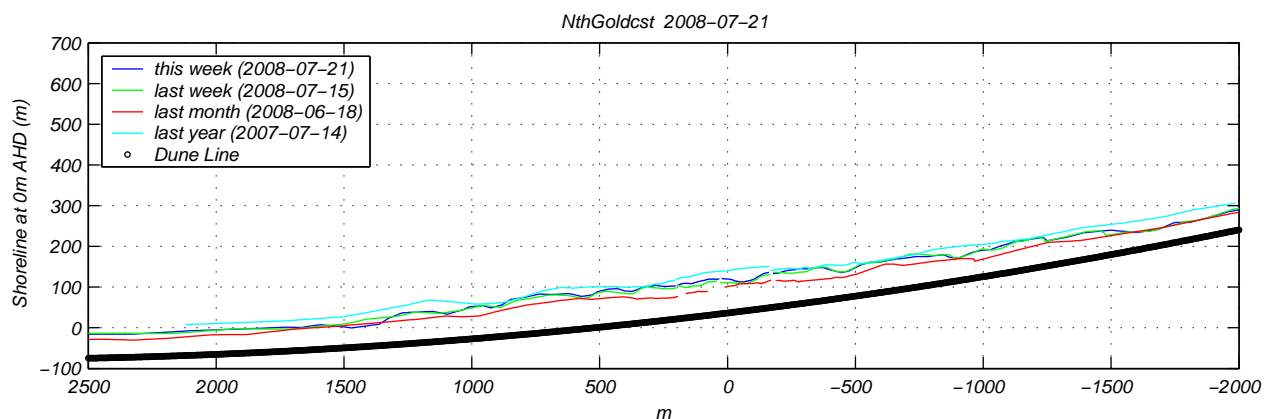
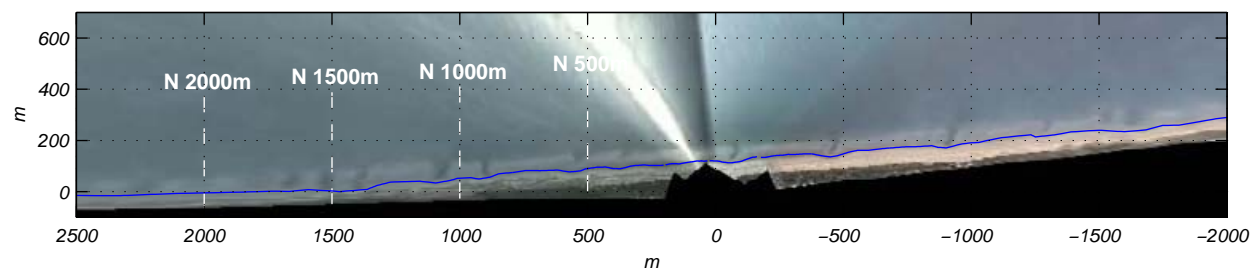
The underlying trend of long term erosion for the monitored section of the northern Gold Coast beaches will require future planning and ongoing management. It is now apparent that the rate of long term erosion of the beaches appears to be accelerating, with both the southern and northern stretches of monitored beach having long term erosion rates of almost 3 m per year. 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.

# BEACH WIDTH: Aug99 – Jul08 goldcst



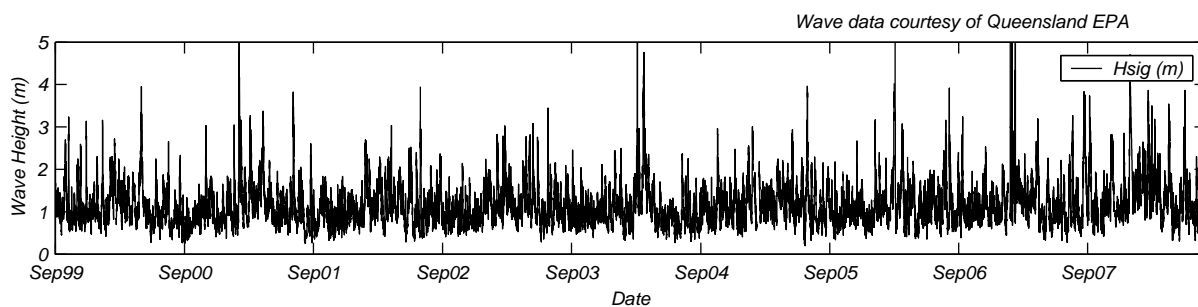
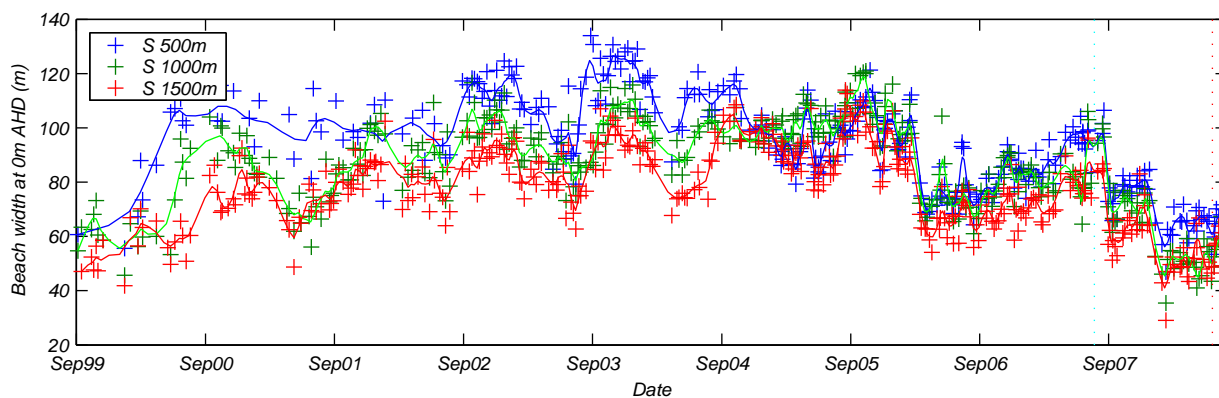
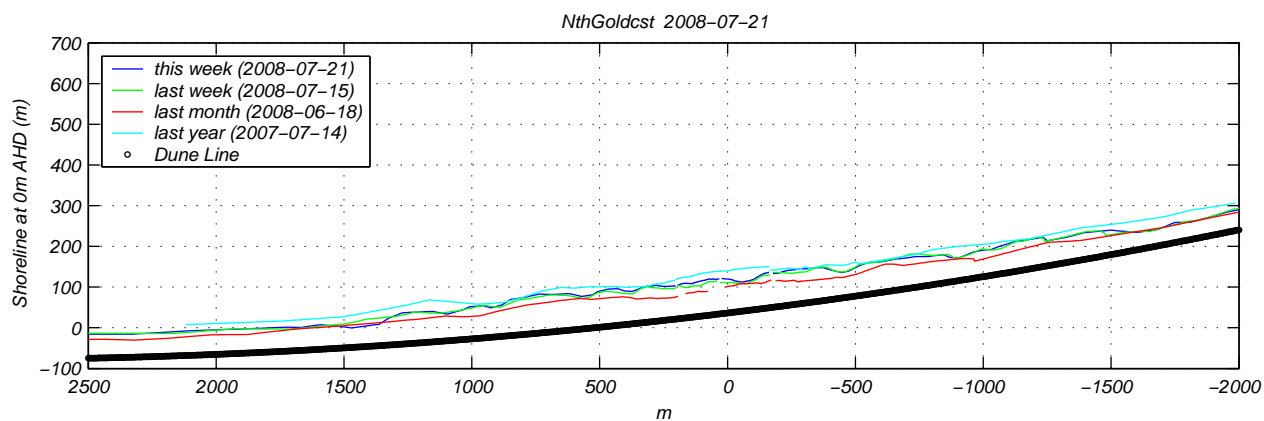
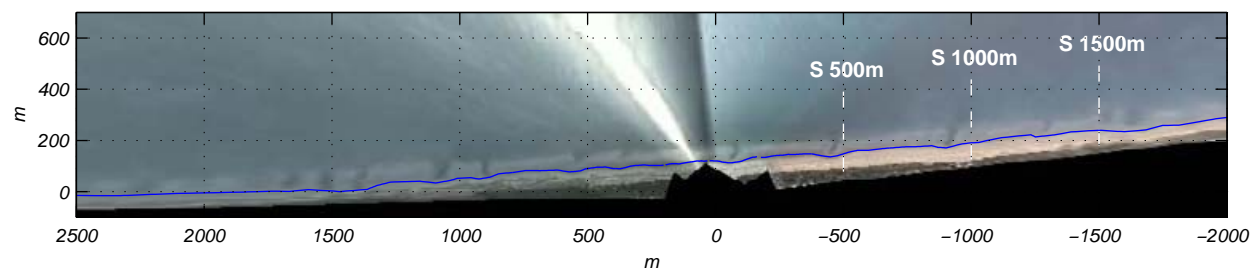




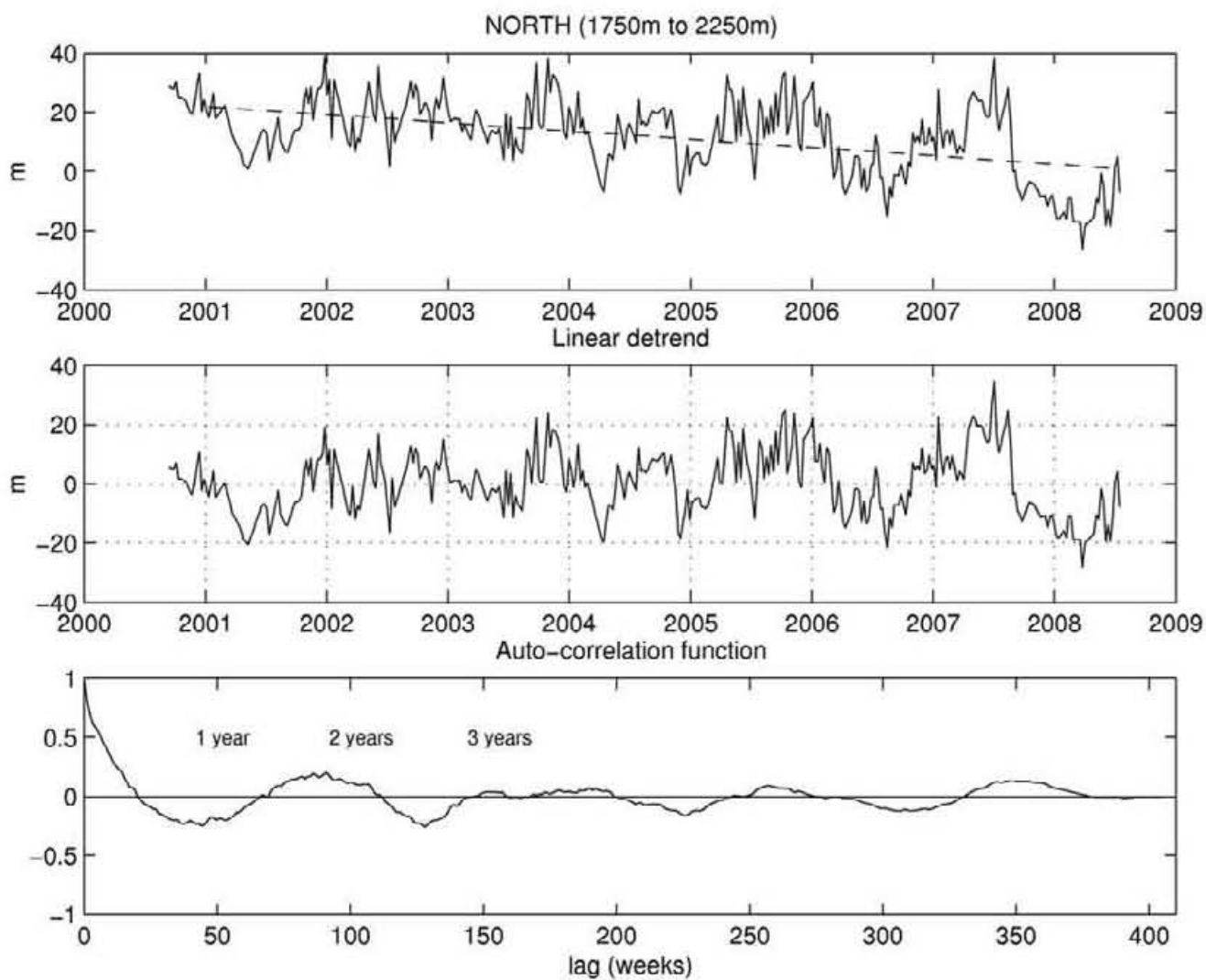


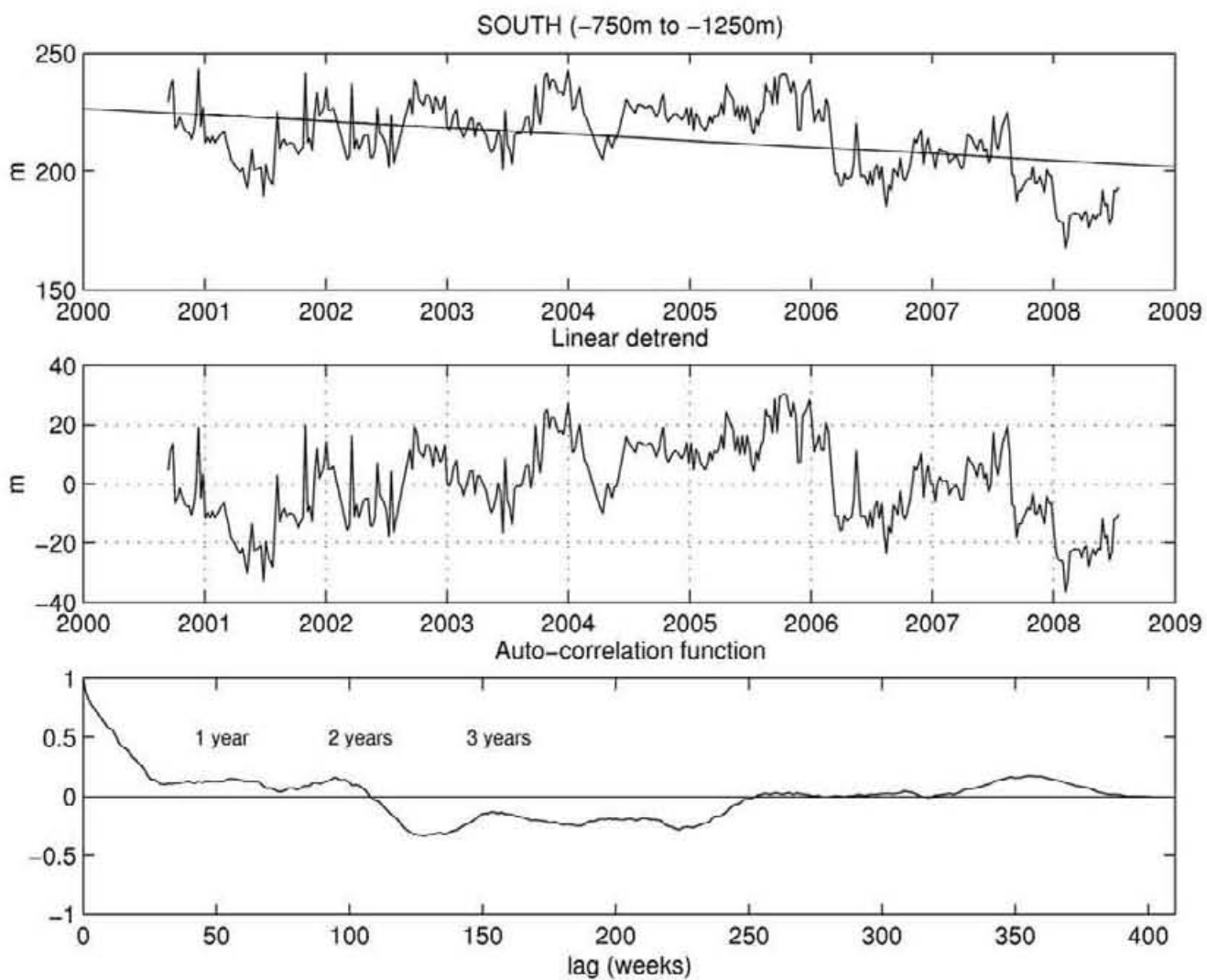
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## 8. ASSESSMENT OF SHORELINE TRENDS IN THE LEE OF THE REEF

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: February – July 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 01/02/08–31/07/08 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 February – July 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 - 40 m alongshore, with the minimum variability occurring at distances of 850 m and 1150 m north of the cameras. Figure 8.3 (upper panel) shows that the maximum and minimum beach width varied from the mean beach width by approximately 5 m, for the section of beach to the north of the reef. In the lee of the reef and further south, the minimum and maximum beach width was observed to vary from only 1 m from the mean shoreline position, to up to 10 m from than the mean shoreline position.

There was no significant observable trend in the standard deviation of weekly shorelines alongshore (Figure 8.3, middle panel) during the present monitoring period. North of the reef, the standard deviation was relatively consistent at approximately 5 m, while south of the reef the standard deviation was significantly more variable. The minimum standard deviation in beach widths of only 1 m occurred at 800 m north of the ARGUS station (just south of the reef location). The maximum standard deviation in beach widths of over 10 m occurred just north of the reef location, at approximately 950 m north of the ARGUS station.

Figure 8.4 shows the weekly shorelines for the present monitoring period February to July 2008, relative to the mean shoreline position for the preceding monitoring period August 2007 to January 2008. The shoreline alignment at Narrowneck through the present monitoring period showed that the entire stretch of beach was generally narrower compared with the previous monitoring period. At times, the beach was up to 10 m wider and 20 m narrower during the present monitoring period, than the mean shoreline position from the previous monitoring period.

Fluctuations of the shoreline position during the present monitoring period February to July 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 this 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 stable beach width throughout February and March, followed by slight accretion during April, then slightly more rapid accretion in June. At transect R1, the beach width was slightly wider at the completion of the current monitoring period, while a burst of erosion in July at transect R2 saw the beach very similar in width at the end of July to six months earlier at the start of the monitoring period in February. At transect R3 (directly in the lee of the Narrowneck reef) the beach narrowed by approximately 20 m from February to April, followed by approximately 20 m of accretion during the period May to July. At the completion of the current monitoring period, the beach was similar in width at transect R3, to six months earlier when the monitoring period began.

At the transects R4 (150 m south of reef) and R5 (300 m south of reef), beach width was reasonably stable during February, March, and April. During the month of May, the beach gained approximately 15 m in width, and was then relatively stable throughout June and July. At the completion of the current monitoring period, the beach width at transects R4 and R5 was approximately 15 m to 20 m wider than six months earlier in February 2008.

## **8.2 Total Monitoring Period: August 1999 – July 2008**

Figure 8.6 shows the changing shoreline position for the entire 108 month monitoring period August 1999 to July 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 through 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, before suffering further erosion during the early months of 2008, at which point the beach was the narrowest it had been at any time during the nine year monitoring period. Steady accretion during the month of June, late in the current monitoring period, again saw the beach return to similar width to that recorded nine years earlier prior to the major beach nourishment campaign.

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 nine 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 been noted to suffer significantly less erosion during large storm events 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. In the immediate lee of the reef there was slight erosion during February and March 2008, while updrift of the reef there was little net change in width. All three transects generally accreted during April, May, and June, with transects R4 and R5 being slightly wider at the completion of the current monitoring period, than nine years earlier in 1999.

By the end of February 2008 the beach in the lee of the reef was up to 40 m narrower than that at the commencement of monitoring eight and a half years earlier. The beach recovered approximately 20 m of width during April, May, and June 2008, to be slightly narrower at the end of the current monitoring period than nine years earlier when monitoring began. South of the reef at transects R4 and R5 the beach was relatively stable during the early months of the current monitoring period, before accreting by approximately 20 m during May, June, and July. At the completion of the current monitoring period the beach is approximately 15 m to 20 m wider than at the initiation of monitoring nine 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 six month period to the end of July 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.



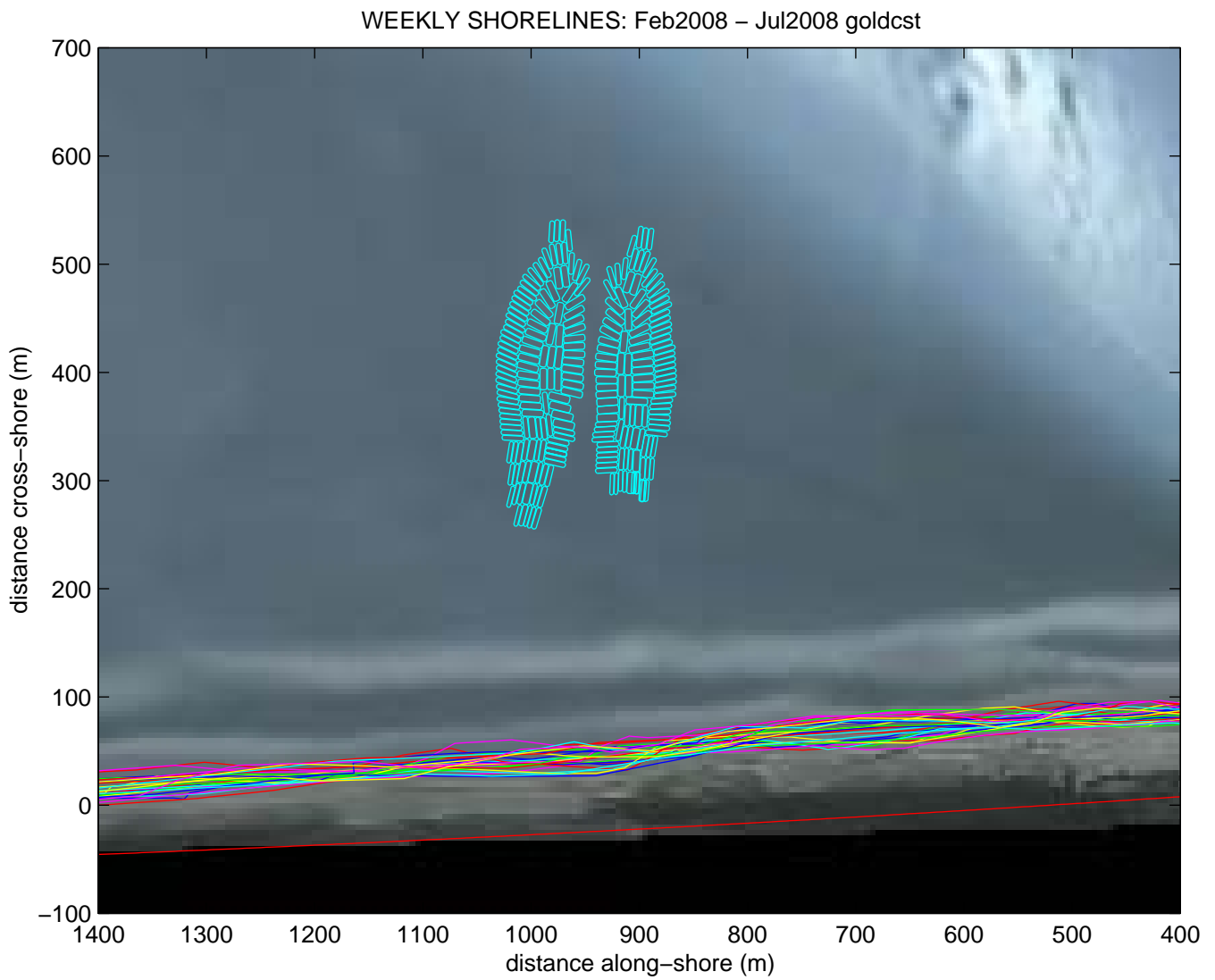
As per the northern and southern sections, the cyclic variation in beach width observed at Narrowneck (middle panel) for the eight year period August 2000 to July 2008 is of the order of  $\pm 20$  m annually. It is interesting to note, however, that the east coast low and associated erosion in March 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 (Figures 7.6 and 7.7), while at Narrowneck, this has not been the case. The occurrence of these large storm events during the last 1.5 years has dominated the erosion/accretion of the beach, with the underlying seasonal variations in beach width less obvious during this period. Referring to the best-fit linear trend to this data as shown in the upper panel of Figure 8.8, the underlying trend at this site for the eight year period to July 2008 is estimated to be of the order of -4.3 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 the magnitude of long term erosion predicted to be the greatest at the completion of the current monitoring period, than at any other stage during the analysis.

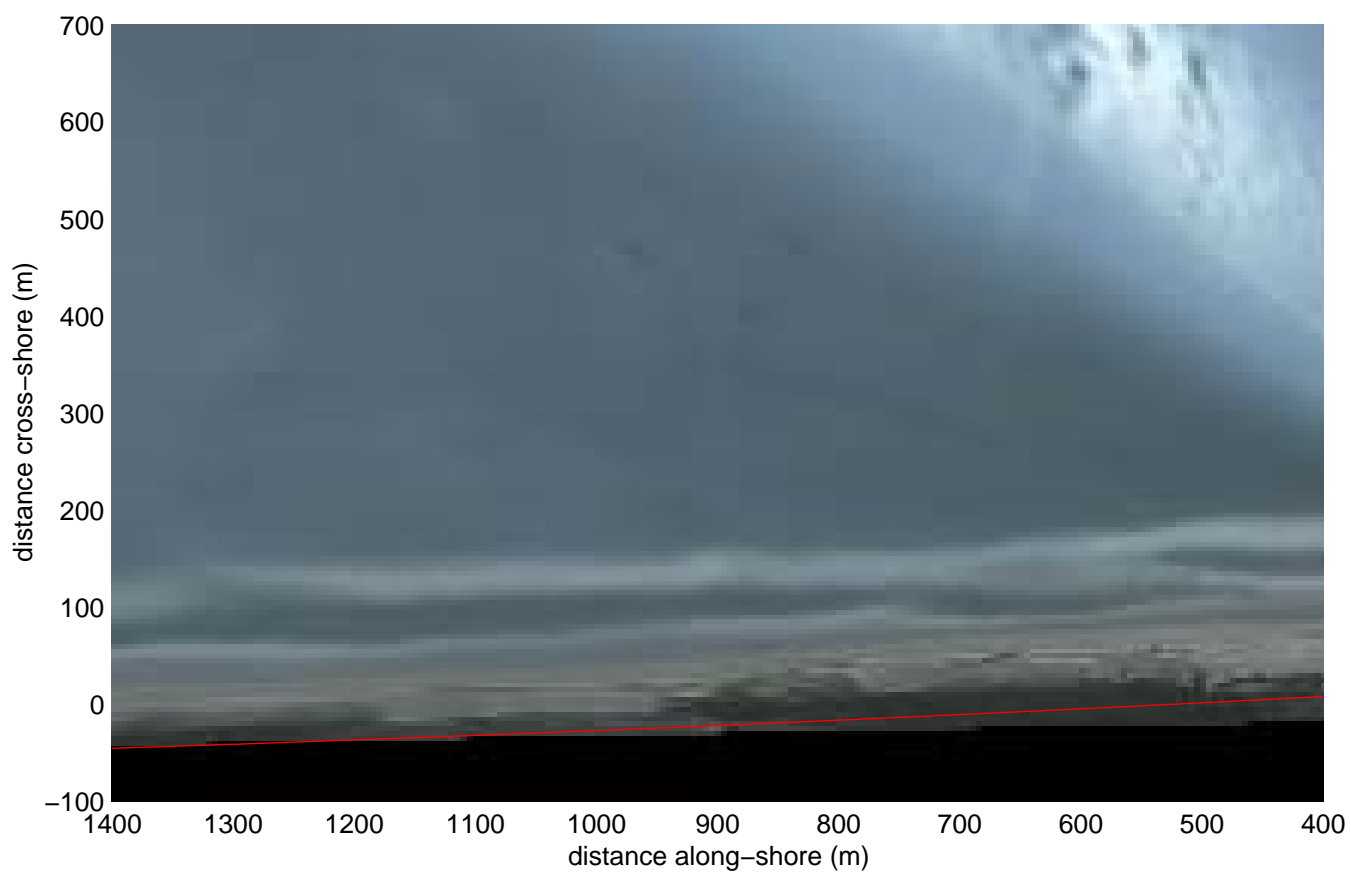
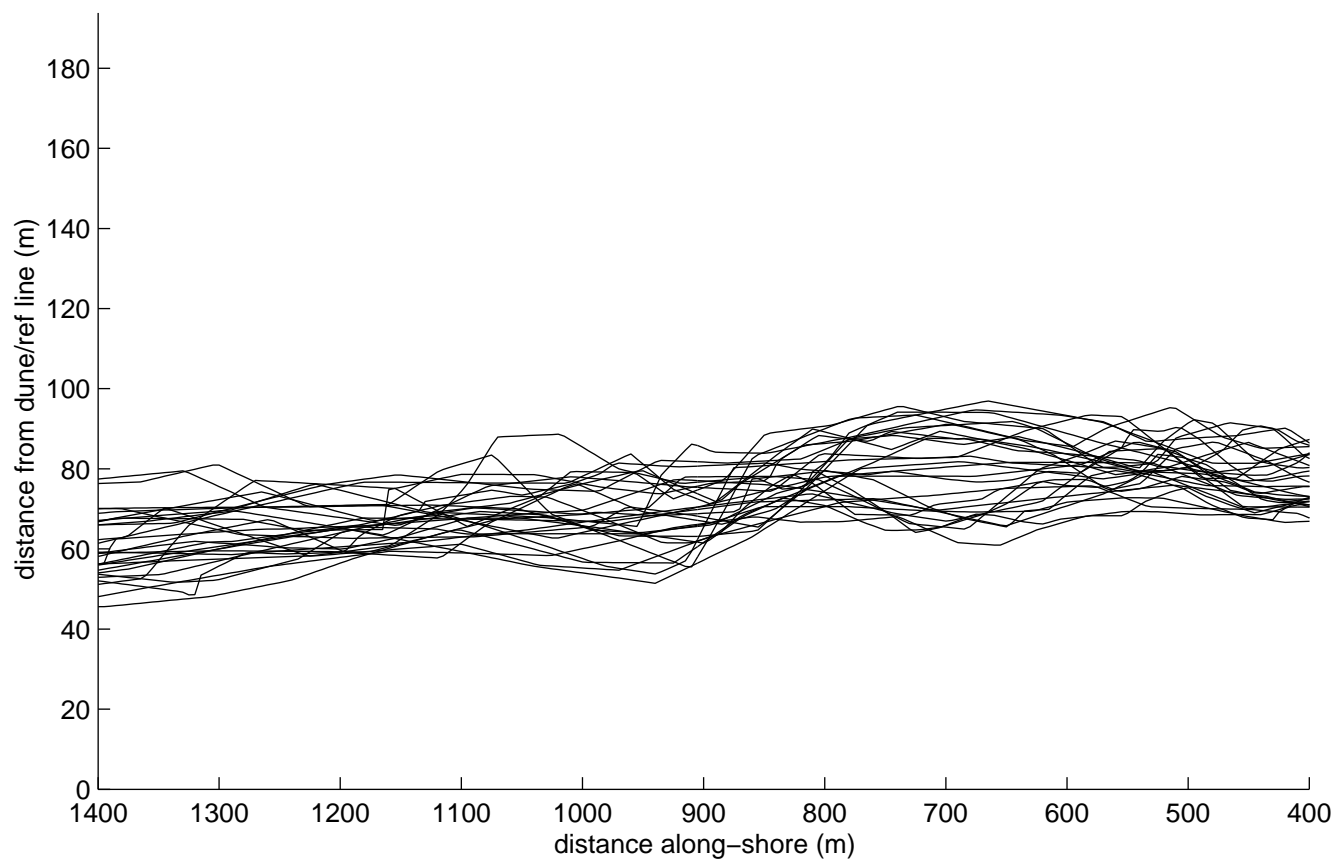
**Table 8.1**  
**Summary of Cyclic-Seasonal Variability versus**  
**Net Erosion-Accretion Trends (Narrowneck)**

<b>Post-nourishment monitoring period</b>	<b>Years</b>	<b>Cyclic- seasonal variability (m)</b>	<b>Net erosion-accretion trend (m per year)  Narrowneck</b>
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
August 2000 – July 2008	8	±20	-4.3

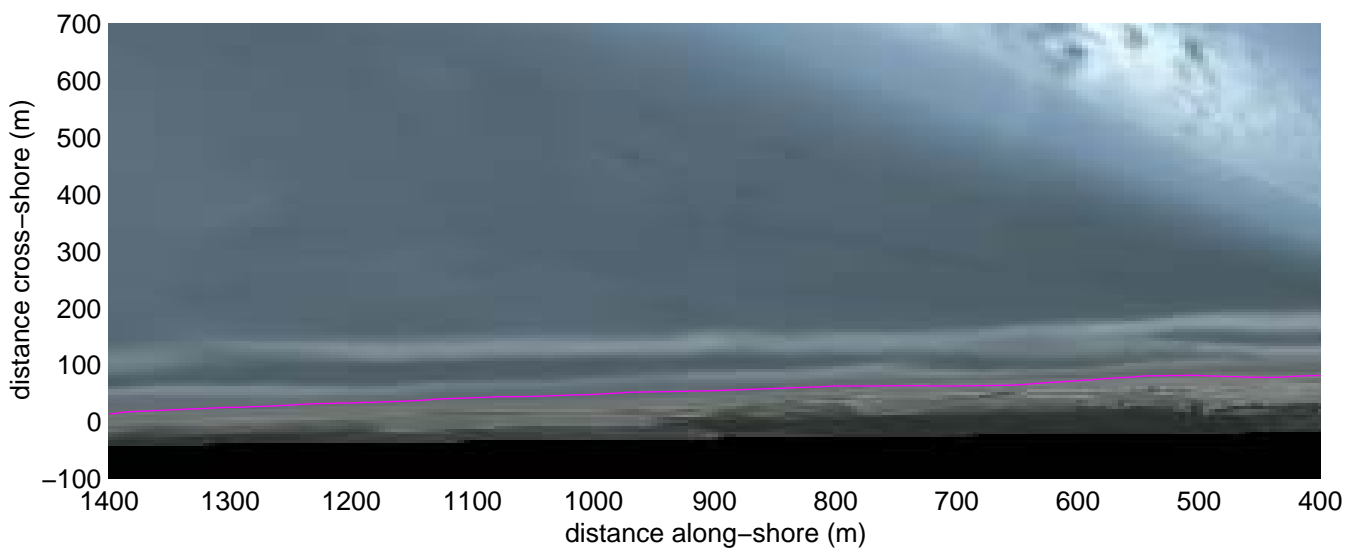
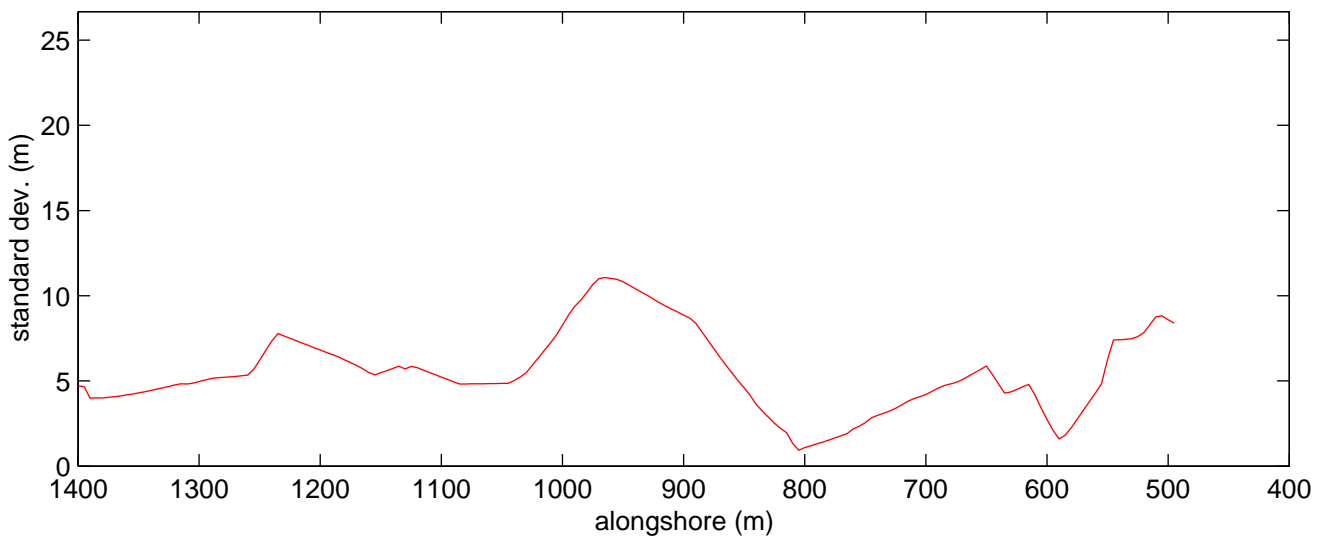
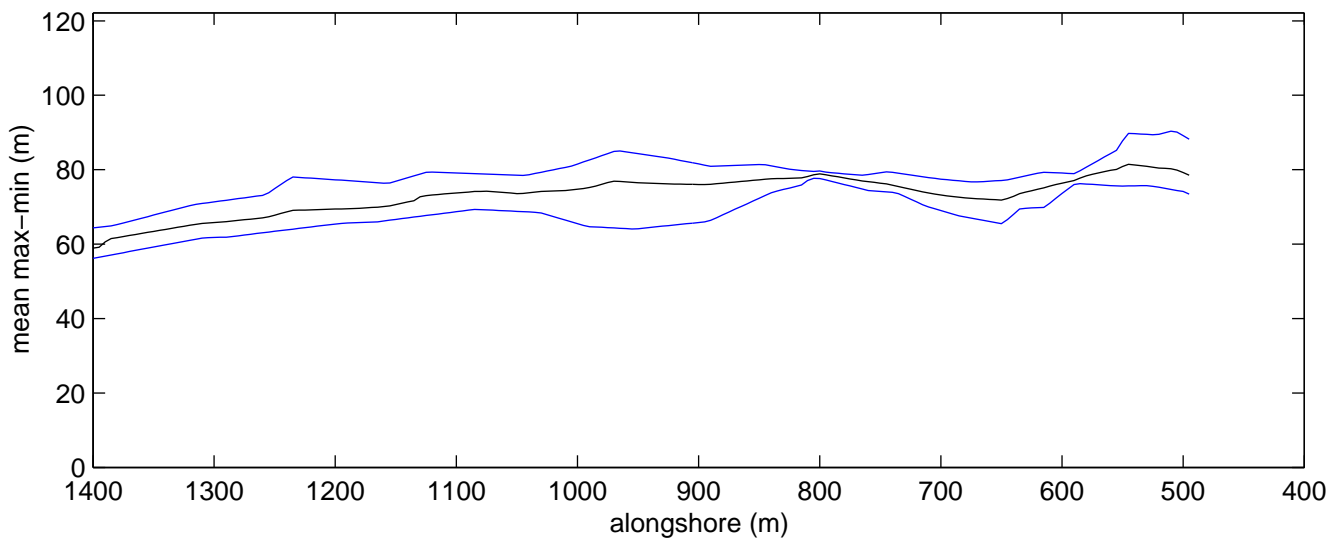
From the results presented in Table 8.1 it is concluded that at Narrowneck the underlying local beach width trend to date, since the completion of sand nourishment in mid 2000, has been modest net erosion of the order of -4.3 m per year (34 m over eight years). More significant to the future management 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 erosional beach width trend.

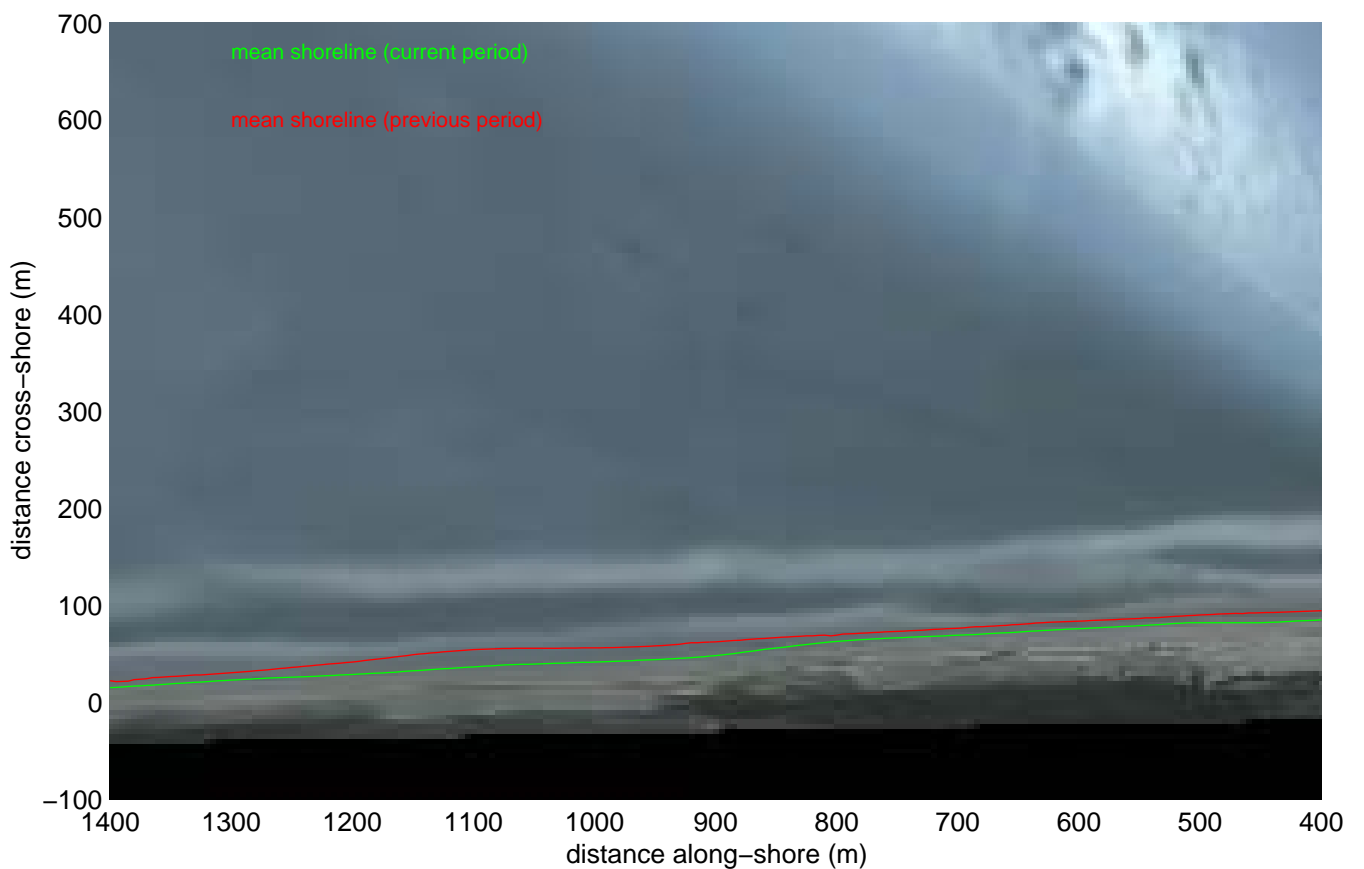
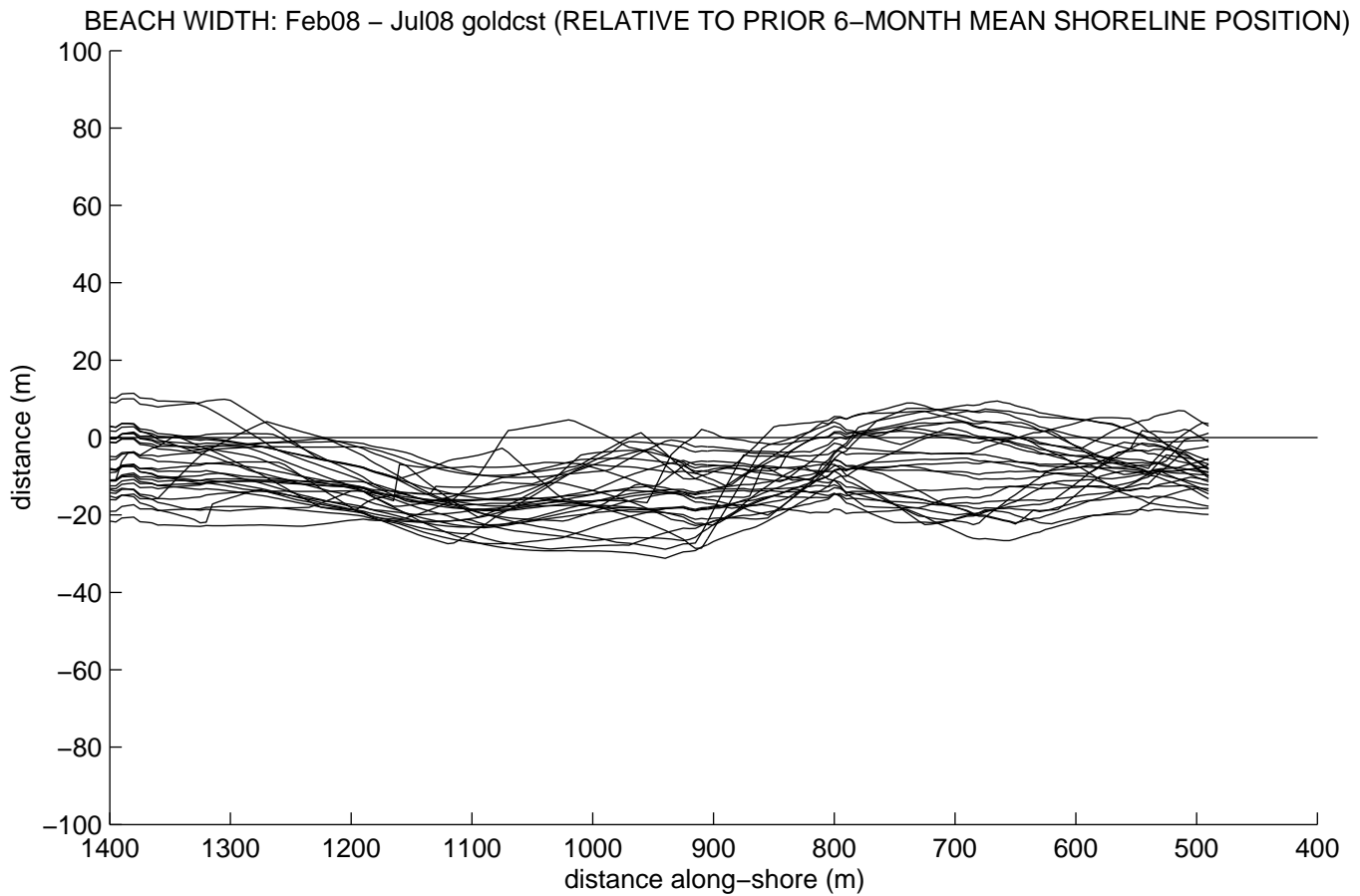


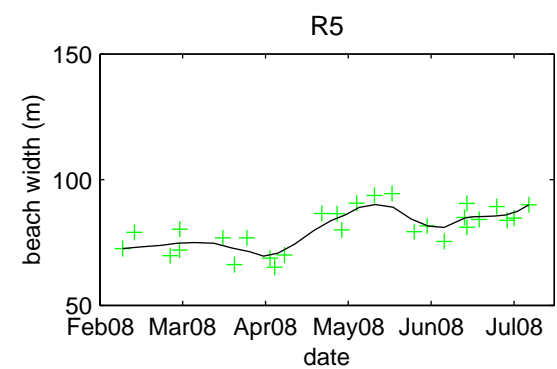
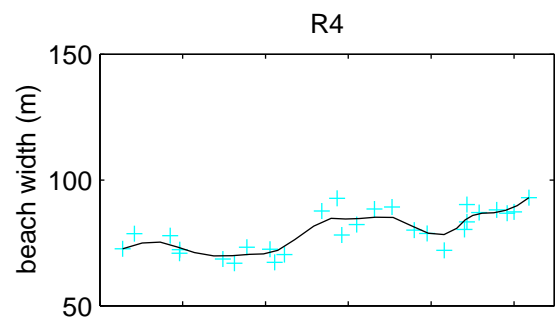
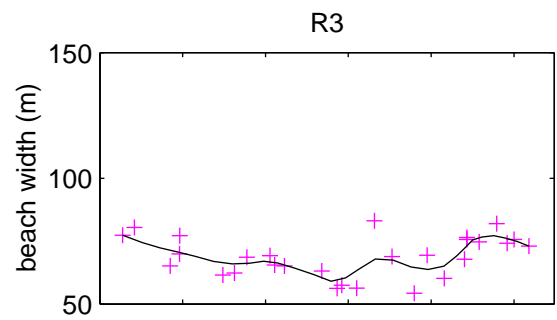
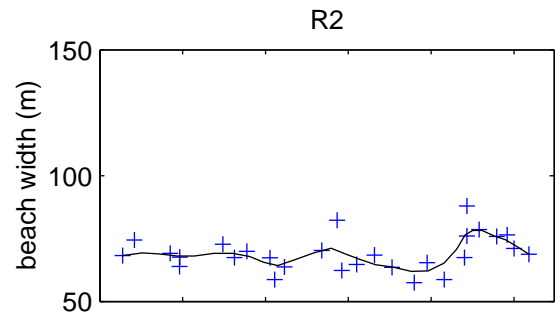
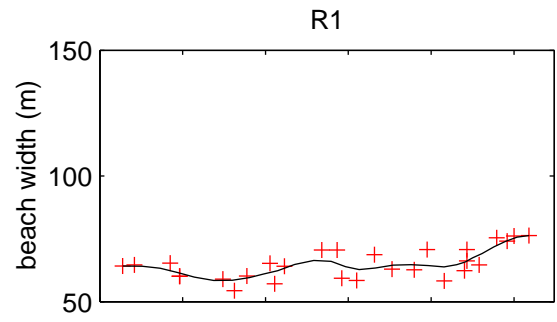
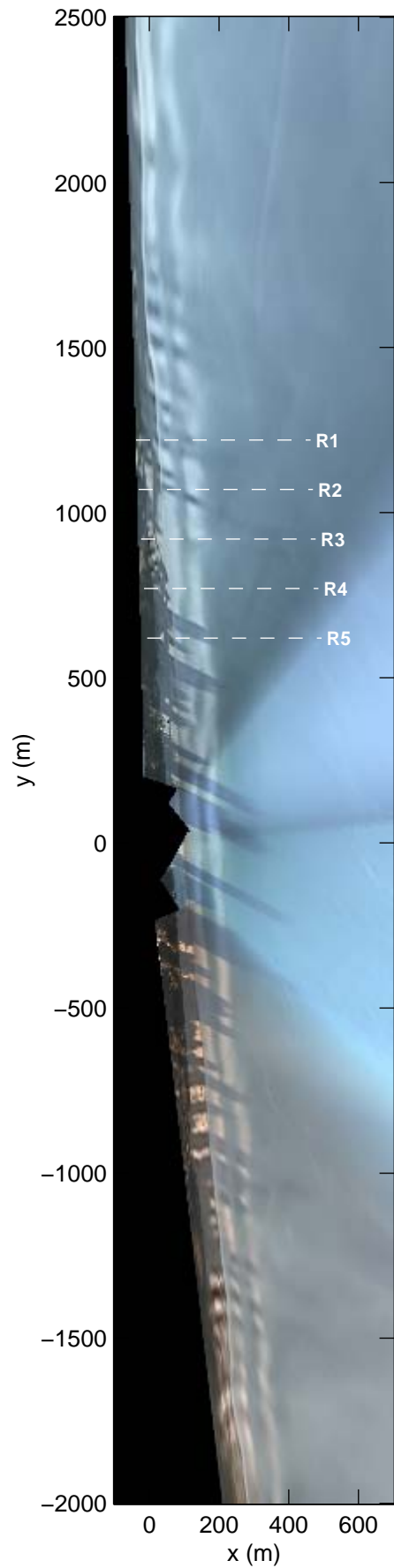
# BEACH WIDTH: Feb08 – Jul08 goldcst

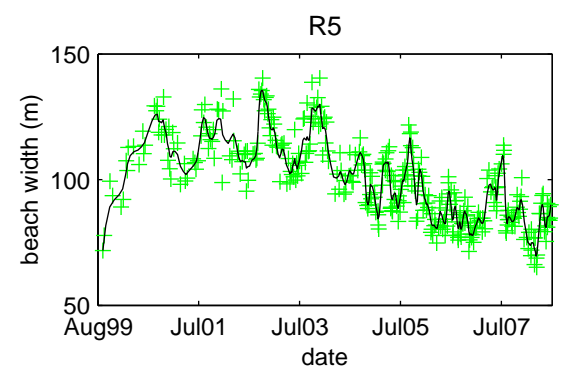
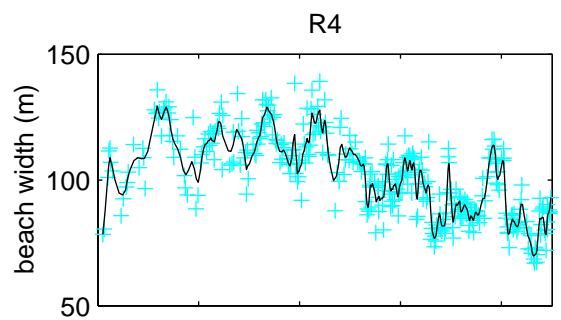
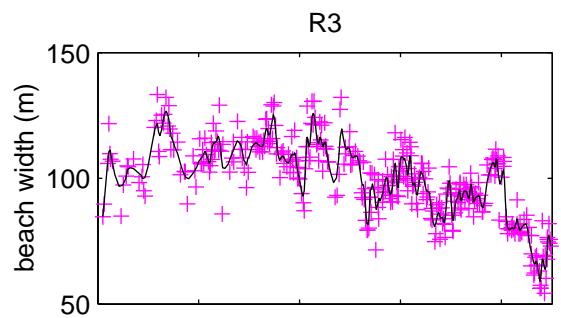
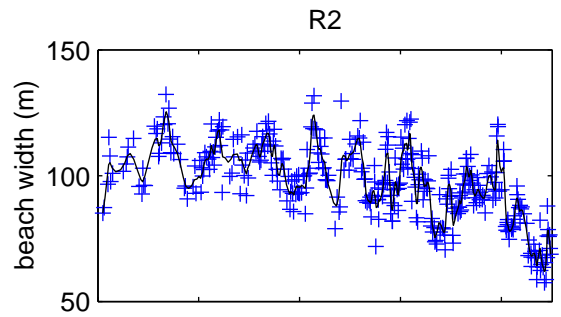
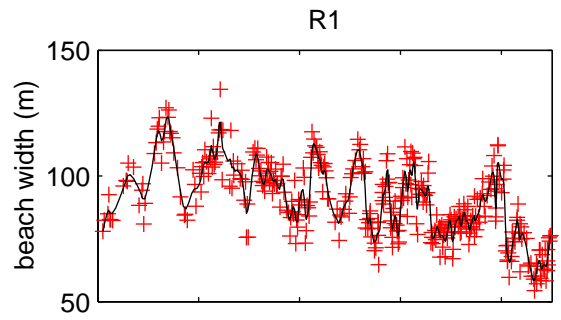
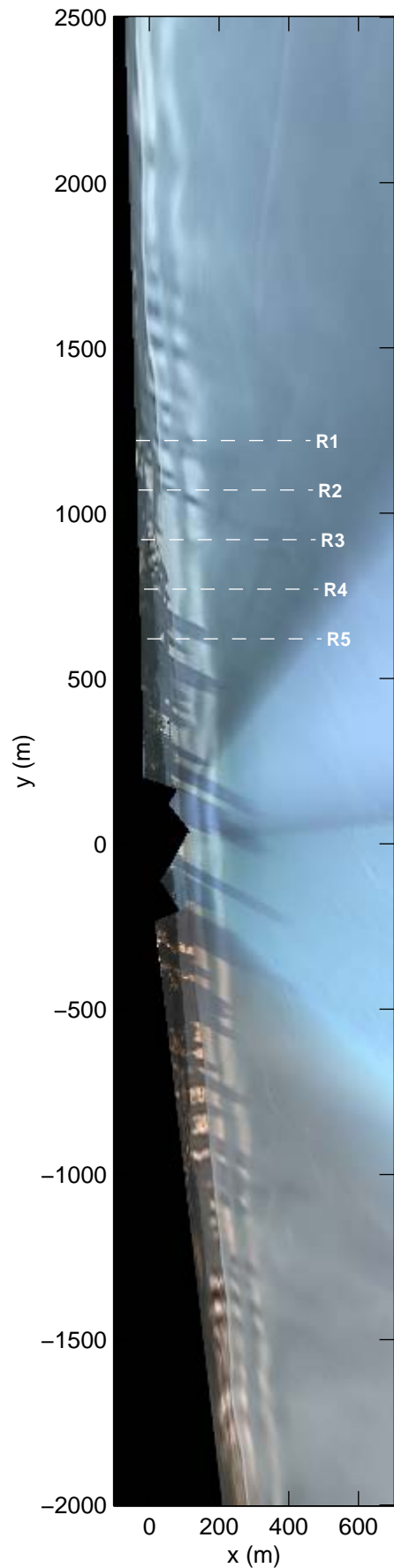


BEACH WIDTH STATISTICS: Feb08 – Jul08 goldcst

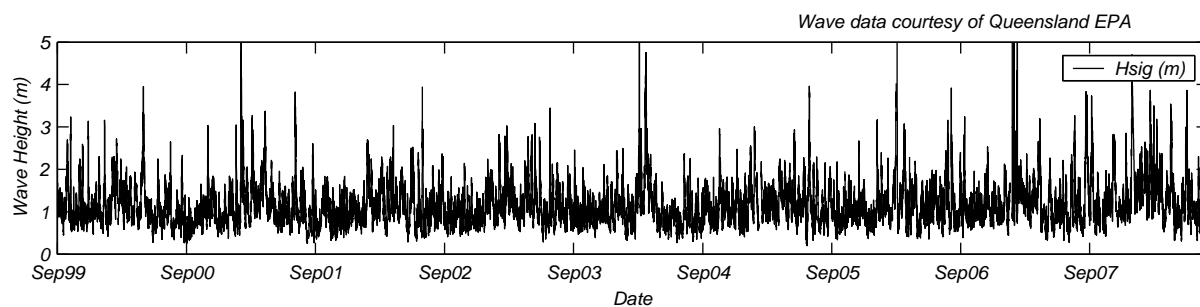
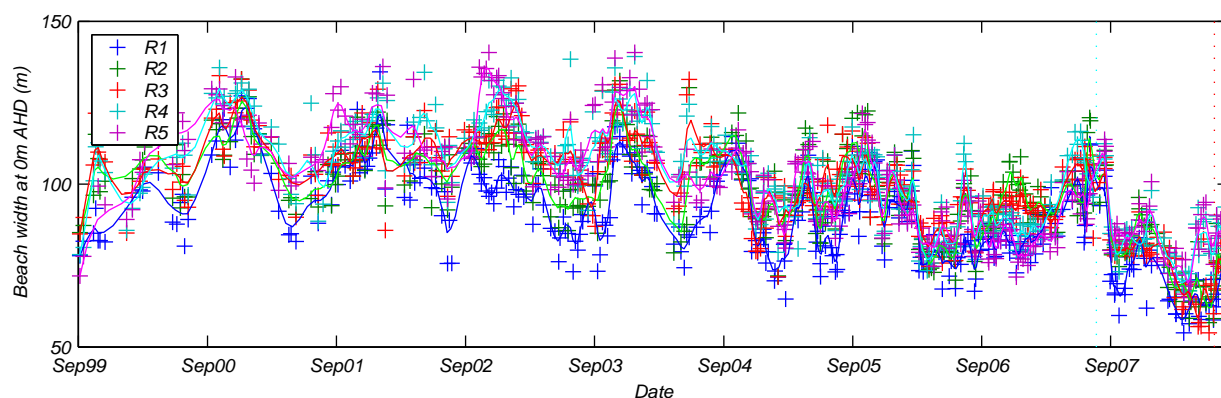
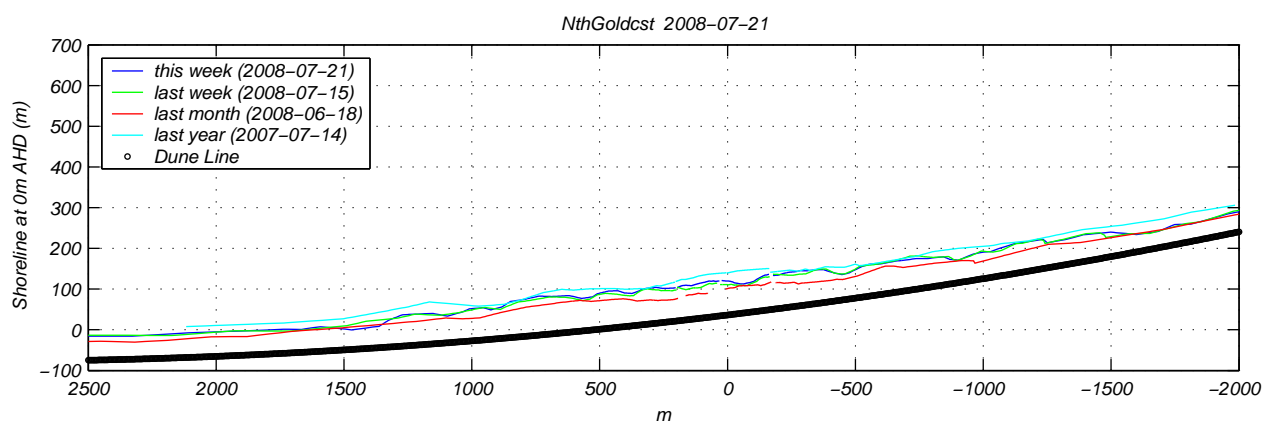
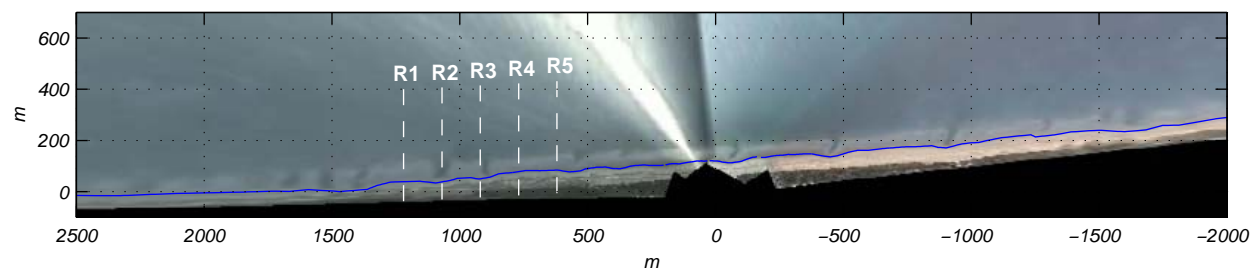




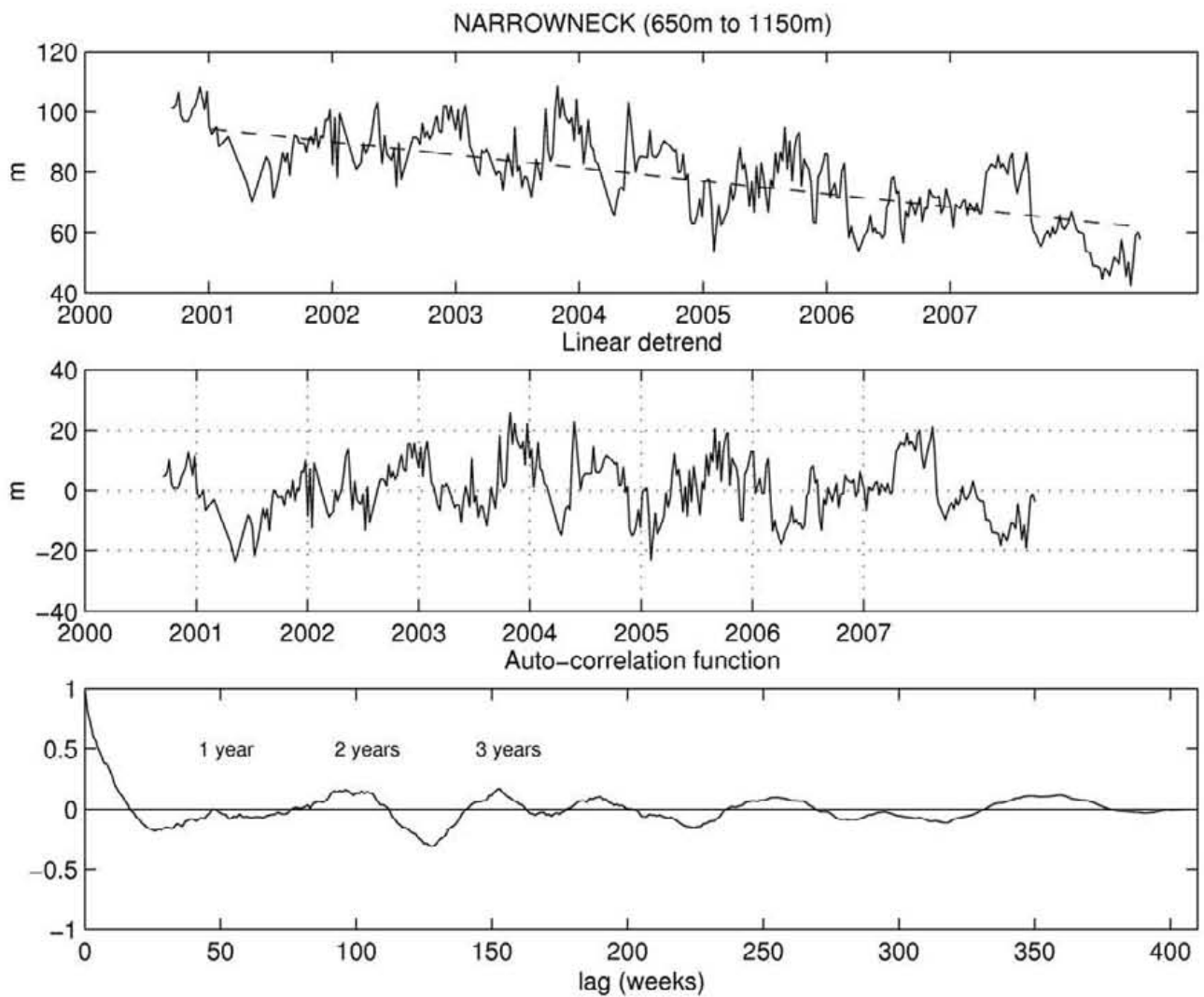








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## **9. ANALYSIS OF EROSION-ACCRETION TRENDS**

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. This data is 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 10<sup>th</sup> February and 4<sup>th</sup> March 2008 are shown in [Figure 9.2](#), 9<sup>th</sup> April and 6<sup>th</sup> May 2008 in [Figure 9.3](#), and 27<sup>th</sup> June and 13<sup>th</sup> July 2008 in [Figure 9.4](#). In all of 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 February 2008 ([Figure 9.2](#) top panel) showed that the beach was uniform in alignment and gradient along the entire stretch of mapped beach. This was a result of the large wave events experienced throughout the previous months, which left the beach in a relatively eroded and two dimensional state. From February to March 2008 ([Figure 9.2](#) bottom panel), the beachface became slightly irregular in alignment as a result of periods of lower wave energy, when the surfzone was dominated by transverse bars and rip currents. During these times, undulations developed along the beachface where sections of accretion occurred.

By April 2008 ([Figure 9.3](#) top panel) the beach had again straightened in alignment, and appeared slighter flatter in gradient. During this time, the beachface migrated slightly landward over the southern stretches of mapped beach, with little change in shoreline position further north. By May 2008 the beachface had again become very irregular in alignment, with the growth of beachface features both north and south of the Narrowneck reef, and landward migration of the beachface directly in the lee of the reef. While the beachface map for May shows a flatter gradient beach, it is expected that this is the result of the formation of low tide terrace features at some locations due to lower wave energy, as opposed to a higher energy more dissipative surf zone.

Between May and June 2008 ([Figure 9.4](#) top panel) the beach was observed to steepen in gradient to the north of the Narrowneck reef, while directly in the lee of the reef there was significant accretion. Immediately south of the reef the beach flattened in gradient, while further south, the beachface was seen to migrate slightly landward. By mid July 2008 ([Figure 9.4](#) bottom panel) the beach had further flattened in cross shore gradient over its entire length. The effect of nearshore rips and bars on the beachface topography was notable, with the beachface dipping landward in several locations.

Throughout the current six month monitoring period from February to July 2008 the net onshore/offshore position of the beachface changed very little. At the end of the six month period, the beachface was seen to be significantly flatter in cross shore gradient, and more irregular in longshore alignment. The most notable change in the beachface appearance was the formation of wide and flat low tide terrace features as a result of lower energy typical wave conditions experienced throughout the later months of the monitoring period.

### **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 January and April 2008, and [Figure 9.6](#) summarises the monthly beachface changes between April and July 2008.

The top panel of [Figure 9.5](#) shows that between January and February 2008, there was relatively minor net beachface accretion along the entire stretch of mapped beach. The most extensive accretion occurred in the far south, where the beachface was seen to increase in vertical elevation by approximately 0.5 m. Approximately +3,711 m<sup>3</sup> of

material accreted over the beachface during this one month period, equating to  $+3.7 \text{ m}^3$  per metre of shoreline.

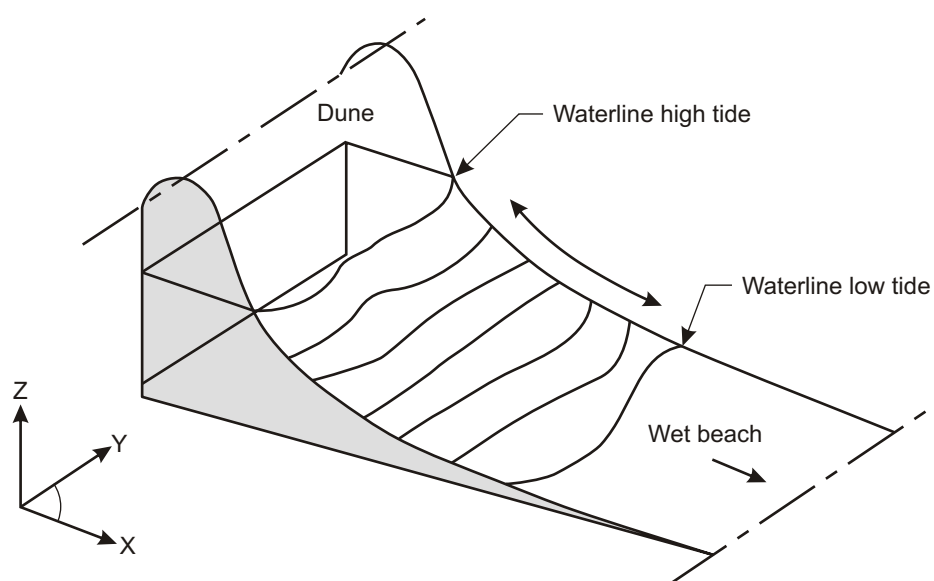
Between February and March ([Figure 9.5](#) middle panel), the dominant change in the beachface was erosion along the beach to the north of Narrowneck, where the beachface was observed to drop by approximately 0.5 m in vertical elevation. South of Narrowneck there was little net change in beachface volumes, with some localised areas accreting while others eroded. The net erosion during this period was  $-2,938 \text{ m}^3$ , which equated to  $-2.9 \text{ m}^3$  per metre between -0.5 m AHD and +0.7 m AHD. During the following one month period between March and April 2008 ([Figure 9.5](#) bottom panel) erosion of the beach continued, but was more focussed over the stretch of beach south of Narrowneck. Most sections of beach suffered little net change, with the most intense erosion resulting in a drop in beachface elevation of approximately 0.5 m, over a 100 m long stretch of beach. Approximately  $-2,774 \text{ m}^3$  of material was eroded during this one month period, equating to  $-2.7 \text{ m}^3$  per metre of shoreline, between the levels of -0.5 m AHD and +0.7 m AHD.

The greatest change in beachface topography occurred during the one month period between April and May 2008 ([Figure 9.6](#) Top Panel), where most parts of the beach accreted by up to 1 m in vertical elevation. The only exception to the accretion occurred for a localised stretch of beach directly in the lee of the Narrowneck reef, where the beachface dropped by 1 m in vertical elevation. During this period, the net accretion along the entire stretch of mapped beach was  $+10,578 \text{ m}^3$ , equating to  $10.5 \text{ m}^3$  per metre of shoreline between the levels of -0.5 m AHD and +0.7 m AHD.

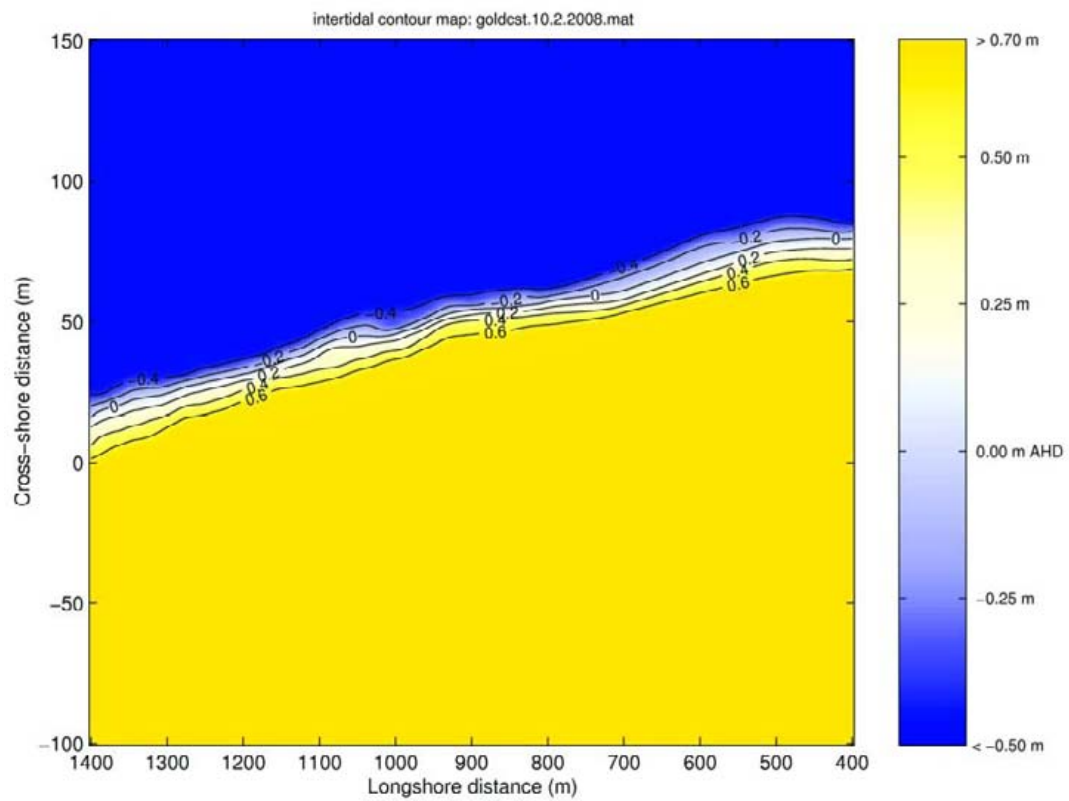
Changes in the beachface topography from May to June 2008 ([Figure 9.6](#) middle panel) were the reverse of the previous month, with intense accretion of up to 1 m in elevation over the beachface for the area directly in the lee of the Narrowneck reef. The stretches of beach south and north of the reef experienced mild erosion, with less material removed than accreted over these areas during the previous month. While the trend over most sections of beach was mild erosion, the localised intense accretion in the lee of the reef dominated the net volumetric change, with  $+791 \text{ m}^3$  of material accreting along the entire beach. This equated to  $+0.8 \text{ m}^3$  of accretion per metre of shoreline between the levels of -0.5 m AHD and +0.7 m AHD. The occurrence of erosion and accretion between June and July 2008 ([Figure 9.6](#) bottom panel) was less localised and less intense than previous months, with little net change in beachface volumes again experienced. Averaged along the entire stretch of mapped beach, between June and July 2008, a net erosion of  $-841 \text{ m}^3$ , or  $-0.8 \text{ m}^3$  per metre of shoreline, was observed to occur between the levels of -0.5 m AHD and +0.7 m AHD.

#### **9.4 Net Erosion-Accretion Trends: January - July 2008**

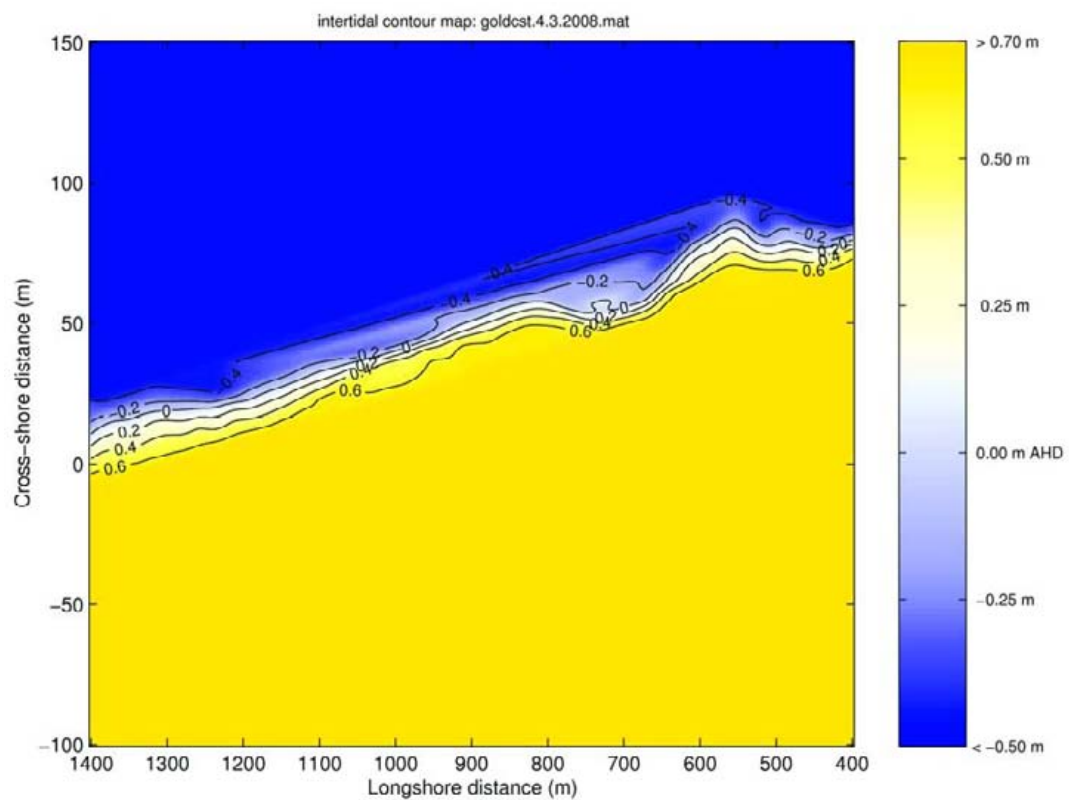
The net trend for the entire six-month period January – July 2008 was modest accretion along the entire 1 km stretch of beach. Referring to [Figure 9.7](#), from 12<sup>th</sup> January 2008 to 13<sup>th</sup> July 2008, the 1000 m length of beach at Narrowneck accreted a net volume of +8,523 m<sup>3</sup>, equating to +8.4 m<sup>3</sup> per metre of shoreline. It can be seen from [Figure 9.7](#) that the area of greatest accretion was south of Narrowneck, where the beachface was observed to increase in vertical elevation by up to 1 m over a beach width of approximately 20 m. In the lee of the Narrowneck reef and further north, only mild net accretion was observed to occur during the current six month monitoring period.



## FEBRUARY 2008

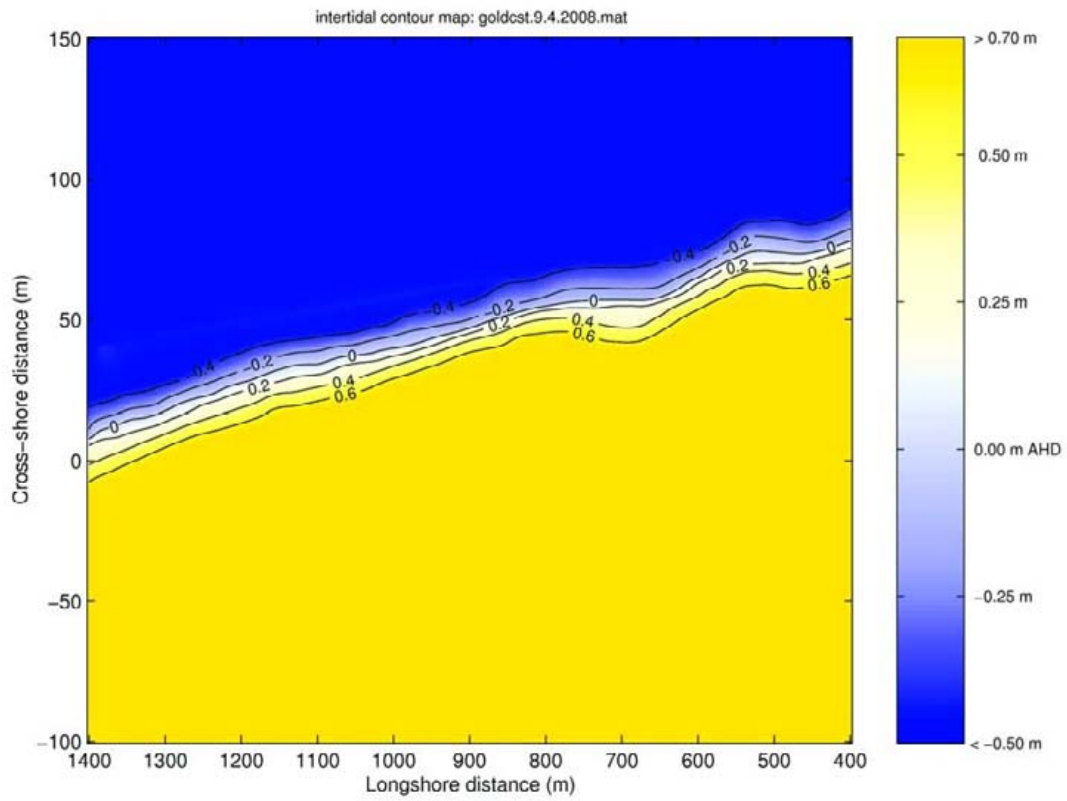


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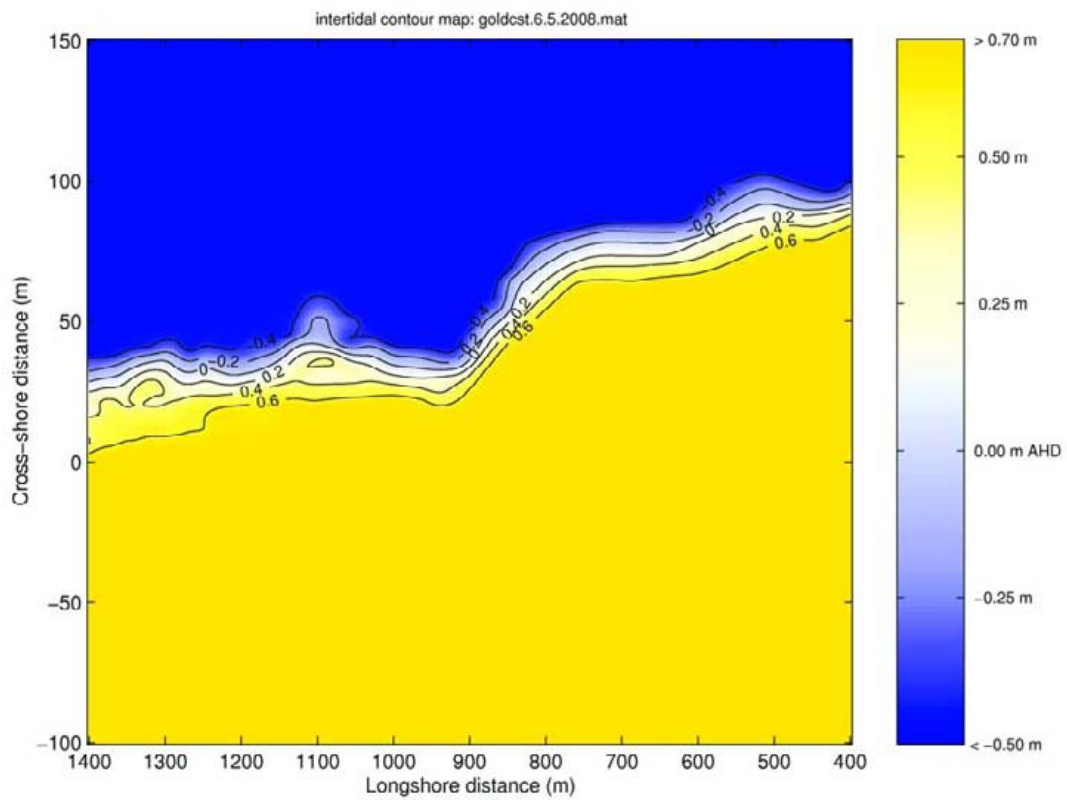




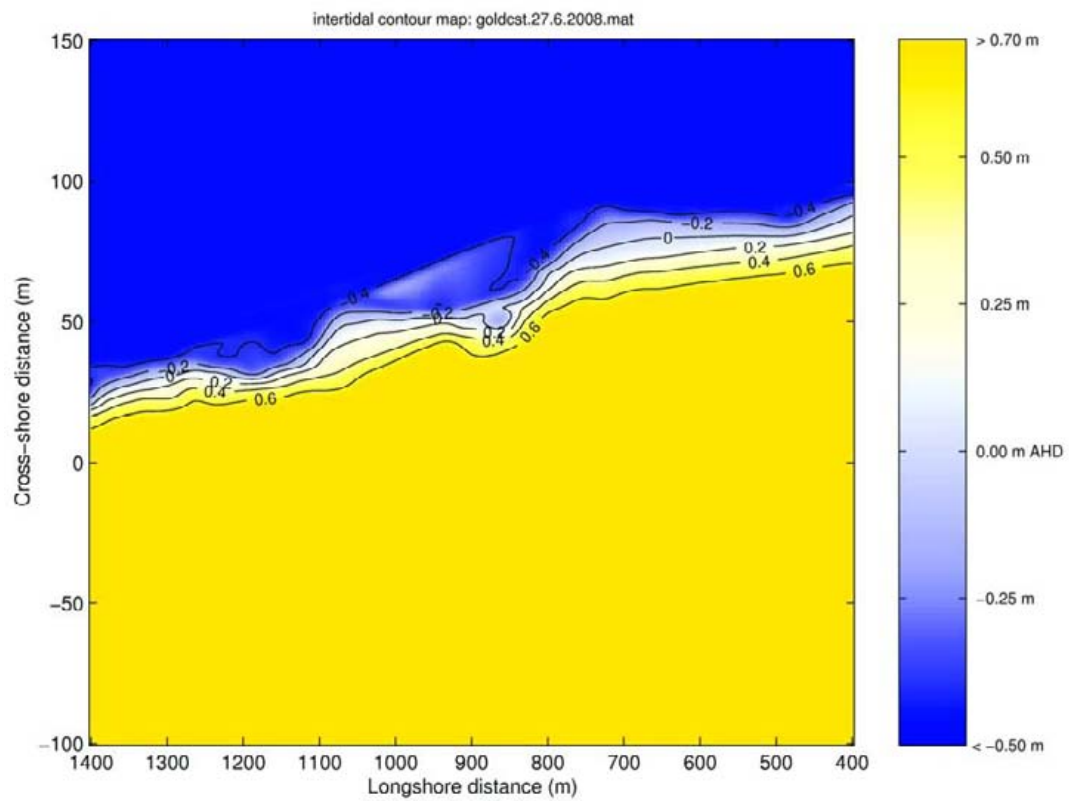
## APRIL 2008



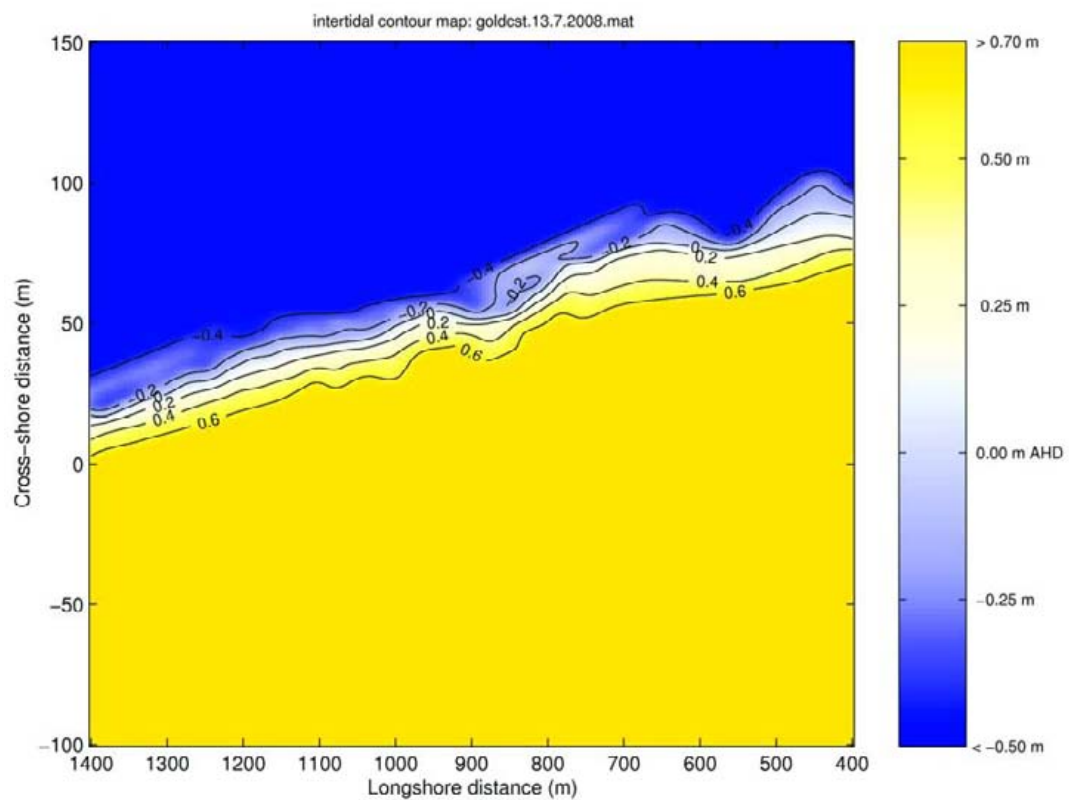
## MAY 2008



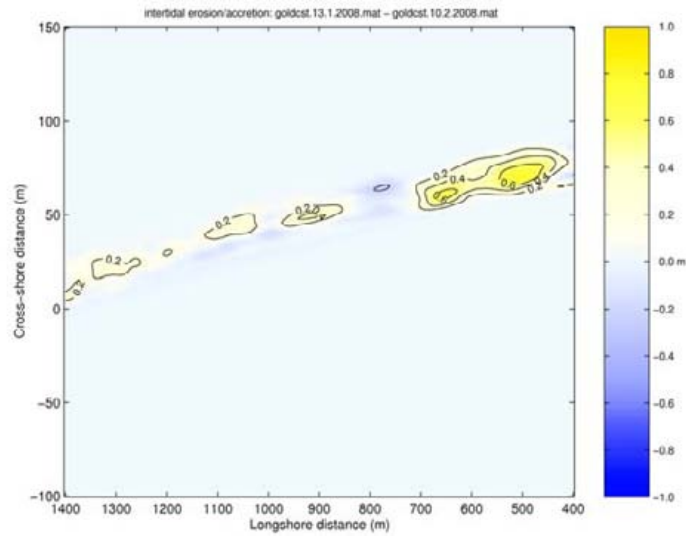
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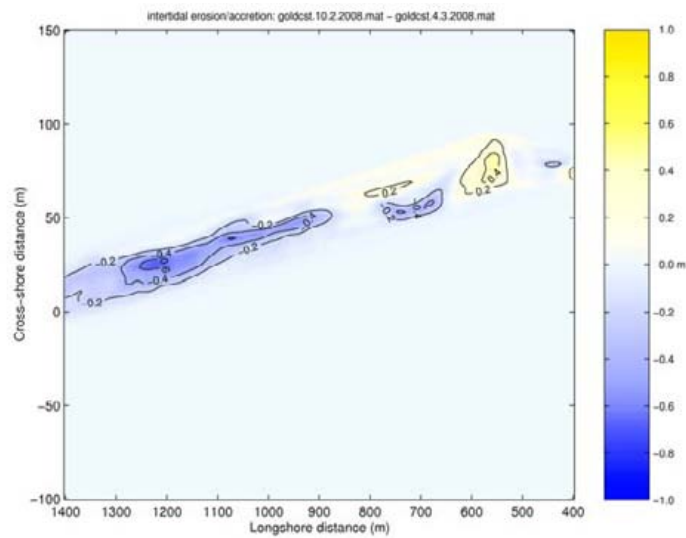
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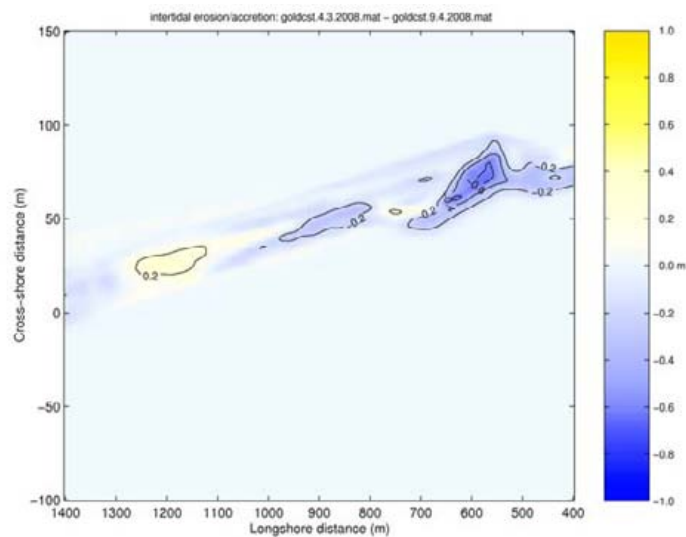
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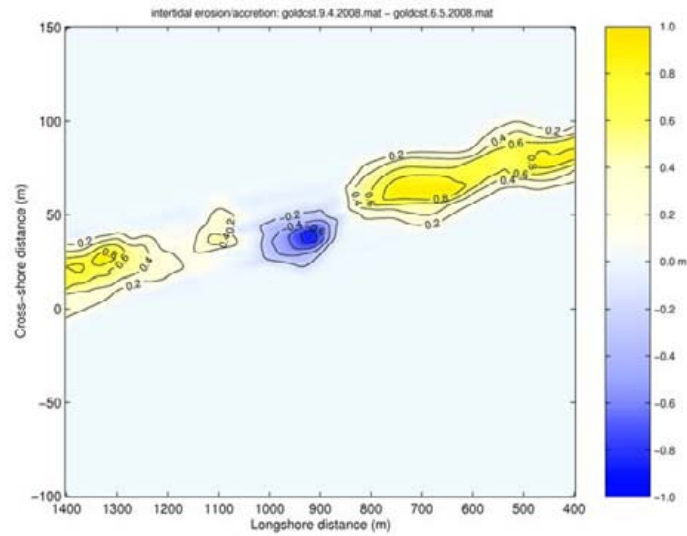
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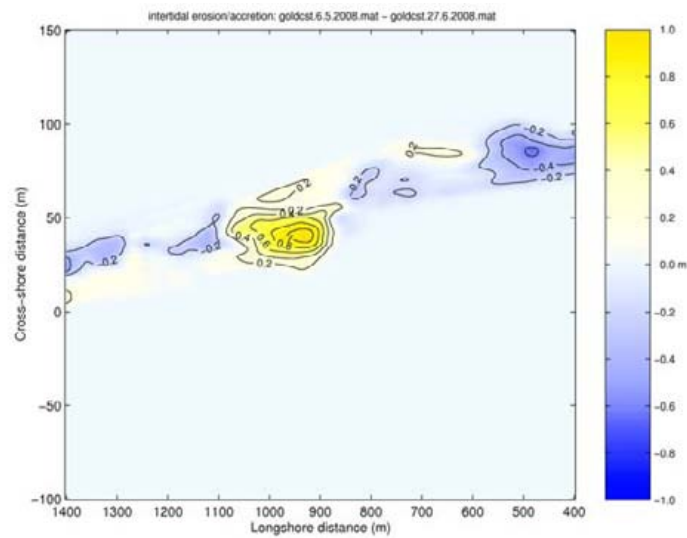
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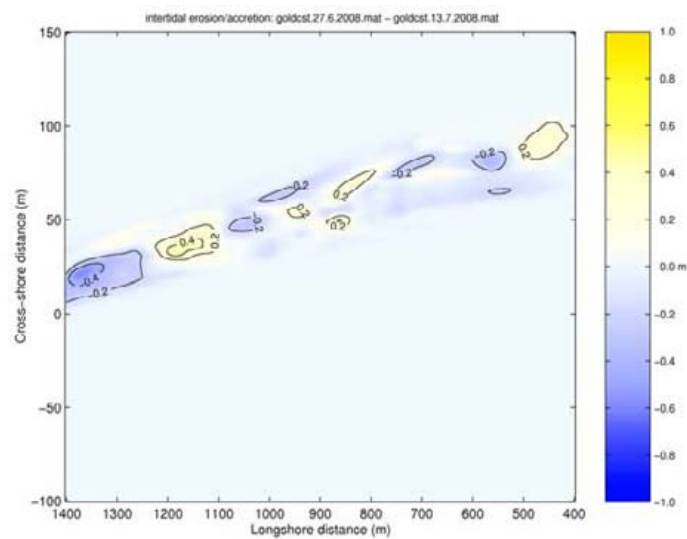
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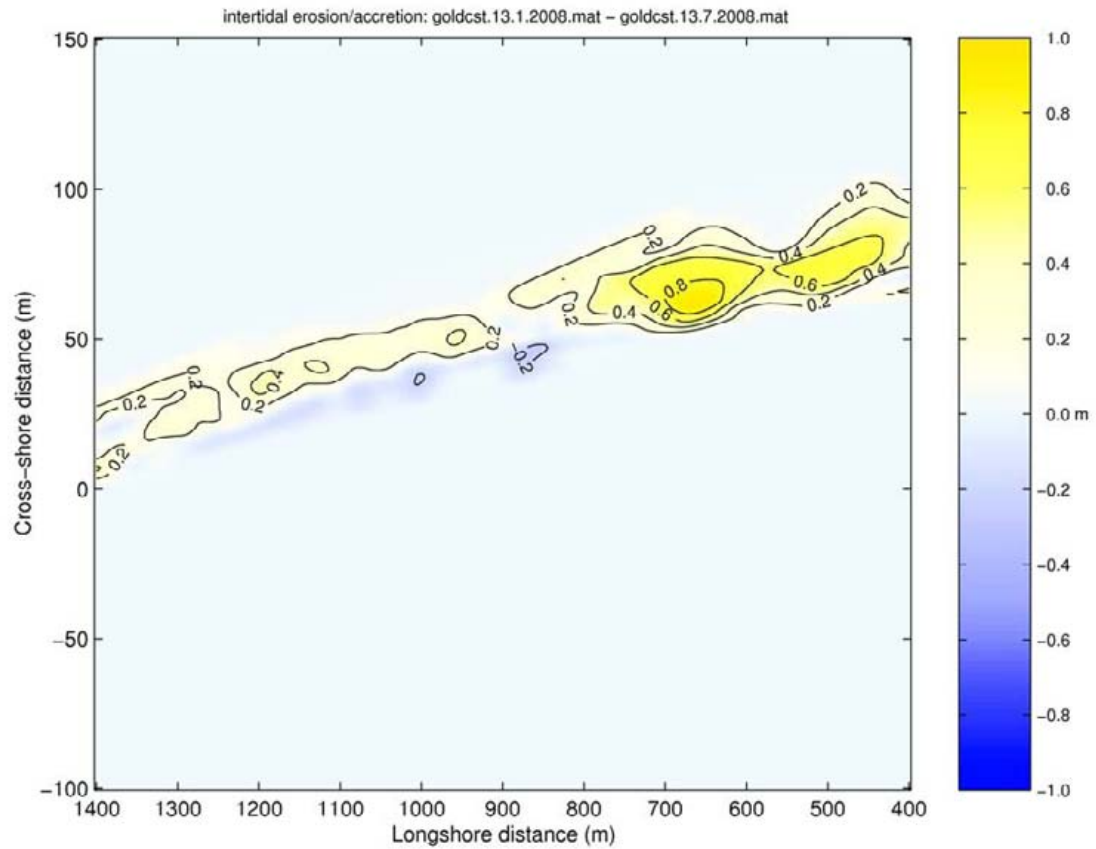
## MAY - JUNE 2008



## JUNE - JULY 2008



# NET CHANGE: JANUARY - JULY 2008

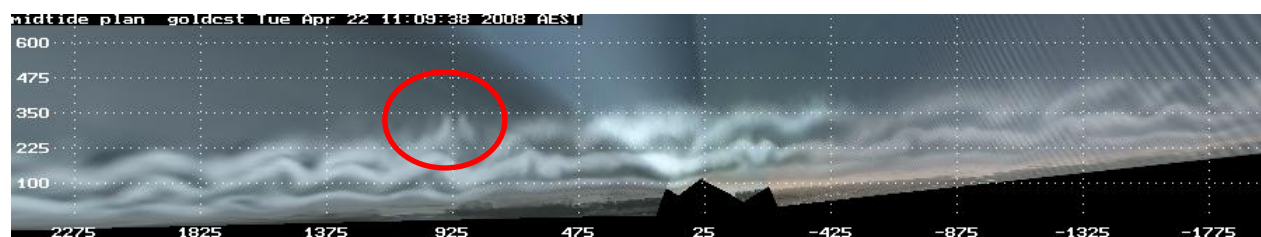


## **10. ASSESSMENT OF WAVE BREAKING AT THE REEF**

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 22<sup>nd</sup> April 2008).

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.



## **11. CONCLUSIONS**

### **11.1 Overview**

The present six month monitoring period to July 2008 marks eight years since the completion of beach nourishment in mid 2000 at the northern Gold Coast, and seven and a half 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<sup>3</sup> of additional sand dredged from the Broadwater was placed along the northern Gold Coast beachfront. Additional minor nourishment of approximately 6,400 m<sup>3</sup> of sand, sourced from excavations undertaken at local development sites, was placed during the period February to July 2007. In November 2007 there was minor nourishment of the beach at Higman Street, with 9,790 m<sup>3</sup> of sand being placed between 16<sup>th</sup> November 2007 and 28<sup>th</sup> November 2007. Between 18<sup>th</sup> December 2007 and March 2008, approximately 80,000 m<sup>3</sup> of sand was placed at Margaret Avenue, Broadbeach. This was outside of the study area covered in this report, but is still a part of the same longshore sediment transport system.

### **11.2 Beach Width**

The morphology of the northern Gold Coast beaches from February to July 2008 was dictated by ongoing moderate wave conditions, with the significant wave height typically in the range of 1 m to 2 m. A nearshore surfzone typical of a TBR morphological state was typically present, with complex bar and rip formations observable over the entire beach length.

Bursts of higher wave energy were experienced during each of the six months of the current monitoring period, during which significant wave heights typically reached 3 m to 4 m. While some of these occasions lasted for only a few days, during the more persistent bursts of higher wave energy, the beach was observed to shift to a higher energy LBT morphological state. The surfzone during these periods was typically wide and two dimensional, with intense wave breaking across a detached offshore bar, as well as the migration of sand from the beachface to form an inner longshore bar.

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 31/01/08 and 31/07/08, 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, it is evident from [Figures 5.2](#) and [5.3](#) that there has been little net change in beach width from the start to the end of the current monitoring period. The surfzone can be seen to be wider and more energetic at the start of the current monitoring period than at the end, predominantly due to the large storms experienced 3 weeks before the start of the monitoring period.

Extending this qualitative visual assessment of images to include the entire nine 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 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 this 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 than was observed six months earlier. Ongoing moderate wave conditions, separated by periods of higher and lower wave energy, resulted in little net change in observable beach width during the current monitoring period, February to July 2008. Typically, the nearshore surfzone was in a complex TBR morphological state, with occasional shifts to a wider and more energetic LBT state. On several occasions of lower energy wave conditions, localised sections of the beach accreted through the formation of terrace or undulation features at the beachface.

Based upon the quantitative analysis of weekly shorelines during the present monitoring period 01/02/08–31/07/08 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 25 m to 100 m. The envelope of beach width changes is the most extensive south of the ARGUS station and north of Narrowneck, varying by 40 m to 50 m during this period.

Mean beach width at mid-tide (relative to the dune reference line) along the 2,000 m stretch of coastline north of the ARGUS station during the period 01/02/08–31/07/08 was in the range of 65 – 80 m. South of the ARGUS station, the beach width was more uniform alongshore and in the range of 40 – 65 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 80 m. The standard deviation of weekly shorelines was the most extreme to the north of Narrowneck, peaking at the far northern end of the monitored section of beach at approximately 17 m. To the south of Narrowneck, the standard deviation in weekly shoreline position was reasonably variable alongshore, and typically ranged from 0 m up to 10 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 February – July 2008 approximately varied between 10 m wider and narrower than the mean beach width from the preceding six month monitoring period, for the region to the south of Narrowneck. North of Narrowneck,

the maximum beach width was typically 5 – 20 m wider during the current monitoring period, than the mean shoreline position of the previous monitoring period. The minimum beach width during the current monitoring period of February to July 2008, was typically 30 – 40 m narrower than the mean beach width observed during the previous monitoring period August 2007 – January 2008. It can be seen from [Figure 6.4](#) bottom panel that the mean beach width was slightly wider during the previous monitoring period compared to the current monitoring period for the entire stretch of mapped beach.

Over the entire 108 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 60m have been recorded at all positions alongshore, which highlights the highly dynamic nature of the beaches of the northern Gold Coast.

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 eroded, 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.

Ongoing bursts of high wave energy every month between August and November 2007 resulted in the beaches generally being in an eroded state for most of the period from August 2007 to January 2008. A detached offshore bar was mostly 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 energy wave 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.

Ongoing moderate wave conditions, separated by periods of higher and lower wave energy, resulted in little net change in observable beach width during the current monitoring period, February to July 2008. Typically, the nearshore surfzone was in a complex TBR morphological state, with occasional shifts to a wider and more energetic LBT state. On several occasions of lower energy wave conditions, localised sections of the beach accreted through the formation of terrace or undulation features at the beachface. The beach width at the four northern and three southern monitoring transects can be seen to be very similar to that observed nine years ago prior to the extensive nourishment program.

At the completion of nine years of monitoring and around eight 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 occurrence of higher than average wave conditions during the period August 2007 to July 2008 and the effects of several large low pressure systems has resulted in the beach being maintained in an eroded state. At the completion of the current monitoring period,

the beach is again as narrow as it was at the beginning of the monitoring program nine 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 has prevailed throughout the entire nine year monitoring period. Following the March 2006 event, the northern beaches steadily recovered, until August 2007. North of the Narrownneck reef, the beach suffered extensive erosion during the period August 2007 to January 2008, and throughout the current monitoring period, the beaches have maintained an eroded state due to ongoing larger than average wave conditions. The beach to the north of Narrownneck is narrower at the completion of the current monitoring period than what it was nine years ago prior to the extensive nourishment program. Immediately in the lee and just south of the Narrownneck 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 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 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 identifying a continuing breakdown of the seasonal cyclic erosion/accretion trends at

the Gold Coast. The current monitoring period of February to July 2008 showed fluctuations in beach width along both the northern and southern stretches of beach, with a weaker trend of accretion than has been observed at this time of year previously.

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  $\pm 20$  m, indicating a range of approximately 40 m annual variability in beach width. Since 2007, both wider and narrower fluctuations of beach width have been recorded that have exceeded the typical window of observed beach widths. This highlights the periods of more extreme ongoing higher and lower wave energy experienced during the last 1.5 year period. In contrast to the relatively high seasonal cyclic variations, referring to the upper panel in both [Figures 7.6](#) and [7.7](#), the underlying trend at both 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	$\pm 20$	+1.1	+7.4
August 2000 – July 2004	4	$\pm 20$	-0.6	+5.2
August 2000 – January 2005	4.5	$\pm 20$	-1.8	+3.1
August 2000 – July 2005	5	$\pm 20$	-1.1	+3.8
August 2000 – January 2006	5.5	$\pm 20$	-0.2	+4.2
August 2000 – July 2006	6	$\pm 20$	-1.3	+1.8
August 2000 – January 2007	6.5	$\pm 10$	-1.8	+0.2
August 2000 – July 2007	7	$\pm 30$	-1.2	-0.4
August 2000 – January 2008	7.5	$\pm 30$	-1.9	-1.5
August 2000 – July 2008	8	$\pm 30$	-2.8	-2.8

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 18 months of monitoring, this trend has now been reversed to indicate long term erosion, at an increasing rate, with the current prediction of -2.8 m per year. Along the northern beaches a more constant (but still accelerating) erosion trend has been observed, with the current estimated erosion rate of -2.8 m per year being the highest rate of erosion predicted during the past eight years.



The eight 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. While there was initially a net minor beach accretion trend in the south, it is becoming increasingly likely that the long term trend is that of erosion, which is now predicted to be of the order -2.8 m per year (-22.4 m recession over eight years). The long term trend for the northern sections of beach also appears to be accelerating net erosion, also of the order of -2.8 m per year (-22.4 m recession over eight years). 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 annual beach width change.

The underlying trend of long term erosion for the monitored section of the northern Gold Coast beaches will require future planning and ongoing management. It is now apparent that the rate of long term erosion of the beaches appears to be accelerating, with both the southern and northern stretches of monitored beach having long term erosion rates of almost 3 m per year. 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 eight year period August 2000 to July 2008 is of the order of  $\pm 20$  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 ([Figures 7.6](#) and [7.7](#)), while at Narrowneck, this has not been the case. The occurrence of these large storm events during the last 1.5 years has dominated the erosion/accretion of the beach, with the underlying seasonal variations in beach width less obvious during this period. 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 eight year period to July 2008 is estimated to be of the order of -4.3 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
August 2000 – July 2008	8	±20	-4.3

From the results presented in the table above, 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 a trend of modest net erosion of the order of -4.3 m per year (34 m over eight years). 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 erosional beach width trend.

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

Between January and February 2008 (Figure 9.5 top panel), there was relatively minor net beachface accretion along the entire stretch of mapped beach, with the most extensive accretion occurring in the far south, where the beachface was seen to increase in vertical elevation by approximately 0.5 m. Approximately +3,711 m<sup>3</sup> of material accreted over the beachface during this one month period, equating to +3.7 m<sup>3</sup> per metre of shoreline. Between February and March (Figure 9.5 middle panel), the dominant change in the beachface was erosion along the beach to the north of Narrowneck, where the beachface was observed to drop by approximately 0.5 m in vertical elevation. South of Narrowneck there was little net change in beachface volumes, with some localised areas accreting while others eroded. The net erosion during this period was -2,938 m<sup>3</sup>, which equated to -2.9 m<sup>3</sup> per metre between -0.5 m AHD and +0.7 m AHD. During the following one month period between March and April 2008 (Figure 9.5 bottom panel) erosion of the beach continued, but was more focussed over the stretch of beach south of Narrowneck. Most sections of beach suffered little net change, with the most intense erosion resulting in a drop in

beachface elevation of approximately 0.5 m, over a 100 m long stretch of beach. Approximately  $-2,774 \text{ m}^3$  of material was eroded during this one month period, equating to  $-2.7 \text{ m}^3$  per metre of shoreline, between the levels of -0.5 m AHD and +0.7 m AHD.

The greatest change in beachface topography occurred during the one month period between April and May 2008 ([Figure 9.6](#) Top Panel), where most parts of the beach accreted by up to 1 m in vertical elevation. The only exception to the accretion occurred for a localised stretch of beach directly in the lee of the Narrowneck reef, where the beachface dropped by 1 m in vertical elevation. During this period, the net accretion along the entire stretch of mapped beach was  $+10,578 \text{ m}^3$ , equating to  $10.5 \text{ m}^3$  per metre of shoreline between the levels of -0.5 m AHD and +0.7 m AHD.

Changes in the beachface topography from May to June 2008 ([Figure 9.6](#) middle panel) were the reverse of the previous month, with intense accretion of up to 1 m in elevation over the beachface for the area directly in the lee of the Narrowneck reef, and mild erosion for sections of beach both south and north of the reef. While the trend over most sections of beach was mild erosion, the localised intense accretion in the lee of the reef dominated the net volumetric change, with  $+791 \text{ m}^3$  of material accreting along the entire beach. This equated to  $+0.8 \text{ m}^3$  of accretion per metre of shoreline between the levels of -0.5 m AHD and +0.7 m AHD. The occurrence of erosion and accretion between June and July 2008 ([Figure 9.6](#) bottom panel) was less localised and less intense than previous months, with little net change in beachface volumes again experienced. Averaged along the entire stretch of mapped beach, a net erosion of  $-841 \text{ m}^3$ , or  $-0.84 \text{ m}^3$  per metre of shoreline, was observed to occur between the levels of -0.5 m AHD and +0.7 m AHD.

The net trend for the entire six-month period January – July 2008 was modest accretion along the entire 1 km stretch of beach. Referring to [Figure 9.7](#), from 12<sup>th</sup> January 2008 to 13<sup>th</sup> July 2008, the 1000 m length of beach at Narrowneck accreted a net volume of  $+8,523 \text{ m}^3$ , equating to  $+8.4 \text{ m}^3$  per metre of shoreline. It can be seen from [Figure 9.7](#) that the area of greatest accretion was south of Narrowneck, where the beachface was observed to increase in vertical elevation by up to 1 m over a beach width of approximately 20 m. In the lee of the Narrowneck reef and further north, only mild net accretion was observed to occur during the current six month monitoring period.

## **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.

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## **APPENDIX A**

### **WEEK-TO-A-PAGE: FEBRUARY – JULY 2008**



01/02/2008 14:09



02/02/2008 09:09



03/02/2008 09:09



04/02/2008 10:10



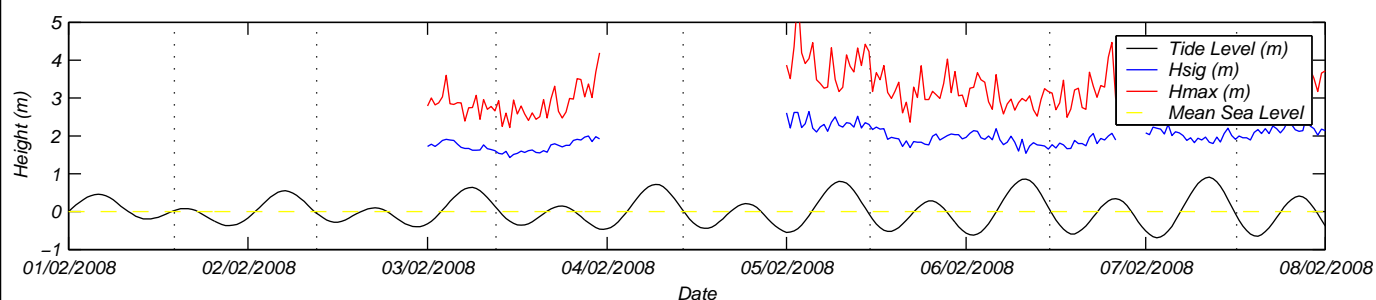
05/02/2008 11:09



06/02/2008 11:09



07/02/2008 12:10



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
01/02/2008 – 07/02/2008

Figure  
A1



08/02/2008 12:09



09/02/2008 13:10



10/02/2008 13:09



11/02/2008 14:09



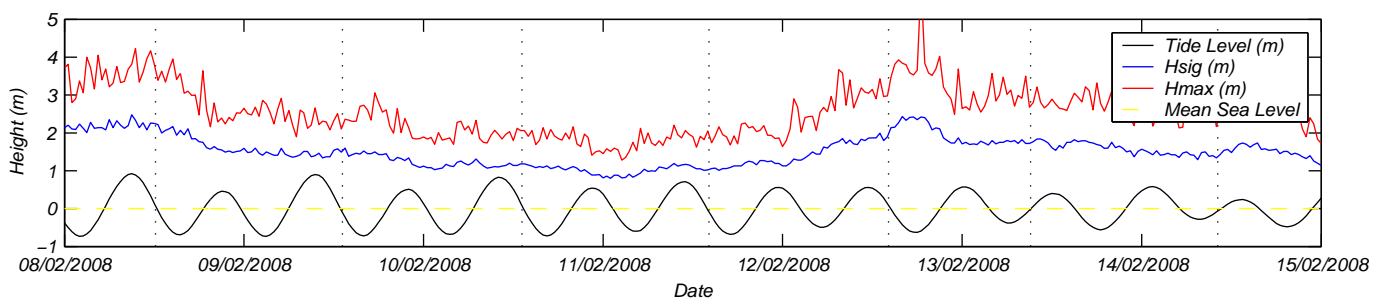
12/02/2008 14:09



13/02/2008 09:09



14/02/2008 10:10



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
08/02/2008 – 14/02/2008

Figure  
A2



15/02/2008 12:09



16/02/2008 14:09



17/02/2008 09:09



18/02/2008 10:09



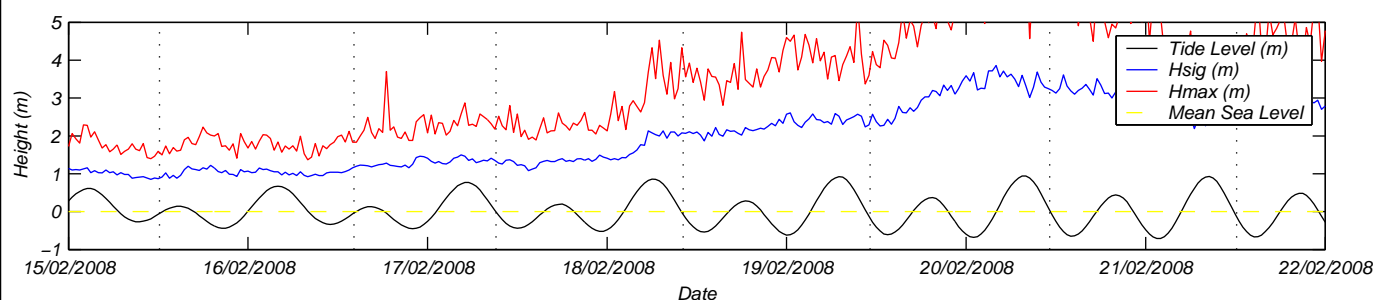
19/02/2008 11:09



20/02/2008 11:09



21/02/2008 12:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
15/02/2008 – 21/02/2008

Figure  
A3



22/02/2008 12:09



23/02/2008 13:10



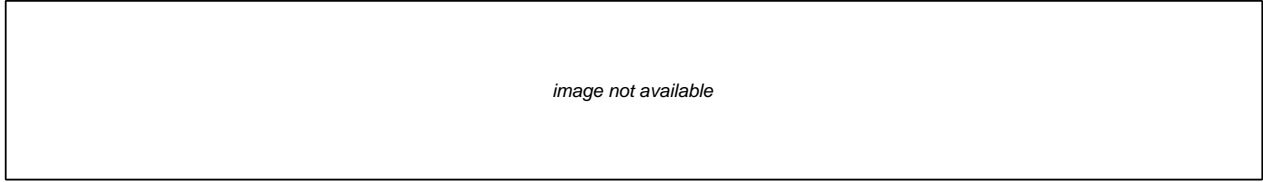
24/02/2008 13:09



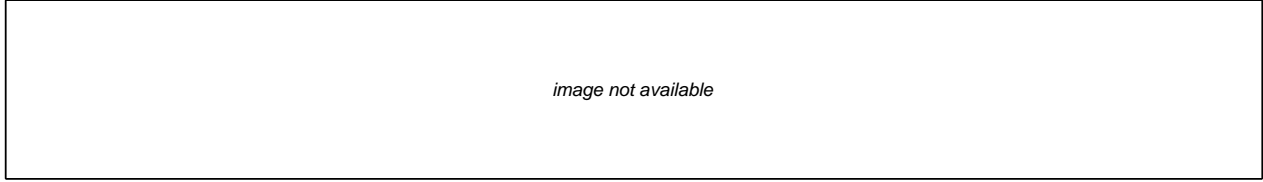
25/02/2008 13:09



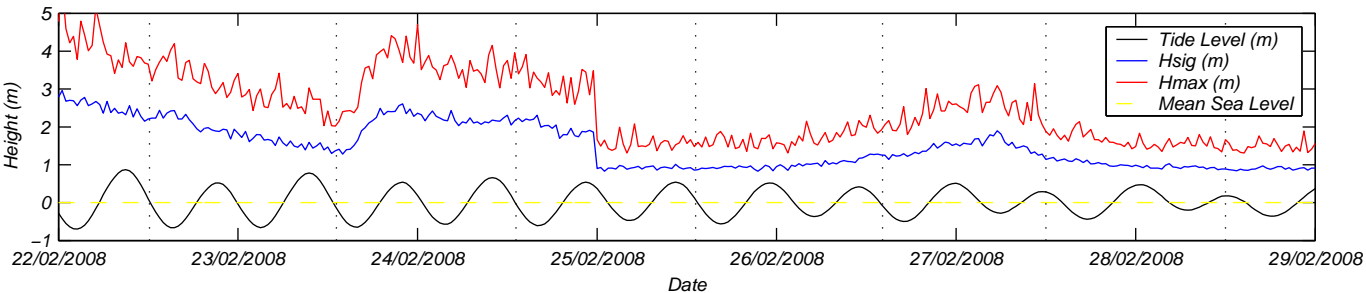
26/02/2008 14:09



27/02/2008 12:00



28/02/2008 12:00







29/02/2008 15:09



01/03/2008 13:09



02/03/2008 15:09



03/03/2008 09:09



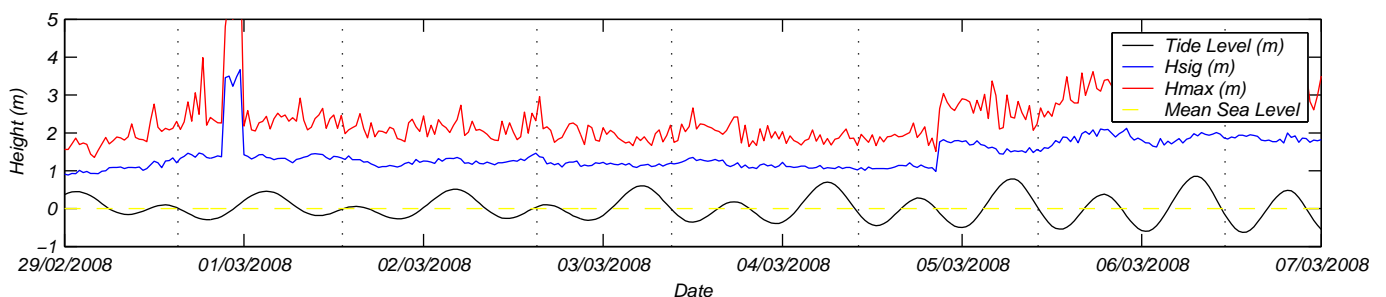
04/03/2008 10:09



05/03/2008 10:10



06/03/2008 11:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
29/02/2008 – 06/03/2008

Figure  
A5



07/03/2008 11:09



08/03/2008 12:09



09/03/2008 12:10



10/03/2008 13:10



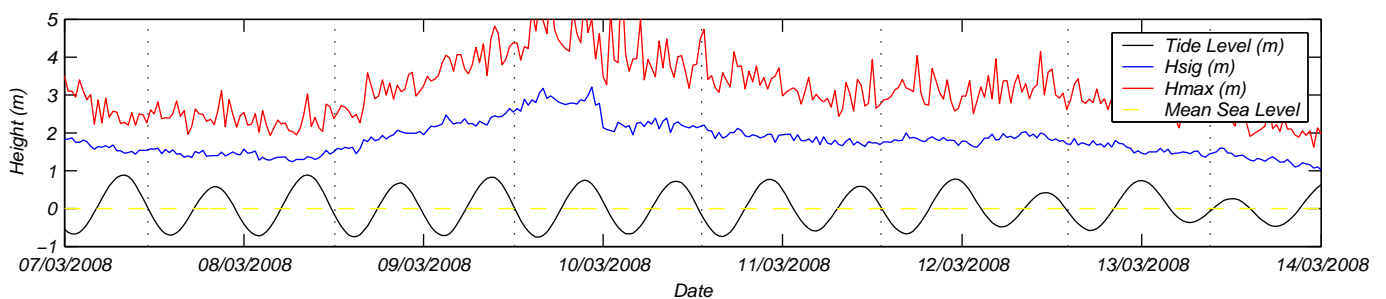
11/03/2008 13:09



12/03/2008 14:09



13/03/2008 09:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
07/03/2008 – 13/03/2008

Figure  
A6





14/03/2008 11:09



15/03/2008 12:00



16/03/2008 14:09



17/03/2008 15:10



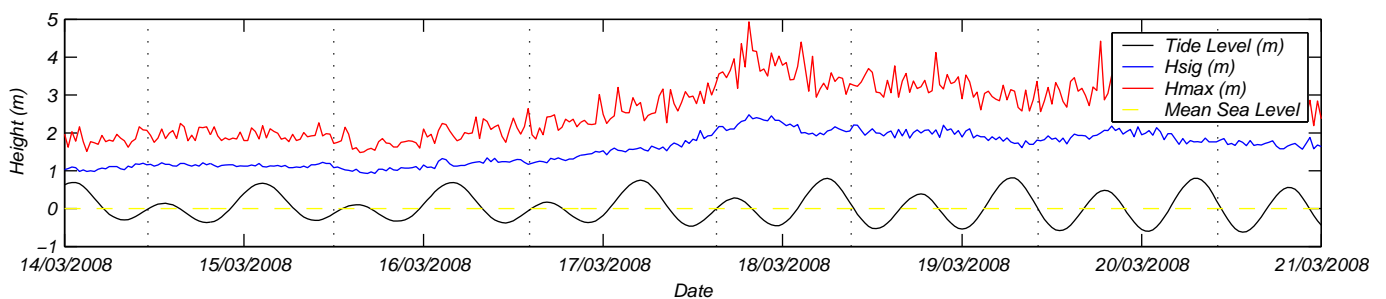
18/03/2008 09:09



19/03/2008 10:09



20/03/2008 10:10



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
14/03/2008 – 20/03/2008

Figure  
A7



21/03/2008 11:09



22/03/2008 11:10



23/03/2008 12:09



24/03/2008 12:09



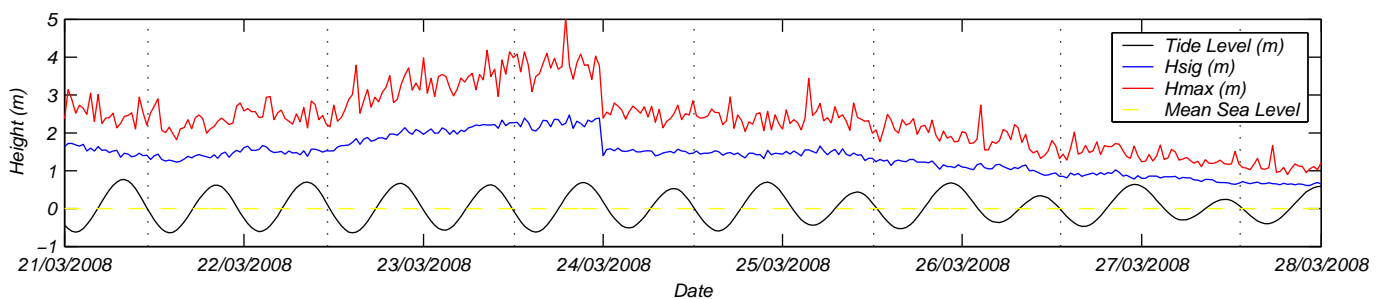
25/03/2008 12:09



26/03/2008 13:09



27/03/2008 13:09



WRL

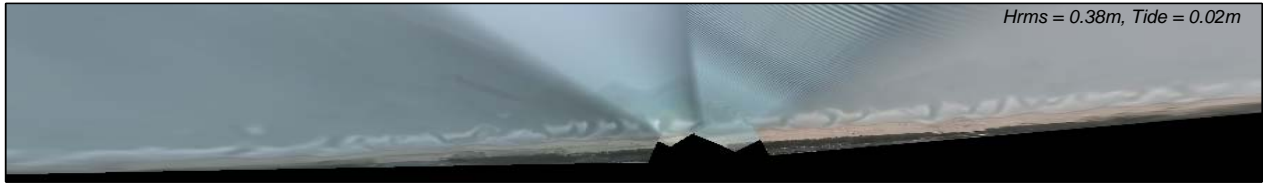
Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
21/03/2008 – 27/03/2008

Figure  
A8



28/03/2008 14:09



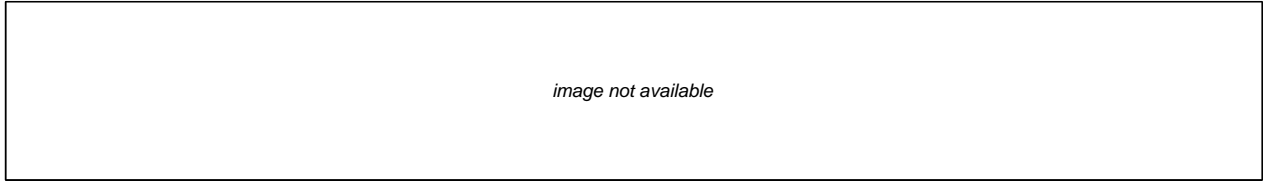
29/03/2008 11:10



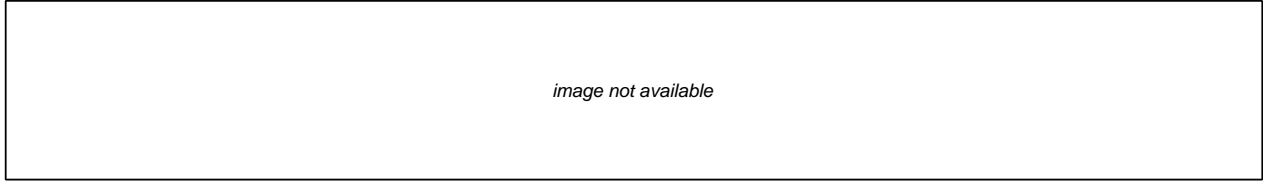
30/03/2008 12:09



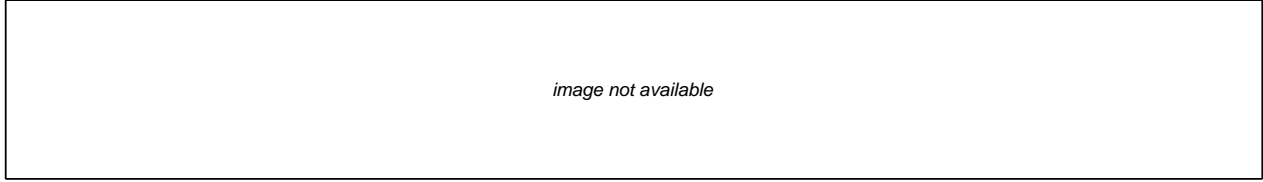
31/03/2008 07:09



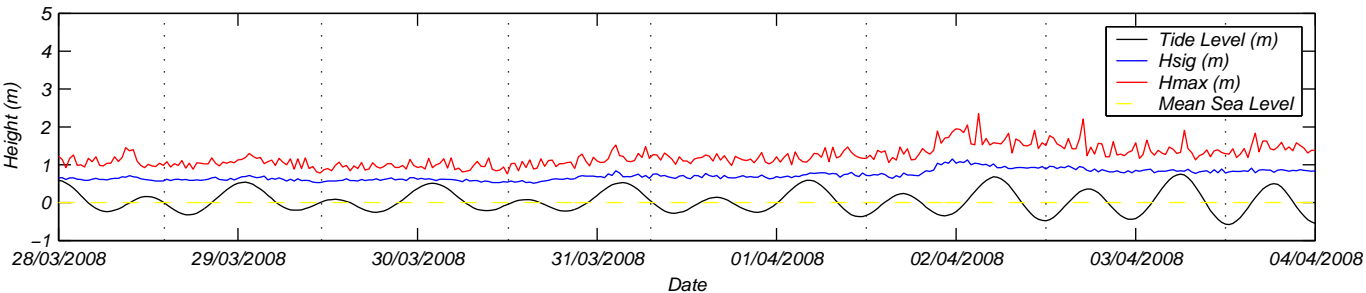
01/04/2008 12:00

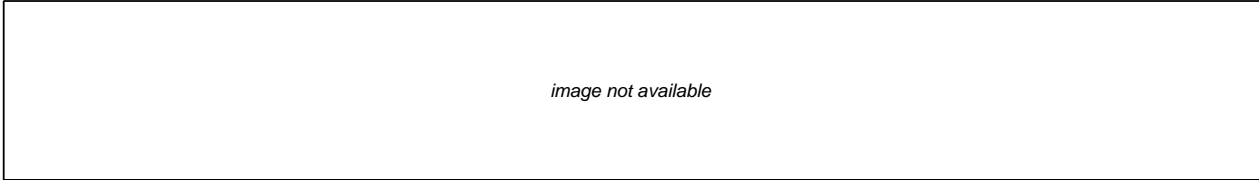


02/04/2008 12:00

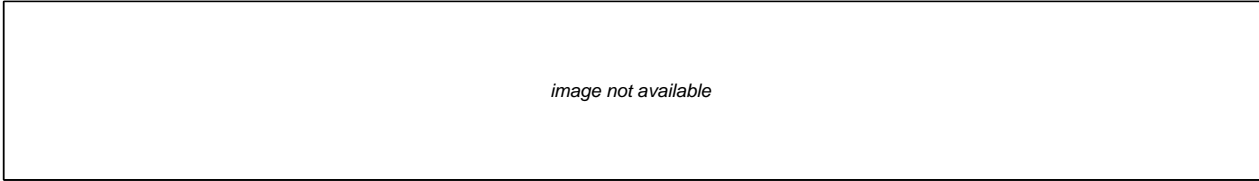


03/04/2008 12:00

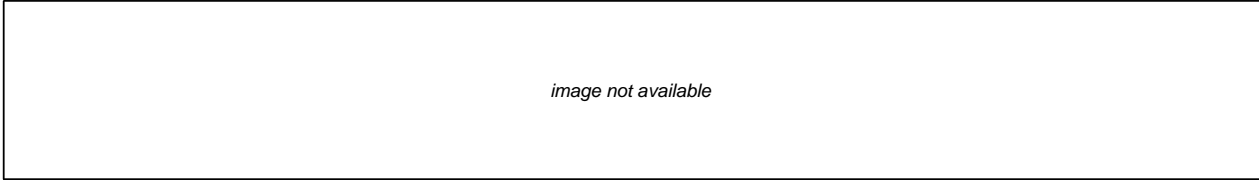




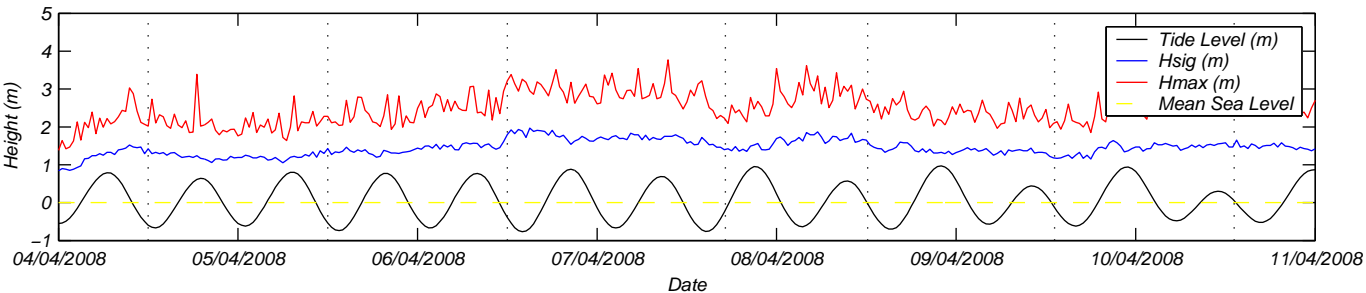
04/04/2008 12:00



05/04/2008 12:00



06/04/2008 12:00





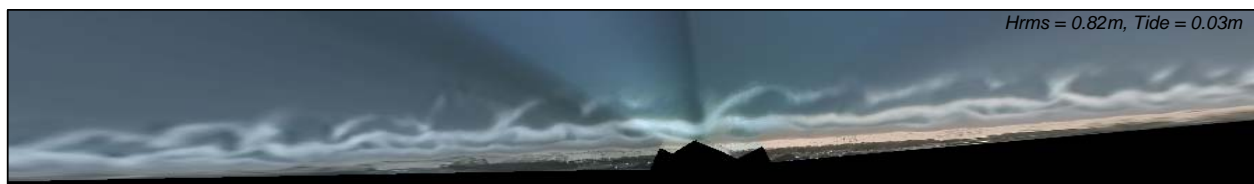
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11/04/2008 10:09



Hrms = 0.85m, Tide = -0.05m

12/04/2008 11:09



Hrms = 0.82m, Tide = 0.03m

13/04/2008 13:09



Hrms = 0.76m, Tide = 0.06m

14/04/2008 14:09



Hrms = 0.9m, Tide = -0.06m

15/04/2008 14:10



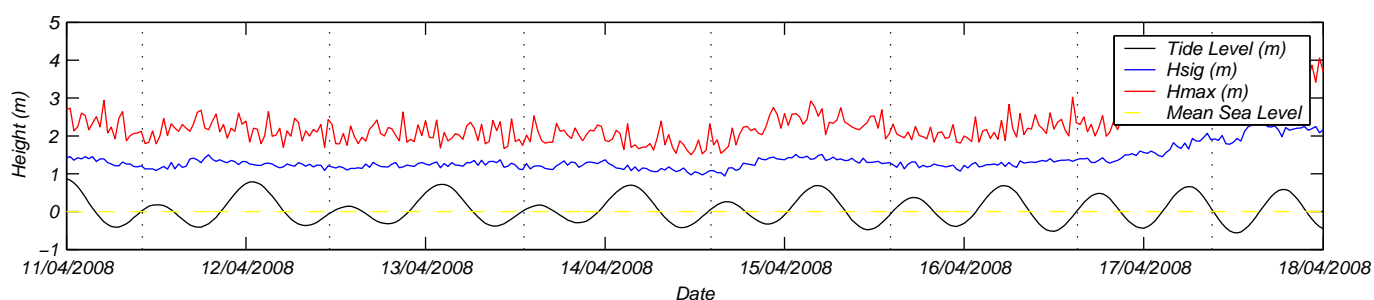
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16/04/2008 15:09



Hrms = 1.35m, Tide = 0.04m

17/04/2008 09:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
11/04/2008 – 17/04/2008

Figure  
A11





18/04/2008 10:09



19/04/2008 10:09



20/04/2008 10:09



21/04/2008 11:09



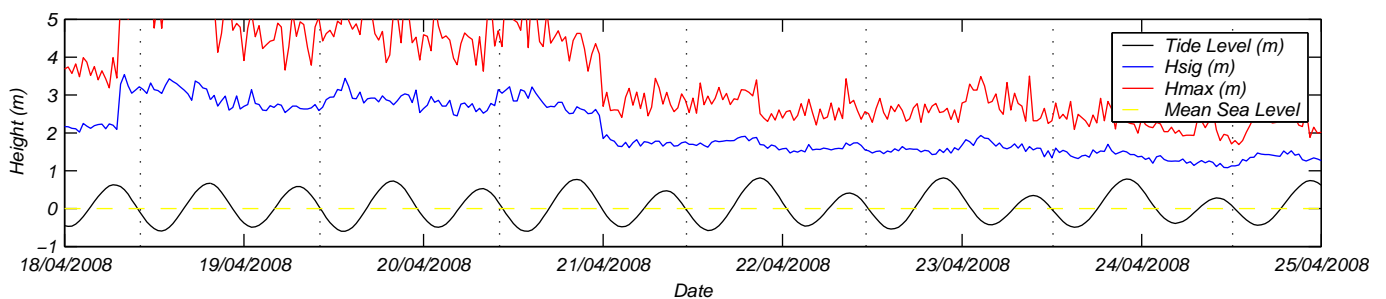
22/04/2008 11:09



23/04/2008 12:09



24/04/2008 12:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
18/04/2008 – 24/04/2008

Figure  
A12



25/04/2008 13:09



26/04/2008 14:10



27/04/2008 10:09



28/04/2008 12:09



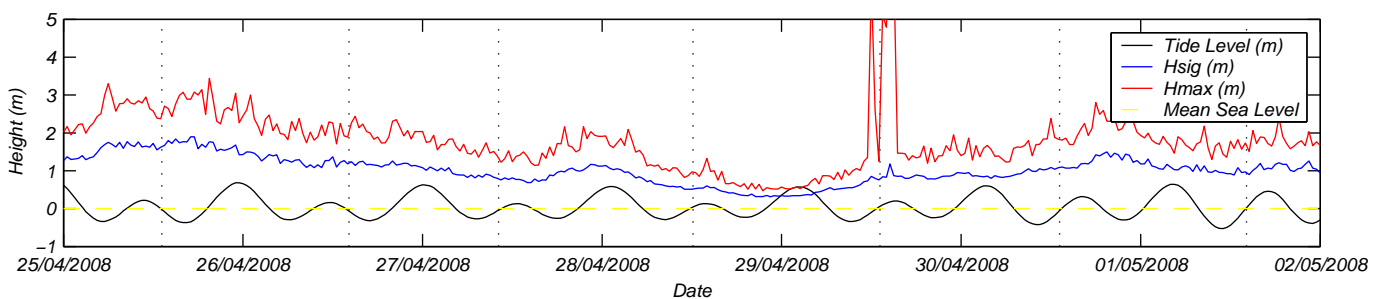
29/04/2008 13:09



30/04/2008 13:09



01/05/2008 14:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
25/04/2008 – 01/05/2008

Figure  
A13



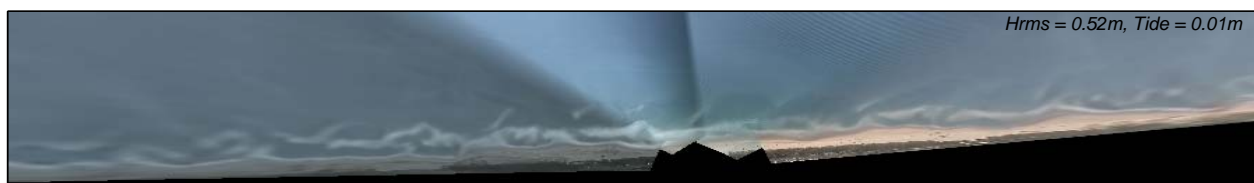
02/05/2008 14:09



03/05/2008 09:09



04/05/2008 09:10



05/05/2008 10:09



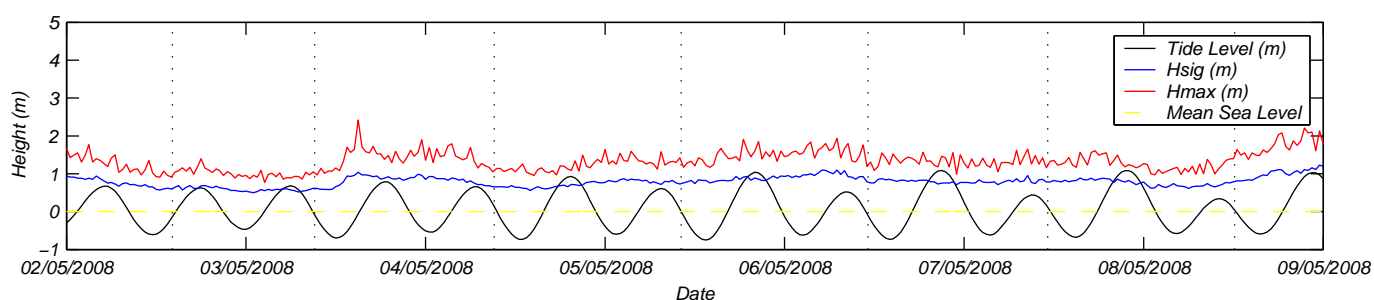
06/05/2008 11:10



07/05/2008 11:10



08/05/2008 12:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
02/05/2008 – 08/05/2008

Figure  
A14





09/05/2008 13:09



10/05/2008 10:09



11/05/2008 11:09



12/05/2008 12:10



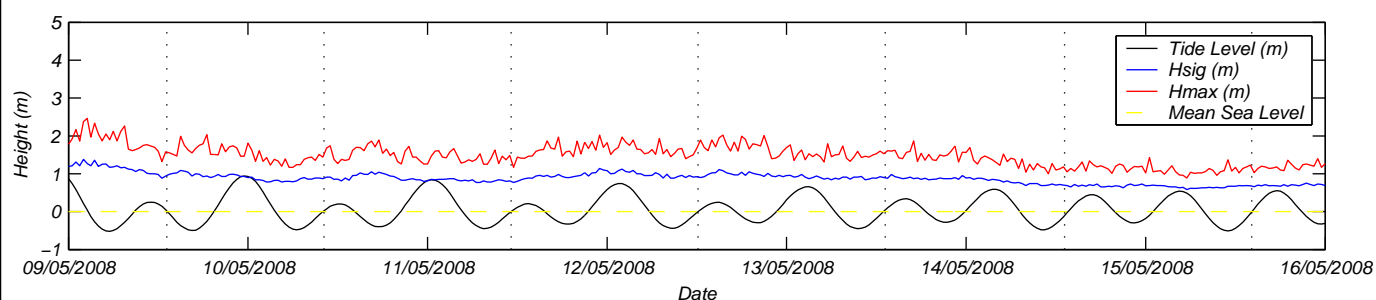
13/05/2008 13:10



14/05/2008 13:10



15/05/2008 14:09

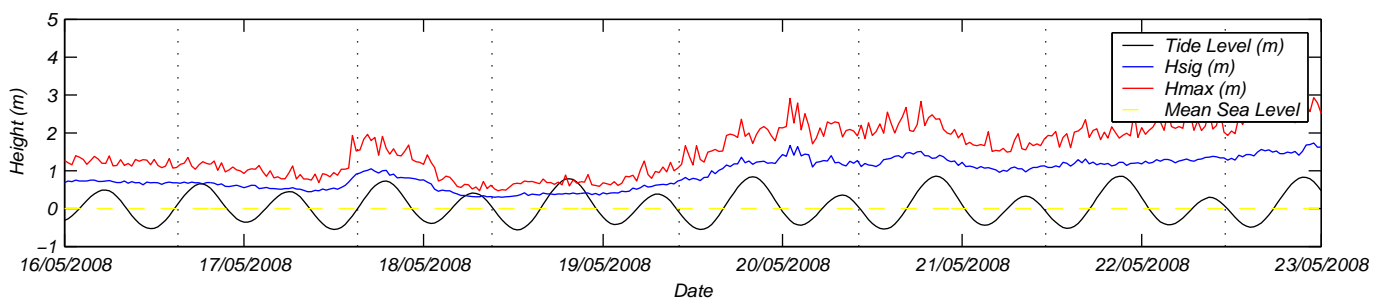


WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
09/05/2008 – 15/05/2008

Figure  
A15





23/05/2008 12:10



24/05/2008 13:09



25/05/2008 13:09



26/05/2008 10:09



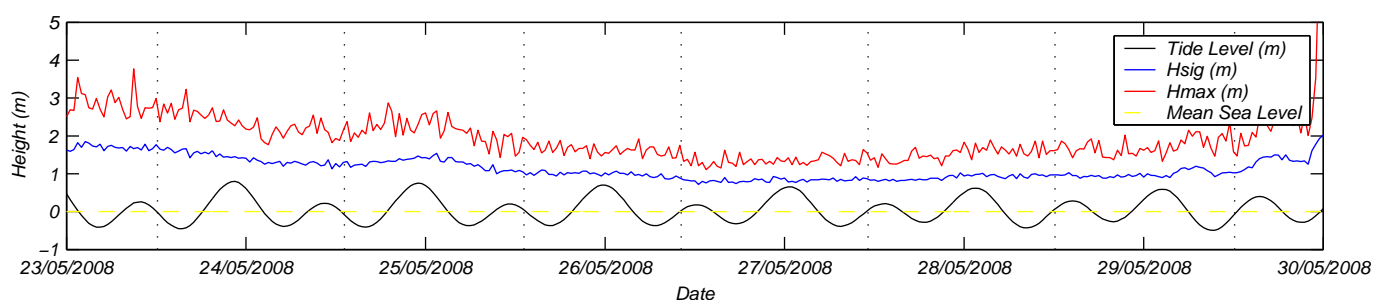
27/05/2008 11:10



28/05/2008 12:09



29/05/2008 12:10



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
23/05/2008 – 29/05/2008

Figure  
A17



30/05/2008 13:09



31/05/2008 14:09



01/06/2008 14:10



02/06/2008 09:09



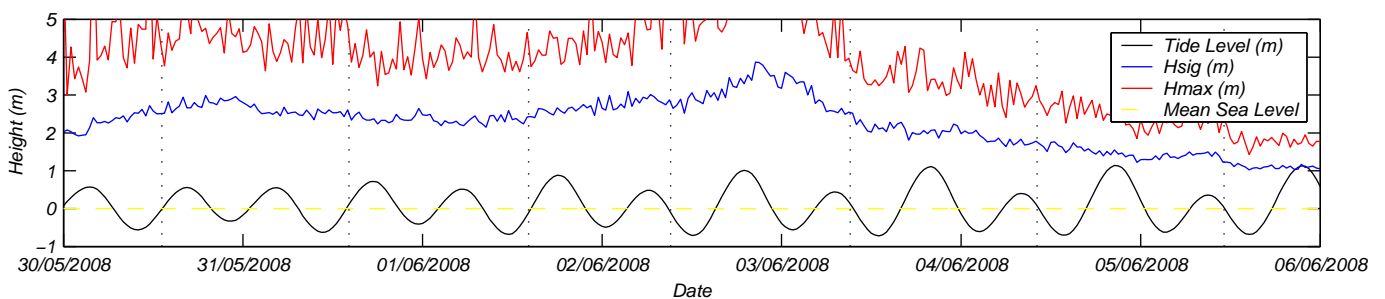
03/06/2008 09:10



04/06/2008 10:10



05/06/2008 11:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
30/05/2008 – 05/06/2008

Figure  
A18





06/06/2008 12:09



07/06/2008 13:09



08/06/2008 14:10



09/06/2008 10:09



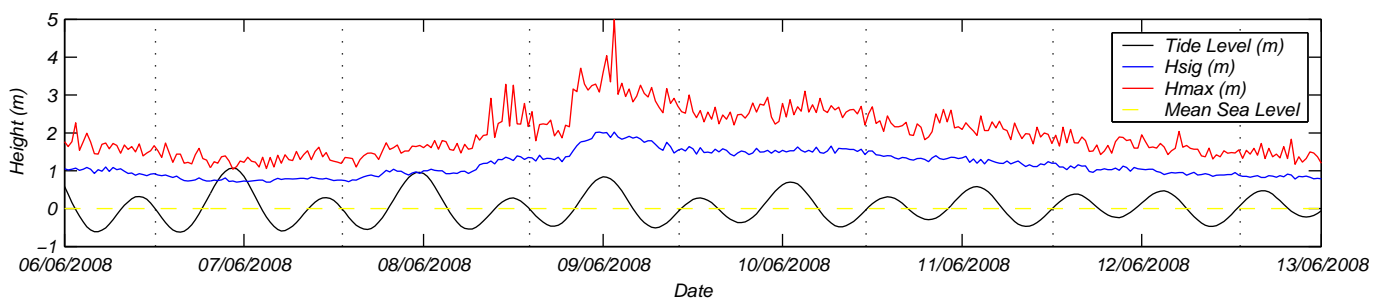
10/06/2008 11:09



11/06/2008 12:09



12/06/2008 13:10



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
06/06/2008 – 12/06/2008

Figure  
A19



13/06/2008 13:09



14/06/2008 14:09



15/06/2008 14:09



16/06/2008 15:09



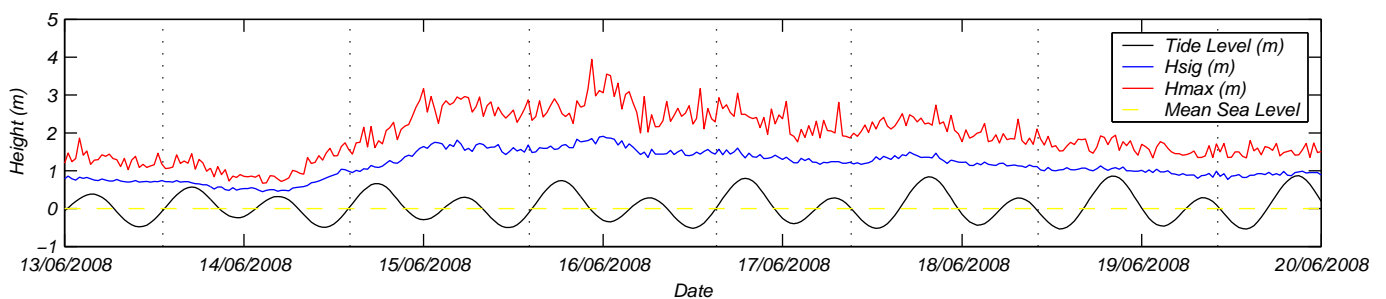
17/06/2008 09:09



18/06/2008 10:10



19/06/2008 10:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
13/06/2008 – 19/06/2008

Figure  
A20



20/06/2008 11:09



21/06/2008 12:09



22/06/2008 12:09



23/06/2008 13:09



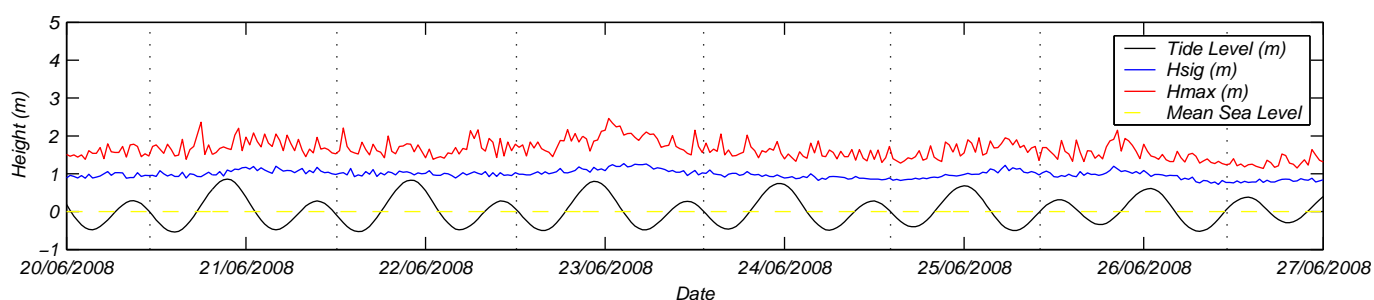
24/06/2008 14:09



25/06/2008 10:09



26/06/2008 11:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
20/06/2008 – 26/06/2008

Figure  
A21



27/06/2008 11:09



28/06/2008 12:09



29/06/2008 13:09



30/06/2008 14:09



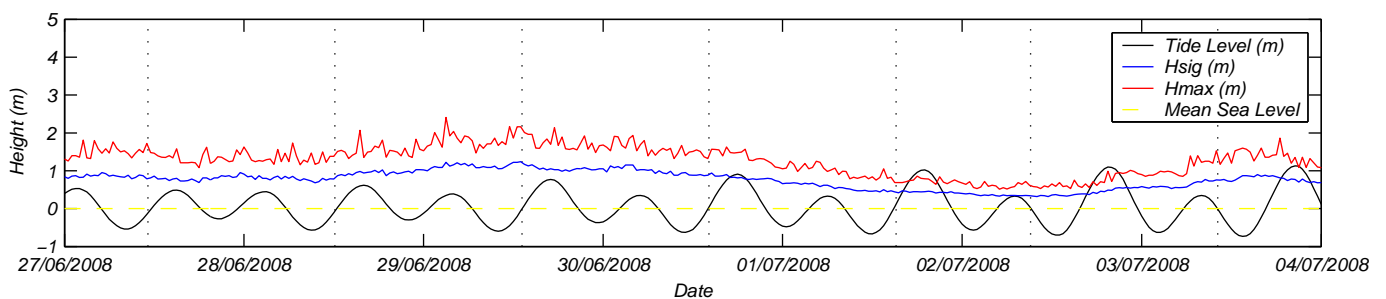
01/07/2008 15:09



02/07/2008 09:09



03/07/2008 10:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
27/06/2008 – 03/07/2008

Figure  
A22





04/07/2008 11:09



05/07/2008 12:09



06/07/2008 13:10



07/07/2008 14:09



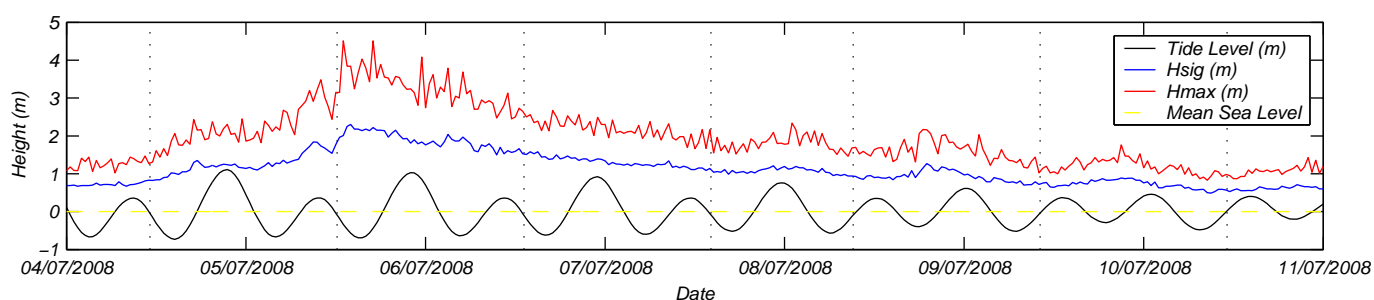
08/07/2008 09:09



09/07/2008 10:09



10/07/2008 11:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
04/07/2008 – 10/07/2008

Figure  
A23



11/07/2008 12:10



12/07/2008 12:09



13/07/2008 13:09



14/07/2008 14:09



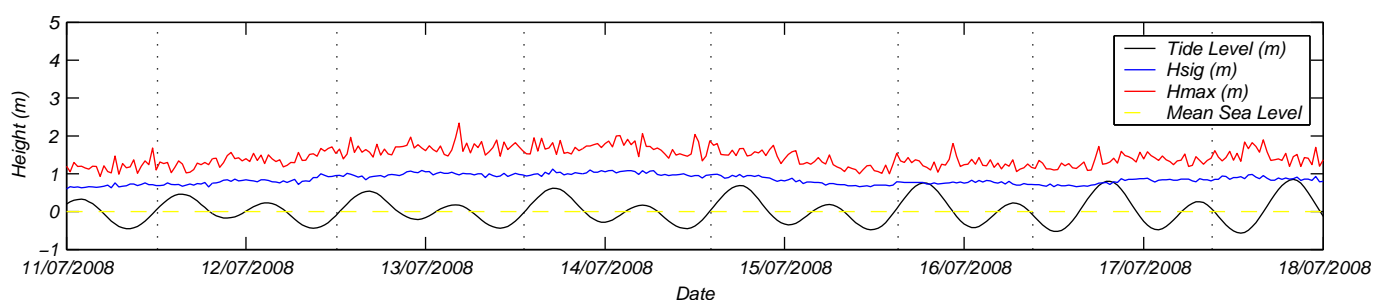
15/07/2008 15:09



16/07/2008 09:10



17/07/2008 09:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
11/07/2008 – 17/07/2008

Figure  
A24



18/07/2008 10:09



19/07/2008 11:09



20/07/2008 11:10



21/07/2008 12:09



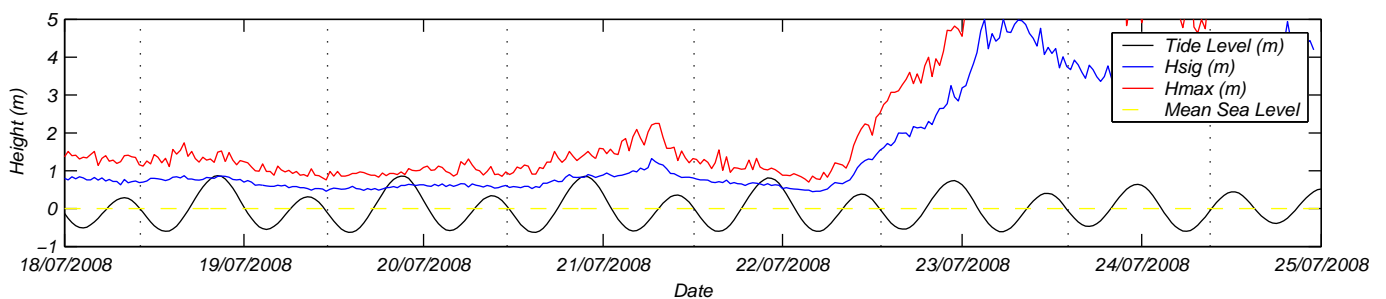
22/07/2008 13:09



23/07/2008 14:10



24/07/2008 09:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
18/07/2008 – 24/07/2008

Figure  
A25



25/07/2008 10:09



26/07/2008 11:09



27/07/2008 12:09



28/07/2008 13:09



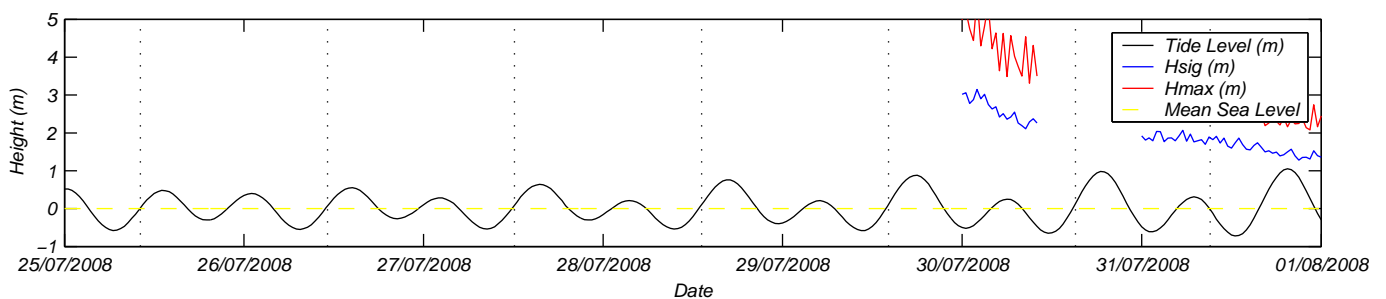
29/07/2008 14:09



30/07/2008 15:09



31/07/2008 09:09



WRL

Report No.2008/27

WEEK TO PAGE SUMMARY: MEAN SEA LEVEL  
GOLD COAST, QUEENSLAND, AUSTRALIA  
25/07/2008 – 31/07/2008

Figure  
A26

## **APPENDIX B**

### **MONTHLY WAVE CLIMATE SUMMARIES: FEB – JULY 2008**

