The Development of Multi-Purpose Reefs for Coastal Protection

In 1995, the Artificial Reefs Program (ARP) was initiated at the Centre of Excellence in Coastal Oceanography and Marine Geology, a joint graduate school in the University of Waikato and the National Institute of Water and Atmospheric Research (NIWA), in Hamilton, New Zealand. By unifying senior scientists and experienced industrial partners, the ARP aimed to:

- enhance the coastal amenity value of developed shorelines by evaluating multiple use options (surfing, diving, recreational and commercial fishing, navigation and swimming safety) for incorporation into coastal constructions.

A team of scientists and industry experts was involved including biologists, physicists, engineers, planners and environmental managers, so that both the environmental aspects and the coastal processes could be fully investigated to enable the complete development of multi-purpose artificial reefs. A series of related studies provided the input into the broader program so that engineers who build offshore protection works became aware of and were able to incorporate the proposed concepts into their structural designs to fulfil the demands and requirements of the marine environment, recreationalists and developers.

Eight years on, ASR Ltd represents the commercial offshoot of the ARP, and although selected graduate students are still involved in the ARP (with joint supervision from ASR Ltd and the University of Waikato), the primary aim of the Program has been achieved. Indeed, in addition to numerous research theses, individual journal and conference papers and consulting reports, Special Issue No. 29 of the Journal of Coastal Research (Winter 2001), "Natural and Artificial Reefs for Surfing and Coastal Protection" includes over a dozen scientific papers on the design, impacts and construction of multi-purpose reefs.

The first reef designed by ASR Ltd at Narrowneck on the Gold Coast in Queensland, Australia, won the State Environmental Award. This project has demonstrated the effectiveness of multi-purpose reef technology, with significant widening of the beach without down stream impacts (the Narrowneck area of the Gold has a net northerly sediment transport of ~500,000 m^3/yr), enhanced marine life and quality surfing waves. A similar project has recently been completed for Lyall Bay (New Zealand), and ASR Ltd has recently been and is currently involved in a range of multi-purpose reef projects that are primarily for either coastal protection (erosion control, submerged port walls), the creation of surfing breaks or ecological enhancement, in New Zealand (8), Australia (5), Fiji (1), Costa Rica (1), the USA (3) India (1), Indonesia (1), Bahrain (1) and the UK (5), with construction of three of these reefs scheduled to proceed in the next 12 months. The majority of these reef projects are in locations where the existing coastline is already developed, and where much of their income is derived from the tourism industry – these projects are often driven by the socio-economic benefits that multi-purpose reefs provide. Indeed, the publics demand for beaches for recreation, combined with the increasing value society places on the natural environment, has led to a dramatic increase in the development of submerged reef projects

world-wide (e.g. Ahren and Cox, 1990; Hsu and Silvester, 1990; Pilarczyk and Zeidler, 1996; Hall and Seabrook, 1998; Black *et al.*, 1998; Harris, 2001; Mead *et al*., 2003; Babtie, 2003).

Example Project – The Narrowneck Submerged Reef, Queensland, Australia

The erosion problem at Narrowneck, 1 km north of Surfer's Paradise on the Gold Coast, in Queensland. The Gold Coast is Australia's primary tourist destination, with the wide sandy beaches being a major attraction. The erosion problem on the Gold Coast was confined to a hotspot at Narrowneck, where only the coastal road separates the Broadwater from the sea. This causeway was breached several times in the previous century and coastal protection was proposed as part of the Gold Coast Beach Protection Strategy to address this problem. The wave climate and sediment transport regime at the Gold Coast is dominated by SE swell, which results in large net sediment transport in one direction (~500,000 m^3/yr).

Traditional coastal protection methods were considered (e.g. groynes, rock rip-rap, etc.). However, a socio-economic assessment found that for every dollar spent on enhancing the beach, $60-80 was returned via tourism (Raybould and Mules, 1997). Consequently, an offshore submerged reef was proposed and design works were undertaken by ASR consultants (Black *et al.*, 1998).

The aims of the project were:

- to widen the beach and dunes along Surfers Paradise Esplanade.
- to improve the surfing climate at Narrowneck.

A comprehensive field program was undertaken, with the results being utilised for reef design and sediment transport modelling (i.e. to assess the functional performance of the reef). The resulting final design was a 128,000 m^3 submerged reef (Figs. 1 and 3). The main purpose of the Narrowneck reef is to retain sand nourishment material that was pumped onto the beach from the Broad water. Figure 3 demonstrates how successful the Narrowneck submerged reef has been at retaining nourishment material on Surfer's Paradise Beach. Argus coastal imaging has shown that wave energy is dissipated by the reef for up to 90% of the time and that Narrowneck reef is an erosion control point on the coast (Turner *et al*., 1999).

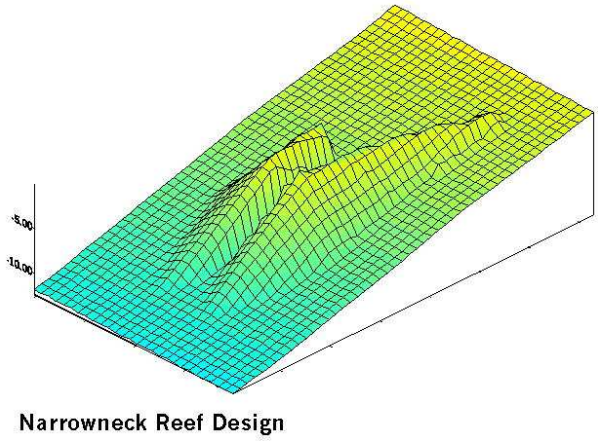


Figure 1. 3-dimensional representation of the Narrowneck multi-purpose reef.

The Narrowneck reef was built using over 400 Terrafix 1200/1209RP geotextile containers, with standard 20 m long by 5 m diameter units. Terrafix 1200RP sand filled containers (SFC's) can be custom designed to suit the required purpose by sewing or ultra-sonically welding large sheets of material together to form enclosed units. A wide range of sand-filled geotextile construction units in a variety of shapes and sizes have been used for coastal projects around the world. At Narrowneck, the ~300 tonne SFC's were filled inside a split-hull dredge, sealed and then positioned with GPS before dropping to the seabed. The resulting reef can be seen in the aerial photograph (Fig. 3), with recently added SFC's still sand-coloured, while SFC's that were placed at an earlier date are colonized by marine life and are much darker (like a natural reef) as a result.

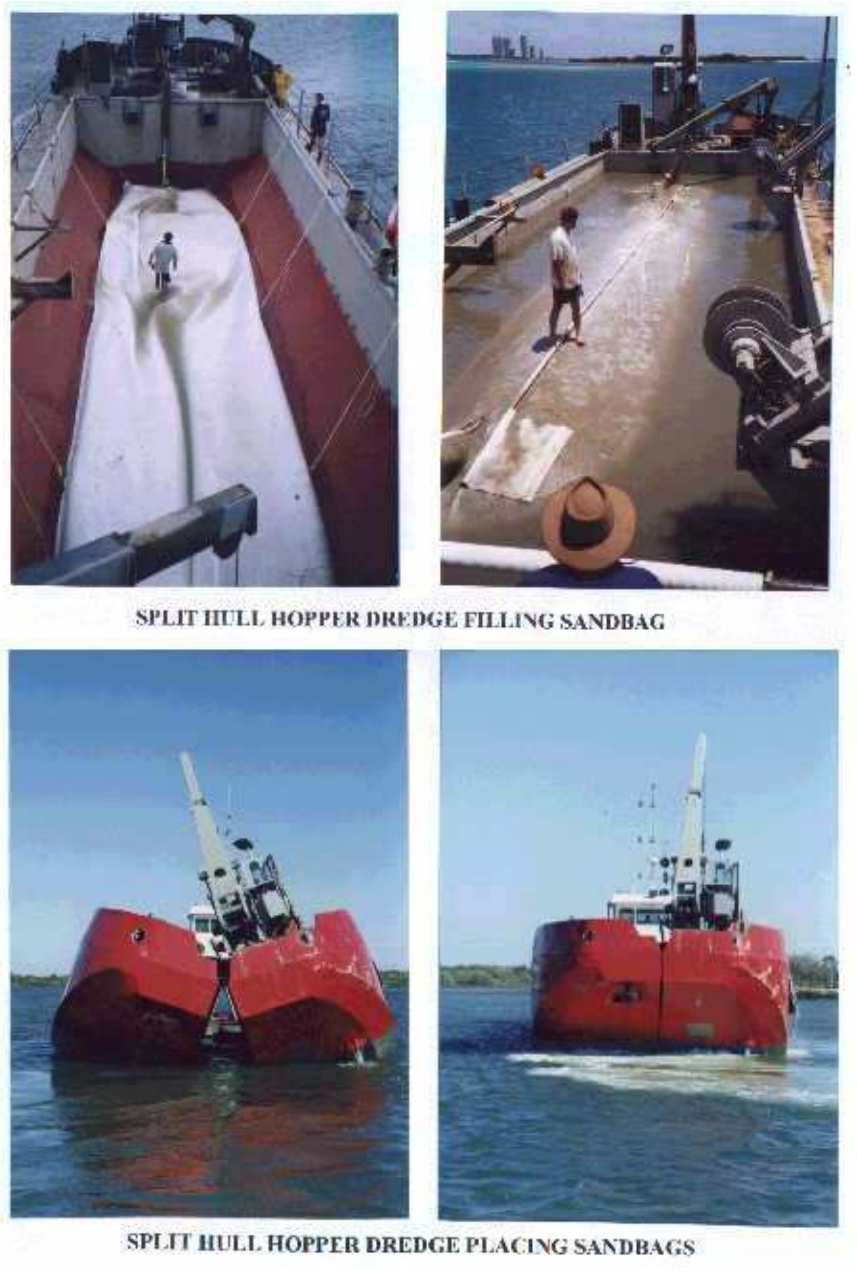


Figure 2. Terrafix 1200R SFC's being filled and placed during construction of the Gold Coast reef.

Figure 3. The view of Surfer's Paradise with the multi-purpose reef in the foreground. The lighter coloured containers had only just been deployed, while the darker containers are colonised by marine life.

The Gold Coast reef has been a huge success, not only in terms of coastal protection (Fig. 4), but also providing a surfing facility (recent reports describe the reef as the 'best surfing spot on the coast') and a 'natural' reef ecosystem that supports a dive trail (Fig. 5). An important outcome of the project was the confirmation (via beach profile monitoring and Argus coastal imaging) of no downdrift impacts on the coast. In 2000, the Narrowneck reef project won the prestigious Queensland State Environmental Award. Recent re-assessment of the economic impacts of the reef have confirmed a benefit:cost ratio of 70:1 (McGrath, 2002).

Figure 4. Coastal protection with the Narrowneck submerged reef. Top to Bottom: Before reef construction (construction commenced in August 1999); After reef construction; The view looking south showing the wide salient in the lee of the reef.

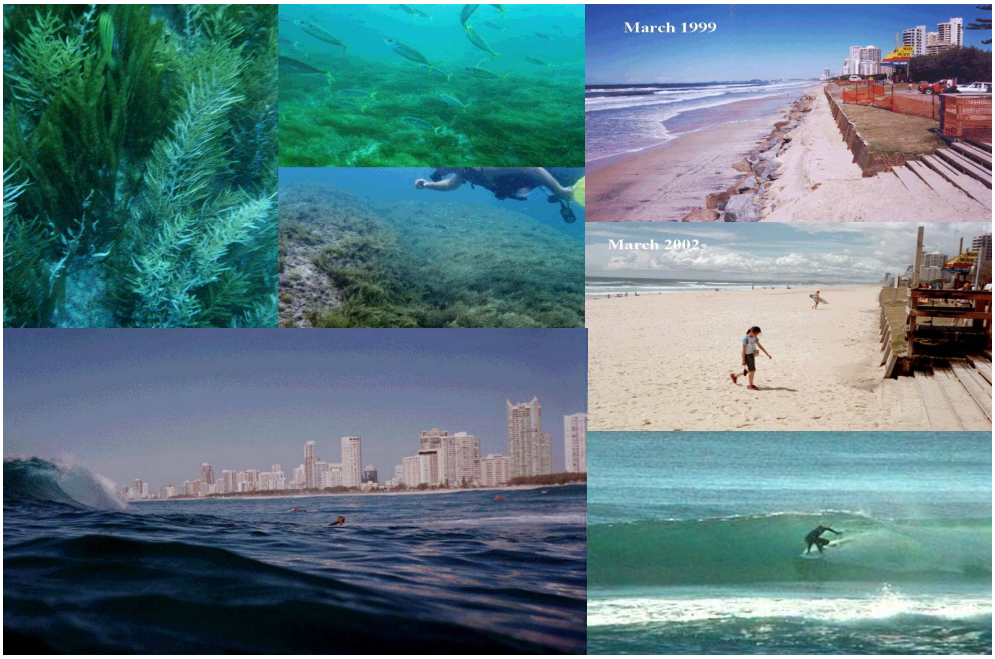


Figure 5. The Narrowneck multi-purpose reef. Clockwise from top left, colonization of the reef has resulted in a dive-trail; before and after reef construction (construction commenced in August 1999); surfing on the reef; the view from the surf.

Narrowneck Reef Monitoring Report Summary:

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

By the end of the present six month monitoring period the beach immediately north of the reef Narrowneck was typically of the order 20 m wider than at the commencement of monitoring in 1999. It should be noted that extensive sand nourishment had commenced in this area prior to the commencement of monitoring (refer Section 2.3), so the actual increase in beach width since implementation of the NGBPS is likely to be somewhat greater than this figure. At the centre of the reef construction site and the two transects to the south (all located in deposition area A3), beach widening of 50 – 60 m was observed through to early 2000 in response to ongoing nourishment during this time. At the centre of the reef construction site and 150 m 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 300 m 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.

By the end of the present monitoring period the beach to the south (up-drift) of the reef was of the order of 40+ m wider than at the commencement of monitoring. In the lee of the reef, an additional 30 m had been maintained.

Wave breaking on the reef at Narrowneck is commonly visible in images obtained by the coastal imaging system (photo 8). 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 2002.2). 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."

Turner, I.L., 2004. **Analysis of Shoreline Change: February 2004 to July 2004. Report 10: Northern Gold Coast Coastal Imaging System**. WRL Technical Report 2004/07, Water Research Laboratory, University of New South Wales.

Further monitoring reports on the beach response at Narrowneck reef can be found at: http://www.wrl.unsw.edu.au/coastalimaging/public/goldcst/index.php?page=goldcstMonitoringReports.html

Summary of the beach changes at Narrowneck based on monitoring data (J. McGrath pers. comm.):

1. Prior to reef construction, the Gold Coast beaches had been nourished on average every ten years since the 1970's. The last nourishment was done in 1987 (prior to 1999 project).

2. The average rate of beach recession was ~5 meters per year prior to the reef project. (Current rates are -1.5 to -3.6 according to WRL 2008/06). The current reduced beach recession is caused by a combination of over nourishment and reef stabilization.

3. The beach in the lee of the reef was purposely over-nourished in 1999-2000 (more so than the other sections of the project) with the understanding that the erosion rates

would be higher at that location as the beach system moved towards dynamic equilibrium. In other words were higher erosion rates behind expected the reef and they expect that to continue until a dynamic equilibrium had been achieved.

4. The south reach experienced accretion for the first 6 years as the salient moved towards equilibrium (WRL 2008/06 table 7.1.).

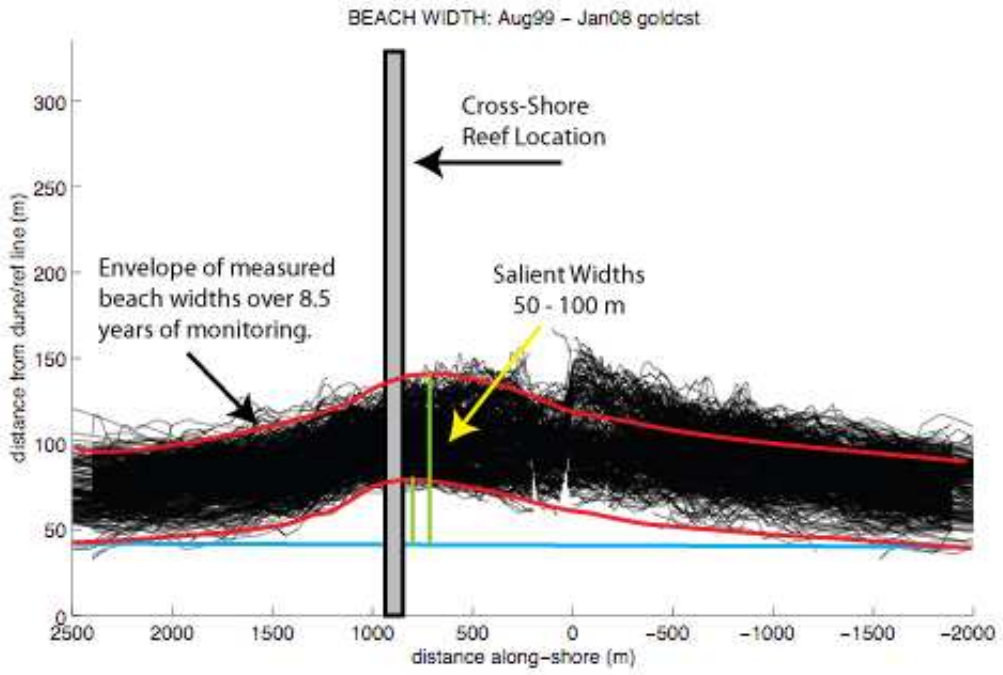
5. Now that the south reach has achieved relative equilibrium the excess sediment is moving northward resulting in the slightly erosional trend of the last two years (-1.5m/yr).

6. The erosion trend is expected to equalize along the project shoreline once the entire system has reached equilibrium.

7. The reef has significantly stabilized the nourishment project and reduced the total rate of beach recession rate along the entire project.

8. It is not anticipated that any nourishment projects will be required in the area until 2030. In other words, the reef has extended the renourishment cycle well beyond the 10 year cycle that was experienced before the reef.

The figure below indicates the impressive beach response achieved by the GC reef, some 3.5 km.



Current and Recent ASR Projects Relevant Coastal Processes and Protection

Project	Commencement date	Client	Works Undertaken
IRE Sand Mining Project, Southern India	May 1999	CESS, India	Instrument deployments followed by wave transformation and sediment transport modelling to ascertain impacts of sand mining on the coast.
Takapuna Boat Ramp/Surf Reef Feasibility Study	Completed 1999	North Shore City Council	Wave transformation modeling to ascertain the impacts of constructing a breakwater on the existing coast and surfing break
Narrowneck Reef: Erosion Control and Surfing Enhancement	Oct 1999 (construction)	Gold Coast City Council	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to protect the coast and provide a high-quality surfing break
Noosa, Australia Beach Erosion Solutions	Stage I August, 1999 - Stage II April 2002	Noosa Shire Council	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to protect the coast and provide a high-quality surfing breaks
New Plymouth Foreshore Redevelopment	May, 1999	New Plymouth District Council	Field investigations, wave transformation modelling and preliminary reef design for a submerged reef to provide a beach and a high-quality surfing break
Mount Maunganui Surfing Reef	February 1999	Tauranga District Council	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to protect the coast, provide habitat for marine organisms and provide a high-quality surfing breaks
Wave and Sediment Dynamics on Beaches	August, 1999	NIWA	A large multi-facetted project that included field investigations, wave transformation modeling and sediment transport modelling
Bournemouth Surfing Reefs Feasibility Study	February, 2000	MAFF, England	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to protect the coast, provide habitat for marine organisms and provide a high-quality surfing breaks
Opunake Surfing Reef Feasibility Study	Stage I September 2000 – Stage II July 2003	South Taranaki District Council	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to provide a high-quality surfing break and habitat for marine organisms
Lyall Bay Surfing Reef Feasibility Study	Stage I October 2000 – Stage II October 2002	Lyall Bay Reef Charifable Trust	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to provide a high-quality surfing break and protect the coast

Project	Commencement date	Client	Works Undertaken
Newquay Surfing Reef Feasibility Study	July 2001	Newquay Artificial Reef Forum	Wave transformation modelling, sediment transport modelling and preliminary reef design for a submerged reef to provide a high-quality surfing break
Westshore Coastal Processes and Erosion Control Investigation	May 2001	Napier City Council	Field investigations, wave transformation modeling and sediment transport modelling to assess the coastal processes and preliminary reef design for a submerged reef to protect the coast
Port Gisborne Expansion	September 2001	Port Gisborne	Field investigations, wave transformation modelling, sediment transport modelling and Port wall design to incorporate Port protection, a high-quality surfing break and habitat for marine organisms
Port Dredge Spoil Disposal	August, 2003	Westgate Transport, Taranaki	Wave transformation modelling and preliminary dredge mound design to ensure no negative impacts to the coast
Oil Piers Sand Retention: Ventura, California	March 2003	The US Army Corp of Engineers	Field investigations, wave transformation modelling, sediment transport modelling and reef design for a submerged reef to protect the coast and provide a high-quality surfing break
Geraldton Surfing Reef Feasibility Study	July 2003	BBIG	Field investigations, wave transformation modelling, sediment transport modelling and preliminary reef design for a submerged reef provide a high-quality surfing break
Borth Multi-Purpose Reef	February 2003	Ceregidion	Wave transformation modelling, sediment transport modelling and Preliminary reef design for a submerged reef to protect the coast and provide a high-quality surfing break
Orewa Beach Multi-Purpose Reef	October 2003	OBRCT and Rodney District Council	Field investigations, wave transformation modelling, sediment transport modelling and preliminary reef design for a submerged reef to protect the coast, provide a high-quality surfing break and habitat for marine organisms
Opunake Surfing Reef	December 2004	South Taranaki District Council	Studies for Resource Consent application for the Opunake Surfing Reef, Taranaki, New Zealand. Detailed design, physical and biological impact studies and hearing evidence needed to obtain Resource Consents.
Palm Beach Coastal Protection Options	May 2004	SOS Incorporated	A review of the design and impact assessment for 3 submerged reefs proposed for Palm Beach in Australia

Project	Commencement date	Client	Works Undertaken
Nanuku Surfing Reef Feasibility Study	June 2004	Hatherly Dunedin	Feasibility study for a surfing reef at Nanuku Island, Fiji, for tourism development
Boscombe Surfing Reef	August 2004	Bournemouth Borough Council	Boscombe surfing reef detailed design - field data collection, numerical modelling and initial design reporting.
Sandbanks Coastal Protection Options	January 2005	H R Wallingford	Desk study of alternative coastal defence options at Sandbanks, Poole, England
Cape Otway	February 2005	Woodside Energy	Assessment of the nearshore wave conditions at Cape Otway in Victoria, Australia for the emergence point of a subsea pipeline. Detailed study with numerical and physical modelling
Urenui Beach Protction	March 2005	New Plymouth City Council	A review of coastal management and an assessment of options for Urenui Beach and first order determination of the coastal processes
Oakura Beach Erosion Control	May 2005	New Plymouth City Council	An investigation of the shoreline erosion along the western beach of Oakura and recommendations for mitigation
Ohau and Oteranga Bay Investigations	June 2005	Meridian Energy	Physical process investigation and breakwater design for Oteranga Bay and Ohau Bay, Wellington, for construction of Makara wind farm construction. Numerical modelling, wave Climate Hindcasting and physical impact assessment
Mount Maunganui Reef	July 2005	Mount Reef Trust	Physical modelling to amalgamate construction materials and methods with detailed design and construction management
Incorporation of Multi-Purpose Beach Control Structures into the Barcelona Beach Development (Spain)	August 2005	Associació Catalana de Surf	Preliminary design options for multi-purpose reefs to provide coastal protection and surfing amenity as part of the Barcelona Beach Development Plan.
Bay View Coastal Hazard Zoning and Beach Nourishment Plan (New Zealand)	September 2005	Fore World Development Ltd	Review of coastal hazard zones and development of a beach nourishment plan for Bay View Beach.
Long Branch Surfing Reef (USA)	November 2005	SEA	Wave transformation modelling, sediment transport modelling and detailed design of a sand-filled geotextile container multi-purpose submerged reef and beach amenities to provide a high-quality surfing break and sand retention.
Cape St Francis Beach Rehabilitation (South Africa)	January 2006	SFBBT	Field investigations, wave transformation modelling, sediment transport modelling and preliminary design of multi-purpose submerged reefs and beach amenities to retain a wide sandy beach and allow for the removal of rock revetments, while

Project	Commencement date	Client	Works Undertaken
			providing high-quality surfing breaks and tourism enhancement.
Pollok Beach and Wells Estate (South Africa), Multi-Purpose Surfing Reefs	May 2006	AfriCoast Engineers	Field investigations, wave transformation modelling, sediment transport modelling and preliminary design of sand-filled geotextile container multi-purpose submerged reefs and beach amenities to retain a wide sandy beach and allow for the removal of rock revetments, while providing high-quality surfing breaks and tourism enhancement.
Boscombe Surfing Reef (United Kingdom)	June2006	Bournemouth Borough Council	Boscombe surfing reef detailed design – physical modelling and construction management. Construction summer 2007
Hydrodynamics and Sediment Transport for the Southern Pipeline	March 2006	URS/Tauranga District Council	Field data collection and numerical modelling to assess the impacts of various submarine and bridge-pile pipeline routes on the inner Tauranga Harbour
Port Phillip Bay and Western Port Water Quality Receiving Model	February 2006	Environmental Protection Agency, Victoria, Australia	Development of a 3-D circulation model to simulate hydrodynamic behaviour of Port Phillip Bay and Western Port and associated estuarine, ocean and catchment (model) boundaries. In addition, the capability to model the water quality constituents of TN, TP, TSS, salt (EC), zinc, lead , pathogens (E.coli, enterococci), Chl-a, and gross pollutants (litter), as well as sediment transport and coastal erosion and deposition due to tidal currents and wave action. Output include in-house use for the EPA with associated training and documentation.
Los Rosadas Beach Access and Amenity Enhancement	January 2007	Costa Chamela Corp, Mexico	The project involves undertaking the feasibility and preliminary design studies for a sand-filled geotextile container multi-purpose structure to provide sheltered boat launching and surfing amenity at Las Rosada, Mexico. Field work (bathymetry survey, instrument deployment and diver surveys) and numerical modelling.
Preliminary Assessment of the Feasibility of Providing a New Entrance to Matakana Island	February 2007	Pritchard Group	Pritchard Group commissioned ASR Ltd to undertaken an assessment to confirm the feasibility of providing a new entrance to Matakana Island. This included reviewing existing information (modelling), site visit and bathymetry survey.
Detailed Design for Beach Enhancement at 4 Port Elizabeth Beaches	March 2007	Nelson Mandela Bay Municipality, South Africa	Numerical and physical modelling for the detailed design of 4 projects in Port Elizabeth. Projects range from retaining sand on the beach to safe-swimming areas and surfing break development. Design layouts and construction plans and costings are also included.

Project	Commencement date	Client	Works Undertaken
Receiving water quality modeling scenarios of Port Phillip Bay and Western Port for the Water Quality Improvement Plan	April 2007	Melbourne Water	Conduct and complete modelling scenarios from the developed receiving water quality model for the Port Phillip Bay and Western Port Water Quality Improvement Plan (WQIP) that integrate with catchment model scenarios outputs, and inform the offsets project (including field data collection).
*North End Beach Development	May 2007	Africoast Engineers	North End currently has no sandy beach, just rock revetment due to the presence of the Port blocking littoral sand transport. This project considers the feasibility of developing a sandy beach at North End through field investigations and numerical modelling.
Dispersion Modelling of Hypersaline Water in Port Phillip Bay and Western Port	May 2007	GHD	Scenario modelling of hypersaline water dispersion from various locations in Port Phillip Bay and Western Port using ASR's existing calibrated hydrodynamic models
Likuri (Robinson Crusoe) Island Marina Development	June 2007	Harrison Grierson	Field studies (wave/current measurements, bathymetry surveys, grab samples) and numerical modelling to evaluate the environmental impacts and functional performance for a super-yacht marina and swimming lagoons. This project is aimed at ensuring sediment transport is not modified in a way that would have negative impacts on the island, as well as ecological impacts on mangroves and benthic invertebrates.
Opoturu Bridge/Causeway Assessment	July 2007	Maunsell Ltd	Review of hydrological modelling and expert advice on sedimentation for a proposed bridge/causeway upgrade, including field data collection and modelling for extreme water level analysis to design the height of the bridge soffit
Establishing Numerical models and Collection of Preliminary Field Data for the Proposed Wonthaggi Desalination Plant	September 2007	GHD	Review of existing information, establishing numerical models and collection of preliminary oceanographic data for the Wonthaggi coast and Bass Strait, for environmental impact assessment of Melbourne's proposed desalination plant.
Orewa Beach Rehabilitation (New Zealand)	September 2007	OBRCT and Rodney District Council	Detailed reef design and Resource Consent Application for sand-filled geotextile container submerged multi-purpose reefs to protect the coast while retaining a wide sandy beach, and providing a high-quality surfing break and habitat for marine organisms
Mossel Bay Fish Farm – Currents and Dispersal Modelling	December 2007	CCA Environmental	An impact study (including deployment of instruments for data collection) of a proposed fish farm offshore of Mossel Bay, South Africa.

Project	Commencement date	Client	Works Undertaken
		(PTY) Ltd	
Raglan Harbour Model	January 2008	Research Grant	Development of a calibrated numerical model for the Raglan Harbour and Bar – field data collection and numerical model development.
Final Design and Impact Assessments of a New Entrance to Matakana Island	February 2008	Pritchard Group	Final design and impacts assessment (physical and ecological) of a new entrance to Matakana Island. The resort application is currently being processes (Nov 2008).
Opoturu Bridge/Causeway Numerical Modelling and Ecological Assessment	May 2008	Raglan Land Co.	Development of a numerical model to test impacts due to the removal of the existing causeway and construction of a bridge at Opotoru. Ecological assessment of the rocky substrates at Opotoru and other areas of the Raglan Harbour. Reports to support Resource Consent Application.
Corniche Bay Beach Development (Mauritius)	April 2008	Arup Consultants	Corniche Bay is a 5-star resort that is to be developed in south western Mauritius. ASR is a part of a large team of consultants, with our particular brief to developing a wide sandy beach for the frontage of the resort, and consideration of additional water-based amenities.
Development of a Coastal Management Plan for South West India	July 2008-2010	Asian Development Bank	Development of beach management solutions for >40 beaches on the southwest coast of India, including field data collection and detailed design for 4 demonstration sites (MPR's).
Boscombe Surfing Reef Construction (United Kingdom)	August 2008 – August 2009	Bournemouth Borough Council	Construction of the Boscombe Multi-purpose Reef. The bottom layer of the ~14,000 m^3 reef has been completed. Remobilization is scheduled for next April (2009) and completion is expected in autumn 2009.
Sustainable Kelp Harvesting, Waihau Bay, New Zealand	November 2008	CASL/Agrisea	A 5 year project of clearance and monitoring of varying sized patches of Ecklonia radiata, a kelp used for developing high potency fertilizer for agriculture and viticulture.
Western Treatment Plant Outfall Study	December 2008 – September 2009 (in progress)	Melbourne Water	Field data collection and establishment of numerical models for determining the dispersion of POC from the Western Treatment Plant outfalls. This project is being undertaken for the renewal of outfall permits.
La Roche Percee, New Caledonia – Beach Renourishment and Multi-purpose Reef Development	January 2009	CAPSE Nord	Field data collection, numerical modelling and design assessment for beach restoration and coastal protection. Previous failed coastal protection methods have left this turtle nesting area unsuitable for turtles or amenity. Renourishment will be

Project	Commencement date	Client	Works Undertaken
			retained by an offshore submerged reef.
Maraetai Beach Coastal Processes and AEE	February 2009	Harrison Grierson Manukau City Council	Bathymetry survey, instrument deployment and numerical modelling of Maraetai Beach, Auckland to assess the coastal processes and likely impact of renourishment for coastal protection.
Uitoe Peninsula Resort Development, New Caledonia	February 2009	CAPSE Nord	Instrument deployment and numerical modelling of tidal currents for the construction of a channel/marina and wave modelling of a breakwater for channel entrance protection.
Whitianga Viral Fate Modelling, New Zealand	March 2009	Thames District Council	Hydrodynamic modelling of viral particles from the Whitianga outfall to determine health issues at swimming beaches and in aquaculture areas.
Re-Imaging the Folkstone Shore, England	August 2009	Strandhouse	Preliminary investigation of a series of options to enhance the coastal amenity while working within the available environmental constraints such as the large tidal range and the small, windy wave climate.
Port Phillip Bay Submerged Reefs, Australia	September 2009	Department of Sustainability and Environment, Victoria	The Victorian Coastal Strategy identifies the development of a strategic plan for the management of coastal protection as a key action items for the DSE to address. This strategic plan is to take into account climate change risks, impacts and determine the relative costs and benefits of any future beach protection management options. As part of this effort, this study investigates the use of detached offshore reefs as a means of coastal protection in Port Phillip Bay.
Borth Reef Detailed Design and Construction Documentation, Wales	October 2009	Royal Haskoning	Undertake numerical and physical modelling and aid in the development of the final design of the Borth multi-purpose reef
Extreme Water Level Predictions for Dixon Island, West Australia	November 2009	RPSMetOcean Engineers	Numerical modelling of extreme water levels due to tides, storm surge and extreme wave events for the design of a new ship loading structure.
Re-Imaging the Folkestone Shore, England	February 2010	Trevor Minter OBE DL	Desktop numerical modelling study to consider creating unique and interesting water-based activities to serve as a focal point for the Folkestone beaches.
Whangateau Harbour Flushing Study, New Zealand	March 2010	Omaha Park Limited	Development of a hydrodynamic modelling and expert witness evidence presentation of the flushing capacity of Whangateau Harbour.
Review of the impacts of the Port Motueka Sand-	April 2010	Ben Van Dyke	A first level review of the potential effects of a 700 m long by 1.5 m high geotextile groyne/breakwater that was constructed in 1995-96 with the intention to deflect

Project	Commencement date	Client	Works Undertaken
Deflection Groyne			southerly directed sand from the Motueka Spit offshore and maintain a navigable channel to Port Motueka.
Wailagilala Island Beach Development, Fiji	May 2010	Sean Howard	Field data collection and preliminary numerical modelling to create a more user-friendly sandy beachfront along the 300-400 m stretch of beach on the southwestern side of the main island.
Firth of Thames Hydrodynamic Model, New Zealand	May 2010	Environment Waikato	Development of a hydrodynamic model of the Firth of Thames for the assistance with future management options.
GoodEarth Port Development, India	June 2010	Silambimangalam Shipyard Port Development	Development of hydrodynamic models to determine tidal, wind-driven and wave-driven currents at the proposed shipyard and to investigate potential environmental impacts on the Pitchvaram mangrove forest and mitigation methods if required.