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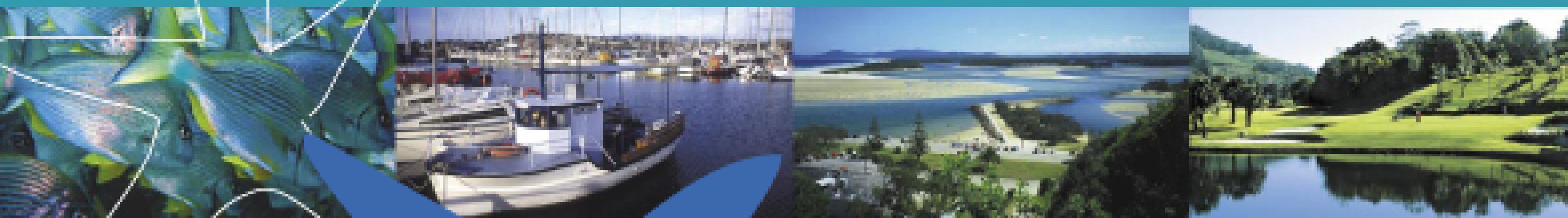

15th NSW

Coastal Conference

7 - 9 November 2006
Novotel Pacific Bay Resort
Coffs Harbour NSW

Coasting towards a sustainable future

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DURANBAH BEACH MANAGEMENT – PRESERVING SURF QUALITY AND BEACH AMENITY THROUGH AN ARTIFICIAL SAND NOURISHMENT PROGRAM.

Introduction

This paper is concerned with the management of Duranbah Beach and dune, within the context of a highly modified coastal environment, and in light of critical factors related to its recreational amenity and use as a surf break.

Duranbah Beach is located immediately south of the NSW and Queensland border, just north of the Tweed River Entrance. The beach is managed by Tweed Shire Council, and affected significantly by operation of the Tweed River Entrance Sand Bypass Project (TRESBP).

Duranbah is the most northerly beach in NSW, and has a national and worldwide reputation as a consistent, high quality surf break. It is possibly the most important venue for contest surfing in Australia, hosting upwards of 40 local, regional and national surfing contests each year, and providing a very important alternative site for the Quicksilver World Championship Tour event. It is also heavily utilised by local recreational surfers, and as such plays an important role in the regions Multi-million dollar surfing industry.

The TRESBP is a joint initiative of the Queensland and NSW State Governments which has been designed and operated to address two issues created by the net northward longshore transport of sand in this section of the coast. The project objectives are to maintain a safe navigation channel into the Tweed River at the Tweed Bar, and to nourish the southern Gold Coast Beaches of Coolangatta and Kirra. This section of the Queensland coast has historically been subject to severe erosion due to restricted natural sand accretion, caused by stabilisation of the Tweed bar in the 1960's.

The TRESBP works by trapping and pumping sand through large jetty mounted pumps on the south side of the Tweed Bar, pumping it in slurry through a pipeline beneath the Tweed River, and discharging it into the nearshore zone across the border in Queensland. A simplified diagram of the project is shown in figure 1. For additional detail on this large and complex project readers should refer to the TRESBP web site: www.tweedsandbypass.nsw.gov.au

Figure 1. Schematic overview of TRESBP (from TRESBP Website)

Operation of the TRESBP has affected Duranbah Beach by restricting the amount of sand which reaches the area to accrete naturally and form offshore sand banks, a beach and dune. It should be noted that Duranbah is itself a man made beach, resulting from the construction of the Tweed River training walls in the 1960's. Since the commencement of TRESBP operations, the dune line at Duranbah has receded by approximately 50 metres, up to 80 metres in places, and the beach will not re-build naturally to attain its pre-project alignment. There is a relationship between the forward alignment of the Duranbah Dune and the depth of the navigation channel in the Tweed River. It is not feasible to maintain the dune at its original position as it could potentially reduce depths in the navigation channel.

The TRESBP is focused on sand delivery to the beaches of Queensland, and like the Tweed River mouth, Duranbah is intended to bypassed by natural longshore sand transport. The beach no longer experiences enough natural sand deposition to maintain its long established recreational amenity and landscape character, and while there are nourishment arrangements in place, these are not sufficient to protect these values.

Since April 2001, Duranbah Beach has been artificially nourished with sand in an attempt to maintain amenity. Sand (approximately 50, 000 cubic metres per year) has been delivered through a temporary pipe, and in some cases this material has been reworked with bulldozers to form a small foredune. This intense modification creates a complex set of management issues for Duranbah, related to surf quality, beach amenity and public safety.

This paper outlines a beach nourishment strategy for Duranbah that has been prepared by Tweed Shire Council. The strategy seeks to formalise an agreement between Tweed Shire Council, the TRESBP and community stakeholders, on how sand should be delivered to the beach in order to preserve its great value as a recreational area and high quality surf break. Such an agreement is essential to provide evidence to the community that concerns regarding the future amenity of this area are viewed seriously, and to demonstrate joint commitment by state and local government to managing the areas existing problems.

A second objective of this paper is to explore options for surf quality monitoring. This subject is worthy of more attention by coastal mangers and the surfing community, particularly in areas like the Gold Coast, where world famous and highly valued surf breaks are created, maintained and potentially destroyed by coastal engineering projects.

Management of any natural resource requires an ability to define and report on condition, observe trends over time and identify threatening processes. The high quality surf break at Duranbah Beach is a resource that generates millions of dollars per year for local economies, and over the next decade will cost large sums to manage. Without an objective analysis of the efficacy of management intervention, it will be difficult for the community to justify additional investment in the maintenance or enhancement of surf quality.

Background

TRESBP EIS Predictions and Commitments

The impact of dune recession at Duranbah was predicted in the EIS for this project where it is stated that:

> *"In the event that there is little sand leakage to Duranbah and the Duranbah Discharge Quantity (50, 000 m^3 / year) is the only supply, then it is likely that the entrance bar and nearshore shoals will be largely removed. In that case, the waves will approach the beach more from the southeast and the beach alignment will tend to rotate clockwise. There could thus be greater shoreline retreat near the southern end, estimated to be up to about 80-90 metres from the existing position in the worst case scenario. In the process of shoreline retreat, the existing dune system will be subject to increased erosion, manifesting predominantly during storms.*

The dune system will reform by wind transport during recovery following each storm erosion event further inland than at present." (TRESBP EIS, p. 7-7)

To mitigate this impact, a commitment is made by the T RESBP to deliver sand to Duranbah. The EIS states:

"…provision exists for direct discharge to Duranbah. Up to 10% of the total quantity delivered by the system (approximately 50, 000 m^3 / year) may be placed there as a long term average.

Sand discharge to Duranbah may be utilised to either:

- *Influence the alignment and shape of the beach itself, or*
- *Assist in providing good surfing conditions.*

In both instances, the beach would benefit from the placement of sand. However, the discharge strategy will be different if the focus of the discharge relates to surfing and not beach maintenance.

Two discharge options have been identified for surf amenity enhancement. These are:

- *Discharge off the northern training wall to provide a longshore bar aligned suitably for good surf, or*
- *Discharge to a location in about 5 metres of water depth about mid-beach to create a shoal suitable for surf wave formation."* (TRESBP EIS, p. 8-7)

It is noted that the second option described above has not been pursued.

With specific reference to Duranbah surf quality management and a **Beach Nourishment Strategy**, the EIS states:

"Depending on the extent to which the permanent bypass scheme fully captures the net longshore transport from Letitia Spit, surf quality at Duranbah is likely to be adversely affected. A leaky bypass scheme, in conjunction with the Duranbah Discharge, could retain much of the valued surfing traits of the site. The actual outcome will depend upon the nature of the successful scheme and there will be a need to monitor surfing conditions and manage the Duranbah discharge to achieve optimum surf quality.

This study has shown that it would be feasible to develop a beach and shoal nourishment strategy for dredging and placement of the Duranbah discharge in a manner that maintains surfing opportunities. The strategy would need to embrace the Tweed entrance bar bypassing configurations, including any sand traps that may be created as part of the sand bypassing system, to the most practicable extent, to create conditions favourable to surfing.

The development of a detailed nourishment strategy would have to consider the practicality and cost implications of any such nourishment in the context of the specific capabilities of the successful bypass scheme.

Detailed numerical process modelling could be used to develop a strategy suited to the adopted bypassing system. There would be a need to closely monitor the system and develop/refine the strategy through feedback. In this regard, it is considered important that the development refinement be done through the community advisory committee which has been set up under the deed of agreement. This will ensure that representatives of the local surfing community are involved in the development of the strategy." (TRESBP EIS, 8.3.5 p. 8-9)

Existing and Future Beach, Dune and Surf Amenity

As noted previously, the Duranbah Dune has receded significantly since commencement of the project. This has reduced the width of the usable beach area, and of course has reduced the width of vegetation. Because Duranbah is such a highly used beach, particularly for surfing competitions, this has resulted in a concentration of human impact on the narrow remaining vegetated dune.

The Dune at Duranbah is a highly valued aspect of the local landscape. Its mature vegetation provides shade and helps to define the character of the area, setting the beach apart from the more urbanised beaches across the border, where mature and natural dune vegetation is virtually absent.

Because the beach is artificially nourished, the dune width is temporarily expanded at least twice per year. Immediately following nourishment campaigns a buffer is created between the remaining dune vegetation and the active erosion scarp. In periods following storms and preceding nourishment however, there is ongoing loss of mature trees due to erosion.

WBM Oceanics Australia has prepared a dune management plan for TSC which took into account predicted realignment of the Duranbah Dune due to the operation of the TRESBP. Their work indicated that the entire vegetated area of the dune could be lost due to erosion and restricted accretion, assuming the existing nourishment regime of 50, 000 m^3 of sand is delivered each year. Figure 2 shows the predicted seaward alignment of the dune, in relation to its position in 2003.

Figure 2. Predicted future alignment of Duranbah Scarp Line

It should be noted that there has been additional erosion since this figure was prepared. Currently erosion is most severe in the southern corner of the beach, and early in 2006 a storm event resulted in the loss of a very popular pedestrian pathway that passed through this area. See figure 3. Loss of the Duranbah Dune is a possibility that Tweed Shire Council and the community are very strongly opposed to, and therefore negotiations with the TRESBP are continuing to try and find a more sustainable and equitable outcome for the area.

Figure 3. Erosion in the southern corner of Duranbah Beach resulting in the loss of a popular pedestrian walkway

One of the most important roles of the dune in this location is to act as buffer between the hind-dune park and the active erosion zone. Without a vegetated dune buffer, Tweed Shire Council would be responsible for management of a dynamic interface between grassed parkland and a beach erosion scarp. This is unsustainable, and would have a serious negative impact on the amenity of the area.

WBM Oceanics original recommendation to mitigate against this possibility was to artificially create a new dune, behind the existing dune, in the area currently used as parkland. This management option has been rejected by the community and has not been adopted by Council. Tweed Shire Council have adopted objectives for management of the beach and dune remnant that aspire to preserve the recreational and aesthetic values of the beach. Preparation of the Duranbah Beach Nourishment Strategy is therefore an attempt to gain commitment from the TRESBP to adjust it's existing Duranbah nourishment program to a regime that will have a greater chance of preserving the areas high values.

Surfing conditions at Duranbah fluctuate seasonally and from day to day, depending on a large variety of factors, the majority of which cannot be controlled by or are influenced by the sand bypass project. However, the elements which make Duranbah so valuable as a surf break are its sand banks in near shore and back break areas, and these are of course significantly affected by the TRESBP.

There have been mixed results on surf quality as a result of sand delivery operations to Duranbah. In the earlier stages of project several very large (40, 000 m^3 plus) sand replenishment campaigns were undertaken, with sand being discharged at single point in the southern corner of the beach. This approach is not favoured by the surfing community, with many individuals blaming the large scale sand discharges for the creation of close-out wave conditions. Overwhelmingly, the surfing community advocates frequent smaller discharges of sand at Duranbah, with sand being deposited along the seaward margin of the dune area, rather than into the southern corner of the beach in the swash zone. Over the past 12 months, surfing conditions at Duranbah have been generally regarded as favourable as far as they can be influenced by the project, however surfers are very concerned with ongoing recession of the dune, and the long-term impact of loss of this sand reservoir on wave conditions.

Need for a Formal Nourishment Strategy

There are no objectives for beach amenity or surf quality stated in the EIS, and no formal strategy developed to plan beach and shoal nourishment in terms of either volume, location of placement or timing. This approach is in accordance with the recommendation in the EIS in section - 8.5.1.3 Duranbah Surf Quality Monitoring - where its is stated that, "*Over the first years of operation of the system a strategy based on trial and error is recommended*." The EIS also notes that, *"Monitoring of the surf conditions at Duranbah and the entrance bar configurations would be beneficial toward optimising the placement of sand for surf quality."* (TRESBP EIS p. 8-17)

Experience gained from the nourishment of Duranbah Beach since the sand pumping system began 5 years ago means that it is now possible to prepare a nourishment strategy. A strategy will provide greater certainty for Council that beach management objectives can be achieved. It will also demonstrate to the community that while Duranbah Beach has, and may be further affected by the Sand Bypassing Project, that Council and the TRESBP are committed to the maintenance of the areas significant values. As recommended in the EIS, the surfing community will be requested to provide input to this strategy and assist with its ongoing refinement.

This nourishment strategy will be viewed as a 'live' strategy that will require revision as more information and understanding is gained about the best way to nourish Duranbah with respect to placement; volumes, locations and frequency.

Objectives of a long term beach nourishment strategy

Tweed Shire Council has adopted the following objectives as a basis for its management of Duranbah Beach. The objectives have not been endorsed by TRESBP.

These objectives were drafted at a meeting held at Duranbah Beach on 27/4/2004 that was attended by representatives of Council, the surfing community and TRESBP.

The objectives were adopted in response to significant community concerns about loss of the Duranbah dune and adjacent parkland, and as per the EIS recommendation in Section 8.3.2.9-Duranbah Discharge, which states,

"A first step in the Duranbah sand discharge strategy is to identify the primary objective and to decide on priorities for action based on likely costs and benefits."

Tweed Shire Council Beach and Dune Management Objectives

- Maintain/reinstate the beach and dune width to an alignment that protects, (through the establishment of a transient fore dune of approx 10 metres) the existing woody vegetation and beach amenity.

- Maintain sand cover over the 2nd level rocks and wreck.

- Maintain surf quality and consistency. The optimum state for surf at Duranbah is agreed to be the maintenance of characteristic "A frame" peaks at a number of locations along the beach, breaking as powerful, hollow waves.

- Maintain the existing park behind dunes.

Performance Indicators

No specific or quantifiable objectives have been set for surf quality, and therefore there are no performance indicators against which it is possible to enhance, maintain or monitor surfing amenity.

Currently, surf quality reports are produced by the project by collating photographs or comment on the state of surf breaks from relevant media sources, primarily surfing magazines. These summaries are limited in their ability to report objectively and quantifiably on surf quality conditions, as for example, it is rare for the surfing media to report on surf breaks when they are not good, and photos of surf breaks are a snapshot in time, and not necessarily representative of the monitoring period.

Summary verbal reports are provided by surfing community representatives at community advisory group meetings facilitated by the project. These reports are a provided by experienced surfers with well a developed appreciation of the bathymetric conditions operating in the area, but do not lend themselves easily to quantification or analysis over time.

Tweed Shire Council is collecting data on surf conditions and use levels at Duranbah, with the objective of amassing sufficient data to draw objective conclusions about surf quality in response to beach nourishment campaigns. A more detailed discussion of this surf quality monitoring method is provided later in this paper.

It would be highly desirable to quantify and record the patterns of sand bank formation, in both the nearshore and offshore zones, that creates the highest quality surf amenity at Duranbah. If these conditions can be mapped it will provide a baseline against which changes in bathymetry due to nourishment can be compared, and allow adaptive management of nourishment to take place, with the aim of optimising surfing amenity. If an effective method of surf quality monitoring can be developed, this can be used to further inform the adaptive management cycle.

Existing Nourishment Arrangements

Duranbah Beach is currently nourished twice per year by way of a temporary pipe outlet which is set up in the weeks preceding a nourishment campaign. Consultation between the community, Tweed Shire Council and TRESBP staff is undertaken prior to nourishment to determine how much sand will be placed on the beach, and when sand discharge would ideally be undertaken.

Because sand is discharged from a temporary pipeline, a project set up time of approximately two weeks is required to install pipes, and the attendant public safety infrastructure. Figure 4 shows a small section of the temporary infrastructure. This work results in the beach and park amenity of Duranbah being negatively affected for a month or more as parts of the area are barricaded my safety mesh fencing and while heavy machinery is operated. Sand discharged onto the beach is redistributed with bull dozers to form the desired dune profile. While this work occurs, security firms are engaged to ensure pedestrians and beach users do not move into areas in which machinery is being operated. The costs of this work are shared by Council and the TRESBP.

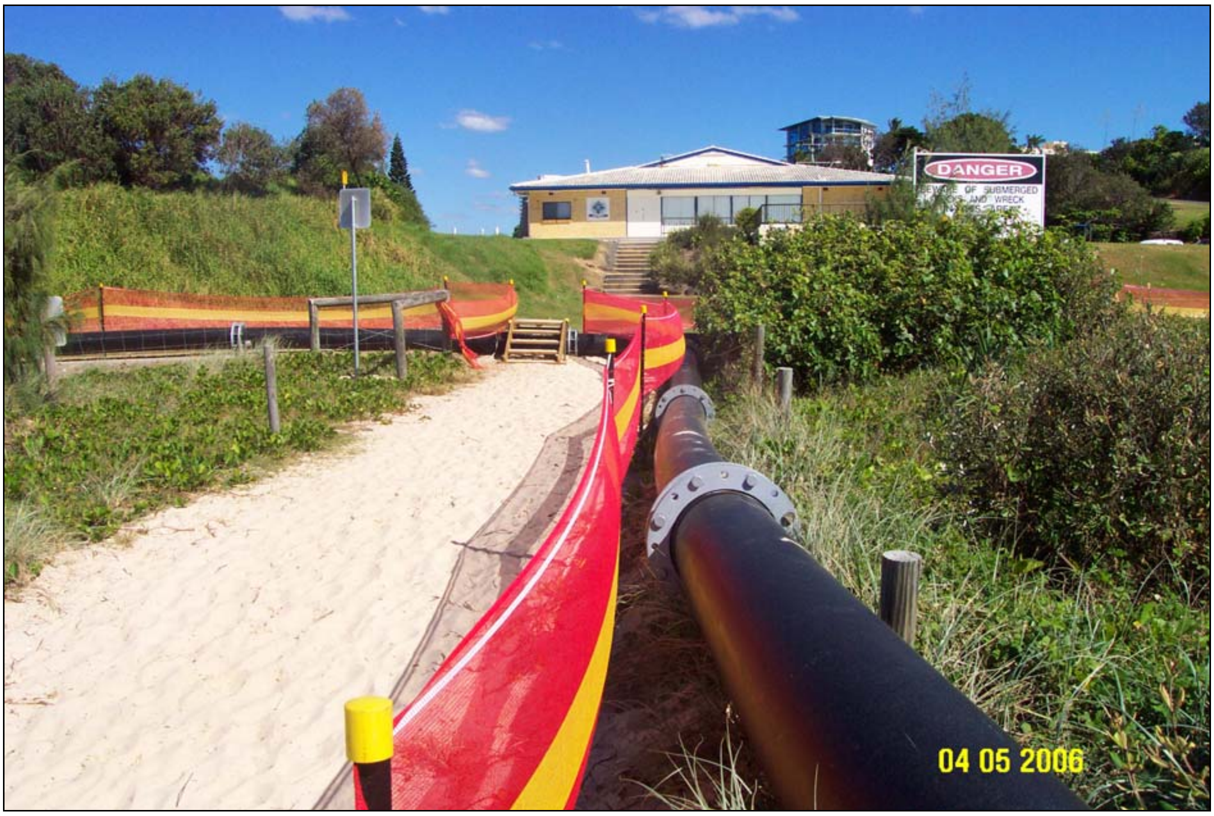

Figure 4 – Temporary pipe work and safety fencing

Nourishment Undertaken Since Project Commencement

As of October 2006, sand nourishment has occurred on 9 occasions (since April 2001), with a total of 275,746 m^3 being delivered. A schedule of the placement dates and volumes is shown in Table 1.

Table 1. Summary of sand delivery to Duranbah since project commencement

Year	Month	Duranbah Placement Volume m^3
2001	April	18,968
	May	48,290
2002	April	30,176
	May	14,339
	September	19,345
	October	8,012
2003	March	14,583
	April	19,853
	June	31,482
	July	4,306
2004	March	36,813
2005	April	6,527
	May	17,821
	November	5231
	December	12, 108
2006	April	13, 715
	May	23, 551

	June	6, 903
Totals		**337, 254 m^3**

Recommended Nourishment Campaigns

As noted, the TRESBP is authorised to deliver up to 10% of the total annual volume of sand transported by the project to Duranbah. This is estimated to equal approximately 50,000m^3 of sand annually. However it is also necessary to build up a credit of sand in the Duranbah supply budget so that there is sand available at short notice in case of the need for an emergency sand placement following severe storm erosion.

Assuming a target delivery of 50, 000 m^3 per year, the following schedule of placements should occur. It is noted that the quantities and dates of discharge cannot be given in absolute certainty, due to the large variation in natural processes that affect operation of the TRESBP. The nourishment strategy should be implemented to achieve the beach management and surf quality objectives, but must retain a degree of flexibility to do so.

It is also important for consideration to be given by the Queensland and NSW State Governments to increasing the annual sand allowance to Duranbah, if it is shown that the current nourishment volumes are unable to preserve the areas public safety, recreational amenity and surf quality. There has been strong and prolonged criticism of the project from Coolangatta residents regarding negative impacts in that area due to too much sand being discharged onto the beaches of this area.

March/April Campaign - Back Beach Placement

The major nourishment campaign for each year should be undertaken at the end of the cyclone season, immediately following the Easter School holidays. Up to 30, 000 m^3 should be placed on the higher part of the beach, and reworked to form and enhance a foredune buffer along the length of the beach.

Sand should generally be placed at a minimum of three locations along the length of the beach. At this stage, the outlet points will range from the southern corner of Duranbah to just South of the stormwater outlet. Currently this will be achieved by placement of a temporary delivery pipeline along the back of the beach with outlet points placed as required.

Following discharge of sand from the outlet locations, it is probable that beach shaping will be required to create a foredune and buffer. This will be undertaken by TSC using dozers.

Public safety and access management is a key aspect of the back beach delivery campaign, therefore commencement dates for sand delivery need to be confirmed one month in advance so that Tweed Council can organise security and notify the public of disruption to normal beach use.

Meetings will be held on site with surfing community representatives prior to each nourishment campaign to discuss the state of the beach and surf conditions immediately prior to sand delivery, and how nourishment can be undertaken to best preserve and enhance beach and surf conditions in accordance with management objectives. It would be in the interests of all parties to undertake follow up meetings within 1 month following nourishment to evaluate surf conditions and other amenity impacts.

November Campaign - Corner Placement

The second annual placement should be to the southern corner of the beach.

Approximately 10,000 to 20,000 m^3 should be placed at this point. This reflects the fact that erosion is most severe in this area, and that severe amenity and safety problems occur as a result of erosion, which need to be addressed.

Should it be required, a dozer will be used to redistribute material discharged in the corner to ensure that a dune buffer is maintained.

It is noted that a single point is not the optimal strategy for beach management. However, due to the high costs of setting up temporary pipe work and using machinery to redistribute sand, a full length beach placement is not possible more than once per year.

Emergency or Interim Placement

Tweed Shire Council and the community are committed to preserving the remainder of the existing Duranbah Dune. As such it is considered essential that provisions exist to make emergency, non-scheduled sand placements. These placements should occur immediately following major erosion events when amenity is severely affected, or when there is insufficient dune buffer to withstand an erosion event that could reasonably be expected to occur.

Based on the delivery volumes projected above, it is expected that approximately 10, 000 m^3 should be made available on an annual basis to undertake emergency or interim placements. However, as far as possible, this volume will be left to accrue to build an emergency placement reserve.

In consideration of emergency placements, it is recognised that sand delivery to Duranbah (or Snapper Rocks East) may not be available via the sand pumping system, as natural sand movement into the sand pumping jetty intake area may be very low in calm periods following stormy conditions.

Emergency placements will be made into the area most affected by storm erosion. In extreme cases, a full nourishment campaign will be required.

Emergency placements will be requested by Tweed Shire Council, as judged necessary by the Director of Engineering Services.

Emergency placements should be undertaken as soon as the placement can be arranged with the system operator subject to sand being available through the pumping system

Establishing a Permanent Sand Delivery Pipe

Due the negative amenity impacts and set up constraints of a temporary pipe system, it is the position of Tweed Shire Council that a permanent pipeline should be established to supply sand to Duranbah. There is a widely held perception within the community that that without a permanent sand delivery pipeline, there is little chance of maintaining a permanent dune at Duranbah. Establishing a permanent pipeline will significantly reduce the project set up times involved in a nourishment campaign, making it operationally realistic to undertake emergency sand placement as described above, and undertake smaller nourishment campaigns more often, potentially allowing greater sensitivity to enhance surfing amenity.

Monitoring, Consultation and Adaptations

TRESBP undertakes a large amount of monitoring in association with the bypass project, which includes surveyed profiles of the beach and offshore bathymetry at Duranbah, as well as digitised photography on a daily basis. This monitoring will continue and should be used to increase understanding of, and guide the implementation of this nourishment strategy.

There has not been a concerted effort made to maximise the value of bathymetric and shoreline profile monitoring by correlating this data with observed surfing conditions and the opinion of local surfing community representatives.

Tweed Shire Council has commenced detailed surf monitoring at Duranbah, collecting data several days per week on wind and swell conditions, numbers of surfers and the quality of waves being ridden. It is intended to build large data set which may be able to be used to test the impacts of sand nourishment on surf quality.

Data collected from Duranbah:

- Date
- Time
- Number of surfers
- Wind direction and speed
- Swell size, period and direction
- Tide

Observations made and recorded:

- Area of beach surfers are catching waves
- Waves barrelling? yes/no
- Percent close outs surfed
- Average length of ride
- Score of surf conditions from 1 to 5

There has not been a full analysis of the data set at this time. It is however probable that sufficient data have been recorded to make a statistically robust determination of the range of conditions, ie. wind, swell and tide, that result in optimal surfing conditions at Duranbah. If these measures are quantified, and it is possible to identify periods when surfing conditions are not optimal despite these environmental conditions being highly favourable, it should be possible to draw a strong conclusion that sand banks are negatively affecting the surf quality. Wether or not bank poor bank formation is directly attributable to operation of the TRESBP, a nourishment campaign, or environmental influence such as a large storm, is not known at this point. The lag time between such an event and the response of sand banks, is not well understood, and therefore typical time periods between good and bad bank formation is not known.

Adoption of the Duranbah Beach Nourishment Strategy

As of October 2006, there has not been a commitment from the TRESBP to jointly adopt a Duranbah Beach Nourishment Strategy containing commitments as described above. It is however hoped that through ongoing consultation with the community and work within the TRESBP community advisory group, that greater security for the beach, dune, surf quality and aesthetic and recreational amenity at Duranbah will be achieved.

SHOALING INDICATOR AND MORPHODYNAMIC MODELLING OF SHOAL DEVELOPMENT AT MOOLOOLAH RIVER ENTRANCE

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Background

Mooloolaba Boat Harbour is one of eleven State Boat Harbours strategically positioned along the Queensland Coast to provide sheltered havens for recreational and commercial boating. It is situated within the Mooloolah River entrance on the Sunshine Coast, approximately 80 km north of Brisbane. The harbour is managed by Queensland Transport (QT). The harbour is the base for the Brisbane Marine Pilots, two commercial marinas, a large commercial fishing fleet and a major launching point for recreational vessels.

The Mooloolah River entrance lies immediately adjacent on the western side of a prominent rocky headland, Point Cartwright. The general locality of the area and the layout of the entrance are shown in Figure 1 below.

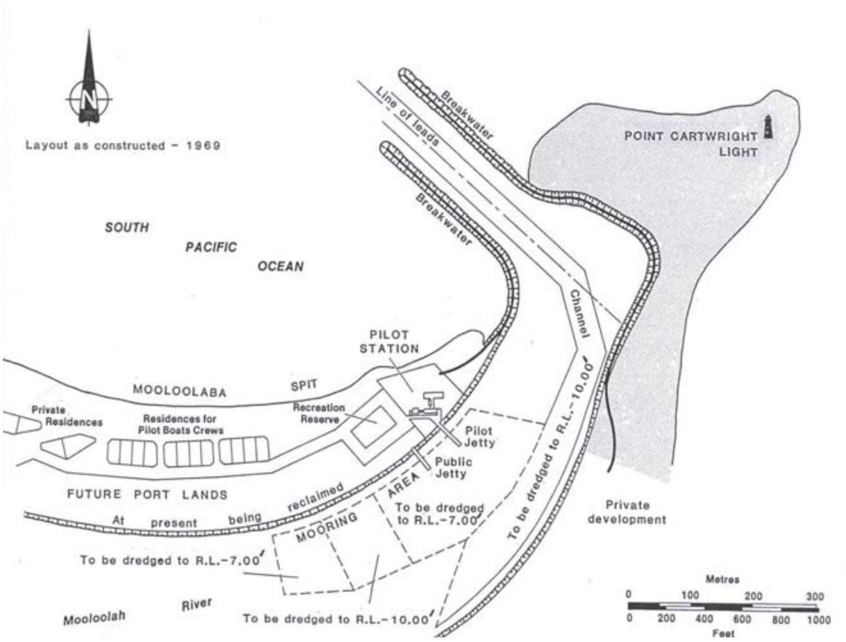

Figure 1 Mooloolah River Entrance

Significant entrance shoaling occurred during the 1980s, requiring maintenance dredging and prompting a study of the problem by the (then) Department of Harbours & Marine in 1987. Following a lengthy period of no significant problem during the 1990s, shoal development occurred again during 2003, extending into 2004. Dredging to restore depths in the entrance channel was undertaken in October 2003 and again in January 2004 and March 2004. The total volume of sand present in the shoal was estimated at 60,000 cum.

WBM were commissioned by QT to investigate the likely processes causing the shoaling. This included firstly the development of a preliminary siltation indicator based on simple transport calculations around Point Cartwright to assist in the management of navigation, surveying and dredging operations. Secondly, a morphological model of the entrance shoal was developed to allow assessments of management options such as training wall extensions and sand traps.

Shoaling Processes

The sediments involved in the shoaling at the entrance to the Mooloolah River are predominantly sands of marine origin and are part of the general transport system operating from south to north around the base of Point Cartwright. Thus, the sand causing the shoaling comes from Buddina Beach past Point Cartwright as follows and as illustrated in Figure 2:

- Longshore transport from Buddina Beach moves sand to a deposition area immediately north of Point Cartwright; and
- Waves and currents move the stored sand along the rocky north shore of Point Cartwright to the river entrance where the capacity to move the sand is reduced and deposition occurs.

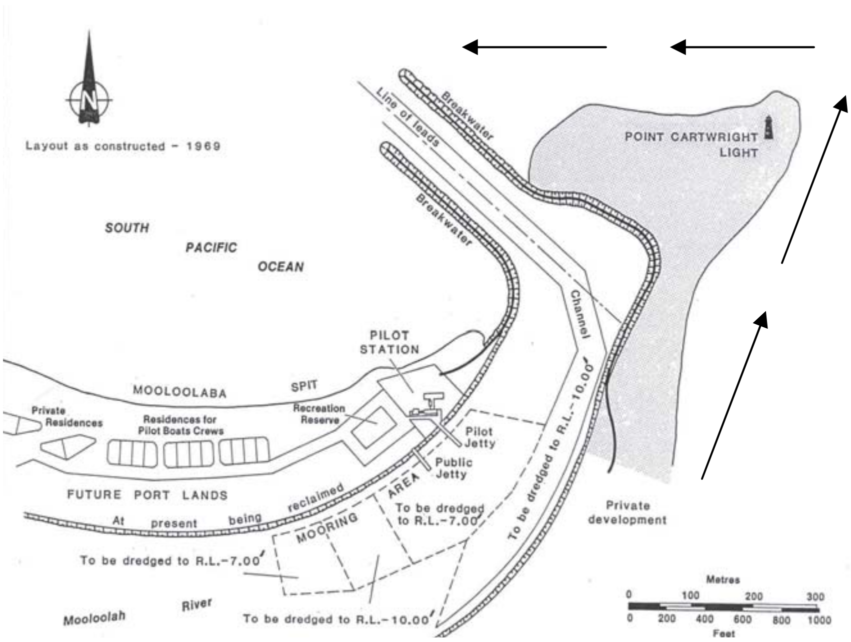

Figure 2 Sand Transport to Mooloolah River Entrance

Some of the sand reaching the entrance would drift past without causing a problem. However, at times of strong and persistent sand transport to the entrance, bar formation develops where the flow from the river and the westward wave-induced movement of sand interact and the capacity to move the sand past the entrance is less than the inflow rate. Thus, it is the differential in sand transport that is the critical factor.

Non-Shoaling Periods

It is of particular significance that strong and persistent shoaling occurred during 2003-04 when, for the previous 15 years (apart from the relatively minor 1996 event), there had been little or no problem.

It is apparent that, in the majority of years, shoaling at the entrance is either negligible or sufficiently minor that it can be accommodated without dredging and disperses within reasonable time (a few months or less). Occurrences of major shoaling events are relatively rare.

On the basis that the existence of sand inflow from the east of the entrance at a rate higher than the rate of transport past the entrance is the trigger for the shoaling, non-shoaling periods would be expected to coincide with times when relatively low sand transport from Buddina Beach occurs.

Shoaling Indicator

The most definitive and simple indicator of future or persisting shoaling of the entrance is the existence of sand shoals at and immediately east of the eastern breakwater. The surveys show this area has water depths less than 3m across a zone about 30-50m wide north of the eastern breakwater tip. At times of strong in-feed of sand to the entrance, the depth may be less than 2m across a zone about 15-30m wide. Under non-shoaling conditions, the water depths in this region are consistently greater than 3m and commonly greater than 4m within about 15m of the breakwater. This indicates a thickness of sand over the underlying rock of up to about 2m.

The spatial extent and thickness of the sand further to the east during strong and persistent shoaling events remains uncertain. Specifically targeted surveys are undertaken at about monthly intervals to define the extent of entrance shoaling and navigation markers are installed and moved if necessary.

An alternative potentially simpler predictive indicator that does not require costly surveys or aerial photography involves use of wave data to analyse the sand transport behaviour at Buddina Beach and across the Mooloolah River entrance. As there was no data for calibration of the particular beach conditions and sand properties at the site, some adjustment of the standard coefficients involved were made to best match the local behaviour as it is presently understood.

Calculations of sand transport at Buddina Beach and the Mooloolah River entrance have been made using wave data from both the Brisbane directional Waverider buoy (EPA) and since April 2005 the Mooloolaba directional Waverider buoy (QT).

It was noted that:

- The shoaling indicator is, in effect, an estimate of the total quantity of sand along the region north of Point Cartwright, including but not specifically exclusive to the entrance itself;
- The Buddina Beach transport may be either upcoast (+ve) or downcoast (-ve) and, for prolonged downcoast transport may result in a negative indicator value represented physically as absence of sand in the region east/south of Point Cartwright;
- Transport across the entrance is always towards the west while sand exists over the rock base;
- A significantly positive value of the indicator suggests a higher potential for entrance shoaling. Its trend (increasing or decreasing) may be useful in indicating future behaviour;
- When the indicator becomes zero (or negative), no sand exists to the north of Point Cartwright and the entrance transport is zero.

The resulting indicator is presented in Figure 3 in the form of a time series of the cumulative value. QT receives an updated indicator plot at the start of each month from the Coastal Sciences Unit (CSU) of the Queensland Environmental Protection Agency who manage Queensland's wave buoy network. CSU inputs the previous month's data from the two directional wave buoys into the shoaling program developed by WBM. The indicator plot is then distributed to various areas within QT for review and appropriate action.

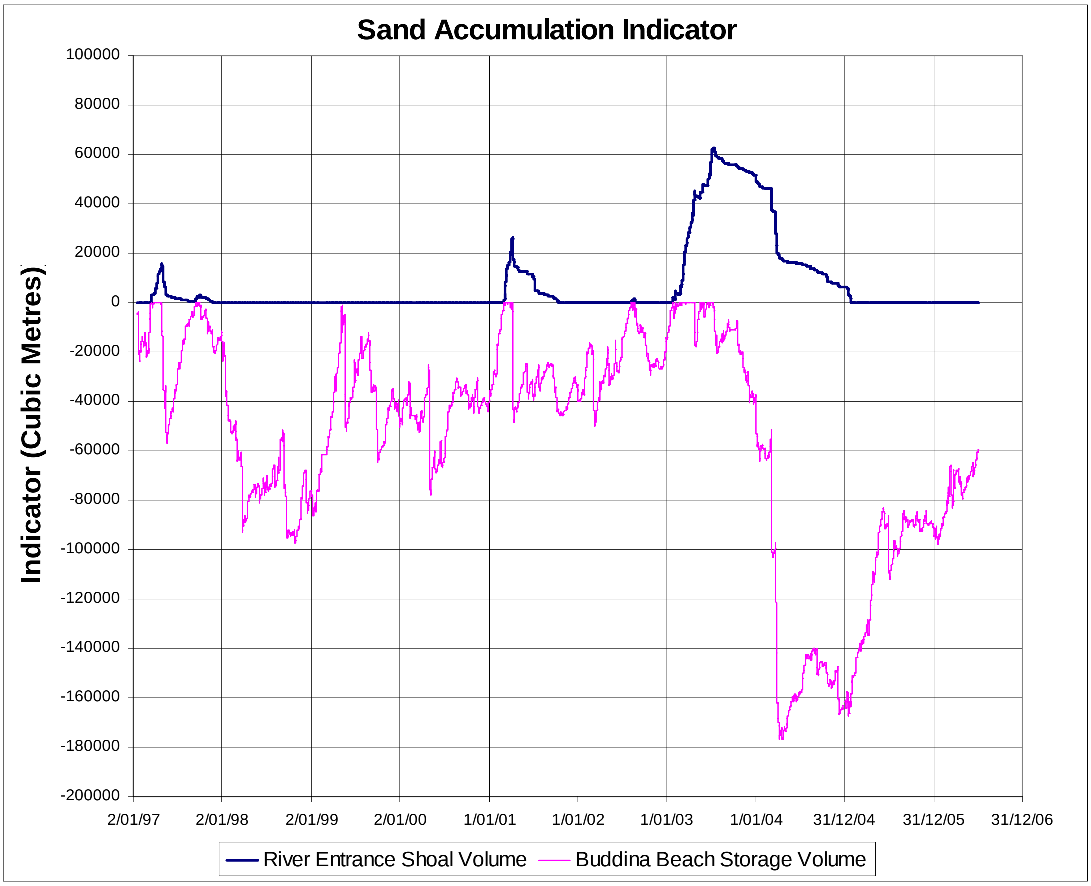

Figure 3 Sand Accumulation Indicator

The lower (light blue) plot shows the volume of sand in the stockpile area to the NE of Pt Cartwright due to sand transport to/from Buddina Beach. At the present setting of the initial parameters the quantity needs to accumulate to above zero before any sand can progress towards the river entrance. Note that since January 2004 this volume has been very low but recently has started to increase.

The upper (dark blue) plot shows the volume of sand accumulated at the entrance. This is of most concern when the plot rises sharply to values in excess of 20,000 cum. Note that the volume rose to 60,000 cum in 2003 when troublesome entrance shoaling occurred. It should also be noted that under some conditions (ie continued E waves) a large volume of sand (say > 20,000 cum) could move across the entrance without forming a shoal.

At this stage it is estimated that the initiation of the dark blue plot above zero would be considered a “heads up” to possible shoal formation and increased hydrographic survey monitoring. Surveys are carried out both in the entrance and along established transects east of the breakwater at 50m intervals over the rocky shelf to Point Cartwright to better estimate the volume and extent of the approaching sand shoal. A continuing sharp rise above 20,000 could be a “trigger” to begin setting up a dredging program.

Since the indicator has been operational there have been no shoaling events so it is still to be validated. The monitoring of future events will help to improve the accuracy of the indicator.

Since the indicator started operating in April 2005, the indicator program has been further refined to make it more user-friendly and improve the stability of the program.

Morphodynamic Model

A process based morphological model of the study area has been developed to further study the coastal processes involved in the intermittent sand shoal formation and to provide a tool for assessment of management options such as training wall extension and sand traps.

Model description

The morphodynamic model uses a coupled RMA10S (providing hydrodynamics, sediment resuspension and dynamic bed evolution capabilities) and SWAN (providing swell and wind-wave forcing) to derive sediment resuspension and transportation induced by waves and currents until it eventually settles out of suspension.
The full finite element mesh for RMA10S is shown in Figure 4 below with greater detail of the mesh in the vicinity of Point Cartwright and the River entrance is shown in Figure 5. The SWAN model was run with nested grids ranging from 400x400m regionally to 25x25 metres locally.

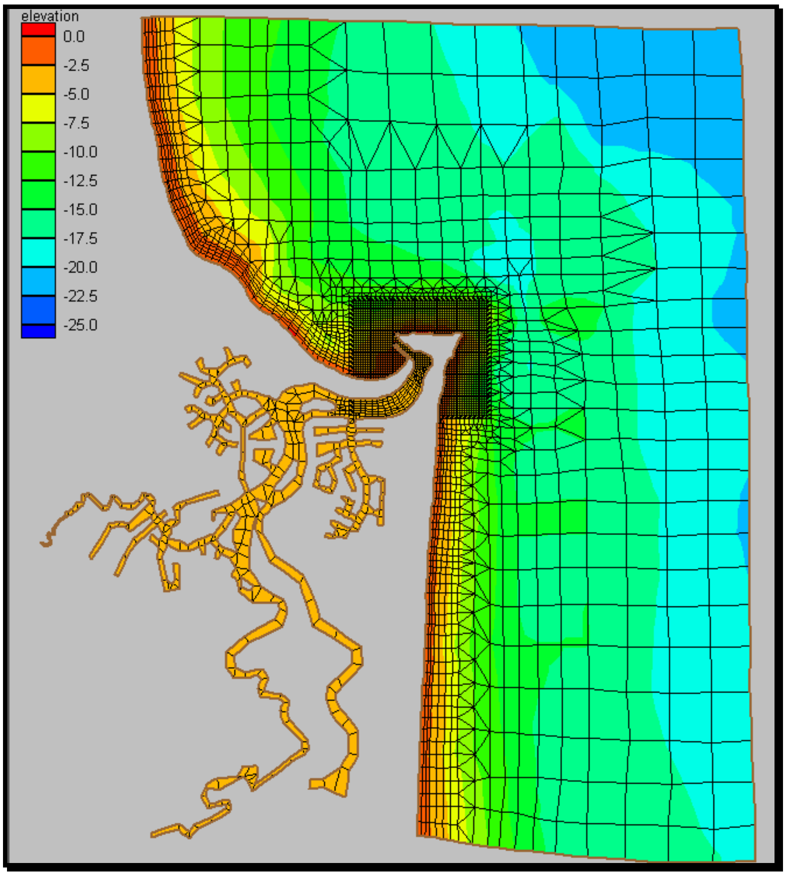

Figure 4 RMA10S Model Mesh

Model BC's

Recorded wave and tide data is used as boundary conditions and the underlying rock shelf is included as a scour limiter to limit sand availability to transport.

Model results

The model has been calibrated against recorded current data near the entrance and survey data of the shoal development and is able to simulate sand transport across the front of the headland and into the navigation channel.

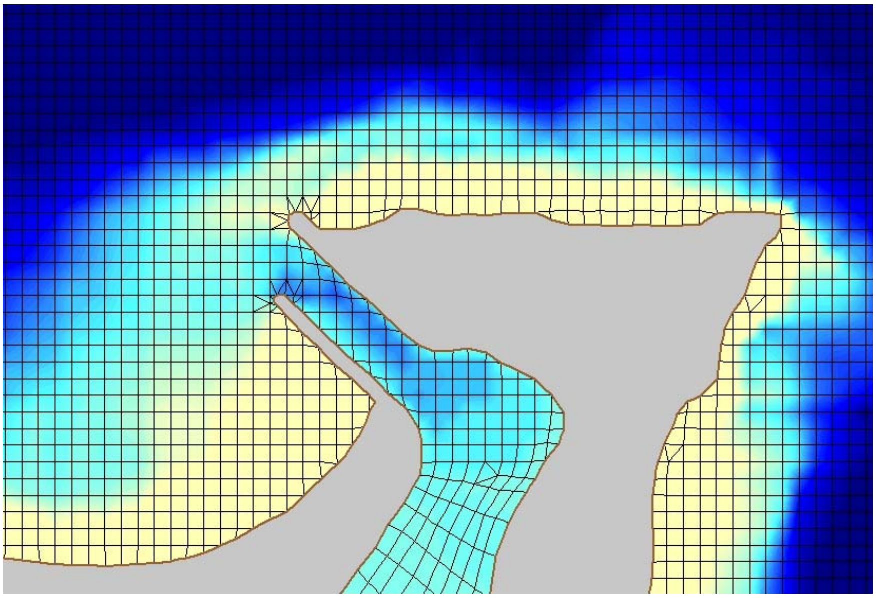

Figure 5 Modelled Shoal Development.

Management Scenarios

The model is now being used to assess possible future management strategies. These scenarios are aimed at reducing the pulses of sand transport across the river mouth and will include and extension of the eastern breakwater and an excavated area to catch sand before it reaches the entrance.

The model is also being used to help determine the feasibility of potential beach nourishment options both inside the entrance, on the southern bank of the river and outside onto Mooloolaba beach, just west of the entrance.

Conclusion

The shoaling indicator has been used for the last 18 months and to date has indicated a slowly growing deposit of sand to the north of Point Cartwright but still well below the level to cause concern. Regular hydrographic surveys confirm that the navigation channel has remained clear of sand for this period. Another significant shoaling event is needed to confirm that the shoaling indicator is performing reliably.

The morphological model has been developed and calibrated and runs to assess the impact of management options have just begun. An evaluation of these should be available for the conference presentation.

References

WBM Pty Ltd (2005) *Mooloolaba River Entrance Shoal Development Indicator, Report for Queensland Transport, January 2005*

DEVELOPMENT OF URBAN MANGROVE MANAGEMENT STRATEGIES FOR PUBLIC FORESHORES

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Abstract

Mangroves and other marine plants are protected under the fisheries legislation in Queensland to ensure sustainable fisheries productivity. Management of these marine plant communities can lead to conflict with public expectations for urban foreshore recreation. Coastal Local Governments are faced with balancing public pressure for foreshore access and maintaining the mangrove communities along riverine foreshores in highly urbanised areas. In conjunction with several key Local Governments, the Department of Primary Industries and Fisheries (DPI&F) has facilitated the development of specific mangrove management strategies to apply to urban riverine foreshores for the Burnett River [Bundaberg City Council] and to urban public riverine foreshores for the Brisbane River [Brisbane City Council]. Other Local Governments are also considering or drafting strategies.

Under a Strategy river foreshores are divided into precincts or river bank units to which one or more management categories are applied: ‘protect mangroves’; ‘restore mangroves’; ‘mangrove free’ and ‘multiple use’. To support operational management requirements, site based management plans are also developed to provide higher resolution for the categories applicable for a nominated period. The strategies provide for planning and management certainty for Councils while affording long-term protection to agreed sections of riverine mangrove communities to support riverine and coastal fisheries. Implementation of the strategies allows for monitoring of activities such as trimming, canopy lifting and restoration. Strategies are linked to other key planning instruments in Councils such as Planning Schemes.

Introduction

Mangroves are a key and very visible component of the intertidal plant community. The total area of about 11, 500 km^2 of mangroves in Australia represents the 3rd largest area of these marine plants in the world (Duke, 2006) with a high diversity of some 41 species. Distribution and diversity are greatest in the tropics reducing to a single species, *Avicennia marina*, in Victoria and South Australia. Adapted to highly stressful conditions of salinity, temperature and regular tidal inundations, mangroves have successfully colonised estuaries and river deltas in many coastal systems along the east coast of Australia, particularly in Queensland where the Great Barrier Reef in the north and large sand islands in the south reduce high wave energy and promote mangrove development. Mangroves may form large stands extending several 100 meters inland or narrow foreshore communities of 1 to 5 metres along coastal rivers. As a result, mangrove communities are often the interface between coastal development and aquatic activities such as boating and fishing.

Mangrove functions and values

In Australia, early Aboriginal use for food, shelter and medicine was followed by an extended and unfortunate period of destruction and reclamation of mangrove and adjacent saltmarsh communities as coastal development, free of any planning regimes, was conducted in a fairly indiscriminate and adhoc manner. Mangroves were first used commercially in Queensland in the early 20th century as a primary source of timber for collecting oyster spat to enhance shellfish culture in Moreton Bay.

Belatedly the benefits of mangroves, social, environmental and economic, have been recognised and incorporated within the statutes, planning instruments and management plans of State and Local Governments. The recognised benefits include inshore and offshore fisheries production (commercial, recreational and traditional), shoreline protection, nutrient fixation, carbon sequestration and sink, deltaic development, honey production, and habitats for epiphytes, mammals, birds, reptiles, fish and invertebrates (Figures 1 & 2).

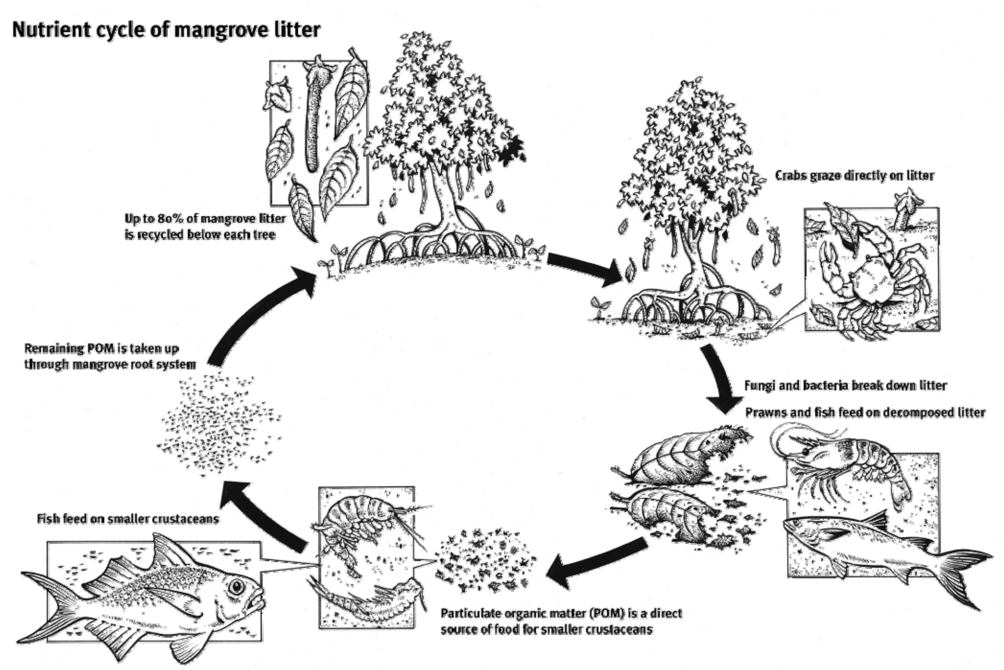

Figure 1 Nutrient lifecycle of mangrove litter

As fish habitats, mangrove communities provide structural complexity, shelter for food organisms and for juvenile and forage fishes at high tide, and feeding opportunities for fish, crabs and molluscs although quantification of the contribution remains insufficiently documented (Couchman *et al.*, 2006). With 75% by weight and 80% by volume of the Queensland commercial fishing catch derived from species that spend all or part of their life in mangrove associated estuarine habitats (Quinn, 1992), the contribution of these habitats to fisheries production is some $250M annually. Queensland recreational catch, targeting many of the same estuarine species as found in the commercial catch, generates some additional $50M per annum based on equivalent prices paid to commercial fishers.

Worldwide, the economic contribution made from mangrove habitats per hectare is estimated to be $US10,000 per hectare per annum (Costanza *et al.*, 1997) with estuaries valued at $US23,000 (Costanza *et al.*, 1998); both estimates reflecting the 'ecosystem services' provided by these habitats. Similar estimates have been made for Australian habitats (Blackwell, Coastal CRC, *pers comm.*) Interestingly the costs of restoring mangrove habitats vary from $US225 to 216,000 per hectare, without the cost of the land (Lewis, 2005). The increased recognition and profile of the key role that mangroves play in fisheries production is demonstrated by the recent holding of the First Symposium on Mangroves as Fish Habitat (Florida, USA - April, 2006) which brought together researchers and managers with common interests.

Figure 2 Mangroves support fisheries production

Protection afforded to mangroves

The primary fisheries legislation, '*The Fish and Oyster Act 1914*', protected mangroves but made provision for short-term permits to cut and remove mangroves. Subsequent fisheries legislation in Queensland has continued the protection and extended this to all marine plants, including saltmarsh and seagrass communities. This reflected the increasing research findings linking mangroves and other marine plants to fisheries productivity.

Currently all marine plants in Queensland are afforded protection under the provisions of the *Fisheries Act 1994.* Through its ESD objectives and as part of the recent integration with the *Integrated Planning Act 1997 (IPA),* there is scope to grant authorities to lawfully remove, damage or destroy a marine plant.

Current mangrove management

The marine plant vegetation within Queensland has been mapped from the Tweed border to the NT border. Mangroves occur in approximately 18% of the coastal environments. In many estuaries, the mangrove communities are relatively pristine but in larger coastal centres, urban mangrove foreshores are under increasing threat from private and public interests. The Department of Primary Industries and Fisheries (DPI&F) role in mangrove foreshore management is to retain mangroves to ensure fisheries sustainability as a key priority.

Original riverine mangrove communities have frequently been cleared to allow foreshore development. Natural colonisation has established new communities of mangroves, with the extent being influenced by the change to the tidal prism and flow regime. For example, in the Burnett River the Ben Anderson barrage reduced the tidal prism by 40% and reduced the mangrove foreshore distribution by some 16.5 km. In the Brisbane River, removal of river mouth sandbars and islands and construction of impoundments upstream has extended the tidal prism, with mangroves now some 80 km upstream due to a reduced freshwater inflow into this system (Duke *et al.*, 2003). These mangrove community changes present ‘moving’ management targets, underlining the need for a strategic approach.

Prior to the integration with the IPA, the DPI&F, in conjunction with local governments, developed a Code of Practice (CoP) under the *Fisheries Act 1994* to enable Councils to undertake maintenance works which involved removal of mangroves within a 3-year strategic permit linked to the CoP. This removed the requirement for Councils to hold individual permits for each maintenance activity and greatly reduced bureaucracy on both sides. An extension to this management approach, i.e. to cover certain prescribed new public works where mangroves would also be impacted, was mooted during discussion and negotiation with Councils when developing the CoP.

Currently Councils are able to undertake maintenance works under IPA through a self-assessable code that defines the nature of works and the extent of clearing or trimming that may be conducted.

Figure 3 Rock gabions used successfully to reduce impacts of vessel wash and foreshore erosion, protecting and enhancing mangrove communities [left] and structures [right] in the Brisbane River, Queensland.

As part of Councils' obligations to satisfy the Planning Scheme requirements of IPA, DPI&F recognised an opportunity to link the future management of urban mangroves to the Planning Schemes and related instruments being developed by Councils across Queensland.

With increasing urban development along major waterways, public expectations for foreshore access and river views have risen. These expectations, together with a Local Government requirement to manage foreshore erosion along public foreshores and provide certain public infrastructure such as pontoons and jetties (Figure 3), led to increased ongoing liaison between Council staff and their DPI&F development assessment counterparts.

The challenge then was to look at these divergent management objectives and find common ground which could result in both Council and DPI&F staff, on behalf of the State Government, being satisfied that an acceptable management regime could be developed and multiple public expectations could be addressed.

As a result, the DPI&F hosted an Urban Mangrove Management Workshop in April 2004 at which invited Councils, fisheries staff, interstate and overseas mangrove/riparian experts participated.

One of the outcomes of the 2004 Urban Mangrove Management Workshop was to foster the development of specific strategic urban mangrove management plans with Local Governments responsible for management of development and infrastructure along river banks within their Local Government Area.

The broad aims of the strategic approach are:

1. To foster shared understanding of the importance of marine fish habitats to fisheries production and to the social, economic and environmental values of the local community.
2. To provide a consistent framework for Councils planning and undertaking public infrastructure maintenance and development works within and adjacent to sensitive marine fish habitats.
3. To support innovative mangrove management techniques such as trimming, canopy lifting and restoration within agreed sections of riverine mangrove communities to achieve long-term protection of these fish habitats and to meet community requirements for passive recreation and access (e.g. fishing, viewing and river based activities).
4. To reduce costs of administration (to both Local Government and DPI&F) associated with the integrated development assessment process and fisheries development approvals.

Within Queensland there are 46 Councils with coastal foreshores and of these, 35 have responsibility for major river systems and are under increasing urban pressures.
To date, Bundaberg and Brisbane City Councils have proceeded with the development of urban mangrove management strategies for the Burnett and Brisbane Rivers respectively. A further 5 Councils (Livingstone Shire, Mackay City, Townsville City, Johnstone Shire, Cairns City) have expressed an interest in or have commenced the development of a strategy.

Development of urban mangrove management strategies for urban foreshores

Bundaberg and Brisbane City Councils and DPI&F share a common objective of a long-term approach that documents the fate of urban mangroves and that provides each Council with certainty to plan, budget and undertake agreed works for public benefit along riverine foreshores.

The agreed strategic approach that is being adopted by both Councils has the following elements:

- Develop mangrove management categories to apply to foreshore mangrove communities.
- Select a section of river for agreed management.
- Undertake bank vegetation mapping and an audit of bank condition.
- Undertake an audit of existing/proposed structures.
- Subdivide the nominated section of river into management units.
- Apply the mangrove management categories to these units.
- Draft an urban mangrove management strategy.
- Key stakeholder consultation.
- Develop site-based operational plans for units requiring higher resolution management prescription.
- Implement actions identified within existing approval process.
- Amend the fisheries legislation to further streamline approval process to accommodate the endorsed strategies.
- Joint evaluation of implementation of Strategy every 12 months.

Outcomes for each element

Develop mangrove management categories to apply to the foreshore mangrove communities

To reflect the overall strategy for the area under consideration (river, estuary, lake, etc.) and its diverse objectives, four categories of management were developed, each of which could apply to one or more section of the waterway selected. The categories are:

- **Protect mangroves** – areas where existing marine plant communities are retained and natural processes, such as further colonisation and marine plant community development, are allowed to occur. *These areas benefit directly from being linked to terrestrial vegetated buffers to provide long-term protection.*

- **Restore mangroves** – areas where opportunities to enhance existing marine plant communities exist and actions may be taken to reduce or remove threatening processes to support natural regeneration and further colonisation.

- **Mangrove free** – areas which are mangrove free and maintained in that state with maintenance activities not specifically promoting colonisation by marine plants.

- **Multiple use** (mangrove modification) – areas where impacts to marine plants are minimised while meeting specific public use requirements and where works may include treatments that remove or modify mangroves (Figure 4). *A site-based operational plan will identify the most appropriate treatments (e.g. canopy lifting, trimming, thinning or replacement of taller varieties of mangroves with smaller or lower-growing forms).*

Figure 4 Mangrove trimming [left] and canopy lifting [right], Brisbane River

Select a section of river for agreed management

The selection and extent of the river section to be covered by the mangrove management plan are determined by each Council.

Undertake bank vegetation mapping and an audit of bank condition

This element provides a baseline of the extent and condition for both the riparian (terrestrial) and marine plant (including mangroves) communities. It also allows for an assessment to be made of bank condition, especially identifying erosion prone foreshores where remedial works may be necessary to protect mangroves and public and other infrastructure. Sites requiring weed control are also documented. It further identifies existing vegetated buffers for marine plants and opportunities for bank rehabilitation to give further protection to the adjacent mangrove community.

Undertake an audit of existing/proposed structures

An audit of the existing structures and of where proposed structures will be required is a key element in identifying the current maintenance requirements and the potential extent of new works along foreshores that may impact on the mangrove community.

Subdivide the nominated section of river into management units

This element allows separation of the river section into management units that are practical and reflect the priorities for works. Units may be classed as 'River Bank Units' (RBUs, Figure 5) as used by Bundaberg City Council or 'Corridor Precincts' as used by Brisbane City Council, with the latter being further sub-divided into 'site-based management' plans where the 'multiple use' category applies. Clear priorities for addressing each unit can then be documented.

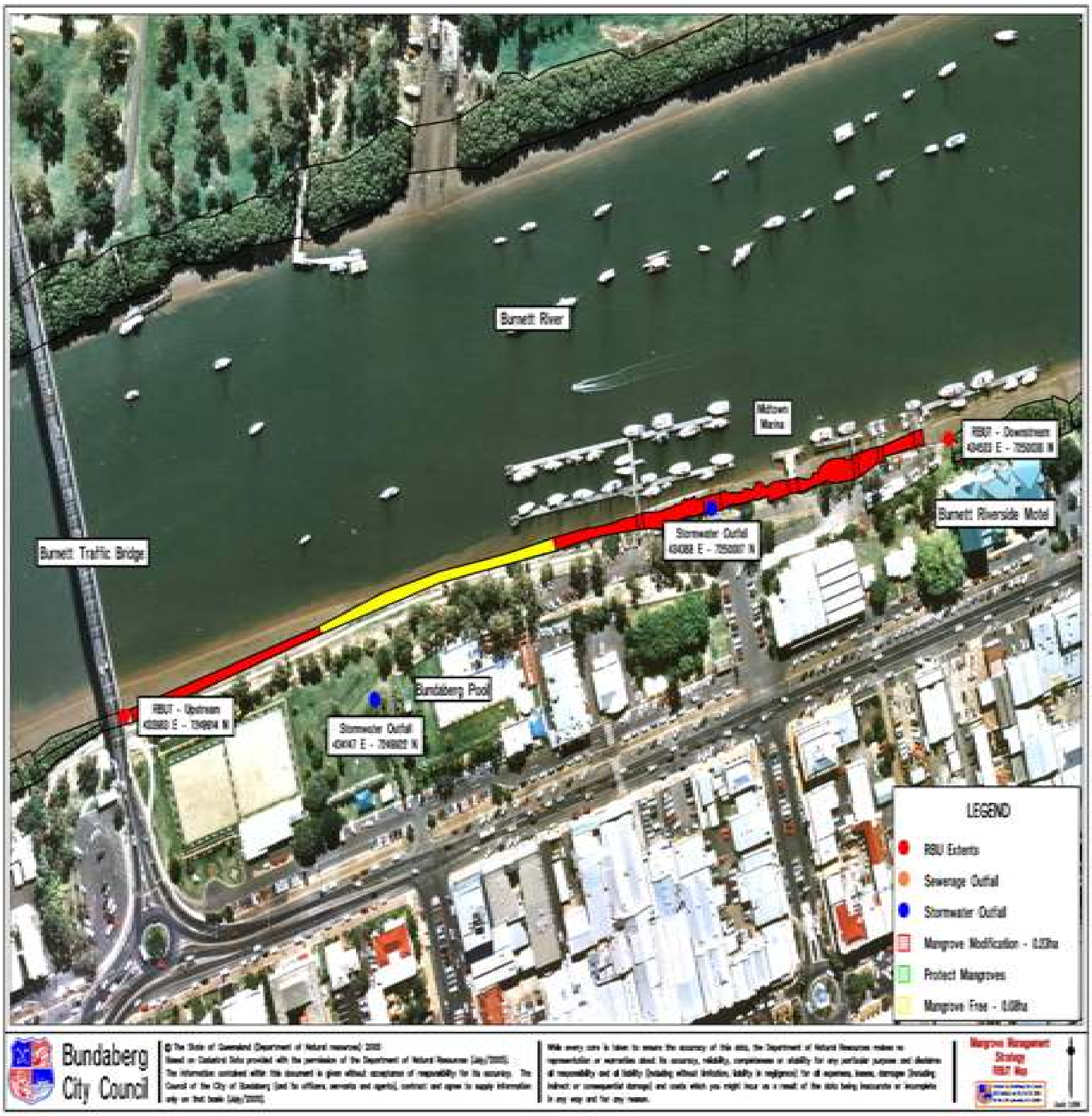

Figure 5 River Bank Unit RBU7 (550m), Burnett River, showing areas for mangrove modification (red) and mangrove free area (yellow)

Apply the mangrove management categories to these units

This sees one or more of the 4 mangrove management categories being applied to a management unit, recognising existing conditions and the management objectives are to be met over an agreed period.

Draft urban mangrove management strategy

The key elements of a draft marine plant management strategy are to include the following:

- information on how it links to the Council Planning Scheme and any other relevant strategic planning instruments (e.g. flood maps, urban stormwater quality environmental management plans, asset management plans);
- explore and take up external funding opportunities to develop and implement the agreed Strategy;
- the responsibilities and jurisdiction of DPI&F and the Council in terms of marine plant protection and management and seek to meet the objectives of the DPI&F Fish Habitat Management Operational Policy for the Protection and Management of Marine plants FHMOP 001 (Beumer & Couchman, 2002);
- detailed maps, preferably recent aerial photographs overlain with the proposed mangrove management treatments for each section / river bank unit / precinct, plus a larger map showing the overall extent of the strategy;
- an insight for the community and developers to the desired future environmental outcomes for the river/estuary/lake and be the basis for an agreed planning instrument for future activities with the Council and relevant Council agencies; and
- a clear process for development of the site-based operational plans and links to the agreed mangrove management categories described above.

Key stakeholder consultation

An appropriate level of public consultation is to be conducted through comment on a draft mangrove management strategy, targeting key foreshore stakeholders with existing access or related issues. This can also involve the establishment of a local Steering Committee or similar group with carriage for moderating contrasting views and expectations during development of the Strategy and for overseeing its implementation. The composition of such a group would include but not be limited to Local Government, State Government, port authority, fishing industry sectors, conservation and wildlife organisations.

Develop site-based operational plans for each unit

These plans incorporate the mangrove management categories and broad actions to be taken to achieve the agreed strategic level of management. These also provide more detailed specifications at ground level for maintenance tasks and a works program for built structures owned and/or controlled by Council. The plans identify usage patterns, role and function of riparian zones, current threats to mangroves and list the specific actions for each sub-section of the unit (Figure 6).

Figure 6 Draft Davies Park site-based operational plan, Brisbane River. 400m foreshore with mangrove treatments: height reduction (F-G and G-H); maintenance clearance around facilities; protection measures (E, F, G and H); selective branch trimming (F and G); restoration (E); and mangrove protection (A, C, D, and I).

Implement actions identified within existing approval process

At this stage Councils will be required to apply for a development approval under IPA. DPI&F will facilitate applications within the approval process, assessments having been undertaken as part of the development of the site-based plans with conditions of approval linked to the strategy and the relevant plan. Monitoring of the actions and their impacts are a key component of the implementation (Figure 7).

Figure 7 Mangrove trimming trial commenced in October 2005 [left] and subsequent growth in March 2006 [right], Burnett River

Amend the fisheries legislation to further streamline approval process to accommodate the endorsed strategies

This is an ongoing element for DPI&F to resolve. A self-assessable code under IPA has been drafted to cover site-based management plans. When gazetted this will allow agreed works within these plans to proceed subject to compliance with the strategy, plans and self-assessable code without requiring further approvals under IPA.

Joint evaluation of implementation of Strategy every 12 months

Conduct joint evaluation of the implementation of the Strategy actions, with an adaptive management approach to modify the direction of the Strategy as appropriate. This applies particularly to mangrove manipulation activities such as canopy lifting and trimming where the responses of different species are poorly understood.

The experience so far

As indicated above, Bundaberg City Council and Brisbane City Council have developed strategies and the strategy for the Burnett River has been endorsed by DPI&F. The strategy for the Brisbane River is expected to be endorsed by December 2006.

For both river systems, impoundments are located upstream. The Burnett River has a tidal weir (Ben Anderson Barrage) upstream, some 26 km from the mouth. The Brisbane River has the Mt Crosby Weir which dictates the tidal limit 90 km upstream with larger domestic impoundments, the Wivenhoe and Somerset Dams, further upstream. These have allowed mangroves to colonise and establish along foreshores that historically were subject to freshwater influences.

Many of the elements of each Strategy have been addressed (Table 1) with implementation occurring through trials with innovative practices such as mangrove trimming, canopy lifting and placement of rock gabions to protect and enhance foreshore mangrove communities.

Table 1 Strategy element summary for Bundaberg and Brisbane City Councils

Strategy element	**Bundaberg CC**	**Brisbane CC**
River Section	Ben Anderson Barrage to eastern extent of Bundaberg City boundary, distance of 12.7 km	Just below Moggill Ferry Crossing to mouth of Brisbane River, distance of some 70 km
Bank vegetation mapping	Completed at 1:1000; 88.92 ha/20.6 km foreshore of mangroves; 4 creek systems	Completed at 1:10000 scale; 34.2 km of continuous mangrove, 30.6 km of scattered mangroves
Bank condition audit	Completed at 1:3500; 2.8km of bank audit	Completed at 1:10000 scale

Strategy element	**Bundaberg CC**	**Brisbane CC**
Audit of structures	Completed - includes the following types: bridges, jetties, slipways, stormwater outfalls; sewerage main crossings; sewerage river outfall; boat ramps	Completed - include the following types: rock banks; river walls.
Management Units	River Ban Units (RBUs) – 16 RBUs – these apply to all foreshores in selected section of river, including private and freehold Lots; mapped at 1:750 to 1:20000	Corridor Precincts – 5 – these apply only to foreshores adjacent to public lands such as parks
Draft strategy	Prepared - links with: ▪ Bundaberg City Plan ▪ Council's adopted flood maps ▪ Urban Stormwater Quality Management Environmental Plans ▪ River Edge Management Strategy	Prepared – links with: ▪ Brisbane City Plan 2000 ▪ Brisbane River Corridor Plan ▪ Brisbane River Mangrove Management Strategy ▪ Brisbane River Bank Inventory & Condition Survey 2001
Consultation	Public consultation process included media releases and selective mail out to interested/affected parties with invitation to comment – 2 responses from public. Steering Group established and ongoing; Council, State agencies, Port Authority, commercial and recreation fishing groups, Central Queensland University	Public consultation process planned for 06/07
Endorsement	By DPI&F – Bundaberg City Council (2005)	Expected December 2006 - Brisbane City Council (2006)
Site-based operational plans	One site-based operational plan approved for RBU7. Further applications for planned works being developed as these become a priority	Draft site-based operational plan for foreshore adjacent to Davies Park where all four management categories apply over ~470 m of foreshore

Strategy element	Bundaberg CC	Brisbane CC
Approvals	Granted over all RBUs, recognising staged approach to conducting works	TBD
Implementation of innovative best management practices	Hedging trials with mono-specific community of *Avicennia* commenced	Gabions established along several sections of foreshore to prevent erosion of mangrove communities from vessel wash Restoration projects at Guyatt Park and Luggage Point Mangrove canopy lifting trials commenced
Fisheries legislation changes	Draft self-assessable code (MP06) prepared and consultation with key stakeholders to be conducted in last quarter of 2006	Draft self-assessable code (MP06) prepared and consultation with key stakeholders to be conducted in last quarter of 2006
Evaluation	Mangrove Watch Pilot Program being established	

Mutual benefits identified to date of the two Strategies developed with Bundaberg City Council and Brisbane City Council include the following:

- Productive collaboration between State and Local Governments
- Agreed management strategies which balance competing and diverse demands
- Capacity to attract funds for Strategy development and implementation
- Integration with other Council planning instruments
- Key mangrove communities retained and shared understanding of roles of these marine plants as foreshore assets
- Alerts adjacent river bank development to constraints and agreed treatment of river banks
- Sites identified for restoration
- Reduced approvals and rationalised bureaucracy
- Enhanced achievement of public expectations
- Works program certainty for Councils

- Budget planning and management enhanced
- Innovative best-management practices supported
- Collaborative monitoring and data exchange

Conclusion

The development of the urban mangrove management strategies has administrative, economic and environmental advantages. Key learnings from the experience to date are that a 'champion' needs to be identified within Council to promote and facilitate debate and resolution; that the process may take several years of concerted efforts from Council and DPI&F staff; and that mutual benefits result. The interest expressed by 5 other Councils is testament to the real benefits seen across local government with adopting a more strategic approach to urban foreshore management of mangrove communities.

References

Beumer, J & Couchman, D 2002, *Fish Habitat Management Operational Policy for the Protection and Management of Marine plants – departmental assessment procedures and policy position.* QDPI FHMOP 001, 40pp.

Brisbane City Council 2006*, Brisbane River Mangrove Management Strategy for Council Land*. 17pp., 19 Map Sheets (1:10000).

Brisbane City Council 2003, *Draft Davies Park Site-based Management Plan.* 17 pp.

Bundaberg City Council 2005, *Mangrove Management Strategy*. pp.36, 16 Map Sheets (1:750 to 1:20000).

Costanza, R, d'Ague, R, de Groot, R, Farber, S, Grasso, M, Hannon, B, Limburg, K, Naeem, S, O'Neill, RV, Paruelo, J, Raskin R G, Sutton, P & van den Belt, M 1997, 'The value of the world's ecosystem services and natural capital', *Nature*, vol. 387, pp.253-260.

Costanza, R, d'Ague R, de Groot, R, Farber, S, Grasso, M, Hannon, B, Limburg, K, Naeem, S, O'Neill, RV, Paruelo, J, Raskin R G, Sutton, P & van den Belt, M 1998, 'The value of ecosystem services: putting the issues in perspective', *Ecological Economics*, vol. 25, pp.67-72.

Couchman D, Beumer J and Kirkwood J 2006, 'Mangrove myths and reality: their connectivity to fisheries production', Abstract of Paper, *First International Symposium on Mangroves as Fish Habitat, Miami, Florida, USA, April 2006*.

Duke, NC 2006, *Australia's Mangroves. The authoritative guide to Australia's mangrove plants,* University of Queensland, Brisbane, 200pp.

Duke, NC, Lawn PT, Roelfsema, CM, Zahmel KN, Pedersen DK, Harris C, Steggeles N & Tack C 2003, *Assessing historical change in coastal environments. Port Curtis, Fitzroy River estuary and Moreton Bay regions, Chapter 6, Moreton Bay, pp125-220,* Report to the Coastal Zone Estuary and Waterway Management, Marine Botany Group, Centre for Marine Studies, University of Queensland, Brisbane.

Lewis, R R III 2005, ‘Ecological engineering for successful management and restoration of mangrove forests’, *Ecological Engineering*, vol. 24, pp.403-418.

Quinn, R H 1992, *Fisheries Resources of the Moreton Bay Region*, Queensland Fish Management Authority, 52pp.

WETLAND MAPPING, CLASSIFICATION & PRIORITISATION

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Abstract

Wetland**Care** Australia have recently completed wetland mapping compilation, classification and prioritisation for the HCRCMA and NRCMA through the Sustainable Wetlands on NSW Coastal Landscapes project, funded by the CMAs through the Australian Government's Natural Heritage Trust.

The project compiled all of the available and suitable, spatial wetland-related data from a range of sources including: State Government Agencies, Local Councils and other NRM organisations, into one wetland GIS map layer. To achieve consistency of wetland classes in the layer, the various wetland descriptions provided with the data collected were used to assign each shape with a wetland class from the Directory of Important Wetlands in Australia (DIWA).

Each wetland polygon was also assigned a range of attributes relating to its potential threats and potential conservation value. Attribute examples include: threatened species, ecosystem contribution, landuse and constructed drainage. A total of 27 attributes were assigned for use in the prioritisation decision support database. The database uses a score and weighting method to determine two scores for each wetland, Potential Conservation Value and Potential Threat Value. For the purpose of prioritisation, individual wetland polygons were grouped into 'wetland complexes'. The average scores of the wetland shapes in a complex were used to determine an overall priority score and rank.

The resulting prioritisation list includes all wetland complexes. The top priority complexes per region were chosen to be allocated funding for on-ground protection and condition improvement works in the final part of the project. A total of 34 complexes are currently being targeted in the NRCMA and 15 in the HCRCMA.

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Project Team

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Introduction

It has long been a battle for natural resource managers to determine 'where to start' in wetland management and rehabilitation. Wetland information is often scattered, patchy and difficult to access and compile. The *Sustainable Wetlands on NSW Coastal Landscapes* project goes a long way toward compiling existing wetland information and increasing accessibility through the development of the decision support tool. It is envisaged that the decision support database will be useful to a wide range of wetland managers.

The project aimed to map, classify and prioritise wetlands, using existing spatial data in the Hunter Central Rivers (HCRCMA) and Northern Rivers Catchment Management Authorities (NRCMA). Project funding was provided by the HCRCMA and the NRCMA from the Australian Government's Natural Heritage Trust.

The project team collected and collated existing spatial data relating to wetlands from a range of sources, including Federal, State and Local Government and various other natural resource organisations. Collated wetland polygons were uniformly classified in accordance with the Directory of Important Wetlands in Australia (DIWA) classification system.

Data relating to the wetland's conservation value and potential threats was also collected from the sources mentioned above. This data was assigned to each wetland polygon for use in the wetland prioritisation process, giving each wetland an overall Potential Threat Score and Potential Conservation Value Score. The priority wetlands identified using this decision support system will guide wetland managers to target sites for wetland protection, conservation and condition improvement.

Key products from the project include a comprehensive spatial layer of wetlands, their DIWA classes and attributes for the HCRCMA and NRCMA areas. A decision support database produces a range of reports to assist wetland managers in prioritising their wetland works, and an interactive CD compiles all products into an easy to use package.

Key recommendations from this project include: periodic updates of the mapping as new and better data is sourced or errors are identified; developing or sourcing more accurate and broad-scale data indicating wetland values or potential threats, determining and implementing a method for identifying areas of wetland that have been 'cleared' or have a 'changed landuse'.

Methods

Mapping

Defining Wetlands

For the purpose of the project it was appropriate to define wetlands as:

Wetlands are natural or artificial areas that are inundated, on a temporary or permanent basis, with water that are usually shallow; may be fresh, brackish or saline; and may be stationary, slow moving or flowing. Wetlands may also have dry phases and include land which has previously been covered with water. The intervals between wetting and drying cycles may be in the order of decades (Modified from the Ramsar definition of wetlands).

Use of this definition assisted in applying DIWA classifications to each wetland polygon. However, not all wetlands under the above definition were included in the mapping, classification and prioritisation process. Only wetland types with previously existing spatial data could be included in the classified maps.

Defining Wetland Complexes

To assist in addressing on-ground management issues in entire wetland systems, rather than the individual wetlands polygon, wetland complexes were created to define groups of individual wetland polygons that could be prioritised and managed together. Wetland Complexes have been named using local features such as waterways or towns and were reviewed to include local wetland names where possible.

Thus, a 'Wetland Complex' for the purpose of the *Sustainable Wetlands in NSW Coastal Landscapes* project is defined using the following parameters:

- Wetland complexes must have at least five wetland parcels of at least two different wetland types (DIWA classes)
- Adjoining wetland parcels are grouped as a complex
- Wetland parcels nearby or in an area shown to be linked by 'historical wetland' information are also included in the complex
- Complexes are often associated with, and named by, a main waterbody, creek or stream
- Large estuaries and their adjoining, permanently open, estuarine lakes are not included in any complex (excepting areas classed as a specific vegetation type such as saltmarsh or seagrass)
- Small estuaries and closed lakes are included as their own complex

Data Collection

Data layers from a variety of sources were provided to the project. The data was sourced from Commonwealth and State agencies, NGO's and local governments

(Table 1). Data was received on CD and also via email where possible. Where required, licensing agreements were signed and returned to the data provider.

Data Format

The majority of data sets were provided in a shapefile format in various projections, the exception being the data provided as a MIF file (MapInfo Interchange Format) that is used for importing files from MapInfo to ArcView. The standard data projection used GDA 1994 MGA Zone 56 for working with and finalising spatial data layers.

Wetland Map Compilation

The following steps were used to compile the provided map layers into one comprehensive wetlands map:

1. Provided layers (Table 1) were opened & checked for correct position over the Spot 5 imagery, and re-projected as necessary
2. Provided layers were queried to return only wetland related data
3. If the provided layer had a mixture of vegetation and water related wetland classes these were separated into two different layers for the purpose of the compilation & classification process
4. All of the vegetation layers were then ‘unioned’ together to produce one wetland vegetation layer with many differing wetland attributes
5. Step 4 was repeated for water and geology layers
6. The three wetland layers (vegetation, water, geology) were then ‘unioned’ to result in a layer with a wetland vegetation description, water description, soil description, data source and data scale
7. The three descriptions were then used to determine the wetland classes (Table 2). It should be noted that most wetlands had only one of the three descriptions above. The following rules applied where more than one description was present:
    a. The vegetation description was considered to be dominant, the main description used to define the class, the water and geology descriptions were used to ensure the correct DIWA class was assigned
    b. Where a vegetation description was not present the water description was considered dominant and the geology descriptions were used to ensure the correct DIWA class was assigned
    c. If only a geology description was assigned to a polygon, this polygon was considered to represent a wetland that may not exist in its current state, for example it may be an historical river channel or a swamp that is now agricultural land. These polygons were classified as “Historical Wetlands” to prevent confusion with the current state of the wetland
8. It was necessary to dissolve the resulting data layer and run processes to remove any errors.
9. Attributes relating to the prioritisation process of the wetlands were then calculated and assigned to each polygon using a variety of query tools.

Table 1. Data layers combined to form final wetland polygons.

Layer Name	***Range***	***Date Completed or Updated***	***Scale***	***Brief Method Description***
Wetlands of NSW (DEC)	All NSW	1/08/2003	1:50 000	Landsat TM Image interpretation
Topographic Map data (Lands)	Where mapped	Unknown	1: 25 000	Digital version of standard 1:25K topo maps
Multi-attribute mapping (DNR)	North-eastern NSW	19/12/2002	1: 25 000	Aerial photograph interpretation
Acid Sulfate Soils mapping (DNR)	Coastal NSW	01/07/1999	1: 25 000	Based on landform elements accurate to 1:25 000 scale, aerial photograph interpretation, and local council maps, with ground truthing.
Estuarine Macrophytes (DPI)	All NSW Coast	31/12/1984	1:25 000	Based on 1970s&80s aerial photos and ground truthing ('81 – '84) (West *et al*)
CCA Estuary Macrophytes (DPI)	North Coastal NSW	1999 – 2005	1:100 000	Aerial photograph interpretation
NRCMA Historical Estuarine Veg	North Coastal NSW	Unknown	Unknown	Unknown
Richmond Wetland Inventory	Richmond Catchment	1/01/1996	1:25 000	Based on DIPNR multi-attribute mapping, developedfrom Aerial Photo interpretation
Tweed & Brunswick Wetland Inventory	Tweed Catchment Brunswick Catchment	28/02/2000	1:25 000	Based on DIPNR multi-attribute mapping, developed from Aerial Photo interpretation
Clarence Wetland Inventory	Clarence Catchment	Unknown	Unknown	Based on DIPNR multi-attribute mapping, developed from Aerial Photo interpretation
Henry James - Detailed Vegetation Mapping	Lower Tweed	1/03/1995	1:10 000	Based on extensive ground truthing, aerial photo interpretation and on-ground data supplied from Tweed Coastal Remnant Bushland Inventory
Coffs Council Rivers & Creeks	Coffs Council	Unknown	Unknown	Unknown
Coffs Council vegetation	Coffs Council	Unknown	Unknown	Unknown
Ballina Shire Wetlands	Ballina Shire	July 2003	1: 4 000	Aerial photograhs and ground truthing
Ballina Shire Vegetation	Ballina Shire	Jan 2004	1: 50 000	Digitised from 1:5 000 aerial photographs
Kempsey Hydrology	Kempsey Shire	Unknown	Unknown	Unknown
Kempsey Rivers	Kempsey Shire	Unknown	Unknown	Unknown
Kempsey Drains	Kempsey Shire	Unknown	Unknown	Unknown
Lismore Hydrology	Lismore City	Unknown	Unknown	Unknown
Nambucca Vegetation	Nambucca Shire	2003	1:25 000	Based on 1997 aerial photographs with ground truthing

Aust Koala Foundation vegetation	Richmond Valley	Unknown	Unknown	Unknown
Richmond Valley Creeks & Drainage	Richmond Valley	Unknown	Unknown	Unknown
Byron Shire Vegetation	Byron Shire	Unknown	Unknown	Unknown
Tenterfield shire waterbodies	Tenterfield Shire	Unknown	Unknown	Unknown
LHCCREMS extent vegetation	Seven southern councils	01/07/2002 – Current	1:10 000	Digitised from 1:5 000 digital ortho photos flown between 2000 – 2001
Pt Stephens water bodies	Pt Stephens Shire	01/06/2003 – 18/06/2004	1:25 000	Captured by digitising Aerial photographs
Great Lakes vegetation	Great Lakes Shire	Unknown	Unknown	Unknown
Greater Taree Vegetation	Greater Taree	30/09/1999 – Current	1:25 000	Compiled from GLCC LGA vegetation species, Aerial Photograph interpretation and Ground Truthing
Greater Taree watercourses	Greater Taree	11/08/1995 - Unkown	1:50 000	Digitised from hand drawn original maps
Gosford City Vegetation	Gosford City	Unknown	Unknown	Unknown
Gosford City creeks, waterways, drainage	Gosford City	Unknown	Unknown	Unknown
Lake Macquarie Riparian Wetlands	Lake Macquarie Shire	1998	1:4 000	Mapped from 1996 aerial photographs
Lake Macquarie Vegetation	Lake Macquarie Shire	1998	1:16 000	Mapped from 1996 aerial photographs
Maitland Wetlands	Maitland Shire	Unknown	Unknown	Unknown
Wyong Shire Vegetation	Wyong	Unknown	Unknown	Unknown
DEC Kooragang vegetation	Kooragang & Hexham	2000	Unknown	Prepared by Geoffrey Winning, Shortland Wetlands Centre Ltd. for the preparation of a management plan for Kooragang and Hexham Swamp Nature Reserves in 1996 for Hunter Region. The digitising was done by Jeff Pickthall, Head Office for the Hunter Estuary Project June 2000.

Quality Assurance Measures

Data was used from a range of sources, where multiple data sets existed for one area the most accurate was used. The data's age, scale and method of development was taken into account. A layer of 'higher' quality data (newest, best scale, proven method of development) was 'overlain' over 'lesser' quality data (older, poor scale, unknown or not proven method of development).

Where 'metadata' was not available to determine age, scale and method of development, the data was checked against 'known areas' for accuracy, for example, areas of the Richmond River. Data layers were not excluded because of a lack of accompanying information.

Attributes for data source and data scale were included for each wetland polygon, where available. This attribute was not always able to be retained where data sets were 'unioined' together.

Data layers were projected to match the maps being produced, where necessary. Random checks of data against the Spot 5 satellite imagery were conducted to ensure the correct alignment of the data. Checks were also conducted of locally known wetland areas (ie. areas staff have ground truthed and through local knowledge workshops) to ensure the correct classes and attributes were being assigned.

GIS spatial and data integrity quality assurance checking procedures were 'run' on the final polygon dataset to ensure that there were no overlapping polygons, minimal slivers (without losing any wetland data), no 'null' value polygons and no void polygons. Where errors were identified, they were corrected using various ArcView 3.3 and ArcGIS 9 functions and extensions.

Classification

Classification System

The compilation of many data layers resulted in each wetland polygon having different descriptions from a variety of sources. To make the wetland descriptions more uniform the Directory of Important Wetlands in Australia (DIWA) wetland classifications were assigned to each wetland polygon.

It was necessary to refine the DIWA classifications in some cases, to incorporate 'sub-classes' to assist in differentiating between wetland types (Table 2). There is also an 'unclassified' class, this was assigned where there was a data layer showing the area as a wetland but the data lacked detail pertaining to the wetland type.

The class assigned to each polygon was determined by the descriptions included in the data layers used to compile the map. To ensure that, where multiple data sets existed for one area, the most accurate was used. The data's age, scale and method of development was taken into account. A layer of 'higher' quality (newest, best scale, proven method of development) was used to determine wetland class over 'lesser' quality (older, poor scale, unknown or not proven method of development).If a wetland polygon did not include a detailed description it remained part of the mapping with an 'unclassified' classification.

Table 2. Directory of Important Wetlands in Australia wetland classifications, including modifications.

A — Marine and Coastal Zone wetlands	
1	Marine waters; permanent shallow waters less than six metres deep at low tide; includes sea bays, straits
2	Subtidal aquatic beds; includes kelp beds, seagrasses, tropical marine meadows
2 (a)	Algal beds
3	Coral reefs
4	Rocky marine shores; includes rocky offshore islands, sea cliffs, intertidal rock platforms
5	Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets
6	Estuarine waters; permanent waters of estuaries and estuarine systems of deltas
7	Tidal mud, sand or salt flats; intertidal or supratidal
8	Tidal marshes; saltmarshes, salt meadows, saltings, brackish and freshwater marshes
9	Tidal forested wetlands; includes mangrove swamps, nipa/palm swamps, freshwater swamp forests
10	Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
11	Freshwater lagoons and marshes in the coastal zone
11 (a)	Freshwater reed / rush swamps in the coastal zone
12	Non-tidal freshwater forested wetlands, permanently or temporarily flooded (Swamp Forests)
12 (a)	Wet heath
13	Karst or subterranean wetlands with a connection to the marine environment, includes anchialine systems

B — Inland wetlands	
1	Permanent rivers and streams; includes waterfalls, permanent waterholes in river reaches
2	Seasonal and irregular rivers and streams; includes minor anabranches, braided channel complexes
3	Inland deltas (permanent and temporary)
4	Riverine floodplains; includes temporarily flooded river flats, river basins, grassland and palm savanna
5	Permanent freshwater lakes (> 8 ha); includes large oxbow lakes
6	Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes, billabongs, claypans
7	Permanent saline/brackish lakes
8	Seasonal/intermittent saline lakes
9	Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation
10	Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes claypan complexes,
11	Permanent saline/brackish marshes
12	Seasonal saline marshes
13	Freshwater shrub swamps; shrub-dominated marsh on inorganic soils, includes lignum, ti-tree swamps
14	(a) Swamp forest, not in coastal zone
14 (b) Riparian vegetation and wet schlerophyll forest, not in coastal zone, above 10m contour	
15	Peatlands; forest, shrub or open bogs
16	Alpine wetlands; includes alpine meadows and pools, temporary waters from snow melt
17	Freshwater springs, oases and rock pools; includes gnamma holes, mineralised mound and artesian springs
18	Geothermal wetlands
19	Inland, subterranean karst wetlands
C — Human-made wetlands	
1	Water storage areas; reservoirs, barrages, hydro-electric dams, impoundments (generally > 8 ha)
2	Ponds, including farm ponds, stock ponds, small tanks (generally < 8 ha)
3	Aquaculture ponds; fish ponds, shrimp ponds
4	Salt exploitation; salt pans, salines
5	Excavations; gravel pits, borrow pits, mining pools
6	Wastewater treatment; sewage farms, settling ponds, oxidation basins
7	Irrigated land and irrigation channels, canals or ditches; includes rice fields
8	Seasonally flooded arable land, farm land
9	Canals, stormwater drains
10	Wetlands constructed for biodiversity benefit; includes for habitat creation, and water quality improvement or maintenance

Prioritisation

The prioritisation process is made up of three components, attributes, indices and scores. Attributes relating to each wetland polygon were identified, these attributes group into indices that make up two final scores, the Potential Threat Score & the Potential Conservation Value Score. These two scores are used to determine wetlands that are a priority for protection, conservation and condition improvement. Attributes also assist in the assignment of relevant wetland management tools, from the toolkit, to each wetland polygon.

Complex Prioritisation

Prioritisation of wetland complexes was also necessary to determine which complexes were essential to focus on for on-ground management. High priority Wetland Complexes will become the focus of ‘Component 3’ of the project, on-ground conservation, protection and condition improvement of wetlands.

Wetland complexes are made up of multiple wetland polygons. Each polygon has all of the attributes assigned to them and scored as described. Each wetland polygon has a total Threat Score and a Total Conservation Score. To combine these scores into a single score to prioritise Wetland Complexes for on-ground management the following formula was applied:
Average Conservation Score + Highest Conservation Score = Complex Prioritisation Score

Priority lists can be developed from the database in many different ways, for the purposes of many different wetland mangers. For the purposes of the *Sustainable Wetlands on NSW Coastal Landscapes* project, funded by the HCRCMA & NRCMA, priority lists of Wetland Complexes have been produced to assist with the third component of the project, on-ground protection, conservation and condition improvement of wetlands. The priority lists have been produced separately for the HCRCMA and NRCMA to meet their individual requirements.

Attribute Relationship & Indices

Each of the two final scores, Potential Threat & Potential Conservation Value are made up of a series of attributes and indices. The Potential Threat Score includes; Landuse Index, Development Index, Infrastructure Index, Environmental Impact Index and Climate Change Index. The Potential Conservation Value Score includes; Rehabilitation Index, Statutory Index, Landscape Index, Condition Index; and Conservation Value Index. The relationships between attributes, indexes & scores is displayed in Figure 1.

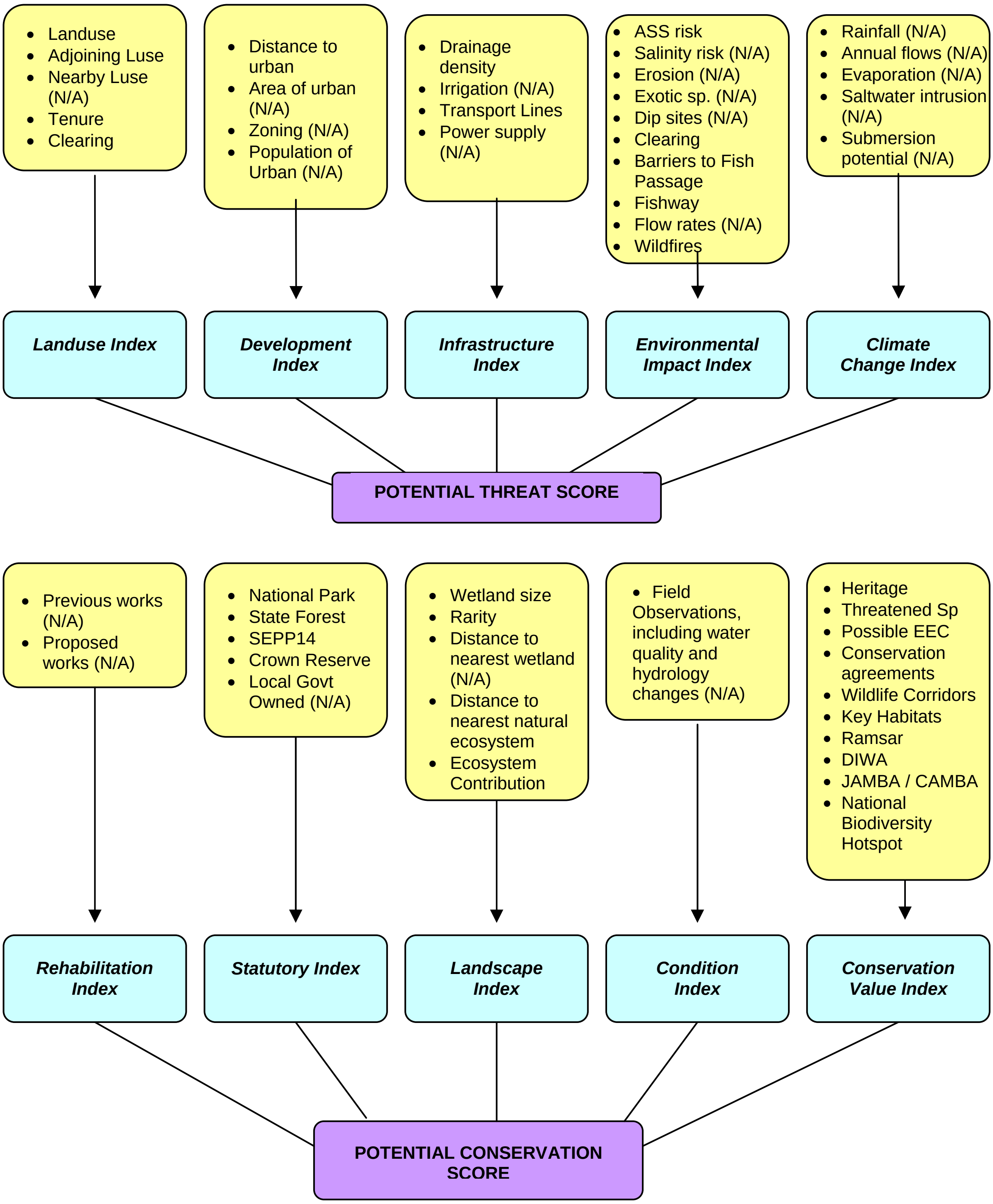

Figure 1. Summary of attribute relationships with Index and Scores used in prioritising wetlands. (N/A denotes data that was not available at the time of prioritisation).

Attribute Scoring & Weightings

Each series of attributes that make up an index has its own scoring system.
Two weightings were also applied to each attribute;
(a) Data Accuracy Weighting – an indication of the scale, age and method that the data was developed by.
(b) Significance Weighting – an indication of the significance of the attribute on the 'threat to' or 'conservation value of' the wetland.

This information was then combined in the following formula, to calculate the overall attribute contribution to the index score for each wetland polygon:

Index score = Total of (Attribute Score x Data Accuracy Weight x Significance Weight) for each attribute within the index

An effort was made to vary the attribute scores from whole numbers to increase the separation of the total scores. Small variations in scores to one or two decimal places do not indicate small known differences in the relative significance of the attribute to the total score. Rather, they have been deliberately introduced to increase the separation in the total scores of the 35000 (approx.) wetland polygons.

Assigning Attributes

Each wetland polygon was assigned a series of attributes, detailed below in three groups;

- General Attributes are used to identify the wetland and its location, they are also used for refining the area of prioritisation (for example; priority wetlands in the 'Clarence catchment' only);
- Threat Attributes are used to compile the threat score used in the prioritisation process;
- Conservation Attributes are used to compile the conservation score in the prioritisation process.

It was important for the prioritisation to be consistent across the project area, thus, only spatial data that was available for the entire project area was able to be assigned to each wetland polygon. In some cases more detailed information relating to an attribute is available, but only for a small part of the project area, this data was not used in the prioritisation process to prevent 'bias' to areas with more detailed information. It is envisaged that this additional and more accurate data will be assigned to the relevant wetland polygons and used in prioritising wetlands on a smaller scale.

Products

Spatial Data

Spatial (or digital) data is available under licence from DNR via the CMAs. Please phone either the Hunter Central Rivers CMA or Northern Rivers CMA to request the data. The spatial data set includes the wetland polygons and all of the attributes used in the prioritisation process, plus their wetland id (relevant to the decision support database) complex number and complex name.

Decision Support Database

The Decision Support database is geared to produce a range of reports to easily provide users with the information they require. The database is equipped with a user-friendly front-page that enables the user to access information easily for both wetland complexes and individual wetland polygons. The diagram (Fig 2) below shows the information readily available to users via the front-page of the database.

Interactive CD

The interactive CD is a user friendly version of all of the information produced during the project. It includes all of the reports that detail the various components of the project, including a metadata statement for the spatial data layer. It also includes maps a 1:100 000 of all of the wetland areas mapped and printable maps for fifty of the wetland complexes in the CMA at 1:25 000 scale. The decision support database and all of the data within it, plus one-click-reports to make the data user friendly is also on the CD to allow users to determine priorities in their area (ie. by complex, LGA, catchment, subcatchment). A CD has been produced for each CMA area.

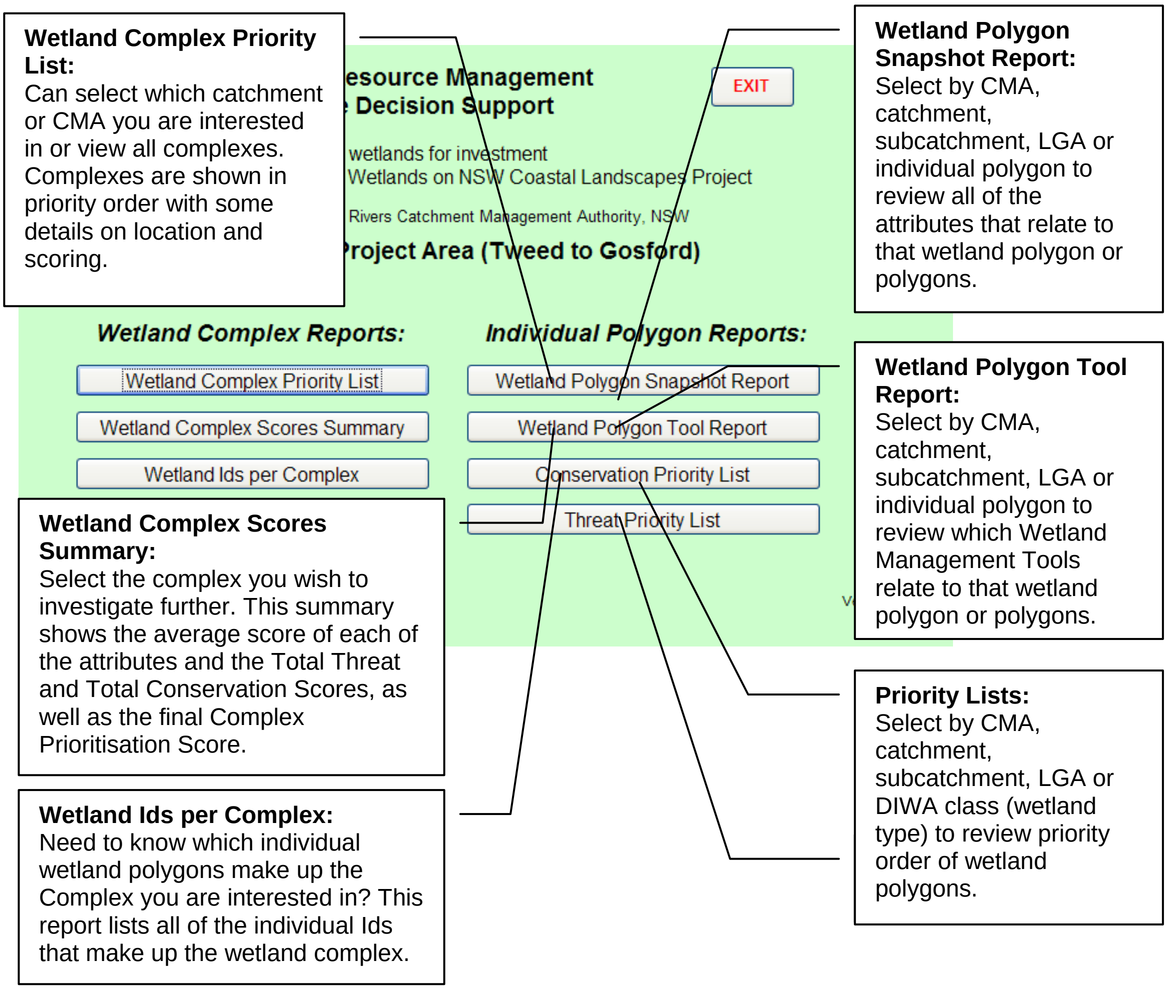

Figure 2. Example of Decision Support Database front page and report options.

Discussion

The tools produced by this project are designed to answer specific questions posed about where to invest in wetland protection and condition improvement in the HCRCMA and NRCMA regions. However, the products are tailored to be flexible enough to have a range of uses and users. All products are adaptable to other regions and all of the data is made widely available for any use.

In the case of the Sustainable Wetlands on NSW Coastal Landscapes project, 34 wetland complexes in the NRCMA and 15 wetland complexes in the HCRCMA have been prioritised to be targeted for wetland investment in protection and condition improvement.

Advantages and Uses of Products

As a result of this project detailed and uniform spatial data is now available for wetlands in the HCRCMA and NRCMA. Having uniform data across these regions allows wetland managers to more easily identify and compare wetlands in their area of interest. Attaching common attributes to these wetlands allows wetland managers to access this baseline data at the touch of a button.

The decision support database and its pre-written reports make deciding on priority areas in which to invest, simple. WetlandCare Australia envisages using this data for many years into the future to determine priorities for wetland investment. The products are also likely to be used by community groups, environmental organisations, local councils and State Government.

The data could have a range of future uses, from determining changes in wetland area and community structure, to determining the best locations for rehabilitating wetland habitat corridors.

Data Limitations

At this stage funds have only been made available to compile mapping and prioritise wetlands in the HCR and NR CMAs. In the future it is hoped that this area can be expanded.

Data in the wetlands maps are entirely from existing data, hence there may be errors and inconsistencies throughout the layer, especially in regard to polygon shape and DIWA class (wetland type). Prioritisation attributes were assigned for the purpose of a decision support database, hence, they are relatively general (lack detail). Some of the prioritisation attributes require more accurate and up-to-date data when it becomes available, including: Heritage; Voluntary Conservation; Rarity; Endangered Ecological Communities and Vegetation Clearing.

Conclusion

WetlandCare Australia hopes that users of these products find them useful, however, suggestions are welcome. It is envisaged that these products and data will be continually updated and improved for continued use in the future. Updates are currently scheduled for every six months, depending on input from users, the next update will occur in January 2007.

The products produced throughout this report are geared to be continually being improved and shaped as new and better data and methodologies are discovered. The products currently being used are, by no means, the final product. WetlandCare Australia hopes to include information and finds from new works as it comes to hand.

References

1. Atkinson, G., Aaso, T., Hallinan, M., Franklin, J., Kemsley, R., Rea, S. and Johnston, P., 2000, Acid Sulphate Soils Drainage Network Mapping, Northern NSW, Department of Land and Water Conservation, Sydney.

2. Banksia Environmental Consultancy & EGIS Consulting, 2002. Wetland, riparian and littoral protection project: Vegetation Protection Plan. NSW, Australia.

3. Brown, S. 2003, Wetland Monitoring Program within Lake Macquarie Catchment. Banksia Environmental Consultancy, Eleebana NSW.

4. Earley, O, 2000, Modelling wetland loss in the Richmond Catchment: an example of historical Vegetation modelling, 4th International Conference on Integrating GIS and Environmental Modelling (GIS/EM4): Problems, Prospects and Research Needs. Banff, Alberta, Canada, September 2 - 8, 2000.

5. Environment Australia. 2001, A Directory of Important Wetlands in Australia, Third Edition. Environment Australia, Canberra.

6. ESRI, 2002, Environmental Systems Research Institute Glossary (Help Manual), HCL Technologies Ltd., New Delhi.

7. Hamilton, A., 1998a, Natural Resources study of the Brunswick River Catchment: Report 1, Department Land and Water Conservation, Murwillumbah.

8. Hamilton, A., 1998b, Natural Resources study of the Tweed River Catchment: Report 1, Department Land and Water Conservation, Murwillumbah.

9. *Hunter-Central Rivers Catchment Management Authority, 2004, Request for Proposals (RFP) for Sustainable Wetlands on NSW Coastal Landscapes Project REF: CMGF168 – RFP.*

10. Kendall, P and Kendall, K., 2003, Nambucca Catchment Vegetation Survey, Kendall & Kendall Ecological Services Pty Ltd, Kempsey.

11. Kingston, M. B., Turnbull, J. W., and Hall, B. W., 2004, Tweed Vegetation Management Strategy (Vol 1-3), ECOGRAPH, Murwillumbah.

12. Lenehan, K., 2000, Tweed and Brunswick River Catchments Wetlands Inventory.

13. Short, G., 1998, Natural Resources study of the Richmond River Catchment: Report 1, Department Land and Water Conservation, Grafton.

14. Wetlands Centre & SWC Consultancy undated. Lake Macquarie Wetlands Management Study, Volume 3. NSW Australia.

Impact of beach nourishment on Coolangatta Bay morphology over the period 1995-2005

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Introduction

Coastal erosion is a worldwide occurrence along sea shores which has been reported in the literature for several decades. Beach nourishment, rather than civil engineering structures, is nowadays used worldwide. Major advances in the technology of beach nourishment have been made over the past 3 decades (Houston, 1991; Dean, 1996; Elko et al., 2005). Generally speaking, beach nourishment involves the placement of sediment on an eroding beach to migrate the shoreline seaward in order to promote storm protection, natural habitat and beach amenity. Due to the widespread use of beach nourishment worldwide (Hamm et al., 2002), it is now important that not only coastal engineers but also geoscientists investigating coastal processes understand the performance of beach nourishments.

Coolangatta Bay (Figure 1), located at the border of the states of Queensland and New South Wales, is a major international and national tourism destination. The Tweed River entrance training walls, located southward to Coolangatta Bay, were extended seaward approximately 380 m in the early 1960s to improve navigation conditions at the entrance. These walls also created a trap for the natural longshore drift, resulting in loss of sand supply to the southern Gold Coast beaches (DHL, 1970), particularly in Coolangatta Bay. Coolangatta Bay beaches eroded to an extent that sea walls were constructed to protect property and infrastructure. Coolangatta Bay beaches had not fully recovered by the early 90s, despite various groyne constructions and beach nourishment works. Since 1995, under the Tweed River Entrance Sand Bypassing Project (TRESBP), a number of dredging campaigns and the implementation of a permanent sand bypass system in 2001 has resulted in significant changes of Coolangatta Bay morphology. Beaches are now very wide and healthy, and they are now thought to be the only Gold Coast beaches able to manage a high succession of high wave events.

This paper investigates the influence of wave climate, nourishment works and permanent sand bypassing on Coolangatta Bay morphology for the period 1995-2005. This study is based on accurate bathymetric surveys, quantification of beach nourishment and artificial sand bypassing and wave modelling.

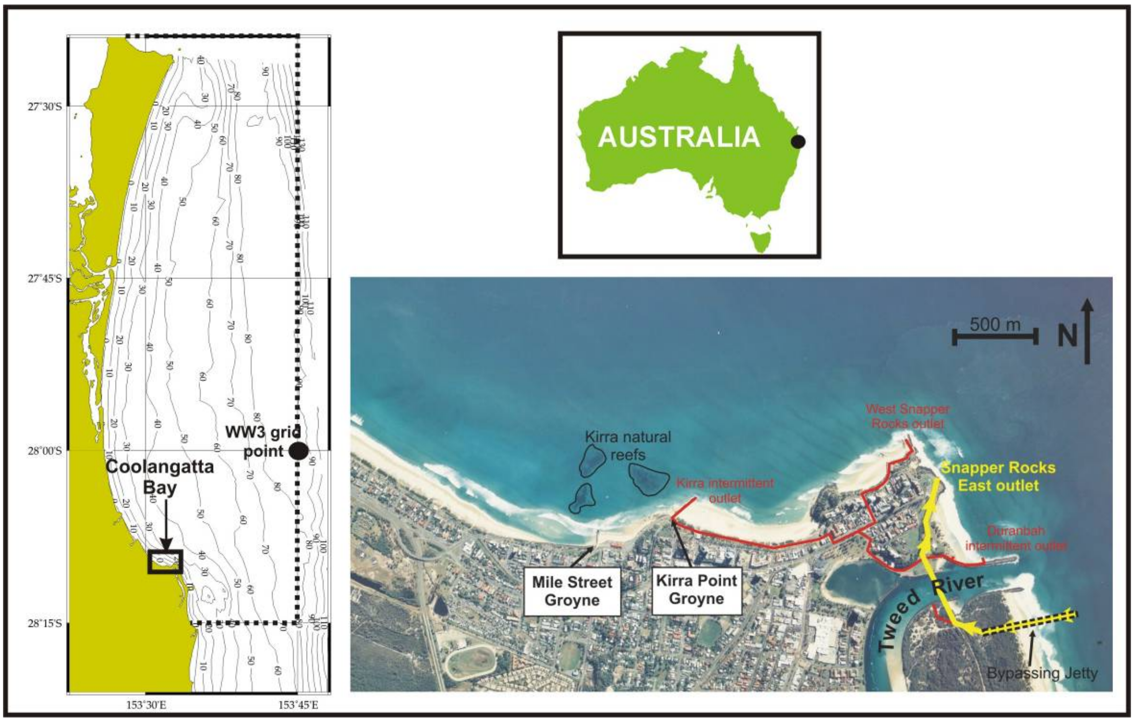

Figure 1. Location and general settings of Coolangatta Bay (Queensland, Australia), and layout of the permanent sand bypassing system

Study area

Location and settings

The 70 km long Gold Coast, in Queensland, has been Australia's premier holiday resort for more than 40 years. Coolangatta Bay is located at the southern end of the Gold Coast and has a northern exposure (Fig. 1). The area is characterized by the presence of the Tweed River entrance and a major headland called Point Danger. The area of investigation covers approximately 6 km of coastline, comprising 3 distinct embayments within Coolangatta Bay: Rainbow Bay, Coolangatta Beach and Kirra Beach.

The tidal cycle is as for all Gold Coast beaches, with a semi-diurnal cycle, varying from 0.2 to 2 m, with a mean of 1 m. The area is exposed to energetic swells. Three swell regimes can be considered dominant on the coastal dynamics (Castelle et al., 2006a). The first one is S to SE swells in winter and spring, which contribute to the main component of the northerly littoral drift. The second swell regime is generated by Tropical Cyclones with a NE to E direction and significant wave height up to 8 m. The third swell regime is generated by East Coast Lows, which is a common storm type in the Gold Coast region, resulting in gale winds and NE to SE wave direction. The sediment consists of fine sand (d_{50}=200 μm). The estimated net rate of littoral sand transport is 500 000 m^3/yr toward the north (Turner et al., 2006). The Tweed River contributes a small sand supply to the Coolangatta Bay and acts more like a sediment sink.

In the early 1960s, the Tweed River entrance training walls were extended seawards approximately 380 m to improve navigation conditions. The loss of longshore sand supply from the south resulted in progressive recession of Coolangatta Bay beaches. The Gold Coast also experienced severe storms in 1967 (McGrath, 1967), 1972 and 1974 when high energy wave conditions and gust winds caused major erosion and devastation to the coast. A few measures were approved such as building groynes and beach nourishment campaigns to try to restore and maintain the southern Gold Coast beaches. Moreover, the wall extensions improved navigation conditions for almost 20 years before a sand bar moved past the end of the southern training wall to infill the channel once more. By the early 1990s, despite previous nourishment campaigns, both southern Gold Coast beaches erosion and navigation conditions were severe. To achieve the Queensland objective of restoring and maintaining beach amenity, a series of nourishment works have been undertaken over the past 10 under the Tweed River Entrance Sand Bypassing Project (TRESBP).

Nourishment works

The TRESBP has been formulated in order to overcome both the significant erosion of the southern Gold Coast beaches and the navigation issues due to the Tweed River entrance infilling. Stage 1 involved removing the sand bar from the Tweed River entrance to provide material for the initial restoration of the southern Gold Coast beaches. As part of this campaign, 600,000 m3 of sand was placed on the upper beaches from Rainbow Bay in the east to North Kirra in the west. Additional sand quantities were placed in the nearshore (Dyson et al. 2001). Stage 2 resulted from refinements to the Stage 1 placement areas (Boswood et al., 2001; Colleter et al., 2001). An exclusion deposition zone also provided a 100 m buffer around Kirra natural reef. Most of the sand was placed in an area to the east of Snapper Rocks (see deposition areas on Fig. 1). Sand placed in this area was transported by the longshore drift and naturally fed the sandbanks and beaches of the southern Gold Coast. The innovative aspect of the TRESBP (Stage 2) was the implementation in 2001 of a sand bypassing system (see Fig. 2) to collect sand from the southern side of the Tweed River entrance and transport it to the southern Gold Coast beaches in perpetuity (Dyson et al., 2001). The sand was pumped in 5 different locations within Coolangatta Bay (see outlet locations on Fig. 1). Most of the sand was pumped at the Snapper Rock outlet, at the eastern extremity of Coolangatta Bay.

The nourishments during the period 1995 to 2005 are detailed below:

- 1995-1996: Stage 1A Dredging of Tweed River Entrance and associated nourishment of the southern Gold Coast beaches (2 300 000 m^3)
- 1997-1998 Stage 1B Dredging of Tweed River Entrance and associated nourishment of the southern Gold Coast beaches (800 000 m^3)
- 2000-2002 Stage 2A Dredging of Tweed River Entrance and associated nourishment of the southern Gold Coast beaches (1 100 000 m^3)
- 2003-2006 Stage 2B Dredging of Tweed River Entrance and associated nourishment of the southern Gold Coast beaches (500 700 m^3)
- 2001: Start of the permanent Sand bypassing system

Methods and materials

Surveys

Figure 3 shows the area of interest for the present study, and the available survey data for the period is from 17/9/1987 to 15/7/2005. Survey data has been collected in this area by a number of organisations for a variety of investigations and projects. Not all the surveys have been taken on the same survey lines and not all the survey data collected has been available for the present study. The main survey lines covering the area were the ETA lines 12 to 18 (generally spaced at about 400 m). In the 1970's and

1980's, due to the severe erosion of Coolangatta Bay, the Gold Coast City Council established other sets of survey lines at Coolangatta Beach (CG lines), Kirra Beach (K lines) and Rainbow Bay (RB lines). Survey data were used to compute the bathymetry map of Coolangatta Bay and sand volumes in different beach units. Specific survey lines were chosen to compute both the shoreline position and beach volume. There is an extensive range of shoreline indicators reported in the literature (Boak and Turner, 2006). In the present study, the shoreline position is defined as the intersection of the beach profile with the Mean Sea Level (MSL) which corresponds approximately to 0 in the Australian Height Datum (AHD) at the Gold Coast beaches. For each survey line, the beach volume is calculated from dune start to the shoreline datum (subaerial beach volume) and from the shoreline to the 15 m depth contour (nearshore beach volume). Indeed, results show that the changes in bottom profiles are not significant seaward to about 15 m below AHD.

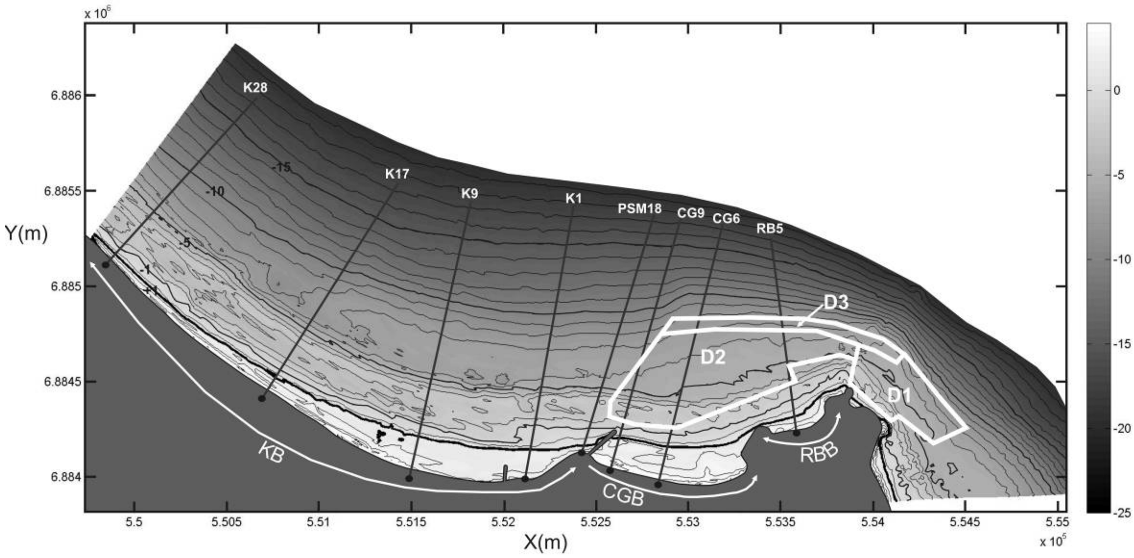

Figure 2. Coolangatta Bay morphology (October 2004) with location of the specific survey lines and the 3 main deposition areas (KB=Kirra Beach, CGB=Coolangatta Beach, RBB=Rainbow Bay Beach)

The location of the specific survey lines are shown on Figure 3. The survey lines cover the bay from North Kirra (transect K28) to Rainbow Bay (RB5). They were chosen because they are representative of the Coolangatta Bay alongshore variations and because a large number of survey were undertaken on these specific transects.

Numerical modelling

In the present study, numerical wave modelling has been undertaken in order to assess the wave condition. The spectral wave model SWAN (Booij et al., 1999) is used in stationary mode. Triad interaction is taken into account in the computations. The breaking wave model chosen herein is the bore-based model of Battjes and Janssen (1978), with a constant breaker parameter γ=0.73 following Battjes and Stive (1983). The wave forcing provided by the global wave model WW3 (Tolman, 1991) nearest output point (see Fig .1) is applied to the offshore and lateral boundaries of the model. A grid at a cell size of 250 m is implemented on the Gold Coast area (see Fig. 1). The tide level is treated as constant equal to 0 AHD, i.e. at mid tide. Stationary computations are done every 24 hours from the 1st of February 1997 to the 1st of August 2005. Wave outputs are requested along Coolangatta Bay at 10 m depth in order to assess the longshore variability of the forcing.

To assess wave-induced currents in Coolangatta Bay, a curvilinear refined grid is implemented on Coolangatta Bay and nested in the coarse wave grid described above. The flow module of the modelling system DELFT3D is used in the present study (Lesser et al., 2004). DELFT3D has been used extensively world-wide for coastal process studies and is well suited for coastal hydrodynamics over complex bathymetries like Coolangatta Bay. The flow module used herein is 2-D mode (depth averaged). The governing equations of the flow module are the depth-averaged continuity equation and the depth-averaged momentum equations in horizontal direction. The wave induced force is given by the spatial gradient of the radiation stress tensor (Longuet-Higgins and Stewart, 1964) and the tide is treated as constant, as for wave modelling.

Results

Evolution of Coolangatta Bay morphology

Figure 3 shows the evolution of the computed Coolangatta Bay morphology over the period 1997-2005. The most significant changes occurred to a depth of 15 m below the mean sea level. For example, the difference between the March 2000 configuration and the July 2005 configuration reveals significant changes of the sub-aerial beach. Rainbow Bay beach is the beach that experienced the least significant changes over the study period, while Coolangatta beach and particularly Kirra beach intensively evolved. Accretion reached 6 m over the period in some areas of Kirra beach and Miles Street groyne is now mostly under the sand. The water reaches Kirra Point groyne only at high tide. Both Coolangatta and Kirra beach are now about 200 m wide with non-vegetated dunes reaching 6 m above AHD. Since 2002, Rainbow beach has experienced a weak erosive state, Coolangatta Beach seems to have reached a quasi-equilibrium state and Kirra beach continues to gain sand.

The nearshore area also experienced intense changes. Before 2001, the nearshore bar was following the embayments and nowadays Coolangatta bay exhibits a wide and straight nearshore bar. This straight nearshore bar development started in 2001 and coincides with the start of the permanent sand bypassing. This nearshore bar eventually changed its orientation westward to Kirra groyne between 2002 and 2005. This change in the nearshore bar configuration is associated with an intense beach width growth of Kirra Beach. Nowadays, this nearshore bar is located within the area of the Kirra natural reefs (see Fig. 1). These significant morphological changes of Coolangatta Bay morphology coincide with the TRESBP implementation and a more detailed investigation is required to assess the relative influence of offshore wave conditions, dredging works and artificial sand bypassing.

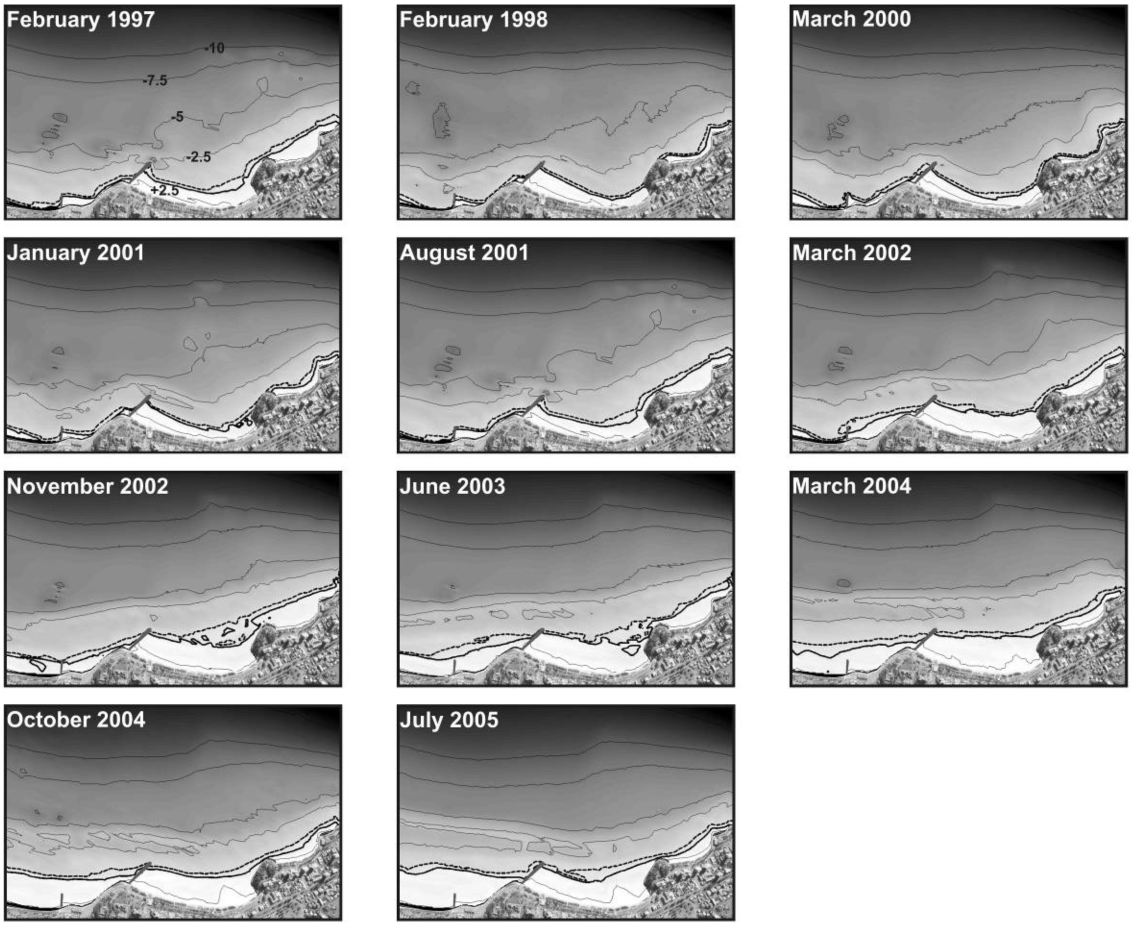

Figure 3. Evolution of Coolangatta Bay from 1997 to 2005: beach widening and formation of a straight and wide nearshore bar. The thick dot line is the shoreline location (0 AHD) and the thick line is the spring high tide sea level

Relative influence of beach nourishment and wave forcing

Figure 4 shows the time series of the shoreline position and beach volume for each specific beach profile, as offshore wave conditions and the monthly amount of both pumped and deposited sand in the bay (with information on deposition areas). Firstly, this figure shows that the recent significant evolution of Coolangatta Bay was mainly due to the TRESBP as would have been expected given that there has been significant over-pumping of sand relative to the natural potential to move sand alongshore. Indeed, offshore wave conditions do not seem to have a significant impact on the global evolution of the bay. Indeed, this period has been relatively calm period for the Gold Coast beaches with no severe erosive event.

Both Stage 1A and Stage 1B dredging had a significant impact on the shoreline position of the eastern part of Coolangatta Bay. The western part of Coolangatta Bay does not experience significant change of the shoreline position over the period prior to the artificial sand bypassing plant implementation. The start of the artificial sand bypassing results in an almost immediate seaward migration of the shoreline in the whole bay (except the eastern extremity: K17 and K28). At the beginning (early 2001), beach width increases are observed at the eastern extremity of Coolangatta Bay i.e. Rainbow Bay (RB5 on Fig. 4). In late 2001, beach width increases at Coolangatta Beach (CG6 and CG9), then at Kirra in 2002. Since 2002, the shoreline position in the eastern part of Coolangatta Bay (RB5, CG9, CG6) is almost stable, with a slight downward trend.

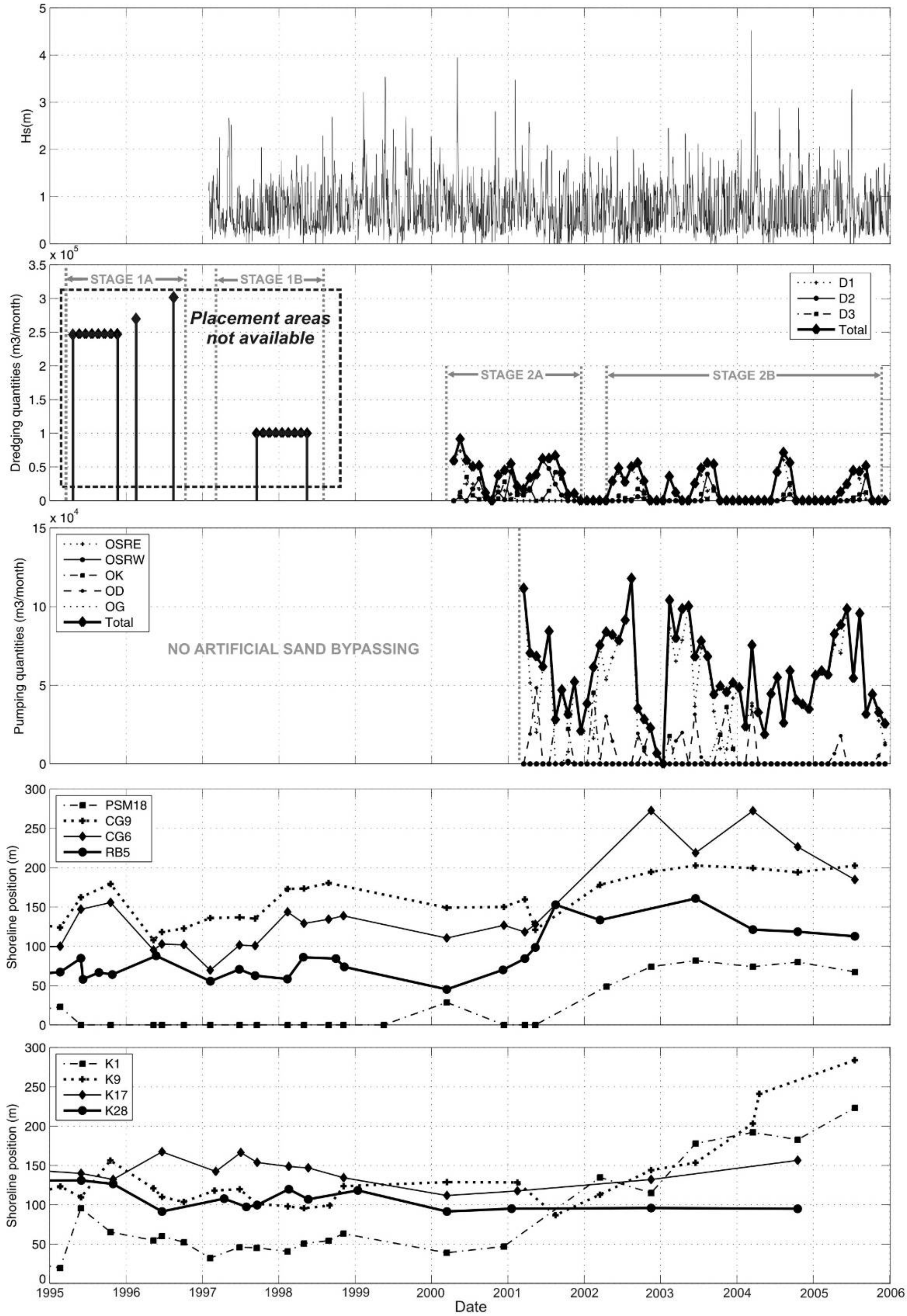

Figure 4. Time series of significant wave height in the Bay, pumping and dredging quantities, and shoreline position at the specific transects over the period 1995-2005. OSRE: Snapper Rock East Outlet; OSRW: Snapper Rock East Outlet; OK: Kirra Outlet; OD: Duranbah Outlet; OG: Greenmount Outlet

The impact of the dredging works is easier to investigate looking at the recent evolution of the nearshore beach volumes. Figure 5 shows the time series over the same period of the nearshore volume of the specific transects. It shows that both Stage 1A and Stage 1B resulted in a significant increase of the nearshore beach volume in the whole bay. Since 2000, the nearshore volume of the bay has been progressively decreasing, particularly in the eastern part. This is due to the combined effect of the shoreline migration of the previously deposited sand which welds to the shore, and the decreasing neashore beach width due to the artificial sand bypassing which results in an immediate increase of the subaerial beach width. Indeed, the plot of the evolution of the subaerial beach (not presented in this paper) shows an increase of the subaerial beach volume which is significantly more important than the decrease of the nearshore beach volume.

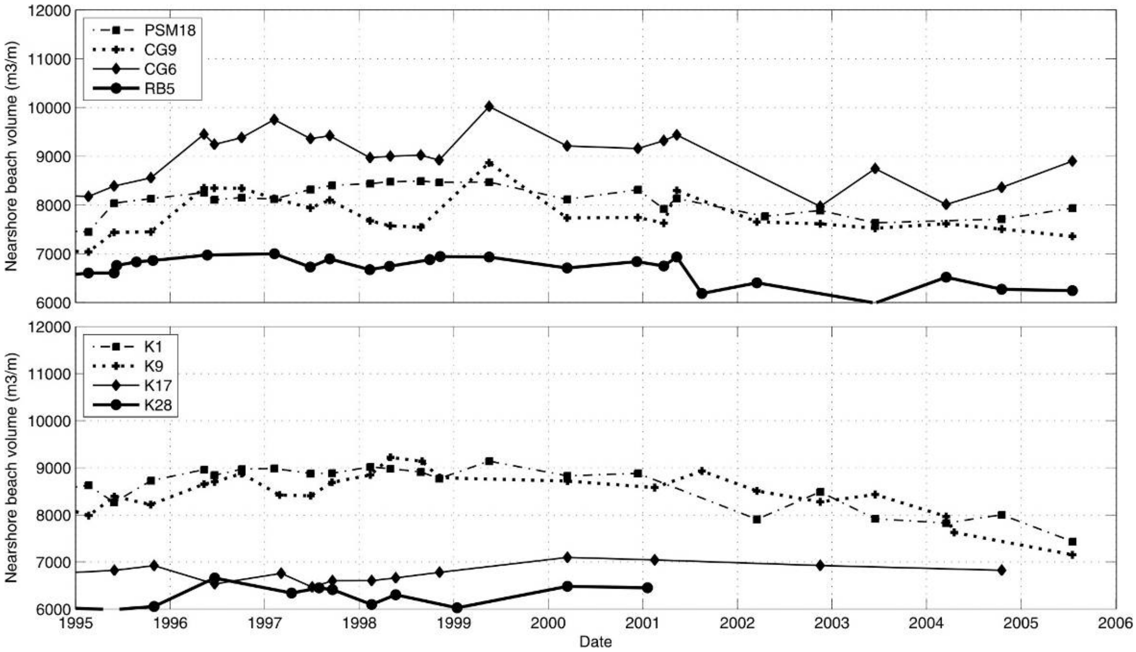

Figure 5. Time series of the nearshore volume of the specific transects over the study period

Changes in coastal processes

This significant and rapid evolution of Coolangatta Bay morphology is due to two main factors: the large amount of sand available updrift, and the intense and quasi-permanent westward longshore sediment transport along Coolangatta Bay. A set of simulations were undertaken in order to assess the evolution of both wave and flow patterns within the Bay over the period 1995-2005.

Figure 8 shows the computed flow patterns in Coolangatta Bay in the 1998 configuration, for offshore wave conditions: significant wave height Hs=2.5 m, peak wave period T=8.5 s and wave incidence to the South/North axis $\theta=110^o$ (E-SE swell). This simulation shows a predominant westward longshore current along the bay. This longshore current follows the embayments, sometimes resulting in the formation of a weak counter-clockwise circulation cell (Fig. 8.C). This longshore current is also accelerated in front of each small headland delimiting an embayment. The wave-induced current magnitude reaches 2 m/s near Rainbow Bay and Snapper Rocks which is a quite significant intensity given Hs only reaches 2 m at the breaking point at Snapper Rocks. Coolangatta Bay is characterized by an intense longshore current all year long, under sufficient offshore wave conditions. Figure 9 shows the flow pattern within the bay for the same offshore wave conditions for the 2004 Coolangatta Bay morphology. Results show the presence of an intense and almost spatially homogeneous longshore current along the bay. Embayments and headlands (except Snapper Rocks) do not have any impact on the longshore current shape to the point where, Greenmount Hill and Kirra Point do not act as headlands anymore.

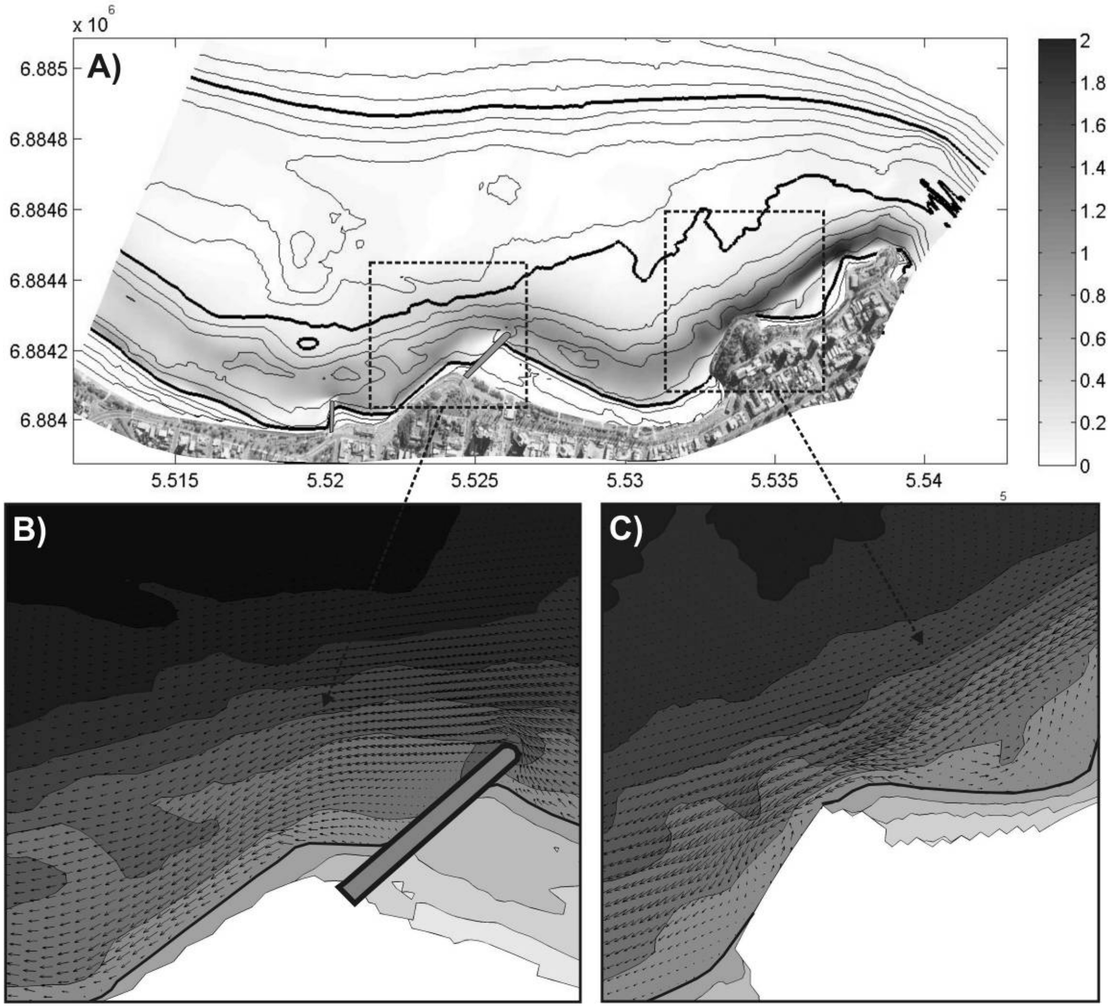

Figure 6. A: Computed wave-induced current intensity (m/s) in Coolangatta Bay (1997 configuration) for offshore significant the offshore wave conditions: E-SE swell with Hs=2.5 m and Tp=8 s.; B: zoom of wave-induced current vectors near Kirra groyne; C: Zoom of wave-induced current vectors near Greenmount Hill.

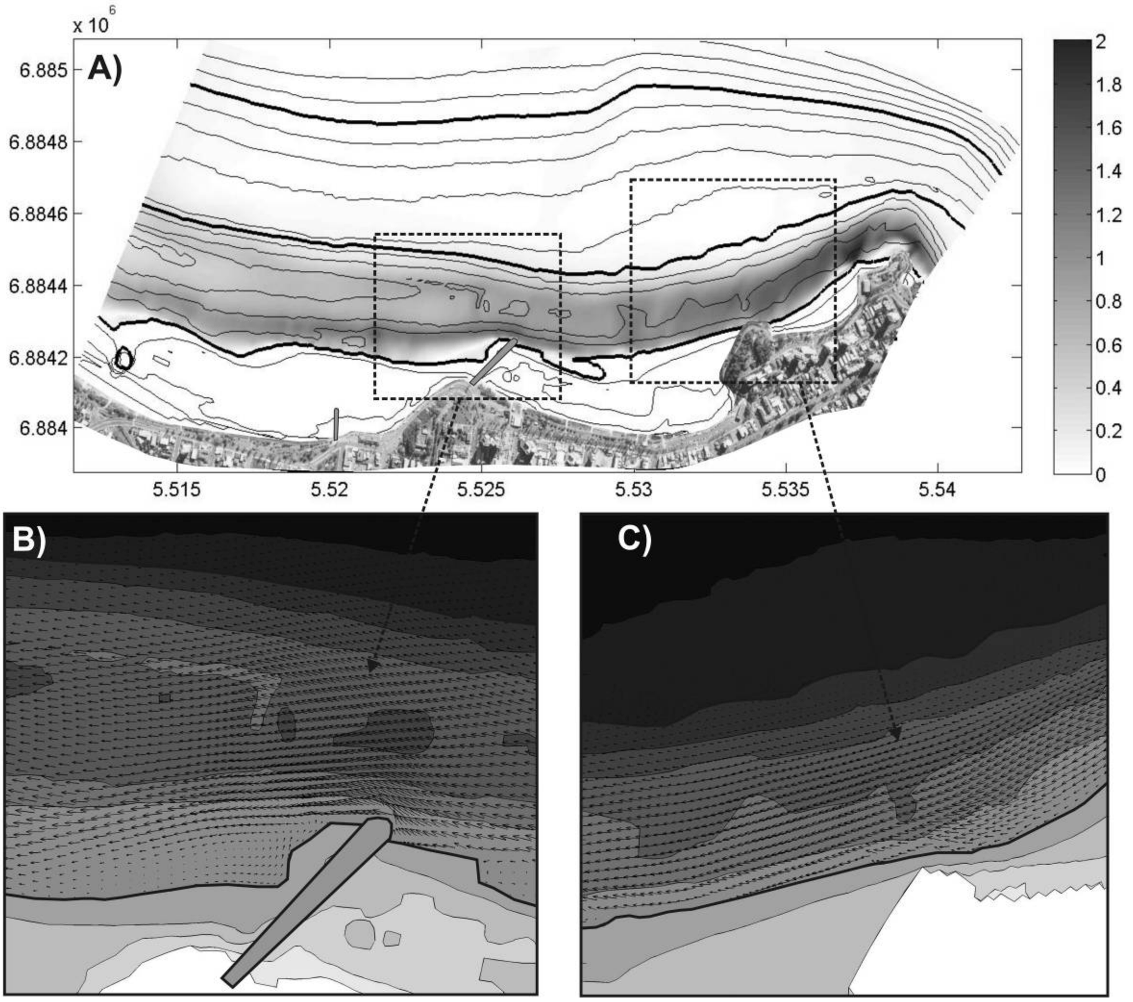

Figure 7. A: Computed wave-induced current intensity (m/s) in Coolangatta Bay (2004 configuration) for offshore significant the offshore wave conditions: E-SE swell with Hs=2.5 m and Tp=8 s.; B: zoom of wave-induced current vectors near Kirra groyne; C: Zoom of wave-induced current vectors near Greenmount Hill.

Discussion and conclusions

Coolangatta Bay experienced significant morphological changes over the past decade. Accretion has reached 6 m in some areas like Kirra Beach where the seaward shoreline migration attained 200 m. In comparison with the catastrophic beach configurations in the 80s, we can affirm that the TRESPB has been successful in both increasing the beach width and enhancing the ability of the southern Gold Coast beaches to manage extreme events. The main outcomes of the present study are:

(1) Artificial sand bypassing has the most significant impact on the Coolangatta Bay morphology. Indeed, the sand is pumped in shallow water (mostly at the Snapper Rock East Outlet) and is immediately transported by the longshore current and naturally feeds the sandbanks and beaches of Coolangatta Bay. This process proved to be much more efficient than depositing the dredged sand in the nearshore area which requires a significant period of low energy condition in order for the deposited bump to migrate shoreward and weld to the shore.

(2) The Coolangatta Bay beaches are very wide. The shoreline seaward migration ranges from 50 m in Rainbow Bay to more than 200 m at Kirra Beach in comparison to the shoreline prior to the TRESBP. The subaerial beach is currently a significant buffer

against a severe storm event. Indeed, a recent study showed that the beaches of Kirra and Coolangatta are currently the most able to manage extreme event of all the Gold Coast beaches (Castelle et al., 2006c).

(3) Kirra beach seems to act as a sink. This is not surprising given that this section of coastline experienced the greatest negative impact of the erosion wave that followed the construction of the Tweed walls. Nowadays, Kirra beach continues to infill despite the recent decrease in pumped sand quantities. This process will end as soon as both the shoreline and the nearshore bar will become straight between transects PSM18 and K17, resulting in an almost morphological equilibrium of Kirra Beach.

(4) There is no equilibrium of Coolangatta Bay yet. Indeed, the nearshore sand bar, the wave, flow and sediment transport patterns are continuously evolving. Moreover, recent information suggests that, within the next few years, the pumped quantities will decrease and probably be around 500 000 m3/yr due to the decrease of the available sand quantities updrift of the Tweed River. So the system needs to be given a few years to settle down in order for the overall success to be judged accurately.

At the time of writing this paper, the TRESBP has been successful in providing wide and healthy beaches within Coolangatta Bay. However, and unfortunately, it can be admitted that, worldwide, no beach nourishment or coastal engineering works program will ever meet everybody's wishes. The TRESBP is another example, as several issues have been raised recently by the community despite the obvious overall success of the engineering components of the project. Nowadays, locals and tourists think that beaches are too wide, especially at Kirra, that surfing, swimming, fishing, diving and beach use amenity has been compromised as a result of overpumping. The nearshore bar is now so wide that the natural reef seaward of Kirra Beach (Fig. 1) is threatened to be fully covered by tons of sand, which raises both fishing and ecological integrity issues. The formation of the straight and wide nearshore bar, known by the surfers as "Superbank", resulted in the formation of 2 km long wave (from Snapper Rocks to Kirra) rated as one of the best surf breaks in the world. However, Kirra's world-class wave disappeared at the same time, and as surf rage boils over at Superbank, a lot of local surfers want to have the early 90s configuration back, when there were distinct surf breaks within Coolangatta Bay.

Again, we have to wait a few years to let the system settle down as a result of overpumping, i.e. the overall success must not be judged yet as the TRESBP is working to a 2009 timeline. However we can say that, given the catastrophic state of the Coolangatta Bay beaches in the early 90s and the cyclone threat on the Gold Coast, the TRESBP resulted in a significant and rapid improvement of beach width. At the time of writing this paper, the Coolangatta Bay beaches are wide and are thought to be the only Gold Coast beaches able to manage extreme events. The nourishment strategy used during this project has successfully delivered large amounts of sand to the Gold Coast embayment, although it has been up to now controversial from many community perspectives.

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References

Battjes, J., Janssen, J., 1978. Energy loss and set-up due to breaking of random waves. In: Proceeding of the 16th International Conference on Coastal Engineering. ASCE, pp. 569–587.

Battjes, J., Stive, M., 1985. Calibration and verification of a dissipation model for random beaking waves. Journal of Geophysical Research 90 (C5), 9159–9167

Boak, E., Turner, I., 2005. Shoreline definition and detection: A review. Journal of Coastal Research 21 (4), 688–703

Booij, N., Ris, R., Holthuijsen, L., 1999. A third-generation wave model for coastal regions, part i: Model description and validation. Journal of Geophysical Research 104 (C4), 7649–7666

Boswood, P., Victory, S., Lawson, S., 2001. Placement strategy and monitoring of the tweed river entrance sand bypassing project nourishment work. In: Proc. Coasts and Ports Conference 2001. pp. 253–258

Castelle, B., Bourget, J., Molnar, N., Strauss, D., Deschamps, S., Tomlinson, R., 2006a. Dynamics of a wave-dominated tidal inlet and influence on adjacent beaches: Currumbin Creek, Gold Coast, Australia. Coastal Engineering, in press

Castelle, B., Bonneton, P., Senechal, N., Dupuis, H., Butel, R., Michel, D., 2006b. Dynamics of wave-induced currents over a multiple-barred sandy beach on the Aquitanian Coast, France. Continental Shelf Research 26(1), 113-131

Castelle, B., Le Corre, Y., Tomlinson, R., 2006c. Can the Gold Coast beaches manage extreme events? Geo-Marine Letters, submitted

Colleter, G., Cummings, P., Aguilar, P.,Walters, R., Boswood, P.,2001.Monitoring of tweed river entrance dredging and nourishment activities. In: Proc. Coasts and Ports Conference 2001. pp. 259–264

Dean, R., 1996. Beach nourishment performance: planform consideration. Shore & Beach 64(3), 36-39

DHL, 1970. Gold Coast, Queensland Australia – Coastal erosion and relative problems. Report R257, Delft Hydraulics Laboratory, The Netherlands

Dyson, A., Victory, S., Connor, T., 2001. Sand bypassing the tweed river entrance: an overview. In: Proc. Coasts and Ports Conference 2001. pp. 310–315

Elko, N., Holman, R., Gelfenbaum, G., 2005. Quantifying the rapid evolution of a nourishment project with video imagery. Journal of Coastal Research 21(4), 633-645

Hamm, L., Capobianco, M., Dette, H., Lechuga, A., Spanhoff, R., Stive, M., 2002. A summary of European experience with shore nourishment. Coastal Engineering 47, 237-264

Houston, J., 1991. Beachfill performance. Shore & Beach 59(3), 15-24

Lesser, G., Roevlink, J., Van Kester, J., Stelling, G., 2004. Development and validation of a three-dimensional morphological model. Coastal Engineering 51, 883–915

Longuet-Higgins, M., Stewart, R., 1964. Radiation stress in water waves: a physical discussion with application. Deep Sea Res. 11, 529–562

McGrath, B., 1967. Erosion of gold coast beaches. J. Int. Eng. Aust. 40, 155-166

Tolman, H., 1991. A third-generation model for wind waves on slowly varying, unsteady and inhomogeneous depths and currents. Journal of Physical Oceanography 21, 782–797

Turner, I., Aarninkhof, S., Holman, R., 2006. Coastal imaging applications and research in Australia. Journal of Coastal Research 22(1), 37-48

Standard Land Use Zone Constraint Maps for Coastal NSW

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Abstract

A series of soil and landscape constraint maps which portray specific land use capability for twenty of the thirty four new standard NSW land use zones have been produced for the NSW coast. The land use zones are those defined in the Standard Instrument for Local Environmental Plans. The maps are based on the relative costs of ameliorating on-site hazards as well as residual on-site and off-site risks. The technology has been developed as part of a project undertaken for the NSW Government Comprehensive Coastal Assessment Project. It includes the objective ranking of multiple soil landscape qualities combined with digital elevation model technology, state-of-the-art erosion hazard modelling and Acid Sulfate Soil Risk Mapping. The resulting raster surfaces comprise 232 million pixels (25 x 25 m) and extend over 3.8 million hectares of the NSW Coast and provide unprecedented levels of spatial resolution for regional planning.

The results can be readily interpreted by land use planners and land managers and should contribute to environmentally sustainable land use decision making in NSW coastal regions. The Department of Natural Resources and the Department of Planning are working together to facilitate the use of these products with local government.

Key Words

urban capability, risk assessment, land use zoning

Introduction

The effective and sustainable use of land involves a matching of site conditions with the specific requirements and potential impacts of different land uses. Significant costs to the environment and society in general may result where land is used for purposes for which it is not physically capable of sustaining. Failing to use land within its capability may have serious consequences. Common environmental impacts occurring both on and off-site include foundation instability, flooding, soil erosion and sedimentation, contamination and eutrophication of water bodies, release of acid solutions from acid sulfate soils and high maintenance costs.

Once land capability is known, there is a **duty of care** for land use planners and land managers **to ensure that all land is used within its capability.**

The NSW Department of Natural Resources, working with the Department of Planning, has recently developed a new innovative approach to capability assessment called *soil and landscape constraint assessment*. This came about as part of the NSW Government Comprehensive Coastal Assessment (CCA) Project, which aimed to guide land use planning over NSW coastal lands. The new process provides information in a

quantitative format that can be readily combined with other natural resource and socio-economic assessment results as required for the CCA project.
The approach recognises the following features of land capability:

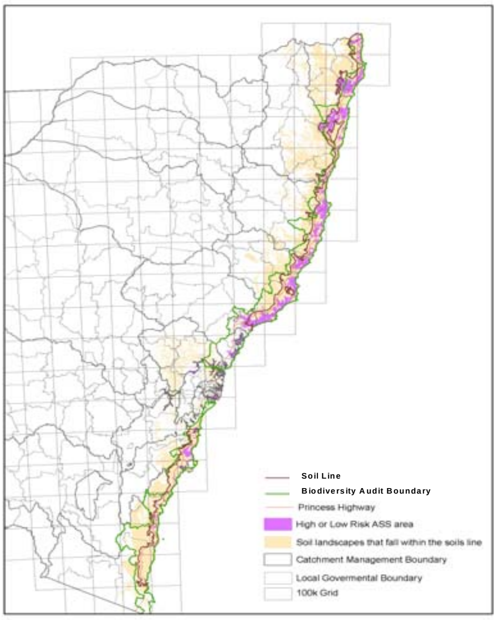
- Capability is about Risk Management. Disparate risk types can be classified
- Impacts differ between land uses
- Impacts depend on site features
- Rules to assess capability can be applied on a consistent basis over large areas
- Risk and Capability can be changed by human intervention
- Interventions can be costed
- Residual risks after intervention can be re-assessed.

Synopsis of the project

We used the capability principles to produce a series of soil and land capability constraint maps for twelve land uses along the NSW. To do this we
1) completed, digitised and strengthened Soil Landscape mapping information
2) used GIS and digital elevation model technology to portray previously described but not mapped soil landscape details and
3) allocated capability constraint scores to each soil landscape facet and
4) combined the resulting detailed soil landscape results with similar ratings for acid sulfate soil mapping and state of the art erosion hazard prediction surfaces.

Study Area and Data Sets Used

The study area encompasses 3.8 million hectares stretching from the Queensland Border to the Hunter River and then continuing along the coastal escarpment from Shell Harbour towards Eden on the South Coast. It includes the entirety of Tweed, Byron, Ballina and Coffs Harbour LGAs and is shown on figure one. It includes



floodplains, catchments of coastal lakes and the Pacific and Princes Highways. It does not generally include National Parks or State Forests.

Soil Landscapes

Soil Landscapes are areas that can be characterised by repeating patterns of soils and landforms. Because similar causal factors are involved in the development of soils and landscapes, it is possible to use soil landscape mapping to naturally group the soil and landscape qualities which effect land capability. In NSW 1:100,000 scale Soil Landscape mapping includes the comprehensive assessment of numerous parameters which effect land use and land management.

Soil Landscape Facet map production

Facets are unmapped subdivisions of soil landscapes. In many instances soil properties can be readily predicted using terrain features. Using digital elevation models we were able to disaggregate, or separately present on a map many individual soil landscape facets. This process provides an extra level of detail that cannot usually be shown directly on 1:100 000 maps.

The Soil and Landscape Constraint Assessment Process

The constraint assessment approach presented here is as outlined in NSW Department of Natural Resources (2006), Chapman & Gray (2005), Gray & Chapman (2005) and Yang *et al.* (2005).

The assessment process involves evaluating the combined effects of a number of key soil and landscape attributes. Key principles behind the approach are:

- Risk management—the risk assessment framework within the Australian and New Zealand Standards AS/NZS 4360:1999 was adopted. To quote this standard: *'Risk assessment is based on the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood'*
- Residual risk management—Residual risk is defined by AS/ANZ 4360:1999 as *'the remaining level of risk after risk treatment measures have been taken'.* For example, large residual risk levels remain on very steep sites with erodible soils in areas subject to intense summer thunderstorms. In such areas, standard soil conservation efforts often prove ineffective
- Quantitative costings—the effective costs associated with each class of constraint are estimated, facilitating the comparison of consequences of land use change. Further detail on the costing process is given in the following paragraphs.

Constraint assessment

The specific soil and landscape constraint assessments are based on the United Nations Food and Agriculture (FAO) framework. The rules for assessing capability for each land use type were bases on extensive literature review and were assessed by an expert panel

Constraint Classes

Five classes of constraint, as applying to individual attributes, are defined:

- Class 1: Very low constraint; very low residual risk; low treatment costs; straightforward or no maintenance; associated with *negligible* financial, environmental or social site costs; acceptable to society.
- Class 2: Low constraint; associated with *minor* financial, environmental or social site costs; straightforward or low maintenance; low residual risk; acceptable to society.
- Class 3: Moderate constraint; *moderate* financial, environmental or social costs beyond the standard; frequent maintenance required; moderate residual risk;

marginally acceptable to society—other factors may intervene. Each attribute falling into this class represents a cost equivalent to approximately 10% of a benchmark cost

- Class 4: High constraint; *high* financial, environmental or social costs beyond the standard; special mitigating measures are required; regular specialist maintenance; moderate to high residual risks and costs; not usually acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 30% of a benchmark cost
- Class 5: Very high constraint; risks very difficult to control even with site-specific investigation and design; very high financial, environmental or social costs beyond the standard; regular specialist maintenance may be mandatory; there is a risk that costs will be incurred even if highly specialised and costly mitigating measures are applied; residual risk is high; not acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 60% of a benchmark cost.

Cost Allocations

It can be seen that these definitions include quantitative proportions of benchmark costs (including financial, environmental and social costs) associated with each class. These benchmark costs vary for different land uses or qualities. For development uses (eg, standard residential or medium density development) the benchmark costs are the estimated initial construction costs (eg, $150 000 for constructing a standard house on an ideal site). Potential costs may accumulate over the life of the development (nominally 100 years). For agriculture, the benchmark cost is the estimated value of annual production. For domestic wastewater disposal, the benchmark cost is the estimated cost of establishing a reliable surface irrigation disposal system, valued at approximately $10 000.

Costs may be attributed to:

- Direct financial expenses for onsite actions including detailed site investigations, additional design work, special construction and impact mitigating measures, ongoing maintenance and for major repair work that may be required; and/or
- Indirect environmental and social (external) costs converted to an equivalent financial cost, which may be required if the special design and mitigating measures are not properly applied or fail. This may be based on the costs necessary to return conditions to pre-impact state, e.g. the cost of neutralising the effect of acid conditions following disturbance of acid sulfate soils, or an estimate of the loss of public amenity.

Whilst some cost estimates for treatments are relatively easy to obtain (such as those that relate directly to commonly used foundation types), there are others that are problematic (e.g. treatment of disturbed acid sulfate soils). This may be due to a large number of variables, a wide range of available treatment methods or the uncertainty of treatment success.

Each constraint class (1 to 5) has been assigned a ‘constraint score’ representing the degree of associated financial, environmental and social costs. These scores apply to individual attributes or constraints, which are added to give a total score for a particular site. Each point of the score represents an approximate additional cost of 10% of the benchmark costs as shown by Table 1.

The constraint score allows a comparison of the costs associated with the land use change at different sites. Classes 1 and 2 both have a zero cost as these represent standard desirable conditions. Classes 3, 4 and 5 receive increasingly higher scores because they indicate detrimental conditions. The higher the constraint score, the lower the feasibility and more costly the proposed land use change.

Table 1: Scoring and costing of constraint classes

(scores apply to individual attributes)

	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint
Score	0	0	1	3	6
Additional cost to land use (%)	0	0	10	30	60

Ranking and Scoring Examples

The process is based around the application of soil and landscape constraint assessment tables for each land use such as shown in Table 2. These tables take into account the concepts of risk management, residual risk and dollar costings referred to above. Each relevant attribute is assigned ranges that fall into the different constraint classes, class 1 (best) to class 5 (worst). For each soil landscape or facet, the relevant values for each attribute are applied to the tables and ranked into one of the classes, gaining the corresponding score. The individual score for all attributes are added to give an overall *constraint score* for that site and land use scenario.

The process is illustrated by the following examples of three sites, A, B and C, being considered for standard suburban residential development.

- *Site A:* current residential area, very gentle slope (2%), low erosion hazard, all other attributes–nil or minor constraints.
- *Site B:* current woodland, mod-steep slopes (25%), high erosion hazard, localised mass movement hazard, all other attributes have nil or minor constraints
- *Site C:* current pasture land, very gently inclined site (2%), high flood hazard (approx 2% probability), slight acid sulfate soil risk, clay rich soils with high shrink-swell potential and high plasticity, local seasonal waterlogging, all other attributes–nil or minor constraints.

Table 2 presents the Standard Residential Constraint Assessment table with constraint ratings applied to the various attributes for the threes different sites. Table 3 gives a summary of the feasibility scoring. The tables shows that Site A has a low constraint score of 0, with no constraints that cannot be easily overcome. Site B has high constraints (score of 7), with additional potential costs amounting to approximately 70% of original construction costs and high residual risks remaining. Site C has very high constraints (score of 12), with additional potential costs amounting to approximately 120% of original construction costs and high residual risks remaining.

The process involves advanced database and Geographic Information System (GIS) analysis. It involves querying from MS Access databases containing most of the required soil landscape information. This is followed by further sorting and analysis using MS Excel to derive preliminary results for each soil landscape or facet unit. These results are imported into ARC GIS and linked with spatial coverages for each unit. At this stage the influence of acid sulfate soils, slope and erosion hazard are added on a 25 m x 25 m pixel basis. Further details are provided in NSW Department of Natural Resources (2006) and Yang et al. (2005).

Table 2: Constraint Assessment Table for Standard Residential Development with worked examples

ATTRIBUTE	1 VERY HIGH FEASIBILITY	2 HIGH FEASIBILITY	3 MODERATE FEASIBILITY	4 LOW FEASIBILITY	5 VERY LOW FEASIBILITY	Limitation Rationale	Data Source	Theoretical Correlation[1]	Correlation using data source[1]
1. Slope %	<4 **A, C**	4-8	8-15	15-35 **B**	>35				
2. Erosion Hazard	very low	low **A, C**	moderate, high **B**	very high	_	loss of soil, pollution of waterways	based on USLE modelling	certain	confident
3. Mass Movement Hazard	not observed **A, C**	-	-	localised **B**	widespread	threat to property and life	landscape limitations table	certain	confident
4. Flood Hazard	nil **A, B**	-	<1 % events in > 100 years	1-2 % event in 50 to 100 years	>2% event in less than 50 years **C**	flooding poses a large potential threat to human life and built structures	from flood risk maps	certain	certain
5. Acid Sulfate Soil Risk	no occurrence **A, B**	low prob, >4m	high prob, >4m, low prob, 2-4m **C**	high prob, 2-4 m; low prob, <2m	high prob, >2 m	threat to aquatic ecosystems and built structures	ASS risk maps	certain	confident
6. Shrink-swell Potential	**A, B**			**C**					
Shrink-swell limitation	not recorded	-	widespread over minority of layers	widespread over majority of layers	-	ground movement, potential cracking	soil limitations table	certain	confident
Volume Expansion (%) *(worst layer)*	<5	5-15	15-30	>30	-	as above	soil material data		confident
7. Soil Strength	**A, B**		**C**						
Unified Soil Classification System *(worst layer)*	all others	CL, OH	OH, MH, OL	CH	Pt	potential deformation and or shrink-swell?	soil material data	confident	confident
Low Wet Bearing Strength	not recorded	-	widespread over any layers	-	-	potential subsidence and cracking	soil limitations table	confident	probable
Organic Soils	not recorded	-	widespread over minority of layers	-	widespread over majority of layers	potential subsidence and cracking	soil limitations table	confident	confident
8. Salinity	**A, B, C**								
Saline soil layers	not recorded	-	widespread over any layers	-	-	potential corrosion and salt attack	soil limitations table	confident	confident
Saline landscapes	not recorded	localised	widespread	-	-	as above	landscapes limitations table		confident
ECe (dS/m) *(worst layer)*	<0.1	0.1-1.0	1.0-2.0	>2.0	-	as above	soil material data	confident	confident
9. Acidity	**C**	**A, B**							
Acid soil layers	not recorded	widespread over minority of layers	widespread over majority of layers	-	-	potential acid corrosion	soil limitations table	confident	confident
pH *(worst layer to 600mm)*	>6	4.5-6.0	3.0-4.5	<3.0	-	as above	soil material data		confident
10. Waterlogging	**A, B**		**C**						
Seasonal Waterlogging	not recorded	-	localised	widespread	-	weakens foundations, corrosion & rising damp	landscapes limitations table	confident	confident
Permanently High W'table	not recorded		localised	widespread	-	as above	as above	confident	probable
11. Rock outcrop	not recorded	localised	widespread	-	-				
Overall Feasibility Score	**Site A: 0; Site B: 7; Site C: 12**								

Table 3: Example of constraint scores at three sites.

Attribute (or group of attributes)	Site A	Site B	Site C
1. Slope	0	3	0
2. Erosion hazard	0	1	0
3. Mass movement hazard	0	3	0
4. Flood hazard	0	0	6
5. Acid sulfate soils	0	0	1
6. Shrink-swell potential	0	0	3
7. Soil strength	0	0	1
8. Salinity	0	0	0
9. Acidity	0	0	0
10. Waterlogging	0	0	1
11. Rock outcrop	0	0	0
TOTAL SCORE	**0**	**7**	**12**

Using the Outputs

The results of the land capability-constraint assessment process will usually be presented as a series of hard copy and digital derivative maps for the range of land uses and qualities being considered. These identify levels of constraint associated with each use throughout the study area.

An example of a constraint map produced for the Coastal Comprehensive Assessment process is shown in Figure 1. The maps are best viewed in electronic format using GIS technology, allowing access to the comprehensive supporting data contained within the maps.

The maps are prepared on a 25 m x 25 m raster basis with constraint scores and associated data being allocated to each cell (see Figure 1). The constraint scores shown on all maps range between 0 and 12, with a green to yellow to red colour ramping representing the increasingly high scores. Although some locations actually have scores higher than 12, these are brought back to the maximum 12 score, which is effectively limiting to any land use.

Other supporting information associated with each pixel is:

- Constraint code - this presents the ratings applied to all constraints/attributes considered in the assessment process. The code begins with the rating of the most limiting factor. As an example, a code of 4_ass1ero4slo3fh1mm3sa1wl1ro2we1 indicates a limiting factor rating of 4, with acid sulfate soil rating of 1, erosion hazard rating of 4, slope rating of 3, flood hazard rating of 1, etc. Other codes may be longer than this, especially where soil material attributes are used. Figure presents another example.
- Confidence rating – this gives the level of certainty associated with each constraint score, being ranked as certain, confident, probable or uncertain, based on theoretical correlations and reliability of data

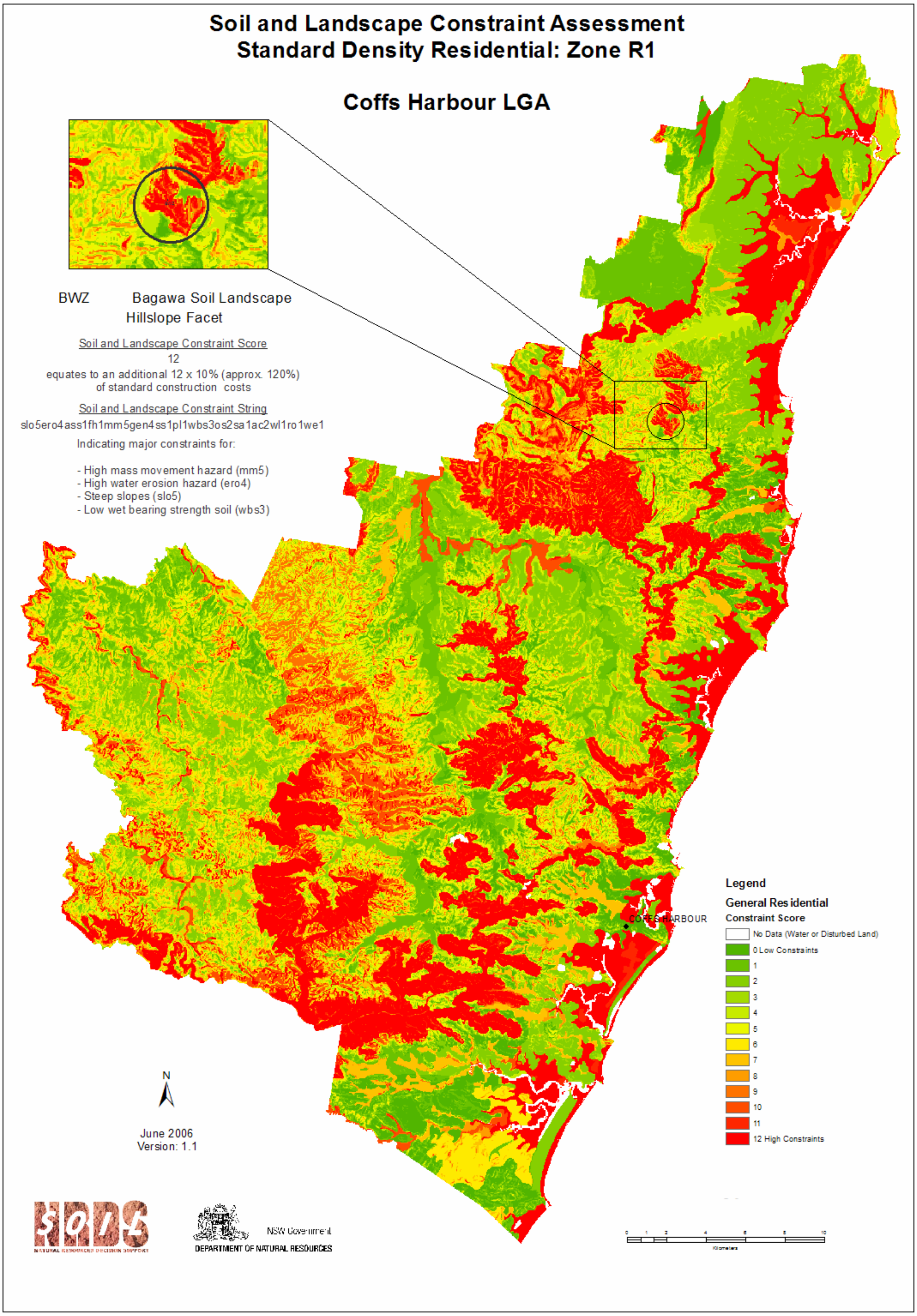
- Unit identifier – the map number, soil landscape code and facet name to which each pixel belongs is provided. For example, 9541cuz_hillslope refers to the Murwillumbah-Tweed Heads 1:100 000 map sheet (9541), Cudgen soil landscape (cuz) and hillslope facet.

Further description of the soil landscape unit may be obtained by referring to the relevant published soil landscape report.

Results and Outputs

Using the above approach we produced raster maps showing the relative cost of achieving sustainable development for twelve types of land use impacts from the Queensland Border to the Hunter River and from Shell Harbour to Bega. Each map covers 3.8 million hectares of coastal NSW. The maps are build from 232 million 25m by 25m pixels. Each pixel contains For each pixel we used rules to assess the severity of known biophysical constraints on land capability. Figure One illustrates the types of outputs produced and the information which is available for each pixel.

Figure 1: Soil and Landscape Constraint Assessment Map for Standard Residential Development (LEP Zone R1) for Coffs Harbour LGA.



Selected land uses included standard, medium density and high density residential development, cropping , grazing and on-site effluent management.

The soil landscape constraint assessment products can be readily applied to standard land use zonings as listed in the Standard Instrument (Local Environment Plans) Order 2006 under the *Environmental Planning and Assessment Act 1979*. They should assist in the effective and environmentally sustainable use of land resources in the NSW coastal zone and elsewhere in the State. Table One outlines which capability assessment methods apply to each of the standard land uses.

Table One: Standard Land Use Zones for LEPs and equivalent Physical Constraint Methods

Standard Instrument (LEP) Land Uses	**Matching Physical Constraint Assessment Method**
Zone RU5 Village Zone R1 General Residential Zone R2 Low Density Residential	Standard Residential Development
Zone R3 Medium Density Residential Zone B1 Neighbourhood Centre Zone B2 Local Centre Zone IN2 Light Industrial Zone B4 Mixed Use Zone IN4 Working Waterfront Zone SP3 Tourist	Medium Density Residential Development
Zone R4 High Density Residential	High Density Residential Development
Zone B5 Business Development Zone B3 Commercial Core Zone B6 Enterprise Corridor Zone B7 Business Park Zone IN1 General Industrial Zone IN3 Heavy Industrial	High Density Development (revised version of above table)
Zone R5 Large Lot Residential Zone RU6 Transition	Rural Residential
Zone RU1 Primary Production	Agriculture – cropping (cultivation)
Zone RU1 Primary Production	Agriculture – grazing
	Wastewater Disposal
Zone RU4 Rural Small Holdings	Rural Residential & Wastewater Disposal combined
Zone RU3 Forestry Zone SP2 Infrastructure	New tables required
Zone RU2 Rural Landscape Zone SP1 Special Activities Zone RE1 Public Recreation Zone RE2 Private Recreation Zone E1 National Parks and Nature Reserves Zone E2 Environmental Conservation Zone E3 Environmental Management Zone E4 Environmental Living Zone W1 Natural Waterways Zone W2 Recreational Waterways Zone W3 Working Waterways	No tables proposed-Land Capability assessment does not apply

Testing the outputs

A rigorous process of testing and review has been undertaken, including comparing results against existing capability ratings, field checking and review by soil surveyors familiar with different areas. This led to identification of minor errors and weaknesses and significant improvements in the process. The results now have a high degree of reliability, and are expected to be correct within one constraint point over 90% of the time.

The process is still subject to ongoing development and a further increase in reliability of results is anticipated. The results tend to give a conservative assessment, with the modelling tool being designed to give a cautious treatment of the identified soil landscape constraints.

Discussion

The soil and landscape constraint assessment maps and supporting information present a clear indication of the nature and degree of soil and land constraints affecting various land-uses at different locations in the coastal area. They provide an indication of the consequences and effective economic costs of proceeding with different land use scenarios. The presentation of constraints in terms of estimated dollar costs, such as proportions of initial development costs, facilitates interpretation by land use planners and land managers. They will also be more meaningful to development proponents and the wider community.

The information can:

- ☑ Assist urban and regional planning processes including the preparation of planning instruments such as Local Environment Plans (LEPs) and Regional Environment Plans (REPs).
- ☑ Inform decisions relating to granting of consent to development applications and applying accompanying conditions.
- ☑ Identify of appropriate specific uses and intensity of land use for land managers and advisers.
- ☑ Help determine project feasibility, appropriate design and likely environmental impact control measures at a particular site.
- ☑ Help to place developments in sites which are most environmentally sustainable

The quantitative nature of the outputs, allows the combination of the soil-landscape constraint information with other natural resource and socio-economic assessment data in the planning process. They may be readily added into multi-criteria planning analysis techniques such as TopDec (James 2001), as being applied in the CCA process.

The NSW Department of Natural Resources and Department of Planning are working together to facilitate the use of these products with local government. Constraint maps can be prepared for 20 of the 34 standard Land Use Zonings as listed in Standard Instrument (Local Environment Plans) Order 2006. These are mostly based on existing maps prepared for the CCA project and others proposed, as shown by Table 4. They will thus directly assist in the preparation of Local Environmental Plans.

The modelled constraint assessment outputs are suitable for broad scale planning purposes They cannot be relied upon with certainty for planning decisions at less than 1:100 000 scale. This is because the information depends on the original soil-landscape information. Where decisions are being made at a local level, it will be necessary to undertake more specific site investigations.

It should be noted that constraint scores between different land uses are not directly comparable. It is apparent that some land uses have resulted in relatively better scores than other land uses. This is mostly because constraint scores are dependent on the relative budget and economics of various land uses, with the costs of overcoming constraints being based on a percentage of initial development costs (or similar factor for non-development uses). For example, the costs of overcoming constraints such as erosion hazard are proportionally smaller for high density development than for standard residential.

The constraint assessment ratings do not equate with traditional capability ratings. It is assumed that land-users will ameliorate and maintain all on-site risk factors, whereas capability assessment does not. Whilst this means that more land can be developed for any particular purpose, the price of this flexibility at local government level is in ensuring compliance in ensuring that all site constraints are addressed. For any development to go ahead in any area it is essential that all constraints that limit capability be ameliorated and maintained at appropriate levels. Constraint assessment provides an indication of the relative costs involved. When comparing constraint ratings with traditional capability ratings these extra expenses must be considered.

Further information is needed to improve the costing information included with the process. Whilst some cost estimates for treatments are relatively easy to obtain (such as those that relate directly to commonly used foundation types), others are problematic. This may be due to the large number of variables, wide range of treatment methods and uncertainty of treatment success, for example in the treatment of disturbed acid sulfate soils. Information concerning the degree of cost of dealing with various landscape constraints, known as site costs in the construction industry, is difficult to obtain and requires further investigation. Where possible assessments of cost have been made (Chapman *et al.* 2004). The value of each constraint score point being equal to 10% of total development costs is arbitrary but allows for convenient calculation and spread of cost increments over the five constraint classes. A higher or lower cost unit may be more appropriate and further research is needed to confirm these costing estimates.

With sufficient resources Soil and landscape constraint maps can technically be extended to cover all coastal local government areas in NSW. The most limiting step is in soil landscape data collection and preparation. Employment of skilled contractors working to DNR supervision and specification may be one solution to this.

Conclusion

An innovative modelling process has been developed, as part of the NSW Government Comprehensive Coastal Assessment Project,. It allows the portrayal of soil and landscape constraints at unprecedented levels of resolution and expands the extent of land which can be sustainably developed- provided on-site constraints are effectively addressed. Detailed constraint maps, with comprehensive supporting data, may now be prepared for 20 of the 34 standard land use zones as listed in the 2006 Standard Instrument for LEPs. These can be readily viewed and interpreted by land use planners and land managers.
The NSW Department of Natural Resources and Department of Planning are working together to encourage the use of these products with local government. It is expected the products will assist in environmentally sustainable land use decision making in NSW coastal regions.

References

Australian and New Zealand Standards (1999), *Risk Management*, AS/NZS 4360:1999, Australian Standards, Homebush Sydney, NSW.

Chapman, GA, Gray, JM and Pavan N (2004) Urban feasibility assessment for land use planning. *SuperSoil 2004,* Australian and NZ Societies of Soil Science Conference, University of Sydney, Sydney, Australia, December 5 - 9 2004.

Chapman GA and Gray JM (2005) Urban Feasibility Assessment for Land Use Planning. *Natural Hazards: How can we Mitigate the Impacts?* Symposium, Wollongong University. Wollongong, Australia 2-5 February, 2005.

FAO (1976), *A Framework for Land Evaluation*, Soils Bulletin 32, Food and Agricultural Organisation of the United Nations, Rome, Italy.

Gray JM and Chapman GA (2005) Feasibility Assessment for On-site Wastewater Disposal*, On-Site 05 Conference,* Armidale 27-30 Sept. 2005

James D (2001), Topdec: Multi-criteria analysis for the NSW Coastal Comprehensive Assessment project, unpubl. report, Dept of Land & Water Conservation, Sydney.

NSW Government (2004*). Guidebook on Data and Methods for the Coastal Comprehensive Assessment*, NSW Department of Infrastructure, Planning and Natural Resources, Sydney.

Yang, X, Chapman, GA, Young, MA and Gray, JM (2005). Using Compound Topographic Index to Delineate Soil landscape Facets from Digital Elevation Models for Comprehensive Coastal Assessment, *MODSIM Conference*, Melbourne, 12-15 December, 2005.

IMPACTS TO THE HYDRAULIC REGIME OF GIPPSLAND LAKES DUE TO A SECOND ENTRANCE

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Abstract:

Gippsland Lakes is a system of linked lakes and channels measuring over 80km in length and generally shallower than 10m. The tidal range in the lakes is generally less than 0.15m. However, mean water level varies in response to ocean long period wave conditions and internal wind setup, and variations in mean water level within the lakes can be over 1.0m. Potential opportunities to improve flushing and water quality within the Gippsland Lakes by the introduction of a second entrance were identified by CSIRO during an Environmental Audit. The Gippsland Lakes Taskforce, through funding provided by the Victorian Government's Our Water, Our Future program commissioned a study on the influence of the second entrance on the hydraulic regime. While the impact on the overall hydraulic regime was minimal, significant localised impacts in the area of the proposed second entrance were identified. This included significant changes to current velocities and tidal variations in and around the Bunga Arm, a popular boating destination. The study concluded that the threats of the proposal far outweighed the benefits.

Introduction

In 1998, CSIRO prepared an Environmental Audit of the Gippsland Lakes (Harris et al 1998). The study found that the lakes system was potentially on the edge of significant and possibly irreversible degradation. Two of the major problems noted were nutrient inputs and associated algal blooms, although bottom water hypoxia was also noted as a major water quality concern.

Numerical modelling was undertaken as part of the CSIRO Gippsland Lakes Environmental Study (Webster et al, 2001) to assist in identifying the potential opportunities to improve water quality and reduce the incidence of algal blooms. One identified option suggested the creation of a second entrance to the Lakes to improve flushing and increase salinity beyond tolerance levels for target algal species. However, due to the approach adopted by CSIRO, the study was not able to fully assess a range of other potential impacts of a second entrance and it was recognised that a range of detailed investigations were required to fully identify the potential impacts of a second entrance.

In this paper, local and broad scale hydrodynamics of the Gippsland Lakes are presented and the impact to these of the proposed second entrance is assessed.

The Gippsland Lakes

The Gippsland Lakes (see Figure 1) are the largest navigable network of inland waterways in Australia. The Lakes are a series of large, shallow, coastal lagoons approximately 70km in length and 10 km wide. They are connected to the ocean (Bass Strait) by a narrow, maintained man-made channel at Lakes Entrance. The surface area of the lakes is approximately 360km^2 and the three main water bodies are Lakes Wellington, Victoria, and King. Lake Reeve, adjacent to the coastal dune of Ninety Mile Beach, has an area of approximately 50 km^2, but it is not tidal and is usually dry, except following periods of high rainfall and/or flooding in the lakes.

Water Quality History

The Gippsland Lakes are susceptible to eutrophication because of a number of factors including poor flushing, high nutrient loads per unit volume of receiving water, and vertical salinity stratification. Algal blooms have the potential to occur all year round, but tend to occur in autumn/late summer when long, dry periods with low river flows are followed by calm conditions conducive to stratification. Blooms sometimes also follow major rain events which are accompanied by high nutrient loads from the catchments.

Large scale blooms of the toxic, blue-green alga *Nodularia spumigenia*, have occurred about every 10 years, although blooms of unspecified algal species including dinoflagellates and diatoms occur more often. Most *Nodularia* blooms have been recorded from Lake King. High concentrations of nutrients in the water and sediments of the Lakes together with elevated temperature and low salinity, provide the conditions conducive to the formation of algal blooms.

Algal blooms in the Gippsland Lakes, and particularly those associated with the blue-green cyanobacterium *Nodularia*, have a range of significant economic, social and environmental impacts throughout the region. In response to the need to investigate strategies for ameliorating the environmental condition of the Lakes and following recommendations from the Gippsland Lakes Environmental Audit (Harris et al. 1998), the Gippsland Coastal Board (GCB) commissioned CSIRO to undertake the Gippsland Lakes Environmental Study (GLES).

The CSIRO Gippsland Lakes Environmental Study

The Gippsland Lakes Environmental Study (GLES) was a partnership between the Department of Natural Resources and Environment (NRE) and CSIRO for the Gippsland Coastal Board and other state and regional stakeholders. The project was designed to help regional managers to understand the biogeochemical function of the Gippsland Lakes to the level of primary production including the factors controlling water quality and algal blooms. It also provided an assessment of a range of management options to address the water quality issues.

The CSIRO model was developed using a 3D finite difference formulation with a focus on representation of vertical stratification, considered to be a principal influence on primary production. The vertical resolution was 0.5m, which was required to adequately reproduce observed stratification. Horizontal resolution was 500m for reasons of computational efficiency. CSIRO acknowledged that a 500m horizontal grid limits the ability to adequately represent the bathymetric features of the lakes, and state that the “horizontal resolution of 500m is not adequate to represent the narrower channels in the system”. Accordingly, topographic and bathymetric features that exist at scales below 500m are not well represented in the CSIRO model. (in particular, the entrance, Reeve Channel, Bunga Arm channels and McLennan Strait). Nevertheless, the CSIRO model was demonstrated to adequately reproduce observed bulk water movement, stratification and water quality processes.

The CSIRO Environmental Study assessed the influence of a second entrance on stratification and water quality/algal bloom dynamics. *Nodularia* are considered to have a salinity tolerance, that if exceeded, may reduce the risk of blooms occurring. The CSIRO study found that a second entrance could result in increased salinity in the lakes, and as a result the risk of *Nodularia* blooms was reduced.

The CSIRO study had successfully demonstrated that a second entrance could reduce the threat of algal blooms. However, due to the horizontal resolution, the effect of the second entrance on sub-scale processes could not be determined. Further, there was a need to assess the potential follow-on effects to other values in the Lakes.

RT2 – Changing Hydrodynamic Conditions

The Gippsland Research Co-ordination Group (GRCG) has commissioned Sinclair Knight Merz (SKM) and Water Technology Pty Ltd to undertake an assessment of the hydrodynamic, environmental, social and economic impacts of a second entrance to the Gippsland Lakes. The project was undertaken as part of the Group's Gippsland Lakes Research and Development Program.

The focus of Water Technology's investigation, which forms the subject of this paper, was detailed numerical modelling to provide improved representation of the topographic and bathymetric features of the Gippsland Lakes system. This enhanced spatial resolution enables examination of issues relating to, for example, detailed hydraulics around the existing and proposed second entrance, and improved representation of horizontal exchange mechanisms within the lakes.

Hydrodynamics

The hydrodynamic regime of Gippsland Lakes is complex, and driven by processes over a range of timescales. These processes play different roles in circulation and flushing of the Lakes. A numerical model of the Gippsland Lakes system was prepared to simulate hydrodynamics and hydraulic flushing behaviour. The model was prepared using the RMA suite of finite element models (King 2004). The advantage of the finite element formulation is that a variable mesh size can be adopted whereby fine resolution can be used in areas of highly variable geometry and/or large gradients in modelled parameters exist. In other areas with less sensitivity much larger resolution can be adopted.

The model was prepared and calibrated against measured water level behaviour throughout the lakes.

Water Levels – Long Term Response

Measured mean water level in Lake King and Lake Victoria correlates with the mean water level in Bass Strait on moderate time scales (1 week or more). These variations are in response to the effect of longer period changes in atmospheric pressure on water level and storm event set up (or set down) of the water level. The resulting longer term variation in water levels dominates the observed pattern of water level variation throughout the lakes and can result in mean water level variations within the lakes of ±0.2m about mean sea level. During large ocean surge events in Bass Strait the lakes respond with variations in mean water level range of as much as 1.0m change. These variations in mean sea level typically occur over periods of a week or more. The upper plot in Figure 2 shows water levels in Bass Strait and a derived variable mean sea level (tidally averaged). The lower plot shows water levels in Lake King and the Ocean mean sea level, lagged by 24 hours, showing significant correlation and demonstrating this long term water level response.

Water Levels – Short Term Response

Due to their size, the tidal signature in the Lakes is highly attenuated. As can be seen from Figure 3, on timescales of a tidal cycle (approx 12.5 hours) water levels in the lakes are reasonably constant with only a small tidal variation (typically ±0.1m). It should be noted however, that wind setup can result in significant variations in water level over short periods.

On the inside of the entrance channel at Lakes Entrance, the tidal range is about 0.8-1.0m, and this quickly reduces to less than 0.2m at Metung. The entrance channel, Reeve and Hopetoun channels are reasonably shallow and constricted, and result in significant attenuation of the tidal signature. Moreover, the volume of water that can pass through these entrance channels in a tidal rise is limited and once distributed over the area of the lakes results in a small change in water level.

Currents

Wind is the primary mechanism for bulk water movement within the lakes (although during periods of flooding, surface water gradients can drive fairly strong surface currents, especially near constrictions and river mouths). There are strong tidal currents near the entrance and along Reeve Channel, but in Lakes King, Victoria and Wellington, 2D and 3D flows are driven by wind stress. Figure 4 shows tidal currents near the entrance for a flooding spring tide with modelled maximum tidal velocities of up to 1.5m/s

Flushing

The lakes are approximately 360km^2 in area, and hydraulic residence times are long. Flushing mechanisms include tidal exchange, long term changes in water level in Bass Strait, and flood flows.

Figure 5 presents a time history of concentration for a conservative tracer introduced throughout the lakes, and flushed due to tidal exchange and river inflows. The average rate of reduction in tracer concentration, even at Metung just 10 km from the entrance, is very low.

During periods of low river flows, flushing times of Lakes Victoria and Lake King are at least 6 months. Over a period of about 6 months, approximately 50% of the water in Lake Wellington is replaced by river base flows from the Latrobe and Avon Rivers. However, 3D exchange mechanisms exist that can enhance or worsen flushing, and these are driven by long term water level variation in Bass Strait and wind induced circulation.

During periods of high flows and/or river flooding the residence times in the lakes reduces significantly, particularly in the upper layers. However, CSIRO (Webster et al 2001) found that flood waters tend to be restricted to the upper layers and can exacerbate stratification.

Second Entrance Concept

The Peel-Harvey estuary in southwest Australia was subject to similar environmental stresses as the Gippsland Lakes. Historically, the estuary suffered from increases in sediment and nutrient inputs from severely modified river systems. Seasonal blooms of the blue green alga *Nodularia* were a common occurrence as tidal flushing was reduced through a single shallow entrance at Mandurah. In an effort to permanently improve water quality in the inlet, a second entrance was excavated at Dawesville in 1994. The channel was cut to flush nutrients from the estuarine basins and increase salinities to levels that inhibit growth of the toxic estuarine blue-green algae, *Nodularia*.

The construction of the second entrance to the Peel-Harvey estuary has considerably improved water quality in the estuary although blooms of *Nodularia* and other phytoplankton species continue to occur in the lower tidal reaches of the inflowing rivers. Water quality in the estuary basins improved due to an increase in mixing and decrease in residence times. Other notable changes were the absence of *Nodularia* blooms since the opening of the channel, an increase in water clarity, a change in substrate from mud to sand and a significant change in biota with an increase in diversity and abundance of fish with marine affinities. An increase in mosquito numbers was noted that was attributed to increased micro-flooding caused by increased tides and some shoreline erosion was observed in sections of the estuary. More importantly, some problems continue to persist, as there has been little change in the inflows of nutrients from the catchment (Turner et al. 2004)

Against a background of poor flushing, stratification and high nutrient loads, a second entrance was suggested by CSIRO as a way to increase saline exchange with the Gippsland Lakes. It was hoped that the benefits observed at Peel-Harvey would also result in the lakes. Initial modelling by CSIRO did indeed indicate that there would be increased average salinity in Lakes Victoria and King, a key factor inhibiting *Nodularia* blooms.

Second Entrance Hydrodynamics

The finite element model described earlier was revised to include a second entrance at Ocean Grange, at the southern end of the Bunga Arm. The modified conditions were based on the second entrance option considered by CSIRO in its 2001 study. It includes an entrance channel similar in dimension to the existing entrance channel at Lakes Entrance, and the “dredging” of the Bunga Arm Channel to a depth of approximately -4.0m AHD.

Changes to the model bathymetry for the development of the second entrance option include modifications to the computational mesh to represent an entrance channel similar in dimension to that at Lakes Entrance and dredging within the Bunga Arm Channel to a depth of approximately -4.0mAHD. The bathymetry of the remainder of the model is identical to existing conditions. Figure 6 shows bathymetric detail around Ocean Grange at the site of the proposed second entrance.

Long Term Response

The second entrance has limited additional influence on long term water levels in the lakes. Generally, water levels in the Lakes continue to follow mean ocean water levels, lagged by approximately 24 hours.

Short Term Response

At Lakes Entrance, the typical spring tidal range is about 0.8-1.0m. This quickly reduces to less than 0.20m at Metung, consistent with existing conditions. However, in the Bunga Arm and nearby channels, the tidal range is around 0.60m. This range progressively reduces to less than 0.20m at the Lake Victoria side of the Bunga Arm channels.

The mean spring tidal range throughout the lakes under second entrance conditions is illustrated in Figure 7.

Currents

In the Bunga Arm, Bunga Arm Channel and Grange Channel tidal velocities up to 1.0m/s are modelled. An example of the flood tide current regime around the second entrance is shown in Figure 8.

Whereas, under existing conditions, current velocities in and around the Bunga Arm Entrance were generally much less than 0.15m/s, tidal currents of greater than 1.0m/s are predicted. Other areas where the existing condition tidal velocity is elevated (around the end of the Mitchell River silt jetties and throughout McLennan Strait) continue to exhibit higher tidal velocities characteristics as before, with no significant changes.

Flushing

The second entrance results in significantly altered but highly localised effect on the hydraulic flushing regime throughout the central part of the lakes. The central sections of Lake Victoria and the southern parts of Lake King show significantly enhanced flushing. As well, flushing in the Bunga Arm is considerably enhanced. However, further from the new entrance, at Metung and Lakes Entrance flushing characteristics are similar to existing conditions. As well, in Lake Wellington, hydraulic flushing does not appear to be significantly improved and remains consistent with existing conditions.

Figure 9 shows modelled flushing results at key locations within the lakes under second entrance conditions.

Key Hydrodynamic Impacts

CSIRO identified a range of potential benefits associated with the second entrance. This investigation, looking at other issues, found that there are a range of hydrodynamic impacts that result from the second entrance. While these impacts tend to be localised, they are considered to exhibit a range of associated negative consequences.

Tidal Range

The change in tidal range for second entrance conditions is localised in and around the Bunga Arm. Elsewhere throughout the lakes, tidal water level variations continue to be small, and although in Lake King tidal variations can double, the dominant effect of long term response to Bass Strait sea levels remains. Accordingly, the changes to tidal range in the bulk of the lakes was considered to have limited consequence.

However, in the Bunga Arm and its approach channels, tidal ranges increased from 10-15cm to up to 80cm. Figure 10 shows a comparison of water level variations in the Bunga Arm and Lake King with and without the second entrance.

The significant change in water levels in the Bunga Arm has a range of environmental consequences. Typical peak range in the Bunga Arm (including mean sea level variations) is -0.3 to +0.5m AHD, varying over timescales of 1-2 weeks. The second entrance would increase this range to -0.7 to +0.9m AHD, varying over timescales of a tidal cycle. This changed water level regime may result in a significantly altered wetting and drying regime, with new areas regularly flooded or exposed during a tidal cycle. This has consequences for benthic in-fauna, shoreline location, aquatic and terrestrial vegetation, wading bird habitat, fish habitat, and navigation etc.

Tidal Velocity

The change in tidal velocity for second entrance conditions is also localised in and around the Bunga Arm. Figure 11 illustrates increases in tidal velocity.

Tidal velocities increase from essentially nil to greater than 1.0m/s. This may result in a range of negative consequences in an area of high environmental significance. For example, bed sediment characteristics in the Bunga Arm and Grange Channel are observed to consist mainly of silty sands, which would easily be mobilised under the modified current regime and replaced with coarser beach sands (as was experienced at Peel-Harvey). This has significant implications for the benthic habitat in this area.

Further, higher tidal velocities, coupled with increased tidal range, may lead to bank erosion and loss of terrestrial habitat, currently reported to be used by a range of bird species (including little tern) as roosting and rookery areas.

The current regime at Lakes Entrance (Figure 4) and the new entrance area (Figure 8) show remarkable similarities. Boating and navigation in and around the Lakes Entrance Channels is typically only undertaken by experienced boaters as these areas are recognised for their strong currents. There is a large radius around this area where rental boats are prohibited for this reason. It is reasonable to conclude that similar restrictions would be placed on the second entrance channels. The Bunga Arm is currently a very popular boating destination and the second entrance would significantly change the navigation to this area, potentially restricting access to only experienced boaters.

Conclusion

The second entrance enhances ocean exchange in central Lake Victoria and Lake King while the tidal range in these areas is not significantly altered. The dominant hydrodynamic process continues to be mean water level variations in the ocean, and the impact of the second entrance on hydrodynamics of the central lakes is negligible. Further, the second entrance does not result in any significant change to the lakes response to long term variations in mean ocean water level (which occurs over periods of a week or more).

The hydraulic exchange of the central part of the lakes is enhanced by the second entrance. This will slightly improve the existing poor hydraulic flushing and increase the capacity to flush pollutants out of the system.

However, the second entrance results in high velocities in the Bunga Arm and associated channels and a comparatively large tidal range in the Bunga Arm. The hydraulic characteristics in the Bunga Arm and around Ocean Grange resulting from the second entrance are similar to those currently observed at Lakes Entrance and the Cunninghame Arm. This would result in a significant changes to the Bunga Arm and its associated channels including changes to bed sediments, aquatic, terrestrial and intertidal habitats, and navigation.

It is recognised that the Gippsland Lakes system is often strongly stratified, particularly in the deeper sections of Lake Victoria and Lake King. Strong tidal currents have the potential to break up stratification, but the area of increased tidal velocity resulting from the second entrance is confined to the Bunga Arm and associate channels, and it is unlikely that the current will reduce stratification more broadly within the lakes. Moreover, the second entrance could result in stronger stratification (particularly in Lakes Victoria and King) as the enhanced ocean exchange will allow more saline water to enter the system.

References

Harris, G., Batley, G,. Webster, I., Molloy, R., and Fox, D., 1998. *Gippsland Lakes Environmental Audit - Review of Water Quality and Status of the Aquatic Ecosystems of the Gippsland Lakes*. Report prepared for Gippsland Coastal Board by CSIRO Environmental Projects Office, Melbourne, October 1998.

King, I.P. 2004. *RMA2 - A Two Dimensional Finite Element Model for Flow in Estuaries and Streams*. Resource Modelling Associates, Sydney, Australia, September 2004.

SKM 2005. *RT2: Changing Hydrodynamic Conditions (Impacts of Second Entrance)* report prepared for the Gippsland Coastal Board, September 2005.

Webster, I.T., Parslow, J.S., Grayson, R.B., Molloy, R.P., Andrewartha, J., Sakov, P., Tan, K.S., Walker, S.J. and Wallace, B.B., 2001. *Gippsland Lakes Environmental Study - Assessing Options for Improving Water Quality and Ecological Function, Final Report*. Report prepared for the Gippsland Coastal Board by CSIRO, November 2001

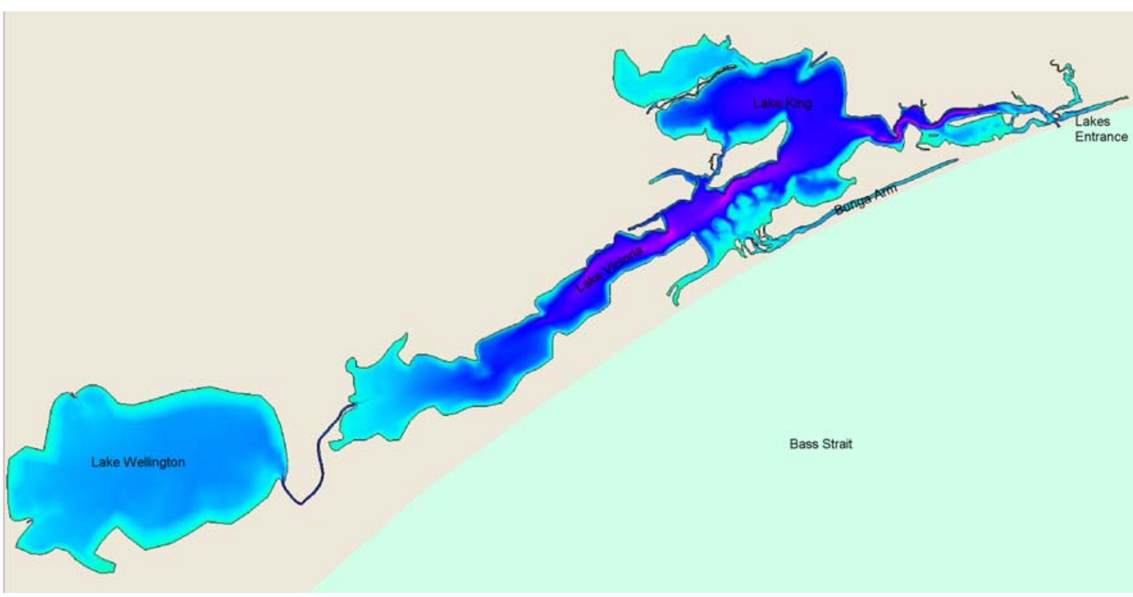

Figure 1 Gippsland Lakes

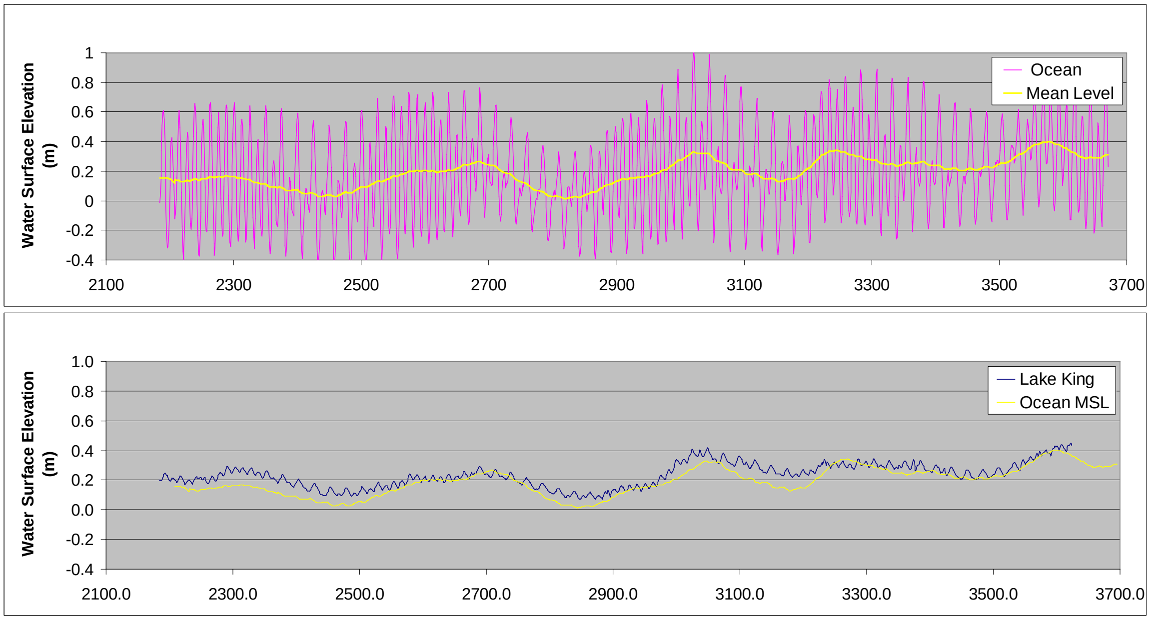

Figure 2 Long Term Response in Water Level – Bass Strait and Lake King

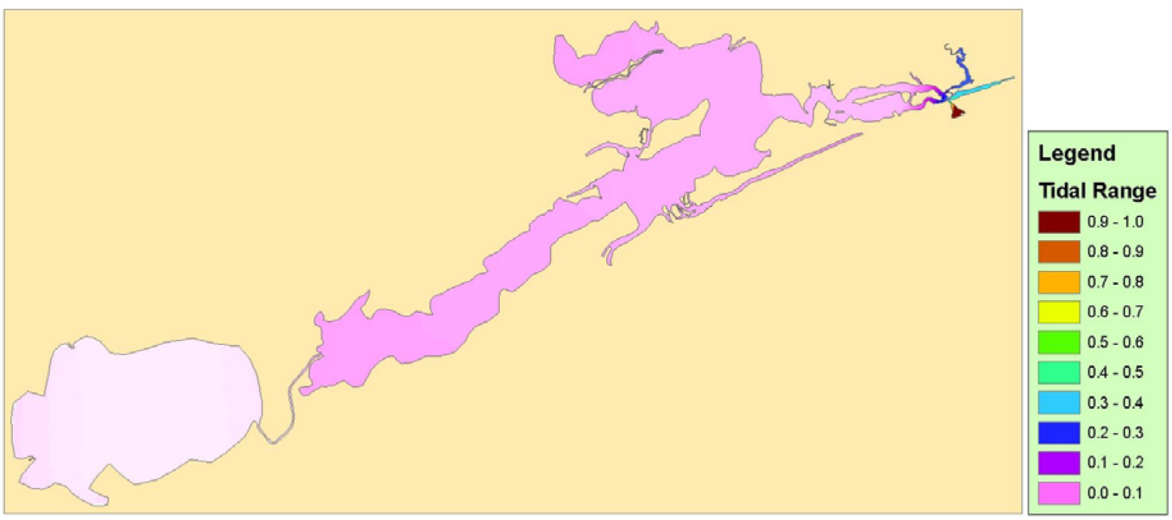

Figure 3 Mean Spring Tidal Range – Existing Conditions

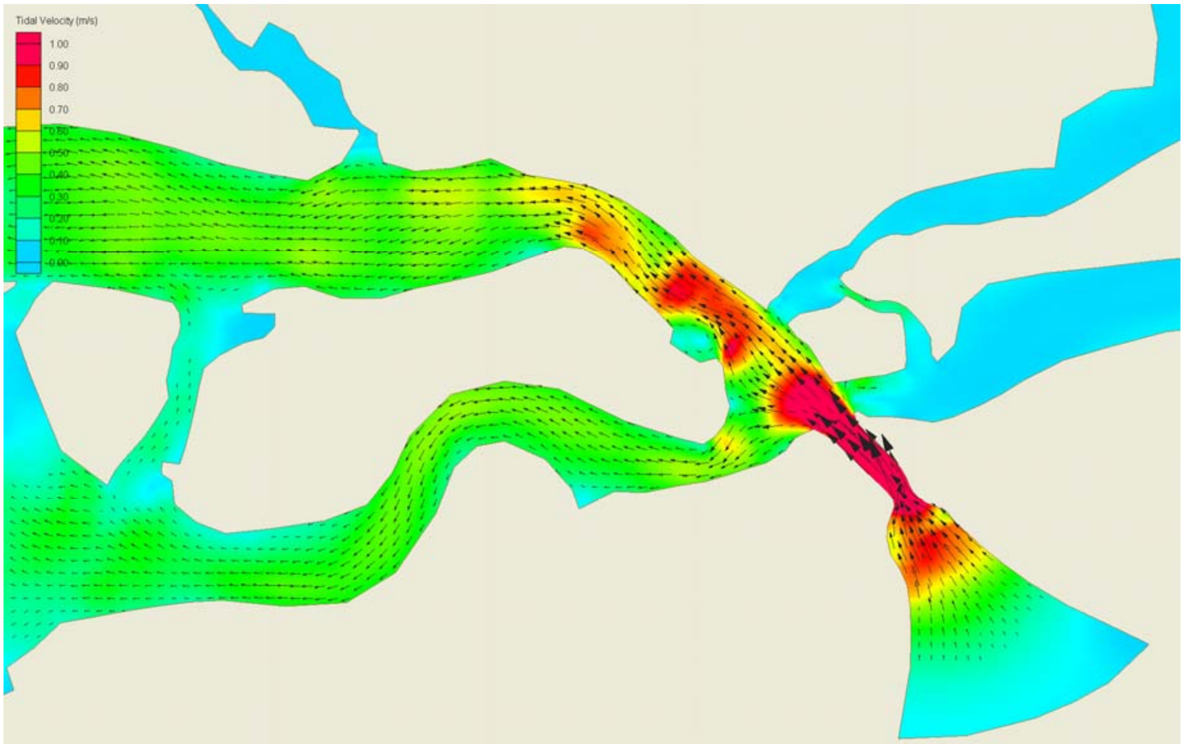

Figure 4 Spring Tide Flood Currents – Lakes Entrance

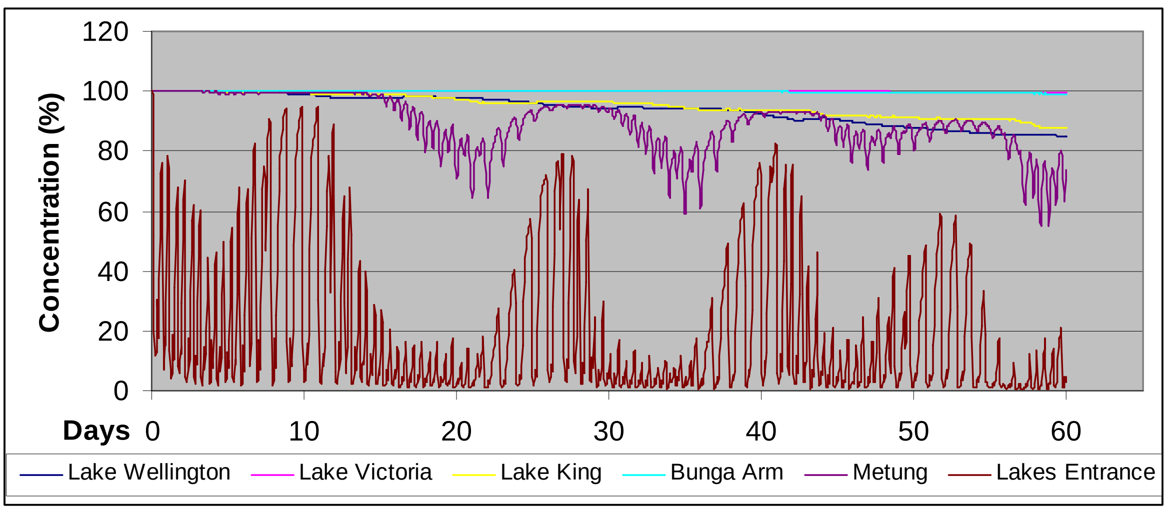

Figure 5 Flushing in Gippsland Lakes

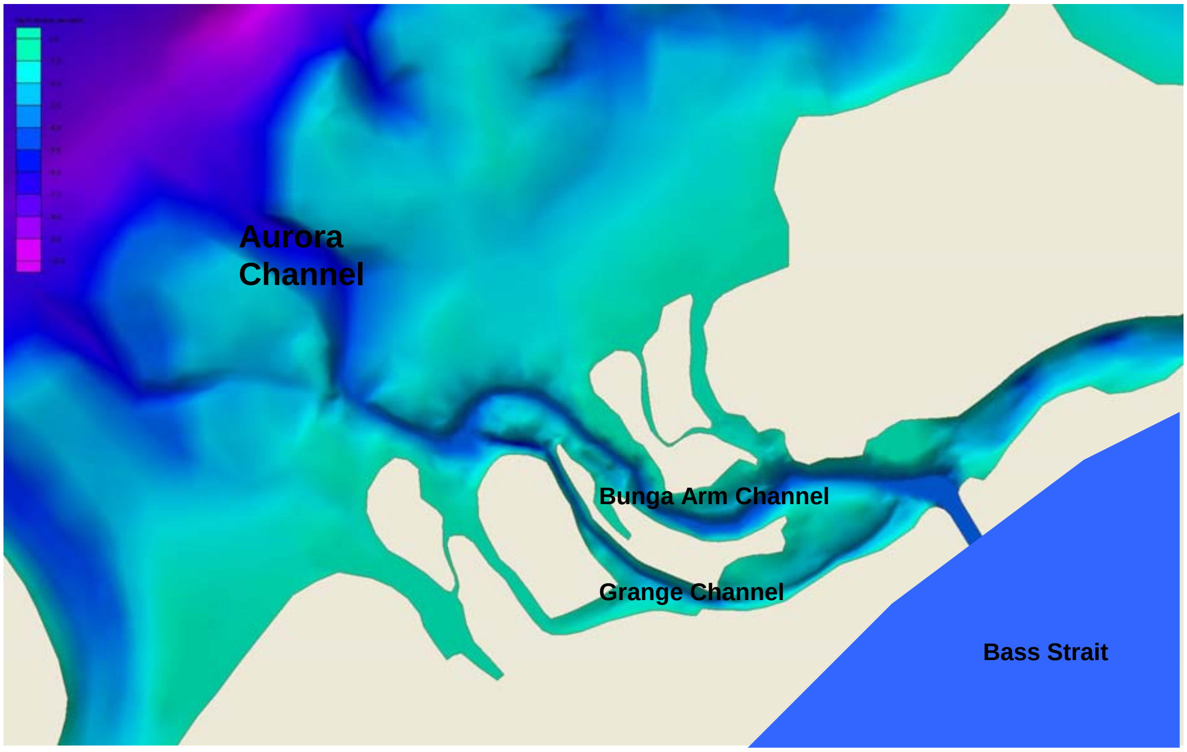

Figure 6 Revised Model Bathymetry at Ocean Grange

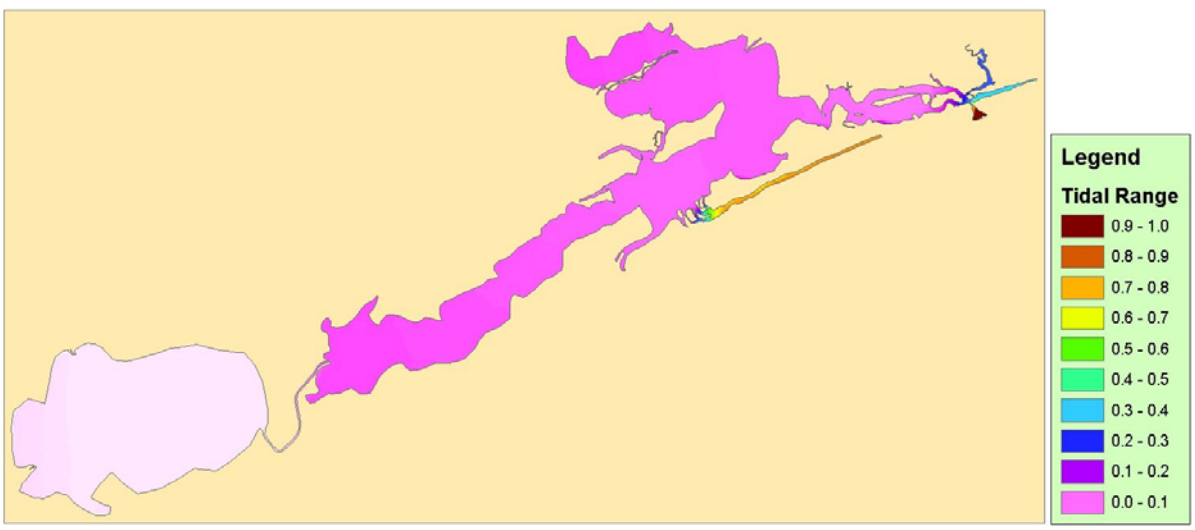

Figure 7 Mean Spring Tidal Range – Second Entrance Conditions

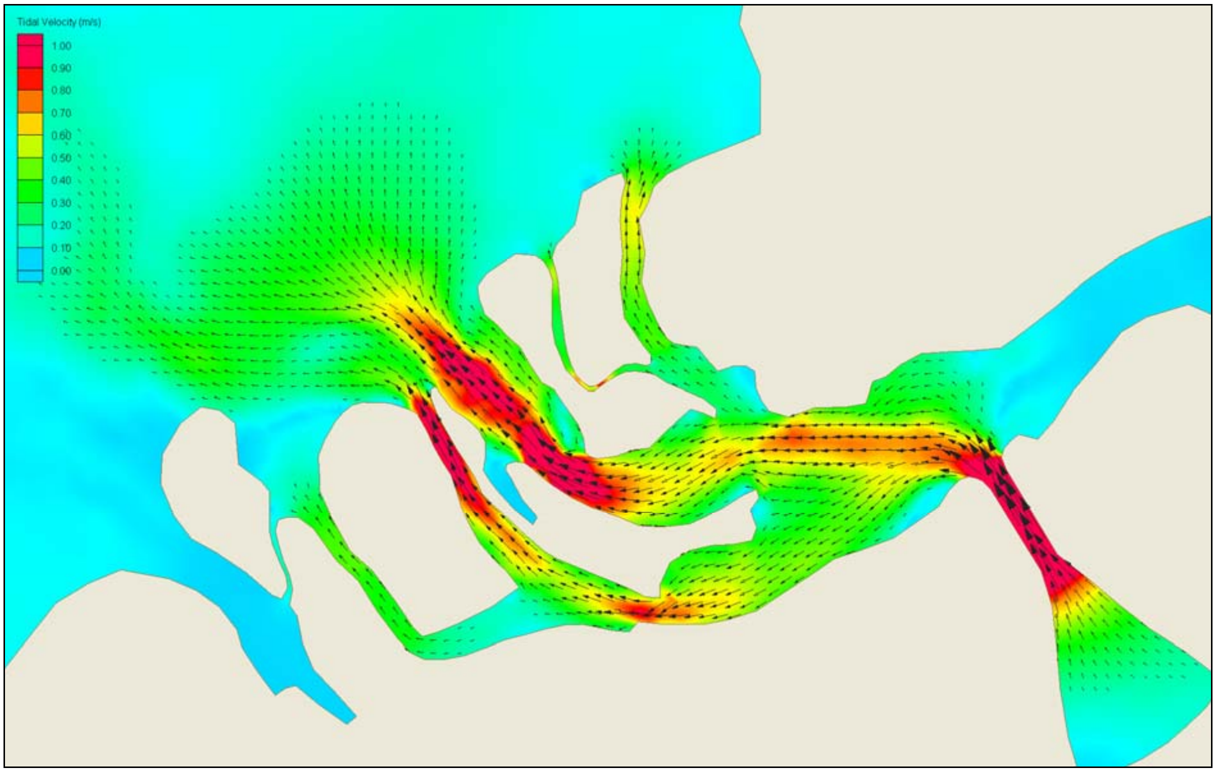

Figure 8 Spring Tide Flood Currents – Bunga Arm Entrance

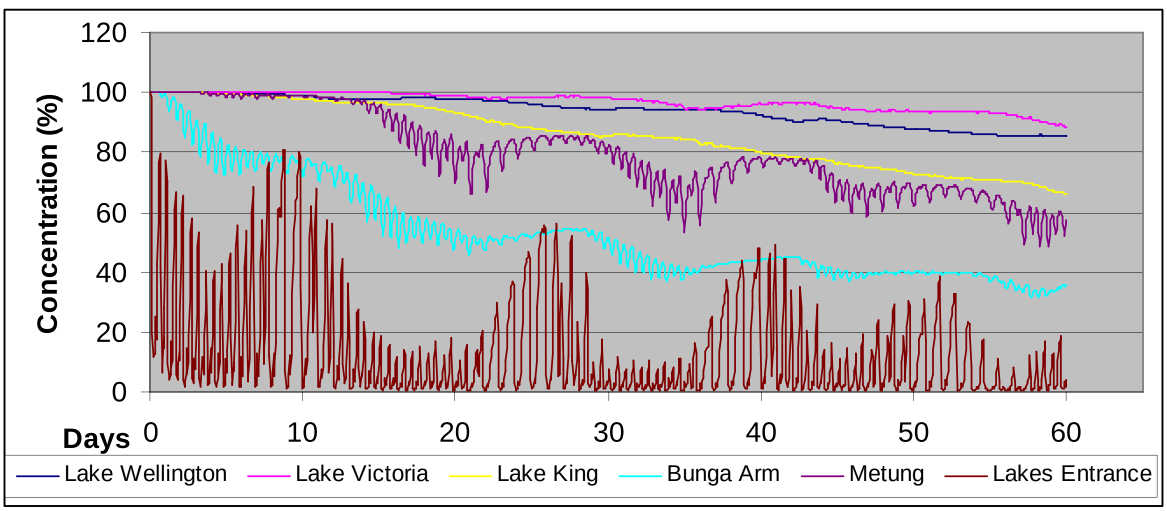

Figure 9 Effect of Second Entrance on Flushing in Gippsland Lakes

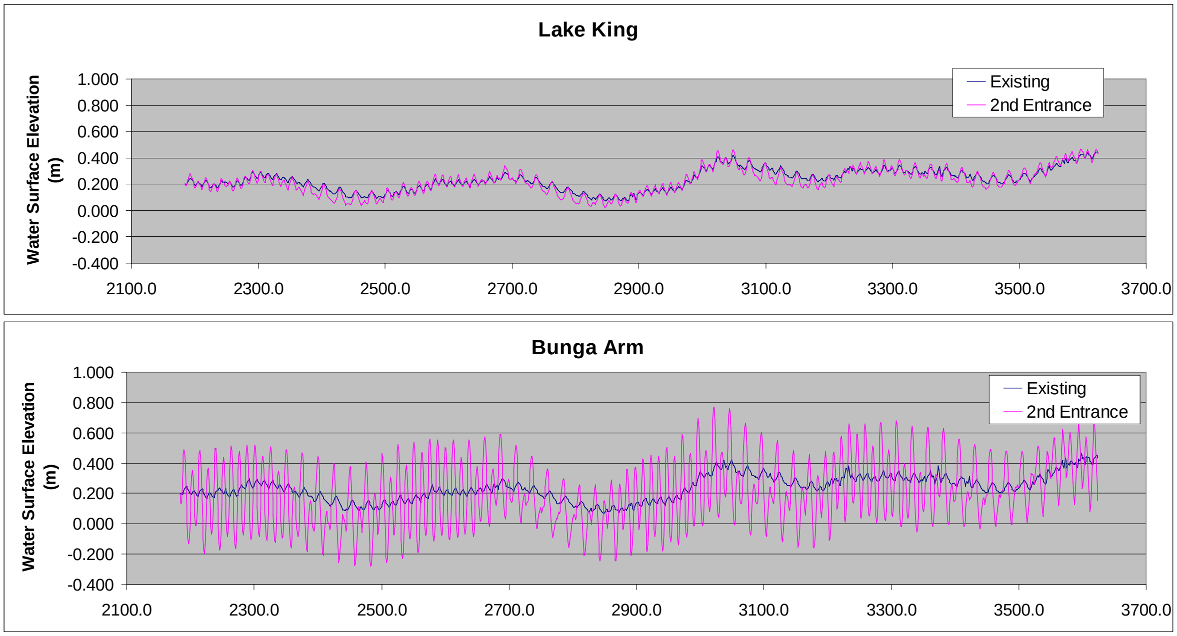

Figure 10 Comparison of Water Level Variations

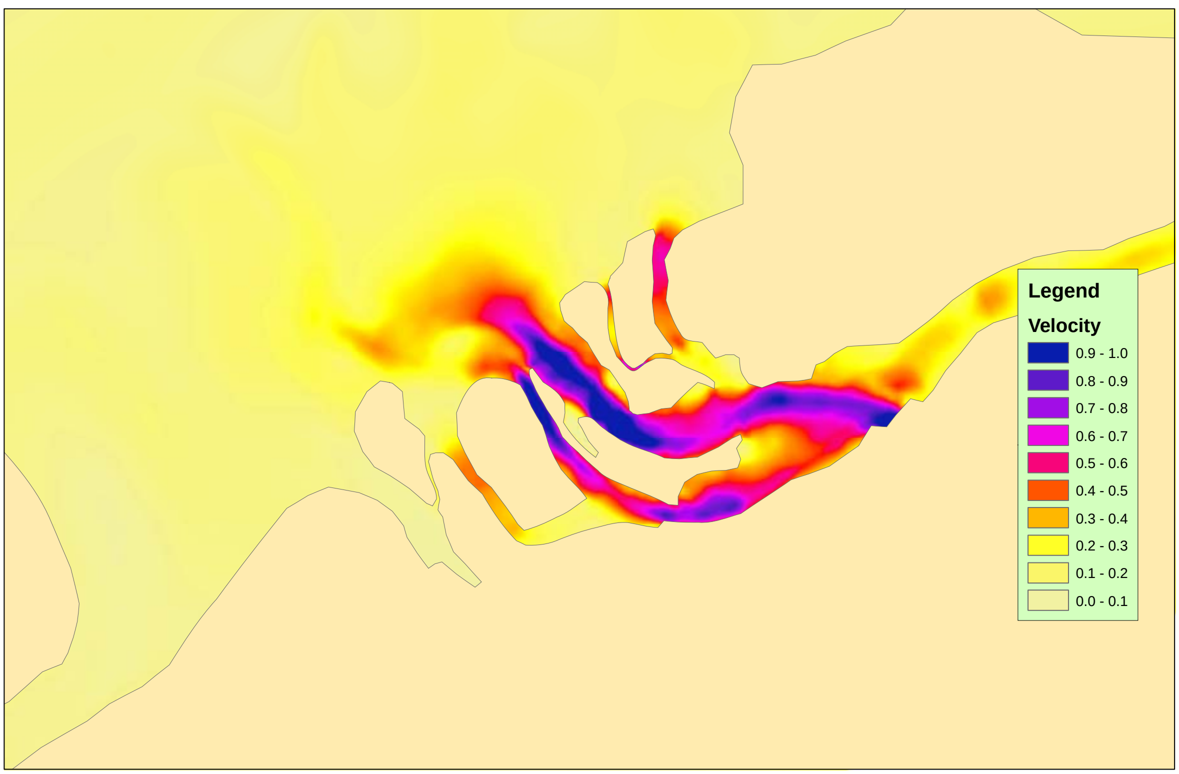

Figure 11 Increase in Flood Tide Velocity

Promoting public enjoyment of the NSW coast through the "*Coastal Lands Protection Scheme*" and the "*NSW Coastline Cycleway Program*"

Abstract

The NSW Government has been promoting public enjoyment of the coast by:

- providing $3 million per year to acquire significant coastal land for public access to the foreshore, and the protection of scenic amenity and ecological values; and

- providing $1.5 million per year to assist local councils construct a coastline cycleway that promotes a healthy lifestyle, tourism and sustainable transport.

The following paper discusses both initiatives administered on behalf of the NSW Government by the Department of Planning.

The Coastal Lands Protection Scheme

In 1973 the then State Planning Authority (SPA) announced:

> *"The Government of New South Wales is conscious of the need to ensure the protection and conservation of the coast and adjoining lands in the interest of the people of this State so that this and future generations may continue to enjoy the beauty of the coast in active and passive recreation"* (SPA 1973).

And so the seed was set for a "protection scheme" that would see the government of the day and successive governments allocate funds for acquisition of 'special' coastal lands bringing them into public ownership for all to enjoy.

History of the Scheme

In the late 1960s and early 1970s both the community and government recognised that development pressures were increasing on the coast.

In 1971 the Minister for Lands and the Minister for Local Government established an Inter Department Committee (IDC) to report on the need for special action toward preservation of the scenic and recreational assets of the coastline and to protect the coast from undesirable development. The Committee comprised representatives from the State Planning Authority, the Department of Lands and the National Parks and Wildlife Service.

In July 1973 the NSW Cabinet adopted the Committee's recommendation and introduced the *Coastal Lands Protection Scheme* under which selected coastal lands were to be publicly acquired or made subject to more stringent planning controls. Areas identified by the Scheme usually included significant coastal features such as headlands, dunes, areas around coastal lagoons and lakes particularly where the original vegetation was still dominant.

Those coastal areas in private ownership that were considered to best meet the criteria of the Scheme, being land generally fronting the coastline, were outlined as "red" lands and classified "acquisition essential". Adjoining private lands, also considered important for their visual character, but not essential for acquisition, were outlined as "yellow" lands and classified as "protection essential".

Maps illustrating the "red" and "yellow" lands were exhibited on 26 August 1973 for a six month period to enable those affected land owners the opportunity to make objections or representations. Approximately 15,554 hectares were subsequently reserved for acquisition.

The Committee also applied the Scheme principles to Crown lands not already reserved for recreation purposes. Many of these areas were later added to the National Parks estate or protected in a Crown Reserve.

Originally, the Scheme applied to lands along the NSW coast except those between Newcastle and Shellharbour (ie between Broken Bay in the north and the Minnamurra River in the south). It was considered that existing planning schemes provided satisfactory reserves for public recreation in these areas. Urban and village zoned lands were also recommended for exclusion from acquisition because of the high cost involved (IDC 1975). However, over time some lands within the excluded areas, that met the Scheme's criteria, have been added to the Scheme and/or acquired as opportunity arose.

Protection under the planning system

Lands identified under the Scheme were progressively incorporated into local government planning schemes and interim development orders. Since the introduction of the *Environmental Planning & Assessment Act 1979* (EP&A Act) the initial zonings have been transferred into council local environment plans (LEPs). Lands for acquisition have generally been zoned *7(f2) 'Environmental Protection – Coastal Lands Acquisition'* (or similar) and/or have an acquisition provision in the relevant planning instrument. The "protection essential" yellow lands were to be afforded proper safeguards and given appropriate development controls. These were generally zoned *7(f1) Environmental Protection-Coastal Protection* (Conlon 2000).

Until recently, the legislation provided for the owner of those lands identified as "acquisition essential" to formally request the Corporation (namely the Minister administering the EP&A Act) to purchase the land at an agreed market value. Recent amendments to the *Land Acquisition (Just Terms Compensation) Act 1991* & the EP&A Act, which came into effect on 28 March 2006 provides for, in part:

- an opportunity for State agencies and local councils to review reservations prior to acquisition and to rezone land reserved for public purposes where the land is no longer needed; and

- a public authority of the State not to be required to acquire land unless it is of the opinion that the owner will suffer hardship if there is a delay in the acquisition of land by the relevant authority.

The purpose of the change is to provide a single procedure for owner-initiated acquisitions throughout NSW (DoP 2006).

Various planning instruments, for example, the *NSW Coastal Policy,* support the continuation of acquiring significant coastal lands under the Scheme (NSW Government 1997). Current planning reforms require standardised acquisition clauses and zones being adopted in new LEPs. This will also provide an opportunity for lands acquired under the Scheme to be provided with consistent and appropriate zones that best reflect their current use, for example, Zone RE1 Public Recreation.

Administration of the Scheme

Over time various State government committees and/or agencies have overseen administration of the Scheme and/or provided independent advice to Government on lands to be acquired under the Scheme (viz the Coastal Council of NSW under provisions of the *Coastal Protection Act 1979,* until disbandment).

Today, the Scheme is administered on behalf of the Minister for Planning by the Coastal Branch of the Department of Planning (DoP). The main role of this Branch is to: co-ordinate the Scheme; prioritise sites for acquisition; and, assess and evaluate new sites in close consultation with DoP regional offices, state agencies and local councils.

The Department's Land Management Branch is also responsible for the negotiation and purchase of lands and transfer to management agencies for their care and control consistent with the Scheme's criteria.

Funding

The Scheme commenced with $558,228 in the early 1970s and was supplemented by $280,000 in 1974/75 under the National Estate Program. In 2003 the Government announced an annual allocation of $1.5m to 04/05 doubling to $3m since 05/06.

The amount can be varied by Treasury at the request of the Department for a one-off expense should a significant property become available that meets the Scheme's criteria. For example, Macauleys Headland at Coffs Harbour was purchased in 2000 at a cost of $3.95 million.

Recent events

Other lands not identified under the Scheme have either been offered to Government for acquisition or compulsorily acquired where inappropriate developments have been proposed. These 'opportunistic' lands are assessed against the Scheme's criteria, with recommendations made to the Minister. Ministerial approval is required for all acquisitions outside the Scheme and for any compulsory acquisitions.

For example, a 100 hectare prime parcel of land with 3 kilometres of ocean reserve frontage at Red Rock Head near Coffs Harbour was offered to the State. This magnificent parcel of land now forms part of the Yuraygir National Park.

In another instance, a site at Plantation Point, Vincentia on the foreshores of Jervis Bay was compulsorily acquired. This followed the Minister for Planning refusing a development application for a yacht club, tourist facility and residential accommodation, considered out of character with the surrounding foreshore reserve. Shoalhaven Council agreed to contribute towards the acquisition of this site.

Community members have played a significant role in influencing government to acquire sites under the Scheme. Sites at Pacific Drive Port Macquarie (Windmill Hill), Gordon Street Tathra (headland), and Captain Street and Plantation Point, Vincentia (adjacent to Jervis Bay) are a few examples of where local communities have rallied to bring these lands into public ownership with the assistance of local councils.

Reviews of the Scheme

Throughout its history land has been added to the Scheme with very little deleted. A number of reviews have been undertaken to identify what lands have been acquired and those that remain to be acquired. Improved management practices have also resulted from these reviews. A data base of sites has been developed by the Land Management Branch. Funding under the *Comprehensive Coastal Assessment* (CCA) provided the opportunity to update data and mapping through the use of geographic information system (GIS) technology. This will improve the management of the Scheme by updating and digitising the maps that identify the Scheme's priority lands. Access to this information will be available when the CCA toolkit is released.

As part of the Coastal Protection Package 2001, the Coastal Lands Acquisition Taskforce (established by the then Coastal Council of NSW) reviewed Government land acquisition programs. It looked at alternate means of protecting and enhancing those areas of the coastal zone required for the benefit of the public and the preservation of ecosystems. In December 2003 the *Coastal Land Acquisition Review* was submitted to the Minister for Planning. The Taskforce made several recommendations including the continuation of the Scheme.

Current position

Since the Scheme's inception approximately 15,314 hectares have been acquired at total cost of $65.3 million.

Since March 1995 the Scheme has acquired 664 hectares at a total cost of $22.3m. Since June 2005, two parcels of land (Port Macquarie and Vincentia) were acquired for a total cost of $3.15m. A snapshot of these acquisitions is detailed in Table 1.

Table 1 COASTAL LANDS PROTECTION SCHEME Lands acquired under the Scheme March 1995 to 19 September 2006				
LGA	**Locality**	**Area (hectares)**	**Acquisition Date**	**Total Costs including incidentals**
Far North Coast Region				
Byron Bay	North Ocean Shores	326.0	24/05/1995	$915,000
Bryon Bay	Paterson Street, Byron Bay	1.1	Jun-03	$1,350,000
Mid North Coast Region				
Clarence Valley	Red Rock Road, Red Rock	100.0	Aug-03	$2,200,000
Coffs Harbour	Arthur Street, Coffs Harbour	11.1	27/06/2000	$3,950,000
Hastings	4 Pacific Drive, Port Macquarie	0.119	Jun-04	$2,070,000
Hastings	6 Pacific Drive, Port Macquarie	0.066	16/6/06	$1,885,000
Greater Taree	Part of Mitchells Island	5.279	8/12/1995	$75,000
Lower Hunter Region				
Port Stephens	Blanch Street, Boat Harbour	0.18	Jan-99	$120,000
Lake Macquarie	Bombala Street, Dudley	0.47	Dec-02	$250,000
Central Coast Region				
Gosford	Cromarty Hill Road, Forresters Beach	0.098	12/12/1996	$321,915
South Coast Region				
Shoalhaven	Captain Street, Vincentia	1.4	Jul-03	$2,000,000
Shoalhaven	Lot 180 DP 536100 Plantation Point Parade, Vincentia *	0.391	16/6/06	$1,350,000
Eurobodalla	Cullendulla Creek, Batemans Bay	80.86	30/06/1997	$1,500,000
Eurobodalla	Off North Cove Road, Batemans Bay	28.0	25/06/2002	$1,500,000
Bega Valley	Nullica Beach, Twofold Bay	2.86	15/06/1997	$200,000
Bega Valley	off Hergenhans Road, Goalen Head	106.0	Dec-98	$2,975,000
Bega Valley	Gordon Street, Tathra	0.1793	Dec-04	$785,000
Total		**663.923 ha**		**$22,316,915**

* Shoalhaven City Council to contribute $550,000 of purchase price.

NSW Coastline Cycleway

Introduction

The NSW Coastline Cycleway (NSWCC) is a visionary project that if, completed, would eventually result in a continuous cycleway along the entire NSW coast between the Queensland border and the Victoria border. The NSW Government's support for this project, as demonstrated by its $1.5m/year funding commitment, was preceded by more than 30 years of involvement and development work undertaken by individuals, bicycle user groups and Government agencies.

This paper provides some background to the NSW Coastline Cycleway project and emphasises how the project is helping to promote the public enjoyment of the NSW coast.

The Vision

The NSW Coastline Cycleway project is based on the 30-year old vision of the now retired urban planning academic Elias Duek-Cohen. Whilst on holiday on the Coffs Harbour coast Elias imagined the benefits that would arise if it were possible to cycle safely between coastal settlements – children would have the freedom of independent travel whilst on holiday, residents would have the opportunity to enjoy active recreation in a safe environment, families without access to a car could make trips at a low cost and tourists would be able to take in the spectacular coastal scenery with a limited impact on the environment.

In planning terms the project has significant merit. The resident population along the NSW coast is growing quickly, with an additional large influx of people during holiday periods. Settlements along the coast are relatively closely spaced and generally no more than 20km apart. The cycleway will connect these settlements, providing healthy, sustainable and accessible transport and recreation opportunities for local people.

In the longer term it is expected that the cycleway will develop to form a spectacular long distance route that would attract international tourists to enjoy all or part of the NSW coastline.

As the project has developed so have the vision and the intended outcomes. The vision and outcomes as included in the project business plan state:

> *Vision*
> *To create a continuous cycle route along the NSW coast which links local communities and is identified internationally as one of the world's greatest long distance cycle rides.*
>
> *Outcomes*
> - *Improved access for local people to schools, work, shops and other local facilities;*
> - *More sustainable mode share for trips in sensitive coastal areas;*
> - *Increased participation in safe and healthy recreational activities;*
> - *Enhanced social equity by providing for independent travel for children, the elderly and people without access to a car;*
> - *More sustainable local economies through an increase in cycle related tourism; and*

- *A long distance route that is internationally recognised as one of the world's greatest cycle rides.*

Initial Planning

During the 1990s the project took a major step towards becoming a reality. Funding from the NSW Roads and Traffic Authority (RTA) and the Department of Planning (DoP) enabled Elias Duek-Cohen, supported by Bicycle NSW, to complete a series of 5 studies (Duek-Cohen 1994, 1995, 1996, 1997 and 2000) that defined a north-south route along the NSW coast. The studies were undertaken by route section (Far South Coast, South Coast, Lower North Coast, Mid-North Coast and Far North Coast) and were developed in conjunction with local Councils and other stakeholders to provide a plan for future capital works.

The route generally follows the coast, although some detours inland are necessary where estuaries or other natural barriers exist to a coastal route. The proposed route avoids major roads and highways where possible and instead utilises local streets, fire/management trails and off-street shared pedestrian/cycle paths, and uses existing bridges and ferries to cross creeks and estuaries where possible.

Route Review

The initial planning reports that were completed by Elias are now in need of review given the extent of development along the NSW coast over the last 10 years and the progress made by some Councils toward completion of the NSW Coastline Cycleway.

This review is currently underway, with activities including a series of visits to meet local Council officers and other representatives, discussions and site visits to view the route, identifying priority projects for future funding and identifying opportunities and constraints along the route alignment.

Approximately 300km (or 20%) of the total route is currently in place or funded for construction, although much of this total is made up of short sections of cycleway.

The route alignment is now captured in a geo-database, which is periodically updated to reflect modifications to the route alignment, existing sections and projects funded for future construction. This format has enabled DoP to easily share the available data with Councils and other stakeholders in order to update the relevant information and to provide information as required.

It is anticipated that in the longer term it may be possible to use the mapping that has been developed through this process to provide information to cyclists planning their ride in a web based format.

NSW Government Commitment

In March 2003 the NSW Government pledged its commitment to the NSW Coastline Cycleway project and announced $6 million in seed funding to be spent over 4 years. The funding for the cycleway is part of a wider package of coastal protection measures, as part of the Government's ongoing commitment to preserve the NSW coastline for future generations and protect it from inappropriate development.

The $6 million funding was to be spent at a rate of $1.5 million per annum starting in 2003/04. The funding was to be used for project management and for grants to non-Sydney coastal Councils to progress the route. All grants were to be matched dollar-for-dollar with Council funding.

Project Management

The NSWCC program is managed by the Coastal Branch of the NSW Department of Planning. The main tasks undertaken as part of the program include managing the funding, running the grants program, reviewing and coordinating the planning of the route with Councils, managing the Steering Committee, liaising with stakeholders and identifying opportunities to further develop and promote the project.

A project Steering Committee has been established to provide advice and promote coordination in the planning, implementation and promotion of the route. The members of the committee reflect the wide ranging interests and benefits of this type of project and include:

- Department of Planning
- Roads and Traffic Authority
- Tourism NSW
- Premiers Department
- Bicycle NSW
- Local Government and Shires Association

Grants Program

The construction of the route is now being funded through the grants program for Councils. The grants program is run annually and is open to all non-metropolitan coastal councils for projects on the defined NSW Coastline Cycleway route.

The majority of grant funding is allocated to Councils for capital works projects. However a small proportion of funding can be granted to Councils to undertake studies for route sections in sensitive coastal environments to ensure that all the necessary issues have been addressed.

The grants are assessed and prioritised based on a published set of criteria. These criteria have been developed to ensure that projects which receive grant funding provide good value for money. For example it is well understood that the existence of a gap in a cycleway is a significant deterrent to people utilising the whole length pf the adjoining cycleway facility – the ‘gap’ could present a safety hazard, lack of clarity of the route alignment or an inconvenience that people are not willing to experience, so they do not use the cycleway at all. Provision of grant funding to projects that fill gaps in the existing cycleway is therefore a high priority and has the ability to provide significant value for money as filling a critical gap often has a multiplier effect on the usage of the adjoining sections of cycleway.

To-date the grants program has been a huge success, with the DoP receiving applications for grants that far outweigh the total funding available in each year. In the first 3 years of the program a total of $4 million has been allocated to Councils by means of dollar-for-dollar grants that will result in the construction of 50 kilometres of cycleway. A summary of each of the grant funding years is provided in Table 2.

Table 2 – Summary of NSWCC Grant Allocation

Year	No of Councils receiving grants	No of projects funded	Kilometres of cycleway funded for construction	Total grant funding allocated
2003/04	13	21	25	$1.4m
2004/05	11	13	14	$1.1m
2005/06	10	10	11	$1.5m
Total	**18**	**44**	**50**	**$4m**

Grant amounts have varied from $1,250 to $515,500 and all have been matched by Council funding, bringing the total invested in the NSW Coastline Cycleway over this three year period to $8 million.

The applications for the 2006/07 round of grant funding are currently being assessed and an announcement of the successful projects is expected in the next few months.

Promoting public enjoyment of the NSW coast through the Coastline Cycleway program

The NSWCC program has the ability to promote public enjoyment of the NSW coast in a number of different areas, including the provision of a transport facility, environmental improvements, health and lifestyle benefits and promoting tourism and economic development. The benefits offered by the NSWCC in each of these areas are discussed below, along with details of a selection of projects that have been funded through the program that illustrate the issues.

Transport

Transport disadvantage by those without access to a car (such as low income earners, children and the elderly) can be acute in regional areas because local services are spatially scattered, public transport services are generally poor and main roads are often not pedestrian or cycle friendly. The NSW Coastline Cycleway will provide an alternative form of access to services by the provision of a direct coastal route avoiding the highway, made possible by the construction of simple bridges or the use of ferry crossings. The NSW Coastline Cycleway will form a spine to which other cycleway links can be connected to widen the catchment area. Importantly, many sections of the cycleway are available for use by motorised scooters for the incapacitated as well as pedestrians.

The grant program has provided funding to Coffs Harbour Council to complete a project which provides a good example of transport benefits that can be gained. The funding will be used to construct Stage 1 of the Northern Beaches Cycleway which will provide an off-road shared path that links coastal settlements to the north of Coffs Harbour. This safe cycle link will allow the community to access shops and other local services and children direct access to schools without having to travel on the Pacific Highway, thereby providing environmental, health and social benefits.

Wollongong City Council has been constructing sections of the Coastline Cycleway over a number of years and has all but completed the length from Thirroul in the north to Windang in the south. This entire stretch of cycleway is off-road and provides a vital link between residential areas, beaches, the eastern edge of Wollongong CBD and the industrial areas around Port Kembla. The cycleway is very popular with commuters and other cyclists and pedestrians undertaking local trips, in part due to the continuous and safe nature of the facility. The DoP has provided Council with two grants to date, one to extend the cycleway to the north at Thirroul and the second to complete a much needed missing link in the industrial area.

Environmental improvement

By allowing access to previously neglected or degraded areas the NSW Coastline Cycleway can act as the catalyst for environmental improvement by local residents and tourists. Trails such as this one perform this function much better than roads as trail users pass through the landscape slowly and notice opportunities for improvement. This can inspire a sense of stewardship, leading to community action, such as bush regeneration campaigns.

The NSW Coastline Cycleway may also be associated with environmental improvements if environmental remediation works, such as drainage works and tree planting, are undertaken during construction. The presence of formal paths also obviates the use of informal paths, thereby reducing erosion threats, which can be particularly significant in coastal areas.

In planning a section of the NSW Coastline Cycleway at Lake Cathie, for example, Port Macquarie-Hastings Council has prepared a comprehensive plan for the management of the coastal reserve area, including revegetation, removal of informal tracks, consolidation of access points and the inclusion of a shared path along the foreshore. DoP has provided funding to construct this shared pathway through the NSW Coastline Cycleway grants program.

Health and lifestyle benefits

Governments, communities and corporations are increasingly recognising the health and lifestyle benefits of cycling. Cycling along safe off-road paths is an accessible and active recreational activity that can be enjoyed by individuals, groups and families alike.

Developers are responding to this increased interest in recreational cycling for locals and tourists through the construction and marketing of their developments as cycle-friendly, often with strong encouragement from local Councils through the development approval process.

The NSW Coastline Cycleway grants program has provided three grants to Tweed Shire Council to construct missing links on their foreshore route that links Tweed Heads (at the Queensland border) in the north with Pottsville in the south, an area that has undergone considerable development over recent years with a significant increase in both residential and tourist populations. These grants are being used to fill vital gaps in the Coastline Cycleway to provide a continuous cycle link that will provide enormous benefits to the local community. Much of this route is now complete, with a large proportion also constructed by developers through a series of residential and hotel developments.

Completion of these missing gaps has enhanced the appeal of the cycleway with Council officers noting a marked increase in the use of the cycleway by recreational riders, tourists and commuters alike.

Tourism and economic development

Cycle tourism is a niche eco-friendly tourism market that is growing rapidly around the world. It can include day or overnight touring cyclists, mountain bikers or event cyclists, where cycling is a significant part of the visit. It is popular with individuals, families and groups attracted to the appeal of an environmentally sustainable “soft” adventure that offers personal health benefits.

The NSW Coastline Cycleway provides a good example of the potential of cycling trails to stimulate economic activity in regional NSW. Service industries such as bed-and-breakfast accommodation, bicycle hire outlets and cafes are expected tol grow to serve the tourists using the cycleway. This is already occurring in some NSW coastal regions.

Shoalhaven City Council actively promotes cycle tourism, supplying information on cycle routes, attractions, accommodation, bicycle hire/service and cycle touring trips. The DoP has provided grant funding to Shoalhaven City Council to complete a number of strategic projects on their section of the NSW Coastline Cycleway. These grants will complete projects that will fill critical gaps in the cycleway and therefore enhance the appeal of the cycleway to the many tourists that visit the area each year.

Eurobodalla Shire Council has also received a number of grants to complete sections of their cycleway. In particular Council is working closely with the local community to develop a cycleway linking Narooma with Dalmeny that will join to existing cycleways and provide an additional attraction for tourists to the area as well as providing a valuable link for local residents of these communities. Cycle tourism in the Narooma area is already popular with the local cycling group promoting routes via a website.

Far North Coast Priority Cycleway Project

The benefits of the Coastline Cycleway project can only be fully achieved through the completion of significant sections of the cycleway. The Far North Coast (Tweed Heads to Ballina) has therefore been selected to investigate as a priority demonstration project on the NSWCC as a means of showcasing the benefits that the overall project can bring to regional coastal areas.

The Far North Coast of NSW is renowned for the richness of its natural environment and a diversity of lifestyle, economic and social opportunities. These attributes have contributed to a rapid population growth over the last 30 years, which has focused on coastal centres. The region is popular with national and international visitors and has potential to develop further as a tourism destination based on its environmental features and recreational opportunities.

It is proposed that the Far North Coast Priority Cycleway will form a continuous 120km link between the regional centres of Tweed Heads and Ballina, passing through the coastal communities of Kingscliff, Pottsville, Brunswick Heads, Byron Bay and Lennox Head. It will provide opportunities and benefits for of a wide range of people:

- allowing children to cycle/walk to school safely with friends;
- providing safe and easy access to the coastline for the elderly community, perhaps in their motorised scooters;
- encouraging local families to enjoy a weekend cycle together;
- reducing traffic congestion, noise and pollution in coastal villages to provide a more pleasant environment for tourists;

- providing people without access to a car an opportunity to walk/cycle to services and jobs in local towns;
- offering an additional day activity for local tourists that allows them to explore the local area; and
- attracting international tourists to undertake overnight cycle tours, utilising accommodation and restaurants in local villages.

Tweed, Byron and Ballina Councils have been constructing sections of the NSWCC for a number of years – almost half of the 120km cycleway between Tweed Heads and Ballina already exists, mainly through urban areas. This project aims to complete the gaps in the existing cycleway in order to create a continuous link – of particular significance are the links between urban areas where there are opportunities for cyclists to enjoy the natural environment.

What needs to be done?

The Department of Planning will work with local councils, state and commonwealth government agencies, local community groups and other stakeholders to develop and progress the project to:
- identify gaps in the cycleway;
- identify funding requirements and potential sources;
- identify additional partners in the project;
- advance implementation;
- develop a signage strategy to provide way-finding and local information for cyclists; and
- market the product to national and international tourists.

Conclusions

The NSW Government is committed to promoting public enjoyment of the NSW coast through a range of initiatives including the Coastal Lands Protection Scheme and the NSW Coastline Cycleway.

The program to protect coastal lands under the Coastal Lands Protection Scheme has been in place since 1973.

Sites acquired under the Scheme provide public access and protect scenic qualities and lands of ecological significance. Public ownership of this land has enabled new coastal national parks and reserves to be created which provides for their long term management and care for public enjoyment.

There are approximately 1,500 hectares of land identified under the Scheme still to be acquired. The Department is currently reviewing these lands and other lands for ongoing protection.

The *Coastal Lands Protection Scheme* is reliant on annual funding from NSW Treasury.

The *NSW Coastline Cycleway* program is a more recent Government initiative, however it ensures that the original vision of the cycleway is now well on the way to becoming a reality. The NSW Government, Councils and other stakeholders are working together to develop and fund sections of the route. Alternative funding sources are being identified and pursued to further progress the route, particularly in relation to longer sections that provide links between coastal communities.

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References

Conlon, Julie (2000), *Coastal Council Initiatives – Waves of Change for Coastal Planning,* paper presented to the 10th Annual NSW Coastal Conference, Yamba

Department of Planning (2006), *Changes to the land acquisition process for reserved land*, Circular PS 06-000.

Duek-Cohen, Elias (1994), *NSW Coastline Cycleway: South Coast Pilot Study*

Duek-Cohen, Elias (1995), *NSW Coastline Cycleway: Lower North Coast Study*

Duek-Cohen, Elias (1996), *NSW Coastline Cycleway: Lower South Coast Study*

Duek-Cohen, Elias (1997), *NSW Coastline Cycleway: Mid North Coast Study*

Duek-Cohen, Elias (2000, incomplete), *NSW Coastline Cycleway: Far North Coast Study*

Inter-Departmental Committee (1975), *Protection of Coastal Lands in New South Wales Report* 30 June 1975.

NSW Government (1997), NSW Coastal Policy 1997: A Sustainable Future for the New South Wales Coast.

State Planning Authority of New South Wales (1973), *Protection of Coastal Lands in New South Wales*.

OPTIMIZATION OF TAX RATES TO BALANCE EFFORT AND BIOMASS IN A SINGLE SPECIES BIOECONOMIC FISHERY MODEL.

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Abstract

Tax rates are one of the most efficient mechanisms to control the utilization of fishery resources since higher tax levels can be used to control the fishing *effort* thus minimizing *biomass* depletion. This paper addresses the issue of optimizing tax levels for a targeted effort and biomass balance in a simplified single species bioeconomic model of S-Systems differential equations. This model mainly accounts for these two objectives which are antagonistic and non-linearly correlated with no single optimal solution but rather a Pareto front of solutions determined by tax rates. Fifty solution points were generated and interpolated to construct a frontier of solutions as a bi-dimensional plot. This approach enables rapid visualization of possible solutions for selection of a target effort/biomass. To optimize the tax level for the desired target an Evolutionary Computation algorithm – Differential Evolution (DE), which is an efficient heuristic method for optimization of continuous non linear solution spaces, was implemented. Results show that the DE rapidly and consistently converges on the near optimal tax rate for any selected target. Here a simple criterion of balancing effort and biomass was adopted, but more complex objective functions for optimization of hundreds of parameters can easily be incorporated. This approach provides the fishery industry with a simple method to rapidly explore and evaluate different balance scenarios and find near optimal tax levels to regulate effort and biomass.

Introduction

Around the world, fisheries represent a valuable source of income. In 2004 the world's fisheries production represented exports of US$ 71.7 billion (FAO, 2006). In Canada commercial fisheries are a critical source of employment and income (FAO, 2000). The Norwegian coastline is home to very rich fishing grounds, making Norway the biggest fishing nation in Europe (FAO, 2005). Similarly, fishing and aquaculture are Australia's fifth most valuable rural industry (DAFF, 2006).

Considerable efforts have been devoted to ensure the sustainability of these resources, particularly since around 60% of the major fisheries are either mature or evidencing declining yields (FAO, 1997). Some of the regulatory mechanisms used by governments to control the exploitation of fisheries include property rights, fishery regulating laws, license fees and taxation. Economists tend to consider taxation as being superior to other controls due to its flexibility (Clark, 1976).

In Australia, the Commonwealth and State governments are pursuing economic efficiency and effective fishery management using bioeconomic modeling and stochastic frontier analyses (Gooday and Galeano, 2003). Independent of the complexity of the model adopted for a given fishery, two main components – *biomass* and *effort* – can frequently be used to provide a handle on the dynamics of the natural system (biomass), the human system (effort) and how they interact (Charles, 2001).

In this paper an evolutionary algorithm based on Differential Evolution (Storn and Price, 1997) was developed to find optimal or near optimal tax levels for a targeted effort and biomass. A simple single species bioeconomic model of S-systems differential equations developed by Chaudhuri and Johnson (1990) was used to benchmark the approach. Since biomass and effort are negatively and not necessarily linearly correlated, there is no unique solution that simultaneously maximizes both objectives; rather, there is a Pareto set of solutions in which, for example, a gain in biomass accrues a reduction in effort. Here a *frontier* is used to enable rapid visualization of the boundaries of the solution space for a given parameterization. This allows for a tactical approach to regulating the fishery, providing a practical means for making decisions based on the current resources and constraints (Kinghorn and Sheperd, 1999; Kinghorn, 2000). The method was implemented in the software FishDE. In the next sections, the fishery model used in this work, the tactical approach/frontier and the optimization algorithm (Differential Evolution) are discussed. Following, we show some optimization runs and discuss the results. The last section covers conclusions and future work directions.

S-Systems Single Species Bioeconomic Model

For this study we used the S-systems bioeconomic single species fishery model developed by Chaudhuri and Johnson (1990). Seldom used in Economics, S-systems have been widely used in modeling biochemical systems (Voit, 2000). S-systems are a type of power-law formalism that uses nonlinear differential equations in which the right-hand sides of the equations consist of power-law functions. This formalism allows the construction of systems of differential equations suitable for the representation of virtually any differentiable nonlinear function (Savageau, 1996; Voit, 1991; Voit, 2000). An S-system with *n* dependent and *m* independent variables consists of a production and degradation term and always takes the general form

$$\dot{X}_i = \alpha_i \prod_{j=1}^{n+m} X_j^{g_{ij}} - \beta_i \prod_{j=1}^{n+m} X_j^{h_{ij}} \quad \text{for } i = 1, 2, \ldots, n. \tag{1}$$

where α_i and β_i respectively indicate the production and degradation rate constants for X_i (dependent variable) and both are ≥ 0. The indexes g_{ij} and h_{ij} are the production and degradation kinetic orders of the elements X_j (dependent and independent variables that affect the expression of X_i). The kinetic orders have activating effects of X_j on X_i if the values are positive and inhibitory effects if the values are negative (a value of zero results in X_j having no effect on X_i).

The bioeconomic model consists of a catch-rate function with exploitation regulated by taxation levels (Chaudhuri and Johnson, 1990). The dynamics of the biomass (χ) and effort (*E*) are described by:

$$\begin{aligned} \frac{d\chi}{dt} &= \gamma\chi(1-\frac{\chi}{K}) - \frac{qE\chi}{aE+l\chi} \\ \frac{dE}{dt} &= \lambda(\frac{q(p-T)\chi}{aE+l\chi} - c)E \end{aligned} \tag{2}$$

with the constants: *T* is the tax rate, *q* is the catchability coefficient, *γ* is the biotic potential of the fish species, *K* the carrying capacity of the fish species, *p* is the constant price per unit biomass of landed fish, *c* is the constant fishing cost per unit effort, λ is a stiffness (delay) parameter and *a, l, q* are positive constants (Chaudhuri and Johnson, 1990). The parameter values used are shown in table 1.

Once recast as S-systems (Voit, 2000), equation 2 becomes

$$\begin{aligned}
\dot{\chi}_1 &= \frac{\gamma}{K}\chi_1\chi_3 - q\chi_1\chi_2\chi_4^{-1}\chi_5^{-1} \\
\dot{\chi}_2 &= \lambda(p-T)q\chi_1\chi_2\chi_4^{-1}\chi_5^{-1} - \lambda c\chi_2 \\
\dot{\chi}_3 &= q\chi_1\chi_2\chi_4^{-1}\chi_5^{-1} - \frac{\gamma}{K}\chi_1\chi_3 \\
\dot{\chi}_4 &= a\lambda q(p-T)\chi_1\chi_2\chi_4^{-1}\chi_5^{-2} - a\lambda c\chi_2\chi_5^{-1} \\
\dot{\chi}_5 &= \frac{l\gamma}{K}\chi_1\chi_3\chi_4^{-1} - lq\chi_1\chi_2\chi_4^{-2}\chi_5^{-1}
\end{aligned} \tag{3}$$

with χ_1 and χ_2 corresponding to χ and *E* in equation 2 (Chaudhuri and Johnson,1990).

Table 1. Parameter values for the S-systems bioeconomic fishery model of Chaudhuri and Johnson (1990).

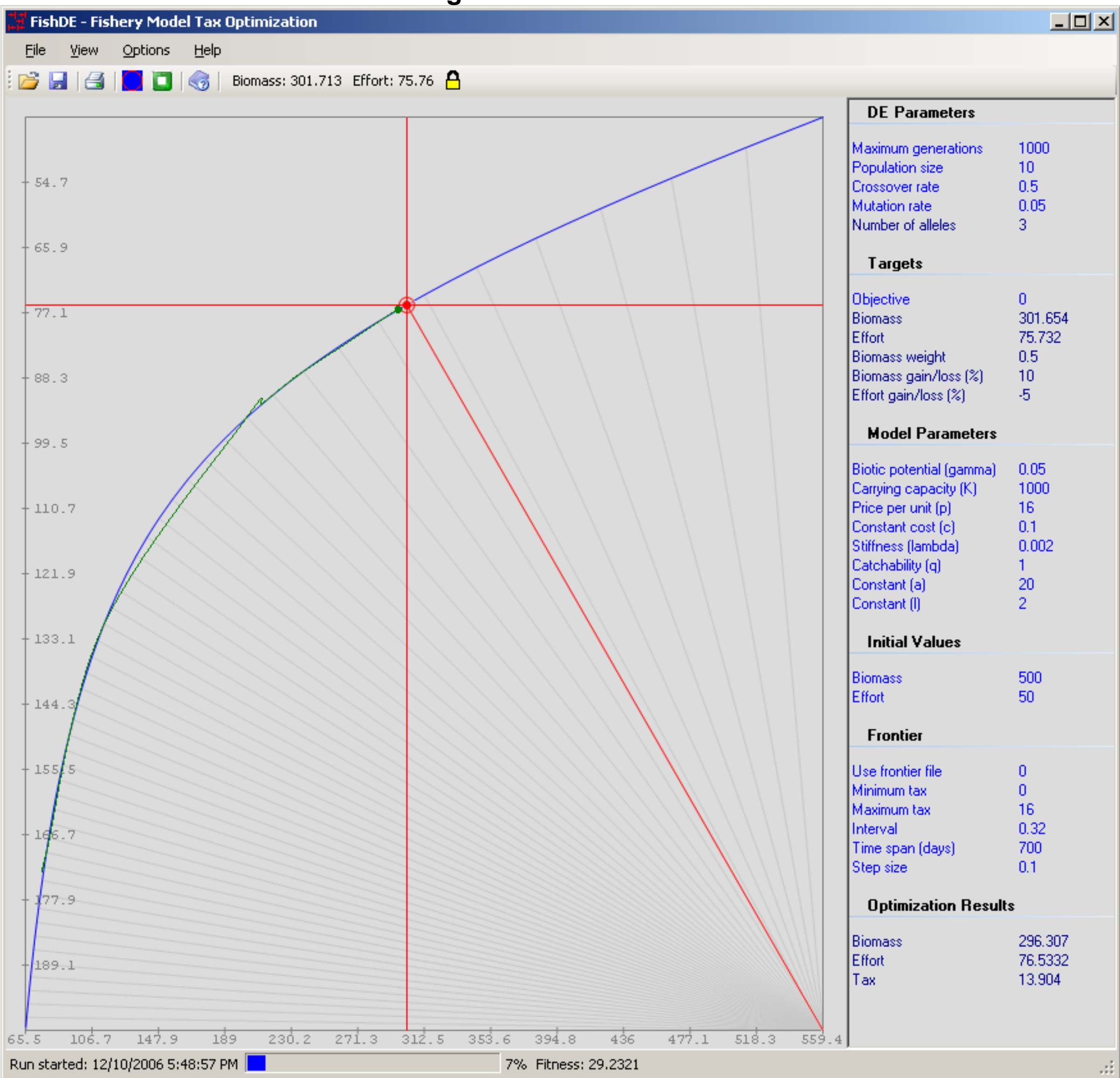
Parameter	Value
γ	0.05
p	16
K	1000
a	20
q	1
l	2
λ	0.002
c	0.1
T	$\in (0,16)$

Tactical Approach – Frontier

The tactical approach provides a practical way of regulating the fishery. The decision maker must consider the various aspects of the system as well as its constraints; the combination of which can have an almost limitless range. One way to move ahead is to evaluate the possible outcomes for different parameterizations which allow prediction of how present decisions will affect the future state of the system (Kinghorn, 2000) and drive it to the one that best meets the desired target.

To exemplify, consider the fishery model previously described (equation 3). Even though it is a very simple one, the concept can easily be extended to more complex models. Given an initial biomass and effort, tax rates can be used to direct the future state of these parameters at a time *t* in the future. To build a *frontier* of possible solutions from which to select a target (figure 1), the upper and lower bounds for tax values are used to estimate biomass and effort at time *t*. Intermediate tax values are used to obtain additional points to improve the accuracy of the frontier. The frontier in figure 1 consists of 50 points obtained between a minimum taxation of *0* and a maximum of *16* with an interval of 0.32 between points. Initial values for biomass and effort were respectively *500* and *50* with the remaining parameters as per table 1. The time span (*t*) was *700* days. Biomass and effort values at time *t* were obtained by numerically integrating the S-systems (equation 3) using a fourth-order Runge-Kutta method (Press *et al.*, 1992) with a fixed step size of 0.1. The resulting plot (*biomass X effort*) allows exploration of the possible balances between the two parameters and selection of a targeted objective.

Figure 1. Screenshot of FishDE evolving to a target. The blue curve is the frontier for an initial biomass of *500* and effort of *50* at *700* days for taxation levels between *0* and *16*. The red lines indicate the values of a targeted objective (biomass = 301.65 and effort = 75.73). The green lines show the path followed by the optimization algorithm. Run parameters can be set using the pane on the right hand side.



Differential Evolution

No optimization heuristic is superior to all others for all types of optimization problems (Wolpert and Macready, 1996). But, given that an algorithm is capable of finding optimal or near-optimal solutions, it will ideally be simple to implement, fast to converge and will not overwhelm the user with a plethora of initial settings. Differential Evolution – DE (Storn and Price, 1997), an evolutionary algorithm for global optimization over continuous spaces, meets these criteria. It can be implemented in approximately 20 lines of code, tends to converge faster than other heuristics and uses a small number of parameter settings. DE has been successfully used in a wide range of optimization problems; frequently outperforming other methods (Vesterstrom and Thomsen, 2004). DE has proven to be a robust optimization algorithm for numerical optimization of complex agricultural systems (Kinghorn, 1998; Kinghorn, 2000; Mayer *et al*., 2005).

Evolutionary Algorithms are computational heuristics that use analogies of natural selection processes such as mutation, crossover and selection to evolve a population of candidate solutions based on an objective function (Bäck *et al.*, 2000a; Bäck *et al.*, 2000b; Bäck, 2003). Differential Evolution lies on the intersection between real-valued Genetic Algorithms (Eshelman, 2000) and Evolution Strategies (Beyer and Schwefel, 2002), using the conventional population structure of Genetic Algorithms and the self-adapting mutation of Evolution Strategies. In a sense DE can loosely be viewed as a population based Simulated Annealing with the mutation rate decreasing, analogously to the temperature in Simulated Annealing (Palshikar, 2001), as the population converges on a solution.

The principle behind DE is straightforward. An initial population of candidate solutions (*chromosomes*) of user defined size is randomly generated. Each chromosome consists of a numeric vector where each position in the vector corresponds to a numeric parameter to be optimized. The size of the vector is equivalent to the number of parameters. The positions in the vector are referred to as *genes*. On initialization each chromosome is assigned a fitness value according to the objective function. The population evolves by iteratively generating a *challenger* for each chromosome using search operators. If the challenger has a higher fitness than the original chromosome, it replaces the latter in the population. If not, the challenger is discarded. Once all chromosomes in the population have been challenged (one *generation*), the process starts again with the new population formed by the surviving chromosomes of the original population and the challengers that had a higher fitness.

Differential Evolution uses discrete generations with elitism (the best solutions are always kept in the population). In each generation all chromosomes are challenged and are only replaced if the challenger has a higher fitness than the parent chromosome. Since an elitist approach is adopted, at the end of each generation the average fitness of the population should increase or remain unchanged. The process is repeated until a maximum number of generations are attained, a fitness threshold is reached or the fitness value does not improve over a certain number of generations.

In our implementation the DE uses only four user defined settings (1) number of generations, (2) population size, (3) recombination rate and (4) mutation rate. The number of generations necessary for convergence varies from problem to problem and the user should perform some test runs to get an indication of the evolution of the process. Storn and Price (1997) suggested a population size of 5 to 20 times the number of genes to be optimized. Recent work by Mayer *et al*. (2005) indicates that small populations (1.4 times the number of genes) can be considerably more efficient. In our runs populations of size 10 were used.

Differential evolution search operators

The focus of DE is numerical optimization; as such each gene in the challenger is a numeric value resulting from the interaction of the search operators and the corresponding genes in other solutions. Operators can be divided into three categories (1) parent selection, (2) recombination and (3) mutation.

Parent Selection – consider that *P1* (parent) is the chromosome to be challenged and *C1*, *C2* and *C3* are three different chromosomes randomly selected from the population. For each gene the challenger (*O* - offspring) is constructed such that with a probability equal to the recombination rate

$$O_n = P1_n \tag{4}$$

where *n* is the gene (vector position), the value of the challenged gene is simply copied into the challenger. If not

$$O_n = C1_n + M*(C2_n - C3_n) \tag{5}$$

where $M*(C2_n - C3_n)$ is the mutation value, whose magnitude is partly controlled by the mutation parameter *M*. The new gene value is simply the value of $C1_n$ plus the difference (hence "Differential Evolution") at the prevailing gene for the other two chromosomes multiplied by the mutation parameter/operator *M*. In this manner four parents are always involved in generating the challenger.

Recombination – Differential Evolution uses a simple variant of uniform recombination. A user defined rate between 0.1 and 1.0 defines the probability with which a gene value is copied from the challenged chromosome (equation 4) or a new value is generated from the other three parents (equation 5). Low recombination rates are more meticulous in exploring the solution space but are also slower. Higher rates converge faster but there is the risk of getting trapped at a local optimum. An initial recombination rate of 0.5 seems to work well in most situations (Mayer *et al.*, 2005).

Mutation – mutation in DE is a user defined real valued parameter. Differently from canonical binary Genetic Algorithms (Goldberg, 1987) in which the mutation rate defines a random uniform probability of flipping a bit at a certain position, in DE the mutation rate is self-adapting. The mutation operator *M* is used as a multiplier of the difference between two randomly selected chromosomes (equation 5) which is then added to a third random chromosome. As the optimization process converges on a solution the population variance decreases and the magnitude of the mutation reduces accordingly. This mimics the self-adapting operators used in Evolution Strategies (Beyer and Schwefel, 2002) without the complexity of having to store and calculate variance and covariance information for each gene to tune the operators.

Storn and Price (1997) suggested a mutation operator between 0.4 and 1.0. Lower rates tend to generate intermediates between the parents and higher rates tend to be extrapolative outside the bounds of the parental values (Mayer *et al*., 2005). To avoid entrapment at a local optimum, particularly at the latter stages of the optimization, Mayer *et al*. (2005) suggest changing the mutation rate to a higher level every few generations to provoke extrapolative mutation. Herein, every ten generations the rate is increased either 10 or 100 fold the original mutation rate and then back again, with a 50% probability for each.

Objective function

The objective function is the key component in the optimization algorithm. Here the focus was limited to simply optimizing tax rates for desired user-defined *targets* (figure 1). The targets are the *biomass* and *effort* outputs of the model under a given set of parameters at a future time *t*, selected from the frontier. The DE uses the objective function to assign a fitness value to the chromosomes of the population; optimization consists of minimizing the fitness function (f). Two different objective functions were used:

Objective function 1: for each candidate solution the taxation value held in a DE gene is used to numerically integrate the model (equation 3) and obtain the predicted biomass and effort, in the same manner as for the frontier. Fitness is measured as the unweighted sum of the squared error between targeted biomass (χ_t) and predicted biomass (χ_p) and targeted effort (E_t) and predicted effort (E_p), as per equation 6. The predicted values are also held in DE genes. In FishDE (figure 1) the targets are selected by simply clicking with the mouse on the desired frontier point on the plot (note that the objective is *0* in FishDE).

$$f = (\chi_t - \chi_p)^2 + (E_t - E_p)^2 \qquad (6)$$

Objective function 2: likewise the previous objective function, the taxation value held in a DE gene is used to obtain the predicted biomass and effort. The main difference lies in how the targets are selected in FishDE. Instead of selecting from the frontier, the targets consist of a desired increase or reduction in biomass and effort at time *t* in relation to the initial values. Depending on the targeted values there is no solution that can simultaneously satisfy both criteria, thus a user-defined weighting (W) scheme is used to assign the importance of biomass in relation to effort. Fitness is measured as the weighted sum of the normalized squared error between targeted biomass (χ_t) and predicted biomass (χ_p) and targeted effort (E_t) and predicted effort (E_p), as per equation 7 (objective *1* in FishDE).

$$f = W(\chi_t - \chi_p)^2 + (1 - W)(E_t - E_p)^2 \frac{\chi_t}{E_t} \qquad (7)$$

Optimization Runs

Four test cases were used to demonstrate the optimization algorithm. Results can vary across runs due to the stochastic nature of Evolutionary Algorithms; thus for each case 20 repeats were performed to test the consistency of results. The run parameters are shown in table 2. For the first test case, objective function 1 was used; for the remainder, objective function 2 was used.

Table 2. Run parameters used for the four test cases.

DE parameters			
Number of generations	1000		
Population size	10		
Crossover rate	0.5		
Mutation rate	0.05		
Number of alleles	3		
Frontier			
Min. tax	0		
Max. tax	16		
Number of points	50		
Time span	700		
Step size	0.1		
Test case 1	**Initial Value**	**Target**	
Biomass	500	301.65	
Effort	50	75.32	
Test cases 2, 3 and 4	**Initial Value**	**Target**	**Change**
Biomass	500	550	10%
Effort	50	60	20%
Biomass weight			
Test case 2	0.5		
Test case 3	0.99		
Test case 4	0.01		

A summary of run results are shown in table 3. For the first test case the target was selected from the frontier, thus there is a possible solution. All runs evolved optimal or near optimal solutions (evolved tax = 13.96) with the average across runs diverging 0.002% (biomass) and 0.068% (effort) from the global optimum. For the worst case the evolved solution was 0.05% and 0.08% from optimal, which indicates that the DE is consistent in its results even though the method is stochastic.

For the other three test cases due to the dimensionality of the problem there is no solution that will simultaneously satisfy the targeted biomass and effort, thus a compromise solution biased by the relative target weights is sought. Here we illustrate using an equal weight for biomass and effort (test case 2 – weights 0.5/0.5) and the extremes: test case 3 – weights 0.99/0.01 and test case 4 – weights 0.01/0.99. For test case 2, evolved solutions are an intermediary point on the frontier between intersects on the *x* axis (biomass = 550) and the *y* axis (effort = 60) in figure 2. The juggle between the conflicting targets yields a greater spread in the results with a variance of 1.413 (variance in test case 1 = 0.0035). Evolved taxation levels varied between 15.84 and 15.86. The effect of the weights on the optimization is easily seen in test cases 3 and 4, with the solutions consistently converging on the targeted biomass (test case 3) for a tax of 15.94 and effort (test case 4) for a tax of 15.05, in detriment of the other target.

Table 3. Optimization results for the 4 test cases showing the target values for biomass and effort, the values of the best evolved solution, the worst evolved solution and the average values across 20 runs.

Test Case 1	Biomass	Effort
Target	301.65	75.73
Best	301.65	75.7
Worst	301.5	75.67
Average	301.64	75.68

Test Case 2	Biomass	Effort
Target	550	60
Best	537.27	46.15
Worst	534.76	45.87
Average	535.47	46.06

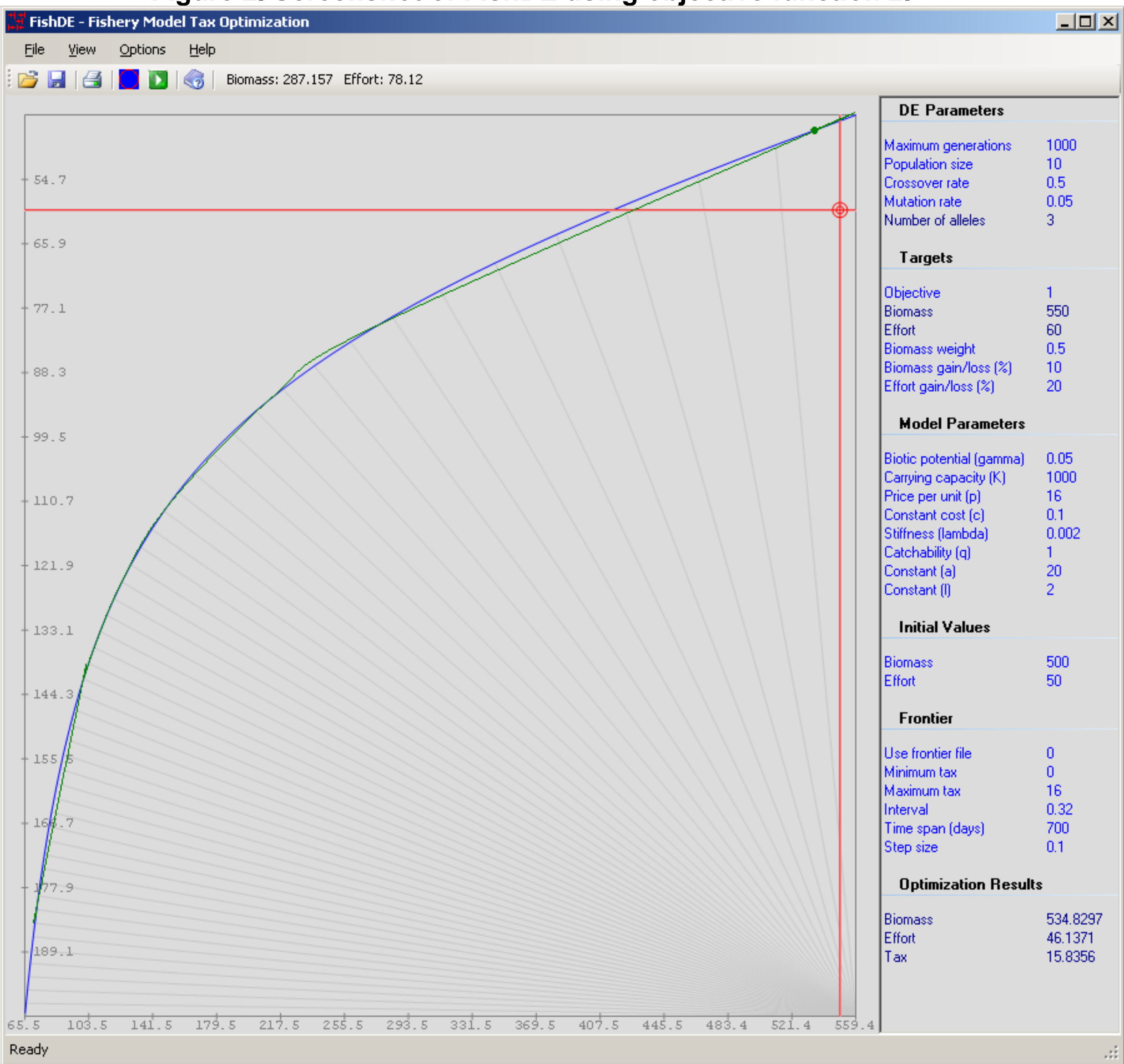
Test Case 3	Biomass	Effort
Target	550	60
Best	549.96	44.59
Worst	549.01	44.5
Average	549.6	44.53

Test Case 4	Biomass	Effort
Target	550	60
Best	424.8	59.79
Worst	423.46	58.96
Average	423.8	59.17

The illustrative examples discussed are clearly trivial and could easily be solved analytically (or even by geometry once the frontier has been obtained) since there is a single parameter to optimize (tax) and only two dimensions (biomass and effort). Nevertheless the framework is set for more complex problems. For example, adding a second control mechanism (catchability, q in equation 3) will expand the dimensionality of the search space. Using the same parameters as test case 2 and optimizing for tax rate and catchability (no constraints on q), the DE evolves to a biomass of *550.16* (target *500*) and an effort of *60.47* (target 60) for a tax rate of *14.87* and catchability *0.88* (average values across 20 runs). Thus optimal or near optimal solutions can be found by regulating taxation levels and catchability (restrictions on fishing limits, seasonality, etc). Additional parameters (and constraints) can easily be added without changes to the DE itself.

An important point in the last example is that the frontier used was the same as for the other runs, but it is not rigorously valid any longer. The frontier indicates the boundary values of optimal solutions (Pareto set); each additional parameter and respective constraints will modify its shape and limits. For a large number of parameters the frontier cannot be construed analytically but can be obtained using the DE to evolve the two extreme and a given number of intermediate points. Since an accurate frontier can be very time consuming to build, a better approach is use a *dynamic frontier* (Kinghorn and Gondro pers. comm.): start with a coarse frontier evolved in a relatively short time and as solutions extrapolate the frontier boundaries these new points are added to the frontier and points that are no longer consistent with the curve are discarded.

Figure 2. Screenshot of FishDE using objective function 2.



Conclusions and future work

In this paper we discussed a tactical framework for regulating a single species fishery model. This approach allows easy visualization and exploration of the solution space through the use of a frontier of possible solutions. We implemented an Evolutionary Algorithm – Differential Evolution – to find optimal or near-optimal tax levels that can be used to obtain a targeted biomass and effort at a defined future time. To develop/test the method we used a simple single species bioeconomic model (Chaudhuri and Johnson, 1990) with a single control mechanism (tax rate) to regulate the levels of biomass and effort in the fishery. Our examples show that the algorithm can easily and consistently converge on near-optimal solutions. The DE can be used to optimize additional parameters (for example catchability rates) without the need to modify the algorithm itself. This makes the method particularly flexible for testing different objective functions and other models.

In future work this framework will be used on a more complex single species bioeconomic model for the Northern Prawn Fishery (NPF) in Australia which includes several additional parameters and constraints. The frontier for the NPF model cannot be obtained deterministically, thus the DE will be used to build the frontier points using a *dynamic frontier* approach.

Acknowledgments

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References

Bäck, T., D. B. Fogel and T. Michalewicz., Eds. (2000a). *Evolutionary Computation 1: Basic Algorithms and Operators*. Bristol, Institute of Physics Publishing.

Bäck, T., D. B. Fogel and T. Michalewicz, Eds. (2000b). *Evolutionary Computation 2: Advanced Algorithms and Operators*. Bristol, Institute of Physics Publishing.

Bäck, T., Ed. (2003). *Handbook of Evolutionary Computation*. Bristol, Institute of Physics Publishing.

Beyer, H.-G. and H.-P. Schwefel (2002). Evolution strategies: A comprehensive introduction. *Natural Computing 1*(1), 3-52.

Charles, A. T. (2001). *Sustainable Fishery Systems*. Oxford, Blackwell Science.

Chaudhuri, K. and T. Johnson (1990). Bioeconomic Dynamics of a Fishery Modeled as an S-System. *Mathematical Biosciences 99,* 231-249.

Clark, C. W. (1976). *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*. New York, John Wiley & Sons.

DAFF (2006). *Fisheries.* Retrieved September 27, 2006, from http://www.daffa.gov.au/fisheries

Eshelman, L. J. (2000). *Genetic Algorithms. Evolutionary Computation 1: Basic Algorithms and Operators*. Bristol, Institute of Physics Publishing: 64-80.

FAO (1997). *Review of the State of World Fishery Resources: Marine Fisheries*. Food and Agriculture Organization of the United Nations, Rome.

FAO (2000). *Information on Fisheries Management in Canada*. Food and Agriculture Organization of the United Nations, Rome.

FAO (2005). *Information on Fisheries Management in the Kingdom of Norway*. Food and Agriculture Organization of the United Nations, Rome.

FAO Fishery Information, Data and Statistics Unit. (2006). *Fisheries commodities production and trade 1976-2004*. FISHSTAT Plus – Universal software for fishery statistical time series. Food and Agriculture Organization of the United Nations, Rome.

Goldberg, D. E. (1987). *Simple genetic algorithms and the minimal, deceptive problem. Genetic Algorithms and Simulated Annealing*. L. Davis. San Mateo, Morgan Kaufmann, 74-88.

Gooday, P. and D. Galeano (2003). A Framework for Assessing Economic Performance - Fisheries Management. *ABARE – eReports,* 03.

Kinghorn, B. P. (1998). *Managing genetic change under operational and cost constraints*. 36th National Congress of the South African Association of Animal Science, University of Stellenbosch.

Kinghorn, B. P. and R. K. Shepherd (1999). Mate selection for the tactical implementation of breeding programs. *Assoc. Advmt. Anim. Breed. Genet*. 13, 130-133.

Kinghorn, B. P. (2000). The tactical approach to implementing breeding programs. *Animal Breeding - Use of New Technologies*. B. P. Kinghorn, J. H. J. Van der Werf and M. Ryan. Sydney, University of Sydney Veterinary Post Graduate Foundation.

Mayer, D. G., B. P. Kinghorn and A. A. Archer (2005). Differential evolution - an easy and efficient evolutionary algorithm for model optimisation. *Agricultural Systems* 83(3): 315-328.

Palshikar, G. K. (2001). Simulated annealing: A heuristic optimization algorithm. *Dr Dobbs Journal 26*(9), 121-124.

Press, W. H., B. P. Flannery, S. A. Teukolsky and W. T. Vetterling (1992). Runge-Kutta Method and Adaptive Step Size Control for Runge-Kutta. Numerical Recipes in FORTRAN: *The Art of Scientific Computing*, 2nd ed. Cambridge, Cambridge University Press, 704-716.

Savageau, M. A. (1996). *Power-law formalism: a canonical nonlinear approach to modeling and analysis*. 1st World Congress of Nonlinear Analysts, Berlin, Walter de Gruyter.

Storn, R. and K. Price (1997). Differential Evolution - a simple and efficient heuristic for global optimization over continuous spaces. *Journal of Global Optimization 11*(4), 341-359.

Vesterstrom, J. and R. Thomsen (2004). A comparative study of differential evolution, particle swarm optimization, and evolutionary algorithms on numerical benchmark problems. *CEC 2004* (2), 1980-1987.

Voit, E. O. (1991). *Canonical Nonlinear Modeling: S-System Approach to Understanding Complexity*. New York, Van Nostrand Reinhold.

Voit, E. O. (2000). *Computational Analysis of Biochemical Systems: A Practical Guide for Biochemists and Molecular Biologists*. Cambridge, Cambridge University Press.

Wolpert, D. H. and W. G. Macready (1996). *No Free Lunch Theorems for Search*. Technical Report SFI-TR-95-02-010, Santa Fe Institute.

THE COMPREHENSIVE COASTAL ASSESSMENT TOOLKIT AND ITS APPLICATION TO COASTAL STRATEGIC PLANNING

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Abstract

The Comprehensive Coastal Assessment (CCA) was initiated as part of the NSW Government's Coastal Protection Package. The aim of the CCA was to provide information and analysis tools to support planning and management of the coast's environmental, social and economic values.

The program has recently drawn to a close and the information is planned for public release in late 2006. Some 27 projects were funded to assemble information and develop assessment methods for various coastal values. The new information and methods have been developed in a defined structure presented as the "CCA information pyramid" to assist coastal planners and managers make decisions in a strategic and integrated way using the best information available.

The key components of the CCA information pyramid are:
- approximately 140 new data sets including a diverse range of GIS information;
- tools and methods to measure impacts on various environmental, social and economic criteria; and
- tools that integrate environmental, social and economic information including a guide and framework on how to do this for any planning challenge.

All of the above information, project reports and guides are referred to from here on as the 'CCA Toolkit'. The Toolkit is being made available on an easy to use double DVD set that will provide an invaluable resource to coastal planners and managers and to all people with an interest in the NSW coast.

Key words: Comprehensive Coastal Assessment, Strategic Planning, Integration, Multi-Criteria Analysis.

Introduction and Background

The NSW coastline has diverse and abundant natural, cultural and economic values. People are attracted to this diversity and the lifestyle that these values present to visitors and residents. However, the coast is under considerable pressure, with almost 250,000 more people expected to be living in coastal areas, outside Sydney, Newcastle and Wollongong, by 2031.

The CCA Toolkit forms part of the NSW Government's Coastal Protection Package. It was initiated to provide information and tools to help analyse and plan for environmental, social and economic values of the NSW coast. It is the compilation of work of several State agencies (Departments of Planning, Natural Resources, Lands, Primary Industries, Environment and Conservation, and State and Regional Development) over a number of years to bring information together to help councils, government agencies and other users undertake strategic land-use planning. The CCA study area covers local government areas north of Port Stephens and south of Shellharbour inclusively. Further detail about the background to the CCA can be found in previous NSW Coastal Conference papers (Donnelly et al, 2003 and Green et al, 2004).

Effective planning across environmental, social and economic values requires some level of integration between environmental, social and economic values so that trade-offs and areas of mutual benefit can be identified and made transparent to all interested parties in the community. Consequently, much of the CCA's effort has been directed towards how to effectively integrate disparate information for strategic land use planning at both the regional and local government level, supported by the provision of quality data, methods and decision support tools. However, CCA methods and information can also be used to inform higher level State planning and broader policies such as the NSW Coastal Policy (1997). The relationship between the CCA and policy and planning is outlined conceptually as a pyramid in Figure 1.

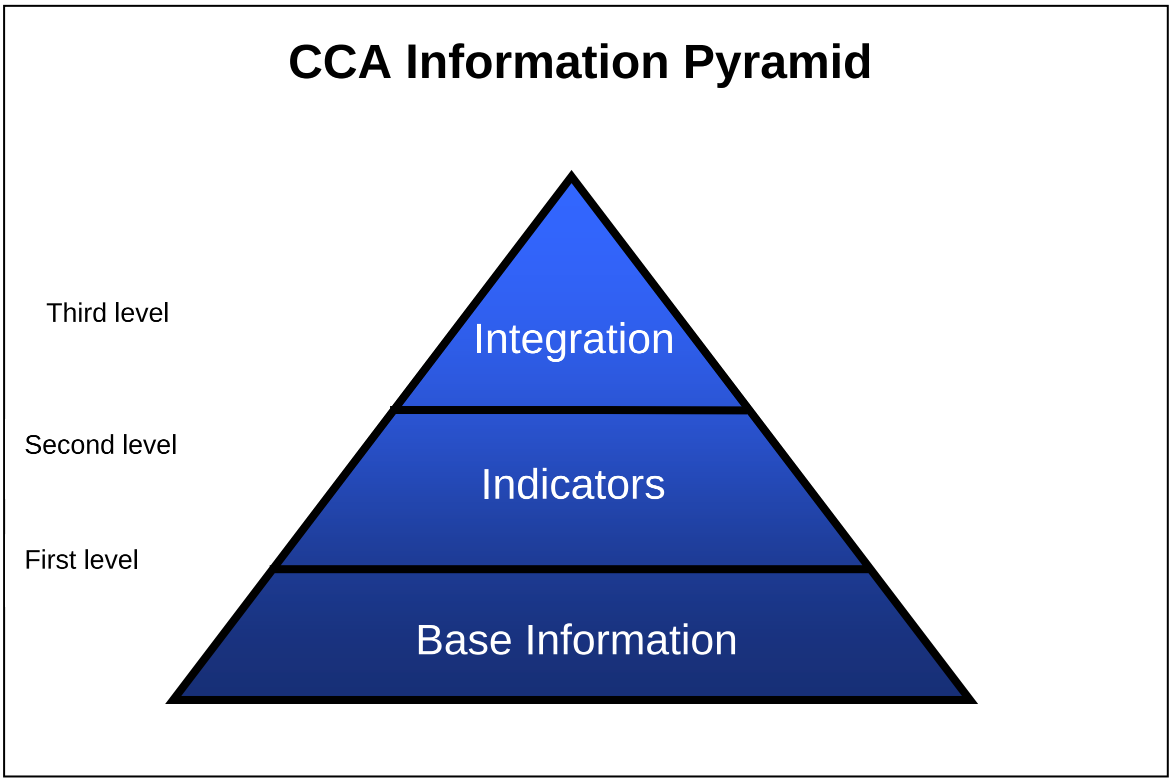


Figure 1: *The pyramid illustrates the information, assessment tools and integration methods provided by the Comprehensive Coastal Assessment and how they come together to assist coastal strategic planning and management.*

The first level provides base information such as GIS layers, databases and other information on coastal values. This information can support the development of the second level indicators. The indicators reflect measurements of change in environmental, economic and social values of the coast. At the peak (the third level) all this information is integrated using tools such as multi criteria analysis to help assess and decide on alternative land use options.

The CCA Toolkit contains a wealth of information about environmental, social and economic issues in the CCA study area. It includes 140 new data sets, many in GIS format, 27 project reports, decision support tools and a guide to an Integrated Decision Framework developed for the CCA. Some of these are described below.

First level information

The CCA makes available newly acquired base information on a suite of coastal environmental, social and economic values. Much of this is in GIS format. This information can be used as it is and/or users can develop indicator values based on this information for use in the integrated decision framework. A short description of a selection of this information is provided below.

Environmental

- geological information – includes detailed quaternary mapping, resources information and tenure information;
- aquatic habitats – location and extent of mangroves, saltmarsh and seagrass; includes information on tenure and potential aquaculture areas (a separate paper is being prepared on this project by the Department of Primary Industries for this conference);
- soil and land feasibility maps; and
- flora and fauna audits consolidating a wealth of information on coastal biodiversity.

Economic

- details of industry structure;
- data on employment and income;
- occupational status for each local government area;
- estimates of value of agriculture;
- details of housing and tourist accommodation;
- consumer expenditure and household characteristics;
- tourism information in the form of a *coastal tourism activity monitor* which has a suite of detailed information such as monthly visits which is critical in planning for peak loads in holiday periods;
- a guide to initiatives and assistance programs of relevant organisations involved in economic development strategies along the coast; and
- economic values of natural resources and natural environments in a GIS format that will assist planners and managers estimate the commercial values of different types of land area and the natural resources that they contain or support.

Social

- demographic analyses that explain different population movements to and from coastal areas; and
- links between social and economic factors, including a report on the economic value of wild resources to the indigenous community in coastal areas of NSW.

Cultural heritage information

- Aboriginal cultural landscape maps;
- a database of historic documents that refer to Aboriginal people; and
- an audit of all known Aboriginal sites data.

Second level information

A number of tools have been developed to measure impacts on various environmental, social and economic criteria. A short description of a selection of these is provided below. The tools can be used in isolation or included in an integrated planning exercise.

Environmental

Soil and Land Feasibility

A new, GIS based system has been developed to analyse existing information on soils and geomorphology to create a soil and land 'feasibility index' for different land uses. The CCA Toolkit contains a detailed report on this system. Councils will be able to use the resulting soil and land feasibility maps as one 'layer' in the decision making process about potential land use in any given area. A separate paper is being prepared on this project by the Department of Natural Resources for this conference.

Biodiversity Forecasting

A report is provided which describes how a tool has been further developed to increase its capacity to forecast changes in biodiversity as a response to different land use changes. In cooperation with the Department of Environment and Conservation, this tool can be applied to assist the selection of the best areas to develop and avoid, or minimise impacts on biodiversity.

Aquatic Ecosystems

Models have been developed to predict the effect of land use changes on nutrient run-off and the potential impacts that this may have in estuaries and coastal lakes. They are described in detail in the CCA Toolkit. The Department of Environment and Conservation is currently extending this work to develop a user-friendly interface so that these tools can be used more broadly.

Social

Social Assessment

A '*Guidebook on Social Impact Assessment'* is provided and it includes an outline of how to develop indicators of community well being.

Visual Assessment

A visual assessment method was developed for the Tweed coast. The method can be applied in other areas and at many scales to determine visually significant areas. Indicator values can also be developed to feed into an integrated assessment.

Economic

Models that assist in the calculation of economic and ecological impacts of development in coastal catchments are provided.

Third level – integration

'The CCA Integrated Decision Framework: a guide for sustainable land use planning' (the CCA Guide) is the cornerstone of the CCA Toolkit. The CCA Guide details how to

use CCA information and methods, how to integrate information to help strategic planning and decision making, including methods to integrate economic information such as the cost of loss of agricultural production and the costs of infrastructure. Although suited to broader local government area scale, the approach can be also applied at other scales and to a range of coastal planning and management challenges. The approach is flexible as CCA information sets can be used with other information that may be sought or available. The type and diversity of information used depends on the planning challenge at hand.

The CCA Guide incorporates a user friendly software package called *TopDec*. *TopDec* helps councils apply multi criteria analysis using all the information they have available relevant to a particular land use decision. It allows councils and communities to assess different land use options and determine the best option for their particular objectives by combining different criteria into the one decision.

It is important to recognise that multi criteria analysis is an aid to decision making that allows the testing of different scenarios and different weighting of criteria. It does not replace the need for coastal decision makers to make decisions in accordance with their statutory responsibilities and within the context set by Regional Strategies and other relevant state policies.

Coastal Lakes

Another integration tool called the Coastal Lakes Sustainability Assessment Tool (CLAM) was developed and tailored specifically for the assessment of seven coastal lakes - Cudgen, Myall, Burrill, Narrawallee, Coila, Merimbula and Back. The seven lakes represent a range of differing lakes in terms of geomorphology, sensitivity and landuse. The tool allows local councils to assess the impacts of different land use and management options on these lakes, to assist them make integrated planning and management decisions from the perspective of sustainably managing the lake. Another paper is being specifically presented on this at the conference.

An application of the CCA integration methods to 4 test sites

The following is a demonstration of one way to use a selection of information and tools from each level of the CCA pyramid in a hypothetical strategic planning exercise. The example uses the *CCA Integrated Decision Framework* to evaluate typical environmental, social and economic criteria to give an overall ranking of a group of 4 example sites for potential urban development.

Problem Statement and Study Area

Four sites for proposed urban development are considered in this example (see Figure 2). The hypothetical problem addressed by this example is “which one(s) best meet the environmental, social and economic objectives identified at the beginning of the planning exercise?”

Integration and Planning Options – Steps

The example demonstrates how the CCA can support planning and assessment processes in the coastal zone. It is important to note that it is not a fully-fledged planning exercise. Instead, it aims to demonstrate the use of typical Geographic Information System (GIS) spatial data layers, ways of exploring potential conflicts in objectives, techniques for assessing the impacts of different plans, and a methodology for evaluating, ranking or modifying possible plans to achieve improved planning outcomes.

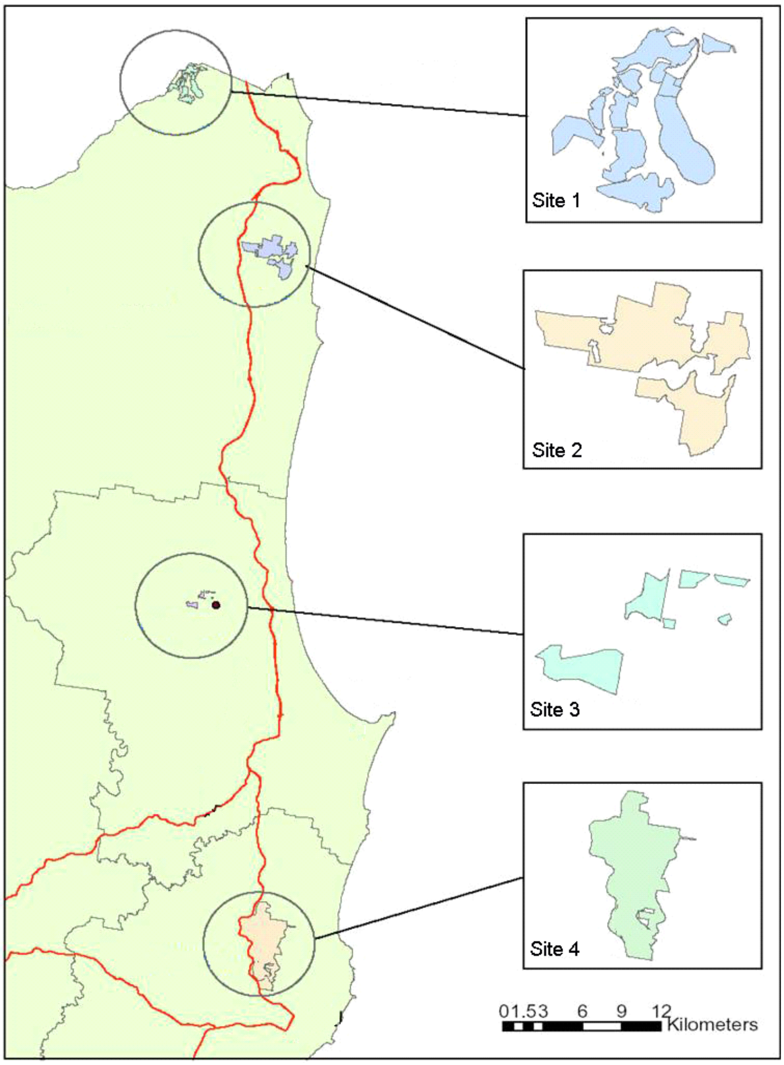


Figure 2: *Location map for 4 test sites*

Table 1: Information about proposed development on each site

Location	***Area (ha)***	***Proposed Population***	***Population Density (per ha)***
Site 1	295	10,000	33.9
Site 2	552	10,000	18.1
Site 3	52	1,300	25
Site 4	1430	8,094	5.7

The area and population increases as a result of each development option are shown and the corresponding population density as persons per hectare.

The four step *CCA Integrated Decision Framework* is outlined in Figure 3. This paper concentrates on Steps 3 and 4 of the framework to demonstrate the assessment and integration of various environmental, social and economic values.

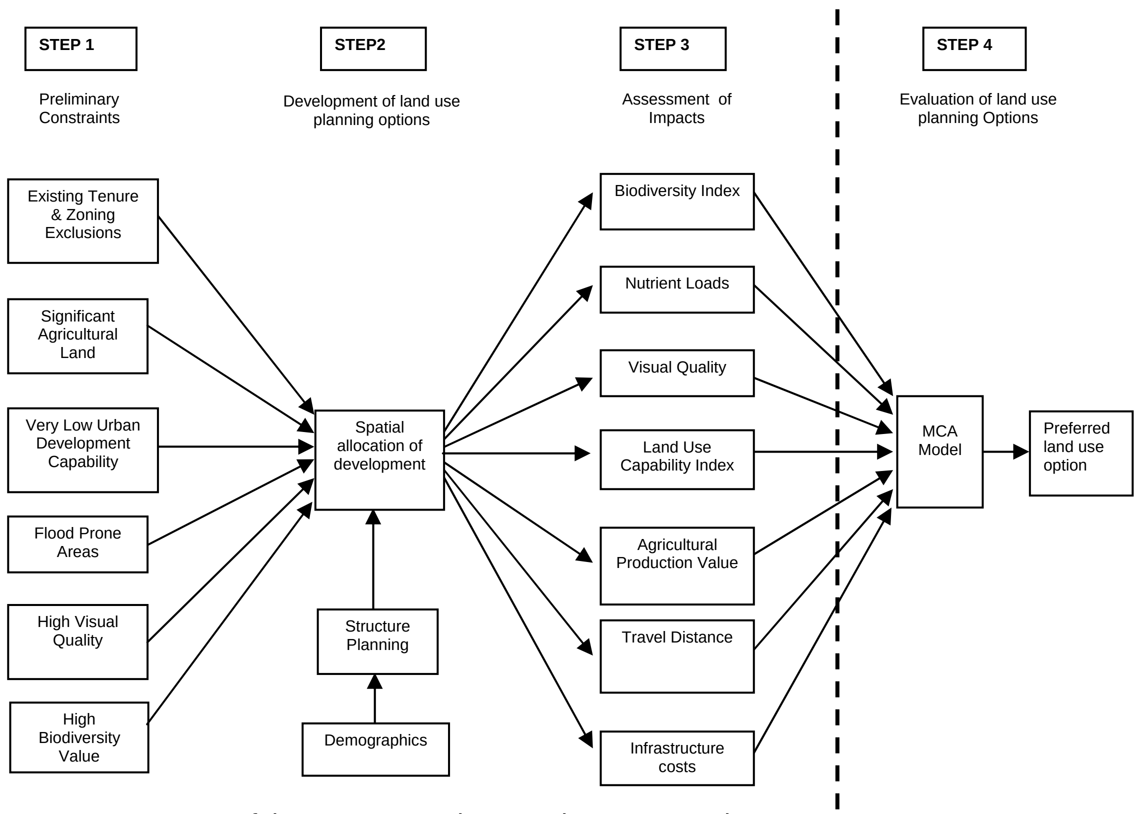


Figure 3: *Components of the CCA Coastal Integration Framework*

Step 1 - Preliminary Constraints

In a 'clean slate' planning exercise (that is, in an area with no existing infrastructure or existing centres) much effort would be placed in locating the potential developments using a preliminary constraints analysis. Examples are given in Figure 3 of the types of land that may be excluded from development in a preliminary constraints analysis. This would usually be done by determining a threshold of the environmental, social or economic attribute being considered and converting it to a GIS layer. For example there may be areas that have high soils and landform constraints that planners should not be developed due to the cost and risk to development. The threshold should be determined using a comprehensive analysis of the attribute. For example, a number of soil and landscape attributes can be used such as slope, dispersibility, acid sulfate potential etc, to determine the threshold for soils. It is important to note that the preliminary constraints analysis component of the exercise does not have to be limited to biophysical values. It could also include social and economic values, for example, setting a maximum dollar cost for the provision of infrastructure or a maximum distance from a town centre. It is important to note that Figure 3 uses examples and other criteria that may be desired, depending on the planning questions being asked.

Step 2 – Spatial Allocation of Development (Planning Options)

Using the GIS layers generated by the preliminary constraints analysis, demographic forecasts and structure planning (i.e. location of development according to its relationship to other relevant physical planning components such as infrastructure and town centres etc), areas of potential development can be determined.

Step 3 – Assessment of Impacts

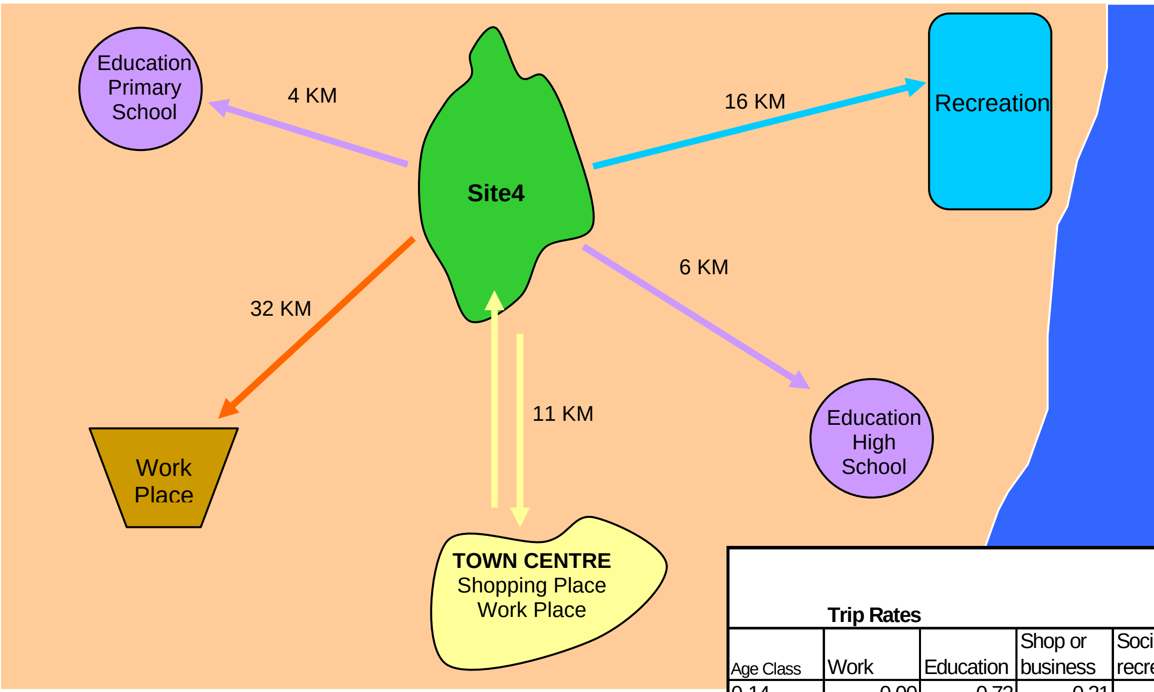
Various techniques exist for measuring different attributes/criteria and for assessing potential impacts on these from alternative land use planning options. In this example, existing agricultural or natural areas are to be replaced with urban development. The impacts of development on each site may involve the following. Attributes used to measure the impact are shown in bold.

- Loss of value of existing land use – **agricultural land lost**;
- Loss of value of surroundings – **visual quality, biodiversity persistence**;
- Changes in environmental processes – **nutrient loads**;
- Social impacts – **travel time** and **vehicle kilometres travelled**; and
- Economic impact – **cost of infrastructure**.

To demonstrate the type of detailed impact assessment that can be applied to develop indicator values for an attribute, details of the calculations are provided for one of the above - travel indicators.

Based on household travel information the distance people will have to travel from the sites of new development to go about their daily activities can be determined. For example, the number of trips to employment, education, shopping and recreation can be determined for people of various age categories and then using demographic forecasts determine which age categories are likely to move into the new developments. From this, an overall determination of trips and total kilometres travelled can be determined for each development. The distance is determined by measurement in a GIS. The major assumption is that the less the distance travelled to go about daily activities the better the development satisfies this social and environmental criterion. This concept is outlined schematically in Figure 4.

Figure 4: Description of the Travel model used for impact analysis in the CCA Integrated Decision Framework.



Trip Rates

Age Class	Work	Education	Shop or business	Social or recreation
0-14	0.00	0.72	0.21	0.55
15-64	0.40	0.10	0.94	0.70
65+	0.02	0.00	0.89	0.62

Figure 4: Assessment of Impacts – Travel Distances

Once the detailed assessment of impacts of each criteria/attribute is done, the impact scores calculated for each of the six criteria/attributes in each site were collated into an impact matrix. The impact matrix is arranged into a format in which data can be entered into a Multi-Criteria Analysis (MCA) computer software package, which evaluates and ranks the scenarios.

MCA is a collection of mathematical techniques described as “Multi-Objective Decision Support Systems”. These techniques are designed to assist decision-makers evaluate options and rank them according to a predetermined set of decision criteria.

MCA dates back to the 1970s when it was used, mainly in France and the Netherlands, for land-use planning decisions (see for example Nijkamp 1977; van Delft and Nijkamp 1997). It is now widely applied to many different kinds of decision problems, with an extensive supporting technical literature (Resource Assessment Commission 1992; Janssen 1992).

The technique provides a useful platform for interactive group decision-making where different stakeholders are involved.

It should be noted that MCA is not simply a mechanical means of determining the “best” decision. Rather, it is an interactive tool that can help to develop a fuller understanding of possible decisions and their consequences. Indeed, the options and criteria are likely to be changed within the overall evaluation process as it unfolds.

The main challenge in using the method is to identify the overall planning objectives, then *which options*, *which criteria* and *what value weights* are to be taken into account when setting up the evaluation framework and deriving the results.

Step 4 – Evaluation of Planning Options (Individual Sites)

The data and information integrated into the impact matrix was evaluated using a simple "weighted summation" MCA model to determine the best options in terms of the stated planning objectives and evaluation criteria. This is the simplest MCA model. Each option is scored according to its performance in relation to each criterion, producing an "effects matrix". The scores are then standardised. Each criterion is given a relative weight; the standardised scores are multiplied by the relevant weights; and the results are summed to derive an overall score for each planning option. The options are then ranked according to their overall score. Sensitivity analysis is typically conducted, especially for the criteria weights.

An MCA software package named '*TopDec*' was used in this case study to analyse the impact matrix. The model ranked the four sites based on the impacts of the eight example criteria / attributes for each. The ranking of sites for this example is shown in graphical form in Figure 5.

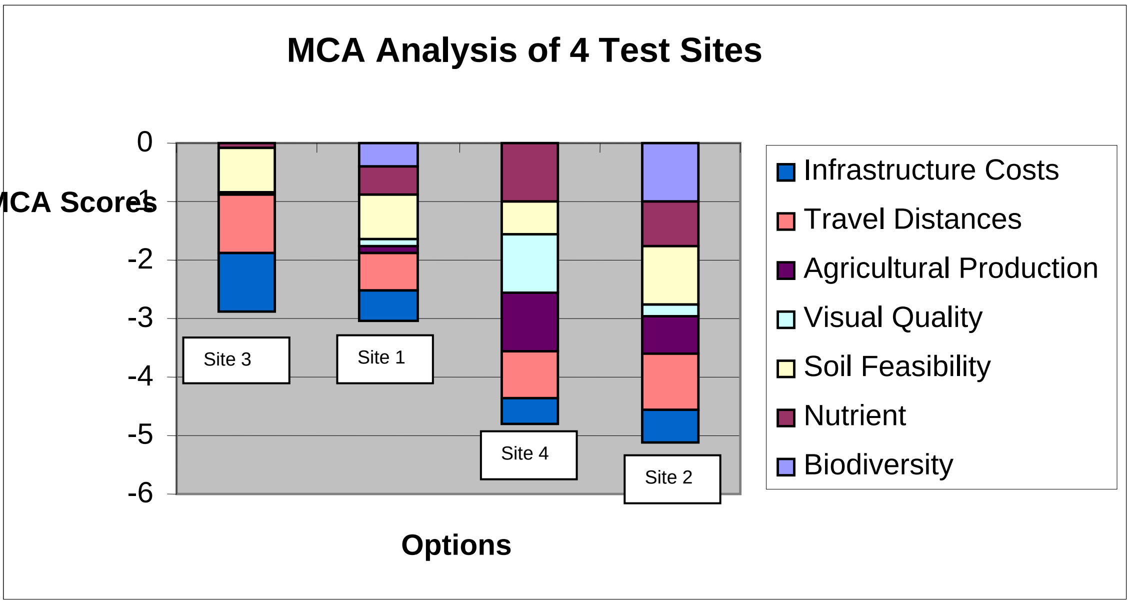


Figure 5: *MCA results for the 4 test sites showing contribution of each criteria to the total impact score and overall ranking (best-worst ranking scenario areas from right to left)*

The analysis reveals that Site 3 is the preferred option as it has the best overall impact in respect to all the chosen criteria. Figure 4 also reveals the contribution of each criteria to the overall ranking. For example, Site 3 performed well against the agricultural production because the development did not remove large areas of productive land. It is also visually unobtrusive compared to the other developments. However, it did not perform as well in terms of travel distances and infrastructure costs because of its distance to major centres.

Site 2 performed poorly overall because there were relatively significant impacts with respect to most criteria especially biodiversity loss, loss of agricultural production, and distance from employment, services and recreation.

Although not demonstrated in this example, the criteria can be weighted to meet specified objectives. For example, planners and the community may desire an economic and social focus and therefore weight infrastructure cost, travel distances, agricultural production loss more heavily than environmental criteria. Alternatively environmental criteria such as biodiversity and visual amenity may be the most importance criteria to the planners and the community and weighted accordingly. This may change the order of the options to reflect the desired objectives. Weighting can be used to determine the sensitivity of the options. If weights are varied and the ranking does not change then there is a low sensitivity and the planners can be more confident that the ranking options reflect the stated planning objectives.

Consequently, the four step framework and MCA provides a useful approach to assess the impacts of various options on selected environmental, social and economic criteria. It also assists in integrating information to assist planning decisions. The process is very transparent and open and it is easy to scrutinise any decisions or information at any of the steps. It also allows planners to use sophisticated modelling tools to develop indicator measurements for criteria (eg biodiversity) and use these with less sophisticated methods such as a simple measure of the cost of provision of infrastructure. Alternatively, very crude measurements can be used for all criteria and the approach is still valid and useful. The value in the approach is that it is easy to determine how much sophistication has been input into the planning exercise and therefore easy to find any weaknesses or discrepancies in the decision making process.

Conclusion

A wealth of information and tools have been compiled as part of the CCA process. The DVD product, conceptual pyramid structure of the CCA information, and tools enables coastal planners and managers to use the information provided by the CCA combined with other information to assist in planning decisions. Most importantly it also provides the framework to guide them on how to fill in the information gaps and how to develop indicator values for an assessment and planning process. The approach is modular, allowing users to use individual components, parts of the framework or all of the framework. It is also transparent as it can be easily unpacked to focus and query any item of information.

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References

Donnelly P, Neirinckx A, and Green W (2003). ***The Comprehensive Coastal Assessment – Guiding Coastal Policy, Strategic Planning and Development in NSW***. NSW Coastal Conference Proceedings 2003.

Green W, Puddey M, Donnelly, P, Neirinckx A, Ochiel V (2004). ***Improved Strategic Planning: Application of the Comprehensive Coastal Assessment Integration Framework***. NSW Coastal Conference Proceedings 2004.

Janssen, R. (1992) ***Multiobjective Decision Support for Environmental Management***. Kluwer Academic Publishers, Dordrecht.

Nijkamp, P. (1977) ***Theory and Application of Environmental Economics.*** North-Holland, Amsterdam.

NSW Government (1997). ***NSW Coastal Policy 1997: A Sustainable Future for the NSW Coast.*** Crown Copyright.

Resource Assessment Commission (1992) ***Multi-Criteria Analysis as a Resource Assessment Tool, Research Paper No 6.*** Resource Assessment Commission, Canberra.

van Delft, A. and P. Nijkamp (1977) ***Multi-Criteria Analysis and Regional Decisionmaking***. Martinus Nijhoff, Leiden.

DIFFERENCES IN EXCHANGE AND FLUSHING CHARACTERISTICS OF TWO INTERMITTENTLY OPEN SHALLOW COASTAL LAKES

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Abstract

Coastal lakes are often found in highly urbanised regions along the coast and are subject to the accumulation of nutrients and pollutants. In coastal lakes with intermittent, restricted or choked inlets, the exchange and subsequent flushing, with the ocean, can become limited and therefore significant in defining the water quality. To examine the exchange and flushing characteristics of intermittently open coastal lakes, two field sites were chosen for a comparative study, with the main difference being the waterway size. The exchange and flushing characteristics were then examined through the use of field data analysis and numerical modeling, and the results illustrated that different processes were dominating the exchange and subsequent flushing, in the two lakes. Tidal processes were found to dominate within the smaller lake, which led to a short flushing timescale (days), and sub tidal processes dominated the larger lake, resulting in a much longer flushing timescale (months). A closer examination of the larger lake identified the dominating sub tidal process as a process defined as spring tidal setup, which is driven by the fortnightly variation in tides and friction within the inlet, and promotes the net advection of waters into and out of the lake on a fortnightly timescale. The numerical modeling was employed to examine the importance of spring tidal setup against different sub tidal forcing (changes in mean sea level and variations in local wind) and the results showed that the exchange, in all of the model runs, was still dominated by the spring tidal setup.

Introduction

Intermittently open shallow coastal lakes, also known as Intermittently Closing and Opening Lakes and Lagoons (ICOLLs) are an important sub category of coastal lagoon, due to their limited exchange with the ocean and their lack of river inflow. These specific characteristics make ICOLLs particularly vulnerable to the trapping of nutrients and contaminants (Roy et al. 2001). In addition, the occurrence of high nutrient loads in these shallow, well lit systems favour the development of substantial biomass of attached and floating macro algae (Collett et al. 1981). When an ICOLL is open to the ocean, exchange through the inlet channel is often restricted due to its shallow nature. Therefore it is beneficial to try and understand some of the processes and timescales associated with the exchange and flushing of intermittent coastal lagoon systems in order to provide better management.

Along the southeast coastline of Australia there are over 135 estuaries of which 45% are intermittently open (Pollard, 1994) and within this sub category approximately 72% are artificially opened (DNR, 2004). The resulting frequency and duration of the opening events can vary between and within ICOLLs, with frequencies ranging from 2-

3 times per year, to once every 2 years, whilst the duration can vary from weeks to months.

This paper examines two ICOLL systems located on the N.S.W coast, both of which are artificially opened, primarily for flood mitigation purposes. The paper will illustrate how these two systems, which appear quite similar in appearance, can act quite differently with regards to their flushing and exchange characteristics. The format of the paper will be split into two sections, the first will examine the exchange characteristics and the second section will examine the flushing characteristics, and then the results will be drawn together at the end by the conclusions.

Field site descriptions and data collection

The two field sites that were chosen for this study were Wamberal Lagoon (Figure 1) and Smiths Lake (Figure 2). Wamberal Lagoon is a small ICOLL system, with a waterway area less than 1km^2. The lagoon opens quite frequently (2-3 times per year on average), but rarely stays open to the ocean for longer than 2 weeks at any one time. During the breakout the channel width can reach approximately 55 m and the maximum depth can reach approximately -1.0 m Australian Height Datum (AHD) (HR Wallingford 1994), with the inlet channel orientated southeast – northwest. The field data collection involved the deployment of a Nortek Acoustic Doppler Current Profiler (ADCP) at the bed, near the inlet channel (Figure 1) and measured horizontal velocities every 10 minutes, with an averaging interval of 1 minute and a vertical spacing of 0.2 m. The ADCP data covered the second week of a two-week opening event in May 2003. During the same time period two Greenspan Conductivity, Temperature and Depth (CTD) probes were also deployed at the same location, one at the bed and one at the surface, suspending by a buoy. The CTD's recorded information at 30 minutes intervals, with an averaging interval of 5 minutes.

The second field site, Smiths Lake, is a larger ICOLL system, with a waterway area of approximately 11km^2. The lake opens less frequently (once every 18 months on average) and stays open between 1-4 months. The maximum-recorded width of the entrance is approximately 60 m wide, and the average depth is approximately -1.0 m AHD (Webb, McKeown and Associates, 1998), with the inlet channel orientated east – west. The field data collection involved a similar field set up to that at Wamberal Lagoon. An ADCP was deployed at the bed, near the inlet channel (Figure 2) and measured horizontal velocities every 10 minutes, with an averaging interval of 1 minute and a vertical spacing of 0.2 m. The ADCP data consists of 2 weeks in July 2003 (2 months after the opening event). At the same time, two CTD probes were deployed at the same location; one at the bed and one suspended near the surface, and recorded information at 30 minutes intervals, with an averaging interval of 5 minutes. The CTD data covered July-August, 2003.

Water levels from within the two ICOLLs and observed offshore sea level heights were obtained for the entire opening period from Manly Hydraulics Laboratory, NSW, Australia, and corresponding meteorological data were obtained from the Bureau of Meteorology, Australia.

Figure 1. Wamberal Lagoon, N.S.W. (DNR, 2006) The X marks the location of the deployed field data.

Figure 2. Smiths Lake, N.S.W. (DNR, 2006) The X marks the location of the deployed field data.

Numerical Modelling

Three-dimensional numerical modelling was also undertaken on the larger ICOLL, Smiths Lake. The Estuary, Lake and Coastal Ocean Model, ELCOM, is a three-dimensional hydrodynamics model used for predicting the velocity, temperature and salinity distribution in natural water bodies subjected to external environmental forcing such as wind stress, surface heating or cooling (Hodges, 2000) The transport equations are the unsteady Reynolds averaged Navier-Stokes (RANS) and scalar transport equations using the Boussinesq approximation and neglecting the non-hydrostatic pressure terms (Hodges, 2000). The surface thermodynamics are governed by bulk transfer models (Hodges, 2000) and a Euler – Lagrange scheme is used to solve momentum advection, while advection of scalars uses the conservative flux limiting, explicit differentiation scheme, Ultimate – Quickest. (Laval and Imberger, 2003). For more information on the model and its previous applications please see Gale (2006)

Exchange characteristics

Defining the tidal exchange

Within Wamberal Lagoon a week of data was examined and a typical tidal cycle was extracted. The tidal cycle occurred one week after the lagoon had been artificially opened to the ocean. The flood tide was represented by a uniform inflow (Figure 3.) dominating the vertical water column. This suggests that the tidal velocities are strong enough to vertically mix the water column, at least in the vicinity of the field instruments. On the ebb tide, the surface waters were advected out of the ICOLL, with negligible flow at depth. The mean circulation over the tidal cycle was represented by a small outflow in the surface waters and minimal inflow at depth.

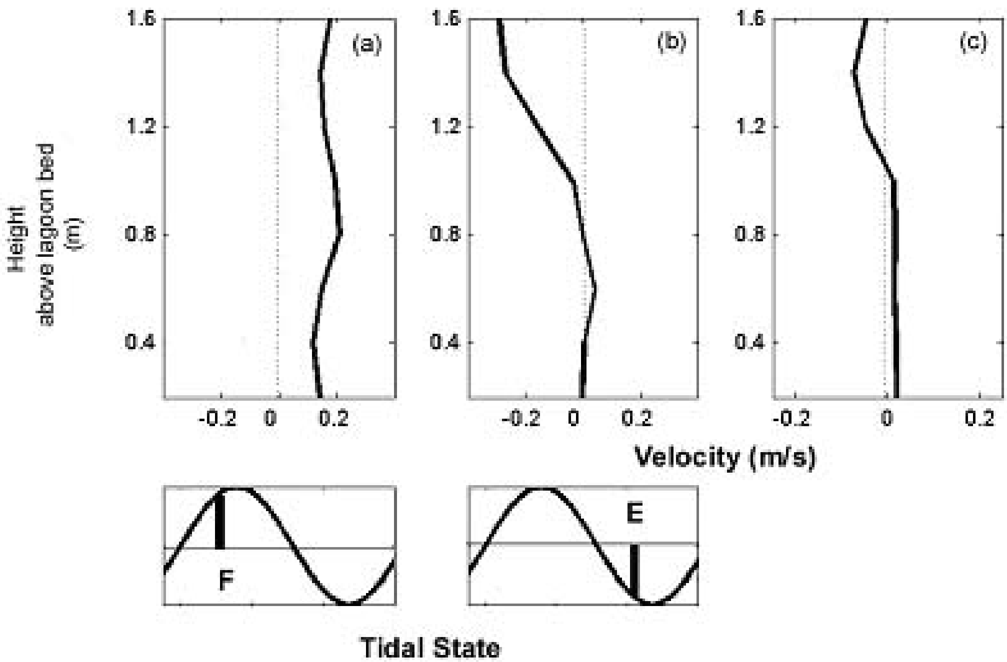

Figure 3. Wamberal Lagoon velocity profiles (a) a typical flood tide, (b) a typical ebb tide, and (c) the mean circulation over the tidal cycle. Positive velocities indicate water flowing into the lake, and negative velocities indicate water flowing out of the lake.

Within Smiths Lake, a week of data was also examined and a typical tidal cycle was extracted (Figure 4.). The tidal cycle data was taken 2 months after the lake had been opened (July 2003). The flood tide shows a different vertical profile to Wamberal Lagoon, with an inflow at depth and an outflow at the surface. This profile suggests the tidal mixing is not strong enough to mix the whole water column and a two-layered flow is present. On the ebb tide, the surface current remains directed out of the lake, and the bottom current reverses to also be directed out of the lake, whilst at mid depth there is no flow. The mean circulation, however, is the same as for Wamberal Lagoon.

The different flood and ebb vertical profiles suggest that the two ICOLLs are experiencing different methods of exchange. The vertically well-mixed water column, in the smaller ICOLL, suggests greater exchange and mixing is occurring than in the stratified larger ICOLL.

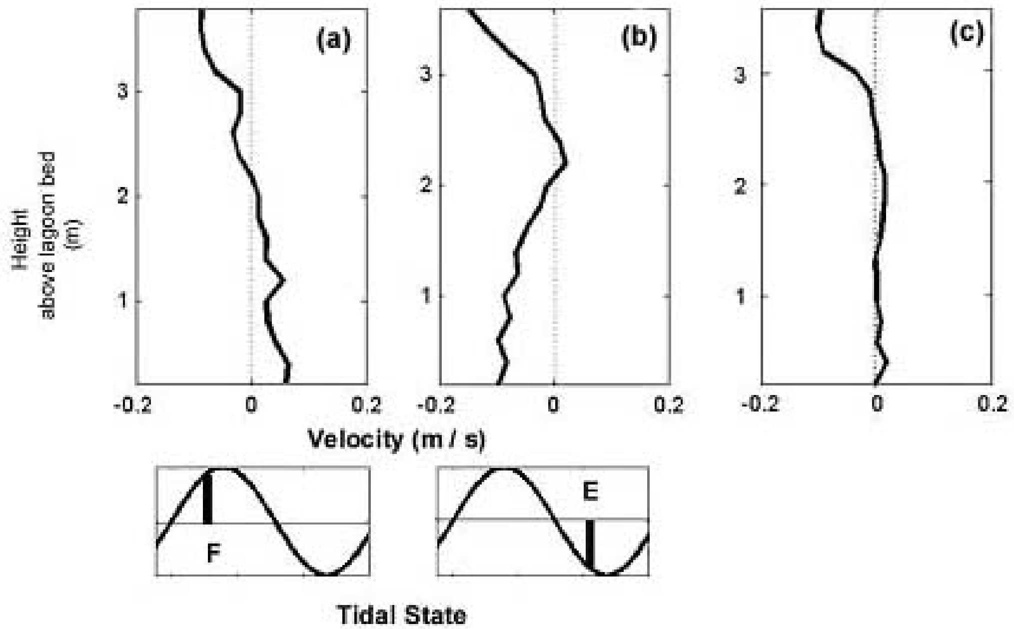

Figure 4. Smiths Lake velocity profiles (a) a typical flood tide, (b) a typical ebb tide, and (c) the mean circulation over the tidal cycle. Positive velocities indicate water flowing into the lake, and negative velocities indicate water flowing out of the lake.

Quantifying the tidal exchange

To quantify the degree of tidal exchange occurring during the tidal cycle, the Tidal Exchange Ratio (TER) can be calculated. The TER, as described in Fischer et al. (1979) and calculates the ratio of new water versus the total water entering the water body on the flood tide:

$$TER = \frac{(S_f - S_e)}{(S_o - S_e)} \qquad (1)$$

Where S_f = the average salinity of water entering the estuary on the flood tide, S_e = average salinity of water leaving the estuary on the ebb tide, and S_o = the salinity of the ocean water. Some caution is needed when applying this method to systems that have variable freshwater inflow, as the lagoon water reaches the salinity of the ocean, the TER reaches zero, even though exchange of new waters may still be occurring.

Two days of data were analysed for Wamberal Lagoon, and corresponded to the time of the tidal cycle shown previously (Figure 3) and the following day. The resulting TER varied from 0.55 and decreased to 0.21, coincidentally, also as the lagoon entrance started to close (completely closed 5 days later). This suggests that the lagoon is either quite rapidly reaching salinities of seawater and therefore probably well flushed by one week, or the dynamics of the closing inlet are restricting the exchange.

In Smiths Lake, a longer period of field data (~ 1 month) was available, and the resulting TER showed a larger variation over the month, from 0.56 to 0.08, but less variation from one tidal cycle to the next. The large variation appeared to correspond to the timing of the spring neap cycle (Figure 5.), where during the neap tides the TER was lower and during the spring tides the TER was higher. The results suggest that Smiths Lake experiences greater exchange with the ocean during spring tides.

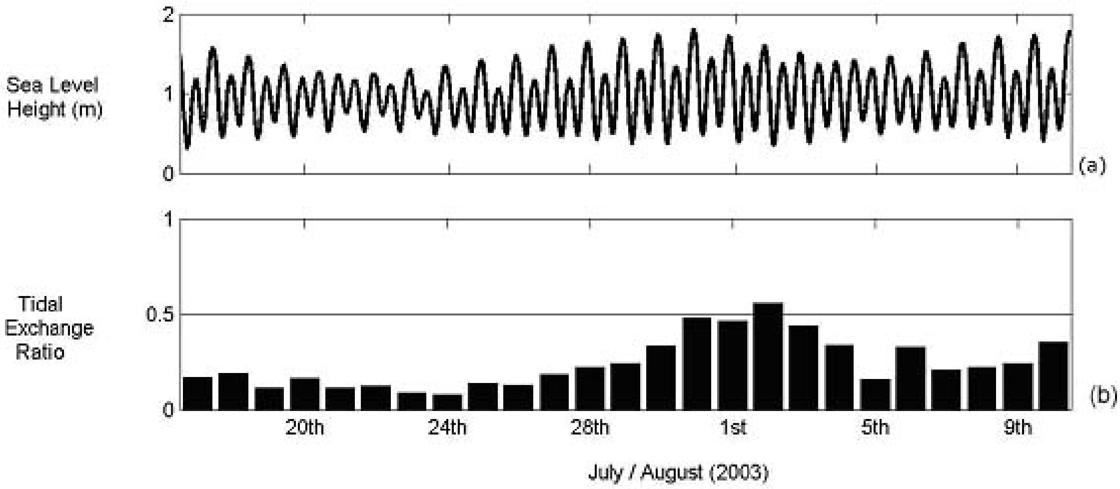

Figure 5. Time series data for Smiths Lake including: (a) Sea Level heights, and (b) Tidal Exchange Ratio (TER). Note the small TER around the time of neap tides (22nd July) and the rise in TER around the period of spring tides (1st August), indicating periods of lesser and greater exchange with the ocean.

The results showed a similar range of TER values for the smaller and the larger ICOLL, suggesting that the exchange between each ICOLL and the ocean is not constant and not dependent on the different vertical velocity and density profiles. The correlation between the TER and the spring neap cycle, in the larger ICOLL, suggests that barotropic forcing operating at a fortnightly timescale may be a significant driver in the exchange.

Processes driving the exchange

To examine the specific processes that may be driving the exchange, salt fluxes have been calculated. The total flux of salt, per unit width, through a vertical section can be averaged over a tidal period to give the net flux, F, as calculated by:

$$F = \int_0^h (us)dz \qquad (2)$$

Where $u(z)$ = observed velocity and $s(z)$ = observed salinity, *z* is the vertical coordinate and *h* is the depth. The flux is considered to be at a steady state, with the advective and diffusive modes of transport balancing the exchange. The flux can be decomposed into the following terms (Restrepo and Kjerfve 2002):

$$\langle F \rangle = \underbrace{\langle h \rangle \langle \bar{u} \rangle \langle \bar{s} \rangle}_{(1)} + \underbrace{\langle h u_T s_T \rangle}_{(2)} + \underbrace{\langle \bar{u} \rangle \langle h_T s_T \rangle}_{(3)} + \underbrace{\langle \bar{s} \rangle \langle h_T u_T \rangle}_{(4)} + \underbrace{\langle h \overline{u' s'} \rangle}_{(5)} \qquad (3)$$

Where u is the observed velocity and is made up of a depth mean velocity component, $\bar{u}$ and a turbulent velocity component, u'. Whilst the mean velocity component, $\bar{u}$, can be further broken down into a time averaged velocity < $\bar{u}$ > and a time varying velocity u_T. The same theory is applied to salinity (s) and $\langle \; \rangle$ represents a tidally averaged term.

The advective flux (term 1) is due to the mean tidal flow and is associated with the change in storage during the tidal cycle, where a net emptying of the system suggests an export in salt and vice versa. Term 2 represents tidal pumping, and refers to the net transport of salt by oscillatory tidal currents over a tidal cycle and is usually directed upstream. This flux usually reaches a maximum when currents and salinity are in phase and is usually the major landward flux component in well-mixed systems (Restrepo and Kjerfve, 2002). Term 3 represents the cross correlation between tide and salinity, which represents any time lag in change in salinity associated with a change in water depth. Term 4 represents the Stoke's drift dispersion, and accounts for the dispersion of salt related to the net drift of water in the direction of wave travel (Masselink and Hughes, 2003). Term 5 represents the salt dispersion due to mean shear produced by the presence of gravitational circulation.

The results (Table 1. and 2.) illustrated that the mean flow ($\langle \bar{h} \rangle \langle \bar{u} \rangle \langle \bar{s} \rangle$) dominated the exchange in both of the ICOLLs, whilst all other terms were negligible. Within Wamberal Lagoon the mean flow accounted for 86-94% of the total flux of salt and in this case the flux was directed out of the lagoon. Within Smiths Lake the mean flow also accounted for a large percentage of the total flux, ranging between 84-99% and was also directed out of the lake.

Tidal cycle	Net Flux	Term 1	Term 2	Term 3	Term 4	Term 5
1	-1.79150	-1.7516	-0.042388929	0.001408	0.014261	-0.013224172
2	-0.38689	-0.3779	0.019504664	-0.000044	-0.035627	0.007142311
3	-1.70374	-1.7752	0.012751433	-0.001571	0.001102	0.059206644
4	-1.53901	-1.5128	-0.027388097	-0.000891	-0.036623	0.038680198

Table 1. Salt fluxes for Wamberal Lagoon. Results are in ppt cm s^{-1}

For a system to be in a steady state, the net flux over a tidal cycle should be close to zero. The results therefore suggest that the systems are not in a steady state and there is a net emptying of each system during the time of data collection. Within Wamberal Lagoon, the processes are potentially complicated by the proximity to closure of the inlet; therefore we have chosen Smiths Lake for further examination.

Tidal cycle	Net Flux	Term 1	Term 2	Term 3	Term 4	Term 5
1	-2.3455798	-2.318230924	-0.011403	-0.000076	-0.00447	-0.011403081
2	-1.6609174	-1.624678074	-0.010764	-0.000070	-0.01464	-0.010764053
3	-4.942466	-4.931902726	-0.003228	-0.000062	-0.00405	-0.003228085
4	-0.9964043	-0.972812703	-0.010643	-0.000042	-0.00226	-0.0106
5	-1.5408193	-1.535362433	-0.002522	-0.000085	-0.00033	-0.0025
6	-0.0774947	-0.064872621	-0.005525	-0.000002	-0.00157	-0.0055

Table 2. Salt fluxes for Smiths Lake. Results are in ppt cm s^{-1}

The salt flux results from Smiths Lake showed a negative trend in net flux suggesting that the lake was in a period of net emptying. To investigate this further, a three-dimensional model of the lake was constructed and the salt fluxes were examined over a spring neap tidal cycle (16 days). For more information on the modelling please see Gale (2006). A series of four model runs were completed using different combinations of forcing (Figure 6.), including two variations in wind (naturally varying wind and a constant westerly wind) and variations in tidal forcing (tidal sea levels only and tidal with sub tidal sea levels included).

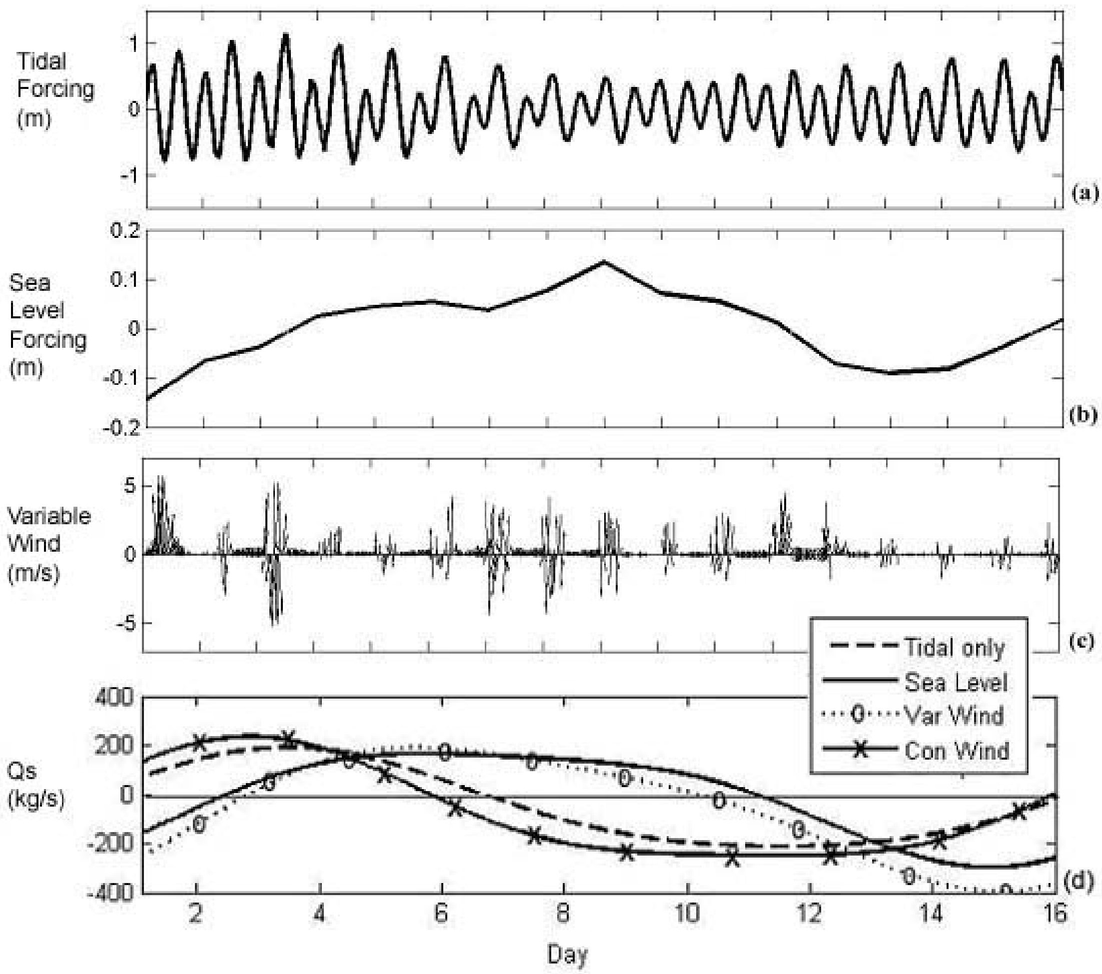

Figure 6. Forcing data and salt fluxes for Smiths Lake, where positive is into the lake and negative is out of the lake (a) tidal forcing (sub-tidal forcing is absent), (b) mean sea level changes (sub-tidal forcing) (c) Variable wind forcing, and (d) sub tidal salt fluxes, for all four simulations

All four of the scenarios (Figure 6.) suggest that the lake cycles through a period of negative flux and positive flux during the spring neap cycle, with the timing of the cycle being affected by the different combinations of forcing. A significant process operating at a fortnightly timescale is the action of spring tidal pumping (Hinwood et al. 2005), which is due to the combination of the spring neap tidal cycle and channel friction. This can produce fortnightly variations in water levels, and in this case it appears to promote fortnightly variations in the salt flux as well. When tidal forcing only was applied the positive flux into the lake occurred during spring tides, and this agrees with the tidal exchange ratio calculations which also suggestion greatest tidal exchange is occurring during spring tides (Figure 5). When the varying wind and the sea level changes are incorporated into the forcing, the timing of the peak moves closer to neap tides.

Flushing Characteristics

There are many various methods to calculate the flushing timescale of a water body, and as the previous work illustrates there are a number of processes that may affect the flushing timescale. This includes the variation in tidal exchange ratio in Smiths Lake, which as we have shown (Figure 6.) can be affected by external forcing. In this paper we have chosen to use a flushing timescale method, as defined in Dyer (1997). This method uses the bathymetry data, tidal amplitudes and TER (from previous section) to calculate the following flushing timescale:

$$T_f = V\left(\frac{S_o - S_{mean}}{S_o - S_e}\right) / \varepsilon P \qquad (7)$$

Where V = the low tide volume, P = the intertidal volume (tidal prism), S_{mean} = mean salinity of the water column and ε = fraction of ebb water not returning on the flood, which can be calculated from the TER.

For Wamberal Lagoon, with a mean depth of -1.5m, and a TER of 55 %, the flushing timescale was of the order of 3 - 4 days. The field data (not shown here) obtained 8 days after the opening (21st May), confirmed that the system was well mixed (salinity of 34 ppt) and that a T_f = 4 days is feasible.

For Smiths Lake, with a mean depth of –3m and a large variation in TER, the flushing timescale was calculated for each day of a 25-day period for which we had field data. The variation in flushing timescale ranged from 39 - 370 days. If we assume that the greatest variations within the TER results and the flushing timescales occurred during the spring neap cycle (15 day frequency), then we can calculate a mean TER, for a 15-day period (19th July – 2nd August) and use it as a representative value for the lake. This provides a mean TER of 0.23, which then produces a flushing timescale of approximately 113 days. Field data collection 60 days after the opening, can only confirm that the lake was still not completely flushed at this time, with mean lake salinities of 28 ppt.

Discussion and Conclusions

The two ICOLL systems, at first glance appear very similar in their characteristics, however at a finer scale there are different dominating processes driving the exchange and flushing. The mean vertical profiles (Figure 3 and 4) suggest that the exchange characteristics are similar in the two ICOLLs, however examination of the flood and ebb profiles shows that the smaller ICOLL experiences a vertically well-mixed water column suggesting that tidal mixing is quite high. Whilst in the larger

ICOLL the presence of a vertically stratified water column suggests that tidal mixing is quite low.

It was difficult to determine any difference between the tidal exchanges though, as the results from the tidal exchange ratio, illustrate that both ICOLLs experience varying degrees of exchange ranging from 0.55 to 0.08. In the smaller ICOLL, the short opening time (2 weeks) suggests that the changing inlet dynamics may play an important role in the degrees of exchange. In the larger ICOLL, the open state was maintained for 4 months; therefore it is assumed that during the middle of that period the inlet dynamics are not changing significantly. The TER, however, did change significantly, correlating well with the spring neap tidal cycle (Figure 5.). The modelling then confirmed the fortnightly variation in the exchange (salt flux)

The timescales for flushing varied between the two ICOLLs, with the smaller ICOLL becoming well flushed within a week, most likely due to tidal mixing and exchange. The larger ICOLL took a lot longer to flush (months) most likely due to the spring tidal pumping and the greater volume.

This work has touched on a variety of aspects that need further investigation to fully understand the exchange and flushing of ICOLL systems. The work highlights that the exchange and flushing characteristics of ICOLLs is complex and can be vary between ICOLLs, incidentally, which are often managed under the same guidelines. Further research is suggested in this area. For a more detailed examination of some of the aspects covered in this paper, the reader is directed towards the thesis listed below by Gale (2006).

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References

Collett, L.C., Collins, A.J., Gibbs, P.J. and West, R.J. (1981). Shallow dredging as a strategy for the control of Sub littoral Macrophytes: a case study in Tuggerah Lakes, New South Wales. *Australian Journal of Marine and Freshwater Research* 32, 563-571

DNR (2006) Department of Natural Resources web site
http://www.dnr.nsw.gov.au/care/water/estuaries/inventory/index_ns.html

DNR, (2004). Discussion Paper: ICOLL Management Guidelines. Department of Natural Resources, N.S.W. Australia

Dyer, K (1997) Estuaries: A Physical introduction. 2nd Edition, Jacaranda Wiley Ltd.

Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J. and Brooks, N.H. (1979). Mixing in Inland and Coastal Waters. 483 pp, Academic Press, San Diego, California.

Gale, E.J. (2006) The hydrodynamics of Intermittently Closing and Opening Lakes and Lagoons (ICOLLs). PhD Thesis submitted to the University of Western Australia

Hinwood, J., McLean, E. and Trevethan, M., (2005). Spring Tidal Pumping. In the Proc. Coasts and Ports Conference: Coastal Living – Living Coast, Adelaide, South Australia, Australia, 601-606.

Hodges, B.R. (2000). Estuary, lake and coastal ocean model (ELCOM): user manual, University of Western Australia, Centre for Water Research, University of Western Australia.

HR Wallingford (1994) Wamberal Lagoon Breakout Investigation: Telemac Application. Report EX 3088. HR Wallingford Ltd. Howbery Park, Wallingford, Oxfordshire, United Kingdom

Laval, B. and Imberger, J. (2003). Mass transport between a semi-enclosed basin and the ocean: Maracaibo System J. Geophys. Res., 108(C7): 3234.

Masselink, G. and Hughes, M. (2003) Introduction to Coastal Processes and Geomorphology. Hodder Arnold Publishing, U.K.

Pollard, D.A. (1994). Opening regimes and salinity characteristics of intermittently opening and permanently open coastal lagoons on the south coast of New South Wales. *Wetlands* (Australia) 13, 16-35

Restrepo, J.D. and Kjerfve, B. (2002). The San Juan Delta, Colombia: tides, circulations, and salt dispersion. *Continental Shelf Research* 22, 1249-1267

Roy, P.S., Williams, R.J., Jones, A.R., Yassini, I., Gibbs, P.J., Coates, B., West, R.J., Scanes, P.R., Hudson, J.P., Nichol, S. (2001). Structure and function of south – east Australian estuaries. *Estuarine, Coastal and Shelf Science* 53:351 – 384.

Webb, McKeown and Associates (1998) Smiths Lake: Estuary Processes Study, for the Great Lakes Council, N.S.W. Australia. Webb, McKeown and Associates Pty Ltd, Sydney, N.S.W. Australia. 75 pp

Preparing for Waves of Destruction – The Emergency Risk Management of Tsunami in NSW

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Abstract

Tsunami can and have affected coastlines of Australia, including the New South Wales (NSW) coast. The NSW State Emergency Service (SES) is now recognised as the combat agency (lead agency) for the emergency management of tsunami in NSW and is responsible for planning for and controlling tsunami response operations when they occur. The SES in 2005 prepared the NSW Tsunami Emergency Sub Plan. To provide further information regarding the threat posed to New South Wales by tsunami, the Department of Natural Resources and SES will lead a tsunami risk assessment scoping study of the NSW coastline. The Bureau of Meteorology is responsible for the issue of public tsunami warnings in NSW.

Introduction

Globally, many tsunami events in history have caused death and destruction. Since, European settlement NSW has been impacted by numerous small tsunami with some damage to property and infrastructure but luckily no reported deaths. No detailed tsunami risk studies have been conducted to assess tsunami risk in NSW, hence little is known about the full extent of tsunami risk posed to NSW communities.

The NSW State Emergency Service (SES) is the combat (lead) agency for tsunami in NSW. It has developed a detailed tsunami emergency plan and is currently leading the emergency risk management for tsunami in NSW. It is being supported by the Australian Bureau of Meteorology in the development of warning systems; and the NSW Department of Natural Resources in the management of tsunami risk studies.

This paper discusses tsunami in the NSW context and outlines advances in emergency planning, warning systems and risk assessment studies for tsunami in NSW.

Characteristics of Tsunami

A tsunami is a series of ocean waves generated by a sudden displacement of large volumes of water. In the process of the sea level returning to equilibrium, waves are generated which propagate outwards from the source region. They may be caused by the vertical movement of the sea floor as a result of large earthquakes; submarine or coastal volcanic eruptions; meteor impacts; or coastal landslides either land based or submarine.

Earthquakes have generated the majority of tsunami recorded on the Australian coast. However, not all earthquakes generate tsunami. To generate a tsunami, the fault where the earthquake occurs must be underneath or near the ocean, and cause vertical movement of the sea floor over a large area. Earthquakes are most common at plate boundaries where moving tectonic plates meet. Shallow focus earthquakes along subduction zones (where one tectonic plate is pushed under another) are responsible for most destructive tsunami experienced world wide.

Tsunami travel outward in all directions from their point of generation (but not necessarily with equal energy in every direction) and can strike coastal areas great distances from their source. Tsunami speed is dependent on water depth. In deep water and open ocean, tsunami can reach speeds of 800 kilometres per hour. Heights of tsunami in deep water are only small and can go unnoticed. As a tsunami enters shallow water its speed decreases rapidly. This causes the wave length of the tsunami to decrease and the height of the wave to increase. It is important to note that despite these changes a tsunami's energy flux, which is dependent upon both its wave height and speed remains nearly constant. Energy begins to be lost once a tsunami begins to rush onshore. Some energy is reflected offshore, while shoreward propagating energy is lost through friction and turbulence.

Destruction from tsunami is the direct result of three factors: inundation, wave impact on structures, and erosion. Strong tsunami-induced currents can lead to the erosion of foundations and the collapse of bridges and sea walls. Floatation and drag forces can move buildings and over-turn vehicles. Tsunami associated wave forces can demolish buildings as a result of exposure to the initial turbulent front of the wave and the outflow of water back to the sea between tsunami surges. Considerable damage is also caused by the resultant floating debris, including boats, building materials, furniture and cars that can crash into buildings, piers, vehicles and people.

Tsunami amplitude at the coast is dependent upon the configuration of the coastline, shape of the ocean floor, reflection of waves, tides and wind waves. Narrow bays, inlets and estuaries may cause funnelling effects that enhance tsunami magnitude. Offshore reefs and shallows can act to reduce tsunami magnitude but may also focus tsunami at particular locations. The combination of these factors means that the flooding produced by a tsunami can vary greatly from place to place over a short distance.

A tsunami is not a single wave, but a series of waves. The time that elapses between the passage of successive wave crests at a given point is usually from 5 to 90 minutes. Oscillations of destructive proportions may continue for several hours, and several days may pass before the sea returns completely to its normal state. The first wave in the series may not be the largest. The approach of a tsunami may be preceded by abnormal ocean behaviour. Depending on whether the first part of the tsunami to reach the shore is a crest or a trough, it may appear as a rapidly rising or falling tide.

History of Tsunami in NSW

The NSW coast has experienced over 30 tsunami since European settlement, many of which have been too small to produce noticeable effects. The largest tsunami recorded in 1960 and 1868 were recorded as tide gauge measurements of approximately one metre (Geoscience Australia, 1996). There has been no recorded loss of life or major damage recorded as a consequence of tsunami, although, some minor damage to boats and coastal infrastructure occurred as a result of the 1960 Chilean and 1868 Peruvian tsunami.

The 1960 tsunami was recorded along the entire NSW coast and appeared as a wildly fluctuating tidal level which went on for several days. The tsunami was generated as a consequence of a large submarine earthquake offshore of the Chilean coast (9.5 Richter Magnitude and 30km focus). The tsunami caused death and destruction throughout the Pacific Basin, with 5000 to 10000 deaths in Chile and a further 2200 deaths across the Pacific. The tsunami took only 17 hours to travel the 12670 kilometres between Chile and the NSW coast. The following newspaper extracts describe the consequences of the 1960 Chilean tsunami in Sydney and Newcastle.

SYDNEY HARBOUR IN CHAOS FROM QUAKE WAVE

SYDNEY. — Tidal waves generated by the earthquakes in Chile smashed into the New South Wales coastline yesterday.

AIR PILOT SEES BEACH DISAPPEAR

MELBOURNE. — Salmon spotting pilot Dick Ritchie yesterday saw Three-Mile Beach, Wilson's Promontory "disappear"

(Hobart Mercury, 25/5/1960)

"Freak currents tore away moored boats and upset shipping. The huge tide tore from their moorings about 30 launches and small craft and two barges at the Spit: Swirled the barges in among drifting launches, overturning several of them and damaging others: Smashed one of the barges into the Spit Bridge. Set adrift 800 logs from moorings at Balmain shipping yard, which were then swept down the Parramatta River. Swept away a strip 100 yards by 60 yards from Clontarf Reserve Point Park and exposed a high tension submarine cable: In one tense moment a 30ft. fishing trawler sank in Throsby Creek near Newcastle. Eight launches were ripped from their moorings in Throsby Creek and swept half a mile into Newcastle Harbour." (Brisbane Courier Mail, 25/5/1960)

"We were being towed from Gore Bay to Pyrmont and became almost stationary in White Bay when we struck an eight knot current"... "Suddenly the freakish current turned and we were swept under the Glebe Island Bridge in a flash." (Hobart Mercury, 25/5/1960)

The 1868 tsunami was caused by a large submarine earthquake centered offshore of the coast of Peru in the Peru-Chile trench. The following newspaper extract describe the effects of the tsunami in Sydney harbour.

"An extraordinary tidal disturbance has been experienced here this morning since about half past 6 o'clock – the vessels at the coal shoots broke from their moorings, one nearly loosing her masts; the sand bank was suddenly uncovered to the extent of a foot, and was rapidly covered again." And "The extraordinary phenomenon which took place this morning, and continues, is termed by nautical men a volcanic wave. At 8.30, the vessels in the harbour were thrown into great confusion. The Alexander broke from her moorings and had to anchor in the stream. The Planter was shaken so much by the action of the tides that the captain expected his masts to fall. The ship Lucibelle, 1000 tons, was swung round four times, although a strong ebb tide was running; and the vessels in harbour swung round in all directions. The tide ran down sometimes at a rate of 12 knots, the same as if there was a strong fresh in the river."(Sydney Morning Herald, 17/8/1868)

The historical record is useful when assessing the tsunami risk, but is limited by its short length of just over 210 years. The absence of impact from large Tsunami over recent history is not on it's own sufficient to preclude the possibility of impact from larger events.

Paleo-tsunami researchers have reported that larger tsunami have impacted upon the NSW coast before European settlement measuring tens of metres (Bryant and Nott, 2001; Bryant and Young 1996; Bryant, Young and Price, 1992). Other researchers, however, have disputed these conculsions (Dominey-Howes, per comm 2005, Synolakis and Fryer 2001, Felton and Crook 2003) and caution has been advised when interpreting such pre-historic events (Davidson and Rynn, 1998).

Sources of Tsunami

The sources of historical tsunami vary and are classified as either; local, regional or distant, depending on the distance of their generation from the coastline of impact.

Local tsunami (also classified as near-field and generally within 100km or one hour travel time from the source) are generated close to the affected coast. They provide little to no warning time, hence communities at-risk are reliant upon observing environmental signals such as strong ground shaking or abnormal ocean behaviour in order to undertake required response actions. No local tsunami have been observed since European settlement, though evidence indicating the existence of previous submarine landslides prior to European settlement has been found on the continental shelf offshore of the NSW coast (Jenkins and Keene, 1992). These landslides may have generated tsunami prior to European settlement.

Regional tsunami are those generated with significant effects normally felt within 3 hours or 1000km of the source. Potential regional tsunami sources for the NSW coast are located in subduction zones along the Indian-Australian and Pacific tectonic plate boundary which runs through Macquarie Island, New Zealand, Tonga, Vanuatu, Papua New Guinea, the Solomon Islands and the Kermandec Islands. Travel time from these locations to the NSW coast varies but is in the order of several hours.

Distant tsunami (also classified as far-field) are generated far away from the affected coastline. NSW may be affected by tsunami generated as far away as North America, South America, Antarctica and Asia. Warning times for distant tsunami vary according to the location of their source, and can be from many hours to almost a day. Distant tsunami may affect the entire NSW coast.

Emergency Planning For Tsunami – NSW Tsunami Emergency Sub Plan

Some arrangements for managing responses to a tsunami have existed in the NSW State Flood Plan for a number of years. The logic behind this inclusion was that in its behaviour and consequences, a tsunami closely resembles a flood. The State Flood Plan is the principal document for establishing the framework within which flood emergency management is undertaken in NSW. The reference in the State Flood Plan was, however, not particularly detailed and furthermore, was not well supported by complementary tsunami-specific arrangements in other plans such as; SES Region and Local Flood Plans, or State, District and Local Disaster Plans (DISPLANs). In particular, some District and Local DISPLANs contradicted State Flood Plan arrangements, by detailing that a response to a tsunami event would be controlled by the Emergency Operations Controller.

To clarify this situation in anticipation of the need to undertake more detailed planning the SES, in 2003, made representations to the peak emergency management committee in NSW, the State Emergency Management Committee (SEMC). In December 2003 the SEMC endorsed the combat agency status of the SES in respect of tsunami and recommended that the SES undertake the required detailed planning.

The development of the NSW Tsunami Emergency Sub Plan by the SES began in early 2004, prior to the Asian tsunami of the 26th of December. It has been an inevitable consequence of that event that the priority for tsunami research and planning has been emphasised. The plan was endorsed at the SEMC meeting held in December, 2005. This followed extensive investigation and consultation by the planning staff of the SES with all agencies listed in the plan. In particular, it was essential that the authors of the plan had a full and detailed understanding of the nature of tsunami and of the current capabilities and limitations of tsunami detection and warning systems.

It was in the process of undertaking the required research that it became apparent that there are significant gaps in the knowledge base for tsunami world-wide and especially in the Australian context. There are differences of opinion within the scientific community about the evidence for past tsunami events and the likelihood and magnitude of tsunami in the future. The most difficult challenge for those involved in the response planning is that there is little or no information available by way of tsunami prediction for actual events.

The Tsunami Emergency Sub Plan is comprehensive in scope and deals with; preparedness, response and the initiation of recovery. The plan accounts for all possible tsunami magnitudes and generating mechanisms. Responsibilities for agencies likely to be involved in tsunami management are listed within the plan. As with all NSW emergency management plans, the plan works from an assumption that agency responsibilities should focus on those activities for which they are naturally best suited by virtue of their usual business orientation. Put simply this means; fire & HAZMAT managed by fire & HAZMAT specialists, rescue managed by rescue specialists, health managed by health specialists, warning and evacuation managed by warning and evacuation specialists, etc.

The Tsunami Emergency Sub Plan identifies that the following specific emergency management functions may be required:

- Tsunami detection and notification
- Warning dissemination
- Evacuation of at-risk residents
- Protection and pre-deployment of resources
- Restriction of access to areas likely to be affected
- Management of waterways
- Reconnaissance of areas likely to be affected
- Search and rescue following the impact of a damaging tsunami
- Damage control to prevent further damage to damaged buildings
- Fire and HAZMAT management
- Media management
- Information management

- Resupply of isolated communities and properties
- Disaster victim identification and registration
- Health care, provided by a wide range of health services to treat affected communities
- Management of energy and utilities
- Transport management
- Communications management
- Management of animals
- Property protection

The plan is publicly available from the emergency NSW and SES websites at www.emergency.nsw.gov.au and www.ses.nsw.gov.au.

Tsunami Warning Systems

Advice about potential tsunami in the Pacific Ocean is issued by the Pacific Tsunami Warning Center in Honolulu. Information regarding the Pacific Tsunami Warning Center and its warning network in the Pacific Ocean is available on its website at www.prh.noaa.gov/ptwc.

The Australian Bureau of Meteorology (BoM) NSW Regional Forecasting Centre is the official channel into NSW for the receipt of all tsunami bulletins from the Pacific Tsunami Warning Center and is responsible for the initial broadcast distribution of BoM NSW Tsunami Warnings. The SES is responsible for directing the dissemination of tsunami warnings at Regional and Local levels.

Warnings will be disseminated by broadcast media; doorknocking; fixed and mobile public address systems; marine radio; variable message signs and the internet. The SES is currently undertaking further research into other possible warning dissemination methods.

Available effective warning time will vary depending upon the distance of our coastline from the point of tsunami generation. In the event of a tsunami being generated directly offshore of our coast, little to no warning will be available at the point of first impact apart from possible environmental warning signals such as the recession of the ocean prior to tsunami impact.

The best warning strategy for local tsunami is public education to ensure that the community is aware of environmental cues and what actions to take when they are observed.

Since the Indian Ocean tsunami on 26 December 2004, the Australian Government has focussed on tsunami risk around the country and the region, and the need to provide timely and effective warning services. In the May 2005, Budget a number of initiatives designed to enhance community safety were announced, one of which included the establishment of an Australian Tsunami Warning Centre to be operated jointly by the BoM and Geoscience Australia. Further information regarding Federal Government tsunami initiatives is available on the BoM website http://www.bom.gov.au/oceanography/tsunami/atws_summary.shtml.

Risk Assessment

The hazard magnitude for tsunami threatening NSW is difficult to assess because of a lack of suitable research. The magnitude is likely to vary along the coast due to various offshore and coastal features. A consequence of the lack of research is that, no detailed tsunami hazard assessments have been conducted to assess what areas may be exposed to the greatest hazard. The general nature of the information available from the short history of tsunami occurrence and lack of detailed modelling also makes it difficult to estimate magnitude-frequency relationships for tsunami.

Davidson & Rynn (1998) in their assessment of tsunami risk in Australia recognised the high risk along the NSW coast. Initial estimates made by the SES using 2001 census information suggest that 250,000 people live within 500 metres of the NSW coast and estuaries and below the 10 metre AHD contour. This estimate rises to some 330,000 people when considering people living within one kilometre of the NSW coast and estuaries and below the 10 metre AHD contour. Approximately 20% of the population potentially at-risk of tsunami is over the age of 65, which is greater than the state-wide average of 13%.

Vulnerability to tsunami is greatest between the Shoalhaven coast and the Newcastle coast, reflecting the high population density in this area. This vulnerability is expected to increase as a consequence of expanding coastal development in response to; continuing population growth, population ageing and the coastal retirement trend. Vulnerability is also seasonal and peaks during the summer months, especially during school holidays from December through to the end of January.

The work to prepare the Tsunami Emergency Sub Plan has identified that both marine and land based elements are vulnerable to tsunami. It is likely that all significant tsunami (i.e. those that are noticeable) will affect marine based risk groups, whilst larger tsunami are likely to cause damage to land based elements. It is therefore important to distinguish between them. Table 1 (below) lists examples of land and marine based elements that are vulnerable to tsunami.

Marine Based Elements	Land Based Elements
• Boats and their crew • Beach users, including swimmers, surfers, sunbathers, and fishers • Divers and snorkelers • Aquaculture industries • Submarine power, telecommunications, fuel and water supply lines • People and facilities in ports, harbours and marinas • Sewerage outfalls	• People and property in caravan parks and camping areas in low-lying coastal areas or on floodplains in tidal river areas • Coastal infrastructure including roads, bridges, power, water, gas, sewerage and telecommunications • Residential, commercial and industrial buildings and their occupants in low-lying coastal areas or on floodplains in tidal river areas • Motorists and vehicles on low-lying coastal roads • Low-lying coastal farmland including animals and crops. • Institutions such as schools and hospitals located in low-lying coastal areas.

Table 1 Examples of land and marine based elements at risk of tsunami.

It is clear that the knowledge gaps regarding tsunami risk must be addressed. To this end the State Emergency Service and the NSW Department of Natural Resources have entered into a partnership to manage a tsunami risk assessment scoping study for the NSW coastline. Funding for the study was successfully obtained through the Natural Disaster Mitigation Program.

The study will compose the following components:

- Identification of tsunami sources, including an assessment of their relative tsunamigenicity.
- Summary of NSW tsunami history, including paleotsunami studies.
- Estimation of travel times for each credible tsunami source.
- Estimation of wave heights along the entire NSW coast to 50m depth for regional and distant tsunami sources.
- Broad based assessment of coastal vulnerability.
- Assessment and collation of available topographic and bathymetric data to facilitate future modelling of tsunami inundation.
- Assessment of inundation and risk modelling requirements.

The outcomes of the study will provide a general assessment of tsunami risk and provide information for the prioritisation of communities for future detailed tsunami inundation modelling.

Risk assessment information will allow for more detailed emergency planning and community specific education programs to be conducted.

Conclusion

The primary focus of current tsunami management initiatives is to maximise the capacity of emergency services to combat tsunami, in particular to enhance the ability to warn and evacuate people at-risk. Without detailed risk assessment information these tasks will be much more difficult to undertake.

Future initiatives will focus upon community education; more detailed emergency planning and advanced warning systems. Community education programs will be aimed at developing understanding of the tsunami risk posed to communities and empowering people to take appropriate action in response to a tsunami. These enhancements also fundamentally depend on the tsunami risk assessment process.

References

Brisbane Courier Mail (25/5/1960).

Bryant, E., Young, R. and Price, D. (1992) Evidence of tsunami sedimentation on the south eastern coast of Australia. *Journal Geology* 100, 753-765.

Bryant, E. and Price, D. (1996) Bedrock-sculpturing by tsunami, South Coast New South Wales, Australia. *Journal Geology* 104, 565-582.

Bryant, E. and Nott, J. (2001) Geological Indicators of Large Tsunami in Australia. *Natural Hazards* 21, 231-249.

Davidson, J. and Rynn, J. (1998) *Contemporary Assessment of Tsunami Risk and Implications for Early Warnings for Australia and its Island Territories*. Bureau of Meteorology and The Centre for Earthquake Research in Australia, Brisbane.

Dominey-Howes D. (2005) *Personal Communication*. Macquarie University, Australia.

Felton, E. A. and Crook, K.A.W., (2003) Evaluating the impacts of huge waves on rocky shorelines: an essay review of the book 'Tsunami – The Underrated Hazard' *Marine Geology* 3304, 1-12.

Geoscience Australia (1996) *The Australian Tsunami Database*. Geoscience Australia, Canberra.

Hobart Mercury (25/5/1960) Sydney Harbour in Chaos from Quake Wave.

Jenkins, C. and Keene, J. (1992) Submarine slope failures of the southeast Australian continental slope: a thinly sedimented margin. *Deep Sea Research* v. 39 n. 2, 121-136.

Rynn, J. (1994) Tsunami and their effect on Australia. In: *Proceedings of the National Tsunami Workshop, August 1994*, Brisbane.

State Emergency Service NSW (2001) *NSW State Flood Plan*. State Emergency Service, Wollongong.

Sydney Morning Herald (17/8/1868).

Synolakis, C.E., and G.J. Fryer, 2001. Book Review: *Tsunami: the underrated hazard* by Edward Bryant, *Eos, Trans. Am. Geophys. Union*, 82, 588

STRATEGIES FOR SUSTAINABLE ICOLL MANAGEMENT

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Abstract

The unique physical and chemical behaviour of ICOLLs necessitates a management regime that is different from other estuary types. For approximately 70% of ICOLLs in NSW, entrances are predominantly closed, meaning that 100% of inputs to the lakes are captured and stored or assimilated by lake processes. Several strategies have been developed to address the sustainable long term management of ICOLLs, with particular reference to lakes within NSW. These strategies address the underlying threats to ICOLL sustainability by considering their physical structure and behaviour, as well as their prevailing chemical and biological processes.

Issues targeted by the strategies include existing and future catchment development and associated pollutant inputs, artificial entrance management, foreshore inundation mitigation, habitat loss, waterway activities, and institutional arrangements for ICOLL management and conservation. The strategies are not designed to provide a complete package for ICOLL management. Rather, they should be used to form the base for individual Management Plans, which are tailored to suit the specific management requirements of each system. They have, however, been developed considering the existing planning and funding constraints that have limited ICOLL management in the past.

Actions associated with the implementation of the strategies have been assigned to various departments of State Government as well as local Councils, depending on jurisdictional roles. The actions include modifications and specific considerations for ICOLLs in a range of planning instruments, including Regional Strategies, Fisheries Habitat Protection Plans, SEPP-35, Local Environmental Plans, and the new Coastal Zone Management Manual. It is also recommended that a new SEPP be prepared specifically for ICOLLs/coastal lakes to bring together all planning requirements that are currently spread across a range of existing instruments, policies and other non-statutory planning provisions.

Introduction

A series of strategies have been developed to address the key management issues facing Intermittently Closed and Open Lakes and Lagoons (ICOLLs) today. The strategies primarily target future development controls and existing management practices, through a range of new or modified planning tools. Overarching the strategies is the long term goal of eliminating the need to artificially opening ICOLL entrances. Artificial management of ICOLL entrances is considered totally unsustainable given the implications of future sea level rise.

Opportunities are available to limit the detrimental impacts of future sea level rise on community and infrastructure. However, if decisions to act are delayed, then the magnitude of the problem will only intensify in the future, as more people move to a coast that is ultimately under threat by the sea. Pro-active, integrated and adaptive management is needed today to minimise the conflict and continued environmental degradation that will happen tomorrow.

While it is acknowledged that the strategies presented herein are not the only management approaches available, they do represent some of the best options for achieving long-term sustainability, particularly when considering existing planning and funding constraints that have generally obstructed effective management of ICOLLs to date.

Strategy 1

<u>Discourage future intensification of development around 'healthy' and sensitive ICOLLs, while allowing 'appropriate' development around more robust or currently degraded ICOLLs.</u>

Reasons for the Strategy

Some ICOLLs are in good condition and provide significant ecological value. These lakes should be conserved to retain their inherent values. Many other ICOLLs have experienced development within their catchments, but as yet have not suffered significant environmental degradation. These lakes may be 'on the brink' of degradation, and should be protected to avoid the systems falling into a downward spiral. Further, some lakes are naturally more susceptible to external inputs, such as ICOLLs that rarely open to the sea.

Water quality data for NSW ICOLLs show that conditions tend to degrade rapidly once more than half of the catchment becomes developed. Therefore, ICOLLs that are approaching 50% development within their catchments are considered to be 'at significant risk' of degradation if further development is permitted.

A relative conservation priority ranking has been established for the NSW ICOLLs and is presented in Haines (2006). This ranking is based on (i) current condition of the catchment; and (ii) natural sensitivity of the waterway to external inputs, ie its morphometric-based classifications (see Haines, 2004b; Haines et al., 2006).

Implementation Approach

The most appropriate method for implementation would be to incorporate this strategy into regional or state-wide planning policies.

Regional Strategies, currently in preparation by the NSW Government, should consider the relative sensitivity of different ICOLLs (as presented in Haines, 2006), defining 'go' and 'no go' areas for different lakes. Preferably, the Regional Strategies should avoid extensive future development within any ICOLL catchment given they are much more naturally sensitive that other estuary types (Boyd *et al*., 1992; HRC, 2002).

For large LGAs that contain many ICOLLs (e.g., Shoalhaven, Eurobodalla, Bega Valley in NSW), there may also be opportunity to include the principles of this strategy into Local Environmental Plans (LEPs).

Strategy 2

Future development should be encouraged in sections of the catchment that are already degraded and have limited ecological value. This way, 'appropriate' development has the potential to reduce catchment pollutant runoff, and improve the state or condition of the ICOLL.

Reasons for the Strategy

For ICOLLs that can accommodate some degree of future development within their catchments, as defined by Strategy 1, the development should result in a net positive environmental benefit to the ICOLL and its catchment.

Locations of future development should be sited to occupy only those areas of the catchment that are currently developed for other landuse activities and generate considerable pollutant loads (e.g. agriculture, horticulture). Also, the future development must incorporate best practice stormwater and total water cycle management to minimise pollutant loads to the environment, including for example water harvesting from rainwater tanks, dual reticulation systems, stormwater infiltration and greywater effluent reuse (WSUD, 2006; Engineers Australia, 2005).

By imposing controls on development that require a net reduction in pollutant loads, land developers will be able to target the most degraded sections of the catchment for future development, as these areas would be the easiest to achieve a net positive environmental benefit.

Implementation Approach

Potential future development areas should be clearly defined within Local Environmental Plans with an initial zoning of Rural (Investigation) (as per the LEP template), before being up-zoned to urban or rural-residential zones, if considered appropriate (following more detailed investigations, such as an LES).

The requirement to achieve a net positive environmental outcome and adopt current best practice stormwater and water cycle management should be incorporated into individual site specific Development Control Plans (DCP). Councils (or State Government) could also prepare a general guidelines policy, used to help prepare individual DCPs, which relates specifically to ICOLLs and their catchments, and would contain such standard provisions.

Strategy 3

Buffers or offsets to development are required around ICOLLs that take into consideration the functionality of the biophysical ecosystem and their expected response to future environmental change.

Reasons for the Strategy

Development around the foreshores of ICOLLs should be kept a sufficient distance away from the waterway to allow it to maintain natural functionality associated with foreshore inundation, and accommodate expected responses to future climate change.

Increasing coastal populations in the future will result in pressure to develop lands close to ICOLLs. When this pressure is combined with the potential physical response of ICOLLs to future climate change, the natural foreshores will be 'squeezed out', significantly limiting their habitat and environmental values.

Implementation Approach

The methodology for determining future development buffers is based on a number of fundamental management principles:

- The ICOLL should be permitted to experience a full range of natural water level conditions;
- Water levels in the ICOLL will increase in the future as a natural response to increasing sea levels, and associated increases in entrance berm conditions (Haines & Thom, in prep.);
- Groundwater levels will increase in response to sea level rise (Bird, 2002), which may compromise the existing functionality of foreshore landuses;
- Vegetated buffers should be provided around the ICOLL beyond the natural range of water level conditions to allow for natural ecosystem functioning and interaction between the estuarine and terrestrial environments; and
- Some ICOLLs, or specific parts of the waterway, may be more sensitive than others, and thus may require additional buffering between the development and the waterway.

Implementation of buffers around ICOLLs is detailed in Haines (2005). The buffers incorporate a vertical component, to allow for the natural expansion and contraction of the waterway, and for allowance of future sea-level rise; and a horizontal component, landward of the lateral extent of the vertical component, to maintain riparian ecosystems, and to protect the waterway environment from the potential impacts of development.

Strategy 4

Prevent the temporary or permanent artificial modification of ICOLL entrances unless for human health reasons, and unless works are part of a formally approved plan or policy.

Reasons for the Strategy

The aim of this strategy is to prevent the on-going degradation of ICOLL environments resulting from future entrance modification, and allow the re-establishment of habitat and environmental values that have been diminished or lost by past practices.

The temporary artificial modification of ICOLL entrances is inconsistent with the principles of Ecological Sustainable Development, and thus the NSW Coastal Policy 1997. Artificial entrance manipulation is a 'quick fix' to redress the issue of inappropriate landuse planning around waterway foreshores, and creates a perpetual onus on current and future generations. Further, a change to the hydraulic regime of the ICOLL as a result of the entrance intervention has the potential to degrade or even destroy fringing wetland communities and other environments.

Implementation Approach

Preventing artificial entrance manipulation should be achieved through declaration of such works as 'prohibited development' under the relevant LEP. For this to be effective, the entrance areas of each ICOLL would need to be zoned accordingly and details of 'prohibited' works included in the LEP description for the zone.

Alternatively, and to achieve a consistent, state-wide approach to limiting artificial entrance activities, it is suggested that a new Key Threatening Process (KTP) be gazetted under the *NSW Fisheries Management Act 1994* and/or the *NSW Threatened Species Conservation Act 1995*. This new KTP could be documented as "temporary or permanent artificial opening of ICOLL entrances at levels consistently lower than natural breakout levels". It is considered that artificial manipulation of ICOLL entrances is justified as it meets the requirements of a KTP as specified in Section 220F (6) of the *Fisheries Management Act 1994*, that is, it adversely affects two or more threatened species, populations or ecological communities, or could cause species, populations or ecological communities that are not threatened to become threatened.

Strategy 5

Existing private and public assets and infrastructure that currently dictate the need for entrance modification should be relocated or permanently modified to restore natural hydraulic functioning of ICOLLs.

Reasons for the Strategy

This strategy is only applicable to ICOLLs that are currently subject to artificial entrance manipulation. For most ICOLLs that are artificially manipulated, assets, infrastructure and private lands have been established within the extents of natural inundation. Trigger levels for artificially opening entrances have been determined based on the level of potential risk or damage to the assets and infrastructure. This strategy involves the progressive removal, relocation or flood-proofing of public and private assets and infrastructure so that trigger levels for entrance manipulation can be progressively increased in the future.

Minimising the impacts of existing entrance management practices should initially target ICOLLs that are in a mostly good condition, as continued manipulation has the potential to degrade these systems (unlike mostly urban systems that are already highly degraded). An indicative priority ranking of NSW ICOLLs has been prepared based on the environmental condition of the lake and the recommendations for future management developed by the Healthy Rivers Commission (2002) (Table 1).

Table 1 Prioritised ranking of NSW manipulated ICOLLs for redressing on-going entrance management issues

> 60% forest ('healthy' ICOLLs)	*Priority 1*	Bournda [a]	Brou [a]	Durras [a]			
	Priority 2	Mummuga [b]					
	Priority 3	Termeil [a]	Wollumboola [a]				
	Priority 4	Back [b]	Conjola [b]	Middle (Tj) [b]	Swan [b]	Tabourie [b]	Wallagoot [b]
	Priority 5	Coila [c]	Curalo [c]	Kianga [c]			
	Priority 6	Corunna [b]					
	Priority 7	Cockrone [c]	Wallaga [c]				
< 60% forest	*Priority 8*	Cakora [b]					
	Priority 9	Avoca [c]	Burrill [c]	Congo [c]	Narrabeen [c]	Saltwater [c]	Wamberal [c]
	Priority 10	Werri [c]					
	Priority 11	Curl Curl [d]	Dee Why [d]	Terrigal [d]			

a: Classified as Comprehensive Protection in HRC (2002)
b: Classified as Significant Protection in HRC (2002)
c: Classified as Healthy Modified Conditions in HRC (2002)
d: Classified as Targeted Repair in HRC (2002)
Note: ICOLLs where existing entrance management / manipulation information was not available have not been included in the table.

Implementation Approach

A range of implementation approaches have been formulated for the progressive removal, relocation or flood-proofing of assets and infrastructure. These approaches are detailed in Haines (2006). The approaches are similar to works recommended by many Floodplain Risk Management Plans. As few NSW ICOLLs have Floodplain Risk Management Plans, it is considered that Interim Flood Management Plans could be developed based on the principles of removing or flood-proofing assets and infrastructure within areas subject to inundation / foreshore flooding.

To implement this strategy, an 'Inundation Zone' should first be determined and mapped for each ICOLL, covering all lands (private and public; urban and rural) around the waterway representing the area that would be inundated by the maximum possible water level of the ICOLL (without entrance manipulation) at the end of an appropriate planning horizon (100 years say). Authorities should retain the right to progressively move the Inundation Zone landward, in response to future climate change and forward planning provisions.

It is recognised that significant existing development (eg residential housing) may prohibit the complete return to natural water level regimes in some ICOLLs. In these circumstances, the maximum Inundation Zone may be capped at a level that is considered to be achievable within the scope and extent of existing development.

Authorities should then carry out an inventory of all private and public infrastructure and assets located within the Inundation Zone. Based on the level of existing assets and infrastructure, combined with the relative priority ranking of the ICOLL (Table 1), authorities can decide on which ICOLLs should be targeted for restoration of natural hydraulic regimes.

For ICOLLs that are targeted for restoration, the Inundation Zone should be identified within local environmental planning instruments (and possibly assigned an appropriate landuse zoning). For consistency with Strategy 3, definition of the Inundation Zone may also incorporate a 50 metre horizontal buffer when included within environmental planning instruments.

As an alternative to a rezoning, the maximum extents of inundation (at the end of an appropriate planning period) may be represented by a 'Foreshore Inundation Line' (FIL). The FIL would be similar to a Foreshore Building Line (as defined by Clause 35 in the draft LEP template, NSW Government, 2005) and would be used to define additional development controls on all lands seaward of this line. Councils would be required to include local provisions for a FIL, if used, within individual LEPs.

Strategy 6

To formalise the requirements of Strategy 5, an appropriate planning framework and associated management guidelines should be developed to facilitate 'appropriate' permitted entrance works.

Reasons for the Strategy

This strategy aims to provide a formal planning mechanism that directs works towards the long-term goal of eliminating the need for on-going artificial entrance management.

Although ideal, it is recognised that periodic entrance manipulation of ICOLLs cannot be stopped immediately without serious detrimental social and economic consequences to the community. A formal policy is required to ensure that on-going entrance works balance the social and economic demands against the environmental consequences of such actions.

Implementation Approach

For each ICOLL subject to artificial entrance manipulation, a formal Entrance Opening Plan (EOP) should be prepared. The recommended contents of an EOP are detailed in Haines (2006).

Works within the entrance of a NSW ICOLL would be subject to assessment under the provisions of the *NSW Environmental Planning and Assessment (EP&A) Act 1979*. The EOP therefore should be accompanied by an Environmental Impact Assessment that satisfies the requirements of this Act. Consent provided for the works should remain valid for a fixed term (say 5 years), so that works can be undertaken quickly, in response to rapidly changing environmental conditions (e.g. sudden increase in water level or degradation of water quality), without the need for additional consultation and assessment.

For NSW ICOLL entrances that are on Crown land, consent would involve obtaining a Crown land licence from the NSW Department of Lands, in accordance with Part 4, Division 4 of the *NSW Crown Lands Act 1989*. For entrances not located on Crown land, consent may involve obtaining a dredging permit from the NSW Department of Primary Industries, in accordance with Division 3, Part 7 of the *NSW Fisheries Management Act 1994*.

State Environmental Planning Policy (SEPP) No. 35 – Maintenance of Tidal Waterways is cited as a governing provision for artificially opening some ICOLLs in NSW (Haines, 2004a). SEPP-35 applies to tidal waterways, which are defined in the SEPP as "a channel or passage within a body of water, where the tide ebbs and flows…". Several court judgements (eg, Attorney General v. Swan (1921) 21 S.R.408) have determined that tides need to be ebbing and flowing <u>regularly</u> to be recognised by the law (Thom, 2004). ICOLLs therefore would be deemed non-tidal waterways, particularly ICOLLs that are mostly closed. SEPP-35 is therefore not a legal mechanism for undertaking entrance opening works in ICOLLs. It is recommended that an amendment be made to the definition of tidal waterways in Clause 3 of SEPP-35 to specifically exclude waterways that are intermittently non-tidal.

The most effective means for legitimising EOPs for all ICOLLs across the state is to prepare and adopt a special planning provision, such as a SEPP. A state-based policy would provide consistency in entrance management across the state, which is a noted problem for existing management practices in NSW.

Strategy 7

<u>To address previous habitat loss from many ICOLLs, the foreshores should be rehabilitated to restore natural ecosystem function, while vegetated corridors should also be established across catchment landscapes to reconnect ICOLLs with other environments and fragmented habitats.</u>

Reasons for the Strategy

This strategy involves the re-establishment of riparian habitat around ICOLLs. Existing riparian vegetation around many ICOLLs has been cleared or denuded by past urban and agricultural development. This strategy also recommends re-establishment of vegetated wildlife corridors across catchment landscapes to reconnect the lake environment with other habitat types, including other nearby ICOLLs and wetlands.

Riparian vegetation plays a significant role in the ecosystem of an ICOLL, providing food and shelter for aquatic fauna when inundated, as well as a source of nutrients for ecological productivity. Riparian vegetation also provides habitat and refugia for wading birds (some of which may be threatened) and other fauna, as it acts as a corridor for wildlife movement around the waterway. Regeneration of ICOLL foreshores should accompany the progressive increase in lake water levels, as sought by Strategies 4, 5 and 6. Significant regeneration of ICOLL foreshores can also be used to help achieve the net positive environmental outcomes for future development as stated by Strategy 2. Ideally, foreshore regeneration should cover the entire Inundation Zone (accounting for future changes in sea level) and associated buffers / offsets defined by Strategy 3.

Wildlife corridors allow the migration of species beyond their original boundaries, which has advantages for food, shelter, genetic diversity, and providing access to alternative habitat during times of drought and bushfire. Corridors should preferably be at least 100 metres wide to maximise their use by wildlife, and to overcome 'edge effects'.

Implementation Approach

Regeneration of foreshores and provision of wildlife corridors should be a condition of future private development on targeted lands around ICOLLs. These lands should be identified within local government planning instruments, policies or natural resource management plans (including Estuary Management Plans, Coastal Zone Management Plans). Regeneration on private lands should also be encouraged, in the interim, on a voluntary basis, with incentives provided by the relevant authorities, including the Catchment Management Authorities.

For public lands, regeneration of foreshore reserves and wildlife corridors should be included as part of appropriate natural resource management plans.

Strategy 8

<u>Prohibit dredging within ICOLLs to avoid changes in benthic metabolism and potential degradation of water quality.</u>

Reasons for the Strategy

This strategy aims to prohibit broadscale dredging within ICOLLs to avoid changes in sediment processes and potential decline in environmental health. This strategy does not include earthworks carried out within an entrance channel to artificially open an ICOLL. Such works should be undertaken in accordance with an EOP (refer Strategy 6).

ICOLLs are natural depositional environments (Roy *et al*., 2001). Fine sediments entering ICOLLs are circulated around the waterway by wind-driven currents before depositing on the bed. This process leads to relatively flat bed profiles in most ICOLLs, particularly those that are mostly closed and have a more circular shape.

Dredging within fluvial deltas would create a 'trap' for new sediment washed off the catchment. The dredged area would infill with relatively coarse sediment at a rate governed by the amount of soil erosion within the catchment.

Dredging within marine deltas would create a deficit of marine sand within the entrance. If the entrance is closed, this deficit would remain latent, however, if the entrance is open, sediment would be reworked into the dredge hole by coastal processes. The sand used to fill the hole would effectively be taken from the adjacent beach. Dredging within marine deltas is therefore comparable to beach mining.

Dredging within the central deep mud basin would create localised deeper sections of the lake bed. Circulation currents within the lake would result in increased deposition in the dredge hole, as the lake tries to restore a 'flat bottom' profile. A concentrated build-up of organic material, rather than an even dispersal across the whole lake bed, would result. Overloading of organics to the bed can have significant consequences on the environmental processes occurring within the bed sediments. Overall, dredging within the deep mud basin would potentially increase nutrients in the water, which may lead to more frequent or longer lasting algae blooms.

Implementation Approach

Prohibition of dredging within ICOLLs can be achieved in a number of ways. First, dredging can be identified as a prohibited development within the landuse zoning that is assigned to the lake. Based on the draft LEP template (NSW Government, 2005), an appropriate landuse zoning for coastal lakes would be Environmental Protection – Conservation. To achieve consistency across the state, however, a new statutory policy (e.g. SEPP) should be prepared that prohibits dredging from within nominated ICOLLs.

Strategy 9

Replace older-style on-site sewage and septic systems around ICOLLs with modern on-site systems, or pump-out tanks where development is low-lying.

Reasons for the Strategy

In an assessment on conditions of septic systems in coastal NSW, Codd (1997, *cited in* Geary, 2003) reports failure of some 50-90% of systems investigated. The mostly rural landscape surrounding most ICOLLs in NSW means that sewage from surrounding development is generally treated by on-site systems. Ineffective older style and poorly maintained on-site sewage systems are considered to be a potentially significant source of nutrients and bacteria to ICOLLs. This strategy aims to reduce pollutant loads through systematically replacing ineffective systems with modern sewage treatment approaches located within 500 metres of the maximum inundation extents (ie within 500m of the Inundation Zone or FIL, as defined by Strategy 5). Eco-friendly alternatives to septic systems would include Aerated Wastewater Treatment Systems (AWTS), sand filters, biological filters, reverse osmosis or micro-filtration filters, waterless composting toilets and greywater reuse systems.

For developments that are within one (1) vertical metre of the maximum inundation level of the ICOLL, it is recommended that on-site systems be replaced by a holding tank and pump-out system, to completely eliminate the potential for effluent to reach the waterway. Tourist developments (including caravan parks, B&Bs etc) should also be required to have pump-out tanks, to accommodate the increase in effluent load during peak holiday periods, or have an on-site system capable of treating the maximum tenancy (even under sub-optimal soil conditions).

Implementation Approach

An inventory of all on-site sewage systems within 500 metres of the maximum inundation extents (Inundation Zone) and within 1 vertical metre of the maximum inundation levels, should be prepared by relevant local government authorities for every ICOLL. Detailed audits of each on-site system should then be carried out by the local government authority, as a matter or priority. For all systems deemed to be deficient or ineffective, landholders should be required to replace the systems within a nominated timeframe (1 year, say).

Specific requirements for pump-out systems within the low-lying areas and requirements associated with tourist accommodation developments should be incorporated into appropriate local government environmental planning instruments (such as local on-site sewage management policies). For new rural or rural-residential developments, Councils could also require the use of a greywater reuse system to minimise the volume of effluent generated from individual properties.

Strategy 10

Formally protect ICOLLs and associated habitats (including development buffer areas as recommended in Strategy 3) through appropriate statutory plans or policies, including allowance for natural shifts in biophysical function in response to future environmental change.

Reasons for the Strategy

This strategy recommends the establishment of statutory policies that formally protect ICOLL environments from future degradation, and assures adequate provision for accommodation of natural shifts in physical and biological conditions of lakes in response to future climate change. Statutory provisions regarding ICOLL conservation would ensure that decisions regarding other aspects of lake management (eg preparation of Floodplain Risk Management Plans, Crown Land Plans of Management etc) give appropriate consideration to environmental outcomes. Statutory provisions would also ensure ICOLL conservation is considered as part of the local Development Assessment process.

ICOLLs are worthy of special conservation consideration, as they are relatively unique from a physical and a biological perspective. Many studies have been carried out on the ecological values of ICOLLs in NSW, and conclude that they play a significant role in the total fisheries value of the state and adjacent coastal waters (Pollard, 1994; Pease, 1999). With respect to conservation, Jones and West (2005) suggest that measures to protect fish diversity within coastal lakes should be carried out at a 'whole-of-lake' scale, rather than selective 'sanctuary' areas within the waterway.

Implementation Approach

Conservation policies relating to ICOLLs should be statutory, and equally applicable to all systems across the state.

The preferred option for consistent statutory conservation involves the preparation of a special state planning policy (e.g. a SEPP), which relates specifically with ICOLLs, and other similar coastal environments. The policy would document restrictions on development and activities within and around ICOLLs (incorporating Strategies 2, 3, 4, 7, 8 and 9) and the need for certain works, investigations and commensurate management frameworks (incorporating Strategies 5 and 6). At a state-wide basis, the policy could additionally restrict development from within entire ICOLL catchments (thus also incorporating Strategy 1).

With respect to entrance management, the SEPP should state that artificial entrance openings are prohibited unless a formal Entrance Opening Plan (EOP) has been prepared and endorsed by relevant government authorities (including DNR, DPI-Fisheries, DoL) and is actively implemented by Council. The preparation of an EOP should be accompanied by an Environmental Impact Assessment, which would be assessed under the *Environmental Planning and Assessment Act 1979*.

Another possible avenue for protection of ICOLLs is the gazettal of a new Habitat Protection Plan (prepared under the provisions of Part 7, Division 1 of the *Fisheries Management Act 1994*) that relates to coastal lakes, or just to ICOLLs. Under Clause 192 (2) of the Act, a Habitat Protection Plan:

(a) may relate to habitat that is essential for spawning, shelter or other reason, and

(b) may apply generally or to particular areas or fish, and

(c) is to describe the importance of particular habitat features to which it applies, and

(d) may set out practical methods for the protection of any such habitat features, and

(e) may contain any other matter concerning the protection of the habitat of fish that the Minister considers appropriate.

Given the outcomes of recent and more historic studies (e.g., Pollard, 1994; Griffiths, 1999; Williams *et al*., 2004; Jones and West, 2005; Dye, 2005; Dye and Barros, 2005), it is considered that a Habitat Protection Plan covering NSW ICOLLs, or indeed all coastal lakes, is justified given their significance to regional and state-wide fisheries and their relatively unique habitat structure.

Another avenue for statutory conservation relates to the contents of future Coastal Zone Management Plans. Specific conservation measures for individual ICOLLs could be included in CZMPs, however, given that individual Plans are to be prepared for different sections of coastline or estuary, gaining consistency between the Plans may be difficult. Furthermore, the timeframe for preparation of each individual CZMP is unknown and based on available funds and priorities of individual Councils and State Government. Greater consistency between CZMPs could be achieved if appropriate provisions are made within the Coastal Zone Management Manual (CZMM) (currently in preparation by DNR), which is to guide preparation of CZMPs (as specified in Part 4A Section 55D of the *Coastal Protection Act 1979*). Consequently, it is recommended that the CZMM be modified to ensure that CZMPs address catchment development pressures, competing waterway values, and the need to accommodate future climatic change. Furthermore, the CZMM should direct CZMPs to aim to return natural hydraulic regimes to ICOLLs, via a formal EOP.

To assist Council Development Assessment planners and ensure that the principles of ICOLL conservation are incorporated into the development assessment process, it is suggested that a ‘planning checklist’ framework be established and applied locally for all development and rezoning applications within coastal lake catchments.

References

Bird, E. (2002) “The effects of a rising sea level on the Gippsland Lakes” in Gippsland Coastal Board, *Gippsland Lakes Shore Erosion and Revegetation Strategy*, Final Report June 2002

Boyd, R., Dalrymple, R., and Zaitlin, B. A. (1992) “Classification of clastic coastal depositional environments” *Sedimentary Geology*. 80, pp 139-150.

Dye, A. H. (2005) “Meiobenthos of intermittently open/closed coastal lakes in New South Wales: spatial and temporal patterns in densities of major taxa” *Marine and Freshwater Research* **56** (8), 1055-1067

Dye, A. and Barros, F. (2005) “Spatial patterns of macrofaunal assemblages in intermittently closed/open coastal lakes in New South Wales, Australia” *Estuarine, Coastal and Shelf Science* **64** (2-3), 357-371

Engineers Australia (2005) “Australian Runoff Quality” Draft, Australia's National Committee on Water Engineering, Engineers Australia, Canberra

Geary, P. M. (2003) “On-site treatment system failure and shellfish contamination in Port Stephens, NSW” Report prepared for the NSW Dept of Local Government. University of Newcastle, Septicsafe Enhancement Grant Project E08

Griffiths, S. P. (1999) “Consequences of artificially opening coastal lagoons in their fish assemblages” *Int. Jnl Salt Lake Res*. **8** (4): 307 – 327

Haines P.E. (2004a) “Current Entrance Management Practices for NSW ICOLLs” Proc. CZAP’04 Coastal Zone Asia Pacific Conf., Brisbane 5 – 9 Sept. 2004, pp 294 – 300

Haines P. E. (2004b) “Application of a morphometric-based classification system on the natural sensitivity of NSW ICOLLs” Proc. 13th Ann. NSW Coastal Conf., Lake Macquarie Nov. 2004, pp 76 – 80

Haines P. E. (2005) “Determining appropriate setbacks for future development around ICOLLs” Proc. 14th Ann. NSW Coastal Conf., Narooma Nov. 2005

Haines, P. E. (2006) “Coastal Lakes Management: Strategies for a sustainable future” WBM Pty Ltd, Broadmeadow NSW

Haines P. E., Tomlinson R. B, and Thom B. G. (2006) “Morphometric assessment of intermittently open/closed coastal lagoons in New South Wales, Australia” *Estuarine, Coastal and Shelf Science* **67** (1-2) 321-332

Healthy Rivers Commission (2002) “Independent Inquiry into Coastal Lakes – Final Report”, Sydney

Jones, M. V. and West, R. J. (2005) “Spatial and temporal variability of seagrass fishes in intermittently closed and open coastal lakes in south-eastern Australia” *Estuarine, Coastal and Shelf Science* **64**:277-288

NSW Government (2005) “Standard Instrument (Local Environmental Plans) Order 2005 - draft” Department of Planning, September 2005

Pease, B. C. (1999) “A spatial oriented analysis of estuaries and their associated commercial fisheries in New South Wales, Australia” *Fisheries Research* **42** (1999), pp. 67-86

Pollard, D. A. (1994) “A comparison of fish assemblages and fisheries in intermittently open and permanently open coastal lagoons on the south coast of New South Wales, south-eastern Australia” *Estuaries* **17**:3, Sept. 1994, pp. 631-646

Roy, P. S., Williams, R. J., Jones, A. R., Yassini, I., Gibbs, P. J., Coates, B., West, R. J., Scanes, P. R., Hudson, J. P. and Nichol, S. (2001) “Structure and function of Southeast Australian Estuaries” *Estuarine, Coastal and Shelf Science* **53**:351-384

Thom, B.G. (2004) "Geography, planning and the law: a coastal perspective" *Australian Geographer*, Vol. 35, No. 1, pp 3-16

Williams, R. J., Louden, B., and Jones, M. (2004) "Fish biodiversity in Lake Illawarra: A review of three recent surveys" *Wetlands (Australia)* 21(2) pp 163-176

WSUD (2006) "Water sensitive urban design in the Sydney region" [online], Available: http://www.wsud.org/planning.htm

PLANNING FOR CLIMATE CHANGE - ASSOCIATED SEA LEVEL RISE ON THE NSW CENTRAL AND HUNTER COASTS

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ABSTRACT

Sea level rise and changed coastal processes associated with global climate change are predicted to increase coastal hazard risks to low lying coastal areas. The NSW Greenhouse Office is funding the Department of Planning's Coastal Branch to lead a strategic planning project under the Cabinet Office *Climate Change Impacts and Adaptation Research Program*.

The project, commenced in June 2006 and to be completed in September 2007, has three main components as follow.

- For a priority coastal area, obtaining base data with which to assess risk from sea level rise for long term strategic planning. This involves the collection of high resolution terrain information using Light Detection and Ranging (LiDAR) technology, also referred to as airborne laser scanning, up to the 10m topographic contour. Below that contour, existing topographic data is inadequate for reliably modelling the potential risks of sea level rise and/or storm surge.
- Demonstration of the potential impacts on the priority coastal area by superimposing existing and proposed development over the detailed LiDAR-derived topography.
- Building capacity with local councils and communities, both in the study area and elsewhere on the NSW coast, through workshops on the project methods and results.

This paper presents the results to date of this innovative State Government sponsored project into planning for climate change for coastal communities.

Introduction.

The growing body of scientific data on global warming and evidence for climate change is prompting state and federal governments to consider a range of climate-related impacts on natural and socio-economic systems to inform strategies for greenhouse gas emission reductions and adaptation to the unavoidable effects of climate change (IPCC, 2001; Australian Greenhouse Office 2003, 2006; NSW Greenhouse Office, 2005).

The NSW Greenhouse Office, a specialist policy unit within the NSW Cabinet Office, has responsibility for the coordination and development of government policy to mitigate climate change, by reducing greenhouse gas emissions from all sectors of the NSW economy, as well as to adapt to those climate change impacts that are likely to be unavoidable.

Accordingly, the NSW Greenhouse Plan (2005) seeks to increase the awareness of the expected impacts of climate change, develop strategies to address those climate change impacts considered to be unavoidable and put NSW on track to meet its target of reducing emissions by 60% by 2050 (NSW Greenhouse Office, 2005). The plan details a number of government commitments, including that the Department of Planning will develop tools and guidelines to assist in incorporating climate change considerations into land use planning and development assessment.[1]

Climate change is seen as a major pressure on sustainable management of the social, economic and environmental well-being of the coastal zone (Natural Resource Management Ministerial Council, 2006). In NSW, climate change is an important consideration in a range of legislation, policies and guidelines including:

- NSW Coastal Policy 1997, objective 2.2;
- State Environmental Planning Policy 71, clause 8(j);
- Standard Local Environment Plan, clauses 30 (1) (iv) and 30 (2) (f);
- Draft Far North Coast Regional Strategy;
- Draft South Coast Regional Strategy;.
- Draft Central Coast Regional Strategy;.
- NSW Floodplain Development Manual;.
- NSW Coastline Management Manual;
- Draft Coastal Zone Management Manual (in prep); and
- NSW State Infrastructure Strategy 2006/7-2015/6.

In 2006 the Department of Planning successfully applied for funding under the NSW Greenhouse Office Climate Change Impacts and Adaptation Research program to conduct a pilot study on the NSW Central and Hunter Coasts aimed at improving capacity to plan for and mitigate the risk to coastal communities associated with climate change induced sea level rise and increased severity of coastal storms. This paper describes the background, structure and status of that project.

Background.

A fundamental driver for the project is that realistic and defensible adaptive responses to changed coastal hazards must use the best information available. The State Government's Comprehensive Coastal Assessment (Department of Planning, in prep) highlighted this issue in relation to the available topographic information for the coast and the general inadequacy of this information for quantifying risk related to coastal hazards modified by climate change.

For much of the NSW coast the best generally available terrain information is based on topographic and orthophotographic maps produced prior to the late 1980's. Importantly, for predicting impacts of climate change these maps define either the 10m or 2m contour as their lowest elevation information inland from the shoreline and must be considered suited to only a generalised assessment of coastal risk (Sharples, 2006; Voice et al., 2006).

The limitations of existing topographic information in land use management has been recognised by a number of coastal councils, particularly where flooding is a significant consideration. Research by the Department of Planning's Coastal Branch in early 2006 established that some 12 coastal councils had independently acquired high resolution terrain data for either all or part of their local government areas. Half of these (6) were in the Wollongong-Sydney-Newcastle metropolitan area. The data had been collected commercially using airborne Light Detection and Ranging (LiDAR) technology, also referred to as airborne laser scanning, with the contractors providing

[1] The requirement for the ongoing application of BASIX is a major element of that commitment.

the data in formats suited to incorporation into council spatial information systems (GIS/CAD).

The digital elevation models (DEM) produced from the LiDAR surveys commonly had vertical and horizontal resolutions of better than 0.3m Root-Mean-Square (RMS) and 0.6m RMS respectively. A range of related elevation products were purchased as part of the surveys including digital terrain models (DTM) at varying resolutions (2m and 10m Grids) and contours at 0.5m intervals. Beyond the highly accurate elevation data produced by the LiDAR surveys, an additional benefit was the definition of above ground features such as building heights and tree canopies to similar vertical and horizontal resolutions. The surveys were not cheap, costing hundreds of thousands of dollars in some instances, and councils sought a range of funding models to secure what was seen as data essential to their business needs. Council officers interviewed as part of the research identified a multiplicity of uses for the data not possible with existing terrain information (eg. detailed assessment of modelled flood heights, locating key infrastructure, checking the accuracy of cadastral information, determining building heights, analysing viewsheds, monitoring vegetation canopy extents and structures etc.). Environmental applications of the data (apart from flood management) appear not to have been an immediate priority for the councils.

General access to these existing LiDAR datasets is hampered by licensing and survey specification issues. Typically, the data have been collected under contract-specific arrangements between councils and the contractor and suited to the individual requirements (specification) of the council. For example, in at least two cases councils have paid for data delivered in different horizontal map datums (ie. Australian Geodetic Datum 1966 and Geocentric Datum of Australia 1994) and to varying levels of accuracy (vertical and horizontal). Moreover, intellectual property rights allowing the distribution of the data have not been handled consistently to allow for free distribution of the LiDAR data and its products (ASCII XYZ laser data, contours, Digital Elevation Models).

The inadequacy and inconsistency of existing terrain information limits quantification of risk related to coastal hazards modified by climate change and, by inference, limits associated coastal planning. While uncertainty around predictions of climate change are understood (IPCC, 2001; Kerr, 2006), less well understood is the fundamental lack of reliable elevation data to test the consequences of these uncertainties on coastal communities and their socio-economic fabric (Walsh et al., 2004). This project aims to procure detailed terrain information, which will assist coastal councils, catchment management authorities and state agencies to plan for and manage more effectively the potential impacts of sea level rise associated with climate change.

Study Area Selection.

The project focus was to be on one region with pressing coastal management issues sensitive to potential climate change-related sea level rise. Recent work associated with regional planning strategies as well as consultation with Catchment Management Authorities (CMAs) and council staff indicated several potential study sites with the NSW Far North Coast and Central and Hunter Coasts seen as priority areas.

The Central and Hunter Coasts were eventually selected on the basis of a combination of coastal vulnerability, project budget and logistic reasons. Key considerations included:

- Financial – as the project was to be managed from Sydney, a decision was made to maximise expenditure on the LiDAR survey by limiting expenditure in other areas such as travel; and,

- Vulnerability to coastal hazards – the Central and Hunter Coasts contain the variety of land use situations suited to an assessment of existing and future vulnerability of coastal communities to climate change-related sea level rise scenarios.

Taken together, it was decided by the project team that savings in travel costs realised through selection of the Central and Hunter Coasts would facilitate maximum expenditure on the LiDAR survey and thereby deliver the greatest coverage possible. The proposed study area (Figure 1) was defined on the basis of cost and requirement for a survey of low lying coastal areas.

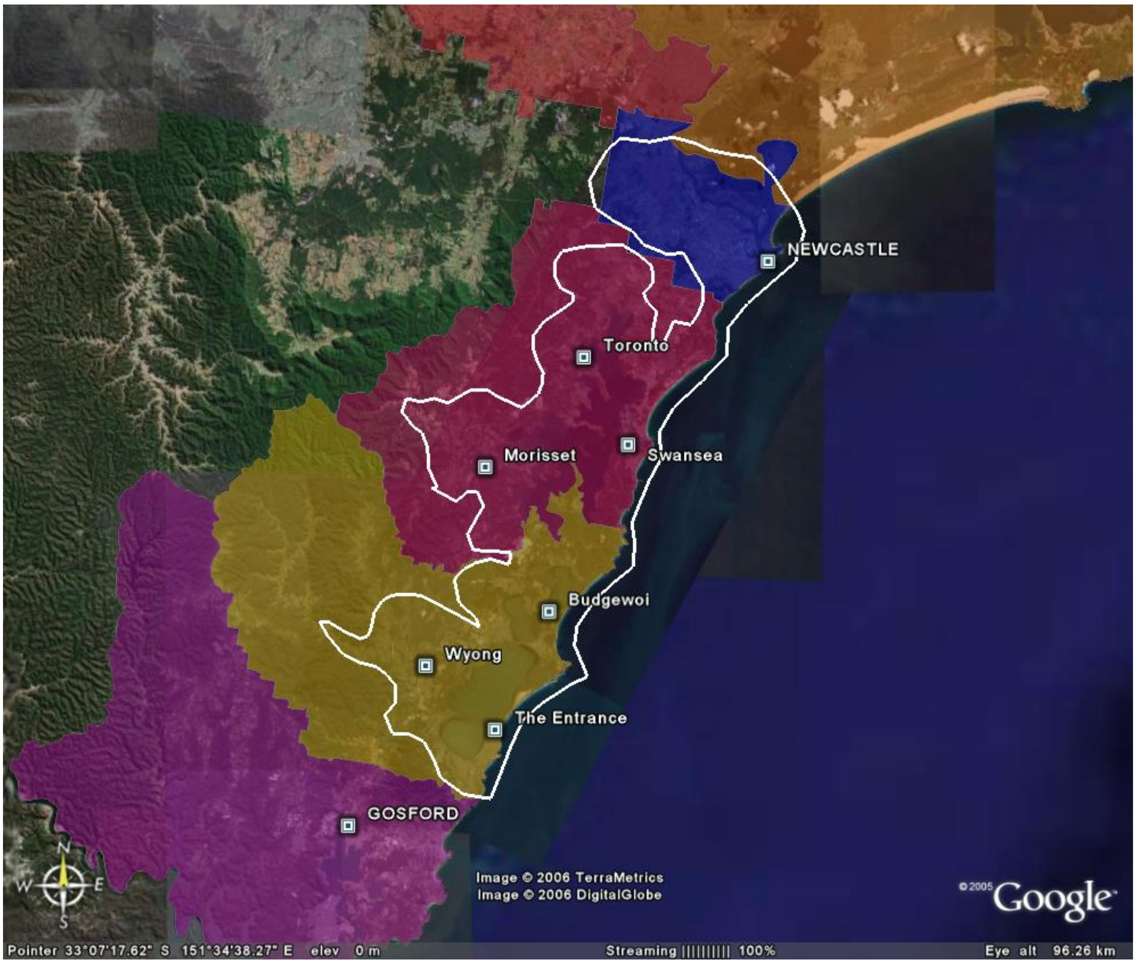

Figure 1. Proposed Central and Hunter Coasts Study Area. Figure shows likely survey footprint of low-lying coastal areas outlined in white. Local Government Areas coloured shading.

The study area is around 1100km^2 and includes low lying land (ie. land below the 10m topographic contour) in Port Stephens, Newcastle City, Lake Macquarie and Wyong Local Government Areas. Final definition of the study area is subject to the contracted extent of the LiDAR survey. It is likely to extend up the estuaries to the tidal limit in order to facilitate a first order assessment of the potential impacts on upstream flooding due to the back water effect of elevated sea levels.

Project Structure and Timing

The project is to be conducted in four distinct phases with provision for delivery of a final report to the Cabinet Office and LiDAR data to the State Government on the project's completion in September 2007. To date, the first project stage is complete with second stage work on tender and conduct of the LiDAR survey underway.

Stage 1: The Study Scope & Project Partners.
The initial project stage involved consultation with representatives of state and local government as well as the CMA's to confirm project scope, study area, detailed survey specification (ie. actual survey extent and accuracy) and contribution (cash or in-kind). Stage 1 was successfully completed in August 2006.

A project steering committee was established consisting of representatives from the NSW Greenhouse Office, LANDS, Department of Planning, Department of Natural Resources, Department of Environment and Conservation, Hunter-Central Rivers CMA, Geosciences Australia and an Independent Expert Advisor. Councils in or adjacent to the study area have either elected to be part of the steering committee (Lake Macquarie and Wyong Councils) or to receive regular project updates (Port Stephens, Newcastle City and Gosford Councils).

Agreement on the study area (Figure 1) and survey specification was reached and subsequently incorporated into the LiDAR survey tender documentation. The project will seek to collect LiDAR data over the study area to vertical and horizontal resolutions of 0.15m RMS and 0.6m RMS respectively. In addition, a range of digital elevation model, digital terrain model and topographic contour products are to be provided under the survey contract. It is hoped that the standardised LiDAR survey specification and deliverables developed for this project will guide similar work in the future, potentially leading to the generation of a consistent high-resolution elevation database for NSW.

An important consideration has been ready access to the LiDAR data. To this end, the project will seek to acquire the rights to free use of the LiDAR data and derived products for all levels of government and the community. Long term management of the data is anticipated to be the responsibility of LANDS with most users accessing the information online through the LANDS Web Spatial Portal.

Promotion of the project objectives to a broad range of stakeholders in government, industry, research organisations and the community was also undertaken. This paper itself serves to promote the project objectives and benefits.

Stage 2: LiDAR Survey
This stage is currently underway with an expected completion date of December 2006 for collection of the LiDAR data.

The successful tender will be required to deliver digital terrain products to the project stakeholders, initially the project partners in state and local government, and eventually all levels of government and the community. It is proposed that LANDS conduct an independent quality check to ensure the LiDAR survey products are delivered to specification. Geoscience Australia will be consulted during this stage to ensure compatibility of the data specification with national initiatives in integrated coastal zone management.

Survey products will include a digital elevation model comprised of point data (ie. ASCII file format with individual point location coordinates, height and intensity value for laser signal return) and derived digital terrain models (ESRI Grid or Tin format) to pre-defined datums (vertical and horizontal). XYZ data will be comprised of raw (all LiDAR returns) and filtered data (ie. first and final LiDAR returns for vegetation canopy / building heights and interpreted ground elevation). Metadata to the Spatial Information Council of Australia and New Zealand standard will be supplied with all data. These data formats are industry standard and suited to incorporation in the majority of spatial information systems used by government and industry.

Stage 3: Case Study.
Utilising data collected at Stage 2, the case study will illustrate the application of high resolution terrain data in coastal risk management and planning. This stage would involve collaboration with DNR and other technical specialists in local government and externally. It is expected that this stage will be complete by June 2007.

The Case Study is anticipated to incorporate the following steps.

Step 1

The selection of a number of climate change related sea level rise scenarios for the next 50 years and 100 years as presented in the latest IPCC reports, including likely additional impacts from storm surges.

An analysis of historic water levels based on existing tide gauge information will be required. The analysis will determine astronomical and meteorological components of the record and their spatial representation (open ocean coast and estuaries). This analysis will be critical in modelling current water levels and will facilitate the analysis of future sea level rise scenarios. GIS processing of water level results and LiDAR terrain model will enable an assessment of the spatial extent of potential coastal inundation from each of the selected sea level rise scenarios.

Step 2

Compilation of a spatial inventory of significant assets, resources and activities in areas modelled as affected by the selected sea level rise scenarios. Such an inventory may include:

- Residential building and development
- Commercial building and development
- Industrial building and development
- Service infrastructure – roads, rail, airstrips, port facilities, telecommunications, electricity, gas, water supply, sewerage and stormwater
- Social infrastructure, such as schools, hospitals, community centres etc
- Agricultural activities
- Grazing activities
- Foreshore amenities for sport and recreation
- Environmental (non-market) assets such as wetlands, near-shore marine areas, estuarine ecosystems, etc

This task will be undertaken through a GIS analysis utilising datasets of the built environment and current/planned land uses and modelled sea level inundation surfaces. State and local government project partners will provide relevant spatial data and conduct analysis and build inventory.

Step 3

An assessment of the potential impacts on the categories of existing assets or activities listed in Step 2 of different sea level rise scenarios.

Step 4

Economic evaluations of potential impacts from Steps 1 to 3 using a variety of valuation techniques available from numerous guidebooks and works in the professional literature.

Step 5

Assessment of projected increases in population, economic development or environmental enhancements in the areas potentially affected by sea level rise.

Step 6

Evaluation of possible policy responses, including land use planning mechanisms, that could prevent or minimise the impacts indicated in Steps 1 to 5 above. The evaluation would assess the likely effectiveness of each measure and provide an estimate of the costs and benefits that each intervention or option might produce.

Stage 4: Workshops
Demonstration of results of the LiDAR survey and related case study highlighting application of terrain data in adaptive coastal management will be promoted in a series of workshops held in each coastal CMA together with regional staff from the Department of Planning. An objective of the workshops will be to build partnerships that may facilitate collection of an expanded dataset to one specification for the entire NSW coast, including to the tidal limit of coastal waterways.

Summary and conclusion.

This pilot project will obtain high resolution data on the existing land surface in low-lying coastal and estuarine areas of the Hunter and Central coasts to the first 10m contour. This is the fundamental data set that is missing from our current topographic mapping and which is essential for future strategic planning associated with climate change.

The data will provide a three dimensional model of the area, including existing assets, with a vertical resolution of approximately 15cm and a horizontal resolution of approximately 60cm.

The 'what if' scenarios developed by the most recent Intergovernmental Panel on Climate Change and CSIRO, combined with the three dimensional model, will allow an assessment of assets and land at risk under different climate change scenarios.

The 'what if' scenarios will change over time as scientific research continues and more detailed information becomes available.

Unlike traditional flood probabilities based on actual past rainfall records, the 'what if' scenarios are not predictions of future sea level rise but scientific projections based on levels of atmospheric carbon dioxide (CO2) and other greenhouse gases. That is, *if* CO2 increases by X, average global temperature is likely to increase by Y, which is likely to increase thermal expansion of the oceans and/or melting of continental ice to produce an average global sea level rise of Z.

The risk assessment to be undertaken in Stage 3 of this project will assist the identification of a range of adaptation strategies that could be developed to minimise the impact of any sea level rise associated with climate change and/or storm surge.

Importantly, the three dimensional model produced from this project will also be able to be used to assess the level of risk from natural hazards under *current* climatic conditions, and in a variety of town planning and flood management applications.

References.

Australian Greenhouse Office, 2003, Climate change: an Australian guide to the science and potential impacts. Pittock, B (ed.), Australian Greenhouse Office, 239p. (Available online: http://www.greenhouse.gov.au/science/guide/index.html).

Australian Greenhouse Office, 2006, Climate change impacts & risk management: a guide for business and government. Australian Greenhouse Office, 73p. (Available online: http://www.greenhouse.gov.au/impacts/publications/risk-management.html).

Department of Planning (in prep) Comprehensive Coastal Assessment Program.

Intergovernmental Panel on Climate Change, 2001, Climate Change 2001: The Scientific Basis *in* Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., Van der Linden, P.J. and Xiaosu, D. (eds.) contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge U.K., Cambridge University Press 944p

Kerr, R.A., 2006, Climate change: a worrying trend of less ice, higher seas. Science 24, v. 311 (5768), p1698-1701

New South Wales Greenhouse Office, 2005, NSW Greenhouse Plan. NSW Greenhouse Office, November 2005, 60p. (Available online: http://www.greenhouseinfo.nsw.gov.au).

Natural Resources Management Ministerial Council, 2006, National cooperative approach to integrated coastal zone management: framework and implementation plan. Natural Resources Management Ministerial Council, 2006, Australian Government, Dept. Environment and Heritage, Canberra, ACT, 55p. (Available online: http://www.deh.gov.au/coasts/iczm/index.html).

Sharples, C., 2006, Indicative mapping of Tasmanian coastal vulnerability to climate change and sea-level rise: explanatory report (Second Edition). Consultant Report to Department of Primary Industries & Water, Tasmania, 173 pp., plus accompanying electronic (GIS) maps. (Available online: http://www.dpiw.tas.gov.au/inter.nsf/WebPages/PMAS-6RG5WX?open).

Voice, M., Harvey, N. and Walsh, K. (eds.), 2006, Vulnerability to climate change of Australia's coastal zone: analysis of gaps in methods, data and system thresholds. Part I: Executive and technical Summaries. Report to the Australian Greenhouse Office, Canberra, Australia, June 2006.

Walsh, K.J.E., Betts, H., Church, J., Pittock, A.B., McInnes, K.L., Jackett, D.R. and McDougall, T.J., 2004, Using sea level rise projections for urban planning in Australia. Journal of Coastal Research, 20(2), p586-598.

EDUCATION AND COMMUNITY ENGAGEMENT IN THE MARINE ENVIRONMENT

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Abstract

Marine education and awareness raising can take many forms but needs to be tailored to the target groups and available resources. Since May 2005 a number of initiatives have been undertaken on the North Coast of New South Wales involving Coastcare, the NSW Marine Parks Authority, the Marine Education Society of Australasia and the Northern Rivers Catchment Management Authority. These initiatives continue to involve the general public, schools, community groups, local researchers and industry. Covering a wide range of interesting marine topics the initiatives have been well received by the community and have provided recognition and support to the work of local marine groups as well as inspiring new groups to form. The development, implementation and outcomes of these initiatives will be discussed with particular focus on the importance of partnerships and collaboration with local stakeholders. Marine biodiversity is not a dry topic and the contribution of passionate marine enthusiasts and professionals has enabled the development of high-quality educational materials and events with a relatively small amount of funding.

Introduction

In recent years Catchment Management Authorities (CMAs) in NSW have been required to look out to sea and tackle with marine issues (to the 3 nautical mile state limit anyway!). In recent years there has also been a state, national and international move towards conserving marine environments in marine protected areas and it is internationally recognised community attitudes and behaviours will influence the effectiveness of marine conservation programs (Arnold, 2004). 2 new marine parks have recently been declared in NSW; the Port Stephens-Great Lakes Marine Park and the Batemans Marine Park. Management targets in the draft Catchment Action Plans (CAPs) of all the NSW Coastal CMAs identify the importance of protecting estuarine and marine habitat. CMAs have also identified the importance of working with government agencies and other groups with a role in the marine environment to increase awareness of marine issues in the general community and increase the capacity of marine user groups to act sustainably.

Volunteers involved in marine conservation activities are rare and those groups that exist often find it difficult to access support and funding with the focus of many programs having a terrestrial bias. Many of these volunteers groups have a focus on educating their local community about protecting the marine environment. This paper will discuss initiatives recently funded by some coastal CMAs including the outcomes of a marine education and awareness project undertaken by Coastcare on the Far North Coast of NSW. This project supported public presentations showcasing the work of local researchers as well as active local marine-based volunteer groups. The project also sponsored local marine enthusiasts to produce locally relevant marine educational material.

Marine volunteers – rarer than Grey Nurse Sharks!

The Solitary Islands Marine Park was gazetted under the Marine Parks Act in January 1998 and was a Marine Reserve prior to this date. Having been established for several years now, the Marine Parks Authority has established a good relationship with one of the longest running volunteer marine conservation groups in NSW, the Solitary Islands Underwater Research Group (SURG). SURG recently marked 20 years since its formation and has played an important and active role in the management of the marine park and has been involved in activities such as marine habitat mapping and research into coral health. SURG has also been active in raising awareness about their local marine environment including establishing an underwater interpretative trail at North Solitary Island and producing a photographic inventory of marine life in the Solitary Islands Marine Park.

Figure 1. SURG members placing a plinth as part of the underwater interpretative trail.

In early 2005, SURG was the only group of its kind on the North Coast of NSW but there were a number of other groups involved in a range of marine conservation activities that are still around today. Examples of these groups include

- Australian Seabird Rescue based in Ballina, which rehabilitate marine reptiles and seabirds, aid in the rescue of marine mammals and are also very active in community education and training of other volunteers.

- Whales Alive is a Pacific based organisation active on the North Coast that provides training to the whale watching industry, delivers marine mammal education and communicates whale research to the general community.

- Belongil Bird Buddies are a community group that work to protect an important shorebird site at the mouth of the Belongil estuary. The group's main focus is education and communication of dog walkers and pedestrians about the impacts of disturbance of shorebirds. They have also produced a high quality documentary titled "Shore Birds of the Belongil Estuary, Byron Bay".

- Marine Environments Field Study and Resource Centre based on the Tweed Coast is an independently run education centre with a strong interest in education about temperate rocky shores.

Byron Marine Wildlife Series

In May 2005, the Byron Marine Wildlife Series commenced as a joint initiative between Coastcare and the Marine Parks Authority (MPA) with public presentations once every two months in Byron Bay. The first event included presentations by a local marine scientist on the benthic life of Julian Rocks at Cape Byron, a presentation from SURG on their work and the screening of an underwater film of Julian Rocks by a local videographer. This presentation was used to engage local marine enthusiasts and with the support of a local dive operator, the Byron Underwater Research Group (BURG) was formed. Since the end of Regional Coastcare Facilitators in March 2006, BURG has continued to run the series in partnership with MPA who contribute the costs of promoting and running the presentations.

The format for subsequent events in the Byron Marine Wildlife Series has continued used a mix of presentations to highlight local researchers, local marine groups and the work of government agency staff. The talks have covered topics including Marine Habitat Mapping, the role of Marine Sanctuaries, whales and dolphins, threatened shorebirds, coral health, and the sex lives of host sea anemones. Local researchers were drawn from Southern Cross University, University of New England and the National Marine Science Centre. Other marine groups presenting included Australian Seabird Rescue, Whales Alive, Belongil Bird Buddies and Marine

Environments Field Study and Resource Centre. Over 300 people have attended the series has generated significant media coverage including highlighting community support for the Cape Byron Marine Park.

Byron Underwater Research Group

Coastcare played an important role in the formation of Byron Underwater Research Group (BURG) with financial resources available to engage and support groups and build partnerships with key stakeholders such as the MPA. The networks available to Coastcare also enabled BURG to connect with other groups and programs such as the Harbourkeepers/Coastkeepers initiative of the National Parks Association. The Harbourkeepers fish survey method uses a dive slate with 50 species common to NSW and as the first “in-water” activity that BURG was involved in it was a useful education and training exercise. The activities of the group have generated positive media for the Cape Byron Marine Park and demonstrate that many people in the community support marine protected areas.

With the assistance of the local Community Support Officer, (funded by Northern Rivers CMA), BURG was able to access funding for clean-up dives from “Looking After Byron” a program sponsored by local businesses to support community projects. While Community Support Officers (CSOs) have traditionally dealt with terrestrial groups eg Landcare/Dunecare, it is important that coastal CSOs now also work with marine groups. The experience of CSOs with running volunteer groups and advice with securing grant funding is an invaluable resource to marine groups.

NEWS | Byron Shire News

Divers tackle reef rubbish problem

Discarded fishing tackle and rubbish on underwater reefs of the Cape Byron Marine Park were cleared recently by a group of community volunteer divers.

Refuse collected included fishing rods, tackle and line, ropes, wire and an anchor.

But the upside for the 11 divers from Byron Underwater Research Group (BURG) was the amount of sea life they encountered including a green turtle, a very large stingray and a wobbegong shark. In a first for the area, the clean-up dives were funded by the Looking After Byron Project which identifies and supports community groups that are making a contribution to keeping Byron beautiful.

BURG formed last year and is dedicated to the study and conservation of marine life.

To date their projects have included fish counts around Julian Rocks and creating an underwater guide for visiting divers.

Group spokesperson Zan Hammerton said that raising the awareness of divers and the community about our natural environment and performing practical works like clean-ups all contributed to the preservation of the underwater world.

Manager of the Cape Byron Marine Park, Andrew Page, said he was thrilled that the clean-up was taking place within a sanctuary zone of the Cape Byron Marine Park.

Simon Hartley and Zan Hammerton from Southern Cross University with some of the rubbish collected

"For years fishing line that has accidently snagged and broken has accumulated on the reefs of the area and this great project by BURG not only allows this harmful material to be removed, but will also help us to see whether fishing closures in the area are being adhered to," he said.

Figure 2. Article from Byron Shire News, 1 June 2006

Another outcome of the Byron Marine Wildlife Series was the influence of Dave Harasti from NSW DPI-Fisheries who gave a presentation on marine threatened species. Dave is a passionate diver and an award-winning photographer and his website (www.daveharasti.com) is a great resource, including photos of hundreds of marine species recorded for his local dive spots around Port Stephens. Dave's presentation and advice to the Byron Underwater Research Group inspired one member to focus on the production of a similar website for Julian Rocks. Her site (www.julianrocks.net) is now a comprehensive, publicly available and locally specific marine education resource for the Cape Byron Marine Park.

Support from Northern Rivers CMA

Following the initial success of the Byron Marine Wildlife Series, the Northern Rivers CMA contracted Coastcare to deliver a marine education and awareness project on the North Coast. This funding ($14,000) enabled the continuation of the Byron Marine Wildlife Series and the opportunity to support some of the marine groups on the North Coast. Projects included

- Extending the Byron Marine Wildlife Series and starting a similar series on the Tweed Coast;
- Sponsoring the production of Byron Underwater, a locally-produced documentary of the marine life of Julian Rocks;

- Sponsoring a redesign of SURG's Photographic Inventory of the Fauna of the Solitary Islands Marine Park;
- Sponsoring the Marine Environments Field Study and Resource Centre to produce a guide to North Coast rock platforms;
- Sponsoring BURG to produce a locally relevant fish identification dive slate for Julian Rocks; and
- Strengthening the marine education network in the area through a North Coast Marine Education Forum held in Ballina.

Sponsoring local groups has proven to be a successful approach to producing marine educational material with the added benefits of recognising the work of these groups and enhancing their ability to educate others in the community. The material produced is not only locally relevant but the expertise of local groups and the thousands of hours involved in collecting underwater footage and images has produced educational tools of a very high quality.

Where to target marine education and community engagement?

Following the establishment of BURG it was important to consider why it was successful and if there were any determining factors in common with SURG. Interestingly both groups have the following factors in common

- Situated in a marine park (support from Marine Parks Authority),
- High quality dive sites (support from local dive industry),
- University campus is nearby.

In both groups, members include

- Marine scientists and marine science students,
- Marine Studies teachers, and
- Extensive diving experience including dive instructors, dive masters etc.

These similarities suggested that other parts of the state where these factors are present should be priority areas for targeting marine education and community engagement programs. With this in mind, the Port Stephens Marine Discovery Series was launched on 7 September 2006 as a joint initiative of the Hunter-Central Rivers CMA and Port Stephens Council. The CMAs Coastal and Marine Officer organised speakers and the format of the presentation and the CSO (jointly funded by Council and the CMA) organised the venue and promotion of the event. The theme was marine threatened species with presentations on threatened fish species and whales and dolphins. Feedback surveys were completed by around half the audience and not only were the responses overwhelmingly positive, the surveys have provided a mailing list for future events and a group of people interested in participating marine conservation activities. It is now important to access funding to enable the local CSO to support these potential marine volunteers becoming active in marine conservation.

One of the speakers was Dave Harasti and his spectacular photos were seized upon by the media generating extensive local, regional and state media coverage including print, radio and TV. This highlights the fact that interesting marine issues can be a useful tool for engaging the general community and educating them about broader Natural Resource Management issues. Positive media is an important mechanism for raising awareness in the general community about the ecological values of marine protected areas. The values and diversity of marine life is often lost in the public debate on marine parks, which is dominated by recreational users angry about being “locked out” of sanctuary zone areas.

Both the Port Stephens Marine Discovery Series and the Byron Marine Wildlife Series provide an easy opportunity for government, educators and scientists to interact with the general public. Supporting and extending these series to new areas would be an efficient and effective means of delivering marine education and promoting the values of local marine environments.

Taking a statewide approach

There are many organisations in NSW with a role in marine discovery, education and awareness raising, some of which are listed in Table 1. However, there is there is currently no statewide network or program that links all these organisations together. A NSW Marine Education and Discovery Forum will be held at the National Marine Science Centre in Coffs Harbour on 7 November 2006. The main aims of the forum are to bring together organisations involved in Marine Education and Discovery in NSW to share ideas and resources and to improve links between different parts of the state and between NGOs, industry and Commonwealth, State and Local Governments.

Improved networking would assist in making the most of the limited resources available for marine education. A stronger network could then form the basis of a broad partnership aimed at increasing awareness and community participation in the management of marine environments. Opportunities would become available through collaboration on marine discovery events and activities, sharing existing resources and sourcing additional funding for the delivery of marine education and discovery programs. The wonders of marine ecosystems capture the imagination of the general public and opportunities for more private sector funding should be pursued. A statewide partnership or program would also increase the chances of attracting corporate sponsorship as there would be greater exposure for a sponsor.

Table 1 – Some of the Organisations Involved in Marine Discovery and Education in NSW

Science/Research	**Underwater Research Groups**
National Marine Science Centre	Solitary Islands Underwater Research Group
Universities (SCU, UNE, etc)	Byron Underwater Research Group
Educational Institutions	**Environment Organisations**
Ballina Marine Resource and Discovery Centre	Central Coast Community Environment Network
Hastings Point Marine Environments Field Study and Resource Centre	National Parks Association – NPA Marine Harbourkeepers/Coastkeepers
Sapphire Coast Marine Discovery Centre	Oceans and Coastal Care Initiatives (OCCI)
Bondi Marine Discovery Centre	Nature Conservation Council of NSW
Schools / Colleges providing Marine Studies	
Department of Education and Training – Field Study Centres	
Government Agencies	**NGOs**
Marine Parks Authority	Oceanwatch
Department of Primary Industries (DPI) – Fisheries • Threatened Species Unit • Fisheries education/Fishcare • Conservation Technology Unit • Fisheries Compliance	Australian Seabird Rescue
Department of Environment and Conservation (DEC) • National Parks Discovery Program • Marine Conservation Science • Threatened Species	Marine and Coastal Community Network
Coastal CMAs	Whales Alive
Coastal Councils	The Wilderness Society
NSW Maritime Authority	Surfrider Foundation
Industry	**Educational Organisations**
Representatives from Dive Industry	Marine Teachers Association of NSW
Sydney Aquarium	Marine Education Society of Australasia (MESA)
OceanWorld Manly	
SeaWorld	
Merimbula Aquarium	
Eden Killer Whale Museum	
Pet Porpoise Pool Coffs Harbour	

Recommendations

In conclusion, it is important to support local marine enthusiasts develop locally relevant education material to promote the values of marine ecosystems within their community. At a regional scale CMAs have an opportunity to promote this by working through coastal Community Support Officers (CSOs) to organise marine presentations and help new and existing groups to access funding. From a statewide perspective, it would be strategic to focus marine education and community engagement in areas within Marine Parks, where there is good diving and a university or research facility nearby. Areas with 1 or 2 of these factors would then be the next highest priority. Government funding programs (such as Envirofund) may need to actively engage marine enthusiasts prior to calls for applications, understanding the process involved in establishing marine groups capable of applying for funding. Support for a NSW Marine Discovery Program would improve communication of marine research and marine issues to the NSW community and lay the groundwork for the formation of active marine volunteer groups.

[Late note: SURG and BURG have both been successful in obtaining an Envirofund grant – 2 of 4 grants for NSW in Round 8 of Envirofund.]

References

Arnold, Allison (2004). A review of public attitudes towards marine issues within and beyond New Zealand, DOC SCIENCE INTERNAL SERIES170, Department of Conservation, Wellington, New Zealand

REPLENISHING THE COASTAL ZONE MANAGEMENT TOOLKIT

The National Cooperative Approach to Integrated Coastal Zone Management - Framework and Implementation Plan (Commonwealth of Australia 2006) has signalled the Commonwealth Government's focus for policy and investment.

The strategies in principle ought to lead to some amelioration of the continuing reduction in the environmental, and in many instances social, values of the coasts.

The plan identifies the need for integration across jurisdictions and landscapes, and highlights the usual culprit issues including pest species, loss of biodiversity, residential sprawl, acid sulphate soil non-source pollution and marine pollution. A couple of key themes should be highlighted. The plan talks in terms of systematic and integrated approaches to a range of issues, across jurisdictional and disciplinary divides. It talks of incorporating demographics into natural resource planning and management, and it aims to bring the market to bear in support of conservation where normally it can be expected that markets on the coasts will support degradation.

The question that this paper seeks to answer is 'what instruments and interventions will be needed to make these desires a reality?'

A reality check.

Strategy is primarily about matching your aims with the available resources, given the context in which you are working. We know the context of coastal systems, the most fundamental character of which is not the beauty or complexity of the systems, but the inexorable pressure to harvest in a range of ways the unvalued or undervalued ecosystem services. Amongst these are the climatic and aesthetic characteristics that generate the enormous economic gains that accrue to those who exploit them, but which result in inexorable pressures on the ecosystems that generate them. Capital flows explain at least as much about modern coastal environments as do biophysical flows, or demographics.

It is easy to predict that the capital flows will continue and perhaps accelerate, and that therefore the pressure on the ecosystems will grow. If there is not a counter-pressure of more or less equivalent strength, then it can be expected that the losses will not be stemmed. Money is the root of behaviour in a modern economy, and the evidence that somehow its pressure will be resisted by coordination or knowledge seems relatively weak.

Environmental impact is a function of individual impact multiplied by the number of individuals creating that impact, therefore strategy must either restrict who is impacting (selective access), or change consumer behaviour. There is no path that does not involve restriction, the choice is only whether that restriction will be forced or voluntary (or at least accepted), and therefore a key issue is 'what tools will we use to achieve this, in the face of a powerful consumer momentum?'

Most people interested in sustainability assume that the tools we will use must come from government. They are used to a world in which regulation is the obvious tool of restriction, and this is coupled with government-funded investment in rehabilitation or protective works. Will this paradigm work in the next 10 to 20 years?

Regulation is resource hungry – or rather, implemented regulation is resource hungry. Australia has a sad history of passing regulation without committing the resources needed to make it effective, as a cheap way of managing the political pressures without necessarily incurring the costs of implementation. In the coastal context it is demonstrably true that governments have used this ploy, and the consequences are evident. Capital works and research, or the provision of incentives or compensation, and on-ground works in rehabilitation are all costly, though a lot of cost is offset by volunteer labour.

Will government have the money and the volunteers?

The answer based on demographics must be ‘no’!

Spending pressures by area by Government: the base case

Age-related government spending to GDP ratios by level of Government

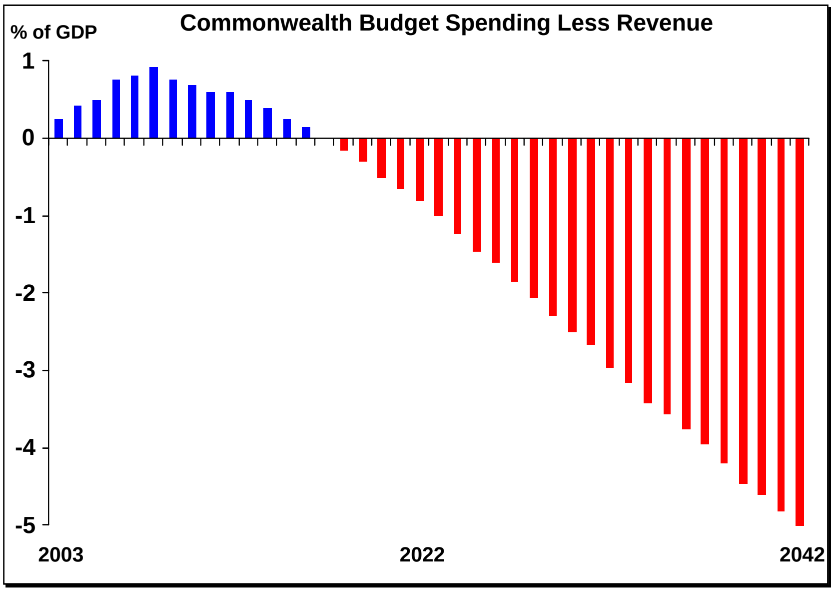
	2003-04	2044-45	Difference (fiscal pressure)
Australian Government summary	%	%	Percentage points
Health care	4.0	7.5	3.5
Aged care & carers	1.0	2.2	1.2
Age pensions	2.9	4.6	1.7
Other social safety net	3.8	3.1	-0.6
Education	2.0	1.8	-0.1
Total	**13.5**	**19.2**	**5.7**
Combined States summary			
Health care	1.8	2.8	1.0
Aged care & carers	0.1	0.3	0.1
Education	3.3	2.9	-0.4
Total	**5.2**	**5.9**	**0.8**

Source: Commission estimates.

Productivity Commission 2005.P 309, Table 13.2.

Government budgets are always tight and politically contested. Ageing will probably impact upon the availability of volunteers in a couple of ways. Healthy retired people are the current key to many volunteer activities, but older working or unhealthy people are not. We are currently pressing to keep people on work, and there will be more work opportunities for those who wish to remain in the workforce (and less structural unemployment among the young in coastal areas). It is hard to predict whether the volunteer cadre will be available. Ageing related expenses at a national government level are predicted to rise by 5.7% to about 20% of the national budget by 2044. State level ageing impacts will increase these costs from about 5% of budgets to around 6%. The total picture is one of federal government budgets going out of surplus around 12 years from now, and then rapidly increasing deficits (Australian Treasury, 2002). These Federal estimates do not seem to include even current levels of environmental investment.

National fiscal projections



A tax-funded paradigm for protection of coastal environments does not seem to be a robust model given such predictions, and if one also factors in the additional costs of (for example) protection of coastal housing from storm surge, overlaid by the exploitative efficiency effects of the march of recreational or commercial technologies, the strategic issues become vexed

The strategic imperatives would seem to be to find ways of generating large-scale systemic behavioural change whilst radically reducing fiscal demands on government which means engaging private funds and energies and making public intervention much more efficient. What then would be the paradigm in 2010 if we are to implement the high ideals of the Coastal Zone Management Framework?

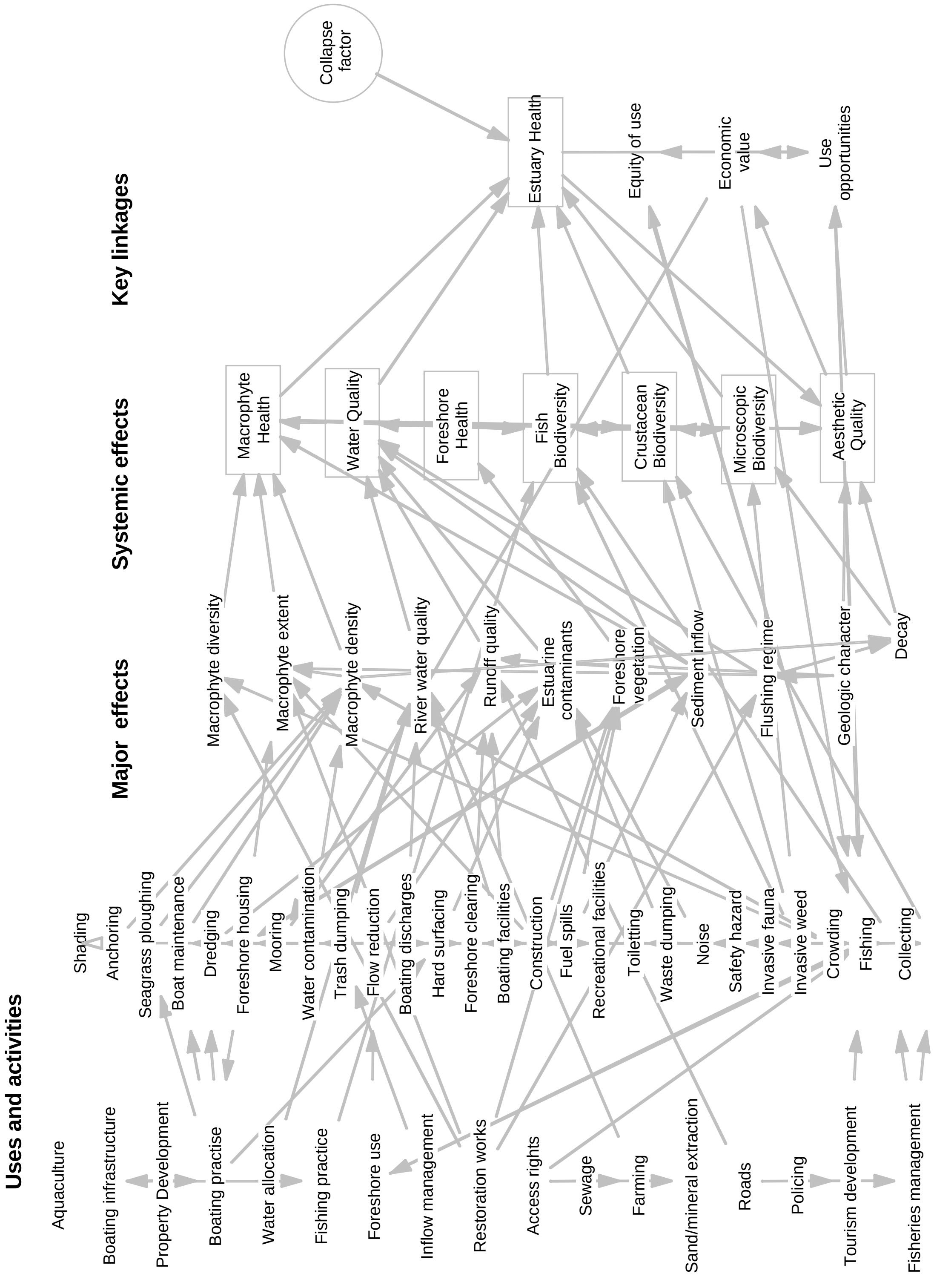
The 2010 NRM paradigm?

Given the above we have a choice to make. We can either pretend that we are implementing the framework but fail because we do not have the resources; use increasingly draconian regulation and higher technology policing to force constraints; or we can move to a different model that is more nuanced and complex, but more likely to work in a different context. The elements in this approach are already known in the natural resource management strategic literature but they are not well incorporated into the strategic approaches that we use today. The elements (Martin and Verbeek 2005, 2003) are

1. System-wide behavioural management, using a mix of intervention points and a mix of instruments to achieve change.
2. Wide scale use of private funds flows, achieved through a combination of more active harnessing of conserving values, market instruments, and new leverage approaches
3. Conscious use of transaction costs, to materially alter the balance towards conservation and away for consumption. This has two components
    a. Reduction of transaction costs associated with desirable activities such as private conservation covenants, volunteer activities, impact-reduction facilities and the like;
    b. Transfer of transaction costs away from government to those whose activities have the potential to do harm; and
    c. Transfer of the risk of failure of protective arrangements away from the government or the guardians and towards those who benefit from continued exploitation.
4. Re-aligned government institutions
    a. A radically reformed regulatory structure, which integrates regulation across the three levels of government, which reduces the number and complexity of laws, and which embeds rights of private action where these will be protective of the environment; and
    b. Fiscal strategies, such as new financing structures and taxation arrangements that can better harvest private capital and stimulate private conservation innovations.

Understanding better where and how to intervene

Coastal systems are complex, and the social systems that interact with them and draw from them add a further level of complexity. The following diagram illustrates this.



It is rarely the case that a single point intervention will be reliable in adjusting consumption patterns, and in most instances there will be unexpected spill-overs. For this reason, contemporary natural resource management looks for multi-point, multi-type interventions across the total system. Strong regulation, market incentives, volunteerism, and the promotion of innovation are not alternatives; they are complements in a total program. Systems-based interventions work on three elements: they adjust resource flows (particularly using funds flows to adjust natural asset access and use or to promote innovation), they adjust information flows (resource data, community education, or knowledge), and they adjust the institutions that control these flows. All three have to be part of the total program for coastal sustainability.

However, a total program can only be efficiently designed if the goals are clear, and this is where political leadership is often lacking. Faced with strong self-interest and a weak voice for the environment, even consultative processes will typically result in a compromised policy setting. The difficult tradeoffs are hidden in the decision to (for example) establish a policy, and emerge strongly once attempts are made to give it life. This is a fundamental challenge that has to be overcome through government so that it can adopt approaches that are less reliant on ongoing government funding.

Such a systematic approach will lead us to a portfolio approach to intervention.

Resource consumption would draw on a mix of constraining, motivating and barrier removal.

Constraint strategies will use policed controls (for example against over-harvesting or illegal structures), but will marry this with pricing of use (for example a bid-based method for allocating a reducing level of moorings). Private rights of action would be enhanced, so that either property owners could better protect their interests (say in a view scape, or against noise or pollution from exploitative actions) or concerned citizens could better force government to exercise its duties. Stronger impact assessment would be aligned with better community information, so that assessments do become more vigorously scrutinised and debated. Investment incentives would be used to support philanthropic or protective arrangements. There are examples of all these types of instrumental interventions, both locally and internationally. The challenge is not to find ideas; it is to find the willpower and the creativity to embark upon some risky experiments with new models of coastal management.

Overcoming the institutional integrity problem

The international literature shows that even much lauded market-based instruments do fail. The prime determinant of success is not the instrument; it is the institutional integrity of the system into which the instrument is introduced. In coastal management we have a major problem in this regard, and it has to be fixed if we are to meet the sustainability/demography challenge for the coast.

Australia has around 250 distinct statutes governing various aspects of sustainable use of natural resources (Martin & Verbeek 2000). That is not counting regulations under these acts nor the various local government rules, nor administrative determinations under these arrangements, nor the various quasi-laws that arise through other decisions. There is simply no way that this structure can be made low cost and efficient, and as its administration is a fixed cost and on-ground action is variable expenditure, one can expect that administration and coordination will take a growing share of a declining government resource base.

To illustrate, in one NSW estuary we were able to identify 14 statutory instruments, 20 formal policies, 10 conventions, and 25 plans all ostensibly supporting sustainable and safe use (Martin 2005). In that same waterway, seagrass loss was occurring at an accelerating rate, there was an uncontrolled outbreak of a serious marine weed, scientifically reported species loss, many documented breaches of the relevant foreshore construction controls, and a myriad of identified illegal structures. The public sector investment pattern was around 90% weighted towards support for the consumption practices that were the prime drivers of harm whilst the volunteer groups and regulators struggled to find basic support. The resourcing gap between rhetoric and reality was astounding, and the outcomes totally predictable.

The role of government in a new regime must be to provide efficient institutional arrangements that really do set the parameters for private action, for otherwise experiments with markets and non-government actions might result in accelerated rather than diminished harm.

What reforms are needed to ensure we have the institutional arrangements that are required to protect the coasts if government funds are not available?

1. A national environmental code, probably reflecting the federalist structure of coordinated and uniform corporations law, to replace a myriad of uncoordinated rules (Martin & Verbeek 2000);
2. A strong set of core behavioural standards (a duty of care perhaps) that create a serious actionable offence to cause material harm to the ecological system, much like the Environment Planning Biodiversity Conservation Act concept in related to threatened species or habitats, or that of the Trade Practices Act in relation to adverse impacts on competition;
3. Private rights to take action for breaches of duty, or to force agencies to acquit their responsibilities in the interests of the public good (Martin 2005).
4. Adjustments to the risk/reward trade-off for private harm to public resources, such that harm-doers do carry the full costs of their actions; and ideally so that harm-remediators secure economic benefits from their actions. This can be done by strategies such as offset funding where those who want to carry out harmful consumption are obliged to fund beneficial practices by others, or to find offsetting ecosystems to protect or rehabilitate.

Such proposals may sound radical, but they have each been used in Australia or elsewhere to tackle similar challenges. Whether they are too radical is a political judgement not a judgement about the institutional reforms themselves.

Resource flows, not rhetoric, shape behaviour

Rhetoric and information can shape values and knowledge, which in turn can shape the pattern of decisions, either towards or against resource consumption. Advertising and other marketing activities (including lifestyle shows) drive purchasers towards more consumption, and knowledge of environmental impacts hope to counter this. The funded information flow is heavily tipped towards consumption (Martin & Verbeek 2006).

Market instruments can alter the balance in favour of consumption. We need market instruments for preservation and remediation of coastal environments. Possibilities might include

1. Tradeable permits to carry out otherwise unpermitted activities, but with a mechanism for clawback to sustainable levels. Examples might include a tradeable fishing right, restricted to particular estuaries, or a tradeable mooring or foreshore construction right married to an auction for clawback (as is occurring with water for the environment under the National Water Initiative);
2. Offset arrangements for development or use, such that those who value the exploitative opportunity are required to find offsetting beneficial investments and fund these. If coupled with taxation arrangements, the potential for very substantial voluntary investment in offsetting harm is present.

It is possible to envisage a range of market-based schemes emerging, limited only by the imagination of entrepreneurs and the capacity of our institutions (Martin, 2003). One of the characteristics of coastal systems (highlighted at the start of this paper) is that they are concentration points for wealth. Many of the values that need to be conserved do have significant private economic value, unlike many of the values that are sought to be conserved in rural and remote areas. This bespeaks the potential for market instruments to harness the self-interest of the rich in the interests of the environment. Provided that the institutional safeguards are credible, then we ought be able to do much with private capital.

Banquo’s ghost

Banquo's ghost was present at Macbeth’s banquet. Unwanted, its presence was the voice of conscience. There is such a ghost within the argument that I make in this paper. The ghost is not the risk that such innovations will fail. If we do not make marked change in our natural resource strategies in the face of declining public funds, then failure in the protection of the natural richness of most coastal ecosystems is highly likely if not inevitable. This ghost speaks of the social component in the triple bottom line.

Not all people who live on and enjoy the coasts are wealthy. Regardless of whether one uses a regulatory or a market instrument, a necessary effect is exclusion of some who previously had free access. In most capitalist systems the distribution of wealth and capability means that the likelihood is that exclusion will fall most heavily on the underprivileged.

In our society, exclusion is also likely to be most culturally difficult for indigenous people who already suffer the pain of cultural exclusion from this most valued of environments. Recent case law may result in the exclusionary burden being shifted away from traditional owners (where these can be found) but regardless of this, there will be both real and felt inequity in any exclusionary regime.

Are there strategies for the sustainable use of the coast that minimise this distributional effect? The most economically efficient and most fair strategy for conservation is always voluntary forbearance, based on ethical or social imperatives. This requires cultural change, and requires that this change be most effective in shaping the beliefs of those who most benefit from the present over-consumption. Such a program will take a lot of funding and a lot of time, and may never work, but must be pursued as part of a total program. In the meantime, we will have to make some conscious attempts to offset the unfairness that can arise with exclusion. Possible programs include affirmative action programs in natural resource management, specifically targeted to ensure that offset investments and offsetting activities, and the job opportunities that arise from these and from enforcement, are used to also offset disadvantage; modification of use-controls such as permitting or regulation to reduce the impacts on such groups, and investment programs that will assist the disadvantaged to share in the benefits and wealth that arise from the coasts.

Can we fix it? Yes we can!

The challenges that we face in implementing the high ideals of the national coastal zone initiative are enormous, particularly when future funds flow patterns are taken into account. However, we can meet the challenge if we are innovative and adventurous in the instruments we use and the way we use them.

The underlying constraint is not opportunity but integrity, in the institutional arrangements we have and in the ethical judgements we make about sharing the riches that we inherit, and that our children will also hopefully inherit.

References

Productivity Commission, *Economic Implications of an Ageing* Australia, 2005

Australian Treasury *Budget Papers Intergenerational Report*, 2002/03.

Commonwealth of Australia Natural Resource Management Ministerial *Council National Cooperative Approach to Integrated Coastal Zone Management - Framework and Implementation Plan* 2006

P. Martin and M. Verbeek *Sustainability Strategies* Federation Press 2005

P. Martin *Are we overburdening regulation?* Australasian Environmental Law Enforcement and Regulators Conference, Brisbane, 2005

P. Martin *The Changing Role of Law in the pursuit of sustainability* IUCN Academy of Environmental Law Colloquium, Biodiversity Conservation, Law and Livelihoods: Bridging the North-South Divide, Macquarie University 2005.

P. Martin *Attacking the Big coastal challenge,* 3rd West Australian Coastal Conference, Balancing the Waves of Change, 2005

P. Martin and M. Verbeek *Rights, institutions and sustainability. How can we make it work?* in Agriculture for the Australian Environment. Proceedings of the 2002 Fenner Conference on the Environment. B.P. Wilson and A. Curtis Charles Sturt University, 2003

National Healthcare Alliance *2004 Federal Budget strategy submission: Towards a healthy and productive older workforce* NHCA December 2003 (C)

P. Martin *Innovation in Estuaries Regulation* Conference Proceedings, November 2003 (publication 2004)

P. Martin & M. Verbeek *Cartography for Environmental Law: Methodology for Law in Context Studies*, Land & Water Australia 2000

P. Martin & M. Verbeek *50,000,000 Australians: Is sustainability possible?* Land & Water Australia 2002

CLIMATE CHANGE FOR COASTLINES: RISKY BUSINESS FOR LOCAL GOVERNMENT

Abstract

With climate change now clearly back on the political agenda it is time to push for a coordinated approach to managing coastal vulnerability and risk.

While science continues to identify more definitive predictions there is reluctance from the upper tiers of government to commit to a holistic management approach. When will climate change be extracted from the "too hard basket"?

Unfortunately, it is local government, at the "coal face" with its extremely limited knowledge and resources, who has been left to address an issue which poses unheralded social, economic and environmental threats.

While funding appears to be readily available the question must be raised - Are the upper tiers of government using this provision of funding as a smokescreen, a tokenistic offer to suspend commencement of real action?

While recent publications released by the Australian Greenhouse Office provide increased insight into climatic scenario predictions their success will be limited without further assistance and commitment from state and federal government. Are partnerships strong enough to tackle climate change in a holistic and strategic manner? All the players realise that we can ill afford to wait but how can we generate coordinated and immediate action?

This paper will look into Local government responsibilities in meeting community expectations in coastal risk management while identifying opportunities and challenges encountered during three years of solid commitment from Manly Council in addressing climate change and coastal risk.

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CLIMATE CHANGE FOR COASTLINES: RISKY BUSINESS FOR LOCAL GOVERNMENT

Historic and Geological Introduction to Manly

The Manly Local Government Area provides an interesting case in the management of the future impacts of climate change due to its landform, popularity as an internationally renowned tourist destination and because of past land use planning decisions. In order to fully appreciate the vulnerability of the Manly coast to climate change one must first understand its history.

Following a rich history of Aboriginal occupation, Manly was visited and named by Captain Arthur Phillip at the same time as Sydney, between 21st and 23rd January, 1788. Manly remained isolated for many years. It was a long journey of 112km by road from Sydney - through Parramatta, Hunter's Hill, Lane Cove and Narrabeen. The other route involved crossing the Harbour by punts at North Sydney and The Spit. When Henry Gilbert Smith founded the village in 1853 there was a very small population which was able to eke out a living from fishing or farming.

> In June 1855, Smith wrote to his brother in England "…*the amusement I derive in making my improvements in Manly is, no doubt, the cause of my greater enjoyment, in fact I never feel a dull day while there. I should long ere this have been with you if it had not been for this hobby of mine, in thinking I am doing good in forming a village or watering place for the inhabitant of Sydney*".

Comment [s1]: While this is all very interesting, it takes up many words and seems to have little connection with the issue?

He purchased large tracts of land with the vision of Manly, with its splendid ocean beach and sheltered sandy coves, becoming 'the favourite resort of the Colonists'. He initiated a ferry service, built hotels and donated land for schools and churches. He also built a camera obscura, a maze and a stone kangaroo to attract visitors. He laid out a grand plan for Manly but changed this later to a more pragmatic design with smaller blocks. Manly Council was incorporated as a local government body on 6th January 1877. Manly's development was slow but by 1880 it had become a thriving seaside resort (Curby 2001).

Today Manly has a rich and diverse character with its natural and developed environment, along with its array of land uses, contributing to making Manly an attractive destination for residents and visitors alike.

Comment [s2]: This needs a reference – I think it comes from the SoE? Same with the next two paras!

The topography of Manly is characterised by a high ridge running east west along Balgowlah Heights with steep south facing slopes above North Harbour and more moderate slopes to the northern catchments of Manly Lagoon. The area plateaus to the west of Balgowlah Heights and Seaforth with a very steep escarpment that drops to the Middle Harbour shoreline. The relief of the area ranges from sea level to the highest point located at Bantry Bay Reserve, a level of 121m AHD.

The major geological formations in the area are middle Triassic Hawkesbury Sandstone, overlying the Newport Formation of the Narrabeen group. These rock units make spectacular cliffs on North Head where the lower halves of the sea cliffs are composed of the Newport Formation, with Hawkesbury Sandstone forming the upper blocky cliffs. A shale sequence marks the top of the Newport Formation. The Hawkesbury Sandstone is characterised by medium to coarse quartz sandstone. The Newport Formation is characterised by interbedded laminite, shale, quartz sandstone and lithic-quartz sandstone. On weathering these rocks have also contributed quartz sand to the beaches but most of the sand on the modern beach was placed during the last post-

Comment [s3]: I'm not sure of the value this sort of detail gives this paper? I'd cull it down

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glacial sea level rise and there is little new sand available to nourish the beach in the face of any further sea level rise.

Manly is located at the southern end of the Manly Warringah Peninsula of the Northern Beaches, immediately to the north west of the entrance to Sydney Harbour. The area is 16.26km² and has a boundary 39.4km, of which 29.9km is a water margin. No part of Manly is more than 1km from either the Harbour or the ocean (Refer to Figure 1). To the north the area is bounded by Burnt Bridge Creek, running from the northwest end of Seaforth to Manly Lagoon. The Manly Town Centre is located on a narrow isthmus of sand, separating the waters of North Harbour from the Pacific Ocean. The isthmus connects the mainland to the northern headland, North Head of Sydney Harbour, creating a tied-island or tombolo. This makes Manly particularly vulnerable to the potential impacts of climate change.

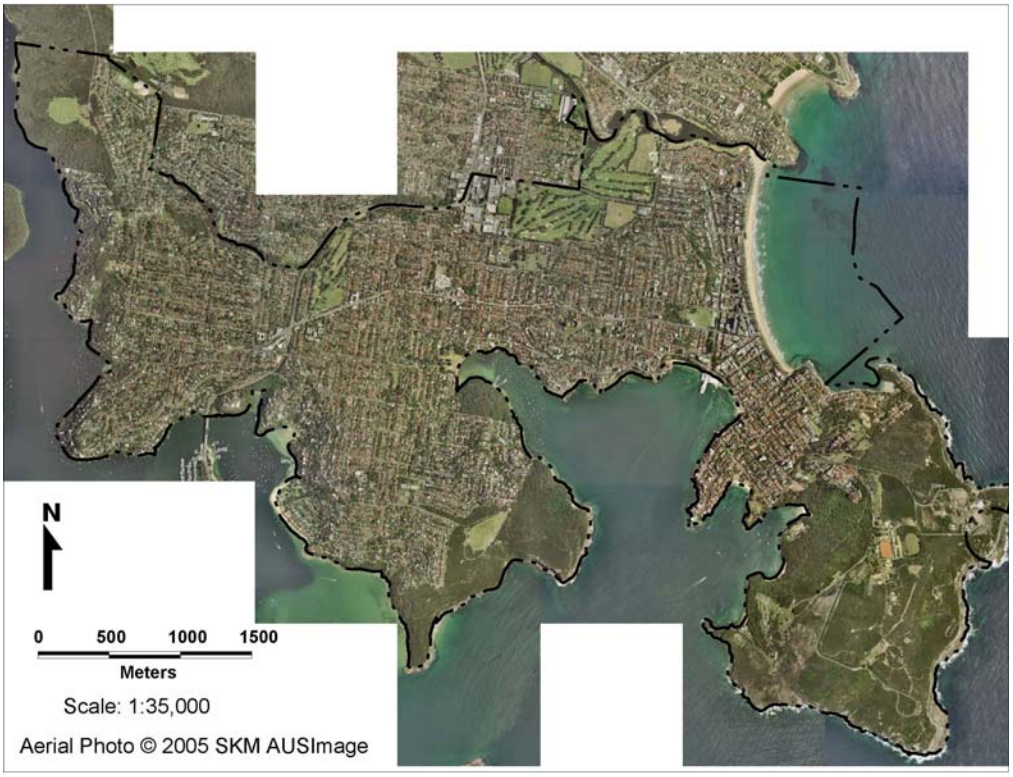

Figure 1 - Aerial view of the Manly LGA.

Current Land Use

Current land use is predominantly residential (37.2%) and open space/National Park (30.7%) with less than 2% dedicated to industrial and business activity. The Manly area currently houses approximately 40,000 residents and caters for some 8 million visitors per year (Manly Council 2006).

Over time there has been an intensification of development with high rise buildings replacing single residential dwellings. This has contributed to pressure upon existing drainage and sewage infrastructure and greater exposure to potential property damage from climate change. The popularity of Manly as an international tourist destination must

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also be considered as an increased risk for Manly Council.

How is Manly Council approaching Climate Change in a coastal risk context?
Climate change will obviously affect many natural and human systems and activities. However, the impact of a given climate change on a particular system or activity depends on its vulnerability and adaptability. If a system or activity does not adapt to the change, the impacts will be larger. Adaptation may be automatic, or it may be conscious and planned. Automatic adaptation tends to occur in natural systems, such as the migration of flora and fauna to more suitable environmental regions. Planned adaptation tends to occur in human systems (Greenhouse Office 2003) highlighting that we can let it happen or we can plan to meet it.

Since 2000 Manly Council has been developing Coastline Management Plans (CMPs) in response to legislative requirements and community issues. This approach encourages current best practice for the management of coastal and estuary foreshores as stipulated in the Coastline Management Manual (1990).

The first step required under the NSW Government's Coastline Hazard Policy (1988) and Coastline Management Manual (1990) was for Council to form the Manly Coastline Management and Manly Harbour Foreshores Management Committees. These community based Committees are in place to oversee the preparation and implementation of the various Coastal and Estuary Management Plans and associated Coastline Hazard Definition Studies.

Coastline Management Plans have been developed and adopted for Cabbage Tree Bay (2000), Little Manly Cove (2003) and Forty Baskets Beach (2003). Council is currently undertaking the development of CMPs for Manly Ocean Beach, Manly Cove and North Harbour with funding also provided under the Department of Natural Resources Estuary Management Program for the development of the Clontarf to Bantry Bay Estuary Management Plan. When these plans are finalised the entire Manly coastal and harbour foreshores will be covered within the framework developed and encouraged by the state government (with the exception of National Parks foreshores).

This approach has been well accepted by the local community and has enabled Manly Council to approach climate change, coastal risk and a variety of other sustainability related issues in a systematic manner.

Funding
Manly Council must acknowledge the various government bodies that have provided financial support for the work outlined in this report. With only a relatively small rateable base, Council would not have been able to achieve the progress it has without the ongoing support of state and federal government assistance. Supplementing grant funding for risk mitigation has been challenging.

The major funding sources for works outlined in this paper include:

- NSW Department of Natural Resource's Coastal Management Program which assisted on a 1:1 basis for Coastline Management Plan development and implementation as well as the various Coastline Hazard Definition Studies.

- Natural Disaster Mitigation Program on a 1:1:1 basis between Commonwealth: State: Local which is assisting with risk mitigation through remediation of specific

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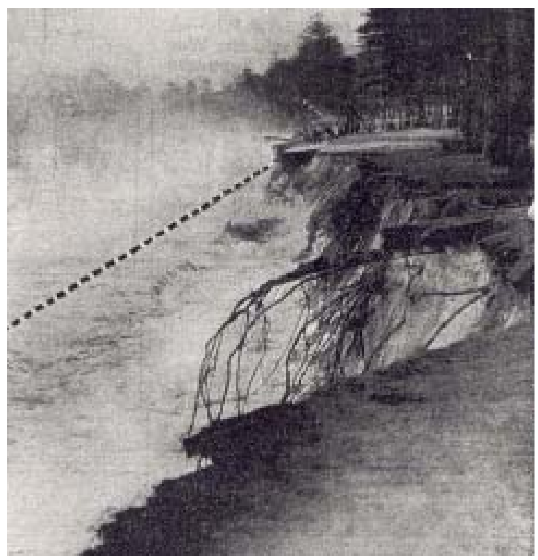
coastal hazards.

This funding has been supported by Council's Environment Levy.

Risk Identification for Manly Council
Council commissioned external consultants to undertake Coastline Hazard Definition Studies (CHDS) for the areas of foreshore within Little Manly Cove, Forty Baskets, Davis Marina to Manly Point and Manly Ocean Beach and Cabbage Tree Bay.

The hazards examined correlate with those set out in the NSW Government's Coastline Management Manual (1990) and include beach erosion, shoreline recession, sand drift, coastal inundation, stormwater erosion, slope and cliff instability and climate change. An assessment of the stability of the existing seawalls was also undertaken. As part of the initial hazard assessment process conceptual coastal management options to address identified hazards were also developed.

To obtain an understanding of the coastline hazards it is necessary to first understand the coastal processes and the performance of historical protection works undertaken to mitigate these hazards in each particular study area (Figures 2-4). It is interesting to note that the Manly Ocean Beach seawall has failed 13 times in the last 50 years with the last real significant storms in 1974. This highlights that there is an entire generation who have not experienced real sea surge and many memories who have forgotten.



Figures 2 & 3 - Storm damage to Manly Ocean Beach seawall in 1950. The dotted line indicates original position of seawall.

The coastal processes are often combinations of a variety of factors with three components contributing to an elevated still water level namely barometric setup, wind setup and wave setup. Barometric setup is a localised rise in ocean level due to a reduction in atmospheric pressure. Wind setup is a result of strong onshore winds causing water to "pile-up" along the coast. Barometric setup and wind setup are collectively referred to as storm surge. Wave setup is an increase in still water level in the surf zone due to a conversion of some of the kinetic energy of waves to potential energy. Individual waves cause temporary water level increases above the still water

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level due to the process of wave runup (PBP 2003). The time at which the peak of a storm coincides with tidal cycle is a very significant factor in determining the level of erosion damage. Following detailed analysis of sediment type, transport, budget and associated storm demand, Council was also able to assess the vulnerability of its beaches to specific storm events.

Comment [s4]: I don't think the technical detail here contributes to the rest of the sentence nor the argument at hand. The last sentence has the most value but I'm not too sure how it links to the rest of the paragraph – it isn't a smooth, obvious link.

The estimates of accelerated sea level rise adopted by Manly Council replicate those identified within the Intergovernmental Panel on Climatic Change (IPCC). Shoreline recession resulting from sea level rise was calculated using the "Bruun Rule" which multiplies the predicted sea level rise amount by the slope of the active beach profile. Results for Manly Ocean Beach can be seen in Table 1 below. Manly Ocean Beach currently has a width varying from about 30 m to 50 m.

Table 1. Shoreline Recession Due to enhanced Greenhouse Sea Level Rise (Patterson, Britton & Partners 2004)

Planning Period (yrs)	Amount of Sea Level Rise (m)	Shoreline Recession Allowance (m)
50	0.19	9.5
100	0.47	23.5

During the assessments it became apparent that the seawall crest level and adjacent promenade level along Manly Ocean Beach is below the limit of wave run up in severe storms. However, it is considered impractical and/or undesirable from an aesthetic and heritage point of view to raise promenade levels at this stage.

Figure 4 - Exposure of rock apron, Manly Ocean Beach in 1988

The seawalls located at both Manly Ocean Beach and Manly Cove have experienced significant damage in the past at an average of around every 12 years. More specifically, storm surge and wave overtopping of the seawall have resulted in seawall failure, damage to coastal infrastructure and risk to persons. Portions of the seawall at Manly Ocean Beach are at risk of failure during storm events. The risk of damage is increasing as a result of the predicted shoreline recession associated with Greenhouse sea level rise.

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In some cases, the magnitude of the slope and cliff instability hazard and the design of stabilisation measures, are influenced by climate change through the increase to sea level rise and storm frequency and intensity, particularly where the slope and cliff instability is due to wave undercutting (See Figure 5 and 6).

Figure 5 - Undercut feature adjacent to Fairlight swimming pool.

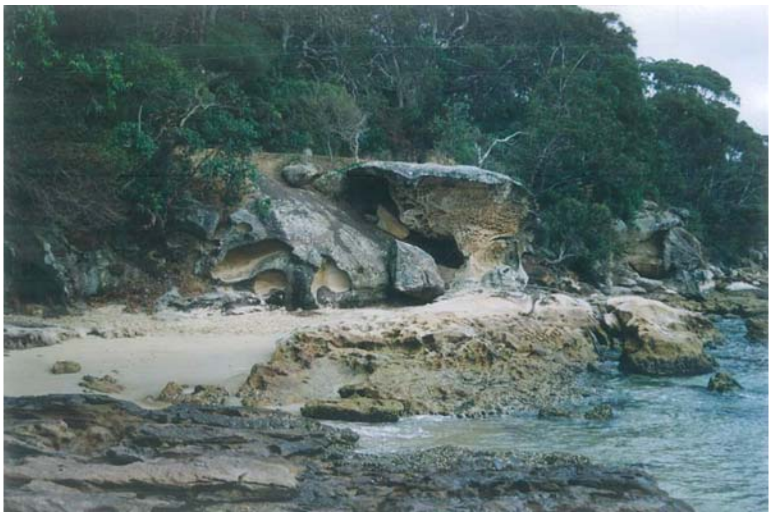

Figure 6 - Collapse of overhang feature likely. Geoheritage and cultural heritage issues have complicated the mitigation of risks yet are important considerations.

The identification of specific coastal hazards forms an integral part of CMP development. The CHDSs identified a number of specific coastline hazards on both public and private lands and proposed management actions to address each hazard. Those hazards identified on public land owned and/or managed by Council have been incorporated into the relevant Coastline Management Plan, which, once adopted, will be implemented on a priority basis by Council. A summary of identified hazards based on land ownership and mitigation responsibility is provided in Table 2 below. Figure 7 provides an indication of the distribution of identified coastal hazards within the North Harbour area irrespective of land ownership.

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Table 2 - Breakdown of coastal hazards identified in Manly.

Study Area	Private	Public	TOTAL
Manly Ocean Beach and Cabbage Tree Bay	1	23	24
Little Manly	8	22	30
Forty Baskets	0	16	16
Davis Marina to Manly Point	17	34	34
TOTAL	**26**	**95**	**121**

Comment [s5]: Maybe shade which areas have been addressed – I think little manly is done isn't it?

The type of hazard and risks posed by individual hazards varied considerably throughout Manly's coast and harbour foreshores. A summary of the main threats is provided in Table 3.

Table 3 - Coastal hazards affecting Manly by Coastline Management Plan study area.

Study Area / Hazard Type	Manly Ocean Beach & Cabbage Tree Bay	Little Manly	Forty Baskets	Davis Marina to Manly Point
Beach Erosion	X	X	X	X
Shoreline Recession	X	X	X	X
Sand Drift				
Coastal Inundation	X			
Stormwater Erosion				
Slope & Cliff Instability	X	X	X	X

Figure 7 - Potential coastal hazards identified for the North Harbour area (Manly Council 2003).

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Emergency Management
Manly Council is in the process of finalising an Emergency Management Plan (EMP) for Manly Ocean Beach. Emergency Action Plans provide the following for Council:

- Identification of the roles and responsibilities of parties that may be involved in coastal erosion emergencies;
- Describes the levels of activity that can be identified in an EMP and the trigger mechanisms that might apply in proceeding from one level of activity to another;
- Clarify the approvals required to implement emergency protection measures for coastal erosion;
- Discussion of the types of emergency protection measures that are potentially available and recommends a preferred emergency protection measure;

The drafting of Emergency Action Plans has raised significant risk issues in themselves. Firstly, the willingness of Council to direct staff and sub-contractors to implement emergency response measures during storm conditions is understandably minimal and is of great concern to internal risk managers. The placement of concrete blocks has been identified as one option for emergency protection on Manly Ocean Beach and has created division of opinion on whether Council staff should themselves be required to work in risky storm conditions.

Added to this, one must question the responsibilities of "peak emergency response" agencies that appear to offer little assistance for emergency response despite dictating emergency frameworks with minimal liaison with local government. Emergency management arrangements in NSW are outlined under the provisions of the State Emergency and Rescue Management Act 1989which requires the establishment of Local Emergency Management Committees (LEMC's) Each LEMC is required to develop Local DISPLAN's which identify roles, responsibilities, control and co-ordination of emergency operations at the local level. This document links with District and State Level Disaster Plans should the scale of the disaster require resources not available within the local community.

Although Local Emergency Management Committee's have been established to address issues relating to emergency management, the role of bodies such as the NSW State Emergency Service appears extremely limited (traffic control, pedestrian safety, removal of possessions) in a coastal context.

Local DISPLANs have been developed for specific areas yet the required Coastal Erosion Annexures (which address the response to coastal erosion and storm surge) are yet to be produced for Manly. Further, the minimal level of local government involvement in the development of such Coastal Annexeres is of great concern. This is emphahsised by the fact that bodies such as the SES appear to dictate the process while drawing clear lines as to their level of involvement during a storm event. Being unaware of the content of such documents appears to leave local government in a predicament with liability influencing the ability of such bodies to assist with emergency response, effectively thrusting responsibility wholly back on local government.

Rock protection has been placed in an *ad hoc* manner over the past few decades as a means of added protection to the toe of the Manly Ocean Beach seawall. This protective measure itself has also lead to increased risk not only to the exposure of people charged with implementing emergency response measures at the time of a storm event but also in regard to amenity and safety problems post-storm.

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Legal Advice
Having identified a range of individual hazards, many of which are located on private lands, Council needed to ensure that it had not exposed itself to potential litigation issues, particularly as the potential hazards identified in the reports may restrict future development of the relevant private properties on which they are located (or adjacent to).

As a result of the identification of specific properties in the report, legal advice on the public release of the information and inclusion of that information on the relevant Section 149(2) certificates was sought.

Councils Consultant Solicitor advised that there is possibly greater risk in not making the Coastline Hazard Definition Study Reports available than in withholding them. If a problem were to arise relating to the slope and cliff instability hazards identified in the report, and the information had not been released, then Council may well be found liable.

Council's Consultant Solicitor advised that the reports should not be made available (in part or full), except where all of the following points have been satisfied:

(a) Council has adopted the Report or the General Manager has approved its release in the manner proposed;

(b) All of the authors responsible for the production of the report (including any annexed reports) have agreed to the contents being released.

(c) That any release occurs in accordance with any conditions or restrictions imposed by the authors.

(d) Council releases the documentation with an appropriate disclaimer.

All of these points are being addressed.

Legal Advice on Section 149(2) Certificates
The Environmental Planning and Assessment Regulation (2000) (Item 7 of Schedule 4) requires that the following information be disclosed in a Section 149(2) Certificate:

Whether or not the land is affected by a policy:
(a) adopted by the council, or
(b) adopted by any other public authority and notified to the council for the express purpose of its adoption by that authority being referred to in planning certificates issued by the council, that restricts the development of the land because of the likelihood of land slip, bushfire, flooding, tidal inundation, subsidence, acid sulphate soils or any other risk.

Therefore in order to include the potential hazards information relating to specific private properties on the relevant Section 149(2) certificates, Council was required to adopt the Coastline Hazard Definition Study reports 'as Council Policy'.

Communication of risk to affected private property owners
Council formally notified a total of 75 private property owners (including high rise developments) that their properties may be potentially affected by specific hazards identified through the CHDS process. This was done in the form of a letter to each

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owner notifying the nature of the hazard, the extent of risk posed (if known), any recommendations from the CHDS and that a copy of the report was available upon request. Concurrently, hazard information was recorded on 149 Certificates for those properties affected.

Of the 75 private property owners only 3 elected to obtain electronic copies of the relevant CHDS. However, copies were made available at the Manly Library for those interested. As a number of Lots contained more than one dwelling the hazards identified directly affected 26 individual Lots (See Table 1).

Of the 26 properties it is estimated that Development Applications have been submitted for six Lots. For those where excavation (or work which impacts upon geology) is proposed Council has required the proponent to undertake detailed geotechnical assessment and (where required) the risk be mitigated. Properties adjacent to hazards have had similar conditions applied to works prior to approval. A challenge for Council is where the Applicant's Geotechnical Assessment contradicts the CHDS finding and recommendation. What do we do?

Coastline Hazards Identified on Public Land

The remediation of hazards identified on Council managed land is the responsibility of Council with mitigation prioritised on the level of risk posed to life and/or property.

In accordance with current best practice as set out in the State Government's Coastal Management Manual, the hazards and associated management recommendations identified in the Coastline Hazard Definition Study reports are included for action in the relevant Coastline Management Plan for that area. Council's Coastline Management Plans will outline the potential hazard and management recommendation in addition to assigning implementation priorities identifying funding possibilities and describing responsibilities.

Council was successful in two separate funding applications submitted under the Federal Government's Natural Disaster Mitigation Program (NDMP) during 2004/2005. These applications allowed Councils to:

- conduct further investigation of cadastral boundaries and geotechnical investigation of public land potentially affected by coastal hazards as identified during initial assessments, and;
- for the implementation of high priority mitigation measures addressing coastal hazards on public lands within the Manly LGA.

Comment [s6]: Grammatically, this should lead from the to: so you can't start with 'for'!

A third application was successful in the 2005/2006 round of NDMP funding which will also be used for implementing mitigation measures and the remediation of high priority hazards.

Following required additional geotechnical assessments and identification of land boundaries Council was able to prioritise hazard remediation. A report outlining the prioritized works was submitted to Council's engineering staff for implementation during 2006/2007.

Initially, six individual high priority hazards were listed for immediate remediation having been assessed to pose an unacceptable risk to life and where risk to property has been assessed to be moderate or high.

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Council then engaged external consultants to provide proposals for the design and construction of stabilisation measures, along with cost estimates. A report is expected during October 2006.

The potential impact of mitigation measures upon geoheritage and Aboriginal heritage has been considered throughout the process and Council must ensure it avoids both degradation of culturally significant sites and that mitigation respects the visual character of coastal and Harbour foreshores.

Council has been liaising with Aboriginal Heritage experts as well as representatives on its Scientific Advisory Panel to ensure geoheritage and Aboriginal cultural heritage issues are adequately addressed prior to seeking contractor interest in the implementation of stabilisation measures.

What are the challenges for Manly Council?
The types of effects of climate change in Manly will be much the same as in most other coastal areas of Australia. But the magnitude of the impact could be much greater because of the nature of the LGA and the work outlined in this paper raises a number of concerns for community and Council alike.

The geology of the Manly landscape has created conflicts between past land use planning decisions and climatic events, resulting in significant rock fall danger, landslip and cliff and slope instability. The approach by both local and state government to encourage pedestrian access to coastal foreshores has only increased the potential effects of climate change. Further, past land use decisions have resulted in minimal ability to implement any system of set backs and rolling easements as cliff lines around Manly continue to naturally crumble (Figure 8).

Many parts of the Manly LGA currently experience a relatively high degree of localised flooding. Council has spent considerable time and money in water cycle management particularly addressing flooding which is closely related to storm frequency, intensity and associated storm surge. Further, the location of stormwater outlets and property within the floodplain and coastal fringes has exacerbated problems when coupled with historic storm surge events.

The ability of Manly Council, and to a lesser extent State Government, to provide the required financial support is questionable. Certainty does, however, lie within Councils commitment to continuing to identify and manage risk in relation to the increasing impacts of climate change.

Although Manly Council has been successful in obtaining funding assistance through various grants there is, and will increasingly be, a shortage of funds to meet demand for risk mitigation. Manly's current population of 40,000 residents allows for only a relatively small rateable base to supplement grant funding for risk mitigation and coastal planning. Added to this is the popularity of Manly as an international tourist destination, creating maximum risk exposure for its 8 million visitors per year who come to enjoy Manly's beaches and coastal foreshores. Perhaps we need to tax the visitors?

A number of side issues have arisen through the risk mitigation process which impact significantly upon timing of remediation works. Firstly, the existence of Critical Habitat for Manly's Little Penguin Population defined by the Department of Environment and Conservation means that any mitigation measures must take into account the presence of penguin habitat and in many cases works are delayed until the close of the eight

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months long breeding season. Further, construction of engineering structures (for example, blade walls, underpins) must not impede penguin movement. Such delays pose problems for Council in mitigation of risk on public lands within the timeframes stipulated within various grant agreements.

Similarly, approvals must be sought to ensure any mitigation works do not impact culturally significant sites, of which there are many throughout Manly's coastal and harbour foreshores. The Environmental Heritage listing of the entire Manly foreshore has also complicated implementation and timing.

Having identified 121 individual potential coastal hazards (95 on public lands) and assessed stability of more than eight seawalls Council is now in a predicament as to how best these hazards and structures can be monitored. It is obviously not feasible for Council or funding bodies to continue to provide funding for monitoring. So how best can this be achieved with the limited resources and technical knowledge of local government? While the process has minimised coastal risk throughout the Manly coastal and harbour foreshores it has also raised many questions.

Another area of concern is in relation to the implementation of beach nourishment as an emergency management and/or beach amenity tool. The effects of climate change, including alterations to sea surface temperature, storm frequency and intensity and ultimate sea level rise, are increasing.

Suitable sand for beach nourishment is no longer sustainably available from terrestrial sources yet governments are reluctant to allow councils to even investigate the feasibility of utilising identified offshore sand resources. Thankfully organisations such as the Sydney Coastal Council Group continue to advocate the government on these often highly political and emotive issues. This issue will become more increasingly important for the NSW coast with many beaches suffering depleted sediment budgets today with nothing but barriers apparent. Council has become well aware of the hurdles needing to be jumped prior to the utilisation of offshore sand resources, however is greatly concerned that industry will be favoured over beach management.

For a location such as Manly whose beach attracts many millions of visitors per year, this issue needs greater consideration by state and federal government. As the associated influences of accelerated sea level rise increase, the ability of modified beach environments such as Manly Ocean Beach to cope with recession and to provide the required storm demand is decreasing. As such it is imperative that government provide Councils with the assistance and support warranted to address the needs of our beaches while minimising difficulties currently posed.

Conclusion

Climate change science is improving in accuracy and the community is reacting with decreasing levels of scepticism. Such information forms the basis for government to improve the ability to make optimal adaptations.

It is the intention of Manly's overall Coastline Management Strategy to identify measures which facilitate adaptive approaches to the management of climate change within each study area. This proactive approach has created positive outcomes for Manly, however successful adaptation to coastal risk and vulnerability still relies heavily in the responsibility of the upper tiers of government to initiate, regardless of the current political systems and ensure Australians are given the best possible support and protection from the increasingly certain future.

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Acknowledgements
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References

Curby P. 2001. *Seven Miles from Sydney: A History of Manly*. Manly Council.

Manly Council. 2000. *Cabbage Tree Bay Management Plan*. Manly Council.

Manly Council. 2003. *Forty Baskets Coastline Management Plan*. Manly Council.

Manly Council. 2003. *Little Manly Coastline Management Plan*. Manly Council.

Manly Council. Online, cited 02/10/06. http://www.manly.nsw.gov.au/Regional-Significance.html

NSW State Government. 1990. *Coastline Management Manual*. NSW Government.

Patterson Britton & Partners. 2003. *Little Manly Coastline Hazard Definition Study*. Manly Council.

Patterson Britton & Partners. 2003. *Forty Baskets Coastline Hazard Definition Study*. Manly Council.

Patterson Britton & Partners. 2004. *Davis Marina to Manly Point Coastline Hazard Definition Study*. Manly Council.

Patterson Britton & Partners. 2004. *Manly Ocean Beach & Cabbage Tree Bay Coastline Hazard Definition Study*. Manly Council.

Pittock B. 2003. *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office.

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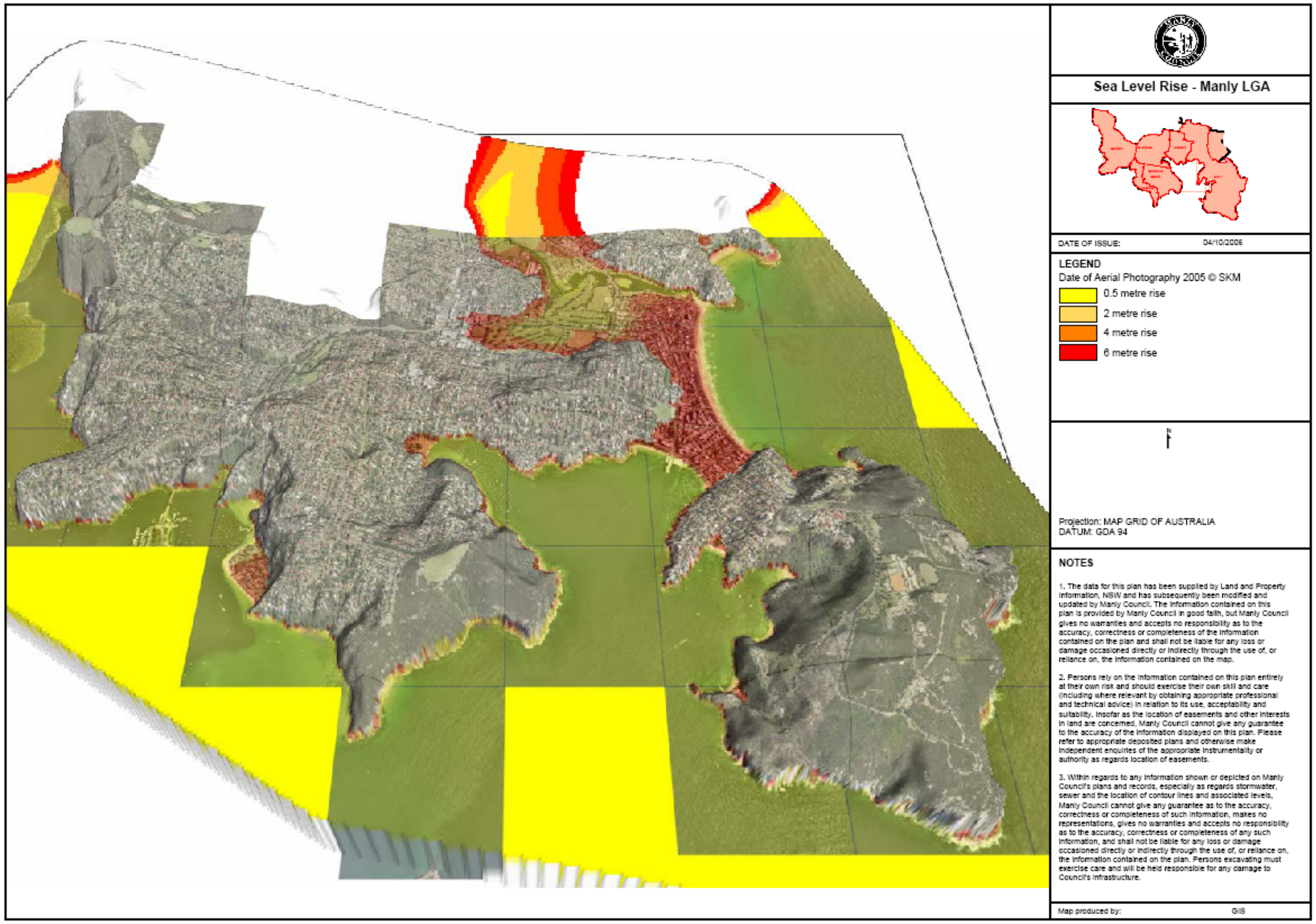

Figure 8 - Just how can Manly cope the threats of climate change?

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Climate Change impacts in the New South Wales Coastal Zone

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Abstract

This paper describes the development of climate change projections that will by used in two studies that investigate the impacts of climate change in the coastal zone. The first of these will investigate geophysical impacts, namely the shoreline and estuarine response to climate change. The second will investigate the social impact of climate change across the Sydney coastal suburbs. Progress on the development of the climate change projections will be presented along with a brief description of the impact studies for which these projections are being prepared.

Introduction

Coastal communities have undergone rapid growth in recent decades. The pressures of urban expansion, the popularity of the coastal zone for tourism and recreation and the need to conserve natural ecosystems are a few of the many competing demands on the coastal zone. Climate change adds new dimensions to the challenges already facing coastal regions, creating additional complexity and challenges to the available management options.

Along the approximately 1500 km length of coastline in New South Wales, the value of coastal properties at risk from coastal erosion/inundation is conservatively estimated to be worth $1 billion over a one hundred-year planning period (DNR Coastal Risk Assessment 2005). If planning and management processes are to remain sound in a future that increasingly feels the effect of climate change, they must be underpinned by advice on how relevant geophysical parameters are likely to vary. For the coastal zone, such parameters include sea levels, severe weather conditions, rainfall, wind and wave climate and their subsequent impacts on coastal geomorphology and flooding.

This paper describes the development of climate change projections for coastal NSW and the scope of two ongoing projects that will utilise the projections. The first project will undertake a detailed study of coastal erosion and estuarine health at two locations on the NSW coast. The second project will involve undertaking a vulnerability mapping exercise over the Sydney Coastal Councils region to identify key sensitivities to climate change and appropriate adaptation responses that can be considered by local government (Withycombe et al. this volume).

The Impact of Climate Change on Geophysical Parameters

Hennessy et al. (2004a,b) undertook a comprehensive general assessment of how the climate of NSW may change in the future based on the analysis of a range of climate model simulations. The overall findings described a future that would be warmer and drier and in which the frequency of extreme weather conditions might increase. A summary of some key findings of these studies are presented below along with a description of how they will be enhanced to provide more detailed information for the impact studies described here.

Temperature and Rainfall

Annual average temperatures in the coastal zone are likely to increase by 0.2-1.6°C by 2030 and by 0.7-4.8°C by 2070, with the strongest temperature increases in spring. There is a tendency for annual average rainfall to decrease with the strongest decreases in spring.

Rainfall, Wind and Weather Systems

While it is possible that seasonal average, especially spring average, rainfall will decrease across much of NSW under enhanced greenhouse conditions, it does not necessarily follow that extreme daily rainfall events will become less frequent or severe. Previous studies based on daily rainfall data from various climate models have indicated marked increases in the intensity and frequency of extreme daily rainfall events under enhanced greenhouse conditions for the Australian region (e.g. Whetton et al, 1993; Fowler and Hennessy, 1995). Extreme rainfall events are most likely to increase in intensity in the central, south-east and north-east regions of NSW. However, more detailed modelling (Abbs et al., 2006) shows that even in regions in which extreme rainfall is projected to decrease on the average, localised areas of increase may occur. These increases in intensity occur predominantly over high terrain and thus may have a significant impact on run-off in coastal locations.

Wind speed changes under enhanced greenhouse conditions are likely to be highly sensitive to season and location. Projections of wind speed changes for the southern NSW coastal region indicate a tendency towards increased wind speeds in summer and winter whereas projections for the central and north coast indicate a tendency towards decreased wind speeds in summer and winter. Projections for autumn tended towards decreases along the entire NSW coast while projections for spring tended towards increases. Projections for extreme (95th percentile) wind speeds were generally more uncertain than those for average wind speeds.

A simplistic application of these projections would be to assume no change in the relative frequencies of occurrence of different weather systems and simply apply the changes to the current climatology of results. However such an approach is inappropriate for the current projects because the frequencies of occurrence of the different systems affect wind direction, wave direction and coastal erosion. The existing projections will be enhanced tol include a more detailed analysis of wind and weather patterns with a focus on wind direction changes to determine how wave conditions may change in the future.

The NSW coast runs from the sub-tropics in the north to the mid-latitudes in the south and as such is affected by weather systems from both climatic zones. To the north depressions developing in easterly troughs are experienced during the summer months along with occasional tropical cyclones. In the south, low pressure systems such as cut-off lows, migratory lows and east coast lows are a major source of severe weather, particularly in the colder months. These systems are all capable of generating extreme winds, storm surges, severe wave conditions and flooding rainfall along the coast. Less severe weather conditions can also impact on the wave conditions in the region. For example, anticyclones can be a major source of wind-generated waves from the northeast, as can sea-breezes during the warmer months of the year.

An investigation of the key weather systems responsible for extreme winds on the NSW coast has already been undertaken. The weather systems associated with the top 1% of wind days were characterised over the NSW coastal region encompassing 25-45°S and 145-165°E over the summer and winter half years from 1961 to 2000 (see Hennessy et al., 2004b for details). Five generic weather types were identified and are illustrated in Figure 1. The Tasman high consists of a ridge of high pressure in the south bringing easterlies to the NSW coast. These accounted for 40% of extreme wind days in summer and 10% of extreme wind days in winter in the NCEP re-analyses. During the passage of cold fronts, the winds on the NSW coast varying from pre-frontal north-westerlies through to post-frontal southerly to southwesterly winds. Cold fronts occurred on 22% of summer and 31% of winter extreme wind days. The remaining synoptic types were low pressure systems and include Tasman lows, cut-off lows in which the low is cut-off from the westerlies to the south by a ridge of high pressure, and lows of tropical origin. Tasman lows accounted for 15% of severe wind days in summer and 30% of severe wind days in winter, and cut-off lows accounted for 17% of summer severe wind days and 28%

of winter severe wind days. Lows originating from further north only occurred in summer and accounted for only 1% of extreme wind days. The proportion of extreme winds associated with the different weather types in summer and winter is summarised in Table 1. The low pressure systems are the main source of high wave conditions and erosion episodes along the NSW coast and so a more detailed analysis of how these classes of weather system change under enhanced greenhouse conditions will be undertaken using the same techniques as applied here.

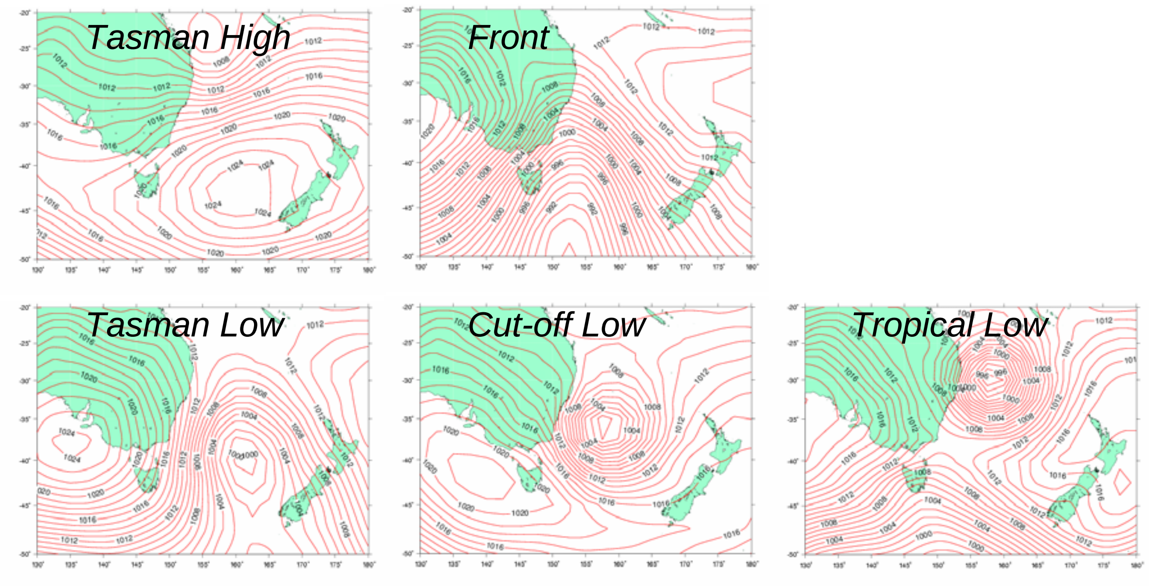

Figure 1: Examples of the five main synoptic weather patterns associated with extreme wind days.

Table 1: A description of the main synoptic weather events associated with extreme wind days over the summer and winter half-years in the vicinity of the NSW coast. The percentage of the total number of days in which the particular synoptic type is observed is also given.

Type	Name	Obs (NCEP) % of days	
		Summer	Winter
1	Tasman High	40	10
2	Front	22	31
3	Tasman Low (not cut-off)	15	30
4	Cut-off low	17	28
5	Tropical low	1	0
	Un-classified	5	3

Sea Levels

Global sea levels have increased over the twentieth century at a rate of around 1.8 mm per year Church et al, (2004). Around Australia the change of relative mean sea level (sea level not corrected for isostatic rebound) around the Australian coastline for the period 1920 to 2000 is about 1.2 mm per year (Church et al, 2006). An analysis of the changes in extreme sea levels in the long tide gauge record at Fort Denison in Sydney was also undertaken. Hourly observations, divided into pre-1950 and post-1950 sections, indicate that a decrease in return period by factors of between 2 and 3 has occurred for extreme levels when comparing the pre-1950 period with the post-1950 period. The data were not corrected for vertical land motion and therefore represent sea level relative to the land. This increase is found to be due to an increase in interannual variability in the latter part of the record (Church et al, 2006).

Sea levels are projected to increase in the future as a result of ocean warming and the melting of ice caps. The IPCC (2001) projects sea level increases of 0.03-0.10 m by 2030 and 0.07-0.49 m by 2070. Increases in mean sea level will have their greatest impact during extreme sea level events such as storm surge and wave events. The severe weather events described in the previous section are mainly responsible for generating these hazardous conditions.

Storm surges occur as a result of localized wind and pressure conditions. Ocean waves on the other hand can be produced by local storms or remote systems, since waves in deep water can travel thousands of kilometres from their point of origin with little loss of energy, arriving at the coast as swell.

The NSW coast features a relatively narrow continental shelf between 30 and 50 km wide. This means that storm surge magnitudes tend to be limited. The typical magnitude of the storm surge is the sum of the pressure fall (barometric setup) and the effect of the wind and is in the range of 0.3 to 0.6 metres (MHL, 1992); McInnes and Hubbert, 2001). The magnitude of the wave effect is in the range of 3.7 to 7.5 metres, with wave-breaking being the largest contribution to sea level extremes. The likely changes to the future characteristics of storm surge and waves will be considered in this study in relation to changes in wind and wave climate and changes in the frequency and intensity of severe storms.

Application to Impact Studies

Addressing climate change is a complex challenge. Developing suitable management strategies and adaptation responses requires a multidisciplinary approach. The scope of two multidisciplinary studies that will utilise the projections developed in this study are described briefly below.

A Preliminary Assessment of the Climate Change Impacts and Adaptation options for Coastal New South Wales

The overarching objective of this project is to assess the environmental and economic impact of potential coastal erosion, coastal inundation and degradation of estuaries due to climate change in coastal NSW.

Long term climate change due to the greenhouse effect has the potential to impact on shorelines in different ways. Rising sea levels and possible increases in severity of storms will increase the rate of erosion, while changes in wind climatology, and hence wave climate, can produce shoreline reorientation. Because of the different physical processes involved, the assessment of coastline response requires different modelling approaches. One dimensional cross-shore profile models are suitable tools for assessing the amount of erosion that occurs due to individual severe storms, whereas the one-line models based on the Bruun Rule assess long-term shoreline recession due to increasing sea levels. However, complex 2D and/or 3D hydrodynamic and sediment transport models are needed to assess the long-shore sediment transfer that is likely to occur in response to changes in wind and hence wave climate.

One of the significant aspects of this project is that it will employ all three modelling approaches above to assess the relative importance of each process in beach response at the two representative sites. It will use best available estimates of changes to sea level, wind climate and severe storm occurrence over the next hundred years. Results of this study will provide guidance of the sensitivity of the beach response to the various future changes and identify which processes will warrant more detailed quantification to assess future changes. In addition, best estimates to changes in rainfall extremes will be used to investigate estuarine processes such as estuarine flushing, mixing, circulation and dissolved oxygen dynamics using a suite of 2D and 3D hydrodynamic models.

A Systems Approach to Regional Climate Change Adaptation Strategies in Cities

The aim of this project is to develop and trial a transferable method for a systems approach to regional climate change impact assessment and adaptation in cities. The climate information will be used to engage key stakeholders in the coastal suburbs of Sydney to consider the sensitivities of the region to climate change, assess their capacity to adapt and formulate and prioritise adaptation strategies. More details of this project can be found in Withycombe et al. (2006)

Conclusion

This paper has described the development of climate change projections and their intended use in two impact assessment studies. The climate change projections will be tailored for use in assessing the impact of climate change in the coastal zone. The aim of the first impact assessment will be to quantify the effect of climate change on coastal erosion and estuarine health through the use of detailed geophysical models. The second impact study will use the climate information to assist stakeholders in the coastal suburbs of Sydney to assess the sensitivities and adaptive capacity to climate change.

References

Abbs, D. J., S. Aryal, E. Campbell, M. Palmer, A.S. Rafter, and B. Bates, 2006: Impact of climate variability and climate change on rainfall extremes in Western Sydney and surrounding areas. Phase 1 report to the Upper Parramatta River Catchment Trust. 66 pp. http://www.cmar.csiro.au:8000/e-print/open/abbsdj_2006a.pdf

Church, J.A., White, N.J., Coleman, R., Lambeck, K. and Mitrovica, J.X., 2004: Estimates of the regional distribution of sea-level rise over the 1950 to 2000 period. Journal of Climate, 17, 2609-2625.

Church, J.A., Hunter, J.R. McInnes, K.L. and White, N.J., 2006: Sea-level rise around the Australian coastline and the changing frequency of extreme sea-level events. *Aust. Meteorol. Mag. (in press).*

Fowler, A.M. and Hennessy, K.J. (1995). Potential impacts of global warming on the frequency and magnitude of heavy precipitation. Natural Hazards, 11 (3), 283-303.

Hennessy, K. J., Page, C. M., McInnes, K. L., Jones, R. N., Bathols, J. M., Collins, D., and Jones, D. (2004). Climate change in New South Wales. Part 1, Past climate variability and projected changes in average climate. Consultancy report for the New South Wales Greenhouse Office. Aspendale: CSIRO Atmospheric Research. 46 p. http://www.cmar.csiro.au/e-print/open/hennessy_2004b.pdf

Hennessy, K, K. McInnes, D. Abbs, R. Jones, J. Bathols, R. Suppiah, J. Ricketts, T. Rafter, D. Collins* and D. Jones, 2004: Climate Change in New South Wales Part 2: Projected changes in climate extremes. Report for the New South Wales regional Office. 79 pp. http://www.cmar.csiro.au/e-print/open/hennessy_2004c.pdf

IPCC (2001a). Summary for Policymakers, in Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., Van Der Linden, P.J. and Xioaosu, D (eds) Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 944 pp.

McInnes, K.L. and Hubbert, G.D., 2001: The impact of eastern Australian cut-off lows on coastal sea levels. *Meteorological Applications,* **8***,* 229-243.

MHL (1992). Mid New South Wales coastal region tide-storm surge analysis. Manly Hydraulics Lab Report 621, 109 pp.

Short, A. D. and N. L. Trenaman, 1992: Wave climate of the Sydney region, an energetic and highly variable ocean wave regime *Aust. J. Mar. Freshwater Res*., 43, 765-791.

Whetton, P. H., Fowler, A. M., Haylock, M. R., and Pittock, A. B. (1993). Implications of climate change due to the enhanced greenhouse effect on floods and droughts in Australia. *Climatic Change*, 25 (3-4): 289-317.

Withycombe, G., Smith, T.F., Brooke, C., Preston, B., Gorddard, R., Abbs, D. and McInnes, K.L., 2006: Managing for climate variability in the Sydney region – issues, needs and new solutions for Local Government. Proceedings NSW Coastal Conference, Coffs Harbour.

Overcoming barriers to coastal sustainability and facilitating improved delivery of regional management: A Case Study of the Sydney Coastal Councils Group

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Abstract
The Sydney Coastal Councils Group Inc. (SCCG) is a Regional Organisation of Councils (ROC) that represents 15 Councils in the Sydney coastal region. The aim of the Group is to promote co-ordination and cooperation between Member Councils on environmental and natural resource management issues. The activities of the Group assist Member Councils address overarching barriers to achieving coastal sustainability in the region. These include; the complexity of coastal zone management in the context of regional Natural Resource Management (NRM) delivery; the loss of programs and lack of an independent advocate for coastal management.

This paper highlights the benefits to Councils of participating in a regional body that advocates and facilitates improved coastal management. Through case study examples of the policy and programs of the SCCG, the paper provides examples of strategies to overcome barriers to sustainability from a regional perspective. Case studies include:

- **Coordination:** Regional coordination of 15 Councils at all levels;
- **Capacity Building:** Through the provision of technical information and resources on key regional management issues;
- **Partnerships:** Stakeholder support and participation for the regional delivery of NRM;
- **Advocacy:** Advocating for improved management, education and resources on key environmental issues including water conservation, climate change, regional planning and biodiversity protection; and
- **Education:** Coordinating and promoting education programs.

This work demonstrates the benefits of being proactive and forming partnerships to overcome barriers to coastal sustainability and provides models that can be applied to other regions. Through membership of a ROC that focuses on coastal environmental issues Member Councils benefit from an increased capacity to implement coastal sustainability initiatives.

Introduction

The coastal zone is one of Australia's greatest assets and the capacity to ensure ecologically sustainable use and development within the coastal zone is important to all Australians (NRMMC 2006). In the past 50 years the coastal zone in many areas of Australia has experienced significant increases in population, tourism and intensive residential, industrial and commercial development. This increased development has lead to a degradation of many fragile coastal ecosystems (SCCG 1998, 2006).

In NSW coastal management and planning is undertaken by all spheres of government in consultation with community groups, research organisations, industry and non-government organisations (SCCG 1998, 2006). Local Government play a significant role in coastal zone management. The role Council's play in planning and managing the coastal zone includes, but is not limited to, detailed land use planning and decision making, infrastructure provision, land management and Natural Resource Management (ALGA 2005a).

SCCG has found that the complexity of coastal zone management in the context of regional NRM delivery, the loss of programs and lack of an independent advocate for coastal management are significant barriers to achieving improved coastal management in the Sydney Region. Middle (2004) lists thirteen barriers to good policy making for the coastal zone and highlights the three most significant barriers to making good coastal policy as:

- The lack of integration between and across government;
- Inadequate and inappropriate public consultation; and
- The lack of resources and the inefficient application of existing resources.

Thom and Harvey (2000) identify four triggers for 20th Century reform of coastal policy. These are global environmental change, sustainable development, integrated resource management and community awareness of management issues and participation in decision making. Each of these has occurred across federal, state and local government levels in Australia (Thom and Harvey 2000). Despite these triggers for reform and the 29 National and State inquires into coastal zone management in Australia that have been undertaken over the last 30 years the barriers experienced by the SCCG and identified by Middle (2004) still persist.

The SCCG, established in 1989, represents 15 Local Governments adjacent to Sydney marine and estuarine environments and associated waterways. The principal aim of the Group is to promote cooperation between, and coordination of actions of Member Councils in consultation with the broader community on issues of regional significance concerning the sustainable management of the urban coastal environment.

The SCCG is a voluntary Regional Organisation of Councils established under the provisions of sections 355, 357 and 358 of the NSW *Local Government Act* 1993. The functions and powers of the Group are provided in its Constitution. The Group was incorporated in February 1998 under the *Associations Incorporation Act* 1984.

Middle (2004) observes that strong leadership in the form of a “champion” and ongoing learning are key elements of the development of good coastal policy. Each of these is essential to overcoming the existing barriers. With this sentiment in mind SCCG aims to support its Member Councils through assisting to advocate, develop, coordinate and implement consistent coastal management policy and programs. The underlying goal is to facilitate better governance for the coastal zone of Sydney. The Group operates under five core outcome statements.

1. The exchange of information on urban coastal management to Member Councils is coordinated and facilitated.
2. Community awareness on matters related to the urban coastal management is enhanced.
3. The role and capacity of Member Councils to manage the coastal environment is improved.
4. Member Council interests are represented on issues in relation to regional and national coastal management.
5. Sustainable and Integrated Coastal Zone Planning & Management is facilitated.

The aim of this paper is to draw on the work of authors such as Thom and Harvey (2000), Middle (2004), Gurran *et al* (2005) and Stuart *et al* (2006) as well as the experiences of the SCCG to provide a case study of how identified barriers to coastal management can be overcome in a regional context. The paper lists barriers to coastal management identified by other authors and provides examples of actions, programs and outcomes regional coordinated by the SCCG that have attempted to overcome these barriers.

Discussion
This section of the paper provides eight case study examples of activities and programs undertaken by the SCCG to overcome existing barriers to sustainability and focus on the key areas of:

1. Coordination
2. Capacity Building
3. Partnerships
4. Advocacy
5. Education

1. Coordination
To minimise the negative impacts of barriers to coastal zone management, Middle (2004) recommends Governments recognise that a lack of integration leads to inefficiencies and less than optimal management. Consistent with this the SCCG was established in 1989 with a key focus being to facilitate the exchange of information on urban coastal management amongst member councils. The primary outcome of this focus is the exchange information, ideas and expertise to identify and address regional issues, solutions and projects.

Case Study 1: Facilitating ongoing coordination
The process through which the SCCG achieves ongoing coordination of 15 Councils and external stakeholders is through the facilitation of committees and working groups made up of elected representatives, professional council staff and representatives from State Government agencies, non-government organisations, research institutions and the community. These committees and working groups address key priorities and areas of concern. Committees the SCGG facilitates include:

- SCCG Executive and Technical Committees,
- SCCG Beach Management Working Group
- SCCG Business Management Plan (Strategic Plan) – Directional Committee,
- SCCG Caulerpa taxifolia Task Force,
- SCCG Coastal Risk Management Forum Working Group,
- SCCG Geotechnical Expert Panel (and National Observer Group),
- SCCG GIS Investigations Working Group,
- SCCG Groundwater Investigations Working Group,
- SCCG / Macquarie University Partnership Advisory Committee,
- SCCG Summer Activities Program Committee.

The purpose of these committees and working groups is to assist Member Councils with the development of action oriented strategic frameworks to focus and guide coastal planning and management practices. An additional benefit of coordinating committees consisting of a range of organisations and stakeholders is the sharing of experience, knowledge and solutions. A result of this is maximising limited resources of many Councils. This model provides an integrated and cooperative approach to coordination in the Sydney region.

In facilitating this process SCCG has learnt many things. Communication between stakeholders within the region is essential to increasing the capacity of all Councils. Driving communication at a regional scale requires cooperation amongst a large number of stakeholders and is often difficult to achieve.

Overall, it relies on a single body (SCCG secretariat) to drive and coordinate in an organised and efficient manner. In facilitating committees and working groups SCCG works to prepare for all meetings to ensure that the time of meeting attendees is not wasted and all stakeholders are informed, motivated and able to make a contribution.

While the coordination of committees is an endeavour that requires a significant time investment on the behalf of the SCCG Secretariat and Member Councils, it is a process that leads to the identification of regional projects and solutions. This results in the increased capacity of all stakeholders and positive environmental and social outcomes. Therefore, it is an essential strategy in overcoming barriers related to a lack of integration as identified by Middle (2004).

2. Capacity Building
ALGA (2005a) identifies the main barriers for Councils to improving the policy and management of the natural resource base in the coastal zone are the lack of adequate funding, trained staff and planners. In a regional context SCCG believes that ongoing learning of all Councils from a diverse regional group of Councils in the region is essential to increasing the capacity of councils.

Increasing the capacity of all Councils in a region as diverse as Sydney is difficult, due to limited resources and competing priorities. The experience of SCCG, Middle (2004) and Stuart et al. (2006) is that increased capacity of Councils through ongoing learning is important especially where there is uncertainty about the science associated with an issue and delaying policy development and implementation is not an option due to immediate pressures, institutional drivers and community expectations.

Two pressing areas of management identified by Councils in the Sydney coastal region are addressing the impacts of climate change and the management of groundwater resources. To tackle each of these current issues the SCCG has undertaken specific regional projects to encourage Councils to consider these issues as well as local and regional solutions. The outcome has been the development of a process that facilitates councils identifying regional issues, working together and with other stakeholders to develop solutions and identifying methods for implementation. This provides Councils with a vehicle for ongoing learning as well as tools and resources to address specific issues.

Case Study 2: A Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises
Local Government is beginning to address the impacts of climate change through a range of activities. Many Councils believe that issues related to the uncertainty of impacts of climate change, the need for a consistent approach to managing climate change and the cost of capital works are preventing adapting to the impacts of climate change (SCCG 2005). Due to this the SCCG is working with research institutions such as the CSIRO to undertake projects that build the capacity of member councils to mitigate and address the impacts of climate change.

The SCCG in partnership with two CSIRO Divisions (Sustainable Ecosystems, and Marine and Atmospheric Research) has recently been successful in gaining significant grant funding from the Australian Greenhouse Office - Urban Integrated Assessment Programme to undertake a project titled “A Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises”.

The project will seek to inform the region's coastal Councils regarding the potential biophysical changes that climate change may cause in the region, with subsequent emphasis on examining local capacities to adapt to potential climate change impacts. These activities will be carried out in a series of stages: i) vulnerability mapping; ii) stakeholder consultation; iii) assessment of adaptive capacity; iv) project assessment. The project will begin shortly.

Case Study 3: The Groundwater Management Handbook – A Guide for Local Government

A survey of SCCG member councils in 2004 found that groundwater management at Local Government level was ad-hoc with varied community and industry understanding. Development of the *Groundwater Management Handbook – A Guide for Local Governmnet* in consultation with the SCCG Groundwater Managment Working Group provided a mechanism through which member councils could share their knowledge and experience on groundwater management with the relevant NSW Government Departments and research organisations. The Handbook assist all stakeholders understand and manage groundwater more sustainably. The key outcome of the Handbook is to provide stakeholders with greater confidence and capacity in the management and assessment of groundwater resources in relation to development assessment and control, protection of groundwater dependent ecosystems and utilisation of groundwater resources.

In developing and undertaking activities to build the capacity of Councils regionally a number of issues need to be considered. Most importantly, the capacity of individual Councils to address coastal management and sustainability issues is highly variable. Additionally, the involvement of all councils in the regional identification of projects. and solutions is essential to ensuring councils have ownership of the outcomes to ensure implementation. Further facilitation of the sharing of experience and resources amongst councils is essential to facilitating meaningful ongoing learning that results in building the capacity and institutional knowledge of all councils in the region.

Many surveys and reports including Middle (2004), ALGA (2005a) and ALGA (2005b) have highlighted the need for councils to receive additional support to increase their capacity to deliver sustainable coastal management. Through the actions outlined above, SCCG has developed a framework for the development of tools and resources that result in the increased capacity of councils to manage the coastal environment.

3. Partnerships

Gurren *et al* (2005) identify enhancing existing sources of funding for local government initiatives and facilitation of local government access to environmental, demographic and economic data and expertise as two key strategies to address emerging coastal management issues. The development of regional partnerships is an action SCCG believes to be very important to facilitating sustainable and integrated coastal zone planning and management.

SCCG supports Councils participating in regional NRM groups such as Catchment Management Authorities. ALGA (2005a) has found that most Councils do not believe their regional plan adequately addresses their local coastal zone management issues. Additionally, for the range of coastal zone management activities that Councils undertake requires more funding to maintain programs such as Coastcare and the Coasts and Clean Sea program (ALGA 2005a).

The experience of SCCG is that repeated restructuring of regional bodies and funding mechanisms leads to a loss of continuity and momentum in programs and outcomes. In light of this, SCCG participates in a number of partnerships that aim to work with existing frameworks for the delivery of NRM and establishing ongoing programs that are not dependent on changing funding initiatives from state and commonwealth governments.

Case Study 4: Sydney Metropolitan Catchment Management Authority (SMCMA)

Due to the significantly reduced funding for coastal initiatives and the fact that many Councils do not believe regional plans adequately consider coastal issues the SCCG is working with the State Government and regional bodies to recognise and support the role Councils play in coastal management. The SCCG has worked closely to the SMCMA to promote funding of projects that focus on the coastal zone and to ensure that the reporting of the health of the coastal zone in the catchment is undertaken meaningfully and accurately. These activities have included:

- Participation in the "Expert Panel" consultation on Estuarine, Coastal and Marine issues on the Sydney Metropolitan Catchment Management Authority Draft Catchment and Management Targets for the Catchment Action Plan;
- Seeking the establishment of a Coastal Advisory Panel, or similar, to advise the Natural Resource Commission (NRC) and to facilitate communication between the Government and coastal stakeholders in NSW; and
- Urging the development of a national funding package for coastal initiatives that provides protection, restoration and capacity building activities similar to the Coasts and Clean Sea Program. In a submission to the Federal Minister for the Environment the SCCG has also recommended a new agreement to govern the distribution of funds from NHT (III) to be a tri-partisan agreement between Commonwealth, State and Local Governments.

Case Study 5: Institute of Environmental Studies UNSW Partnership Program

The SCCG and the Institute of Environmental Studies (IES) at the University of New South Wales entered into the Memorandum of Understanding (MOU) partnership agreement in 2004. The program is designed for the SCCG, its Member Councils and the IES to jointly focus on addressing contemporary and strategic environmental management issues. Through a project nomination process, the SCCG and Member Councils submit proposals for projects that are to be undertaken by Masters Students as part of the program. Projects include a number of disciplinary and/or sector perspectives with the principal objective of advancing the management framework of sustainability. Each project involves a critical literature review that can be expanded to include the application of best practice applied techniques and models.

Case Study 6: Department of Physical Geography at Macquarie University

The SCCG has developed a partnership program with the Department of Physical Geography at Macquarie University. A partnership MOU signed off in 2005 has been agreed to by both organisations and includes a commitment of both parties to develop and undertake workshops, research projects, industry guest lectures and participation in academic advisory boards. The objectives of the program include:

1) To promote academic cooperation which enhances the above mentioned goals.
2) To encourage visits by staff between our institutions for the purpose of engaging in research, and
3) To foster the exchange of academic publications and scholarly information.

There are two clear benefits to these activates. Firstly, working with relevant stakeholders in the region maximises the resources of all stakeholders through the coordination of existing activities. It also provides the opportunity to investigate gaps in existing projects and funding needs for the delivery of coastal natural resource management initiatives with the regional bodies responsible for the distribution of funding.

Secondly, it bridges the gap between policy and science, which has been a key focus of the SCCG for many years. From these partnerships it has been identified that the provision of technical information in a condensed format is valuable to communicate the importance of particular issues to both council staff and elected representatives. Strategies such as this are important to address emerging coastal management issues identified by Gurren *et al* (2005) and maintaining continuity and momentum of programs.

4. Advocacy

There has been a steady evolution of legislative and other measures to regulate coastal management and planning in NSW (Thom 2004). One of the drivers for this evolution of policy has been greater stakeholder awareness of management issues and greater community participation in decision making (Thom and Harvey 2000, Thom 2004). Unfortunately this has not always resulted in an improvement in coastal management. A lack of integration between and across governments combined with inadequate and inappropriate consultation with stakeholders has prevented the successful implementation of coastal policy (Middle 2004).

Another barrier preventing the development of improved coastal management identified by SCCG is that policies will often fail to be developed or implemented if there is inadequate political support within government and corresponding grant programs. This also effects the allocation of resources to government agencies or other stakeholders to address specific issues (Middle 2004). One example of evolving policy where Councils are seeking increased policy guidance and funding is in relation to beach nourishment.

Case Study 7: Promoting beach management options

With the pressures facing beach areas due to coastal recession, climate change, and recreational usage, the SCCG formed a Beach Management Working Group in late 2005.

The Working Group includes Councils, interagency and research representatives and aims to assist with finding solutions to the beach erosion and protection issues. The Working Group is providing a forum for discussion and activities in relation to beach management processes, issues and needs now and into the future. It provides a link between SCCG member councils, State and Commonwealth Government Organisations, academia, industry and the community.

In late 2005, early 2006, as part of the activities of the SCCG Beach Management Working Group, the SCCG wrote to all 38 coastal councils in NSW requesting information on each councils views on beach nourishment and support for an investigation into the impacts and opportunities of offshore sand mining. Other Working Group activities include:

- Preparing the Natural Disaster Mitigation Program grant application for investigation Sydney offshore sands and their suitability for Beach nourishment valued at $100,000 (still pending notification)
- SCCG engagement of Dr. Roy and Dr. Cowell to provide a report on sand deposits of the NSW inner continental shelf (completed)
- Successfully applied to undertake a PhD research project to *Quantifying the Value of Sydney (NSW) Beaches* in order to assess cost / benefit of necessary coastal protection / abatement measures as a result of enhanced climate change impacts.

In undertaking these activities the SCCG is providing information and advocating a solution to government agencies, elected representatives and the community that will improve the capacity of Councils to deliver a sustainable coastal environment. This provides a vehicle for influencing both local and state coastal policy and ensures ongoing recognition of the important role Councils play in the delivery of sustainable coastal management. SCCG has found this process raises State Government and community awareness on environmental as well as the needs of Councils to address these issues.

5. Education

Middle (2004), notes that a lack of community support and understanding of environmental problems is a barrier to improving coastal management. Through assistance with coordination and promotion of Council education activities the SCCG aims to enhance community awareness on matters related to the urban coastal management. These education activities also assist Councils to promote improved coastal management to wider audience in the community than they traditionally meet with formal consultation and participation mechanisms. The education activities SCCG undertakes include: production of quarterly newsletters and monthly e-news, facilitation and coordination of forums, maintenance of a website and promotion of council organised education programs.

Case Study 8: Summer Activities Program

The January Summer Activities Program is an initiative of the SCCG. Since the demise of Coastcare in NSW, the SCCG has taken responsibility for coordinating this regional promotion of education activities during the summer holidays. The aim of the program is to coordinate and promote coastal activities. It consists of a range of planned activities run throughout the summer holidays. The 2006 Summer Activities Program consisted of 60 events run though January with over 1,100 people participating in the various events including coastal walks, snorkelling learn to surf lessons and household sustainability advice workshops.

Education is important to the development of good coastal policy. SCCG recognises this and sees the coordination and promotion of education as an essential tool to overcoming the barrier that a lack of community support and understanding presents to improved coastal management.

Conclusion

The work of SCCG demonstrates the benefits of being proactive and forming partnerships to overcome barriers to coastal sustainability. It also provides an effective model that can be applied to other regions nationally. Over 15 years SCCG has found that increasing the capacity of Councils in a regional context requires all Councils to participate in identifying issues, projects and solutions to existing barriers.

The regional coordination of activities that facilitate information exchange, advocate improvements in State Government policy, identify funding opportunities and engage community requires a “champion”. The experience of SCCG is that driving these activities improves capacity of councils and assists to overcome barriers to coastal sustainability. This leads to Councils having a greater confidence to successfully manage the coastal environment.

References

ALGA (2005a) 2004-05 National NRM Survey of Coastal Councils, Australian Local Government Association, 7 February 2005.

ALGA (2005b) 2004-05 Increasing Coastal Councils Capacity to Manage the Natural Resource Base: Discussion Paper, Australian Local Government Association, 22 August 2005.

Gurran, N, Squires, C and Blakely, E (2005) Meeting the Sea Change Challenge: Best Practice Models of Local and Regional Planning for Sea Change Communities, Report No. 2 for the National Sea Change Taskforce, 30 June 2005, Planning Research Centre, University of Sydney.

Middle, G (2004) Institutional arrangements, incentives and governance – Unlocking the barriers to successful coastal policy making, A theme report from the Coast to Coast 2002 Conference, Cooperative Research Centre for Coastal Zone Estuary and Waterways Management.

Natural Resource Management Ministerial Council (2006) National Cooperative Approach to Integrated Coastal Zone Management. Framework and Implementation Plan. Australian Government, Department of Environment and Heritage, Canberra, Act.

Stuart, G, Withycombe, G and McGrath, J (2006) Barriers and Opportunities for local government in coastal management and planning, Coast to Coast 2006.

Sydney Coastal Councils Group (1998) Sydney Regional Coastal Management Strategy, Regional Steering Committee, Sydney.

Sydney Coastal Councils Group (2005) Climate Change Forum Summary www.sydneycoastalcouncils.com.au

Sydney Coastal Councils Group (2006) Groundwater Management Handbook- A Guide for Local Government, SCCG Groundwater Management Working Group, Sydney.

Thom, B and Harvey, N. (2000) Triggers for Late twentieth century reform of Australian coastal management, Australian Geographical Studies 38, pp.275-90.

Thom, B. (2004) Geography, Planning and the Law: a coastal perspective, Australian Geographer 35, pp. 3-16.

Withycombe, G, Smith, T, Brooke, C, Preston B, Goddard, R, Abbs, D and McInnes, K (2006) Managing for Climate Variability in the Sydney Region – Issues, needs and new solutions for Local Government. Coasting Toward a sustainable future, 15TH NSW Coastal Conference.

Coastal lakes in NSW – working towards a sustainable future.

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Abstract

The ecological health of many NSW coastal lakes and waterways is at serious risk as a result of increasing pressure from human activities particularly urban development, land use intensification and changes to natural lake opening regimes. In 2002 the Healthy Rivers Commission of NSW released an Independent Public Inquiry into Coastal Lakes. The subsequent NSW Government Statement of Intent outlined Stage 1 of the *Coastal Lakes Strategy*. Stage 1 requires the preparation of sustainability assessment and management strategies for a group of eight priority lakes.

As part of the NSW Comprehensive Coastal Assessment, the Department of Natural Resources and the Australian National University developed the Coastal Lake Assessment and Management (CLAM) decisions support tool to underpin the sustainability assessment and management strategy process.

The tool allows a range of management scenarios to be modelled and can incorporate a wide range of social, economic and environmental parameters to assist decision makers assess the impacts of various decisions. The tool has potential to be developed further and can be applied to coastal river systems and other environments.

Preparation of the Coastal Lakes Management Strategies is underway, although they have not been completed the methodology has been favourably received and is being adopted widely throughout NSW and will become part of the NSW Estuary Management process. This paper will discuss the methodology for carrying out sustainability assessments and developing management strategies, their broader application and current status of the project.

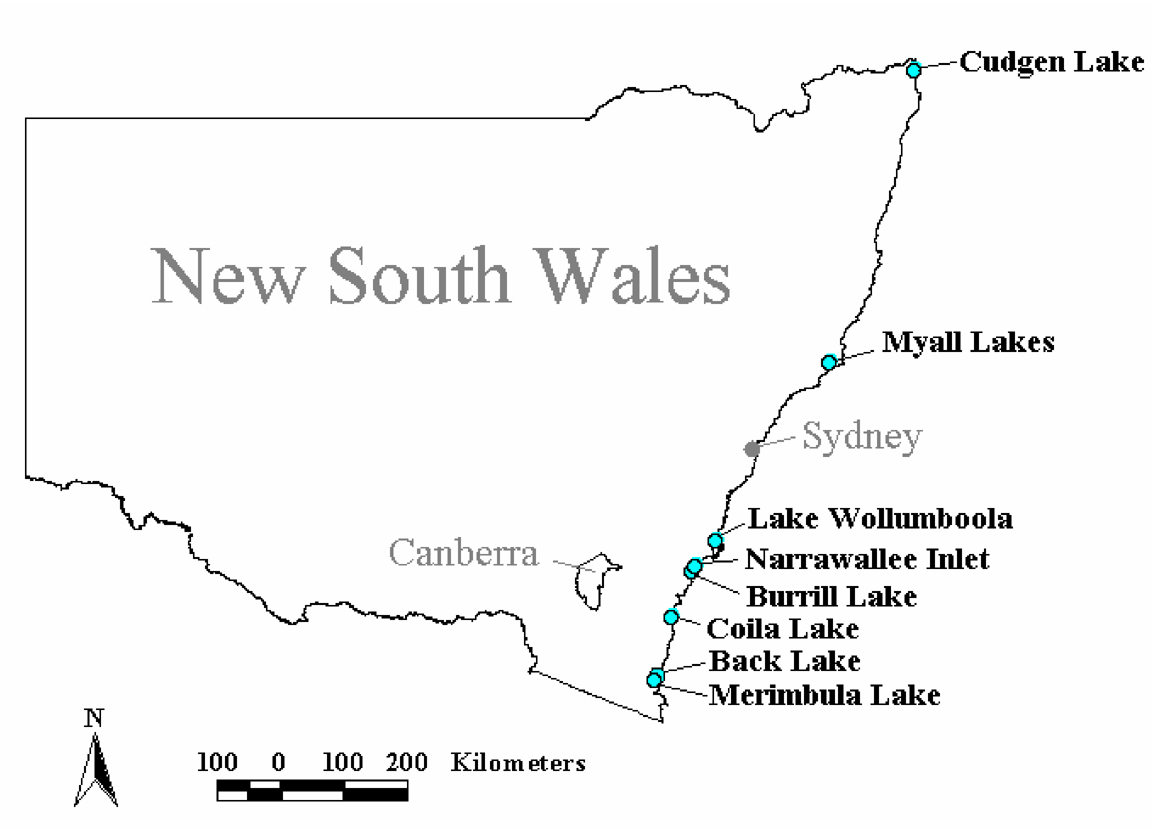
Background

The ecological health of many NSW coastal lakes and waterways is at serious risk as a result of increasing pressure from human activities particularly urban development, land use intensification and changes to natural lake opening regimes. These pressures if not managed appropriately have the potential to reduce the considerable tourism, recreation, amenity, aesthetic and ecosystem values of these areas and have consequent impacts on regional economies.

Over 60% of the State's estuaries are coastal lakes or lagoons many of which have intermittent connections to the sea. In 2002 the Healthy Rivers Commission of NSW (HRC) released an Independent Public Inquiry into Coastal Lakes. The report developed the *Coastal Lakes Strategy* to improve the management of coastal lakes and their catchments. One of the recommendations was the preparation and implementation of sustainability assessment and management strategies.

Following release of the strategy, the NSW Government (2003) released a Statement of Intent for coastal lakes, in which it outlined Government's commitment to a first stage of implementation of the *Coastal Lakes Strategy*. The first stage focuses on a priority group of lakes for the preparation of sustainability assessments and management strategies and lists a range of supporting initiatives. The first stage also requires the identification of recommendations for implementing the Strategy to other coastal lakes upon stage one completion. The priority lakes for the preparation of sustainability assessments and management strategies are Cudgen Lake, Myall Lakes, Lake Wollumboola, Burrill Lake, Narrawallee Inlet, Coila Lake, Merimbula Lake and Back Lake (**Figure 1**).

Figure 1. Location of priority coastal lakes.



Sustainability refers to the long-term maintenance of natural processes and functions within coastal lakes and to the long-term maintenance of economic and social considerations of the community of the lake catchment. This is consistent with the definition of Ecological Sustainable Development adopted by the NSW Government in 1992.

In addition to the outcomes specified for each lake in the *Coastal Lakes Strategy*, each sustainability assessment and management strategy determines and records any other outcomes sought for a given coastal lake, its capability and limitations to sustain existing and likely human activities, the actions to be implemented (including remedial actions), and the most appropriate selection and design of management tools.

Classification of Coastal Lakes by the Healthy Rivers Commission

Classifying coastal lakes was seen by the HRC (2002) as a first step towards the identification of a set of realistic goals for each lake and a management strategy able to achieve them cost effectively.

Each coastal lake was classified by the HRC (2002) according to its natural sensitivity, condition of the water body and catchment, recognised ecosystem and resource conservation values, and other significant socio-economic factors. Four management frameworks were developed, as listed in **Table 1**. Each of the 90 coastal lakes in NSW was assigned to a management framework. Each framework describes the management orientation and provides intended outcomes and indicative actions.

A number of lakes received provisional classifications, as more detailed assessment was required. For those lakes classifications are to be confirmed in light of the outcomes of sustainability assessments and management strategies.

Table 1. Management Framework for priority coastal lakes

Management Orientation	Primary Outcome	Priority Lake
Comprehensive Protection	*All* natural ecosystem processes restored and preserved.	Lake Wollumboola
Significant Protection	*Critical* natural ecosystem processes restored and preserved.	Myall Lakes Back Lake (provisional)
Healthy Modified Condition	Key natural and/or highly valued modified ecosystem processes rehabilitated and retained.	Cudgen Lake Burrill Lake (provisional) Narrawallee Inlet Coila Lake Merimbula Lake
Targeted Repair	Habitat conditions for selected key species established.	

Sustainability Assessments and Management Strategies

The sustainability assessment and management strategies for the priority lakes are being prepared within the context of the relevant management framework. Each assessment and strategy determines and records any other outcomes sought for the priority lake (in addition to those specified in the management framework), its capability and limitations to sustain existing and likely human activities, the actions to be implemented (including remedial actions) and the most appropriate selection and design of management tools.

Each assessment and plan seeks to identify the public authorities or private entities that are responsible for each specified action and the timing and allocation of resources relevant to its implementation.

The key factors to be addressed in each sustainability assessment and management strategy are:

- key ecosystem processes and thresholds (eg lake type and maturity, entrance behaviour, nutrient loads, lake hydraulics, flooding, sea level change);
- catchment processes and characteristics (eg soils, vegetation, river flows);
- environmental and ecosystem values (eg water quality and river flow objectives, threatened species, representativeness, wetlands, aquatic and terrestrial weeds);

- Aboriginal values (eg access, food, spiritual, Native Title claims);
- sustainable (commercial) resource use and values (eg fish, oysters, tourism, forestry, boating, farming, water extraction, mining, aquaculture);
- citizen values (eg heritage, recreation, amenity, odours, fire hazard);
- public health implications of lake conditions (eg swimming, oyster cultivation and consumption, drinking water); and
- existing and possible public and private institutional, jurisdictional and management mechanisms, which could be used to implement actions.

An Interdepartmental Steering Committee was established to oversee the sustainability assessment and management strategy preparation. The ISC was made up of staff from the Department of Natural Resources (DNR), Department of Primary Industries (Fisheries), Department of Environment and Conservation (DEC) (including both the Environmental Protection Authority and the National Parks and Wildlife Service) and Department of Planning.

One of the Steering Committee's initial tasks was to oversee the development of a modelling or decision support tool for sustainability assessments and to determine the nature of management strategies that will be underpinned by sustainability assessments.

Coastal Lakes Assessment and Management (CLAM) tools

The Statement of Intent on Coastal Lakes directed that funding of the preparation of sustainability assessments be from funds available from the NSW Comprehensive Coastal Assessment (CCA). The CCA process was initiated by the NSW Government to provide comprehensive data bases and decision support tools to improve strategic planning, land use, natural resource protection and socio-economic development in the coastal zone.

After assessing a number of approaches the Steering Committee endorsed engagement of the Integrated Catchment Assessment and Management Centre, of the Australian National University to develop the Coastal Lake Assessment and Management (CLAM) tool. The tool is designed to show the potential impacts given certain management decisions. The CLAM utilizes Bayesian Decision Network techniques to integrate social, economic and ecological values for a community and the results are incorporated into an easy to use software interface, **Table 2** provides a summary of the features of the CLAM software and **Figure 2** shows example screenshots from the CLAM tool.

Bayesian Decision Networks consist of a series of decision variables (scenario choices), interim variables (state indicators) and utility variables (outputs or goals). These are connected by causal links; see **Figure 3**. The data behind each variable is represented as a conditional probability, given the distribution of the input link(s). The probability distributions are used to represent the certainty of the results (Ticehurst *et al.*, 2005).

The methodology for preparation of each of the CLAM tools is outlined in greater detail in Department of Natural Resources (2006). The steps followed are summarised in **Table 3**.

It is essential to note that the Bayesian Decision Network is unique to each waterway, it's catchment and issues, as such relevant networks must be developed for each of the lakes considered.

Table 2. Summary of features available in the CLAM software (Ticehurst *et al.*, 2005).

Software Page	Features available
Welcome	Project background, contacts and licensing agreements.
Information	Photograph gallery of the catchment, brief list of facts about the catchment and information on the current status of the lake and its catchment.
Maps	Series of catchment properties which can be overlaid, including land uses and zonings, protected areas and potential acid sulphate soils.
Approach	Brief description of Bayesian Decision Network approach and the framework for the catchment.
Inputs	Description of how the probability distributions were attained for each variable, including the assumptions and weaknesses for each.
Scenarios	Each scenario choice option, plus a map locating various scenarios and a description of the assumptions underlying each scenario.
Outputs	Resultant probability distribution of each state variable.
Utilities	Change in the dollar value for the economic variables within the model.
Report	A summary of the inputs, scenario choices and the output probability distributions, which can be exported and saved.

Figure 2. Example screenshots from the Merimbula Lake CLAM.

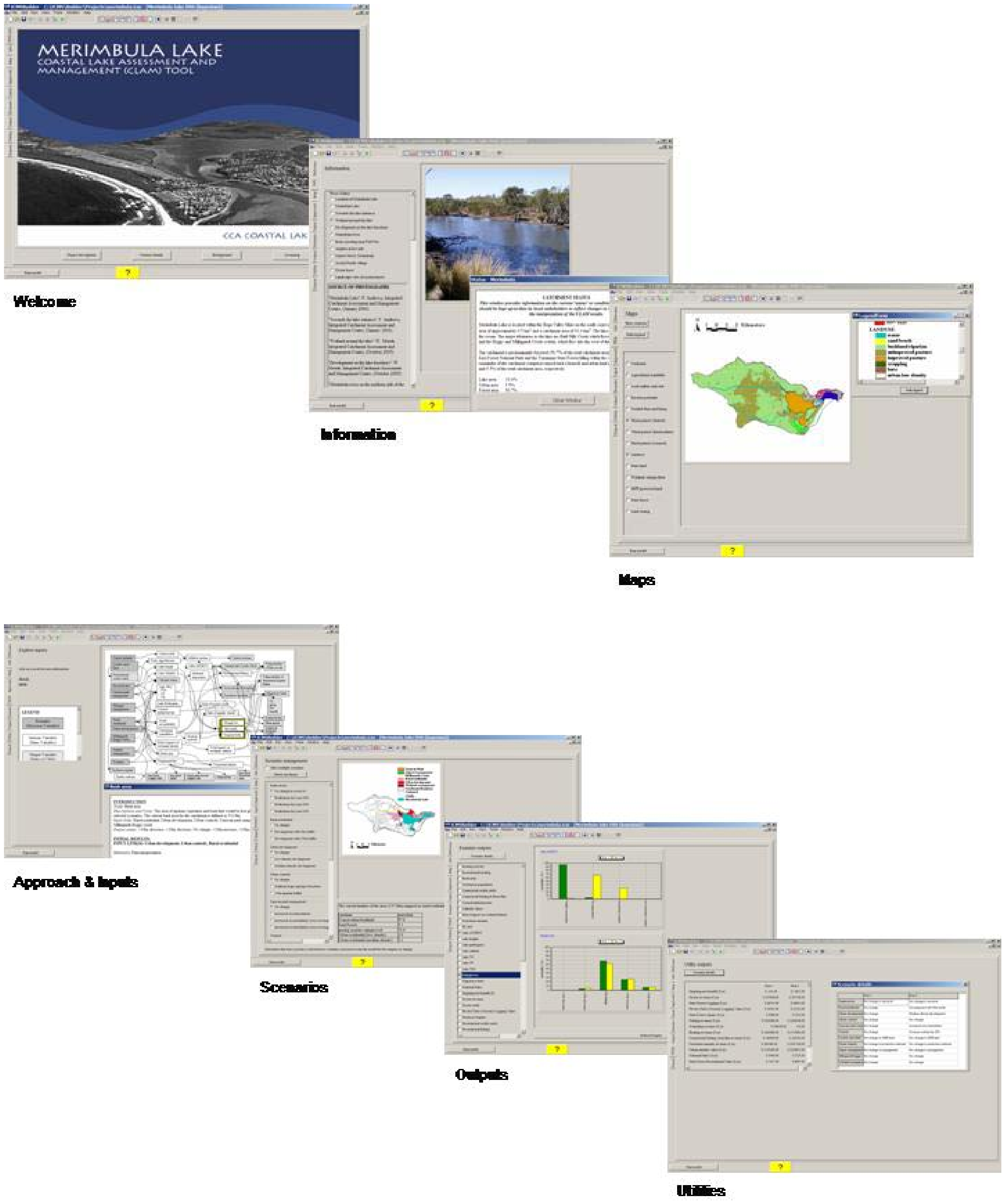
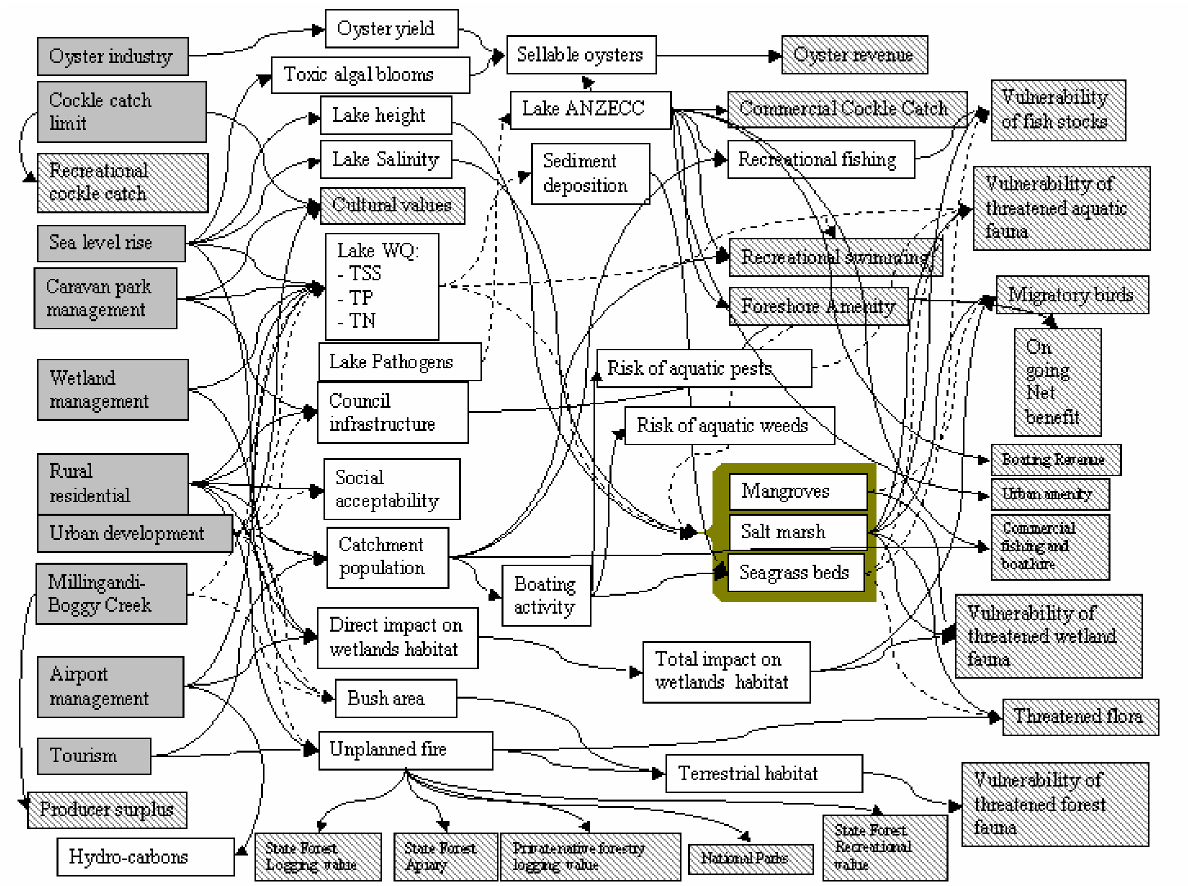


Table 3. Methodology for development of the CLAM software (from DNR, 2006).

Step	Features available
Identify constraints and issues/values	Information collation to identify constraints, issues and values.
Develop BDN framework	An initial conceptual BDN framework using potential management scenarios were developed for each coastal lake and its catchment.
Targeted consultation	Presentation of the initial BDN framework for confirmation or modification. Consultation with Local government, State agencies (including DEC, DPI, DoP and NSW Maritime Authority), CMAs, Aboriginal representatives (where this could be arranged), relevant Estuary Management Committees and stakeholder forums (and further discussion with identified individuals). All initial BDN frameworks were modified, including modification and addition of scenarios and linkages between state and output variables.
Populating BDN links with data	Based on initial collation of data the BDN links were populated with data where available. Additional critical information required was identified and was obtained through either data collection programs (including the Comprehensive Coastal Assessment), expert advice or modelling exercises
Making the BDN user-friendly	The revised BDN model framework and the probability distributions were coded into the ICMS software to create a user-friendly software platform.
Reality checking	Each CLAM tools was reviewed by a number of reviewers from Local government or State agencies.
Distribution and training	A CLAM training manual has been developed as is distributed with the CLAM tools. Training workshops were held in areas in proximity to the priority coastal lakes. The CLAM tools are distributed as part of the Comprehensive Coastal Assessment.

Figure 3. Example of Bayesian Decision Network for Merimbula Lake.



Shading: Solid = scenario (decision variable); unshaded = interim variable (state variable); diagonally hashed = output variable (state or utility variable).
Abbreviations: ANZECC = Australian and New Zealand Environmental Conservation Council guidelines (2000), STP = sewage treatment plant, TN = Total nitrogen, TP = Total phosphorus, TSS = total suspended sediment, WQ = water quality.

Management Strategies

Management strategies are currently being prepared for seven of the eight priority coastal lakes. The management strategy for the eighth lake (Lake Wollumboola) will be prepared when processes associated with the draft South Coast Regional Strategy have been completed. The management strategies are being prepared by a number of consultants contracted to DNR: GeoLink (Cudgen Lake), HLA-Envirosciences (Myall Lakes) and WBM Pty Ltd (Narrawallee Inlet, Burrill Lake, Coila Lake, Merimbula Lake and Back Lake).

The short and long-term management options developed during the sustainability assessments phase are being assessed on environmental, social and economic grounds to provide guidance to the sustainable future of the lakes.

In order to prepare a management strategy for each lake consistent with the aims and objectives of the *Coastal Lakes Strategy*, the following steps are being used to develop management actions for the sustainable planning, management and decision making for each lake:

- consideration of output from the sustainability assessment phase;

- further consultation with major stakeholders in relation to use of the CLAM tools, the sustainability assessment and the development of management actions;
- review and assessment of existing management plans for the catchment and for the waterway with the view to integrating them within the strategy (particularly those plans exhibited or adopted subsequent to development of the CLAM tool such as Catchment Action Plans and draft Regional Strategies);
- development of management actions (with each assigned a level of priority, a suggested time frame, roles and responsibilities of relevant management agencies and indicative costs of implementation) and associated implementation strategy and monitoring and evaluation plan.

Draft management strategies will be completed during November 2006, public exhibition of the documents is scheduled for early 2007.

Where to next?

Following completion of the first stage of the *Coastal Lakes Strategy*, a report to Government is required on the outcomes of the first stage and options for applying the *Coastal Lakes Strategy* to other coastal lakes across NSW. A detailed cost benefit analysis of each option is also required.

Recommendations as to the implementation of the management strategies and options for funding of the implementation will also be made. In relation to funding, the Statement of Intent indicates that the declaration of specific areas of Crown land identified through sustainability assessment and management strategies as having outstanding conservation value as reserves under the National Parks and Wildlife Act 1974, the Crown Lands Act 1989, the Marine Parks Act 1997, or the Fisheries Management Act 1994, are to be dealt with through the State Budget process on a case by case basis.

The methodology used in the preparation of sustainability assessments and management strategies is currently being applied to other coastal lakes beyond the eight priority lakes, these include sixteen coastal lakes management strategies currently being prepared in consultation with local government through funding from the Northern Rivers Catchment Management Authority. Additionally CLAM tools have also been prepared for Wallis and Smiths Lake.

As with all tools and models, best results can be obtained where relevant estuary data is available and the natural processes are well understood. The need for technical expertise in the development of the tool, understanding of natural processes and their relationship to catchment pressures is essential to achieve realistic results. All the trial lakes that have been evaluated have estuary data compilation and process studies available under the Estuary Management Program, and hence data and process information was already available for the preparation of sustainability assessments for these lakes. Application of the model to other lakes with only limited data would rely heavily on expert assessment of Bayesian Decision Network relationships and would require collection of additional data to confirm or quantify relationships.

It is important to note that the application of the sustainability assessment tool identifies key estuary data gaps and processes which may help to better identify important performance indicators and monitoring programs required to measure the effectiveness of adopted management strategies. Research may also be better focussed through using the tool to identify key gaps in understanding of natural resource relationships linked to catchment pressures.

Each estuary has its own unique characteristics and social, economic and environmental interactions. Consequently, a tool for each estuary must be developed considering its unique nature. A tool with its underlying network of relationships for one estuary cannot be directly transferred to others.

There is also the opportunity to apply the concept of sustainability assessments more broadly to other water bodies, such as large river estuaries. As such, upon completion of stage one of the Coastal Lakes Strategy, one of the likely recommendations will be the incorporation of sustainability assessments into the coastal zone management process (which includes the current estuary management process). Thus, ongoing technical and financial support would be provided through the NSW Estuary Management Program.

DNR is also working with other States on possible national applications of this approach through the National estuaries Network, which is a consortia of State and Commonwealth agencies focussed on improving the health and condition of Australian estuaries.

References

Department of Natural Resources (2006) Final Report CCA-24 Preparation of Sustainability Assessments for Coastal Lakes, *Comprehensive Coastal Assessment DVD, Volume 1*. Report prepared by Department of Natural Resources for Department of Planning, Sydney.

Healthy Rivers Commission of New South Wales (2002), *Independent Inquiry into Coastal Lakes (Final Report)*. Healthy Rivers Commission of New South Wales, Sydney.

New South Wales Government (2003), *Statement of Intent Coastal Lakes (Incorporating decisions of the New South Wales Government on the report on the Healthy Rivers Commission on Coastal Lakes)*. Healthy Rivers Commission of New South Wales, Sydney.

Ticehurst, J.L., D. Rissik, L.T.H. Newham, R.A. Letcher, S. Powell, W. Merritt and A.J. Jakeman (2005) Development of a decision support tool for the integrated management of NSW coastal lake catchments. *Proceedings of the NSW Coastal Conference, Narooma, 9th – 11th November 2005.* Eurobodalla Council, Moruya.

BUILDING A FOUNDATION FOR WATER QUALITY IMPROVEMENT BY ENGAGING PEOPLE IN PLANNING – THE GREAT LAKES COASTAL CATCHMENTS INITIATIVE.

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Introduction

Encouraging ownership and commitment to water quality improvement through the Coastal Catchments Initiative (CCI) is building a foundation for improving water quality and the contributing to the sustainability of Wallis, Smiths and Myall Lakes.

The Coastal Catchments Initiative is a partnership project between State, National, Local Governments and the local community. It aims to improve water quality in Wallis, Smiths and Myall Lakes by reducing pollutants at the source and developing water quality improvement plans. These plans will be established over two years and will outline the actions required to achieve water quality improvements to the level identified by the local community. The plans will also outline the education, incentive and legal measures required to achieve the desired water quality objectives and establish a legislative framework for implementation.

Having a sound basis for developing water quality improvement plans through science and planning frameworks is critical however, the sustainable management of water quality largely relies on individuals taking responsibility for activities that impact on water quality in the Catchment.

The challenge is to find ways to work with the community so that there is a commitment to improving water quality at the outset. The CCI is based on the principals of power sharing and recognising the need to move into collaborative space and establish a level of trust and transparency in the development of water quality improvement plans. To do this the CCI is embarking on an engagement strategy that will encourage ownership and lead to the sustainable management of Wallis, Smiths and Myall Lakes.

Background to developing the Water Quality Improvement Plans (WQIP)

The Coastal Catchments Initiative (CCI) is part of a national program that aims to improve water quality in coastal areas. The Great Lakes was selected as the ‘hotspot’ for this area of New South Wales. As such, Great Lakes Council has received funding from the Australian Department of Environment and Heritage for the Great Lakes CCI program.

Located on the lower mid north coast of NSW approximately 300km north of Sydney, the Great Lakes Coastal Catchments Initiative includes the Wallis Smiths and Myall Lakes and their associated catchments (Figure 1).

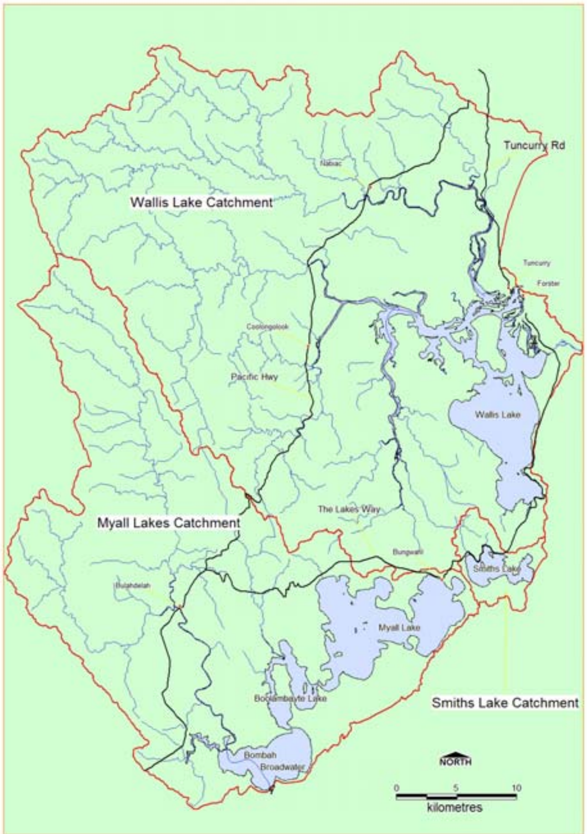


Figure 1: Catchment area included in the Great Lakes Coastal Catchments Initiative

The Coastal Catchments Initiative builds on what we already know about the Great Lakes and combines on-ground actions for water quality improvement with the collection of new information. The new information we collect will help identify the most cost-effective water quality improvement projects that will manage the sources of pollution and get the best water quality results.

The main aim of the Great Lakes CCI program is to produce Water Quality Improvement Plans (WQIPs) for Wallis, Myall and Smiths Lakes. The Water Quality Improvement Plans will provide a sound basis for managing water quality in the lakes. The plans will provide a guide for investment by all parties — including the Australian Government, State and Local Governments, and community and environment groups. They will outline what Local Councils, State agencies, land managers, owners and residents will need to do to achieve water quality objectives identified by our local community.

There are a number of stages involved in developing the Water Quality Improvement Plans, these stages are described below and are shown graphically in Figure 2, although the stages are ordered numerically, they will often progress simultaneously.

Stage 1. Understanding how people use and value the waterways- setting water quality objectives

Reviewing existing environmental values and establishing draft objectives

In the initial stages of the project stakeholders throughout the catchment will be involved in providing information on the way they use and value the lakes and waterways of the area. This will help establish whether the existing environmental values set with the community by the Environmental Protection Authority in 1997 are still relevant. Understanding how the community value their waterways and how they want to use them now and into the future will help to define the water quality levels required to support their use and values. This will be the first step toward defining the water quality objectives for the plans.

Stage 2. Coming up with draft management options

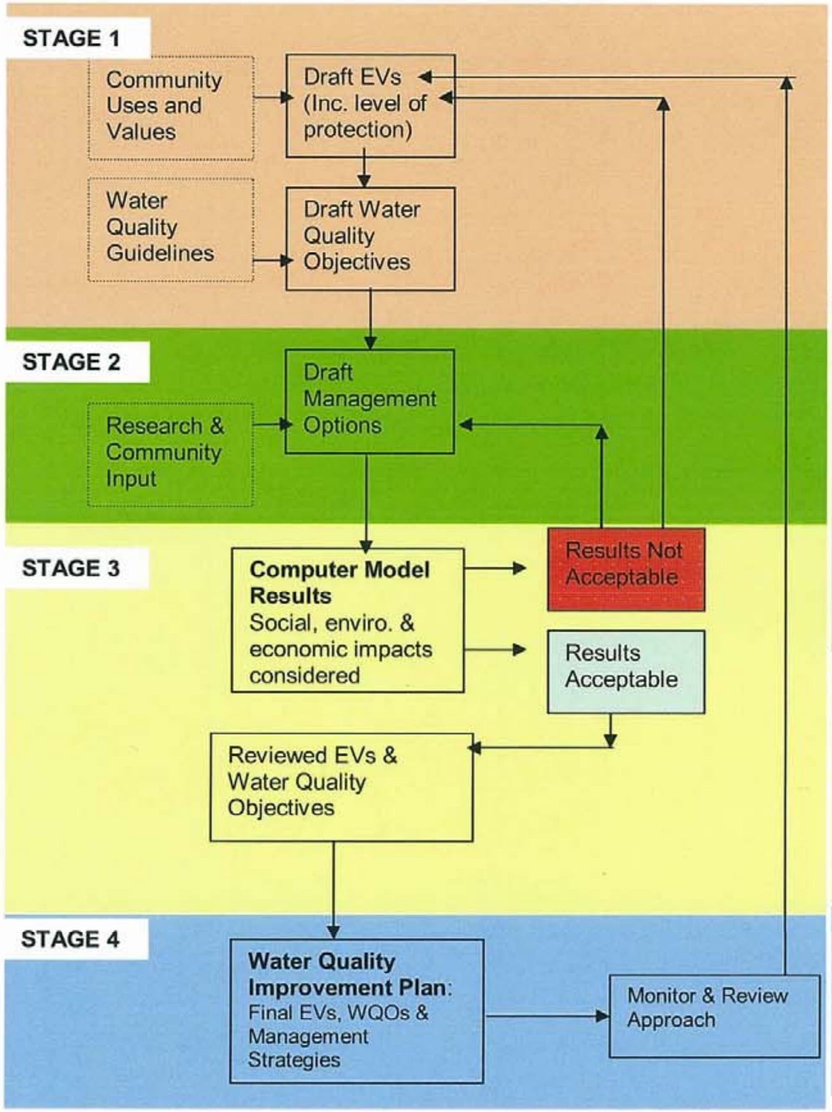
Catchment and Estuary Research

Through this project, catchment and estuary water quality models are being developed by the Department of Environment and Conservation (DEC). These models will identify the sources of nutrients and sediments in the catchments and quantify their relative contribution to nutrient and sediment loads to the receiving waters. These models will help us determine how management practices in the catchment will affect water quality in the Great Lakes.

Research is also being undertaken by DEC to assess the effectiveness of current catchment management practices for improving water quality. In rural areas, this will involve determining the relative effectiveness of management practices like riparian fencing and off stream watering for improving environmental health and water quality.

In urban areas the effectiveness of constructed wetlands for trapping organic matter, reducing sediments and decreasing nutrient concentrations in urban runoff will be assessed. This research will be focusing on the uptake of nitrogen by microscopic plants and animals on the sediment surface.

Figure 2. Key Stages for Developing Water Quality Improvement Plans for the Great Lakes Coastal Catchments Initiative



Stage	Key Activities	Methods
1. Understanding how people use and value their waterways – setting water quality objectives	• Review existing environmental values with committee and community • Establish draft water quality objectives	ES
2. Coming up with draft management options	• Gathering information to understand the flow of nutrients and sediments in the catchments and estuaries • Assessing the effectiveness of current management practices in rural and urban areas • Working with stakeholders to come up with management options based on local knowledge and current research • Establishing a legislative and incentive framework for implementing management options in urban, rural and rural residential areas • Supporting catchment management projects for water quality improvement	ES Modelling Framework for WSDD MP
3. Testing draft management options against objectives	• Refine draft water quality objectives through modelling • Use the Decision Support System tool to consider a range of draft management options to see if they meet the water quality objectives • Incorporate stakeholder feedback on proposed management options	DSS Modelling ES
4. Water quality improvement plan	• Document management options that will achieve water quality objectives • Document the legislative and incentive framework for implementing management options • Develop a monitoring strategy to assess the Water Quality Improvement Plans • Report to stakeholders	ES

EV=Environmental Values, WQO=water quality objective, ES=Engagement Strategy, Modelling= Catchment / Estuarine modelling,
DSS= Decision Support System, MP= Rural and urban management practice options review / research, WSDD=Water Sensitive Development and Design

Establishing a legislative and incentive framework for implementing management options

For urban and rural residential areas the project will develop a framework for water sensitive design and development. This framework will facilitate the implementation of water quality objectives in Council's forward planning documents such as the Local Environmental Plans and Development Control Plans, and recommend methods for increasing uptake of water sensitive design and development. The framework will include:

- The identification and assessment of barriers to the uptake of water sensitive design and development
- A strategy for overcoming barriers to water sensitive development and design
- An incentive scheme for water quality protection in the catchment e.g. nitrogen offset or trading scheme to achieve specific water quality objectives such as no net increase in pollutants.
- A development offset scheme that is used to help achieve water quality objectives
- Legislative and planning scheme amendments for water sensitive development and design.

Stage 3. Testing draft management options against objectives

Using a Decision Support System tool to consider a range of draft management options

The CCI project will develop a computer based Decision Support System (DSS). This system will provide a user friendly interface for catchment managers and Council staff that will help predict the effect of different management scenarios on water quality. The DSS will present the results of the computer based Catchment and Estuarine models developed by DEC. The DSS will also take into account social and economic impacts of different management approaches. The Decision Support System will establish a transparent process for decision making allowing Councils and government agencies to carefully consider water quality issues during land use and catchment management planning.

Stage 4. Water Quality Improvement Plans

The Water Quality Improvement Plans (WQIPs) will be the key output of the Great Lakes Coastal Catchments Initiative. The WQIPs will outline what actions need to be taken over the next seven years to achieve the water quality objectives identified with the community. The plans will outline how the actions will be achieved as well as providing a monitoring strategy to assess improvements in water quality and the implementation of the plans

A framework for the implementation of water quality improvement actions will also be established linking water quality improvement to statutory planning and other decision-making processes such as Local Environment Plans and Development Control Plans.

Principals of the Great Lakes Coastal Catchments Initiative Engagement Strategy

The basic concept behind the Great Lakes CCI is that everyone in the Wallis, Smiths and Myall lake catchments have an influence on water quality and thus have a role in the care and management of the lakes. Just as this statement recognises the role that individuals play in the improvement of water quality, the engagement strategy for the Great Lakes CCI recognises that if people are to take responsibility they need to have the opportunity to be involved in the development of the WQIPs.

The engagement strategy focuses on inclusion rather than exclusion, firstly to gain support for the water quality improvement plans being developed and more importantly, to develop a solid foundation for implementing the water quality improvement plans that will improve water quality of the Great Lakes into the future. The engagement strategy focuses on two key areas:

- capacity building and joint learning with key individuals within organisations and key sectors of the community to support and drive change
- awareness raising within the general community to find out how people would like to be involved in the project

Implementing the engagement strategy

Capacity building and joint learning with key individuals from within organisations and key sectors of the community to support and drive change

Identifying opportunities for capacity building and joint learning is the focus of this projects engagement strategy. Building the capacity of individuals who will need to make changes to the way they or their organisation operates in order to implement the WQIP will be critical to ensuring water quality objectives in the plan are achieved. By focussing on involving people in this way, we are drawing the link between the models, research, decision support tools and implementation frameworks being developed through this project and people. Since people are required to implement the plans, approaching the project in this way will result in a higher chance of implementation than if these outputs were developed in isolation.

Capacity building and joint learning opportunities have been identified at two scales:
- The CCI project scale and
- Operational scale (projects within the CCI).

Capacity Building at the Project Scale
In the initial stages of the project, key organisations and groups with an interest in catchment management were invited to be part of the Great Lakes CCI project in an advisory capacity. The role of the CCI Advisory Committee is largely to guide the development of the WQIP, ensuring the relevance of the project outputs.

Given the broad scope of the project, the range of skills and expertise on the Advisory Committee is also broad and includes representatives from the rural community, the catchment management authority, professional fishing groups, oyster growers, Hunter Councils representatives, community catchment and estuary management groups, researchers and other key agencies. To build the knowledge and capacity of individuals on the committee and to effectively guide the development of the WQIPs meetings have involved:
- Presentations on the latest results from the research and model development to build understanding of catchment and estuarine processes
- A workshop to review existing environmental values for the waterways in this study
- A workshop to scope the role of the Decision Support System including how it will be used and the types of management scenarios we would like to test.

In the process of working closely with the advisory committee to develop the WQIPs, existing partnerships are being strengthened and new ones are developing. Continuing to build the knowledge and capacity of the committee will hopefully also help to build political support for the project and the implementation of the WQIP.

Capacity Building at the Operational Scale

Opportunities to build capacity at the operational level are currently being identified within the Great Lakes CCI. One focus for capacity building is in developing the framework for water sensitive development and design. There are plans to involve council operations staff including planners, strategic planners, environmental staff, stormwater and subdivision engineers at each stage of framework development, giving individuals the opportunity to contribute to and be part of the decision making for the framework they will be implementing once the WQIPs are completed. Staff will have the opportunity to be involved in and guide the project in the following areas:

- localising the options for water sensitive development and design as well as identifying the local barriers to uptake
- Developing and agreeing a strategy to overcome the barriers to water sensitive development and design
- Work with experts in the field of offset schemes to come up with a scheme suitable to the Great Lakes catchments
- Identifying where the council planning scheme can be used to implement the options identified for water sensitive development and design.

It is also envisaged that the end users (developers and builders) will also have the opportunity to be involved at key stages to provide a 'reality check' on the implementation of the development bonus and nutrient offset schemes that will be developed through this project.

Awareness raising within the general community and finding out how people would like to be involved in the project

Expanding the engagement strategy beyond the advisory committee and the operational scale, there is a focus on inclusion rather than exclusion. This stage involved the comprehensive identification of stakeholders. Each time the project was introduced to groups and individuals in the project area the list of stakeholders was reviewed and added to, and will continue to be developed throughout the project ensuring that all interested people have had an opportunity to contribute to the development of the WQIPs.

The stakeholder list was then used to invite groups to find out more about the project and to be involved in the first stage in developing the WQIPs 'understanding how people use and value their waterways' (Figure 2). The information collated at these sessions will be used to ensure that the current and future uses and values of the waterways identified by the community will be protected by the water quality objectives set out in the plans. There will be three key outcomes of these meetings:

- awareness raising about the Great Lakes CCI
- facilitating involvement in the project (stage 1)
- finding out if and how they would like to be involved in developing the WQIPs.

While some opportunities for involving stakeholders in the project have been identified (Figure 2), workshop sessions with stakeholders may identify further opportunities for involvement in the project and this will help to better define the projects engagement strategy including identifying the specific groups and individuals who want to be involved at various stages of the project.

Another aim of the workshop sessions is to take stakeholders through the project process and involve them in decision making to make future project implementation more sustainable.

Challenges for the Great Lakes CCI

Some of the inherent challenges in working with a wide cross section of people to develop the WQIPs have and will be:

- Differentiating the CCI and the development of WQIPs from other plans such as Estuary Management Plans and Catchment Management Plans to ensure support for the project
- Identifying key areas where individuals and groups can be involved in developing the WQIP and finding ways to demonstrate that their input will be used.
- Establishing an open and transparent process for reviewing the input of groups to the WQIPs
- Involving everyone interested in being involved in the CCI while still meeting project deadlines
- Maintaining interest in the community for the project over a two year time frame when project outputs are in the developmental phase.

The Great Lakes CCI recognises it is essential to have a sound basis for developing water quality improvement plans through science and planning frameworks however, people are the key to implementation. Despite the inherent challenges of working with a wide range of stakeholders, to ensure the sustainable management of Wallis, Smiths and Myall Lakes, we need to continue to involve individuals, organisations and groups interested in being involved in developing the WQIPs.

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CZM APPLICATIONS OF ARGUS COASTAL IMAGING IN EASTERN AUSTRALIA

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Abstract
The last five years has seen the rapid advancement of new image analysis methods specifically targeted to support and enhance coastal management practice. In parallel to these developments, greater attention has been given to the use of the internet to build more manager-oriented information delivery systems. This paper draws upon experience from eastern Australia using a network of Argus coastal imaging sites, to illustrate and discuss the suite of image derived CZM 'products' that is now available to the coastal manager. Both qualitative and quantitative information is routinely delivered via the internet, ranging from hourly images of the monitoring site to weekly summaries of shoreline variability and longer-term beach width trends. All monitoring program results and data summaries are accessed via a world-wide-web interface, providing 'real-time' delivery direct to the managers' desktop computer.

Introduction

Coastal researchers are increasingly turning to remote sensing methods to observe and quantify beach and nearshore change, across spatial-scales ranging from centimetres to kilometres and time-scales ranging from seconds to years. In particular, since the early 1990's nearshore research originating from Oregon State University's Coastal Imaging Laboratory has focused on the development of the low-cost Argus coastal imaging system (Holman et al., 1993; Aarninkhof and Holman, 1999). Supported by a growing number of international user groups, increasingly sophisticated image-based analysis techniques are being developed to observe and quantify a broad range of nearshore hydrodynamic and morphological processes.

The deployment of a network of automated, video-based monitoring stations was originally conceived of primarily as a research tool. More recently, the application of coastal imaging technology to a growing range of coastal zone management (CZM) applications has been recognised (Turner et al., 2004; Wijnberg et al., 2005; Turner et al., 2006). The temporal and spatial coverage provided by video-based coastal imaging systems are proving to be of particular value to coastal management applications along engineered coastlines.

The last five years has seen the rapid development of new image analysis tools specifically targeted to support and enhance coastal management practice. In parallel to these developments, greater attention has been given to the use of this technology to build more manager-oriented information delivery systems. Rather than the traditional reliance upon paper-based reporting (that is limited by definition to the description of retrospective coastal behaviour), the objective of this research has been to provide coastal managers with a range of tools and regularly-updated information that summarise and quantify the present coastal conditions, within the context of past observations.

In Australia, a nation whose population and industry are very much clustered around the coastline, the rapid growth of CZM projects supported by coastal imaging-based monitoring systems is in large part due to the relatively early acceptance by state and local governments of these new capabilities (Turner et al., 2006). To date, coastal imaging is being utlised at four Australian sites by local government authorities in Queensland and New South Wales, and at a further four sites through joint cooperation between the Queensland and New South Wales State governments (Figure 1). These eight sites compliment around 40 other Argus sites presently operating in Europe and the USA. This paper provides a description of the various components that together comprise the web-based and real-time beach management system currently deployed in Australia. This is followed by illustration and discussion of the core information and analyses that together comprise the suite of image-derived CZM 'products' that is now available to the coastal manager.

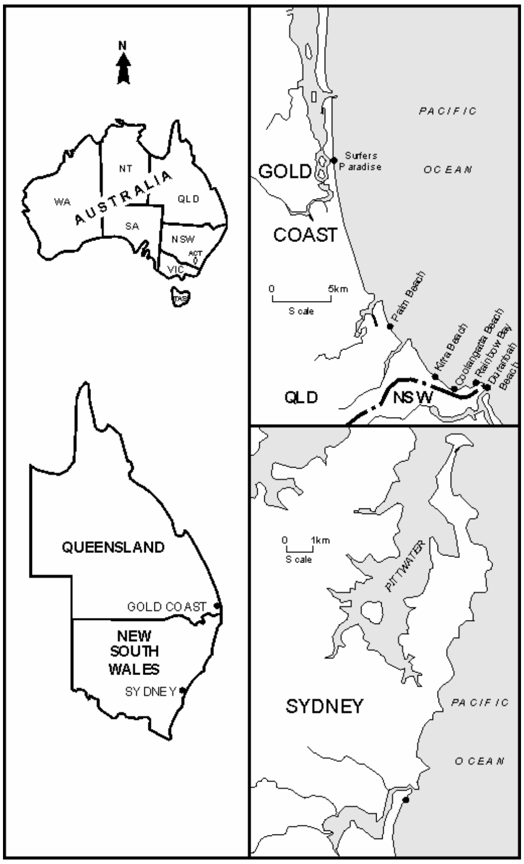

Figure 1: There are currently eight coastal imaging stations located along the south-east coast of Australia where 'real-time' beach monitoring and management functions are being routinely performed. CZM applications include the monitoring of beach protection works (Surfers Paradise and Palm Beach), operational management of a river entrance sand bypassing system (Duranbah, Rainbow, Coolangatta and Kirra Beaches), estuary entrance management (Narrabeen Lagoon) and monitoring of a coastal erosion 'hot spot' (Narrabeen Beach). (adapted from Turner et al., 2006).

Operation of Beach Management System

The beach management system described herein consists of a data acquisition system, a data archiving and assimilation system, an image pre-processing and shoreline detection system, a data development and summation system, and a web interface. Together, these systems collect, analyse and summarise a variety of core 'coastal state indicators' (Van Koningsveld et al., 2005). To the end-user coastal manager, the data acquisition, archiving, assimilation, image pre-processing, shoreline detection and data development tasks are transparent. A world-wide-web browser interface provides access to all monitoring program information and analyses in 'real-time' from any web-enabled PC. The degree of public access to this information is determined on a project-by-project basis at the discretion of coastal managers, with a secure login provided to the full suite of results, where required.

Data Acquisition, Archiving and Assimilation Systems

The acquisition of image data utilises the Argus coastal imaging system. From the coastal managers' perspective, 'coastal imaging' simply refers to the automated collection, analysis and storage of pictures, that are subsequently processed and analysed to observe and quantify coastline variability and change. At the core of this approach is the ability to extract quantitative data from a time-series of high quality digital images. In contrast, conventional 'surfcams' are more limited to applications where a series of pictures of the coastline is sufficient, and no quantitative information is required.

A schematic of a typical Argus station is shown in Figure 2. The key component is one or more cameras pointed obliquely along the coastline. The camera(s) are connected to a small image processing computer, which controls the automated capture of images, the initial pre-processing of images, and the transfer of images via the internet from the remote site to the laboratory.

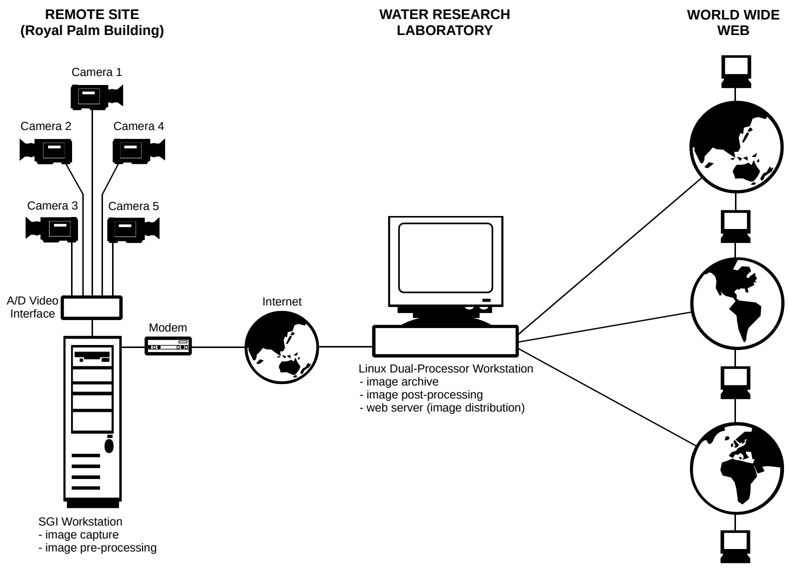

Figure 2: Schematic of a typical five-camera ARGUS (version II) coastal imaging system of the type presently in use at all the Australian sites described herein.

The three basic image types of hourly snap-shot (snap), time-exposure (timex) and variance pictures underpin the great majority of present CZM applications. Snap images provide simple documentation of the general characteristics of the management site, but are not so useful for obtaining quantitative information. Timex images, 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, are much more useful. Time exposures of the shorebreak and nearshore wave field provide a quantitative 'map' of the underlying beach morphology, by 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 (Lippman and Holman, 1990; Van Enckevort et al., 2004). The variance image displays the corresponding variance of light intensity during the same 10 minute time period, and can be useful to define a 'waterline' feature where the ambient sand colour closely matches the colour of wave foam at the shore.

At the laboratory, all images are automatically assimilated into a readily accessed and searchable database, along with concurrent wave and tide data obtained from third-party sources. This host workstation also serves as a world-wide-web server. Images are available to view and download via the web within minutes of their capture.

Image Pre-Processing and Shoreline Detection Systems

Once the hourly oblique images (snap, timex and variance) are archived in the database, merge-rectification software combines multiple camera views from a single site, to produce and archive panoramic and plan-view images of the beach (Figure 3). Fundamental to the use of image data to CZM applications is the ability to interconvert between image coordinates (*i.e.*, individual pixels) and real-world ground coordinates. For any particular object located by its three-dimensional (3-D) ground coordinates, the associated two-dimensional (2-D) image location can be found uniquely using one of several transformation algorithms. The opposite process, the determination of the 3-D ground location of a 2-D image feature, is undetermined in a mathematical sense, and further information is needed. A common photogrammetric solution is to use stereo techniques, requiring multiple cameras focussed on the same point of interest from two or more different locations.

Conveniently, one camera station only is required per site for the special case of coastal imaging. At the open coast waves can be assumed to propagate across a horizontal plane, the elevation determined by a local tide gauge. The geometry of open coast images is therefore naturally constrained. Following the careful calibration of the individual camera/lens systems prior to installation and the one-off surveying of a limited number of ground control points within the image field of view, a unique set of mathematical equations (Holland et al, 1997) are used along with the concurrent tide measurements to convert between image coordinates and real-world position within the coastal study area.

All the above pre-processing of images is fully automated. On a weekly basis, an operator maps the position of the waterline using sophisticated image analysis techniques (manually, or in an automated batch mode) and stores this information in a database. The range of methods that have been developed to identify and map the shoreline from time-series maps, aerial photography and digital images were recently reviewed in Boak and Turner (2005). There are several specific techniques available to map the changing configuration of the foreshore using Argus images, and to convert this to a weekly shoreline position (Plant et al., in press). In Australia, the Pixel Intensity Clustering or 'PIC" method (Aarninkhof et al., 2003) has been adopted at all monitoring sites, due to its ability to objectively identify waterline features under a wide range of conditions. Briefly, the technique delineates a waterline 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 are converted to Hue-Saturation-Value (HSV) colour space, to separate colour (Hue, Saturation) and gray 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, which in turn defines a discriminator to enable the mapping of the 10-minue time-averaged waterline. The computer interface that is used within the laboratory to map successive waterline features is shown in Figure 3. Concurrent tide and wave information (used to calculate setup and runup) is integrated with this waterline analysis, to model the corresponding elevation of the mapped waterline. In this manner, a growing archive of three-dimensional shoreline features is obtained.

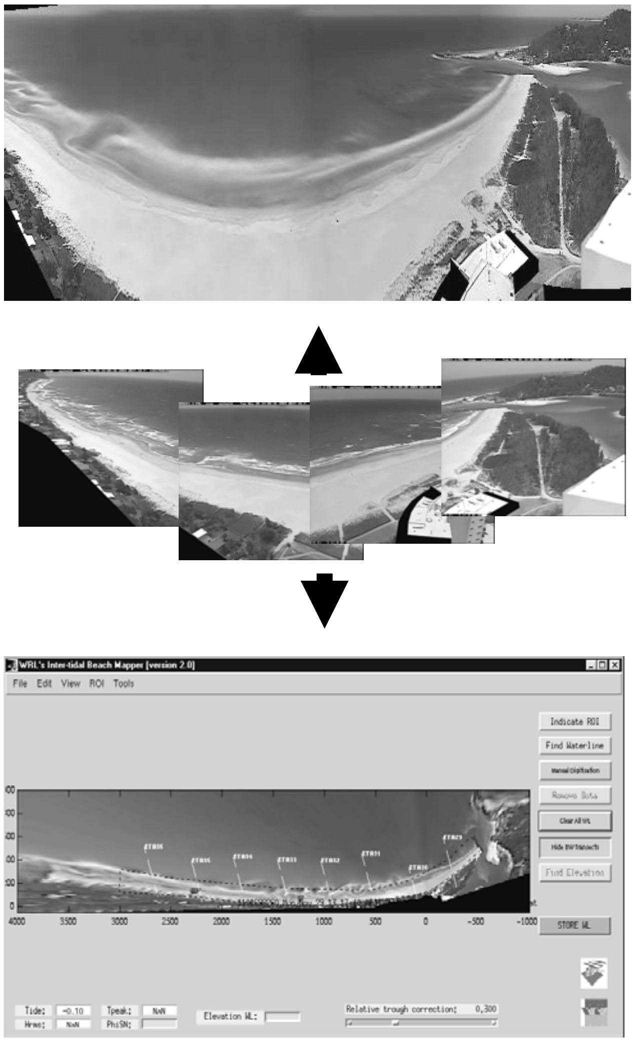

Figure 3: Merging of images obtained by multiple cameras is used to obtain a panoramic view of the entire coastal embayment (upper image). Rectification of this merged image to real-world coordinates permits the resulting plan-view image to be processed using sophisticated image analysis techniques to determine the instantaneous shoreline position alongshore (lower image). The lower image also shows the user interface to the software tool that is used in the laboratory to map weekly shorelines. The monitoring site illustrated is the 3.5km Palm Beach embayment in QLD, that was nourished during 2005 – 2006 by the nearshore placement of 350,000 cubic metres of sand.

Data Development and Summation System

The processes described above generate approximately half a gigabyte of data per monitoring site each month. Key data includes:

- hourly snap, timex, and variance images,
- merged and rectified plan-view images (at low-tide, mid-tide, and high-tide), and
- a database of weekly shoreline positions.

In its raw form, this large and growing volume of information is of limited practical use to coastal managers. The objective of the critical data development and summation component of the beach monitoring system is to summarise this available information into a variety of succinct CZM ‘products’ that can be used directly by managers for both retrospective impact assessment and ‘real-time’ operational decision-making.

Working with coastal managers across a range of monitoring sites, automated post-processing software has been developed to summarise the image-derived information. The objective of the data development and summation system is to produce practical CZM information of the type and format that is both accessible and immediately applicable to the coastal managers’ site-specific needs. The range of data summary ‘products’ made routinely available by this system are detailed in the following section.

World Wide Web Interface

The beach monitoring system is accessed by coastal managers via an easy to use web site. This intuitive interface provides a 'real-time' portal to all the current and historical raw and analysed data. By this on-line approach to data delivery, project managers have direct access to all the qualitative and quantitative monitoring program results via their own desktop computer.

On-Line Access to ‘Real-Time’ CZM Monitoring Information

Until around 2003 coastal imaging systems installed at coastal management sites in Australia, Europe and the USA typically provided 'real-time' access only to the raw image information via the world-wide-web. Quantitative information on beach conditions was developed manually and subsequently provided to project managers via paper-based reporting. The research and development that has resulted in the advent of the on-line beach analysis system described herein represents a significant step forward for coastal monitoring, engineering and management. The range of information that is currently available via the web site for all the Australia sites (*www.wrl.unsw.edu.au/coastalimaging*) are described below.

Hourly images (including zoom tool)

Every hour the web-site is updated with the latest snap-shot, time-exposure and variance images. These images can be viewed to provide an immediate first-pass (qualitative) assessment of beach conditions, and a ‘zoom tool’ function enables more detailed examination of a particular region or feature of interest.

Image archive

All hourly images are archived within a database structure that facilitates searching and viewing of images via a standard web browser interface as shown in Figure 4. Coastal Managers have complete access to this archive, enabling the qualitative comparison of trends and changes in beach conditions.

Plan-view images

Every day the beach monitoring system identifies the times of low-tide, high-tide and mid-tide. Once the hourly images are indexed in the image archive, the system generates plan-view images of the beaches that are then available for viewing and download. These rectified images facilitate more rigorous qualitative assessment of the present beach and nearshore conditions. Again, small-scale features may be magnified and investigated with the on-line zoom tool function.

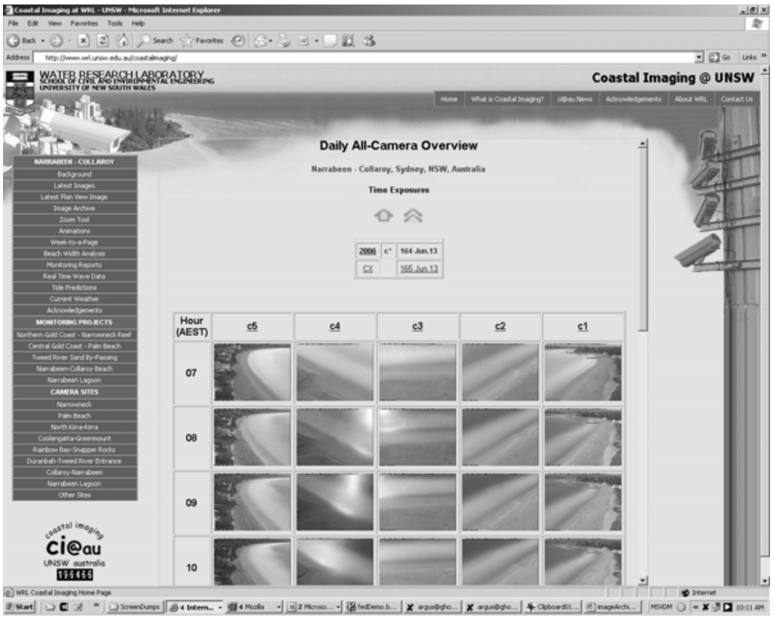

Figure 4: The on-line image archive enables quick and convenient access to the full archive of all hourly images. The monitoring site illustrated is Narrabeen Beach in NSW, the site of a coastal erosion 'hot spot'

'Week-to-a-page'

Each week (typically at midnight every Sunday) the beach monitoring system automatically compiles daily mid-tide plan-view images for the preceding week in to a compact 'week-to-a-page' figure, as illustrated in Figure 5. The purpose of this one-page weekly summary is to provide the coastal manager a means of quickly and efficiently interpreting the daily changes in beach morphology and nearshore conditions, without continual recourse to the hourly images. An archive of previous 'week-to-a-page' image data summaries can also be easily viewed (and downloaded as required) for the purpose of longer-term qualitative assessment. This, and all other summary data products downloadable from the project web site, is preformatted to a standard page size, to facilitate the ready inclusion of this information within any external reporting that may be required.

'Beach-width-analysis'

Each week the mid-tide plan-view images are processed (manually, or in an automated batch mode) to map the present shoreline position along a pre-defined region or regions of interest. This information is then automatically analysed along with previous shoreline data to generate a single 'beach-width-analysis' figure (Figure 6), summarising: The shoreline alignment for that week, superimposed on a current plan-view image of the beach; Shoreline variability and trends, by comparing the current shoreline position to previous shorelines (last week, last month, last year) and an optional reference shoreline, often corresponding to a target beachfront alignment or threshold shoreline position; and beach width variability and trends throughout the total monitoring history, at pre-defined cross-shore control lines selected on a project-by-project basis, to meet the specific requirements of the local coastal managers.

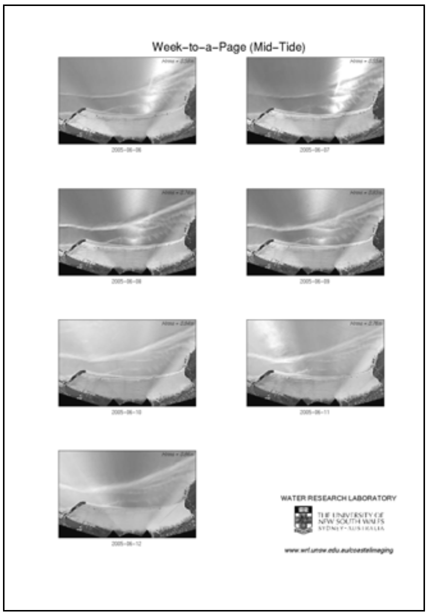

Figure 5: 'Week-to-a-page' data summary – provides the coastal manager a means of quickly and efficiently interpreting the daily changes in beach morphology and nearshore conditions. The site illustrated is Coolangatta Beach in QLD, one of the down-drift beaches impacted by the operation of a permanent sand bypassing system at the nearby entrance to the Tweed River.

In addition to these data being made available each week via a single 'beach-width-analysis' summary figure, the raw weekly shoreline and time-series beach width datasets are also archived and accessible via the project web site. Via a secure login that is provided to the coastal managers and other authorised stakeholders, these data are updated each week ready for download as ascii spreadsheet files.

Beach change animations

The creation of a time-lapse video of daily mid-tide images provides a particularly intuitive tool to identify dominant and more subtle longer-term beach trends. The beach management system provides access to beach change animations in two forms. At the end of each month, an animation is automatically created from the daily mid-tide plan-view images for that month, and linked to the web site for immediate viewing and/or download. In addition, an on-line animation tool is available to coastal managers via a secure login area of the web site, that enables animation parameters such as start and end dates, tidal stage, image type and frame-rate, to be customised. Once selected, the central host computer undertakes the necessary processing to create the required animation, and the user is then automatically emailed an acknowledgement and link to the newly-created animation. The creation of custom animations is computer processor intensive, necessitating the restriction of this functionality to a more limited number of authorised users.

'Special' images

The final CZM 'product' that is routinely and automatically created by the beach management system is special images created on a project-by-project basis, to address location-specific requirements. A present example of this type of image is a close-up (higher resolution but limited field of view) in the region of an historic shipwreck in the intertidal zone at one of the monitoring sites, that is episodically exposed and covered by the onshore-offshore movement of sand. Other examples include images of the beach in the immediate vicinity of a temporary sand outlet point for sandy by-passing operations, and at another site the area surrounding a beach outlet of a major storm drain is captured.

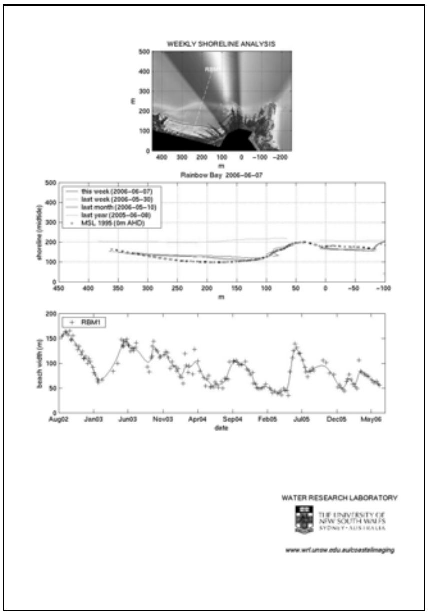

Figure 6: 'Beach-width-analysis' data summary – provides quantitative analysis of present and past shoreline movement and trends. The upper panel shows the present shoreline alignment, superimposed on a current plan-view image of the beach. The middle panel contrasts the present shoreline to previous shorelines, while the lower panel shows time-series of beach width at one or more selected cross-shore transects. The site illustrated is Rainbow Beach in QLD, located immediately adjacent to the main sand outlet from the Tweed River entrance sand bypassing system.

Discussion

In addition to the online delivery of image-derived data as describe and illustrated in the preceeding section, other data products are available via the beach management system, though currently not provided on-line. A relatively recent addition to the CZM products now being used across all the Australian sites is the completion of regular (monthly) 'virtual surveys'. In short, further processing of waterline information enables a three-dimensional surface to be extracted from the two-dimensional images. Briefly, the waterline is mapped every hour through a spring tide cycle. 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 (Aarninkhof et al., 2003). As illustrated in Figure 7, if this process is repeated at all points alongshore throughout a complete tide cycle, a three-dimensional bathymetry of the beachface (extending from spring high to low tide) is obtained. Difference calculations between two bathymetry maps spanning any time interval of interest reveal the spatial distribution of net changes in beachface elevation, and even quantitative estimates of sand volume changes alongshore (Figure 7). This and other image-based analysis techniques are presently the focus of ongoing research.

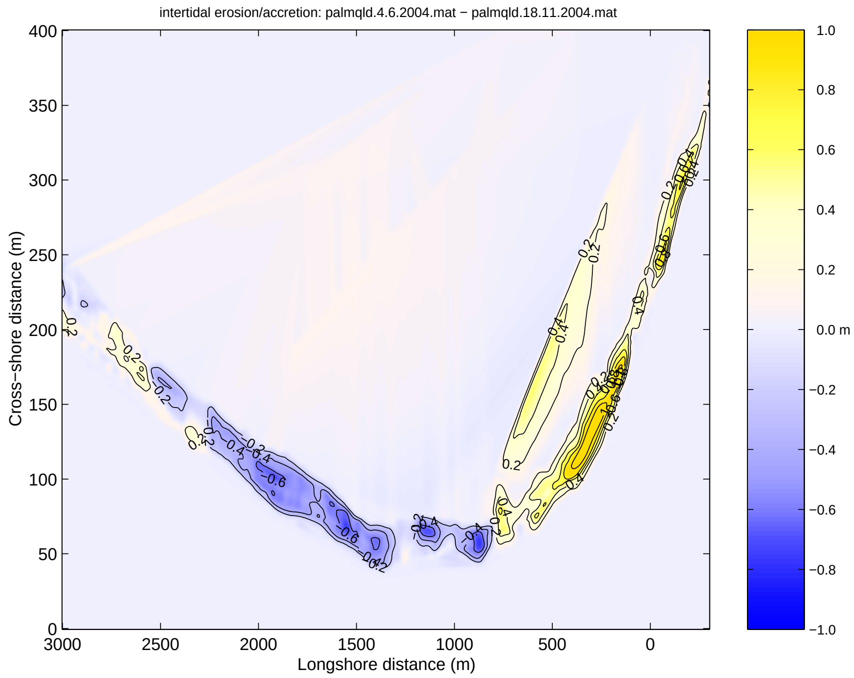

Figure 7: Estimate of net change in beachface elevation and sand volume, derived from the extraction of 3-D 'virtual' survey information from 2-D images. The site illustrated is Palm Beach in QLD, where the impacts of recent sand nourishment to the southern region of the beach was observed and quantified.

(Van Koningsveld et al., 2003) identified the gap between knowledge-developers and knowledge-users in the fields of coastal research and coastal zone management, and further extended this work (Van Koningsveld et al., 2005) to suggest an improved 'frame of reference' for matching science with coastal management needs. The development of the beach management system described herein goes some way toward narrowing this traditional research-management divide. Key to the success of this system is that the range of resulting CZM 'products' were developed in an iterative manner by researchers in close collaboration with managers, across a diverse range of sites in Australia. These sites in 2006 include construction and post-construction monitoring at the location of an artificial (surfing) reef, several large-scale beach nourishment works, and the operation of a permanent sand-bypassing system (described in further detail in Turner et al (2006).

From growing experience and end-user feedback, the key capability of the beach management system is the ability to provide continuous and regularly-updated shoreline monitoring, as is succinctly illustrated in Figure 8. The upper panel shows the monthly sand delivery to this site over a 12 month period by a river entrance bypassing plant located close by, and the lower panel shows the surveyed beach response to this nourishment, based upon conventional (total station) and image-derived techniques. The imaging system first became operational at this site in August 2002 (Turner et al., 2006). The existence of quarterly survey data (for the first twelve months of the beach management system's operation) is relatively frequent for this type of project. However, the information that is lost when compared to the weekly image-derived surveys is readily apparent. The rate of beach recovery in response to nourishment was much more rapid than the quarterly surveys suggested. Similarly, erosion-recovery cycles were entirely missed by the quarterly survey effort. For operational applications, the dependence upon imaging methods removes the risk to managers that key behaviour within the coastal system may be missed. Not every image need be the subject of routine detailed analyses. However, the coastal manager can be confident that all 'events' will be recorded and available as required (Turner et al., 2004).

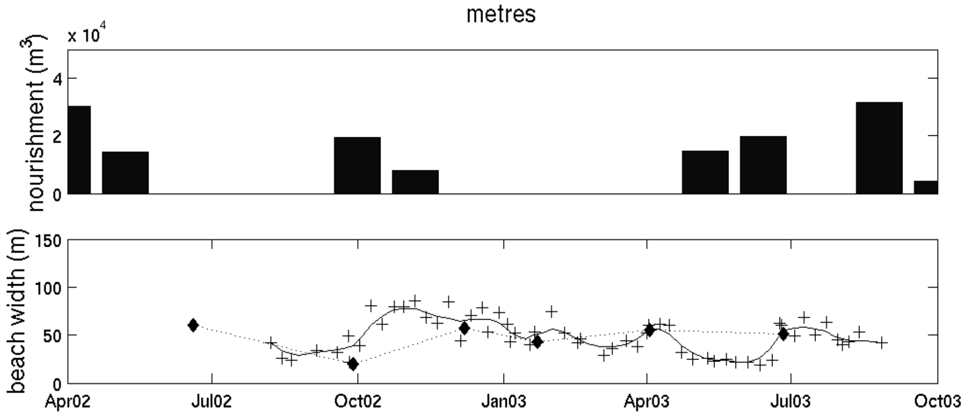

Figure 8: Comparison of the results of quarterly conventional surveys (dots) and weekly image-derived beach width analysis (crosses), resulting from beach nourishment. Note that the rate of beach recovery is greatly underestimated when based upon the less frequent conventional surveys, and erosion-recovery cycles were entirely missed by the conventional survey effort. The site illustrated is Duranbah Beach in NSW, adjacent to the northern training wall of the Tweed River, and the site of temporary sandy pumping from the Tweed River entrance sand bypassing system. (Adapted from Turner et al., 2006).

Finally, while the emphasis in this paper has been to describe the role of the beach management system as it relates to coastal manager requirements, it is noted here that the project web site also provides a valuable opportunity to promote this information to a much wider range of stakeholders. By linking the monitoring web site to other locations on the world-wide-web that contain background or related information, the opportunity is provided for much wider dissemination of CZM objectives, methods and outcomes. While the Australian beach management web sites presently do not fully exploit this capability, current interest runs at more than 50,000 hits by the general public and other interested parties each year. In addition to the advantages of on-line delivery to the coastal manager, there is clearly considerable potential to greatly enhance the wider communication of project-specific CZM objectives and strategies via this same approach.

Conclusions

The application of image-based analysis techniques to specifically address CZM requirements is in its relative infancy. Based upon the experiences of the last five years, continued rapid advances can be anticipated. Increasingly sophisticated image analysis tools will become available, that in turn will assist coastal managers to identify and quantify coastal variability and trends. The true value of the internet to deliver this information direct to the managers' desk, of the type and format that is tailored to site-specific CZM requirements, is only just beginning to be explored. Key to the continued development of this approach will be the engagement of coastal managers along with coastal researchers in the iterative design and implementation of imaging-based monitoring programs.

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References

Aarninkhof, SGJ and Holman, RA, 1999. Monitoring of the nearshore with video. Backscatter, 19(2), 8-11.

Aarninkhof, SGJ, Turner, I.L, Dronkers, TDT, Caljouw, M and Nipius, L, 2003. A video-based technique for mapping intertidal beach bathymetry. Coastal Engineering, 49(4), 275-289.

Boak, E.H. and Turner, I.L. 2005. The shoreline detection-definition problem: a review. Journal of Coastal Research, 21(4), 688-703.

Holland, KT, Holman, RA, Lippman, TC, Stanley, J and Plant, N, 1997. Practical use of video imagery in nearshore oceanographic field studies. IEEE Journal of Oceanic Engineering, Vol.22 (1), 81-92.

Holman, RA, Sallenger, AH, Lippmann TCD and Haines, JW, 1993. The application of video image processing to the study of nearshore processes. Oceanography, Vol.6(3), 78-85.

Lippmann, TC and Holman, RA, 1990. The spatial and temporal variability of sand bar morphology. Journal of Geophysical Research, 95(C7), 11,575-11590.

Plant, NG, Aarninkhof, SGJ, Turner, IL and Kingston, K, (in press). The performance of shoreline detection models applied to video imagery. Journal of Coastal Research.

Turner, IL, Aarnihkhof, SJD, Dronkers, TDT and McGrath, J, 2004. CZM applications of ARGUS Coastal Imaging at the Gold Coast, Australia. Journal of Coastal Research, 20(3), 739-752.

Turner, IL, Aarninkhof, SGJ and Holman, RA, 2006. Coastal imaging research and applications in Australia. Journal of Coastal Research (Special Issue - Australian Coastal Geomorphology 2004), 22(1), 37-48.

Van Enckevort, IMJ, Coco, G, Ruessink, BG, Suzuki, K, Turner, IL, Plant, NG and Holman, RA, 2004. Field observations of nearshore crescentic sandbars. Journal of Geophysical Research, 109, C06028,17p.

Van Koningsveld, M, Davidson, MA and Huntley, DA, 2005. Matching science with coastal management needs: the search for appropriate coastal state indicators. Journal of Coastal Research, 21(3), 399-411.

Van Koningsveld, M, Stive, MJF, Mulder, JPM, de Vriend, HJ, Ruessink, BG and Dunsbergen, DW, 2003. Usefulness and effectiveness of coastal research: a matter of perception? Journal of Coastal Research, 19(2), 441-461.

Wijnberg, KM, Aarninkhof, SGJ, van Koningsveld, M., Ruessink, BG and Stive, MJF, 2005. Video monitoring in support of coastal management. Proceedings, 29th International Conference on Coastal Engineering, ASCE, Lisbon Portugal, 3, 3136-3148.

Coastline Management in New South Wales
What's on the Horizon?

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ABSTRACT
This paper examines the recent history of coastal zone management in NSW, considers the efficiency of the existing legislative and planning approaches and most importantly, explores the many challenges that lie ahead both for the NSW Government and local councils in developing Coastal Zone Management Plans which preserve the very attributes that draw people in ever-increasing numbers to make the coast their home.

INTRODUCTION
Coastal Zone Management (CZM) is emerging as one of the key challenges for the NSW Government over the next 15 to 20 years. Recent policy and legislative reform have provided the necessary initial steps to cope with current, unprecedented development pressures and ominous population growth forecasts. Given the complexity of these issues, it is likely that further policy development and legislative reform will be necessary over the coming decade to manage the Coastal Zone of NSW in a sustainable manner that balances amongst other considerations: continued economic prosperity, development opportunities, infrastructure demands, management of natural assets and preservation and enhancement of recreational amenities for future generations.

HISTORICAL CONTEXT
Focused coastal zone management evolved from necessity in NSW in response to the widespread damage inflicted on the coastline by ocean storms in 1974. In February and March 1974, Tropical Cyclones "Pam" and "Zoe" devastated much of the north coast highlighted by the loss of 17 houses at Sheltering Palms immediately north of the entrance to the Brunswick River (Gordon et al, 1978).

On 25 and 26 May 1974 a southern secondary depression (a "bomb") developed off Port Kembla and moved north past Sydney causing the worst damage to the Greater Metropolitan coast in recorded history (Foster et al, 1975). The May storm was followed by another erosion event three weeks later in June. High rise units at Collaroy were again threatened and houses were lost or property badly damaged at many locations, including Bilgola Beach where almost every beachfront residence suffered some form of damage (Gordon 2003).

Since 1974 there have been a number of storms resulting in property loss and damage at various locations on the NSW coast, however, it is generally accepted, as stated by the NSW Supreme Court (Egger vs Gosford City Council), that 1974 was the defining year after which a new understanding of the coastal processes of the NSW coast came into being (Gordon 2003).

1970s
In direct response to the widespread coastline damage of 1974, the NSW Government recognised a skills gap in coastal process understanding and embarked upon a range of CZM initiatives during the mid to late 1970s. As testament to the vision of government operatives at that time, several of these initiatives remain, in one form or another, and have proven fundamental to effective CZM in New South Wales. CZM initiatives instituted by the NSW Government during the 1970's included:

- Establishment in 1975 of an expert **Coastal Engineering Branch** within the (then) Public Works Department;
- Establishment of a **deepwater offshore "Waverider" buoy network** managed by Manly Hydraulics Laboratory (1975);

- Introduction of **Beach Improvement Program** (BIP) which provided 100% funding assistance to local councils to protect and enhance heavily used recreational beaches and their associated dune systems (NSW Government, 1990). A total of approximately $20M was distributed over the life of the BIP (1975 to 1989);
- Introduction of the **Coastal Protection Act** on 1 July 1979. This Act allowed for the formation of the Coastal Council of New South Wales to provide independent advice to the NSW Government on coastal matters. The initial thrust of the Act was centred on preventing inappropriate development in areas subject to threat from coastal processes;
- Development of in-house expertise and completion of the first comprehensive coastal and estuarine process studies in New South Wales of Byron Bay (Gordon et.al., 1978) and the Tweed River Estuary (Druery et.al., 1979).

1980s

During the 1980s many more coastal process and hazard reports were prepared in house by the Coastal Engineering Branch of PWD to initiate improved long-term management of identified coastal hazard areas. Other CZM initiatives instituted during the 1980s included:

- Coastal Engineering Branch of PWD **investing in photogrammetric technology** to expand capacity to determine historical long-term recession rates and measure various beach erosion parameters with great accuracy for planning purposes (early 1980's). The Branch also established and developed offshore hydrographic survey capacity with particular shallow water capability;
- The Coastal Council ceased operation in 1986;
- The NSW **Coastline Hazards Policy** was adopted by the Government in June 1988. The primary objective of the policy was *"to reduce the impact of coastline hazards on individual owners and occupiers of coastal lands and to reduce private and public losses resulting from such hazards"*;
- The Coastline Hazards Policy announced the establishment of the **Coastline Hazard Program** (CHP). The CHP administered by the PWD was set up to provide financial assistance on a 1:1 basis with local government for works and studies leading to reduced hazard exposure and improved beach amenity. The former BIP was phased out;
- Preparation of detailed coastal and estuary investigations were outsourced from the late 1980s with overview and project management shared jointly by State and Local Government. This fostered the establishment of a strong coastal consulting industry in NSW;
- In 1989, the **NSW Coastal Committee** was established to provide independent advice to the Minister for Planning and Director General Department of Urban Affairs and Planning on coastal matters.

1990s

During the 1990s coastal management and related policy continued to evolve. The policy emphasis shifted however, from one primarily associated with the protection of assets to one of preserving public access and the natural and recreational amenity of the State's beaches, waterways and headlands. CZM initiatives instituted during the 1990s included:

- In 1990, The NSW Government released **NSW Coast: Government Policy**. The Policy provided a framework within which optimal land-use decisions could be made on private and public land along the full length of the NSW Coast excluding the Greater Metropolitan Region. The NSW Coastal Committee would oversee the implementation of the Policy;
- The NSW Government's **Coastline Management Manual** was released in September 1990 and the draft **Estuary Management Manual** in 1991. These Manuals articulated a step-wise approach to development of Coastal and Estuary Management Plans formulated by Coastline and Estuary Management Committees established under the stewardship of local councils;
- Section 733 Local Government Act 1993 provided **immunity from liability to Councils**, other agencies and their staff in respect of advice provided or acts done in good faith in

respect of coastline matters, provided they followed the principles set down in the Coastline and Estuary Management Manuals;

- In 1994, the Coastal Committee released a revised **draft Coastal Policy** for comment;
- On 1 September 1994, the **Coastal Protection Regulation** was introduced through the legislature to provide the Minister administering the Coastal Protection Act 1979 with a concurrence role over development occurring within the offshore marine waters of the state.
- On 5 February 1996, the Minister for Planning **gazetted the Coastline Management Manual** 1990 to give effect to S733 Local Government Act 1993;
- In October 1997, the NSW Government released the ***NSW Coastal Policy 1997: A sustainable Future for the NSW Coast***. The Policy set a new direction for coastal zone management, planning and conservation in NSW outlining 9 specific goals based upon ecologically sustainable development. The Policy formally included estuaries, ICOLL's and other coastal water bodies within the Coastal Zone, though the GMR remained excluded;
- Coastal Protection Act 1979 was amended in June 1998 to give effect to the boundary of the Coastal Zone redefined in the NSW Coastal Policy 1997;
- On 23 February 1999, the **NSW Coastal Council** was reconstituted under provisions of the Coastal Protection Act 1979 for a three year term, replacing the NSW Coastal Committee. In addition to providing independent advice to Government on coastal matters, the main focus of the Coastal Council was to oversee and report on the implementation of the 1997 Policy.

Beyond 2000 to present (2006)

In the short period since 2000, there have been further legislative and policy reforms for coastal NSW. There has been a significant response to ominous long-term population growth projections, coupled with unprecedented development pressures in the Coastal Zone. At the same time, the NSW Government has embarked upon the most significant natural resource management reform in NSW history through a delivery model centred on Catchment Management Authorities and the establishment of the Natural Resources Commission. Since 2000, CZM initiatives have included:

- Coastal Council **review into Management of NSW Beaches** and MHWM boundary re-determination processes (January 2000);
- On 26 June 2001, the State Government announced a **Coastal Protection Package** (CPP) valued at some $11.7 million. The CPP was necessitated by the extensive development pressures facing the coastal zone and in response to the scale of future population growth projections. A range of measures introduced within the CPP including the Coastal Protection SEPP 71, amendments to the *Coastal Protection Act 1979* and the Comprehensive Coastal Assessment (CCA) were designed to better inform long-term decision making processes and provide mechanisms for immediate protection to sensitive coastal areas, beaches and public access to them;
- $8.6M **Comprehensive Coastal Assessment** (CCA) program which was a key element of the CPP, spread over 3 years from June 2002. The CCA was designed to assess the environmental, social and economic values of the NSW coast. The CCA was also established to standardise and integrate existing data sets and to identify and fill significant data/information gaps to underpin decisions about coastal development and conservation;
- **Coastal Protection Amendment Bill 2002** significantly amended the *Coastal Protection Act 1979*. Some of the more significant amendments included extending the 'coastal zone' to include the Greater Metropolitan Region of Sydney (except Sydney Harbour and Botany Bay), enabling the Minister for Natural Resources to direct Councils to prepare and gazette coastal zone management plans and modifying the doctrine of erosion and accretion;
- Introduction of the **Coastal Protection SEPP 71**, which came into effect on 1 November 2002. The SEPP provides specific strategic planning guidance for development within "sensitive" coastal locations;
- On 4 March 2003, the Minister for Planning released the "Coastal Design Guidelines for NSW";
- On 29 May 2003, the Premier announced the establishment of the **Department of Infrastructure, Planning and Natural Resources (DIPNR)** as a new "super ministry" to

integrate and improve land use, infrastructure and transport planning, and natural resource management in NSW, bringing together for the first time the coastal planning and coastal process expertise within one Department;

- Natural Resources Commission Bill 2003, Native Vegetation Bill 2003 and Catchment Management Authority Bill 2003 emanated directly from the recommendations of the Native Vegetation Reform Implementation Group (NVRIG). These Acts, assented to on 11 December 2003, fulfilled an historic watershed for natural resource management in NSW which would now be delivered through **Catchment Management Authorities** in conjunction with the Natural Resources Commission and Natural Resources Advisory Council;
- The establishment of the Natural Resource Advisory Council led to the abolition of some 11 advisory committees and Councils, including the Healthy Rivers Commission and the NSW Coastal Council. The Coastal Protection Act 1979 was further amended to remove the provisions for establishment and maintenance of the Coastal Council.
- On 1 September 2004, the **Coastal Protection Regulation** was re-introduced through the legislature to provide the Minister administering the Coastal Protection Act 1979 with a concurrence role over development occurring within the offshore marine waters of the state;
- On 1 August 2005 **Part 3A Environmental Planning & Assessment Act 1979** was introduced to streamline approval processes for Major Significant Developments;
- On 26 August 2005 **DIPNR was formally abolished** and replaced with separate Departments of Natural Resources and Planning, once again separating the coastal process and coastal planning expertise;
- On 31 March 2006, the **Standard Instrument (LEPs) Order 2006** was gazetted to both streamline and standardise LEP preparation statewide. All councils are required to update LEPs to accord with the new template through staged implementation; and
- From 2005 onwards, Department of Planning have successively released a range of **Coastal and Metropolitan Regional Strategies** for public comment. These strategies have been formulated principally to guide settlement patterns and address infrastructure needs in the fastest growing areas of the state.

CONSTRAINTS AND CHALLENGES

The extent of policy development and strategic planning direction evident within the Coastal Zone since 2000, reflects the complexity associated with managing the peak economic margin in Australia in an economically, ecologically, socially and environmentally sustainable manner.

There are many constraints, challenges and competing interests that must be accommodated in order that urban society doesn't risk degrading the very values and opportunities that make the NSW coastline one of the most envied worldwide. Some of these constraints and challenges are summarised below:

Population Growth

The coastal regions of NSW are projected to experience the greatest population growth within the state between 2001 and 2031 with an anticipated growth rate of approximately 1% forecast over the next 20 years (Mackintosh & Parr, 2004).

Interestingly, this growth rate is forecast to slow markedly from that experienced over the period 1981 to 2000 (2.2%). This is a general state-wide trend which is "*due to the magnitude of change in fertility, mortality and migration and the size of the population. The larger the population, the greater the increments needed to sustain growth*" (Mackintosh and Parr, 2004). Macintosh and Parr (2004) forecast the mid-north coast will experience the greatest population growth rates in coastal NSW over the period to 2031, followed by the Richmond-Tweed and South-Eastern Regions. These forecasts project the total population of Coastal NSW (excluding Sydney, Newcastle and Wollongong) to exceed 1.22 million by 2031.

In a report on the fastest and largest growing areas of Australia, the Commonwealth Bureau of Statistics noted that for the census period (1996 to 2001), New South Wales central coast regions (Gosford, Wyong and Lake Macquarie) experienced the largest population growth in the country behind Sydney. A total of 20,427 residential dwelling houses were approved in these three regions over the 5 year census timeframe, equating to an average of approximately 3.7 dwelling houses per day per region (ABS, 2001).

The challenge for all spheres of government lies in finding how to distribute or accommodate population growth in a manner that does not diminish the quality of life for future generations or degrade irreplaceable, valuable, natural and environmental assets. In particular, water supply, waste treatment and disposal, energy supply and consumption and transport infrastructure, coupled with issues associated with a rapidly aging demographic profile, will become the critical issues around which broader strategic planning in the coastal zone will be based throughout the 21st century.

Large sections of the NSW coast are already protected in reserves and National Parks and these must be rigorously retained. If population growth forecasts are considered absolute and inevitable, then strategic planning will have to establish the point at which areas of coastal NSW have reached population saturation. Such endeavours will also require identification of areas which can continue to grow and at what rate, and consider the prospect of enabling some of the larger coastal urban centres to consolidate as high density urban metropolises. In this manner, the footprint of contemporary, slow, lateral, urban sprawl across coastal landscapes may be minimised into the future. Without such forward planning the role becomes one of simply managing the slow and orderly degradation of the coastline as we now know it.

Availability/Affordability of Housing

Our national iconic affinity with the coast is largely responsible for the burgeoning development pressures experienced within the coastal regions of the state.

The decision to live closer to the sea and enjoy the natural ambience and recreational amenity afforded, have fuelled a staggering recent property price boom within coastal areas and adjacent to tidal waterways, which started in NSW but has spread Australia-wide. The many natural resource management, physical constraints and natural hazards (including flooding, long-term shoreline recession and projected long-term rise in mean sea level due to climate change, etc) impose severe limitations on the availability of new land releases in these areas. Ironically, the closer property is to the coast, the higher the risk from these natural processes yet the higher the perceived property value.

An article by Samantha Turnbull (2006) which appeared in the *Northern Star* on 7 February 2006 titled *"Prime Byron Bay land sells for record $8M"*, is testimony to these observations. The property sale involved the consolidation of six adjoining lots with direct beach frontage along Belongil Spit, Byron. This landholding is subjected to some of the more severe coastline hazards experienced state-wide and currently has limited development opportunity under the "planned retreat" philosophy which is enshrined in relevant planning instruments governing the site. Coupled with the increasing demand driven by population growth, prices for direct beach frontage in NSW have soared over the past decade in particular.

Property valuations for rate and land tax purposes conducted by the NSW Valuer-General noted an average 24% rise in valuations for seaside towns during 2005 alone. This issue was featured in an article by Mark Skelsey, Urban Affairs Editor, Daily Telegraph on 27 January 2005. The article highlighted an extraordinary example of valuations for a beachside fibro dwelling in the tiny north coast hamlet of Minnie Waters which has no sewerage system or footpaths, one general store and a population of only 200 people. The subject property was recently valued at $800,000 compared to $500,000 in 2003 and $130,000 in 2001.

Management of Coastline Hazards

There is a range of coastline hazards which impact directly upon the NSW coastline. Of primary importance for strategic planning are the immediate hazard of beach erosion and the longer-term threat posed by shoreline recession and climate change.

At present in NSW, significant infrastructure, hundreds of dwelling houses and additional structures have been identified to be at immediate threat from beach erosion processes during an extreme oceanic storm event. When considering the additional implications from shoreline recession and climate change impacts (such as increased mean sea level) over longer term planning horizons (say 100 years), several thousand properties would be considered at varying levels of risk in the absence of large scale physical protection strategies. Management of this conflict will require major Government initiatives.

Contemporary understanding of coastal processes and quantification of associated coastline hazards for planning purposes in NSW, is relatively advanced. This advanced knowledge enables infrastructure, dwelling houses and other built assets on “Greenfields” sites to be set back sufficiently to accommodate coastline hazards, environmental and recreational buffers (as necessary) over designated planning horizons. Future strategies, however, beyond those planning timeframes will still be required.

Almost without exception, all development currently at direct threat from coastline hazards can be traced back to the establishment of residential subdivisions over a century ago, when the level of understanding of the dynamic fluctuations of the coastline was comparatively primitive. Despite the establishment of setbacks, generally from the MHWM of the sea at the time, many have proven manifestly inadequate, particularly on quickly receding sectors of the coastline.

Many areas of the coast currently under direct threat from coastline hazards, have developed into med-high density residential urban landscapes. In these circumstances, long-term management strategies to address the direct threat are limited to either retreat or protection. Planned retreat and property acquisition strategies have proven to be limited, complex and difficult to regulate or enforce, and socially divisive for coastal communities. The sheer cost of beachfront properties, which generally exceed $1M anywhere in NSW, are now making retreat/acquisition strategies virtually unachievable for local government from an economic perspective.

Large scale, physical protection works designed, constructed and maintained to an appropriate engineering standard (including seawalls, groynes, offshore breakwaters, artificial sand nourishment, etc,) are similarly prohibitively expensive to implement. Seawalls which have proven to be the most popular form of physical protection along the NSW coastline range in price generally from $6K-$10K/linear metre. When augmented with artificial sand nourishment to offset the loss of recreational amenity over the longer term, the cost of physical protection strategies is ongoing and generally lies well beyond the financial means of the vast majority of local government authorities.

Funding assistance has traditionally been available to local government authorities for the implementation of coastal zone management strategies via the NSW Government’s Coastal and Estuary Management Programs (on a dollar for dollar basis). Considerable pressure on the State budget in the areas of health, public transport, infrastructure and education have resulted in steady cutbacks to available funding under these Programs in recent years. In addition, available funding is provided through the Programs on an annual basis, which is not suitable for commitment to ongoing sand nourishment strategies, a necessary component of most protection strategies.

One of the solutions to meeting the considerable financial implications inherent with large scale physical protection works, rests with developing more flexible methods of funding the onerous long-term financial commitments involved. In these situations, it may be prudent for state/local government and affected stakeholders to consider more innovative, perpetual, self-funding mechanisms. Examples of contribution mechanisms may include special rates/levies/taxes, user and adjoining landowner contributions, similar mechanisms to bed taxes in tourist areas, percentage of sale price at exchange for properties directly benefiting from physical protection works, land swaps, commercial partnerships, etc.

This change in funding philosophy is essential if funds are to be available for aspects of the management strategy when required. In addition, such a contributory system may circumvent sourcing large, singular, financial commitments at indeterminate junctures in the future when traditional funding assistance streams may not be available. With so many fiercely competing budgetary pressures, the capacity to accommodate the full cost of implementing coastline management strategies, are currently proving to be beyond State/Federal Government.

Artificial Sand Nourishment

Some of the key themes of the NSW Coastal Policy 1997 relate to enhancement of the recreational amenity of, and public access to, our state's sandy beach environs. The ready presence of beaches feeds our iconic national affinity with surf and sand and is intrinsically linked to social wellbeing. Similarly, the waterways and beaches of NSW provide the focus of domestic travel in NSW with several beaches, in particular Byron Bay, Manly and Bondi, recognised internationally. There is considerable opportunity for this industry to continue to grow provided the beach amenity is retained.

Dramatically increasing coastal populations place increasing pressures on these valuable recreational assets. These pressures will be exacerbated into the future by projected rises in mean sea level due to climate change impacts, particularly where receding embayments are constrained by the presence of development or natural topographical and geological features (including rock outcrops, headlands, etc).

There are several significant residential developments along the NSW coastline where large scale physical protection works have already been proposed to address the immediate and longer term threats from coastline hazards. In most instances large scale, on-going, artificial sand nourishment programs have been proposed to augment the works and offset reduction in beach width and amenity (Kingscliff, Belongil Spit, Brooms Head, Yamba, Coffs Harbour, Jimmys Beach, Shoal Bay, Stockton, Wamberal, Collaroy/Narrabeen, Manly and Cronulla).

Locating suitable source sites to facilitate these nourishment requirements has proven problematic for a range of reasons. Terrestrial sources of sand have generally either proven to be of limited scale or naturally deposited through aeolian processes in which case, the grain size is generally finer than that of most open coast beaches. Under these circumstances, the source material is sub-optimal for nourishment purposes. There are significant and immediate adverse environmental impacts associated with further exploitation of these onshore resources.

However, in recent years there have been a small number of SEPP 35 (Maintenance Dredging of Tidal Waterways) activities where the dredged sand spoil has been used to renourish degraded nearby beaches (eg. Shoal Bay, Tweed Heads, Cronulla, Evans Head and Bermagui). Although successful in providing partial nourishment, these exercises have been undertaken on an opportunistic basis involving comparatively small volumes of sand compared with open coast nourishment requirements. These exercises generally do not increase the quantity of sand in the coastal system, merely redistribute it.

There is a significant difference between the volume of sand dredged under SEPP 35 approvals compared with the volume of adequate marine sand required to satisfy existing and future artificial nourishment demands for open coast beaches. Nonetheless, a more comprehensive integration of SEPP 35 dredging with nourishment opportunities (where physically and economically feasible) should be pursued in earnest to maximise the use of limited marine sands to assist with restoring/enhancing the amenity of the state's beaches.

Clearly, with so many long-term coastline management strategies currently being prepared that are reliant, in part on ongoing sand nourishment as required, the consideration of offshore marine resources of sand becomes a more urgent issue. Although widely adopted in Queensland (Gold Coast) and within many other countries of the world, the use of offshore marine reserves of sand for NSW beaches has not been considered widely to date.

Several proposals have been put forward in the past for commercial extraction of sand offshore of Sydney. None have been successful, having been withdrawn on each occasion by proponents in the face of adverse environmental and community reaction and general government opposition.

To sustain the amenity of the State's prized natural beaches, in the face of both increased pressures from population growth and natural processes (including climate change impacts), it will be imperative to identify and secure suitable sand sources for beach nourishment with some urgency.

Research/Development and Data Systems

It is an unfortunate reality, particularly over the past 10 – 15 years, that coastal research and development activities to resolve knowledge gaps has been diminishing. Historically, governments have responded to severe storm events and the relatively quiescent period since the late 1980s, coupled with increased demands across other areas of public administration, has not created such a feeling of urgency. In particular, the decline of large scale physical modelling ventures and long-term monitoring projects, which have traditionally provided the cornerstone of technical understanding and advancements in the field of coastal engineering have been most noticeable and reflect declining coastal investigation budgets. If decision making within the coastal zone is to continue to be predicated on sound information, science and engineering, these professional fields need to be sufficiently resourced in order to continue to build on conventional knowledge streams and address knowledge deficiencies. Other emerging knowledge gaps in the areas of coastal zone economics, social surveying and associated modelling trends will be pivotal to justify the increasing and necessary expenditure to implement coastal zone management strategies.

Technological advancements and computing power have given rise to an array of numerical modelling software tools in coastal engineering that can be of tremendous assistance to coastal zone managers. Whilst numerical modelling offers a unique and valuable opportunity to scenario test design oceanic events of any magnitude, in general, the drawback to date with their more widespread use and application has centred on the paucity of data for adequate model calibration and validation processes.

This situation has been highlighted through the recent trend toward the use of semi-empirical, one-line numerical models to establish short-term beach erosion parameters for planning purposes. With extremely limited measured data before and after extreme or defining coastal erosion events (generally sub-aerial photogrammetric data from aerial photographs several years apart) to calibrate the models, the confidence in the predictive model outputs is substantially undermined. Until more sophisticated and ongoing data collection programs to support these modelling initiatives are undertaken by local/state governments, the future of these valuable predictive tools may remain limited to coarse, sensitivity analyses.

It is extremely fortunate that our predecessors had the foresight to invest in fundamental long-term data collection systems and associated technologies like offshore Waverider buoys, ocean and river water level recorders, hydrographic surveying and photogrammetry for hazard definition and design purposes. We now have a solid, historical data base emerging. In the same manner, contemporary coastal zone managers must look carefully at augmenting these systems with rapidly developing imaging and data acquisition technologies in a cost efficient manner that will enable better use of sophisticated analytical and predictive tools as they become available.

CONCLUSIONS

The management of the NSW Coastal Zone, the peak economic margin in Australia, is a complex and multi-facetted task requiring a whole-of-government approach that will ensure community expectations are satisfied for:

- continued economic prosperity and opportunity;
- sustainable natural resource management practices;

- appropriate levels of infrastructure;
- management of water supply, sewerage and waste disposal;
- appropriate long-term strategic planning for an increasing and ageing population demographic; and
- preservation/enhancement of the natural attributes and amenity of the coastal zone for the use and enjoyment of all future generations.

The current conflict between increasing urbanisation and ongoing shoreline recession and climate change impacts will necessitate strong, ongoing initiatives in coastal zone management.

The complexity of the task can be measured by the pro-active response of the NSW Government over recent years embarking upon landmark natural resource management and planning reforms. The strategic planning and management of the Coastal Zone will require flexibility to address, for example, the inherent challenges of population growth and climate change impacts, both of which will continue to evolve over extended timeframes.

Although this paper touches on some of the emerging issues in Coastal Zone Management in NSW, these are by no means intended as an exhaustive list. It is an imperative for State/Local Government and the broader community to continue to work collectively and energetically to resolve such issues as they are identified. It is only through such strong collaborative action that the NSW coastal zone will remain an icon for the benefit of future generations.

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REFERENCES

Australian Bureau of Statistics (ABS, 2001). "*Largest and Fastest Growing Areas in Australia"*, Article published in Building Approvals, Australia ABS Cat. No 8731.0, November.

Coastal Council of NSW (2000). *Management of NSW Beaches*,. Report commissioned by Minister for Department of Land and Water Conservation, January.

Druery B.M. and J.W. Curedale (1979). *Tweed River Dynamics Study*. Public Works Department, NSW Coastal Branch Report, May.

Egger vs Gosford City Council (1988), 67L GRA304

Forster, D.N, Gordon, A.D and Lawson, N.V, (1975). "*Storms of May-June 1974, Sydney, NSW"*, Proceedings 2nd Australian Conference on Coastal and Ocean Engineering, Institution of Engineers, Australia, Publication 75/2, Gold Coast, Queensland, April 1975, pp 1-11.

GeoQuEST (2005). *"Planning for Natural Hazards – How can we Mitigate the Impacts?".* Proceedings of a Symposium, University of Wollongong, 2-5 February 2005. Technical Paper by Phil Watson, DIPNR, Published by GeoQuEST Research Centre, ISBN 1 74128 115 6, pp. 117-127.

Gordon, A.D, Lord, D.B and Nolan, M.W, (1978). *Byron Bay – Hastings Point Erosion Study*, Public Works Department, NSW, Coastal Branch Report No. 78026, November.

Gordon, A.D, (2003). "*The Boundaries of Ignorance",* A Presentation to the College of Law, 2003 Autumn Intensive, Ref 03/127, 26 March.

Lord, D.B, (2001). "*The NSW Coastal Management Program – A 10 year Review*", Proceedings 11th NSW Coastal Conference, Newcastle NSW, 13-16 November.

Mackintosh, M and Parr, A, (2004). "*New South Wales State and Regional Population Projections 2001 – 2051*", Proceedings of the 12th Biennial Conference of the Australian Population Association, Canberra, 15-17 September.

NSW Planning (2003) *Coastal Design Guidelines for NSW*, Guideline developed jointly by the NSW Coastal Council, Planning NSW's Urban Design Advisory Service and Tourism NSW, 4 March.

Skelsey, M (2005), "*Rising land tax hits hideaways*", The Daily Telegraph, 27 January, p 9.

Thom, B (2003) "*Beach Protection in NSW – New Measures to Secure the Environment and Amenity of NSW Beaches",* Environmental Planning and Law Journal, Vol 20, No. 5, pp. 325-358, October.

Turnbull, S (2006), "*Prime Byron Bay land sells for record $8M*", The Northern Star, 7 February, p 3.

Watson, P.J and D.B Lord (2005). "*Coastline Management in New South Wales – Over Regulation or a Sound Investment in the Future*". Proceedings of the 17th Australasian Coastal and Ocean Engineering Conference, Adelaide, South Australia, September.

The Comprehensive Coastal Assessment (CCA): Estuarine Resources of NSW

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Abstract

Given its statutory responsibility for aquatic resources, the NSW Department of Primary Industries (DPI) assisted NSW Planning in the Comprehensive Coastal Assessment (CCA). Because the habitats of fishes, prawns, oysters and other aquatic animals have high conservation value, information was sought on the current status of these estuarine habitats in NSW. Their appropriate management and enhancements benefit coastal economies at the regional and local scale, and need to be appropriately managed as human population density along the NSW coast increases.

NSW DPI undertook six mapping tasks within a geographic information system (GIS) and one data integration task which provide the building blocks for the creation of a decision support tool for the conservation of estuarine resources. The mapping tasks were to: 1) produce aquatic habitat maps of the current cover of seagrass, mangrove and saltmarsh and compare with maps produced 20 years ago, 2) display for the first time in visual fashion the 480 fishing closures along the NSW coast, 3) produce maps of existing aquaculture areas under the terms of SEPP 62, 4) differentiate classifications and tenure of aquatic habitats and adjacent land held by the Crown, 5) integrate available fish species diversity data, and 6) identify habitat distribution of listed threatened species and populations. A seventh task was to investigate ways of integrating complex data layers into a spatially explicit model for NSW estuaries to assist in identification of sensitive planning issues.

Introduction

The Comprehensive Coastal Assessment (CCA) was a data gathering and integration exercise, the aim of which was to compile a database to assist in coastal planning over the next several decades. NSW Department of Primary Industries (DPI) was engaged to provide information on the current state of the aquatic resources within NSW estuaries. In particular, information was sought on the habitats in which fish, prawns, oysters and other aquatic animals live as the maintenance and conservation of these habitats is critical to the sustainable production of the state's aquatic resources. Protection and enhancement of coastal economies at the regional and local scale will follow, particularly as human population density along the NSW coast increases.

The aquatic resources of the estuaries of NSW include the animals that live there and the habitats in which these animals live. Fish, including prawns and oysters and other species defined as fish in the NSW *Fisheries Management Act 1994* (FM Act), need protection due to their inherent value but also because they add to the value of local and regional economies.

Within the marine, estuarine and freshwaters of NSW there are more than 1700 species of fish (D. Hoese, pers. comm. 2006). There are of the order of 200 resident species in the estuaries but this number is swelled by fish that come in from the ocean. The number of species of interest is further enhanced when estuarine crustaceans and molluscs are considered.

The estuaries of NSW are home to a range of recreational and commercial activities. A recent survey (2000-01) showed that, of over six million residents in NSW, nearly one million were anglers, and of these, most spent at least five days per year in shore-based or boat-based activity (Henry and Lyle, 2003). Commercial catch from NSW estuaries is worth of the order of $20 million per year (S. Errington, pers. comm. 2006). Aquaculture, primarily oyster farming, occurs in about 30 estuaries and is worth approximately $38 million dollars per year (T. Gippel, pers. comm. 2006).

Seagrass has been shown to be a habitat of prime importance for many fish species. Reviews of the importance of seagrass for the whole of Australia (e.g., Butler and Jernakoff 1999) have been followed up by field guides for use by local communities (Laegdsgaard 2001). Similar conservation arguments to those for seagrass follow for mangrove and saltmarsh. The latter two habitats were once regarded as "swamps", but in the 1970s the reassessment of the role of mangrove began (e.g., Lear and Turner 1977). Similarly, recent studies have begun to elucidate the role of saltmarsh in estuarine ecosystems (e.g., Mazumder *et al*. 2005a, 2005b, 2005c, 2006)

A recognition of the need to better understand the role played by estuarine habitats was seen over 25 years ago when a simple inventory of the estuaries and coastal lagoons of NSW was prepared (Bell and Edwards 1980). Since then, estuaries have been perceived as important "spawning grounds" which is true for species that are fully resident. However, for other species whose reproductive activity takes place offshore, estuaries may provide shelter for the young to grow thus serving as "nursery grounds" for many species of commercial and recreational importance.

Two decades ago, the then NSW State Fisheries used aerial photographs to prepare a comprehensive set of maps of over 130 estuaries showing the cover of estuarine macrophytes (West *et al.* 1985). These maps, though 20 years old, have been used as planning and management documents for state and local authorities as well as consultants engaged for specific projects (e.g. McEnally and Thompson 1989, Carter 1995).

Our present understanding of the change in cover of estuarine macrophytes in NSW over time is limited. Williams *et al*. (2003) undertook an assessment of change in cover of seagrass for 22 coastal water bodies. While different mapping techniques were used in the assessment, the magnitude of change at some locations reliably indicates that change has occurred (Williams and Meehan 2004, Meehan *et al*. 2005). Where change is detected it should be thoroughly investigated to determine whether it is the result of natural events such as storms (Meehan *et al*. 2005), or human activity.

Along the coast the ambit of the FM Act extends up to mean high tide, and all seagrass and mangrove species in NSW on public water land (intertidal and subtidal land within public ownership) are protected under the Act, and are specifically dealt with as protected marine vegetation. To assist with the conservation of seagrass and other habitats, Estuarine Habitat Management Guidelines were produced by the then NSW Fisheries in the 1980s. In addition, saltmarsh was listed as a Threatened Ecological Community under the NSW Threatened Species Act (NSW Scientific Committee 2004) and there is a legal imperative to monitor its distribution.

The forthcoming rise of sea level is likely to have a significant impact on the distribution of plants that live around and in estuaries. It has been hypothesised that intertidal vegetation, such as saltmarsh and mangrove and submerged vegetation such as seagrass will move further upslope of their present locations, as well as extend further upriver (Vanderzee 1988, Williams 1990, Hughes 2003).

The management of foreshore land around estuaries needs to be cognisant of the values of the habitats as well as of the species that live there. The sustainability of species that are under threat or that could come under threat as human population increases along the coast needs to be directly related to the wise and sustained management of the habitats. In this way the aquaculture, commercial fishing, recreational angling and tourism values of estuaries can be maintained into the future.

NSW DPI contributed to the CCA by assessing the current distribution of estuarine habitats and other related resource issues. Six mapping tasks were undertaken within the two sections of coast identified as the CCA study area. The maps produced from these tasks were assembled as shapefiles within a geographic information system (GIS). Ultimately, these six tasks will provide the building blocks for the creation of a decision support tool relating to the management of estuarine resources of NSW. A seventh task was to investigate ways of integrating complex data layers into a spatially explicit model for NSW estuaries.

Methods and Results

Study Site

The coast of NSW is approximately 1900 km in length (Wilson 1988). It is a high-energy coastline subject to storms from the south and southeast, but with a micro-tidal regime (range <2 m). One consequence of the frequency and intensity of storms is that wave energy prevents the establishment of offshore seagrass beds, open coast mangrove stands, or meadows of saltmarsh. Estuaries, therefore, are the prime home of certain large aquatic plants (macrophytes).

The Great Dividing Range, at a maximum distance of 200 km from the Australian east coast forms the backstop from which the longest of 950 water bodies drain to the Tasman Sea (Williams *et al*. 1998). Of these, the majority (~820) are small, ephemeral streams that flow only during heavy rainfall events. The remainder have more fully developed estuarine characteristics. The total water surface area of the estuaries in NSW is approximately 150,000 hectares, with individual estuaries ranging from two hectares (Mollymook Creek) up to 20,500 ha (the Myall/Karuah/Port Stephens complex; West *et al*. 1985). Of the larger estuaries, 131 have been classified into four major types by Roy *et al*. (2001): 8 drowned river valleys, 54 barrier estuaries, 64 intermittently closed and open lakes and lagoons (ICOLLs) and 5 ocean embayments. A series of mapping and other projects was initiated to provide data layers and to commence the integration of those data layers into a future decision support tool. The 21 estuaries in the Sydney metropolitan region, i.e., from the Hunter River to Lake Illawarra, were not part of the CCA study area.

***Task 1*: Produce aquatic habitat GIS layers for seagrass, mangrove, and saltmarsh**

A fundamental component of the CCA project was to update the earlier maps (West *et al.* 1985) given persistent anecdotal reports of change at sites in some estuaries.

Aerial photographs were scanned, ortho-rectified and resampled to give a final resolution of 1m. A presumptive map of the estuarine macrophytes was then created via onscreen digitising at a scale of 1:1500. The presumptive map was loaded onto a real time mapping system and used in the field for validation of the air-photo interpretation (see Williams *et al*., 2003).

GIS layers for the cover of these vegetation types were then prepared for 125 estuaries. The data were tabulated and estuaries were categorised on the basis of whether gain, loss or no change in cover was seen in relation to the values of West *et al.* (1985). An arbitrary value of 10%, chosen to cater for irregularities in methodology, was used to determine estuaries where a re-evaluation was needed. An estimate of change could not be calculated for estuaries that had no initial area estimate or that were not previously mapped. Change for these estuaries was classified as unknown. Comparisons are presented for each of the 4 identified bioregions in the CCA area of the NSW coast (IMCRA, 1998).

Seagrass was found in 94 of the 125 estuaries surveyed during the CCA study, compared to 91 of the 110 surveyed in the 4 bioregions in the earlier study (West *et al.* 1985). The total area occupied by seagrass increased from 91.5 to 104.2 km^2 (Table 1). Increase in cover was seen at 53 locations, no change (i.e., less than 10%) was detected at 17 locations and a decrease occurred at 43 locations. Change in cover could not be estimated in 13 estuaries. Most of the increase was seen in the Manning Shelf Bioregion, with small increases in the Tweed Moreton and Twofold Bay bioregions. A loss of 3.5km^2 occurred in the Batemans Shelf bioregion.

Mangrove was found in 63 estuaries in the CCA study compared to 60 in the earlier investigation, but the total area increased from 71 to 85 km^2 (Table 2). Unlike seagrass, there was a trend of stability or increase in cover, with expansion seen at 47 locations, no change at 64 locations and a decrease at only 8 locations. Change in cover could not be estimated at 14 locations. Increase occurred in all bioregions, most notably in the Tweed Moreton with an expansion of over 6km^2. Increases of 4km^2 were seen in each of the Manning Shelf and Batemans Shelf bioregions.

Saltmarsh was found in 92 estuaries in the CCA study compared to 89 in the earlier investigation, but the total area increased from 48 to 60 km^2 (Table 3). Sixty seven estuaries demonstrated an increase in cover, whereas no change was seen at 22 locations and a decrease was noted at 22 locations. Change in cover could not be estimated at 13 locations.

Table 1. Change in cover of seagrass in the bioregions of NSW in relation to the amount estimated to be present 20 years ago

Bioregion	Number of estuaries surveyed		Number of estuaries with seagrass		Area of seagrass (km^2)		No. of estuaries showing increase	No. of estuaries showing no change	No. of estuaries showing decrease	Unknown
	West *et al.*	CCA	West *et al.*	CCA	West *et al.*	CCA				
Tweed Moreton	27	29	20	17	2.318	2.606	15	8	5	1
Manning Shelf	16	18	13	15	52.701	67.744	6	4	8	1
Batemans Shelf	54	64	48	50	32.774	29.259	26	4	24	10
Twofold Shelf	13	14	10	12	3.708	4.639	6	1	6	1
Total	**110**	**125**	**91**	**94**	**91.501**	**104.248**	**53**	**17**	**43**	**13**

Table 2. Change in the cover of mangrove in the bioregions of NSW in relation to the amount estimated to be present 20 years ago in NSW estuaries.

Bioregion	Number of estuaries surveyed		Number of estuaries with Mangrove		Area of Mangrove (km^2)		No. of estuaries showing increase	No. of estuaries showing no change	No. of estuaries showing decrease	Unknown
	West *et al.*	CCA	West *et al.*	CCA	West *et al.*	CCA				
Tweed Moreton	27	29	23	24	17.166	23.571	19	7	2	1
Manning Shelf	16	18	13	12	41.601	45.279	9	7	1	1
Batemans Shelf	54	64	19	23	11.614	15.289	17	40	3	11
Twofold Shelf	13	14	5	4	0.916	0.954	2	10	2	1
Total	**110**	**125**	**60**	**63**	**71.297**	**85.093**	**47**	**64**	**8**	**14**

Table 3. Change in the cover of saltmarsh in the bioregions of NSW in relation to the amount estimated to be present 20 years ago in NSW estuaries.

Bioregion	Number of estuaries surveyed		Number of estuaries with Saltmarsh		Area of Saltmarsh (km^2)		No. of estuaries showing increase	No. of estuaries showing no change	No. of estuaries showing decrease	Unknown
	West *et al.*	CCA	West *et al.*	CCA	West *et al.*	CCA				
Tweed Moreton	27	29	25	24	5.529	8.169	18	3	7	1
Manning Shelf	16	18	15	14	31.467	39.77	9	6	2	1
Batemans Shelf	54	64	40	42	9.495	10.324	32	10	11	10
Twofold Shelf	13	14	9	12	1.462	2.000	8	3	2	1
Total	**110**	**125**	**89**	**92**	**47.953**	**60.263**	**67**	**22**	**22**	**13**

***Task 2**: **Produce fishery GIS layers (fishing closures**)*

The management of fishing activities in NSW estuaries is done, in part, by fishing closures created under the legislative provisions of the FM Act. These closures are relevant to commercial fishers, recreational anglers or both. Closures (approximately 480 of them at time of writing) were classically gazetted as written descriptions. The closures within the estuaries of the CCA area, including Recreational Fishing Havens, were mapped and ground-truthed for the first time.

There are two general types of closure within the waters of NSW. Closure type is determined by the manner in which the closure is declared, with one group of closures recognised as permanent waterway fixtures to prevent the use of certain nets or traps or the access of spear fishers. A second group of closures is implemented with more flexibility and these are under Section 8 or Section 11 of the FM Act. The latter are renewed, subject to modification, usually on a five year basis.

Recreational Fishing Havens permanently exclude commercial fishers. There are 30 Recreational Fishing Havens (RFHs) in NSW waters, and they exclude all forms of commercial fishing.

All closures are described in their respective gazettal notices, and these notices are reproduced on the DPI website. With the exception of a few estuaries, however, there are no maps, and hence the spatial extent of one or more closures is difficult to visualise, particularly when one type of closure overlaps another. Each gazettal notice was examined, the boundary markers were located and mapped on GIS layers for individual estuaries and the draft maps were ground-truthed with local Fisheries compliance staff.

Task 3**: **Produce aquaculture GIS layers

The NSW aquaculture industry is worth of the order of $38 million per year and has significant potential to expand. In 1999 the then NSW Fisheries initiated a project to map all of its oyster lease data. At that time there were in excess of 3,000 working leases. At present there are of the order of 2,500 oyster leases in 30 NSW estuaries. The total area under cultivation approximately 3,000 ha. In addition to oyster culture, other types of aquaculture activity adjacent to the estuaries include the land-based industries of prawn and fish farms. The latter two types of activities occur mostly on the far north coast, whereas oyster culture is evenly distributed along the NSW coast.

Oyster lease maps are continually updated, and the most current maps were integrated into this project.

Task 4**: **Differentiate classifications and tenure of aquatic habitats.

Land and water tenure overseen by various state agencies has both direct and indirect capacity to protect aquatic habitat. NSW DPI administers not only fishing closures and aquaculture leases, but also intertidal protected areas, aquatic reserves and marine parks (with DEC). Other agencies, via SEPP 14 wetlands, state forests, national parks and Crown Land reserve, also have an administrative role relating to coastal aquatic resources. These tenure layers were collected and compiled in the GIS.

All data layers were composited to serve two purposes. The first was to provide a general assessment of land that was in the public domain and so provide a conservation function for estuarine habitats and species. The second was to facilitate the construction of a pivot table that could be interrogated in relation to the amount of macrophyte cover that was within public ownership.

***Task 5**: Integrate fish species diversity data (GIS)*

While some regional and local assessments of fish assemblages have been done in NSW estuaries, the resources necessary to conduct whole-of-state assessments of fish diversity have been difficult to obtain. One exception to this is the NSW DPI data set for the fish found along estuarine foreshores from the Queensland to the Victorian borders. These data were obtained during a National Heritage Trust funded biodiversity project (http://www.fisheries.nsw.gov.au/__data/assets/pdf_file/43924/Complete-list-research-projects.pdf - Con2000/005), and were subsequently summarised on an estuary-by-estuary basis and extracted as a table of species lists. The table was incorporated into a geodatabase with links to estuarine water body features. This facilitated an indication of species occurrence per estuary and a comparison of the species that had been caught during sampling with species and populations listed as threatened or protected (e.g., Syngnathids; see Task 6).

***Task 6**: Identify habitat distribution of listed threatened species, populations*

The *FM Act* makes NSW DPI responsible for all species of fish, including sharks and rays, aquatic invertebrate animals and all seaweeds, seagrasses and marine algae. Other aquatic organisms, such as whales, are the responsibility of the Department of Environment and Conservation. The FM Act also has provision for the listing of threatened species, populations and ecologic communities, key threatening processes, and critical habitats.

The list of threatened species, populations, communities and key threatening processes in the FM Act is set out on the NSW DPI website (http://www.fisheries.nsw.gov.au/threatened_species/threatened_species). The geographical distributions of any of the listed species, as known from actual surveys or based on historical information and expert opinion, were mapped in a GIS format.

Six species were found to have a distribution that intersected the coastal catchments covered within the CCA project. The relevant Endangered species are Eastern freshwater cod *(Maccullochella ikei)*, Green sawfish *(Pristis zijsron)* and Oxleyan pygmy perch *(Nannoperca oxleyana)*, while the Vulnerable species are Black Cod (*Epinephelus daemelii)*, Great white shark *(Carcharodon carcharias)* and Macquarie perch *(Macquaria australasica)*. Although some of these fish rarely venture inside estuaries, some of the Protected species (e.g., the Sygnathids) rely heavily, if not exclusively, on estuarine habitats such as seagrass beds. The Oxylean pygmy perch, a freshwater species, is of particular concern in terms of changing landuse patterns in the coastal zone because its distribution is restricted entirely to coastal wallum swamps in the northern portion of the CCA study zone.

Task 7: Data integration

This task was the culmination of the efforts invested in the other tasks. Progressively, GIS layers were integrated to highlight foreshores for which increasing levels of sensitive planning and management were needed for aquatic resources. A preliminary model was created in ArcGIS using the Modelbuilder tool and applied to estuaries of the Far North coast, from the Tweed River to the Evans River inclusive.

The model was run using the mapped estuarine macrophytes (Figure 1), and the following tenure layers: SEPP14 wetlands, National Parks Estate, Crown Reserve and Crown Other, Aquaculture leases, State Forests and Marine Parks. The final output of the preliminary model (Figure 2) has all of the attributes of the associated tenure layers as well as the original macrophyte information. Test outputs from this model suggest that 67% of all estuarine macrophytes within the CCA pilot study area are covered by some level of protective or fixed use tenure.

When fully developed, this model will incorporate aquatic conservation values, take account of threatening processes and identify potential fishery and aquaculture rezoning needs.

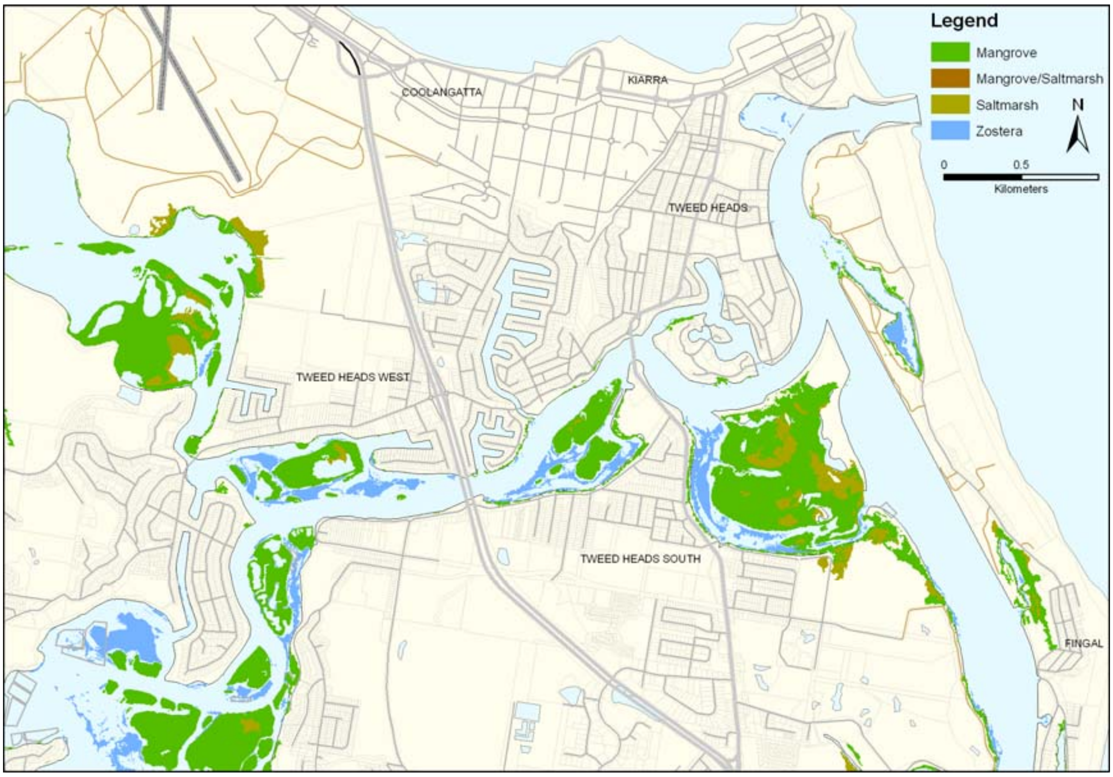

Figure 1. Estuarine macrophytes layer created from digitised ortho-rectified aerial photos.

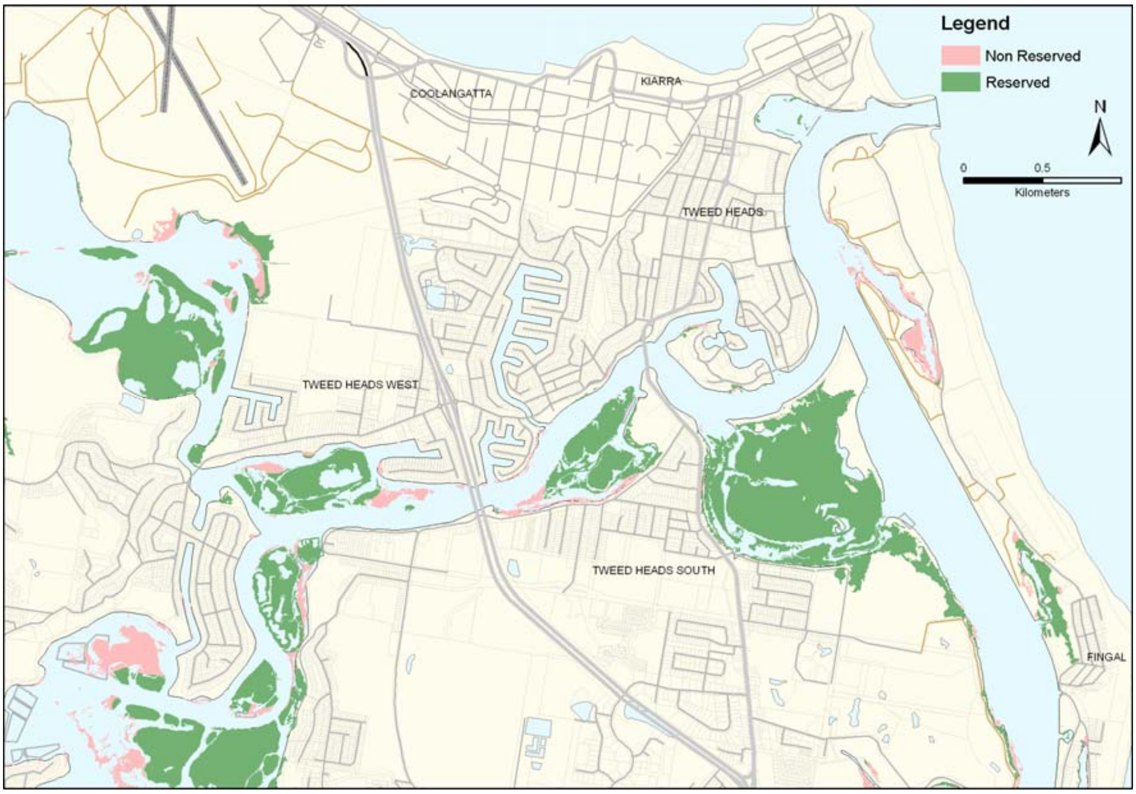

Figure 2. The final result of the preliminary model. All tenure layers are combined with the macrophyte layer to indicate the tenure status of the key estuarine habitats.

Discussion

This study has helped to underline aspects of variability primarily through the comparison of extent of three important habitat types over the past 20 years. While a different analytical technique was applied in the earlier analysis by West *et al*. (1985); (see Williams *et al*. 2003 for procedural details) than is currently used, the older maps provide an invaluable baseline for an assessment at the whole-of-coast scale. Subsequent investigations (e.g. Meehan *et al*. 2005), have indicated a generally high level of accuracy for the former technology, albeit there can be a need for further investigation in some instances.

There appear to have been large changes over the past 20 years (Table 4) and these warrant additional investigation. Loss of cover is considered important in this context: there are 38 estuaries that need to be re-examined for loss of seagrass cover, 20 for loss of saltmarsh and four for mangrove. In contrast, gain of mangrove is considered important in relation to deposition of eroded sediments and for rise in sea level; there were gains in mangrove at 36 estuaries. For some of these estuaries a comprehensive analysis of one or more types of vegetation can be done. As a first step, the aerial photos used by West *et al*. (1985) should be examined and compared to the photos used in this study to ascertain the presence and likely extent of artefacts. From this initial examination a list of estuaries, or where possible, sub-catchments within estuaries, should be created at which large-scale change is obvious. These sites will need to be highlighted within the current planning process. Simultaneously, a more rigorous analysis of the old photos should be commenced with the GIS technique described in this report to confirm the area lost or gained. It might then be necessary to extend the analysis to inspect intermediate dates for which photos exist (or even to earlier decades) to determine the rate at which change has taken place. It is, for example, possible that loss of seagrass has levelled off in recent years, meaning that a different type of management intervention is warranted compared to a steadily declining state. The former situation was described by Williams and Meehan (2004) for Port Hacking.

Table 4. Suggested monitoring requirements for cover of estuarine macrophytes in NSW based on apparent loss of 10% or more of seagrass and saltmarsh, and gain of 10% or more of mangrove in comparison of this study with West *et al*. (1985).

Bioregion	No. of problematic estuaries	Loss of seagrass	Loss of saltmarsh	Gain of mangrove	Loss of mangrove
Tweed Moreton	20	5	5	15	0
Manning Shelf	14	8	2	9	0
Batemans Shelf	36	19	11	11	3
Twofold Shelf	11	6	2	1	1
Total	81	38	20	36	4

It is also important to note that the characteristics of estuaries change through time. For example, rainfall will influence the amount and character of runoff and that will, in turn influence estuarine water quality, particularly salinity. Rainfall is affected by latitude but, over the longer term, is driven by weather cycles occurring at various frequencies. A 50-year drought/wet cycle for southeast Australia was proposed some decades ago (Erskine and Warner 1988), and this cycle appears to be modified by oscillations at the inter-decadal frequency as well as by the Southern Oscillation Index (Cowell 2000). Furthermore, a large proportion of the estuaries in NSW have entrances with variable opening regimes. Where the entrance is intermittently open, it is to be expected that even greater levels of change in habitat features will occur than where an entrance is either naturally permanent or has been modified to be permanently open (Haines *et al*. 2006).

Conclusions

Task 1-Habitat layers

Given that estuarine macrophytes are recognised nationally and internationally as aquatic habitats of very high conservation value, any apparent losses should be thoroughly investigated. Some such losses, particularly for seagrass and saltmarsh, were suggested by the comparison of data collected during this CCA project and those collected 20 years ago. In addition, some detailed time-series analyses have been done for selected estuaries and more are underway (e.g., Meehan *et al*. 2005). A list of "hot spots" should be generated and from it a secondary assessment of sites could be initiated. Ideally, a long-term inventory using all available historical photographs (e.g. Port Hacking, Williams and Meehan 2004) could be prepared for all priority estuaries.

Mangrove is also a habitat of conservation value and there were apparent large gains in cover of this plant at some estuaries. These increases might represent regrowth or might be related to inappropriate land use management where erosion and deposition of sediments has created new substrata on which mangrove can grow. The fact that foreshore protection and rehabilitation has been implemented by Land Care groups and Catchment Management Authorities should help to manage bank side erosion and control the growth of mangrove.

To ensure ongoing protection of estuarine habitats, more regular monitoring of the spatial extent of those habitats would allow data sets to be continually updated. A routine program for monitoring the condition of NSW estuaries, related to the estuarine targets set by the Natural Resources Commission under its Standards & Targets program, clearly warranted.

Task 2-Fishing closures

The current status of fishing closures is complex, with many hundreds mapped in the CCA study area. A more simple array of closures may be warranted to improve compliance and hence to provide better protection for key estuarine habitats. This and other data layers developed during this CCA project would benefit from regular updates so that current information about NSW estuaries is readily available to coastal planners.

Task 3-Aquaculture

Aquaculture in NSW is a viable and growing industry, with substantial controls on its evolution and expansion. The industry must be recognised as dynamic and flexible, and able to adjust to changes in the natural and human-influenced environment.

Task 4-Tenure of land

There is a need to conserve estuarine 'wetlands' comprised of seagrass, mangrove and saltmarsh habitats. Initiatives of the past, such as SEPP 14, have helped manage this need, but boundaries may need to be checked either because they were not accurately described in the first instance or because boundaries can be dynamic and the demarcations of the past may not be appropriate at present. Some parcels of vacant Crown Land are serving a useful purpose as buffers to protect aquatic resources in NSW estuaries.

Task 5-Fish species diversity

Our understanding of the diversity and distribution of fish in NSW coastal catchments is limited, but there are clear indications of the importance of seagrass, in particular, in maintaining estuarine biodiversity. Additionally, estuaries that are intermittently open will have a subset of species compared to those that are permanently open. Further investigations are warranted and the development of robust indicators based on estuarine fish assemblages would greatly assist in monitoring changes in estuarine condition consistent with the Natural Resource Commission's Standards & Targets program.

Task 6-Distribution of threatened species

There are three aquatic species in the Endangered category as defined in the FM Act that can be present within the study area defined by the CCA project. In addition, there are three species listed as Vulnerable, and another eight taxa including marine vegetation are also listed. Some of the habitat of these species may be coincident with non-aquatic species that have been declared under the Threatened Species Act but at present these data sets have not been integrated such that appropriate land use management arrangements can be established. Further efforts to integrate these datasets are warranted, especially for species such as the Oxylean pygmy perch. Again, this should be consistent with the Natural Resource Commission's Standards & Targets program to monitor the status of threatened species, including marine species in estuaries and freshwater species on coastal floodplains.

Task 7-Data integration

Finally, Tasks 1 through 6 provided data layers that can be used as inputs into decision support tools by which to achieve sustainable fishing and aquaculture. OISAS, as well as the Fisheries Management Strategies for estuary-based commercial fishing (Estuary General and Estuary Prawn Trawl), have incorporated the protection of key estuarine habitats as a component of their commitment to long-term ecological sustainability. The data generated in this CCA project will also assist in achieving sustainability objectives.

Nevertheless, it must be understood that estuaries are dynamic entities with variable timeframes of disturbance from natural and man-made stimuli. Furthermore, the respective tasks within this project were variable in terms of robustness and temporal validity. The model developed in Task 7 commenced the process of developing a viable support tool for future coastal planning, but needs further refinement to incorporate temporal uncertainty. This could be done in conjunction with other modelling initiatives being undertaken or planned along the NSW coast (e.g., the Coastal Lakes Assessment Tool, and NSW DPI/CSIRO's sustainable coastal development project).

Overall planning issues

The continued presence and health of seagrass, mangrove and saltmarsh is so important that their conservation and management needs to be adopted as a fundamental planning principle for coastal NSW. That the cover of these plants is dynamic means they have to be adaptively managed, particularly in light of fluctuations in human population density along the coastal margin of NSW and the likely rise in sea level in decades to come. Strengthening the relevant legislation as well as updating DPI's Fisheries Habitat Management Guidelines would provide a sound basis for this sort of adaptive management. Fortunately, some tracts of Crown Land currently protect aquatic estuarine resources but more could be done. Future planning should consider the need for minimum foreshore setbacks to ensure that land development does not encroach too closely onto estuarine foreshores.

References

Bell, F.C. and A.R. Edwards (1980). An environmental inventory of estuaries and coastal lagoons in New South Wales. Report by the Total Environment Centre, Sydney, NSW. 187 pp.

Butler, A.J. and P. Jernakoff. (1999). Seagrass in Australia: Strategic Review and Development of a R & D Plan. CSIRO Publishing, Collingwood, Vic. 210 pp.

Carter, S. (1995). Coastal Resource Atlas for Oil Spills from Crowdy Head to Port Stephens. Report of the Environment Protection Authority of New South Wales, Sydney, NSW. 87 pp.

Cowell, P. (2000). Bondi Beach Volleyball Stadium Impacts Review. Unpublished report to the Sydney Olympics Committee.

Erskine, W.D and R.F. Warner. (1988). Geomorphic effects of alternating flood- and drought-dominated regimes of New South Wales coastal rivers. Chapter 11 in Warner, R.F. (Ed.) *Fluvial Geomorphology in Australia*. Academic Press, Australia, pp. 223-244.

Haines, P.E., R.B. Tomlinson and B.G. Thom. (2006). Morphometric assessment of intermittently open/closed coastal lagoons in New South Wales, Australia. *Estuarine, Coastal and Shelf Science* 67: 321-332.

Henry GW, Lyle JM (Eds) (2003) 'The national recreational and indigenous fishing survey.' Final report to FRDC, Report No. 99/158 (NSW Fisheries: Sydney)

Hughes, L. (2003). Climate change and Australia: Trends, projections and impacts. *Austral Ecology* 28: 423-443.

IMCRA (1998). Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments, Version 3.3. Environment Australia, Commonwealth Department of the Environment. Canberra.

Laegdsgaard, P. (2001). *A Field Guide for Identification and Monitoring of the Seagrasses and Macroalgae in Wallis Lake*. Centre for Natural Resources, Parramatta, NSW. 60 pp.

Lear, R. and T. Turner. (1977). *Mangroves of Australia*. University of Queensland Press, St. Lucia, Qld. 84 pp.

McEnally, J.M. and G.B. Thompson. (1989). Coastal Resource Atlas for Oil Spills in and around Port Kembla. Report of the New South Wales State Pollution Control Commission. Sydney, NSW. 32 pp.

Mazumder, D., N. Saintilan and R.J. Williams. (2005a). Temporal variations in fish catch using pop nets in mangrove and saltmarsh flats at Towra Point, NSW, Australia. *Wetlands Ecology and Management* 13: 457-467.

Mazumder, D., N. Saintilan and R.J. Williams. (2005b). Comparison of fish catches using fyke nets and buoyant pop nets in a vegetated shallow water saltmarsh flat at Towra Point, NSW. *Wetlands (Australia)* 23:37-46.

Mazumder, D., N. Saintilan and R.J. Williams. (2005c). Fish assemblages in three tidal saltmarsh and mangrove flats in temperate NSW, Australia: a comparison based on species diversity and abundance. *Wetlands Ecology and Management*.

Mazumder, D., N. Saintilan and R.J. Williams. (2006). Trophic relationships between itinerant fish and crab larvae in a temperate Australian saltmarsh. *Marine and Freshwater Research* 57: 193-199.

Meehan, A.J., R.J. Williams and F.A. Watford. (2005). Detecting trends in seagrass abundance using aerial photograph interpretation: problems arising with the evolution of mapping methods. *Estuaries* 28: 462-472.

NSW Scientific Committee. (2004). Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions - endangered ecological community listing-final listing. (Ed. L. Hughes). Department of Environment and Conservation (NSW). 5pp.

Roy, P.S., R.J. Williams, A. Jones, B. Coates, P. Gibbs, P. Scanes, J. Hudson, and S. Nicol. (2001). Structure and function of estuaries in southeast Australia. *Estuarine, Coastal and Shelf Science* 53: 351-384.

Vanderzee, M.P. (1988). Changes in saltmarsh vegetation as an early indication of sea-level rise. In: Pearman, G.I. (ed.) *Greenhouse: Planning for Climate Change*. CSIRO, Melbourne. pp. 147-160.

West, R.J., C.A. Thorogood, T.R. Walford and R.J. Williams. (1985). An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2. Department of Agriculture, New South Wales. 140 pp.

Williams, R.J. (1990). Projecting a Greenhouse rise in sea level on saltmarsh and mangrove habitats in New South Wales. *Wetlands (Australia)* 10: 15-19.

Williams, R.J. and A.J. Meehan. (2004). Focusing management needs at the sub-catchment level via assessments of change in the cover of estuarine vegetation, Port Hacking, NSW, Australia. *Wetlands Ecology and Management* 12: 499-518.

Williams, R.J., A.J. Meehan and G. West. (2003). Status and trend mapping of aquatic vegetation in NSW estuaries. In (Woodroffe, C. D. and Furness, R. A., eds.) Coastal GIS 2003: an integrated approach to Australian coastal issues, Wollongong Papers on Maritime Policy, No. 14, pp. 317-346.

Williams, R.J., Watford, F.A. and Button, M. (1998). New South Wales coastal aquatic estate. *Wetlands (Australia)* 18: 25-48.

Wilson, J. (1988). *New South Wales Year Book*. Australian Bureau of Statistics. Sydney.

Managing for Climate Variability in the Sydney Region – Issues, needs and new solutions for Local Government.

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Abstract

Coastal research and management often has an issue-specific focus, with little attention paid to the interdependencies between them. Climate variability is one such issue that is impacted by, and impacts on, several other areas (eg. coastal processes, infrastructure, health, and regional economies). These interdependencies create challenges for local councils to scale-up so as to tackle these issues at a regional scale. Critical to this process of scaling-up is the adaptive capacity of local councils. In order to support local councils in the Sydney region to deal with the impacts of climate variability and change, the Sydney Coastal Councils Group and CSIRO have begun a project through the Australian Greenhouse Office National Climate Change Adaptation Program ("Systems Approach to Regional Climate Change Adaptation Strategies in Metropolises"), which will run over the next 2 years. The goal of this project is to work with local councils to determine key vulnerabilities and their capacity to adapt in order to manage these risks at a regional scale. The project approach will be tested to allow transfer to other regions throughout Australia.

Introduction

As part of the Australian Greenhouse Office (AGO) National Climate Change Adaptation Program, the Sydney Coastal Councils Group (SCCG) have partnered with two CSIRO Divisions (Sustainable Ecosystems, and Marine and Atmospheric Research) to undertake research on regional approaches to managing climate vulnerability in the Sydney region. The project was scoped over the last 18 months following interest in systems approaches to the management of climate variability in the Sydney region by local governments, which was documented in a paper presented at the 2005 NSW Coastal Conference (Smith *et al.*, 2005). The project has recently commenced and will be completed over the next 2 years. This paper discusses: (i) the AGO Adaptation Program; (ii) planned research activities; (iii) key concepts and issues to be addressed; (iv) potential benefits to local government; and (v) the next steps for the project.

Australian Greenhouse Office National Climate Change Adaptation Program

At the national level, Australia's efforts to assess the implications of climate change and facilitate the implementation of adaptation strategies are largely initiated through the National Climate Change Adaptation Programme (NCCAP). This four year (2004-2008), $14.2 million program is an initiative of the Australian Greenhouse Office within the Department of Environment and Heritage. The three expressed goals of the programme are,

- help Australians understand the likely impacts of climate change
- develop practical tools to support decision making on climate change adaptation
- assist in planning ahead to reduce the risks and capture opportunities.

To date, a range of projects and activities have been executed under the NCCAP including national scoping assessments of climate change vulnerability, which have been followed in some instances by more focused, sector-specific assessment projects. A number of guidance documents have also been generated to build understanding with regards to the costing of climate change impacts and the application of risk management approaches to ameliorate adverse consequences. The Sydney regional integrated assessment project is one of a portfolio of regional climate change assessment projects recently funded through the NCCAP. Other study areas include the Clarence City Council, TAS; Gold Coast, QLD; Western Port, VIC; and the ACT. Each of these studies is being developed and carried out independently, with each seeking to address a different suite of issues based upon the interests and concerns of local stakeholders.

Planned Activities

Over the course of almost two years, the Sydney integrated assessment project will seek to inform the region's coastal councils regarding the potential biophysical changes that climate change may cause in the region, with subsequent emphasis on examining local capacities to adapt to potential climate change impacts. These activities will be carried out in a series of stages: i) vulnerability mapping, ii) stakeholder consultation; iii) assessment of adaptive capacity; iv) project assessment. Each of these activities is discussed further below.

Vulnerability Mapping

In order to provide an initial basis for awareness raising and discussion, a vulnerability mapping exercise will be conducted for the Sydney region. This vulnerability analysis will utilise existing and emerging modelling outputs from CSIRO and other relevant projects (e.g. UPRCT project) and present them as simple spatial overlays that can be integrated with local contextual knowledge regarding infrastructure, networks, and systems that are likely to be exposed and adversely affected by climate change.

Sound planning and management of the coastal zone in a future that is affected by a changing climate requires knowledge on how relevant geophysical parameters are likely to vary. For the coastal zone, such parameters include sea levels, severe weather conditions, rainfall, wind and wave climate and their subsequent impacts on erosion and flooding. Hennessy et al. (2004a,b) undertook a comprehensive general assessment of how the climate of NSW may change in the future based on the analysis of a range of climate model simulations. The overall findings were for a future that would be warmer, drier and for which extreme weather conditions may increase. As part of the present study, a set of projections that are particularly relevant to the coastal zone will be developed in support of the broader project.

An investigation of the key weather systems responsible for extreme winds, rainfall, and storm surges on the NSW coast in high resolution climate model simulations under present and future greenhouse gas forcing will be undertaken using a synoptic map-typing procedure to characterise the weather systems and examine how they may change in the future. Previous studies of wind changes over the southern NSW coastal region indicated that winds would increase in summer and winter whereas the central and north coast tended towards decrease in summer and winter under enhanced greenhouse conditions. In the present study, there will be a greater focus on wind directional changes to determine if there are systematic changes to the wind climate as a result of climate change.

These data regarding the potential implications of climate change on the physical climate system of the Sydney coastal region will subsequently be integrated within a geographic information system with data that convey the spatial diversity in vulnerability to climate change. Such data include the region's topography, land use, and the locations of critical infrastructure and high-value assets (e.g., property, ecosystems, and heritage sites) as well as socioeconomic indicators. The integrated vulnerability maps will subsequently serve as a risk communication tool for engaging stakeholders about climate change impacts and adaptation.

Stakeholder Engagement

As the goal of this integrated assessment project is to assess and facilitate adaptive capacity within local governments, a series of workshops will be conducted to bring climate change experts together with local governments to explore local vulnerabilities to climate change, analyse their capacity to adapt to climate change and the factors determining or influencing that capacity. In order to focus stakeholder interactions on local concerns and vulnerabilities, separate workshops will be conducted in each of the 15 councils within the Sydney Coastal Council Group.

Analysis of Adaptive Capacity

Following the stakeholder workshops, three local councils will be chosen as case studies of local council adaptation to key issues that emerged from the regional and local workshops (e.g. water, infrastructure/asset protection, public health). The three case studies will include councils that have identified that they are either: (i) doing well in terms of implementing adaptation strategies; (ii) doing average in terms of implementing adaptation strategies; or (iii) doing poorly in terms of implementing adaptation strategies. The analysis of adaptive capacity will highlight potential barriers to adaptation and allow recommendations to be made to councils on how to improve their adaptation processes.

Project Assessment

Though focused on the Sydney coastal region, it is hoped that the lessons learned regarding climate change adaptation in local government will be readily transferable to other areas within Australia. Therefore, a central component of the project is to evaluate the overall process of communicating climate risk and interacting with stakeholders to develop some generalisable principles. In particular, the project seeks to better understand the communication and decision-making networks within local governments through which adaptation decisions must travel and the endogenous and exogenous barriers to effective adaptation.

Key Concepts and Issues to be Addressed

Integration

'Integration" has become a guiding principle across a number of natural resource management spheres, including Integrated Coastal Zone Management. Integrated resource management is an evolving concept. Elements of its underlying philosophy are that there are no simple or short-term solutions; that no single perspective is adequate to deal with complex resource use issues; that problems are beyond the scope of purely technical solutions; and that managing change in natural resource use is a long-term process involving the continuing integration of community action and statutory, policy and institutional adjustments (Bellamy *et al.* 1999).

The move towards integration has also been apparent in climate change assessments. This has significantly increased the potential analytical power of studies, but has consequences in terms of size, cost and complexity. Large climate change research programmes in the US have found that integrative research on complex sustainability issues is best carried out in a place-based context, because the local scale facilitates assessment as a social process and promotes exchanges of information and understanding between investigators and stakeholders (Wilbanks 2002).

Two defining features of Integrated Assessments are that they reach beyond the bounds of a single discipline, and address more than one sector or aspect of the problem, and that their purpose is to inform policy and decision making (Tansey *et al.* 2002). Integration can refer to disciplines, sectors, scales, or methodological approaches. One of the frontiers of integrated assessment is transcending the boundary between quantitative analysis on the one hand and non-quantitative aspects of the assessment on the other- by including expert judgement, narrative stories, scenarios, and stakeholder knowledge (Wilbanks 2002).

Regions

In Australia, regions have emerged as a key scale at which to address natural resource and ecosystem management problems. Regions have imprecise geographic boundaries defined by factors such as clusters of local government areas, water catchments and historically identified regions. It is a scale at which new issues often emerge, and at which a range of institutions can begin to coordinate to address complex issues that cut across existing institutional responsibilities. Regional scale governance is often focused on networking, coordination and strategic planning; however formal regional scale organisation and institutions are also emerging. As such regions are a key focus for societies adaptive capacity, and are important in dealing with cross scale effects, and linking local issues with state and federal government.

Adaptive Capacity

The Millennium Assessment defined adaptive capacity as "The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences." Adaptive capacity is important in dealing with complex human ecological systems where limited foresight is possible and their behaviour is characterised by abrupt changes of unknown nature. Given the uncertainty involved, assessing and improving adaptive capacity is obviously an inexact exercise. For a region adaptive capacity will have many elements, including the ability to identify and articulate the issues, values and groups affected by novel event, the capacity to effectively research and understand new issues, and the ability to adapt the organisation of society to effectively address them. All of these elements can involve long lag times and therefore limit adaptive capacity. A broad- systemic assessment of capacity is therefore required. Improved frameworks for characterising the behaviour of complex adaptive systems, and developing improved management strategies, such as Resilience thinking (Walker and Salt 2006) are also important in improving our capacity to mange these systems.

The importance of adaptation to climate change has been recognized by both Australian Commonwealth and State governments. In addition to the $14.2 allocated by the Commonwealth via the NCCAP, $2.5 million has been allocated in NSW towards an impacts and adaptation research programme, with a further $2 million planned for capacity building for climate change (NSW Greenhouse Office 2005).

The coastal zone has historically been the focus of many climate change studies, because early climate change projections highlighted the possibility of sea level rise and its associated physical and economic impacts. One of the earliest methodologies for assessing the implications of climate change was the *IPCC Common Methodology for the assessment of the vulnerability of coastal areas to sea level rise* (IPCC 1991). Reviews of the many studies that followed this framework uncovered several important weaknesses. These included the need to reflect local differences, to consider the wider socio-economic, traditional, aesthetic and cultural aspects of a study area, and to integrate the results of the analysis into local environmental planning processes (Yamada *et al.* 1995; Kay *et al.* 1996; Klein and Nicholls 1999).

Whereas in the past many climate change studies took a simplistic approach to adaptation, generating a list of possible adaptation measures with little or no consideration of the process by which communities could implement them, current adaptation research falls within the domain of ‘sustainability science’ (Kates *et al.* 2001). This new direction, or second generation of adaptation studies (Burton *et al.* 2002), considers the localised social and economic conditions that contribute to vulnerability, together with the extent to which a society copes with its current climate. Adaptive capacity refers to the ability of a system to adjust to climate change and variability to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (McCarthy *et al.* 2001). It is, however, a complex concept, involving many elements such as social capital, institutional memory, creativity, and resilience.

In practical terms, adaptive capacity is a function of a number of factors:

- Recognition of the need for adaptation;
- Belief that adaptation is possible and desirable;
- Willingness to undertake adaptation;
- Availability of resources necessary for implementation of adaptation strategies;
- Ability to deploy resources in an appropriate manner; and
- External constraints on, or obstacles to, the implementation of adaptation strategies. (Adger *et al.* 2004)

The current project will investigate adaptive capacity in the Sydney Coastal Councils region by looking closely at a number of these aspects.

Changing Role of Science

Adaptation to climate change is an area in which scientists are required to focus on problem solving in regional and local contexts. The need for close interaction between scientists and the public has not been central to climate change science but has been a common theme in other areas such as forestry and integrated catchment management. Experience within these fields, particularly with forestry debates in the US, shows that working within the science-policy interface is a highly politicized exercise, where issues are often about different ends rather than means (Clark *et al.* 1998; Mills and Clark 2001). A closer interaction between scientists and the public can be both positive and negative. Participatory processes can lead to greater demands for certainty, making scientists more risk-adverse and challenging the freedom to engage in the self-examination that is the essence of scientific enquiry (Bradshaw and Borchers 2000). In contrast, public perceptions of the value and credibility of science may be higher if it is regionally specific and provided by local experts in the context of sustained interaction, good communication and trust (Bales *et al.* 2004). The term ‘post-normal science’ (Funtowicz and Ravetz, 1991; Ravetz, 1999) has been used to describe scientific approaches that acknowledge uncertainty; recognise the value-laden nature of research; and approach research in a participatory manner to achieve shared objectives.

Local government partnering with research organisations (eg. CSIRO)

Despite the complexity involved, taking a regional approach to adaptation to climate change is useful for a number of reasons. Some regions are more affected by climate change than others due to the negative synergies between climate change and other stressors; many practical adaptation strategies will be applied at a regional rather than sectoral scale; and two or more vulnerable sectors may be important to a particular region, with the risks and vulnerabilities of the region depending on the cumulative effect of climate change on a number of sectors (Allen Consulting Group 2005).

Although many past climate change impact studies have focussed on particular sectors (e.g. Howden *et al.* 1999; Hennessy *et al.* 2003; Howden *et al.* 2003; Hennessy *et al.* 2005), CSIRO has recently undertaken a number of projects that aim to facilitate adaptation at a regional scale and build capacity among local government stakeholders. In conjunction with the Victorian Department of Sustainability and Environment, CSIRO is undertaking a series of pilot studies in three Victorian regions: Gippsland, Western Port, and North Central Victoria. These studies are aiming to more fully integrate adaptation to climate change, by treating adaptation as a component of regional sustainability. They are seen as pilot studies because there is no established methodological approach to understanding and building adaptive capacity at a regional scale.

In the Western Port study, stakeholders assessed their own respective vulnerabilities and priorities for adaptation. Whereas in the past, such assessments were the result of a top-down analysis that showed where the biophysical impacts of climate change were greatest, this study recognised that vulnerability was a function of the sensitivity to various aspects of climate, and also of the localised capacity to adapt to it. Although scientific information on climate change impacts was presented to the workshop participants, they assessed the climate sensitivity of their areas of interest based on their local knowledge. They also considered how capable they were of adapting to future climate change in these areas. Based on the output of a number of workshops and sub-groups, 8 high-priority cross-sectoral issues were identified. Two of these issues are due to be investigated further in a larger integrated assessment of the Western Port region, funded by the Australian Greenhouse Office.

What's in it for Local Government?

Understanding issues such as climate vulnerability through a systems approach can highlight both the direct and indirect drivers of change; as well as, the direct and indirect consequences of those changes. This understanding can uncover key management interventions that may have far reaching positive impacts, and at the same time highlight unintended negative consequences of current or alternative management actions. However, while a systems approach to understanding where to make management interventions is critical, an understanding of the adaptive capacity of local government to effectively implement and monitor those interventions is also needed. This project seeks to actively work with local councils to gain a better understanding of both systematic issues associated with climate vulnerability; as well as, understanding barriers and opportunities to improving the adaptive capacity of those local councils.

Call for Input

Apart from the workshops being planned with Sydney councils, the project team are interested in documented case studies of local council initiatives to deal with climate vulnerability. If your council has relevant information please contact Geoff Withycombe at the Sydney Coastal Councils Group.

Conclusions

SCCG and CSIRO have begun a 2-year project through the AGO Adaptation Program. The project is focused on climate vulnerability in Sydney, and the adaptive capacity of local councils to scale-up to deal with regional issues. The project also explores key themes of systems approaches to climate vulnerability; integration; and partnering for science impact. The project will be rolled out through a series of workshops with local councils to determine climate vulnerability and barriers and opportunities to adaptive capacity. The project will have substantial benefits to understanding the direct and indirect consequences of management actions and the barriers and opportunities to successfully implementing those actions for local governments in the Sydney region and throughout Australia.

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References

Abbs, D. J., S. Aryal, E. Campbell, M. Palmer, A.S. Rafter, and B. Bates, 2006: Impact of climate variability and climate change on rainfall extremes in Western Sydney and surrounding areas. Phase 1 report to the Upper Parramatta River Catchment Trust. 66 pp. http://www.cmar.csiro.au:8000/e-print/open/abbsdj_2006a.pdf

Adger, W. N., Brooks, N., Bentham, G., Agnew, M., and Eriksen, S. (2004). "New indicators of vulnerability and adaptive capacity." Technical report 7, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich.

Allen Consulting Group. (2005). "Climate Change: Risk and Vulnerability: Promoting an Efficient Adaptation Response in Australia." Report to the Australian Greenhouse Office, Department of Environment and Heritage, Canberra.

AGO (Australian Greenhouse Office) (2005). National climate change adaptation program. Department of the Environment and Heritage, Canberra, Commonwealth of Australia, 6 pp. http://www.greenhouse.gov.au/impacts/publications/pubs/nccap.pdf

Bales, R. C., Liverman, D. M., and Morehouse, B. J. (2004). "Integrated assessment as a step toward reducing climate vulnerability in the Southwestern United States." *Bulletin of the American Meteorological Society*, 85(11), 1727-1734.

Bellamy, J. A., McDonald, G. T., Syme, G. J., and Butterworth, J. E. (1999). "Evaluating Integrated Resource Management." *Society & Natural Resources*, 12(4), 337-353.

Bradshaw, G. A., and Borchers, J. G. (2000). "Uncertainty as information: Narrowing the science-policy gap." *Conservation Ecology*, 4(1), 7.

Burton, I., Huq, S., Lim, B., Pilifosova, O., and Schipper, E. L. (2002). "From impacts assessment to adaptation priorities: the shaping of adaptation policy." *Climate Policy*, 2(2-3), 145-159.

Clark, R. N., Meidinger, E. E., Miller, G., Rayner, J., Layseca, M., Monreal, S., Fernandez, J., and Shannon, M. (1998). "Integrating science and policy in natural resource management: Lessons and opportunities from North America." Report no PNW-GTR-441, US Forestry Service, Pacific Northwest research station.

Funtowicz, S. O. and Ravetz, J. R. (1991). "A new scientific methodology for global environmental issues", In Costanza, R. (ed.), *Ecological Economics: The Science and Management of Sustainability*, pp. 137-152. Columbia University Press, New York.

Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R., and Ricketts, J. (2005). "Climate change impacts on fire-weather in south-east Australia." Climate Impacts Group, CSIRO Atmospheric Research and the Australian Government Bureau of Meteorology, Aspendale.

Hennessy, K. J., Page, C. M., McInnes, K. L., Jones, R. N., Bathols, J. M., Collins, D., and Jones, D. (2004). Climate change in New South Wales. Part 1, Past climate variability and projected changes in average climate. Consultancy report for the New South Wales Greenhouse Office. Aspendale: CSIRO Atmospheric Research. 46 p. http://www.cmar.csiro.au/e-print/open/hennessy_2004b.pdf

Hennessy, K., Whetton, P., Smith, I., Barthols, J., Hutchinson, M., and Sharples, J. (2003). "The impact of climate change on snow conditions in mainland Australia." CSIRO Atmospheric Research, Aspendale.

Howden, M., Hughes, L., Dunlop, M., Zethoven, I., Hilbert, D. W., and Chilcott, C. (2003). "Climate change impacts on biodiversity in Australia. Outcomes of a

workshop sponsored by the Biological Diversity Advisory Committee, 1-2 October, 2002." CSIRO Sustainable Ecosystems, Canberra.
Howden, S. M., Reyenga, P. J., and Meinke, H. (1999). "Global Change Impacts on Australian Wheat Cropping." Report to the Australian Greenhouse Office. Working Paper series 99/04, CSIRO Resource Futures program, Canberra.
IPCC. (1991). "The seven steps to the assessment of the vulnerability of coastal areas to sea level rise: A common methodology." Intergovernmental Panel on Climate Change Response Strategies Working Group, The Hague.
Kates, R. W., Clark, W. C., Corell, R. J., Hgall, M., Jaeger, C. C., Lowe, I., McCarthy, J. J., Schellnhuber, H. J., Bolin, B., Dickson, N. M., Faucheux, S., Gallopin, G. C., Grubler, A., Huntley, B., Jager, J., Jodha, N. S., Kasperson, R. E., Mabogunje, A., Matson, P., Mooney, H. A., Moore, B., O'Riordan, T., and Svedin, U. (2001). "Sustainability science." *Science*, 292(5517), 641-642.
Kay, R. C., Eliot, I., Katon, B., Morvell, G., and Waterman, P. (1996). "A review of the Intergovernmental Panel on Climate Change's common methodology for assessing the vulnerability of coastal areas to sea-level rise." *Coastal Management*, 24(2), 165-188.
Klein, R. J. T., and Nicholls, R. J. (1999). "Assessment of coastal vulnerability to climate change." *Ambio*, 28(2), 182-187.
McCarthy, J., Canziani, O. F., Leary, N. A., Dokken, D. J., and White, K. S. (2001). "Climate change 2001: Impacts, adaptation, and vulnerability." Third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
Millennium Ecosystem Assessment (no date). "Strengthening Capacity to Manage Ecosystems Sustainably for Human Well-Being". www.millenniumassessment.org/en/index.aspx, last accessed 12th October 2006.
Mills, T. J., and Clark, R. J. (2001). "Roles of research scientists in natural resource decision making." *Forest Ecology and Management*, 153(1-3), 189-198.
NSW Greenhouse Office (2005) NSW Greenhouse Plan. The Cabinet Office of the Government of NSW, Sydney.
Page, C. M., and R. N. Jones. (2001). "OzClim: the development of a climate scenario generator for Australia." Ghassemi, F., P. Whetton, R. Little, and M. Littleboy, eds., Integrating models for natural resources management across disciplines, issues and scales (Part 2). MODSIM 2001, International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, Canberra, Aust., 667-672.
Ravetz, J. R. (1999). "What is post-normal science?", *Futures*, 31, pp. 647-653.
Smith, T. F., Preston, B., McInnes, K. and Withycombe, G. (2005). "A Systems Approach to Coastal Research and Management." Proceedings of the 14th NSW Coastal Conference: Living on the Edge, 8-11 November, 2005, Narooma, NSW.
Tansey, J., Carmichael, J., VanWynsberghe, R., and Robinson, J. (2002). "The future is not what it used to be:participatory integrated assessment in the Georgia Basin." *Global Environmental Change*, 12(2), 97-104.
Walker, B. and Salt, D. (2006). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press.
Wilbanks, T. J. (2002). "Geographic scaling issues in Integrated Assessments of climate change." *Integrated Assessment*, 3(2-3), 100-114.
Yamada, K., Nunn, P. D., Mimura, N., Machida, S., and Yamamoto, M. (1995). "Methodology for the assessment of vulnerability of South Pacific island countries to sea-level rise and climate change." *Journal of Global Environment Engineering*, 1, 101-125.