Consultation draft

NSW Coastal Management Manual

Part C: Coastal Management Toolkit

A guide to managing estuary ecosystems

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1. Introduction

This guide has been prepared to help councils and their communities care for their local estuaries.

Estuaries are semi-enclosed waterbodies with open or intermittently open connections with the ocean. NSW estuaries vary in their shape and size, ranging from large coastal embayments and drowned river valleys such as Port Stephens and the Hawkesbury River, to coastal lakes such as Lake Macquarie and Wallis Lake and the smaller intermittently open coastal lakes and lagoons such as Manly Lagoon and Tabourie Lake. With this variation in physical form comes a variety of estuarine processes and ecosystems.

It is important that estuaries are actively managed as they are valued by local communities for the many commercial, cultural, tourism and recreational services they provide. Collectively, these benefits are known as ecosystem services. The health of the estuarine ecosystem is one of the key factors that determines if community uses and values, including aquaculture, fishing, boating and swimming, will be met. The way we use and manage estuaries can affect how they function and their overall health.

The health of an estuarine ecosystem is often referred to as its 'condition' or 'state'. Information on the 'condition' or 'state' of an estuary allows us to plan and respond when needed to protect or improve estuary health and where community expectations that are determined by estuary health are not being met. In simple terms ecosystem health will be determined by the dominant processes and their interactions, the influence of pressures and stressors, their magnitude and the system's ability to adapt and respond to any changes caused by them.

This guide provides advice on assessing and managing estuary ecosystem health as part of a coastal management program. A coastal management program should identify proposed actions to be implemented by a council, other public authorities and potentially by the private sector to address priority management issues in the coastal zone.

An integrated approach to managing estuary ecosystem health and community values is recommended, this includes:

- estuary ecosystem health assessment
- understanding pressures on estuary ecosystems
- managing threats to estuary ecosystems
- estuary ecosystem health monitoring.

Where an estuary is an intermittently open and closed lake and lagoon (ICOLL), there may be a number of specific issues related to entrance management. As such this guide also provides advice on ICOLL entrance management (Section 8).

2. Estuary ecosystems

A healthy estuary can be thought of as an ecosystem with its various components (biological, physical and chemical) operating effectively to maintain a functioning system within the limits of natural variability. It should also be resilient to some level of stress (Rapport *et al*., 1998). The condition of one estuary may naturally be quite different to another as the morphology, dominant processes and interactions vary between estuary types.

Just like a human body there are numerous attributes that contribute to being healthy, and often it is the symptoms of being unwell that attract attention. As such an assessment of estuary health should firstly focus on the ecology (e.g. algal biomass, turbidity or seagrass

beds) to determine the ecosystem's health rather than pressures that may or may not be the cause of problems (Fairweather *et al.*, 1999).

Determining the ecosystem health status of the estuary or estuaries will include:

- a description of the key components of the estuarine ecosystem (Section 2.1) and the key biological, physical and/or chemical processes and interactions so as to understand how the ecosystem functions (Section 2.2)
- a description of the key pressures impacting on estuarine processes and the nature of their influence on estuary ecosystem health and community uses and values. Pressures will include both anthropogenic (including waterway and catchment activities, climate change) and natural (including flood and drought) (Section 3)
- a description of the resilience and/or vulnerability of the estuary to pressures, an understanding is required to provide a sound basis for designing management actions and understanding their effects (Section 3.3)
- an assessment of current estuary ecosystem health. This should include determining objectives for ecosystem health and community uses (see Section 4.1), evaluation of indicators (Section 4.2) against relevant criteria or values (Section 4.3) and targets that set the outcomes sought from implementing management actions (Section 4.4).
- identification of priority threats and pressures on estuary health that can reasonably be addressed (see Section 5), through the development of management actions (Section 6).

The estuary health status can also act as a benchmark against which changes in condition can be assessed through an ongoing estuary health monitoring and reporting program (Section 7). Periodic assessments of estuary health supports the review and update of a coastal management program and can provide input to other processes such as State of the Environment reporting.

A scoping exercise and/or literature and information review may have been carried out prior to an estuary ecosystem health assessment. These studies will have identified available information to be used in assessing estuary health or critical data gaps that need to be addressed prior to progression of a coastal management program. Similarly, if the community's values for the estuary and their issues associated with its management have not been identified, community consultation may also be required prior to progression of the plan.

Where little information is available, or able to be collected, information from other estuaries in NSW with similar attributes may inform the assessment. A number of classification schemes that group similar estuaries exist for NSW estuaries. Including classification schemes based on geomorphology and evolution (e.g. Roy *et al*. 2001), response to stressors such as the response of phytoplankton to increased nutrients (Roper *et al.* 2011), the management framework for coastal lakes in NSW (HRC, 2002) and condition assessments and estuary typology (NLWRA, 2002).

Estuary information, data and tools that may assist in assessing estuary ecosystem health and designing management actions are listed in Section 9.

2.1 Key components of the estuarine ecosystem

A description of the key components of the estuarine ecosystem should include an overview of the estuary, including.

- the key physical features of the estuary (e.g. estuary extent, area and volume, catchment area, geomorphological type, entrance configuration and evolutionary history)
- the key ecological attributes of the estuary that contribute to its overall structure and function. This can be done in a number of ways, including defining:

- physical zones (e.g. benthic, demersal, pelagic, intertidal, littoral etc.),
- salinity zones (e.g. freshwater, brackish, estuarine, marine),
- habitat types (e.g. open water, unvegetated bed sediment, saltmarsh, mangroves, seagrass beds, intertidal sand and mud flats, beaches etc.) or biota present (e.g. submerged aquatic vegetation, fish species, benthic species etc.) and/or
- geomorphic zones (e.g. marine tidal delta, central mud basin, fluvial delta, riverine channel).

2.2 Key processes and interactions

Numerous processes interact within and around estuaries. They include physical, biological, chemical, social and economic processes. Interactions between processes determine the form and function of estuarine ecosystems and the key threats and risks to estuary ecosystem health and community values.

For example, various processes will determine the magnitude and fate of nutrients exported from catchments. These processes include catchment land use (determining the loads to the estuary), physical dynamics (such as residence times and flushing), biogeochemistry (including nutrient cycling) and primary production (including uptake by benthic algae, phytoplankton and macroalgae).

A range of processes should be considered in understanding and managing estuaries. The relevant processes and the level of understanding will vary according to estuary type and the pressures on estuary health to be addressed. These processes include, but are not limited to:

- tidal behaviour and freshwater inputs
- salinity regimes and mixing processes
- nutrient and sediment inputs (catchment and marine) and transport
- nutrient cycling
- primary and secondary production (including the dominant contributors and their distribution such as phytoplankton, seagrass, mangrove and saltmarsh)
- recruitment (plant and animal).

For many estuaries, we may not fully understand all the relevant processes and interactions; and depending on the local threats to estuary ecosystem health further data collection may be required, this may become a management action. Notwithstanding this, based on current knowledge, key estuarine processes should be identified and interactions recognised in the design of management actions.

It is important to acknowledge that estuaries can be influenced by a complex range of factors. Where a coastal hazard study and assessment of community uses is also being undertaken, those assessments should also be used to inform management actions.

3. Pressures on estuary ecosystem health

Human activities have had major impacts on the health of estuarine ecosystems in NSW. In terms of estuarine habitats it is estimated that the distribution of saltmarsh has been severely reduced (e.g. by 80% in the Sydney region, Stricker 1995), whilst areas of seagrass have also declined in some estuaries over recent decades (e.g. see Meehan *et al.*, 2005 and Williams *et al*., 2006).

Pressures are activities such as land clearing and development, resource use and waterway use, while stressors refer to physical, chemical or biological components of the environment that transfers the impact of a pressure onto resource condition (Scheltinga and Moss 2007).

For example, intensification of land use may be a pressure with the associated stressors being increased nutrient and sediment export.

In NSW there are many pressures and stressors that can influence the ecosystem health of estuaries. Understanding the potential impacts and relative magnitude of these can help to avoid or manage undesirable outcomes.

The influence of the main pressures on estuary ecosystem health and community values should be considered and the level of investigation should be sufficient to identify the pressures which can be reasonably targeted through the implementation of management actions.

3.1 Common pressures

When identifying pressures impacting on estuary ecosystem health and community values it is important to consider not just the existing pressures (or combination of pressures), but also likely future scenarios, such as those posed by changes in catchment land use or climate change. Pressures can be natural (e.g. flood or drought) or anthropogenic (e.g. land use change or pollution). A number of tools are available that may assist in evaluating current pressures, future risks and designing management actions, some of which are listed in Section 9.

Common catchment and waterway pressures and their associated stressors are shown in Table 1, the resultant impacts can be significant and varied. The potential impacts of climate change are discussed in Section 3.2.

Assessing the relationship between pressures, stressors and ecosystem health can be complicated as the health status can be the result of a number of pressures acting cumulatively. The pressures influencing ecosystem health and community values should be identified and prioritised so that appropriate and realistic management strategies to avoid or mitigate the effects of those pressures can be developed.

The analysis of pressures should always be based on the best available information and techniques, whether that is expert opinion or detailed numerical modelling. Where uncertainties or assumptions are apparent, a precautionary approach to subsequent decision-making should be applied.

3.2 Climate change

In assessing estuary ecosystem health and determining management responses over the longer term, the pressure associated with climate change may be considered. Successful adaptation will reflect both the unique vulnerabilities and circumstances of particular estuaries and local community expectations and priorities. When managing estuaries, the extent and degree of risk and costs to implement adaptation measures should be realistically assessed, and actions should be flexible enough to respond to changing conditions and understanding.

In providing estuaries with the best chance to adapt to climate change the goal should be to reduce the threats associated with current pressures and stressors so as to increase resilience (see Section 3.3). While climate change may increase the risk associated with existing threats (such as eutrophication and loss of habitat), many best management practices to reduce the impacts of these threats may also be applied as part of adaptation strategies for climate change.

Potential climate change impacts on estuaries include:

- Sea level rise, resulting in inundation of low lying areas and impacting upon ecological communities, public infrastructure and assets.

- Increased water temperature, may result from a strengthening of the East Australian Current and impact on the distribution, dispersal and productivity of species, including the increased risk of invasion by nuisance or pest species.
- Increased wind and waves, resulting in increased disturbance to shallow environments and foreshore erosion may be exacerbated along sandy/unconsolidated shorelines.
- Increased rainfall intensity, may impact upon urban stormwater systems as well as urban streams and increase catchment sheet and gully erosion.
- Changes in river flow, increases in water extraction may result in a need to assess the environmental flow requirements for an estuary.
- Ocean acidification, is likely to have negative effects including on calcareous shell forming organisms and have flow-on effects to estuaries.

The exact response of estuarine processes to climate change may not be well understood and the impacts of climate change are likely to be complex. However, where possible an adaptive, risk-based approach to managing the impacts of climate change should be adopted.

An initial approach to understanding climate change pressures could be to consider sea level rise and the impact on estuarine habitats most susceptible to inundation. For example, the increasing threat of inundation of fringing, low-lying ecosystems such as saltmarsh may be a concern. While the rate at which accretion may occur in saltmarsh may not be well understood, an appropriate strategy would be to identify adjacent areas where migration to elevations commensurate with ongoing sea level rise may be possible and planning undertaken to protect those areas for that purpose.

Table 1: Common threats and pressures to NSW estuaries

Threat	Pressures (examples)	Stressors (examples)	Potential impacts
Eutrophication	Land clearance Land management practices Point source pollution, such as sewage treatment plants Non-point source pollution, such as runoff from urban & agricultural environments	Increased nutrient loads Increased sediment load	Algal blooms Fish kills Unpleasant odours Reduction in recreational amenity Reduction in habitat & biodiversity Reduction in fishery & aquaculture production
Loss of habitat & biodiversity	Land clearance Land management practices Wetland filling & foreshore reclamation Bank erosion Dredging Waterway usage (ports, boating, infrastructure etc.) Unsustainable harvesting	Habitat removal or disturbance Introduced & pest species Excessive fishing	Reduction in biodiversity Changes to food webs Reduction in fishery production Increases in threatened species & endangered ecological communities Shifts in trophic structure Reduced resilience of aquatic habitats
Changed flow conditions	Extraction & river regulation In stream barriers Land clearance Land drainage & floodgates Altered entrance conditions (ICOLL entrance intervention, entrance training works)	Changed hydrodynamics Changed tidal limits & salinity zones Changed sediment supply Black water events	Change in vegetation community structure Reduction in fishery & aquaculture production Altered salinity regimes & sediment patterns Changes in groundwater dependent ecosystems
Sedimentation	Land clearance Poor land management practices Bank erosion Water extraction In stream barriers	Accelerated sedimentation Changed hydrodynamics Changed sediment supply Increased turbidity	Accelerated growth of deltas Smothering of aquatic plants Reduced light penetration limiting aquatic plant growth Hazards for navigation
Pollution	Land clearance Poor land management practices Point source pollution, such as industrial discharges Non-point source pollution, such as runoff from urban environments.	Increased nutrient loads Increased sediment loads Pesticides & organic pollutants Changed temperature Increased pathogenic organisms.	Algal blooms Fish kills Unpleasant odours Reduction in recreational amenity Reduction in fishery & aquaculture production Reduction in habitat & biodiversity

Threat	Pressures (examples)	Stressors (examples)	Potential impacts
Acid Sulfate Soil disturbance	Land clearance & drainage Poor land management practices (including drain & floodgate management).	Acid runoff Monosulfidic black ooze Anoxic conditions	Water quality deterioration Toxic quantities of soluble iron & aluminium Reduction in fishery & aquaculture production Ulcerative disease in fish Fish kills.

3.3 Resilience and vulnerability

An understanding of the resilience or vulnerability of an estuary to pressures and threats will inform management future actions for an estuary.

Resilience is a capacity to deal with or recover from pressures or stressors so that an ecosystem maintains its health status rather than changing into a different state (e.g. from a low nutrient and seagrass dominated mesotrophic state to a high nutrient and phytoplankton dominated eutrophic system). Conversely vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of pressures or stressors. When changes to a system result in it crossing from a desirable condition to a poor condition can be described as crossing a threshold. By understanding where a threshold point lies, and what causes a system to move towards that point, managers are able to target investment towards the most appropriate actions to protect the systems that are most at risk (Section 4.3.3).

An estuary's resilience or vulnerability will depend on factors including its physical form and processes (many of these factors are inherent e.g. entrance condition, residence time, dilution capacity, waterway depth and configuration and catchment soil characteristics), ecology, condition, and the nature, severity and duration of pressures. Generally, vulnerability will increase as the number, intensity, and frequency of pressures and stressors increases (Bradley and Smith, 2004), such that highly vulnerable systems are unlikely to sustain change without adverse effects. Actions should seek to maintain or improve resilience through the protection or rehabilitation of key ecosystem processes and components.

A 'state and transition model' can be used to define and explain cause and effect relationships, by identifying the attributes of an estuary for a range of different ecosystem states or condition (e.g. good, fair and poor ecosystem health), the threats or pressures that have a direct influence on health, and potential management actions that may modify the impacts of the threats and pressures. An example 'state and transition model' for estuaries is provided in Figure 1.

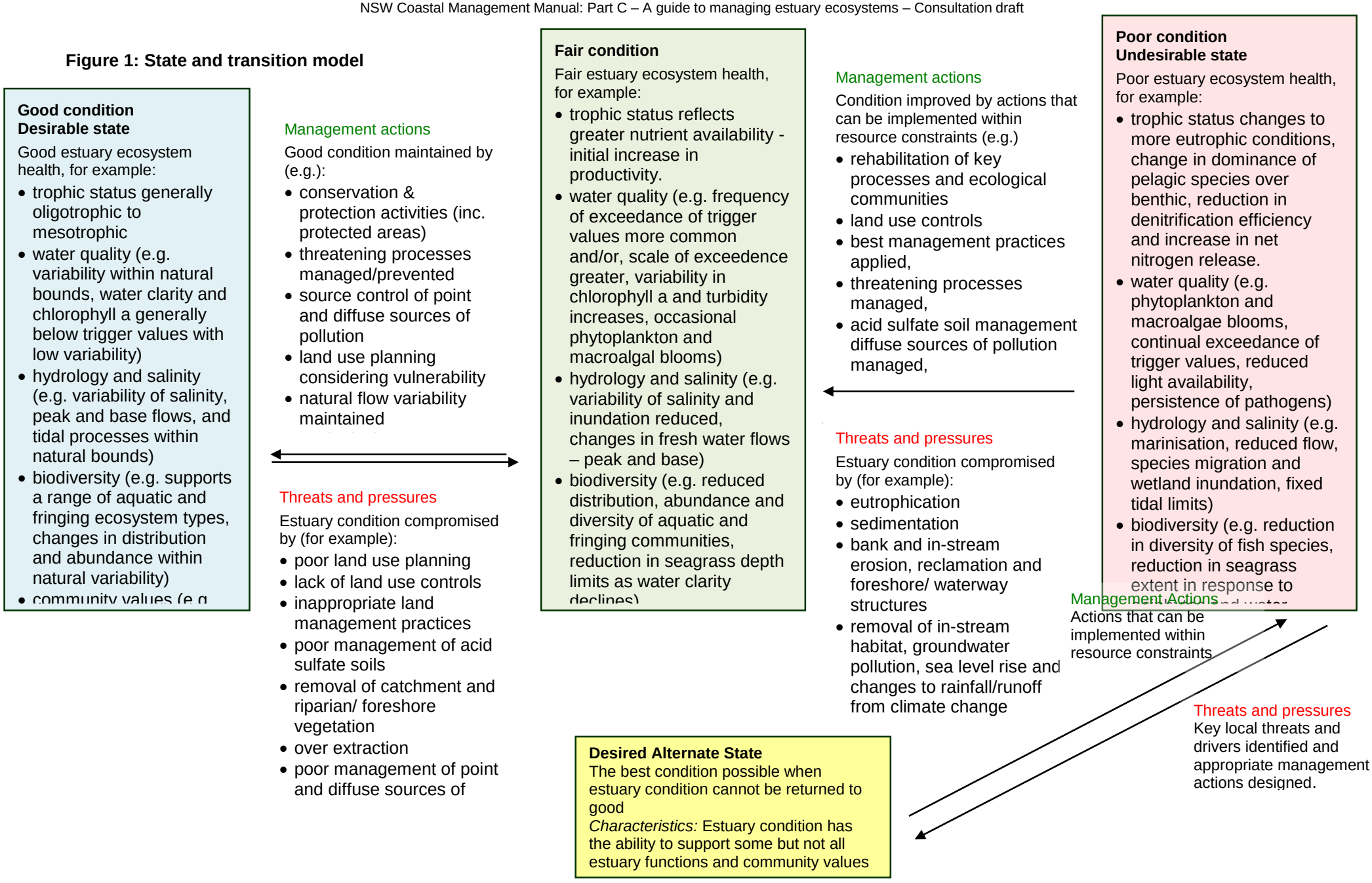
The intermediate or 'fair' state represents the attributes that could be expected if the pressures acting on an estuary are such that its condition has begun to decline. An estuary may remain in a 'fair' state, however if the number, intensity, and frequency of pressures increases the condition is likely to decline further until a 'poor' state is reached. An estuary could also be returned from a 'poor' state to an altered desired state through management intervention where some level or types of ecosystem function or community value can be attained.

Understanding resilience or vulnerability will assist managers to:

- predict which estuaries or ecosystem components may be vulnerable to degradation in the future (e.g. small, shallow coastal lakes and lagoons are more vulnerable to land use change than larger, deeper systems with good dilution capacity (DLWC, 2000))

- identify where it may be possible to improve resilience through the rehabilitation or improved management of ecosystem components (e.g. actively rehabilitating damaged areas to improve overall health)
- understand the likely outcomes from key pressures and stressors so as to prioritise management actions and understand any associated trade-offs in terms of estuary health e.g. determining the location and nature of changes in land use.

Figure 1: State and transition model



4. Estuary ecosystem health assessment

Understanding the ecosystem health of an estuary allows the appropriate approach to managing that estuary to be determined. The management approach and actions required will not just depend upon its current health status depend but also the objectives for that estuary.

If not already available, the health assessment will act as a benchmark against which changes in condition can be assessed through an ongoing estuary ecosystem health monitoring program (see Section 7). The following steps guide the development of an estuary ecosystem health assessment.

4.1 Setting objectives

Estuary management objectives can be derived in a number of ways. They should reflect the community's environmental values, desired uses and long-term goals for an estuary. Some of these values and goals have been previously determined through community consultation and are incorporated in the NSW Water Quality Objectives (WQOs) (NSW Government, 1999). Others may also have been determined during earlier community and stakeholder consultation or through other complimentary consultation processes. Objectives should also reflect the environmental conditions required to maintain or improve ecosystem health.

Management objectives should be consistent with state-wide natural resource management targets (NRC, 2005) and the WQOs. Where there are other objectives or a need to review or refine the previously derived objectives, this can be done locally. In some cases the objectives will be aspirational, representing the community's desires for the uses of an estuary.

For each objective, there will be a range of ecosystem characteristics that are used to assess whether the condition of the estuary supports that objective. These are referred to as indicators.

4.2 Selecting indicators

To undertake an estuary ecosystem health assessment, the indicators that will be used should be selected. The indictors should be relevant to the type of estuary, pressures on the estuary and management objectives. A suite of relevant indicators can be developed that should provide not only a snapshot of current status, but also a perspective on longer-term trends.

Indicators are simplified measures that represent key elements of a complex system. Since ecosystems consist of interacting components, an ideal assessment incorporates a suite of indicators representing different elements of the ecosystem. Using multiple indicators adds reliability to an assessment. The most commonly used framework for indicators is the pressure-state-response model commonly used in State of the Environment reporting. This involves the use of indicators to measure:

- **state or condition**, these indicators provide a snapshot of the health of the estuary at the time of measurement. Generally, they will be representative of the biology of the estuary (e.g. phytoplankton, seagrass, fish). They are often compared to a trigger value or target to communicate their status (e.g. good, fair or poor). Trends in health can be assessed by monitoring condition indicators over time (Section 4.2.1).
- **pressure**, these indicators reflect the impacts to habitats, ecosystem processes and uses. For pressure indicators to be useful they must measure factors causing a change in condition where a clear relationship between cause and condition can be demonstrated (Brooks *et al.* 2006) (e.g. land use and nutrient export resulting in

increased algal production). In estuaries where there are a range of pressures and stressors it can be difficult to demonstrate a clear relationship between a pressure indicator and condition indicator (Section 4.2.2).

- **response**, these indicators reflect how successful management regimes have been in reducing impacts or improving the health of the estuary. These indicators are also referred to as performance indicators. Performance indicators must reflect responsiveness to a management action and relevance at the management spatial and temporal scale (Brooks *et al.* 2006) (Section 7.2).

There are a number of reference documents that detail potential indicators for monitoring estuaries, for example, water quality, biological and sediment quality (ANZECC & ARMCANZ 2000, Scanes *et al*., 2007 and 2009), sediment quality (Simpson *et al*., 2005), condition indicators relevant to the former Southern Rivers CMA region (Fraser 2008), estuarine macrophytes (Creese *et al*., 2009) and NSW MER Program indicators (Roper *et al*., 2011).

An estuary ecosystem health assessment should firstly concentrate on condition indicators as ecosystem health underpins many community uses and values. Whilst this guide note does not specifically address the assessment of indicators of community uses that may impact on human health such as the assessment of recreational water quality (see Section 9: Beachwatch protocols) or the status of shellfish harvesting areas (see Section 9: NSW Shellfish Program protocols), there may be opportunities to include additional indicators or utilise monitoring information from those programs in the assessment.

Where pressure and response indicators are available they should also be used in an assessment but they should not generally be used as substitutes for condition indicators.

4.2.1 Condition indicators

Statewide data on condition has been reported in State of the Catchment reports (DECCW 2010a, b, c & d). This dataset was collected to monitor, evaluate and report on indicators. The following condition indicators have been monitored at a statewide level (Roper *et al*., 2011) and reported on. They are:

- pelagic chlorophyll *a*
- water clarity/turbidity
- extent of estuarine macrophytes (saltmarsh, mangroves and seagrass)
- fish assemblages, and
- macroalgae abundance.

The indicators and the way in which they are monitored provide a focus on state-wide issues, whilst not all indicators will be applicable to all estuaries they provide a starting point of indicators that are known to be responsive to common pressures (Roper *et al.*, 2011). At the local scale, estuary ecosystem health monitoring and assessment should consider additional indicators that reflect the specific estuary and pressures (e.g. acid sulfate soil management may be an issue).

To provide guidance on the way that the above condition indicators should be monitored and reported, the Office of Environment and Heritage (OEH) is preparing sampling, data analysis and reporting protocols for estuary ecosystem health assessments.

4.2.2 Pressure indicators

To support condition assessments a range of pressure indicators are have also been assessed to better understand the major pressures acting upon estuary health (Roper *et al.*, 2011). The pressure indicators include:

- cleared land
- population density

- sediment and nutrient input (total suspended solids and total nitrogen increase for current land use compared to an undisturbed catchment condition)
- change in freshwater inflows (through catchment clearing and water extraction)
  - change in mean annual flow above pre-European settlement
  - licensed water entitlements normalised by mean annual flows
- tidal flow (presence of entrance breakwater or training walls, or level at which intermittently open estuaries manually opened)
- disturbed habitat (presence of foreshore structures and aquaculture leases)
- riparian disturbance (land use within a 100m buffer around estuaries), and
- fishing (commercial finfish and shellfish catch data).

The indicators and the way in which they are monitored provide a focus on key state-wide issues and the full suite of indicators will not necessarily be applicable to all estuaries. At the local scale if pressure indicators are to be included within an estuary health monitoring program (Section 7), it is essential to consider a variety of indicators that reflect the specific estuary, the main pressures and their relationship to condition, and that the spatial and temporal frequency of monitoring is adequate.

4.3 Criteria for assessment

A key aspect of assessing estuary health against objectives is to identify criteria for the indicators to be assessed against. Where the objective relates to a change in indicators, then a comparison over time will be the appropriate approach. Where the objective is to support a particular community use or environmental condition, then numerical or descriptive criteria may be necessary. There are a range of approaches to selecting these criteria and it is necessary to consider the most appropriate approach in each case.

4.3.1 Trigger values

Trigger values indicate the level at which management intervention or further assessment should be considered as there is a risk that an objective may not be met. ANZECC and ARMCANZ (2000) and Roper *et al*. (2011) set out methodologies that can be followed if a local trigger value is to be derived. Trigger values should take into account the desired level of protection, these could be derived based on known biological effects or reference data (see Reference condition).

Whilst deriving localised trigger values is the recommended approach (ANZECC and ARMCANZ, 2000), where these cannot be derived, default trigger values are available for water quality indicators, e.g. ANZECC and ARMCANZ (2000) and NSW MER Program condition indicators (Roper *et al*., 2011). Where there is overlap, the NSW MER Program triggers should be used as these have been derived using data from NSW estuaries. The *Sampling, data analysis and reporting protocols for estuary ecosystem health assessments* (OEH, in prep), should be referred to for the most up to date trigger values and assessment methodology.

Trigger values will generally be expressed as a target concentration, such as for turbidity and chlorophyll *a,* or a descriptive statement.

Reference condition

Determining reference conditions is one way to develop trigger values. Depending upon the indicator, reference condition could be defined by:

- historical data collected from the site being assessed, before key pressures became significant (e.g. historical distributions of mangroves or saltmarsh prior to extensive foreshore development);

- a given percentile of the data at the site being assessed, that represents the healthier portion of the recorded data.
- data collected from similar sites or areas nearby that are considered to be reference systems or in a healthier condition; or
- data derived from other sources (e.g. modelling, expert opinion, published literature).

4.3.2 Temporal analysis

For indicators that are not suitable for comparison against trigger values an alternative approach may be an evaluation of temporal trends. For example, chosen indicators of estuary health may be the distribution of seagrass, mangrove and saltmarsh. Without an understanding of the factors controlling macrophyte distribution and extent it is not possible to define the optimum mix and distribution in any given system. The approach adopted could be to report on the change in macrophyte extent based on comparable repeated surveys of extent over time (e.g. Meehan *et al*., 2005 and Roper *et al*., 2011).

4.3.3 Threshold for change

As discussed in Section 3.3, where there is sufficient local data and research it may be possible to determine threshold values for indicators. The values represent a threshold for change in condition where objective(s) are no longer met and the change in condition will be difficult to return from. It is not always possible to identify the threshold for change.

This approach is consistent with the resilience thinking approach and 'state and transition models' (see Figure 1).

4.4 Setting management targets

Coastal management programs should focus on actions that councils can implement to help move towards achieving estuary health objectives. Monitoring estuary ecosystem health against the overall objectives is important to check whether management actions undertaken in the estuary and its catchment are maintaining or improving estuary health. However, often it will not be possible to determine the degree of improved health directly attributable to a specific action.

Councils may wish to develop targets that relate more specifically to the outcomes sought from individual actions or groups of actions. Management actions that are most likely to contribute to attainment of the targets can then be prioritised. Monitoring against these targets will also inform coastal management program reviews.

Targets should:

- be specific in that they are well-defined and clear in their intent (e.g. an increase in the distribution of saltmarsh in a specific area)
- be measurable so that their achievement or otherwise can be tracked (e.g. reduction in nutrient load or increase in the amount of time a chlorophyll *a* trigger level is met)
- be achievable given the understanding of estuary type, key processes and current estuary health – it is unlikely that where an indicator of estuary health is impacted by multiple pressures, all pressures can be addressed within short or medium time frames
- be realistic given the resources available to implement management actions and the ability to manage pressures, focusing on aspects of estuary health that can be influenced by council
- provide a timeframe for achievement (where it is unlikely a target could be met during a defined implementation period, the strategic nature of the target should be expressed, and actions should support the strategic target).

4.5 Reporting on estuary ecosystem health

The estuary ecosystem health assessment will provide the baseline condition against which management strategy implementation can be assessed. At this stage council may wish to communicate the outcomes of the estuary health assessment; this could be in the form of a report card. Report cards generally assess a number of aspects that contribute to the health of an estuary and use those indicators to provide an overall assessment of estuary health, often communicating the health status as a score.

In addition to the State of the Catchment Reports (DECCW, 2010a, b, c & d), examples of reporting on estuary health through report cards is available from a number of other jurisdictions (e.g. Tweed Shire Council, 2009 and South East Queensland Healthy Waterways Program, 2010). Councils are also required to prepare their own State of the Environment reports which should include the results from estuary health monitoring and assessment.

The review and update of a coastal management program should utilise relevant estuary health assessments and ongoing results from estuary health monitoring programs to provide information on an estuary's health status and trend (is it getting better or worse?) to ensure an adaptive approach to management.

5. Managing threats to estuary ecosystems

Understanding the potential impacts and relative magnitude of existing and potential pressures and stressors on estuary ecosystem health is a precursor to developing management actions.

Development of coastal management program should consider the influence of existing and potential pressures and stressors on estuary health, their relative magnitude and the level of risk they pose. Appropriate management actions can then be designed to mitigate or remove existing pressures and avoid unacceptable future risk. A risk based approach to identifying pressures will allow resources to be targeted to provide the greatest gain.

Actions should identify the pressures which can be reasonably targeted through the implementation period. Links to other programs and activities that contribute to meeting estuary management objectives should also be identified and feedback processes established if needed. Given the range and combination of pressures acting upon estuaries it is not possible to provide a definitive list of management actions, rather this section aims to provide guidance on determining appropriate management actions and provide examples of the type of management actions that may be appropriate.

5.1 Applying a risk based approach

Threats to estuary ecosystem health and community values, such that estuary management objectives and targets will not be met, come from a variety of pressures and stressors. The risk is determined by assessing the likelihood of a particular threat, and its consequences.

Both ANZECC & ARMCANZ (2000) and the NSW Government (1999 and DEC 2006) advocate a 'risk based' approach to managing water quality. This approach can be extended to managing other aspects of estuary ecosystem health and community values. The approach means that any investigation into the pressure influencing estuary health reflects the level of risk associated with it. A more comprehensive assessment is required where there is a higher likelihood or greater consequence of a pressure negatively affecting estuary health.

The risk will vary depending on the nature and location of a development or activity (e.g. activities on land closest to water bodies generally have the greatest effects on the health of a water body and its ecosystems, Brooks *et al*., 2006), current condition and the vulnerability

of the estuary. Scenarios that reflect likely future estuary and catchment activities should be developed and considered as part of a risk based approach.

The risk based approach should be used to identify which pressures are affecting or have the greatest potential to affect the estuary and community values. The judgement of the level of risk will need to be made on a case-by-case basis with most activities falling somewhere between the following examples of very low and very high risk.

- Uncontrolled public access arrangements along an estuary foreshore currently impacts on sensitive adjacent areas through increased erosion and sediment transport. Whilst the impacts on estuary health are relatively localised, upgrading to formalised walking tracks or moving access points to less sensitive areas would mitigate the ongoing risk to estuary health. Provided appropriate sediment and other controls are utilised a localised improvement in estuary health may result.
- A proposal for a rezoning of a large area of land adjacent to an estuary from environmental protection to general residential could potentially impact significantly on estuary health depending on the vulnerability of the estuary and its current condition. The assessment of this type of development should comprehensively consider the likely impact on indicators of estuary health and uses of the estuary. For example, urban runoff or unsewered areas could pose a risk to any nearby oyster growing areas, potentially contribute to eutrophication and impact on recreational water quality. If the risk is deemed unacceptable it may be possible to apply mitigation or control measures such that the level of risk is reduced and the risks to estuary health are deemed acceptable.

Where a preferred management action will result in clear risks estuary ecosystem health but social and economic benefits are seen to outweigh those risks the trade-offs should be clearly articulated and where possible actions to mitigate the risks identified.

6. Actions to manage risks to estuary ecosystem health

The estuary management objectives and opportunities to maintain or improve condition will guide the development and prioritising of management strategies and actions. The input and expertise of relevant stakeholders should also be used in developing and assessing management actions.

The general approach that should be adopted is:

- if estuary ecosystem health is good and community uses of the estuary are supported, maintain this condition through appropriate land use and infrastructure planning decisions. It is generally easier and more cost effective to protect estuarine ecosystems that are in good condition than to return those in a poor condition toward their natural state.
- if estuary ecosystem health is poor or uses of the estuary are impacted, improve this condition through:
    - minimising further impacts on estuary health through appropriate land use planning and development decisions
    - reducing the pressures on ecosystem health, and identifying and managing future risks – in some situations removing the pressure may allow the system to naturally recover, in other situations active rehabilitation may be required
    - rehabilitating priority habitats or reinstating key processes – if funding for rehabilitation is limited, consider staged implementation with demonstrable outcomes to illustrate progress, and

- remediation activities generally involve the transformation of a site or process when it is extremely degraded or contaminated. It is likely that remediation activities will be expensive and it may be many years before changes in estuary health are measured.

6.1 Types of management actions

Management actions are likely to fall into a number of categories:

- **Planning and development controls** are useful for preventing inappropriate future use and development of land or managing the form of redevelopment. Planning controls also have the potential for resolving existing problems when linked with appropriate incentive mechanisms.
- **Works programs** include measures that repair or rehabilitate estuarine environments, prevent or mitigate pressures and potential threats and improve public amenities or infrastructure.
- **Education and awareness programs** can be designed to increase knowledge and awareness, reduce detrimental activities and promote community involvement in management and rehabilitation.
- **Monitoring and assessment programs** can provide ongoing information for assessing changes in estuarine ecosystems, the effectiveness of management strategies or addressing information gaps. This information should be used to refine or improve management practices and review and update coastal management programs and management actions.
- **Strategic priorities and links** are broader areas where actions can contribute to improving ecosystem health but individual actions cannot realistically be specified in detail, cannot realistically be implemented during the period of the plan or where information or actions can inform or link to other plans and programs (e.g. informing the setting of environmental flow requirements in water sharing plan or priority actions in catchment action plans).

Potential actions which should be considered are shown in Table 2. This list is not exhaustive and other potentially feasible options should also be considered.

6.2 Evaluating management actions

There may be a number of ways for actions to contribute to meeting the estuary health objectives or targets. Evaluating and narrowing the range of options should be undertaken by assessing the effectiveness of combinations of management actions. In some cases, management actions will have multiple benefits and this should be taken into account. Detailed investigation of some actions may be required, particularly where these are likely to be costly or the benefits from them can only generally be qualified.

A variety of methods and tools can be used to assist in the evaluation of management options. These include cost-benefit analysis, multi-criteria analysis, social impact assessment and decision support tools. Methodologies are available that assign economic values to natural ecosystems and their components; it may be possible to use these as part of a cost-benefit analysis of management scenarios (e.g. Gillespie and Clarke, 2005).

6.3 Implementation of management actions

Management actions may require implementation through other mechanisms or in conjunction with other parties. Where this is the case the mechanism for implementation should be clearly stated, where other parties are nominated for implementation their agreement must be attained. These include:

Local council integrated planning and reporting framework: the framework consists of a hierarchy of documents including a Resourcing Strategy and a Delivery Program for each

elected council term and a yearly Operational Plan to outline the specific details of councils' activities and the budget. It also will be necessary for the implementation schedule to link to the council Delivery Program and Operational Plans to ensure the implementation of relevant actions.

Local environmental plans (LEPs): Zoning of land through LEPs is probably the most effective control on land use and land use change. There are a number of directives that councils must consider in drafting LEPs (e.g. Direction No. 29 – Oyster Aquaculture, Direction No. 30 – Implementation of Regional Strategies) that may have an impact upon managing estuary health.

There are 'local provisions' or 'model local clauses' that can be included in LEPs, relating to development control plans (clause 6.3), foreshore building lines (clause 6.5) and acid sulfate soils (clause 7.1). In consultation with the Department of Planning, councils may be able to make minor alterations to those clauses to suit their specific circumstances.

Reservation: Where areas are of high conservation value, consideration should be given to reserving land for future public acquisition. Due to the high costs of land acquisition, this option is generally only suitable for proposals with the highest priority. A council may not identify land for acquisition by another public authority (e.g. through the NSW Government's Coastal Lands Protection Scheme) without the agreement of the authority concerned.

Plans of management for community land or Crown reserves: Under the *Local Government Act 1993*, all land vested in a council is to be classified as either 'community' or 'operational'. Generally, community land is land intended for public access and use, such as public reserves. The use and management of community land is regulated by a plan of management. Crown reserves are generally managed by either reserve trust boards, local councils or State government authorities.

Boating plans: NSW Maritime prepares boating plans to guide the shared use and access to waterways. Amongst other things they are designed to protect and sustain the recreational and environmental values of a waterway (NSW Maritime, 2011).

Table 2: Potential actions for managing threats to estuary health. (Actions should be tailored for the specific need, situation and location).

Threat (potential)	Pressures (potential)	Example management actions	Example Program linkages
Eutrophication	Land clearance Land management practices Point source pollution, such as sewage treatment plants Non-point source pollution, such as runoff from urban environments	Zoning of critical areas (e.g. draining to poorly flushed embayment) for environmental protection* Water sensitive urban design in new and re-developments* Riparian and foreshore rehabilitation and protection (e.g. buffer areas)* Improved effluent management (e.g. sewage treatment plants, dairy effluent etc.)* Stormwater control devices* Monitoring and evaluation of condition indicators* Actions to support: • meeting targets in Catchment Action Plans • water quality objectives in the NSW Oyster Industry Sustainable Aquaculture Strategy.	Catchment Action Plan programs that contribute to reducing eutrophication e.g.: • waterway protection through land and stock management* • riparian and foreshore rehabilitation and protection • education programs for improved land management
Loss of habitat and biodiversity	Land clearance Land management practices Wetland filling and foreshore reclamation Bank erosion Dredging Waterway usage (ports, boating, infrastructure etc.)	Zoning of critical areas for environmental protection* Protection and rehabilitation of wetlands and foreshore areas* Control of introduced species Creation and maintenance of buffer zones around wetlands, riparian zones and endangered ecological communities* Protection of seagrass through mooring design and location* Incorporation of habitat into existing or proposed seawalls* Rationalising uncontrolled public access* Reservation of land for future public acquisition* Education including interpretive signage* Monitoring and evaluation of condition indicators* Actions to support: • managing threats to key fish habitat mapped under the *Fisheries Management Act*.	Catchment Action Plan programs that contribute to managing biodiversity e.g.: • riparian and wetland rehabilitation programs • threatened species programs. Fish Habitat Protection Program and *Caulerpa* Control Plan (administered by NSW DPI).

Threat (potential)	Pressures (potential)	Example management actions	Example Program linkages
		• Implementation of the Threatened Species Priorities Action Statement.	
Changed flow conditions	Extraction River regulation In stream barriers Land clearance ICOLL entrance intervention Entrance training works and foreshore works	Improved understanding of environmental flow requirements* Raising ICOLL entrance intervention levels (e.g. through education, raising, retrofitting or relocation of assets)* Weir removal or modification* Modification of road crossings and culverts, and management of floodgates* Removal of unauthorised or redundant foreshore structures to reinstate intertidal areas*	Development and review of Water Sharing Plans prepared under the *Water Management Act 2000.* Catchment Action Plan and DPI programs to manage the impacts of weirs, road crossings and floodgates.
Sedimentation	Land clearance Poor land management practices Bank erosion Water extraction In stream barriers	Planning and development controls (including water sensitive urban design)* Unsealed road management and maintenance* Stormwater controls, sediment and gross pollutant traps* Erosion control and rehabilitation* Land rehabilitation* Streambank protection through stock management*	Catchment Action Plan programs that contribute to managing sedimentation e.g.: • land management and rehabilitation programs. PROfarm program (administered by NSW DPI)
Pollutants (inc. heavy metals, pathogens and litter)	Land clearance Poor land management practices Point source pollution, such as industrial discharges Non-point source pollution, such as runoff from urban environments.	Manage point source pollution (where council is regulatory or management authority e.g. sewer overflows, management of onsite sewage disposal systems)* Water sensitive urban design* Stormwater controls, including gross pollutant traps* Stock management and control* Actions to support implementation of the NSW Diffuse Source Water Pollution Strategy*.	Programs under OEH's Waste Avoidance and Resource Recovery Strategy. Catchment Action Plan & DPI programs that contribute to managing pathogens e.g. • land and livestock management programs.
Acid Sulfate Soils	Land clearance and drainage Poor land management practices (including drain and floodgate management).	See Tulau (2007) for a range of remediation actions including: Neutralise and dilute acidity and other oxidation products by restoring a regular exchange of saline waters Floodgate and drain management*	Catchment Action Plan and DPI programs to e.g. • manage the impacts of floodgates

Threat (potential)	Pressures (potential)	Example management actions	Example Program linkages
		Rehabilitate saltwater wetland and aquatic habitats*	• rehabilitate degraded areas.
Climate change	Sea level rise Increased wind and wave action Increased rainfall intensity	Improve infrastructure design including stormwater systems * Elevation of assets such as sewage infrastructure* Horizontal and vertical buffers around estuaries* Reservation of land for migration of saltmarsh*	

* Potentially addresses multiple threats and pressures

7. Estuary ecosystem health monitoring

An adaptive approach to managing estuary ecosystem health and community values is recommended. Monitoring, evaluation and reporting is the key to adaptive management.

Whilst the scale and nature of a monitoring program will reflect local circumstance, a well-designed condition monitoring program will provide information on an estuary ecosystem's health and trend (is it getting better or worse?) that can be used in ongoing implementation, evaluation and reporting.

An ecosystem health monitoring program can also support or link to other programs (such as the Integrated Planning and Reporting framework for local councils including State of the Environment reporting), provide an additional source of information for the community, and integrate with other processes, programs and monitoring (such as land use planning and catchment-based programs).

As previously discussed (Section 4.2), existing indicators and protocols may provide a baseline for ecosystem health monitoring programs. Additional indicators to address specific issues or estuary uses (e.g. recreational water quality or the status of shellfish harvesting areas) can be also added or linked to monitoring and assessment programs. Guidance material such as Beachwatch and NSW Shellfish Program protocols are available.

Organisations that may be able to provide data, advice or other support in the design or implementation of estuary health monitoring programs include agencies participating in the monitoring and evaluation programs, other councils or Local Land Services.

Monitoring programs that are poorly defined and rarely reviewed can be costly and unable to provide the information expected. Whilst monitoring is often considered to be expensive, costs should be considered relative to the possible consequences of having no means to gauge the effectiveness of management actions, such as continuing investment in ineffective management practices that hamper outcomes, waste resources and potentially degrade the environment.

With a good conceptual understanding of the relevant processes, pressures and vulnerability of an estuary, assessment frameworks can assist in designing monitoring programs to assess the ongoing condition of, and pressures acting on, estuaries. There is considerable information available to assist in the various steps associated with monitoring design, implementation, evaluation and reporting.

7.1 Estuary specific monitoring

The components of an estuary ecosystem health monitoring program are listed below, a range of protocols, objectives and standards that may assist in the design of an estuary health monitoring program are also provided:

- setting objectives and targets based on relevant indicators, an understanding of ecosystem components, processes and interactions (Section 4.1 and 4.4)
- definition of the aims of the monitoring program – questions that the monitoring program is to answer should be clearly defined and relevant to the estuary health objectives and targets previously defined
- collation of existing data sources relevant to the aims of the sampling program – the monitoring program should avoid duplicating sampling carried out for other programs but should aim to access other information available, use the information and complement it where possible
- selection of robust and relevant indicators (Sections 4.2)

- design of sampling program – the monitoring of different indicators is likely to require monitoring at different locations and at different frequencies (see OEH, in prep.). Where advice on spatial and temporal replication of monitoring for additional indicators is not available it may be necessary to undertake a pilot study to determine the number of samples required, sampling location and frequency. Sampling design must ensure that monitoring will be adequate for the type of statistical analysis eventually to be undertaken. Where necessary seek specialist advice to ensure adequacy of design.
- field collection and quality assurance/quality control procedures – e.g. ANZECC & ARMCANZ (2000), EPA (2003) and OEH (in prep.)
- laboratory analysis – use of laboratories accredited by the National Association of Testing Authorities is preferable, their analytical methods will generally follow recognised standards (e.g. EPA, 2003 and APHA, AWWA and WEF, various dates) and appropriate quality assurance and quality control (QA/QC) procedures (e.g. more rigorous QA/QC is essential for difficult analytes such as dissolved nutrients at low concentrations)
- data management – data should be stored in appropriate databases accompanied by metadata that complies with the appropriate standard. Advice on creating metadata is available from the NSW Spatial data catalogue, metadata should be stored in the catalogue to promote access to data.
- data analysis – the analysis and presentation of data will be dependent upon the indicator being monitored and the sampling design used. In addition to comparison of data to trigger values (Section 4.3 and OEH, in prep), there are numerous statistical techniques with which to analyse data, including descriptive analysis to explore patterns and variability in the data and time series analysis. Analysis, such as exploring the relationship between condition and pressure indicators may involve more detailed statistical analysis tailored to the specific datasets.
- reporting – in order for the results of monitoring programs to be useful they should be reported in a meaningful way. The results from monitoring by local councils may be reported in a number of ways including through regular updates (e.g. report cards, web based data updates etc.), review and update of plans and State of the Environment reporting.

7.2 Performance monitoring

In addition to monitoring to assess ecosystem health, monitoring can be conducted for many other purposes. Performance monitoring can be used to assess the environmental changes associated with a management action or an activity. Performance monitoring may be required to assess the success or otherwise of individual management actions.

Detecting change in a naturally variable environment and attributing it to a particular management action requires a well-designed monitoring program. Consideration needs to be given to effects arising from other factors and processes that may not be the direct focus of study.

This guide does not intend to provide specific advice on performance monitoring as monitoring design will depend upon the specific circumstance however, it is important to recognise that the objectives, design, analysis and reporting of a performance monitoring program will usually be different to that of an estuary health monitoring program.

8. ICOLL entrance management

Estuaries in NSW with entrance channels that become blocked by the build-up of marine sand are often referred to as intermittently closed and open lakes and lagoons or ICOLLs. Over 60% of NSW estuaries are ICOLLs (Roper *et al*., 2011).

Due to the unpredictable nature of rainfall in south-east Australia, the opening behaviour of ICOLLs can be intermittent and erratic, with water levels and the salinity regime comparatively variable (Roy *et al*. 2001).

In order to consider and balance the often competing issues associated with ICOLL entrance management, the preparation of an entrance management policy is recommended (Section 8.1). Where entrance constriction or closure contributes to the severity of flooding of urban areas and associated public infrastructure entrance management is also often considered amongst the suite of management options within a floodplain risk management plan (NSW Government, 2005).

The most common trigger for artificial opening of ICOLL entrances is mitigating potential damage or inconvenience to low-lying properties and assets inundated or threatened by rising water levels (Section 8.7). Intervention in the behaviour of ICOLL entrances, generally involves either opening entrances at a level lower than the natural breakout range or managing the height, location or configuration, of the beach berm.

As the opening and closing of estuary entrances occurs naturally, the aquatic and fringing plant and animal communities have adapted to the accompanying environmental conditions. Intervention can be accompanied by negative environmental impacts some of which may be directly apparent whereas others may take many years to become evident (Section 8.8).

8.1 Preparing an entrance management policy

In the past there has been some confusion as to whether ICOLL entrance management should be considered as part of a coastal management program or floodplain risk management plan. ICOLL management can be considered as part of either process. For example:

- Where flooding affecting residential properties and public infrastructure, justifies adaptive entrance management it should be considered as one of the suite of options within a floodplain risk management plan prepared in accordance with the Floodplain Development Manual (NSW Government, 2005).
- Generally a coastal management program will address relatively minor inundation affecting assets such as foreshore reserves, yards, boat ramps, jetties or access roads. Some consideration may need to be given to permanent inundation due to the impacts of projected sea level rise.

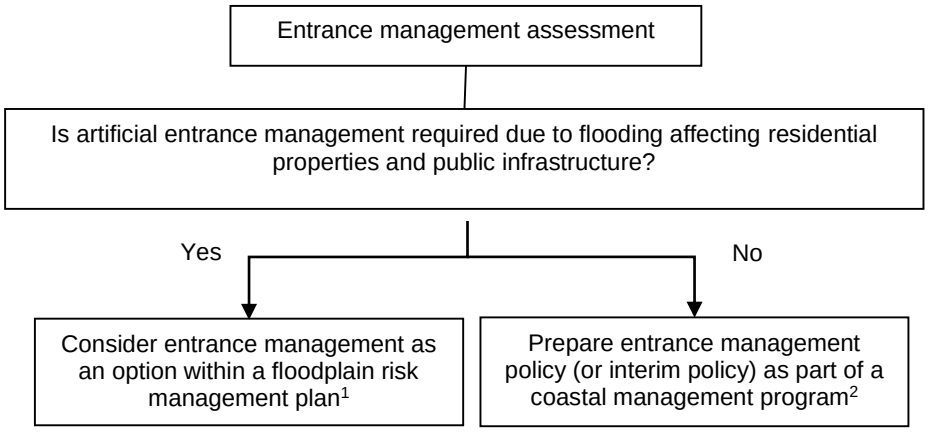
Interim entrance management policies may be appropriate where the need for entrance management is apparent but preparation of a floodplain risk or coastal management program is yet to begin or negotiations regarding critical assets are likely to be lengthy. Where interim policies are being developed they should be placed on public exhibition and the adopted policy made available through council's website. These policies should also be regularly reviewed.

If applicable, where an estuary management plan has been prepared in accordance with the previous guidance and does not include an entrance management policy, an interim entrance management policy could be prepared as a stand-alone policy until the existing plan is reviewed and revised.

Whilst entrance management may be used to manage existing flood risk, it is generally not desirable to rely on entrance intervention to set flood planning levels for future development particularly where the risk can be otherwise avoided. This is best managed through the use of planning and development controls.

The process for preparation of an entrance management policy is shown in Figure 2.

Figure 2: Preparation of an entrance management policy.



[1] Consistent with Floodplain Development Manual: the management of flood liable land (NSW Government, 2005).

[2] Consistent with this guideline.

8.2 Entrance management policy requirements

An ICOLL entrance management policy should identify if a council intends to artificially manage the entrance. If so, the policy should include triggers for actions to manage the opening of the entrance, which were developed considering the impacts of entrance opening on:

- flood levels and tidal inundation
- estuary ecosystem health, including inundation of fringing wetlands and water quality
- community uses of the estuary.

The policy should achieve a reasonable balance between these considerations, and should also consider the longer term impacts of climate change on entrance management. In some situations the entrance management policy may simply support maintaining a natural entrance regime, in others intervention may actually be reduced (e.g. Shoalhaven City Council, 2004).

8.3 Entrance management framework

An entrance management policy should establish the framework for managers to make informed decisions about the management of an ICOLL entrance, often whether or not the entrance should be artificially opened, its frequency and how this should occur.

The following should be considered when developing entrance management policies:

- entrance opening following as natural a regime as possible within the constraints of property inundation and flooding of infrastructure
- a clear decision-making and approval process, based on the best available data and information
- engaging with local communities so they are aware of any arrangements for entrance management, and deterrence of unauthorised openings.

Considerations should be given to the long-term goal of an entrance management policy being to retain or progressively reinstate natural entrance behaviour. Implementation of policies to meet this goal may require the progressive removal, relocation or modification of assets and activities that are affected by inundation or that may create public health

problems when water levels are high (e.g. stormwater and sewerage systems). Such an approach may benefit the affected community by reducing their risk exposure under both existing and changed climate conditions in the long term.

Given the pattern of development around some estuaries this may not be a realistic or cost effective goal in the short term, but policies should consider whether there are opportunities to utilise future asset renewals and development decisions over time to work towards meeting this goal. In circumstances where adaptation is deferred entrance management should take into account critical ecosystem processes and emphasise the need for long-term planning to ensure entrance management does not further compromise estuary health or asset inundation due to oceanic processes.

A high level of debate in the community as to the pros and cons of artificial entrance management usually precedes the adoption of any entrance management policy. The process of developing a clearly set out policy enables the broader community to become more informed about issues associated with entrance management.

8.4 Entrance management policy content

In order for entrance management policies to provide a useful tool for ongoing adaptive entrance management, an entrance management policy could include:

- the purpose of the policy
- a description of the entrance management activity/activities to be undertaken including trigger values for artificial opening, the approval process to be followed and the corresponding level of environmental assessment required (Section 8.5)
- description of the state of the entrance and physical processes contributing to its state, including water levels, rainfall response, historical opening frequency, location and opening duration (Section 8.6)
- description of the ecological and social values associated with the entrance area (e.g. roosting site of migratory birds etc), ICOLL and fringing areas. Including the likely short and long term impacts of entrance management on estuary health (including inundation of fringing wetlands) (Section 8.8)
- identification, location and elevation of affected assets and impacts upon the local community
- consideration of the impacts of climate change on entrance condition and behaviour and inundation of assets (Section 8.9)
- any proposed monitoring protocols both before and after opening events, including water levels, berm height, water quality, tidal behaviour and sand egress, channel configuration, presence of threatened species
- the decision-making process leading to intervention including responsibilities, procedures and accountabilities in relation to entrance management
- measures to be implemented to avoid or mitigate impacts
- a communication strategy to increase community understanding and communicate protocols for entrance opening
- a mechanism for reviewing and updating the policy, including actions required to minimise intervention in the longer term and linking these to a review of opening conditions.

The policy should be accompanied by the necessary environmental assessment addressing the likely impacts of the policy on the relevant environment, social and economic assets (see Section 8.5).

Relevant agencies, including those from which approvals, licences or permits will be required, should be consulted during formulation of the policy.

8.5 Entrance management legislative and policy framework

There are a number of statutes, policies and plans in NSW that are likely to be relevant to ICOLL entrance management. These include:

- *Environmental Planning and Assessment Act 1979,* is the primary legislation controlling development activity in NSW. The development assessment system is set out in the Act. Where an ICOLL entrance management policy requires the artificial opening of an entrance it is likely that the activity will require assessment under either Part 4 or Part 5:
    - Part 4 controls development assessment. Most development proposals are in the form of a development application that is considered by local councils. If a development application is required for the opening of an ICOLL entrance it is likely that the development would be integrated development (not only requiring development consent from the council but also a permit or licence from relevant State government agencies).
    - Part 5 establishes an environmental assessment system for certain activities that do not require development consent under Part 4. Planning policies set out the type of activities that can be assessed under Part 5, these are often infrastructure proposals determined by the public authority undertaking them, many ICOLL entrance openings are assessed under Part 5. The obligation under Part 5 is to consider the likely environmental impacts of the activity and to consider the appropriate level of environmental assessment that is required. For opening of an ICOLL entrance, this may be in the form of a Review of Environmental Factors, but if the potential impacts were considered significant, an Environmental Impact Statement may be required. The need for other relevant permits or licences remains.
- *Crown Lands Act 1989,* provides for the administration and management of Crown land, which includes most beaches and estuaries. Where a local council has care and control of the entrance area of an ICOLL this may only apply to the area above mean high water mark. In opening ICOLL entrances excavation is often below mean high water mark and may therefore affect Crown Land.

  Councils proposing dredging on Crown land are required to obtain a licence from the Department of Primary Industries under Part 4, Division 4 of the Act. Where the material dredged will be removed from the system, that is, taken, stockpiled or sold it would generally be undertaken under a licence agreement with the relevant authority or the authority's contractor (s 49).
- *Fisheries Management Act 1994,* under the Act a public authority (other than a local government authority) is required to consult with the relevant Minister prior to carrying out dredging or reclamation (s 199). A local government authority proposing to undertake dredging works is required to obtain a permit (s 200). However, s 200 does not apply if the dredging is authorised under the *Crown Lands Act 1989* or by another relevant authority (other than a local government). Section 205 (harm to marine vegetation) of the Act could apply if seagrasses were to be damaged in carrying out the entrance opening.

  To support the *Fisheries Management Act 1994* the Department of Primary Industries (DPI) also has Fish Habitat Management Policies and Guidelines (NSW Fisheries, 1999) that provide guidance on ICOLL entrance management.
- *SEPP (Infrastructure) 2007* provides a planning regime for infrastructure and the provision of services across NSW. The SEPP specifies a number of activities, including for flood mitigation that may be permitted with or without consent when carried out by public authorities. Where opening an ICOLL entrance, or maintaining an entrance berm at a certain level for the purposes of flood mitigation, a public authority may use the SEPP to assess the activity in accordance with Part 5 of the *Environmental Planning and Assessment Act 1979*.

- *Local environmental plans* set out what types of development are (or are not) permitted in different zones in a local government area. As a council's primary land use planning tool, ICOLL entrance management must be consistent with the relevant local environmental plan.

Depending upon the local situation, such as the presence of threatened species and migratory birds, the *Environment Protection and Biodiversity Conservation Act 1999, Threatened Species Conservation Act 1995* or *Heritage Act 1977* may also be relevant. Similarly, where ICOLL entrances are located within the reserve system the *Marine Parks Act 1997* or *National Parks and Wildlife Act 1974* may also apply.

8.6 Entrance processes

The interaction between fluvial, tidal and wave processes determines the morphology and entrance condition of NSW estuaries. Put simply, the balance between wave processes and flood tides (moving sediment into estuary entrances) and ebb tide and fluvial processes (moving sediment out of estuary entrances) will determine whether an entrance is open, closed or in a transitional state between the two (see Roy 1984, Dyer 1997, Roy *et al*., 1997, Hanslow *et al*., 2000).

When entrances close, rainfall, runoff and wave overtopping increase water levels in the ICOLL and often cause inundation of low-lying foreshore areas. Depending upon the amount, intensity and location of rainfall and catchment size and morphology, water levels will either creep up slowly or rise rapidly until they overtop the level of the entrance berm. When this occurs the berm breaches and high velocity outflows scour a natural entrance channel (Haines and Thom 2007).

The frequency and duration of entrance opening is known to vary considerably across ICOLLs. The entrances of some ICOLLs with relatively small catchment to waterway ratios can be closed for many years between natural openings. Wallaga Lake (BVSC 2004) and Lake Wollumboola (Kinhill 2000) are documented as regularly closing for periods of between six to eight years. Conversely, water levels in ICOLLs such as Fairy Creek and Towradgi Lagoon with relatively large catchment areas are known to rise rapidly resulting in multiple entrance openings in any year (Cardno Lawson Treloar, 2007 a & b).

The duration of entrance openings can also be highly variable between ICOLLs and for individual ICOLLs. However, there is some evidence that the higher the break out level the longer the duration of the opening as a result of a more efficient scour of the entrance channel (e.g. Spurway *et al*., 2001).

In some relatively shallow and broad coastal lakes weather conditions may result in evaporation exceeding inflow resulting in water levels in the ICOLL falling, potentially to levels below mean sea level (e.g. Kinhill 2000).

8.7 Triggers for entrance management

The most common reasons given for artificially managing ICOLL entrances are:

- mitigating potential damage or inconvenience to low-lying assets inundated or threatened by rising water levels (e.g. residential properties, jetties, on-site sewage systems)
- pressure from local communities who prefer open entrances
- alleviating actual or perceived water quality problems, through the introduction of tidal processes
- attempts to enhance fish and prawn recruitment.

For about half of the ICOLLs in NSW artificial opening is undertaken to manage foreshore inundation (Haines 2008). The need to open ICOLLs for this reason is often the result of past

land use planning decisions, which have led to development on land vulnerable to inundation. These entrance opening practices have not necessarily considered the necessary approval and environmental assessment processes (HRC 2002) or the long-term impacts of the activity.

The opening or attempted opening of ICOLL entrances by members of some local communities has also occurred, largely for the above reasons but also in some locations to seek to improve surf breaks.

Whilst water quality is often cited as a trigger for opening ICOLLs, the opening of the ICOLL alone is not likely to significantly improve water quality problems. The limited tidal flushing and entrance exchange efficiencies whilst entrances are open means that pollutants (particularly those entering from tributaries furthest from the entrance) may be moved around within the system but may not be removed (e.g. Spurway *et al*., 2000). Opening an ICOLL does not address source control of problematic pollutants (e.g. sediment and nutrients from diffuse sources). Source control remains the most effective way to manage water quality problems.

The certainty of achieving benefits from opening ICOLLs for the purpose of fish and prawn recruitment is unclear. It is virtually impossible to artificially manipulate entrance opening with any certainty of enhancing fish or prawn recruitment and subsequent production without a detailed sampling and analysis of offshore and coastal larval populations (Gibbs, 1997). The artificial opening to promote production of one species or a group of species may in fact disadvantage other species, with the final outcome being no net benefit (NSW Fisheries 1999).

8.8 Environmental impacts of entrance management

Whilst there is evidence that the macroinvertebrate ecology of the beach berm may recover relatively quickly after an artificial opening (Gladstone *et al*., 2006), ecosystems within and fringing the ICOLL are likely to be subject to more significant and longer lasting impacts.

Potential environmental impacts of artificial entrance management within the ICOLL and its fringing environments include:

- marinisation through increased and more stable salinities, leading to changes in aquatic vegetation communities, e.g. moving to more regular tidal inundation may promote the establishment or expansion of mangroves.
- the hydrology of fringing wetlands is changed, when consistently opening entrances at lower levels through the reduction in inundation levels and periods (Spurway *et al*. 2000). Many ICOLLs support communities of the endangered ecological community coastal saltmarsh that relies on periodic inundation.
- fish kills can occur as a result of anoxic conditions in ICOLLs following artificial opening (see Wilson *et al.* 2002 for a description of processes leading to anoxia). Fish kills can be the most immediate environmental impact and have the greatest visual and olfactory impact for local communities (Wilson *et al.* 2002, Arundel 2006 and Stephenson 2011).
- reduced fish habitat and stock (Jones and West 1995). Direct loss of habitat can occur where seagrass beds have established in entrance channels that then change as a result of artificial opening. Whilst the impact of artificial entrance opening on fish communities remains largely unpredictable, Jones and West (1995) document the short-term visitation of larger economically important fish species to the detriment of the abundance of smaller resident species after artificial entrance opening. The salinity regime of individual lakes contributes to the structuring of fish assemblages on a regional scale (Jones and West 1995, NSW Fisheries, 1999).
- increased sand shoaling at the entrance (Haines 2008) and reduced opening duration (Spurway *et al*. 2000) due to inefficient scour of entrances at low opening levels.

8.9 Climate change considerations

In understanding the entrance behaviour of ICOLLs in the longer term, risks associated with climate change will be a major consideration. ICOLL entrance management policies will need to realistically assess the impacts of, and vulnerabilities to, climate change impacts such as sea level rise. Under projected sea level rise, the level and frequency of asset inundation due to oceanic processes may increase and the ecological character of an estuary may change. Entrance management policies and triggers for opening should therefore be adaptable, or reviewed periodically, to reflect changing circumstances and estuarine behaviour.

Hanslow *et al*., (2000) describe berm building processes, potential berm level, and berm level variability for ICOLLs, they also discuss the likely impacts of sea level rise. With increased sea levels, general beach recession is likely to be accompanied by landward and upward translation of the berm. In those ICOLLs where entrances are not managed higher berm levels will allow the water in the ICOLL to be stored to a greater height, thus also potentially introducing or increasing the flood risk. Although the tidal range may remain comparatively constant, another implication of sea level rise on opening ICOLL entrances at fixed trigger levels may include a reduced head capacity as the oceanic low tide level increases.

9. Additional resources

Acid sulfate soils remediation guidelines

Acid sulfate soils are widespread along the NSW coast, in estuarine floodplains and coastal lowlands, including urban areas, farmland, mangrove tidal flats, salt marshes and tea-tree swamps. The Acid Sulfate Soils Remediation Guidelines for Coastal Floodplains in NSW (Tulau, 2007) have been developed to provide a framework for designing the most effective acid sulfate soil remediation projects.

Australian and New Zealand guidelines for fresh and marine water quality

Commonly referred to as the ANZECC guidelines (ANZECC & ARMCANZ, 2000), they provide a set of tools for assessing and managing ambient water quality in a range of natural and semi-natural water resources. Guidance is provided on indicators, assessment, deriving and applying guidance values, and monitoring design.

Beachwatch

The Beachwatch programs provide regular and reliable information on beach water quality to enable people to make informed decisions about where and when to swim. A total of 127 swimming locations are monitored in the Sydney, Hunter and Illawarra regions, with a further 129 sites monitored in partnership with local councils along the NSW coast. The Beachwatch Partnership Program provides ongoing assistance to local councils wishing to undertake beach monitoring and reporting programs. A range of resources and training materials is available to assist councils in undertaking recreational water quality monitoring programs.

Coastal design guidelines for NSW

The Coastal Design Guidelines for NSW (Coastal Council of NSW 2003) provide urban design principles and guidance for the design of urban development and redevelopment in the NSW coastal zone. Councils are required to include provisions that give effect to and are consistent with the Coastal Design Guidelines in preparing a draft local environmental plan.

Coastal eutrophication risk assessment tool (CERAT)

CERAT was developed to assist managers and decision makers to assess the potential ecological impacts of their planning decisions and to prioritise estuaries that are at risk of degradation (specifically eutrophication) from land use activities (DECCW, 2009). CERAT provides estimates of the amount of nutrients and sediments exported from land based activities, and assess the potential extent to which the exports impact the ecological condition of NSW estuaries. CERAT can also be used to estimate a 'sustainable' load/limit required to meet a management target such as a trigger value for chlorophyll *a* in estuarine waters.

CERAT is available from the Office of Environment and Heritage as a DVD version and will be available through the OzCoasts website.

Conceptual models

Conceptual models are a useful tool for describing, understanding and communicating estuary type, relevant processes, and the effects of pressures and stressors. To support the NSW Monitoring, Evaluation and Reporting Program a series of conceptual estuarine models

were developed (Claus and Imgraben 2009), the models are available from OEH. The models simplify complex estuarine systems and identify the major ecosystem processes and key pressures and stressors for different estuary types. The models illustrate the effects of pressures and indicate which management actions may be appropriate for addressing them.

Environmentally friendly seawalls

Environmentally Friendly Seawalls – A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries (SMCMA and DECC, 2009) provides options for improving the environmental value of existing seawalls and creating new seawalls.

Environmental monitoring

The Environmental Monitoring website maintained by Sydney Coastal Council Group provides an introduction to environmental monitoring as well as a number of useful resources. The focus of the site is water quality monitoring, but many of the resources may be useful in other environmental monitoring programs.

Estuaries of NSW

The OEH website contains a section on the Estuaries of NSW that provides a range of data and information collected from NSW estuaries including tidal and hydrographic surveys.

Estuarine habitat mapping and geomorphic characterisation

The Estuarine Habitat Mapping and Geomorphic Characterisation of the Lower Hawkesbury River estuary (Astles *et al*., 2010) project developed and trialled a qualitative ecological risk assessment methodology for better understanding of the distribution of estuarine habitats and applying a risk based approach to the potential threats to those habitats from human activity. The project then identified the issues that need to be addressed if the risks were to be reduced.

Estuary ecosystem health assessments – sampling, data analysis and reporting protocols

These protocols (OEH, in prep) support the guidelines by providing practical advice on estuary ecosystem health monitoring including sampling, data analysis and reporting. In particular, the protocols should, where relevant, be used by councils receiving grants from the Estuary Management Program to carry out estuary ecosystem health assessments to support CZMPs.

Fish passage

DPI has produced a number of guidelines and policies in relation to the management of fish passage. They have also undertaken an audit of fish passage barriers along NSW coastal catchments and have provided a prioritised list for each CMA region. The reports also offer suggestions remediation of priority sites

Fisheries policy and guidelines for aquatic habitat management and fish conservation

These policies and guidelines were designed to achieve consistent management of aquatic resources in NSW waters and apply to all planning and development proposals and various activities that affect freshwater, estuarine and marine ecosystems.

Floodgate management

DPI has undertaken an audit of floodgates along NSW coastal catchments and prioritised according to environmental impact. The reports also offer remediation options for priority sites.

Mapping the estuarine habitats of NSW

DPI has mapped the estuarine habitats of NSW (Creese *et al*., 2009) including seagrass, mangrove and saltmarsh within 154 NSW estuaries, the information is available for use in estuary health assessments.

NSW Estuary Management Program

The NSW Government's Estuary Management Program provides support to councils to improve the health of NSW estuaries and understand the potential risks from climate change.

The support provided to councils under the program includes technical and financial assistance to:

- prepare (or update) CZMPs and associated technical studies (including estuary health and coastal hazard assessments)
- undertake actions to manage the risks associated with coastal hazards and to protect or improve coastal environments and estuary health.

Grant offers are subject to availability of funds for each financial year and statewide priorities.

NSW Spatial data catalogue

The NSW Spatial data catalogue provides information and access to NSW Geospatial Data through the State Metadata Node. A range of estuary related data sets can be accessed via the data catalogue.

NSW Water quality and river flow objectives

The NSW Water Quality and River Flow Objectives (NSW Government, 1999) provide the agreed environmental values and long-term goals for NSW surface waters, including estuaries. The objectives are accompanied by guidelines for their application (DEC, 2006).

NSW Shellfish Program

All oysters and mussels in NSW are harvested in accordance with the NSW Shellfish Program, which has adopted the Australian Shellfish Quality Assurance Program as a minimum standard. All the requirements of the NSW Shellfish Program are contained in the NSW Shellfish Industry Manual.

State of the catchments reports

The State of the catchments reports (DECCW, 2010a, b, c & d) provide an assessment of the condition and the pressures acting upon the 184 largest NSW estuaries. Scientific reports, datasets and data collection protocols provide the information used in State of the catchments reports, and support ongoing data collection.

Saltwater wetland rehabilitation manual

The Saltwater Wetland Rehabilitation Manual (DECC, 2008) focuses on the rehabilitation of wetlands influenced by brackish or saline waters including swamp forests, saltmarsh, mangrove forests and seagrass beds. It aims to increase knowledge and understanding of saltwater wetlands and to be a key resource in the field of rehabilitation and management.

Water level data

On behalf of OEH, Manly Hydraulics Laboratory maintains a network of water level recorders. The location of recorders and data for these sites can be obtained through Manly Hydraulics Laboratory.

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