INDEX OF ESTUARY CONDITION IMPLEMENTATION TRIAL YEAR 1 UPDATE: 2009/10

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INTRODUCTION

1.1 OBJECTIVES OF THE INDEX OF ESTUARINE CONDITION

There is currently no consistent method available for assessing the environmental condition of Victorian estuaries to optimise resource allocation for threat mitigation and asset protection. This inability to adequately and comparatively assess estuarine condition is an impediment to effective management of Victoria’s estuaries and the implementation of Regional Catchment Strategies. The development and trialing of the Index of Estuary Condition (IEC) aims to address this and improve the monitoring, evaluation and reporting of the condition of Victorian estuaries using a suite of recommended themes, each of which contains a number of specific measures (or indicators) (Arundel et al., 2009). The IEC was developed to be consistent with the Index of Stream Condition (ISC) and the recently developed method for Aquatic Value Identification and Risk Assessment (AVIRA). It recommended six themes and specific measures within each theme.

The ISC has been used widely across Victoria, fitting into an existing and successful structure for managing aquatic natural resources. The IEC is consistent with this approach of assessing Assets, Threats and Condition (Condition Indicators) to enable adaptive management of natural resources. The IEC themes and measures were developed around estuary assets identified in Arundel et al. (2009). Threats to these assets were broadly identified in Barton et al. (2008), being Upstream Catchment Modification, Freshwater Extraction, Urban and Coastal Development, Recreational and Commercial Uses, Artificial Mouth Opening and Climate Change.

The IEC was initially developed based on existing knowledge and using a workshop approach with estuarine experts as participants (Arundel et al. 2009). In keeping with the framework of the ISC, in which five sub-indices are used to group indicators, six themes were identified for use in the IEC: Physical form, Hydrology, Water quality, Sediment, Flora and Fauna. Several specific measures within each theme were recommended to assess estuary condition. Using pre-established criteria, eighteen measures were selected from a more extensive list in consultation with scientists with expertise in a broad range of aspects of estuarine ecology. The selected measures vary from those feasible for immediate implementation to others that require some further development to guide data collection and/or data interpretation.

The IEC (Arundel et al. 2009) identified that its practical application needed to be tested, baseline conditions identified and scoring thresholds developed through a trial implementation across the full range of Victorian estuary types. This would also allow necessary redefinition of sampling protocols and data recording methods, thereby enabling a more accurate assessment of the feasibility of implementing the IEC and its component measures across the State and through time. Once fully trialled, the IEC will provide a method for consistent statewide assessment of the environmental condition of estuaries. This will enable better:

- Condition reporting for Victorian estuaries at regional, state and national levels;
- Prioritisation of resource allocations; and
- Evaluation of management interventions in estuaries.

1.2 OBJECTIVES OF THE IMPLEMENTATION TRIAL OF THE IEC

The primary focus of the implementation trial was to refine data collection and interpretation. This included:

- Developing or refining sampling method including spatial and temporal replication required within and/or between estuaries and estuary types.
Developing or refining field sheets
Establishing baseline condition
Developing scoring condition
Developing weighting methods that provide an accurate and representative overall IEC score

During the first year of the trial funding was made available to extend and expand the program over 2010/11 and nominally for 2011/12.

The 2009/10 component of trial consisted of using the available data on Victorian estuaries and some targeted sampling to generate data to evaluate the selected measures where existing data are inadequate.

- Selection of estuaries for the trial varied with measure however some principles that guided selection were:
  - Presence of existing data of the quality and type required
  - Representation of estuaries from each CMA region
  - Representation of estuaries in each estuary type (sensu Barton 2003)
  - Estuaries representing different levels of pressure.

The recommended IEC measures were developed from research generally undertaken in other states or countries (Arundel et al. 2009). For these measures it has been assumed that they will also indicate estuarine condition in Victorian estuaries. This program is not designed to test the validity of this assumption, although substantial information on the validity of this assumption will be an outcome of the trial. Some assessment was also made on the response and sensitivity of each measure and whether it should be included in the final IEC method.

Assessment of the measures in the Fauna theme were outside the scope of this trial because of the high level of development required for both data collection and interpretation and associated costs. Results for these measures to date are from a Melbourne Water funded trial in selected Port Phillip Bay and Western Port Bay estuaries in 2010 with further collection of data to assess the measures in 2011 and 2012 by the Arthur Rylah Institute.

Data collection and cost

Implementation of a particular measure depends on the investment required to both collect and interpret the required data. The time and cost associated with data collection primarily depend on, whether there is an established sampling procedure, how frequently data needs to be collected and the level of expertise required for collection. While existing data for some measures may be available it is important that a standardized protocol is used for broad scale programs to enable valid and accurate comparison over time and between estuaries. For many measures, sampling procedures were available from in studies of specific estuaries or interstate and overseas programs. Generally protocols used in the IEC trial were decided at the workshop and recommendation stage and have not been tested or compared to identify the most suitable for statewide application in Victoria.
Baseline condition

Interpreting the data relies on the establishment of baseline conditions. While some biotic condition measures were recommended for the IEC, all required a lot of further work to establish the baseline condition and develop descriptions and scores which reflect the extent of deviation from that condition. For many other measures, descriptions and associated scores have been developed for estuary assessment programs used elsewhere. Their suitability for use in Victorian estuary assessments requires testing.

Condition descriptors

The next steps required prior to a measure being adopted into the IEC will vary depending on the particular measure and its current stage of development. Relevant references and programs to assist with selection of data collection methods and data interpretation are provided for each recommended measure in Section 4. For most measures, condition descriptions for good and poor are provided, however assigning intermediate scores in most cases will require further data collection and analysis. For some measures, where information is available, it is important to ensure that data are collected using protocols that allow valid and accurate comparisons through time and between estuaries and reaches. Scores and estimates of their distributions will be required for all measures before it is possible to combine measures within sub-indices, or to combine sub-indices into overall condition categories.

The trial implementation of the recommended IEC measures in a selection of estuaries was recommended as it would provide an opportunity to:

- Establish/confirm baseline conditions
- Assess the suggested sampling methodologies, including the delineation and assessment of reaches, for practicality/efficiency of collection
- Examine sensitivity of measures to change
- Assign and/or refine scores from 0-4 to reflect condition of the measure
- Ensure measures provide a spread of values to allow adequate discrimination between estuaries and also reflect the potential range of estuary condition
- Determine if there are ambiguities in interpreting data
- Investigate options for combining scores (if multiple measures are recommended) in a way that best reflects the condition of the theme content.
- Investigate aggregation and integration methods which best reflect overall estuary condition.
1.3 PURPOSES OF THIS REPORT

This report aims to report on the 2009/10 component of the IEC trial, recognising that the trial is a continuing project and so does not contain detailed analyses of results as assessments will be more thoroughly and profitably made when the 2010/11 and 2011/12 data are available for analysis.

Aims specifically addressed in this report were:

- To refine protocols proposed in the draft IEC, to refine field techniques, scoring and develop field sheets as necessary.
- To undertake targeted sampling for measures where existing data was not adequate. During 2009/10 sampling, data were collected to support the IEC across 24 estuaries, while another 6 were sampled by Deakin as part of an associated Melbourne Water funded project.
- To assess the measurability of the draft IEC measures. To develop and assess baselines, scoring distributions, response and sensitivity of individual measures and make recommendations for the rollout of the IEC.

2 METHODS AND BACKGROUND

2.1 VICTORIAN ESTUARIES

For the IEC, the selection of estuaries to be assessed was guided by those estuaries considered in Barton et al. (2008), originally based on estuaries identified by local and regional managers as systems of interest. This list was updated following discussions with each of the CMAs and Melbourne Water. A consistent definition of these systems is that estuaries:

- are at least 1km long, or have lagoonal lengths of at least 300m;
- include surrounding animal and plant communities that are affected by waters of the estuary;
- include tributary estuaries that run into Corner Inlet, Gippsland Lakes, Western Port and Port Phillip bays and fulfil the above length criterion; and
- have substantial variation in salinity due to the mixing of marine and fresh waters.

This definition captures the majority of the Victorian estuaries that the community recognises and uses. Ninety five Victorian estuaries met the criteria and are considered suitable to assess using the IEC, although a few still need to be verified as suitable (Table 1). Freshwater and estuarine catchments of most of these were delineated and threat levels from land use and population density patterns determined by Barton et al. (2008).

Various authors have identified the lack of Victorian estuary data sets for assessing changes in environmental condition (Mondon et al. 2003; Barton, 2003; Sherwood & Fenton, 2003; Barton & Sherwood, 2004; GHD, 2005; Molloy et al. 2005; Arundel, 2006; Barton, 2006, Arundel & Barton, 2007; Barton et al. 2008). Coastal NRM managers in CMA’s and Melbourne Water were visited and interviewed to establish what current data existed for each IEC measure (Appendix 2). This built on the results of Barton et al. (2008) and helped inform the choice of estuaries for further data derivation. It was established that limited data sets existed for the recommended methods or sampling frequency. In general terms, existing data from the west of the state were available for more systems than the east and larger systems were more likely to have been studied in the past than smaller systems. Summaries of discussions and available datasets were compiled and confirmed with each CMA after the meetings.
### Table 1. List of estuaries for which the recommended IEC is applicable

<table>
<thead>
<tr>
<th>NRM Region</th>
<th>IEC Estuaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melb. Water/</td>
<td>Little R, Werribee R, Skeleton Ck, Laverton Ck, Kororoit Ck, Yarra R, Elwood Canal, Mordialloc Ck, Patterson R, Kanonook Ck, Balcombe Ck, Merricks Ck, Cardinia Ck, Deep Ck, Bunyip R, Yallock Ck, Yallock drain, Lang Lang R, Bass R</td>
</tr>
<tr>
<td>Port Phillip &amp;</td>
<td>Corangamite</td>
</tr>
</tbody>
</table>

*: need verification that they meet criteria

![Figure 1. Locations of estuaries sampled in the DSE component of the IEC trial 2009/10](image)

### 2.2 EXPERIMENTAL DESIGNS

#### 2.2A FUNCTIONAL TYPES

To ensure the measures and condition scores are applicable to all Victorian estuaries Arundel et al. (2009) recommended that trials be conducted on estuaries that represent the range of possible responses to particular threats. Barton et al. (2008) assessed current estuary classifications for Victorian estuaries and developed a classification of four Victorian estuary types based on their physical characteristics in the...
absence of extensive ecological data (Table 2). These broad physical attributes of estuaries and their estuarine and fluvial (freshwater) catchments encompass most of the statewide variability in the major drivers (e.g. catchment size and steepness and orientation with regard to wind and current direction) that are likely to influence their ecological functioning. Within each type, estuaries exposed to a range of human threats such as land use intensity and population density, were identified (Barton et al. 2008). Arundel et al. (2009) recommended that the trial of the implementation of IEC measures should include estuaries from each of the four types exposed to high and low levels of threat.

Table 2. Descriptions of functional types of Victorian estuaries Source Barton et al. 2008

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>Run to open, west facing coasts. Large to moderate size estuaries &amp; catchments. Intermittent mouth often with lagoon. Sandy, high energy coast facing major weather patterns.</td>
</tr>
<tr>
<td>East</td>
<td>Run to open, east facing coasts. Small, intermittent estuaries with steep catchments. Rocky, moderate energy coast at angle to major weather patterns.</td>
</tr>
<tr>
<td>Bay/Sheltered</td>
<td>Run to embayments, sheltered coasts. Small to moderate, generally permanently open estuaries without lagoons. Flat small to moderate catchments. Muddy, low energy coast, some with large tides.</td>
</tr>
<tr>
<td>South</td>
<td>Run to open, south facing coasts. Large to moderate size estuaries &amp; catchments. Intermittent mouth often with lagoon. Limited seasonal difference in rainfall. Sandy, moderate energy coast facing major weather patterns.</td>
</tr>
</tbody>
</table>

The design of the trial implementation included type as an upper level factor to reduce variability in threat-response relationships and, where necessary, derive separate baselines and scoring methods.

**2.2B ESTUARY SECTIONS AND ZONES**

Any tool that assesses condition of a natural system should have clearly defined spatial boundaries and scales at which it can be applied. For the purpose of the IEC it was necessary to:

- determine the size and type of subestuary to be included in assessments; and.
- establish protocols, if required, for dividing the estuary into sections e.g. upper and lower

It was suggested that the IEC should include sections of estuaries, analogous to reaches in the ISC that can be assessed independently of each other. Two types of section are proposed for development of definitions based on either riverine or lagoonal shape (Figure 2). An individual estuary may consist of either of these or a combination of (usually) one lagoonal section and one or more riverine sections. Some of the measures can be scored for individual sections or reaches while others can only be scored for the estuary as a whole (but can then be applied to each section). While estuaries can have an influence on nearshore marine environments, the IEC does not attempt to assess the condition of these regions.
For measures where sampling across the whole estuary was necessary, estuaries were divided into 3 longitudinal regions based on geomorphologic and vegetation boundaries. Subestuaries/tributaries if present were zoned using the same criteria.

2.2C SAMPLING

As described in Section 3, only a subset of measures were practical, or required, trialling over a large number of estuaries. For the subset trialled across the state in the 2010 field campaign three different sampling designs were used depending on the measure being assessed. Each design overlayed the other two, with efficiencies of sampling made by combining sites where possible. Designs included:

1. Longitudinal sampling for salinity distribution, mouth and head observations along the full length of each estuary and major subestuaries (tributaries and lagoonal complexes);
2. Stratified sampling of water chlorophyll, microphytobenthos water quality and particle size in upper, middle and lower zones of each estuary and subestuary; and
3. Random sampling of three sites within each previously defined section (e.g. riverine and lagoonal) as outlined in the recommended method for bank erosion, lateral connectivity, water clarity and dissolved oxygen measures.

In the 2010 component of the trial twenty-four estuaries were sampled, including thirty-nine subestuaries (tributaries and lagoonal complexes) and sixty sections (riverine or lagoonal section, intended to be analogous to an ISC reach). A list of these subestuaries and sections is given in Appendix 1.
During preparation for the major field program, a proforma for data collection was developed (Appendix 3), as were designs and methods for assessing the following measures from Arundel et al. (2009):

3. Upstream Barriers (presence, type & location)
4. Lateral Connectivity (# & type of artificial structures on foreshore)
5. Marine Exchange- b) structures and behaviours (dredging & training walls)
7. Salinity Regime
8. Water Clarity (turbidity)
9. Dissolved Oxygen (mg/L & %)
10. Sediment Particle size
11. Bank Erosion (ISC method)
15. Microphytobenthos (Phaeophytin (&/or Chl a) biomass)
16. Phytoplankton (Chlorophyll a)

Table 3 lists designs associated with each theme and measure.

In the summer of 2010 24 estuaries across the state from the Glenelg River to Shipwreck Creek near Mallacoota were sampled (with an additional 6 sampled as part of an associated Melbourne Water project - Appendix 1). Two teams with two or three staff each worked in parallel throughout the field program, which involved 53 days sampling over nine weeks between 31 January and 5 April. Estuaries were sampled across the state throughout the sampling period to avoid confounding longitude with any time/season-related changes in the estuaries. During the field trip, staff from EGCMA, WGCMA, MW and CCMA participated in making observations and collecting samples as well as providing further local information and commenting on the field recording sheets and methods.

Table 3. Summary of the temporal and spatial replication needed for defined IEC measures

<table>
<thead>
<tr>
<th>Theme</th>
<th>Measure</th>
<th>Temporal replication</th>
<th>Spatial replication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrology</td>
<td>Mouth- intermittent</td>
<td>Continuous</td>
<td>mouth</td>
</tr>
<tr>
<td></td>
<td>Mouth - permanent</td>
<td>&amp; event even</td>
<td>mouth</td>
</tr>
<tr>
<td></td>
<td>Upper salinity extent</td>
<td>Defined tides</td>
<td>Length of estuary</td>
</tr>
<tr>
<td>Water Quality</td>
<td>Turbidity</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Dissolved oxygen- profile</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Dissolved oxygen - sag</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Additional parameters</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Bottom pH</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Bottom conductivity</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Top conductivity</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td></td>
<td>Stratification status</td>
<td>Monthly</td>
<td>Section</td>
</tr>
<tr>
<td>Flora</td>
<td>Chlorophyll a</td>
<td>Monthly but process</td>
<td>Zone</td>
</tr>
<tr>
<td></td>
<td>Dominant algal id &amp; counts</td>
<td>only if bloom</td>
<td>Zone</td>
</tr>
</tbody>
</table>
Figure 3. Estuaries sampled in 2010 by functional type and threat level within type.
2.3 Approaches to Determining Baselines and Scoring Criteria

Arundel et al. (2009) assessed the feasibility of immediate implementation of each measure based on numerous aspects of data collection and data interpretation. A score from one to five was derived to describe the immediate feasibility of implementing a measure. For example, the existence of established sampling protocols, baseline conditions and scoring descriptions meant that immediately implementing the measure was very feasible and so was scored as one. If any of these aspects were only partially developed (PD) or yet to be developed (TBD) the feasibility score increased. A ribbon displaying this information graphically is given above each measure, the colour range from dark green for immediately feasible implementation to red for least feasible.

3 Results of Implementation of Physical Theme

3.1 Changed Bathymetry

| Sampling protocol PD | Baseline condition TBD | Scoring description PD | Implementation Score 4 |

This measure was proposed as an accurate measurement of change in bathymetry, occurring along cross-sectional transects in depositional locations. Depositional sites to be targeted include fluvial & flood tide deltas, the area of maximum turbidity, and tidal flats and basins. The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to require a deal of work and be hard to achieve. Assessment of implementation of this measure was identified primarily as needing testing of sampling and scoring methods and the development of baseline condition.

Coastal managers were interviewed to assess what previous studies and data existed. Little data was located. During the 2010 fieldtrip depositional sites were identified. The assessment of this measure is proposed to be the limited re-measurement of a few well surveyed estuaries. At the moment it is proposed to assess the bathymetric change in Werribee, Gellibrand and Snowy.

It is also proposed that in the second stage of the implementation trial post-European deep cores will be taken and dated using nuclear techniques in a few targeted estuaries to help inform current day bathymetric mapping. This work would be undertaken in collaboration with Ballarat University and some additional funding has been granted by the Australian Institute of Nuclear Science and Engineering (AINSE) for core dating in cores taken from estuaries running into Port Phillip Bay. This assessment is planned to be completed by late 2011. This measure also relates to those of sediment load and particle size (see Sections 3.2 and 6.1). An assessment will also be done of the efficacy of remote sensing, primarily LiDAR, for deriving data for this measure.

Scoring proposed for this measure is still broad and at either end of the condition spectrum:

Poor: large change from natural and a reduction from baseline; Good: close to natural and no anthropogenic change from baseline.
### 3.2 Sediment Load

<table>
<thead>
<tr>
<th>Sampling protocol PD</th>
<th>Baseline condition PD</th>
<th>Scoring description PD</th>
<th>Implementation Score 3</th>
</tr>
</thead>
</table>

This proposed measure requires modelling of natural loads and modelling and/or measurement of current loads into the estuary from the catchment. Contextual information is provided by the history of sedimentation in an estuary and its catchment which also relates to the measures of changed bathymetry and particle size. The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be moderately achievable. Assessment of this measure was identified primarily as needing derivation of data through modelling.

No estuary specific modelled sediment load was located through literature searches or interviews with coastal managers. The two catchment sediment load methods of SEDNET and E are too coarse for estuary specific modelling for estuaries at the smaller end of the IEC scale. Hydrological modelling for the Climate Change component of stage 2 will feed into this measure. Further assessment of the implementation of this measure will focus on modelling natural and current sediment loads for a few estuaries, with emphasis given to estuaries sampled in 2010, and that are being assessed as part of the bathymetry or incubated core measure.

In NSW a scoring method based on percentage increase in sediment load from natural has been developed while in Queensland a scoring method based on absolute load has been suggested (Scheltinga & Moss, 2007).

Scoring proposed for this measure is still broad and at either end of the condition spectrum:

- **Poor**: large change from natural (NSW >483% increase; Qld >10kg/year/m³); **Good**: small/no change from natural (NSW <12% increase; Qld <5kg/year/m³)

### 3.3 Upstream Barriers

<table>
<thead>
<tr>
<th>Sampling protocol E</th>
<th>Baseline condition PD</th>
<th>Scoring description E</th>
<th>Implementation Score 1</th>
</tr>
</thead>
</table>

This proposed measure requires the identification of the presence of anthropogenic barriers to upstream movement of water or biota in addition to their location relative to estimated natural upstream limit of estuary. The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be very achievable. Assessment of this measure was identified primarily as needing to collate, derive and field measured data. A lot of data on the location of upstream barriers was collated and measured in the Estuaries Threats project (Barton et al 2008). Additional data was collected during the 2010 field campaign. The particular challenge of assessing and implementing this measure is developing a method to derive natural heads of estuaries. This requires an assessment of the applicability of remote sensed LiDAR data in collaboration with the Climate Change component of stage 2.

Scoring is related to presence/absence, distance of the barrier downstream from the 'natural' head', permanency of the barrier and to the degree to which the barrier restricts movement of biota (eg. weir vs sand slug). A tentative scoring system modified from one that was suggested for assessing estuaries in the RiVERS(II) workshop, November 2008 is shown in Table 4.
### Table 4. Provisional scoring system for ‘Upstream barriers’

<table>
<thead>
<tr>
<th>Intermittent or selective interference with movement of biota or water (in typical year)</th>
<th>Completely blocked movement of biota or water (in typical year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50% of estuary area affected</td>
<td>1</td>
</tr>
<tr>
<td>25-50% estuary area affected</td>
<td>2</td>
</tr>
<tr>
<td>0-25% estuary area affected</td>
<td>3</td>
</tr>
<tr>
<td>No barriers to water or biota</td>
<td>4</td>
</tr>
</tbody>
</table>
3.4 LATERAL CONNECTIVITY

This proposed measure requires the measurement of the percentage of the estuary perimeter comprising artificial structures such as seawalls, levee banks, jetties, bridges, platforms. The implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be reasonably achievable. Assessment of this measure was identified primarily as needing to collate, derive and collect field measured data. Field assessment of lateral connectivity was carried out in the summer of 2010. Difficulties were encountered in assessing lateral connectivity from the water as fringing vegetation can obscure the presence of levees, which are also sometimes difficult to distinguish from natural banks. As this measure is a whole of estuary measure it is probably best determined by remote sensing with targeted ground truthing in the field. This requires an assessment of the applicability of remote sensed LiDAR data in collaboration with the Climate Change component of stage 2. Remote sensed data would provide whole of estuary coverage. Another proposed method is to use whole of estuary video surveys to identify impediments to lateral connectivity. Data is not currently available to assess the sensitivity of this measure in measuring change over the proposed six year assessment cycle. This presents challenges in trying to develop scoring with the currently available data.

Scores distributed at equal intervals between 6 and 25 % were calculated based on the distribution of NSW data. This would need to be revised for Victorian estuaries. Refinement of the measure could also incorporate measure 14 (Fringing macrophyte extent) and the types of structure present.

The scoring system in Table 5 was developed at the IEC workshop and modified at the RiVERS(II) workshop November 2008. This could be used pending refinement of this measure for Victorian estuaries.

Table 5. Provisional scoring system for ‘Lateral connectivity’

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&gt;15% of the estuary perimeter has artificial structures OR Wetlands no longer connected to the estuary;</td>
</tr>
<tr>
<td>2</td>
<td>1-15% of the estuary perimeter has artificial structures OR Wetlands connected to the estuary but less than natural;</td>
</tr>
<tr>
<td>4</td>
<td>Estuary has no artificial structures AND EITHER Wetlands fully connected to the estuary OR No estuarine wetlands exist.</td>
</tr>
</tbody>
</table>
Figure 5. Examples of structures affecting lateral connectivity.
4 RESULTS OF IMPLEMENTATION OF HYDROLOGY THEME

4.1 MARINE EXCHANGE
Records need to be made of the marine exchange at the estuary mouth, with different methods used for intermittently and permanently open estuaries.

4.1A MOUTH OPENINGS
Intermittently open estuaries

Artificial openings (% of total)

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Baseline condition</th>
<th>Scoring description</th>
<th>Implementation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>TBD</td>
<td>E</td>
<td>2</td>
</tr>
</tbody>
</table>

Height (AHD) of opening

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Baseline condition</th>
<th>Scoring description</th>
<th>Implementation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>PD</td>
<td>PD</td>
<td>2</td>
</tr>
</tbody>
</table>

This recommended measure is the recording of all openings and whether natural or artificial over the entire six year reporting cycle to account for interannual changes. As part of this the water height (AHD) within the estuary before artificial opening needs to be recorded. This measure needs to be interpreted with rainfall, stream flow and sea state records.

Implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be reasonably achievable. Assessment of this measure was identified primarily as needing to collate and derive data. Some data is available for artificial opening from CMA records for the last couple of years but not all natural openings are recorded. As these measures need to be recorded for the entire six year reporting cycle they are probably best done by installing water depth data loggers and recording all artificial openings. Water depth loggers will also provide valuable information on the duration of openings and tidal exchange when open. Logged water depth data is currently available for fourteen estuaries along the west coast for the last couple of years and will be used to examine the frequency and duration of natural openings for these estuaries. An example of such data (Figure 6) is an shows logged water height over three separate ten week periods showing the three clearly identifiable different mouth states of closed, perched and tidal, the temporal distribution of which is affected by artificial openings.

Records of mouth openings for the east coast are predominately from Powlett and Snowy Rivers and there are no long term water depth loggers to derive natural openings. There is not enough existing data to assess either part of this measure over the recommended 6 year cycle. Insufficient records exist to assess change over twelve years as would be done for consecutive IEC assessment.
A tentative scoring system for the percentage of artificial opening has been modified from a threat-based scoring system developed at the AVIRA estuaries workshop (Table 6).

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&gt;50% artificial openings;</td>
</tr>
<tr>
<td>1</td>
<td>25%-50% artificial openings;</td>
</tr>
<tr>
<td>2</td>
<td>&lt;25% openings artificial;</td>
</tr>
<tr>
<td>4</td>
<td>no artificial openings</td>
</tr>
</tbody>
</table>

These scores will need to be combined with heights (when locally calibrated) in a matrix that weights artificial openings at low elevations as worse for estuarine condition. Should an artificial opening take place primarily for the benefit of the estuarine ecosystem following an EEMSS-based assessment it may be disregarded.

The estuary water height at artificial opening can be broadly scored as poor with low water levels and good for high water levels. This needs to be compared with water levels at natural openings to derive more specific scores.
4.1B STRUCTURES & BEHAVIOURS

Permanently open estuaries

Dredging

This measure requires the record of any dredging and/or training walls at the mouth of the estuary. Implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be very achievable. Assessment of this measure was identified primarily as needing to collate and derivation data. This measure is a mixture of desk top analysis and on ground field assessment. Information on frequency and volume or number of days of operation and capacity of the dredge or how much has been spent on dredging from the Port Boards is needed to derive past quantitative data. For implementation of the dredging measure it is recommended that an information agreement with the responsible port authority or dredging agent be made. Field assessment was made of built structures at the mouth in summer 2010. Methods on how to score this measure and its sensitivity to change over the six year reporting period need to be resolved.

Scoring proposed for this measure is still broad and at either end of the condition spectrum:

Poor: Dredging present and two training walls
Good: Dredging absent and no training walls

Intermediate scores related to frequency and degree of dredging is desirable, depending on the numbers of estuaries affected and the scales of dredging activity.
4.2 FRESHWATER FLOW
These suite of measure aims to measure the degree of freshwater driven hydrological change. Where an Index of Stream Condition reach exists upstream of the estuary its hydrological sub-index score should be used. Where there is no ISC reach a combination of freshwater flow modification due to farm dams and water extraction needs to be done. Also in the hydrology theme is the upstream extent of salinity in the estuary as this is most likely to increase with freshwater extraction and climate change.

4.2A ISC HYDROLOGICAL MODIFICATION (UPSTREAM ISC REACH)

This measure requires the ISC hydrological modification score for the reach immediately above the head of the estuary. Immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be very achievable. Assessment of this measure was identified primarily as needing to derive data. This measure is predominately available for large to medium estuaries, and the ISC hydrology score is derived from gauged freshwater flows or modelled flow change. ISC hydrological modification scores are available for 60 of the IEC estuaries. The scores are based on low, high and zero flow, and flow seasonality and variability. Where there is no ISC reach immediately upstream of the estuary, the degree of hydrological change needs to be determined by assessing the number of dams and/or extraction licences in methods outlined below.

The ISC hydrological modification score is based on freshwater ecosystems and responses. Direct translation of scores from the ISC sub-index should be used with caution as no specific assessment of their relationship to estuarine condition has been made. An estuary specific hydrological modification method EEFAM has been developed for Victorian estuaries but has only been trialled in Werribee and Gellibrand so far. In future, the availability of multiple EEFAM assessments may allow some calibration of the ISC hydrology index to estuarine flow requirements.

Current assessment of the response and sensitivity of this measure is not possible. ISC hydrological change was assessed in both 1999 and 2004 but major methodological change makes assessment of change not appropriate. Results from the current 2010 ISC assessment will be available in 2011 to allow an assessment of this measures response and sensitivity.
Melbourne Water has assessed the degree of hydrological modification of the freshwater reaches of 17 estuaries through its Index of River Condition. The IRC is based on the ISC but modified for urban systems. Generally the IRC rates the hydrological modification as less than the ISC and the ISC should be used for the IEC hydrological modification score.

Scores for this measure are based on a reference of a natural flow regime and should modify the 1 to 10 scores of the ISC hydrology index to a 0 to 4 score to align with the rest of the IEC measures. For the ISC poor is scored 1 and good 10.

**4.2B NUMBER OF DAMS (NO UPSTREAM ISC REACH)**

<table>
<thead>
<tr>
<th>Sampling protocol PD</th>
<th>Baseline condition PD</th>
<th>Scoring description</th>
<th>Implementation Score 3</th>
</tr>
</thead>
</table>

This measure is based on the number of dams in estuary catchments standardised by catchment area. The immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be moderately achievable. The size and volume of the dams needs to be taken into consideration, not just the number. Assessment of this measure was identified primarily as needing to derive data. Some state wide mapping of farm dams has been undertaken as part of the new water strategies. Geosciences Australia mapped farm dams at 1:25,000 and this was being updated by SKM to give volume as well as area. This measure will be assessed in the second stage when the dam layer is finalised and in collaboration with the Climate Change component. A few catchments will be selected for the trial of this measure. A comparison of this measure will be made between equivalent catchments with ISC hydrology scores. A good score for this measure is represented by no dams while the upper end of this measures score is not yet known. It will not be possible to determine the sensitivity of this score with existing data.

**4.2C NUMBER OF EXTRACTION LICENCES (NO UPSTREAM ISC REACH)**

<table>
<thead>
<tr>
<th>Sampling protocol PD</th>
<th>Baseline condition PD</th>
<th>Scoring description TBD</th>
<th>Implementation Score 4</th>
</tr>
</thead>
</table>

This measure requires the number and volumes of fresh water extraction licences in estuary catchments to determine the extraction volume relative to the mean annual flow immediately above the estuary. Immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be hard to achieve. Assessment of this measure was identified primarily as needing to derive data. A few catchments are to be selected for the trial of this measure with the number of licences obtained from the water boards that manage extraction from those catchments.

A comparison of this measure will be made between equivalent catchments with ISC hydrology scores. Good is no extraction and the upper end of this measures score is not yet known but is a high proportion of the MAF. It will not be possible to determine the sensitivity of this score with existing data.

Ground water extraction is poorly documented and is thought to play an important role in the hydrology of freshwater and estuarine systems. Further work needs to be done to incorporate ground water extraction into this measure.
4.3 **SALINITY REGIME**

| Sampling protocol PD | Baseline condition PD | Scoring description PD | Implementation Score 3 |

The salinity regime measure is designed to assess whether the salinity regime has moved upstream in the estuary over the reporting period. This measure requires depth profiles of salinity at fixed sites along the length of the estuary measured on spring and neap and high and low tides (for open estuaries) during high flow and low flow periods. Data should be collected each year and assessed on a 6 yearly basis to integrate longer term variability. Immediate implementation of this measure with existing knowledge and data for Victorian estuaries was thought to be moderately achievable. Assessment of this measure was identified primarily as needing to collate existing data, refine the method and field sheets and derive new data. Considerable resource issues could be incurred trying to assess this measure. It is important that the salinity data is collected in a good design so that trend analysis can be conducted. Sampling was conducted in the 2010 field trip that has informed the refinement of methods. Data is being assessed and collated from other studies and theses. Particularly useful data for this purpose are results from long-term monitoring conducted by Glenelg Hopkins in 6 of its estuaries from October 2003. However there were still not sufficient time series of data available to determine the response and sensitivity of this measure.

There are many possible distribution patterns of salinity that vary in response to estuary size and shape, prevailing weather, and marine and tidal inputs. Despite this variety of patterns, a common trend associated with reduced freshwater flows and increased marine connectivity is for upstream movements of the overall salinity distribution. Scoring at the moment is relatively coarse with poor an upstream movement of salinity distribution (as a yet undetermined percentage of natural or baseline), and good no net upstream movement of salinity distribution.

A high level of expertise is required to assess trends in salinity distribution as patterns may be variable on a range of spatial and temporal scales. There may also be differences in the specific changes in pattern depending on the type of estuary which will need to be assessed with development of this measure. Unless there are existing data, the first assessment round will provide a baseline condition. There are opportunities in stage 2 of the IEC trial to collaborate with the EEMSS component to refine the method and collect data. Data collection and derivation should also be achieved in collaboration with the Climate Change component. Estuaries with artificially increased base flows may require a refinement of scoring criteria.
5 RESULTS OF IMPLEMENTATION OF WATER QUALITY THEME

The water quality theme consists of two measures, water clarity and dissolved oxygen.

5.1 WATER CLARITY (TURBIDITY)

Water clarity as measured by turbidity (NTU) was to be collected following the recommendations of Scheltinga and Moss (2007), avoiding high flow events. This water quality measure is to be collected monthly over an assessment year. Immediate implementation of this measure was thought to be reasonably achievable as it is based on the existing methods (of Qld EPA)(Scheltinga & Moss, 2007). The major impediment to trialling this measure is the limited amount of data that was located across Victoria’s estuaries when collation of data was undertaken. Like the Salinity measure the best data set is the monitoring of six estuaries by Glenelg Hopkins CMA. Some single-site monthly data is also available for up to 3.5 years for 8 estuaries from early 2000 sampling by EPA (Curdies, Gellibrand & Aire, with 6 months sampling in Barham, Painkalac, Powlett, Franklin and Tarra). Corangamite EstuaryWatch also measures turbidity in 5 estuaries but the method is coarse (<10, 10-15 & 20-30 NTU). Surface and profile measurements were taken at multiple sites in the 2010 field trip but as one-off snapshots rather than at the sampling frequency recommended by Scheltinga and Moss (2007). Selected results from the 2010 field campaign are shown against single-sample preliminary guidelines (Figure 10).
Preliminary assessment of the snapshot results indicates that turbidity in most estuaries is below the preliminary guideline value. Exceedances were all in estuaries with high threat ratings and were observed across all functional types except South-facing open coast estuaries. The skewed distribution of turbidity results suggests a similarly skewed scoring method may be required. Analysis of existing monitoring data by control charting will also contribute to development of scoring distributions.

Development of method should be focussed on the estuary wide design, identification of sites and position within sites in which to measure. It is recommended that sampling should be undertaken at three sites within each riverine and lagoonal section in the estuary (Figure 2, Table 9). The three sites should be randomly chosen within predefined sections at the start of the monitoring program. Contextual information such as tidal flow, depth, channel width of dissolved oxygen concentration, temperature and salinity need to be recorded when the data is collected. To be able to compare results to the EPA estuarine water quality guidelines (EPA, 2010) additional parameters need to be collected, specifically bottom water pH, top and bottom water conductivity, stratification status and the average daily flow over the previous week.

Natural turbidity levels are influenced by the type and size of particles and hence will be affected by a range of estuarine characteristics such as tidal flow, soil type, geology, slope, orientation, prevailing wind direction, depth and width. These factors will need to be taken into account (initially using functional type) when setting baseline conditions for particular estuaries and site specific baseline conditions may need to be considered.
Scoring for turbidity has been recommended as poor if the annual median is > 20 NTU over a year (based on NSW and Vic data) and good if < 6 (Victorian EPA 5 (surface)-7 (bottom); NSW 6). Based on initial assessments of snapshot data from 2010 these values appear to be appropriate. Additional sampling in 2011 and 2012 will add to the diversity of estuaries sampled and the data set from which to refine scoring from, in collaboration with the EEMSS component.

Method refinement will concentrate on scoring based on EPA guidelines and clear guidelines for the design and placement of sampling sites. For the extension of the trial a monitoring program needs to be developed for the eleven Melbourne Water estuaries to collect monthly data. Similar monthly monitoring programs in estuaries of all functional types, particularly south-facing estuaries in Gippsland also need to be established.

![Aire river estuary – riverine section](image1)

![Anderson Inlet estuary – Tarwin riverine section](image2)

Figure 11. Examples of sites with low (Aire) and high (Anderson) turbidity in Feb 2010

### 5.2 DISSOLVED OXYGEN

<table>
<thead>
<tr>
<th>Sampling protocol E</th>
<th>Baseline condition PD</th>
<th>Scoring description PD</th>
<th>Implementation Score 2</th>
</tr>
</thead>
</table>

This measure is based on monthly surface measurements over an assessment year. In addition to monthly surface measurement, vertical daytime (late afternoon) dissolved oxygen profiles (at 3 sites mid stream) are suggested to detect anoxic bottom waters and algal blooms. The IEC also recommends assessing the diurnal oxygen sag by collecting 24 hour surface measurements at the most vulnerable of three sites collected once every six years. The immediate implementation of this measure was thought to be reasonably achievable and requires collating existing data, refining field sheets and deriving new data particularly 24 hour oxygen sags.

As for the Salinity and Turbidity measures the best available data set is from the monitoring of six estuaries by Glenelg Hopkins CMA. Some single-site monthly data is also available for up to 3.5 years for 8 estuaries from early 2000 sampling by EPA (Curdies, Gelibrand & Aire, with six months in Barham, Painkalac, Powlett, Franklin and Tarra). Corangamite EstuaryWatch does not measure dissolved oxygen. Surface and profile measurements were taken at multiple sites in the 2010 field trip but not at the sampling frequency recommended by Scheltinga and Moss (2007). Selected results from the 2010 field campaign are shown against single-sample preliminary guidelines (Figure 12). Analysis of existing monitoring data by control charting will also contribute to development of scoring distributions.
Figure 12. Mean dissolved oxygen saturations +/- std error for 3 random sites in selected sections of estuaries sampled in 2010. EPA preliminary guidelines for single samples are shown (EPA, 2010). Full assessment of this measure relies on monthly data over a year and control charting guidelines.

Few locations had oxygen concentrations below the minimum values of the single-sample preliminary guidelines for either surface or bottom waters. Exceedances of the maximum guideline were more common although the time of sampling was during late summer, when highest concentrations of oxygen from algal blooms would be expected. In contrast to the data for turbidity, some of the greatest exceedances of preliminary guidelines were recorded from estuaries with low threat levels (i.e. Aire, Shipwreck).

Overnight logged DO was conducted in 23 estuaries in the summer of 2010. Summary results from these logger deployments is shown in (Figure 13). Overnight dissolved oxygen concentrations were generally lower in estuaries with higher threat levels, the exception of south-facing estuaries was due to the sole low-threat estuary sampled being Shipwreck Creek estuary which was experiencing an algal bloom at the time of sampling. A limited number of estuaries also have permanently-installed oxygen loggers that can also be used for oxygen sags.
Contextual information on temperature and salinity should also be collected. To be able to compare these measures results to the EPA estuarine water quality guidelines (EPA, 2010) addition parameters need to be collected, specifically, bottom water pH, top and bottom water conductivity and stratification status.

Method refinement will concentrate on scoring based on EPA guidelines and clear guidelines for the design and placement of sampling sites. Sampling for dissolved oxygen is recommended to be undertaken at three sites within each riverine and lagoonal section in the estuary. The three sites should be randomly chosen at the start of the monitoring program. For the extension of the trial a monitoring program needs to be developed for the eleven Melbourne Water estuaries to collect monthly data. Similar monthly monitoring programs in estuaries of all functional types, particularly south-facing estuaries in Gippsland also need to be established. Additional sampling by Deakin and ARI (EEMSS component) in 2011 and 2012 will add to the diversity of estuaries sampled and the data set from which to refine scoring.

The percentage exceedance of environmental trigger values identified in the Victorian EPA guidelines for estuaries could provide condition descriptions and scores. Initial figures for scoring were poor if surface waters < 50% or >110% saturation and good if between 80-100% saturation. Scheltinga and Moss (2007) provide condition scores (1 to 5) for two oxygen indicators. One based on the minimum sustained dissolved oxygen values during the days following an inflow event and the second on a measure of ambient dissolved oxygen i.e. the percentage of zones/sites that exceed QLD EPA guidelines. Condition descriptions also need to accommodate naturally occurring low and high oxygen levels of some individual estuaries (Barton, 2006; Mondon, Sherwood & Chandler, 2003).
6 RESULTS OF IMPLEMENTATION OF SEDIMENT THEME

6.1 SEDIMENT PARTICLE SIZE

This measure is based on the proportion of sediment in the top 10cm of the estuary bed that are <125 µm in diameter (i.e. clays, silts and very fine sands) as a measure of sedimentation. A design of eight replicates at depositional locations in the upper, middle and lower zones of the estuary was suggested by IEC. Sampling was recommended to be repeated twice a decade but would fit in better with the IEC reporting cycle if done once every six years. Immediate implementation of this measure was considered hard to achieve as there is very little existing data identified as being collected in depositional locations. Identifying depositional locations that could be revisited/resampled in 6 years was difficult in the 2010 fieldwork and requires a higher than moderate level of skill. A moderate level of skill and specialized equipment is required for particle size analyses but can be done by a range of commercial laboratories. A range of Australian Standards have been published regarding measurement and representation of sediment particle sizes (e.g. AS 1141.11—1996 for dry sieving of coarser sediments). Analysis of collected sediment samples needs to be finalised with some estuaries needing dispersant. A comparison of change over 6 years might be possible in Painkalac and Anglesea using data from Pope (2006).
Either end of the scoring range for this measure have been identified as poor condition is a >20% increase in the fine fraction by weight compared to the last survey and good condition <20% increase or decrease in the proportion of fines. More detailed scaling of this measure will be possible once a baseline dataset is available for a range of Victorian estuary types and conditions from both stage 1 and stage 2. Following collection of such data it is likely that a range of scoring scales will be required for differing groups of estuaries.

This measure was one of several possible measures of sedimentation/erosion recommended as national indicators but for Queensland estuaries it was excluded as impractical for those systems (Scheltinga & Moss, 2007). In South Africa mapping of the distribution and sedimentary composition of shoals in each estuary is combined with particle size information from 6 benthic sites and used as a basis for an expert opinion on the percentage similarity of total intertidal area and sand fraction compared to an undisturbed system (Taljaard et al., 2004).

For Victorian estuaries interpretation of these data will need to take into account influences of estuary type (particularly with respect to the availability of depositional areas and the frequency of scouring). Contextual information for this measure includes major flooding, extended droughts, presence of large dams and the existence of riverine sand slugs.

A summary of median particle sizes collected at depositional sites in 2010 is shown in Figure 15. The spatial comparison between estuaries does not show a trend for smaller particle sizes in low threat estuaries, although as mentioned, the measure is intended as a temporal one at specific locations within estuaries. In some cases, such as Cardinia estuary, gravel washed down in recent floods was evident as a discrete layer and contributed to higher particle sizes in the samples. This highlights the need for expert interpretation of the data and potential sources as well as the context dependency of the measure. The component of the trial assessing sedimentation events using dating (Section 3.1) will assist in developing interpretation of this measure and in assessing its viability.
Figure 15. Mean and std error of median particle size at depositional locations by estuary type (n=4).
6.2 BANK EROSION (ISC METHOD)

Data for this measure is recommended to be collected as per the ISC method for assessing bank stability. Three sites within each estuarine section (e.g. reach) are be assessed. Photos of the sites being assessed are taken for reference (eg Figure 16). Collection of data could be done by relatively unskilled personnel. Immediate implementation of this measure was considered very achievable as it is based on the established ISC method. It was thought that the trial of this measure needed derivation of data through field sampling. The existing ISC method was trialled for estuaries in 2010 and difficulties of scoring when the majority of the bank was not exposed with different water depths (tidal or mouth state) were evident as was the need for substantial adaptation of the ISC scoring method for estuaries.

![Figure 16. Examples of banks across the scoring range for the erosion measure.](image)

A comparison of the field recorded data to the photos will be made and a library of good to bad bank conditions made for field use. Future photos taken for this measure should be geolocated and published online in a photolibrary such as one freely available at <http://picasaweb.google.com.au >.
Figure 17. Overall distribution of bank erosion scores using the preliminary scoring method adapted from the ISC.

The distribution of erosion scores collected at random sites in 2010 is skewed for both lagoonal and riverine reaches (Figure 17). Scores were slightly higher for riverine sites than lagoonal sites. The presence of several records where a score could not be decided (the ‗.5 scores) indicate that refinement of the criteria is required. The skew of the data also suggests that the scoring methodology needs to be modified to produce a better distribution of scores, and hence better resolution between sites. Issues with the scoring method that arose related mostly to general morphological differences between estuaries and rivers in combination with the typically reduced velocity and bi-directionality of flows in estuaries. Examples include scoring methods, if relevant, for mobile sand flats which were typically scored as 4 and areas of mud flat fringing large portions of estuaries.

LiDAR erosion assessment method being developed for the ISC should be assessed for the IEC as it could give whole of system coverage rather than small sections of bank. Field assessment to validate the automatic LiDAR classification will be needed as the method that works for streams will not necessarily work for estuaries. Difficulties will be encountered if the estuary LiDAR is being flown in conjunction with the ISC LiDAR due to water levels. The IEC LiDAR needs to be collected at low tide in open systems, this will be particularly problematic for intermittently open estuaries. LiDAR does not penetrate through Phragmites beds.

The extremes of the scoring range for this measure have been identified; Poor rated as increased bank instability and good being stable, intact banks. Data for this measure will initially be scored on a five point scale as per ISC scoring. The erosion ranking developed by this trial should ideally be reviewed by an estuarine geomorphologist and rated for potential sediment contribution. The importance of bank erosion as
a measure of estuarine condition will vary between estuaries in response to geomorphology (e.g. narrow, riverine estuaries vs broad lagoons) and proportional contribution to suspended sediment concentrations and loads (i.e. links to water quality and physical form themes).

Ultimately scoring for this measure should be interpreted in context of the type of estuary and the influence of other sediment sources in the estuary. Bank erosion in some systems may be a response to a reduced fluvial sediment supply disrupting the sediment balance of intertidal areas, in these systems there may be an offsetting benefit elsewhere in the estuary and this measure should be scaled appropriately.

Scaling of this measure should be based on percentile distributions of initial scores for this measure across groups of estuaries.

6.3 SEDIMENT RESPIRATION RATE

The sediment respiration measure uses incubated core tubes and the NSW EPA technique. Five pairs of cores are taken at each of three sites axially along the estuary from shallow areas (i.e. that are not light limited). They are then lab incubated in light and dark conditions. Immediate implementation of this measure was thought to be moderately achievable primarily because of the collaboration of NSW colleagues. It depends on the derivation of data and field assessment of method. There is some variation in the NSW method Scanes suggested at the IEC workshop vs Potts and Ferguson recent work. The team from NSW will be conducting a collaborative sampling trip in Great Ocean Road estuaries with the IEC trial team members in the first week of February 2011. It is hoped that a number of measures can be compared, including fish and perhaps birds. The design at the moment is four estuaries over one week contrasting high threat and low threat estuaries. Rather than sampling axially along the estuary multiple sites and samples in the lower estuary will be compared. Water quality, particularly dissolved oxygen and turbidity are sampled for a few months prior to the incubated core sampling.

Scoring at either end of the range is based on NSW results of poor is < -105 µMO₂/m²/day: i.e. heterotrophic where it is unexpected (e.g. shallow margins with good light) and good is autotrophic to zero (≥0  µMO₂/m²/day). The collaboration with NSW DECC will examine if the results from similar systems in NSW apply to Victorian estuaries.

7 RESULTS OF IMPLEMENTATION OF FLORA THEME

7.1 AQUATIC FLORA

The lack of standing monitoring protocols and problems differentiating natural changes in macrophyte extent from anthropogenic induced change may make their inclusion in the IEC at this stage difficult.

7.1A MACROPHYTE CHANGE

This measure is based on the percentage cover change from historical to present. The preference is for change from historical (i.e pre-European settlement) but more recent or current estuary condition may have to be the baseline for further assessment. Immediate implementation of this measure was thought to be hard to achieve due to the high level of skill needed. It depends on the collation of available mapping, derivation of data and field assessment of method. The sampling protocol is still to be determined, a high
level of skill will probably require remote sensing (such as aerial photography or multispectral scanning) in addition to field assessment requiring diving and taxonomic expertise. Quarterly collection of data quantifying percent cover is tentatively recommended. Frequency of assessment would probably only be required every six years to coincide with the IEC reporting cycle, but this depends on the method recommended, quarterly collection of data to quantify percent cover across seasons was tentatively recommended in the IEC. Both the frequency of data collection and the skill level required will be confirmed once a sampling method is confirmed. Data will be collected in collaboration with the Climate Change component of stage 2.

The methods of previous aquatic submerged vegetation studies such as Ball and Blake (2009) and the Seagrass Mapping of Victoria’s Inlets series need to be reviewed as it is important to make the most of previous mapping where it does exist. IEC mapping may require a simplified method. Data also exists from thesis studies such as Pope (2006) for Anglesea and Painkalac and Ierodiaconou & Laurenson (2002) for the Hopkins. Previous studies are particularly important as they allow assessments of change that are critical in developing this metric. Current remote sensing intertidal vegetation mapping projects may also provide large scale and coverage appropriate for the IEC.

Variation in seagrass extent and cover in intermittently-open estuaries can occur due to natural changes in water levels associated with flow regimes and entrance condition (Pope, 2006). Both act to alter the amount of potential habitat available for seagrass beds. Development of a monitoring program of these factors may provide information to differentiate natural changes from those associated with human activities.

The resolution of the method used will influence condition scores. IEC tentatively suggested scoring of >20% poor, 10-20% fair and < 10% good condition and assume a 10% mapping error. Scheltinga & Moss (2007) score 1 to 5 for change in seagrass extent & cover (both as %loss/year).

### 7.1B Macroalgal Cover

| Sampling protocol PD | Baseline condition PD | Scoring description TBD | Implementation Score 4 |

This method is based on the percent cover of macroalgae. Sampling protocol is still to be determined. It will probably involve remote sensing (such as aerial photography or multispectral scanning) in addition to field assessment requiring diving, video survey and taxonomic expertise. Quarterly collection of data quantifying percent cover is tentatively recommended. Immediate implementation of this measure will be hard to achieve because of the high skill level required, method development needed and amount of data collection required due to lack of existing data.

Existing data on macroalgal cover in Victorian estuaries is limited, with the most comprehensive data to date described in Ball and Blake (2009). In many estuaries large beds of macroalgae can form and it is likely that some knowledge of the extent and productivity of these beds will be required to interpret data for both microphytobenthos (Section 7.3) and phytoplankton (Section 7.4). An extension of the IWC approach may be useful to explore for this measure.

Either end of the scoring range has been suggested as poor is >50% macroalgal cover and good <15%. A review by Scanlan et al. (2007) includes a decision table which combines algal biomass and percentage cover to assign quality status levels of 1 to 5. This scoring method was refined by Patricio et al. (2007) for a 1 to 4 score when biomass data is not available. They also examined how scores differed if data were
collected during different sampling periods. Data from estuaries state-wide is required to confirm the description for good and poor and assign intermediate scores.

7.1C NUMBER OF MACROALGAL BLOOMS

<table>
<thead>
<tr>
<th>Sampling protocol PD</th>
<th>Baseline condition E</th>
<th>Scoring description E</th>
<th>Implementation Score 4</th>
</tr>
</thead>
</table>

Immediate implementation of this measure was thought to be hard to achieve as the sampling protocol needs to be developed. Documenting macroalgal blooms requires regular observations and monthly monitoring is recommended. Concentration of observations during the warmer months should be considered. This measure could be developed so that it is suitable for community monitoring through EstuaryWatch. There has been no systematic reporting of macroalgal blooms in Victorian estuaries.

Either end of the scoring range has been suggested as poor is 1 or >1 per reporting period, and good 0. This was extended and refined in the development of AVIRA which recommended scoring based on the % of estuary with excessive instream plant growth with poor >25% and good<1%.

7.2 FRINGING MACROPHYTES (EXTENT AND CONDITION)

<table>
<thead>
<tr>
<th>Sampling protocol PD</th>
<th>Baseline condition PD</th>
<th>Scoring description PD</th>
<th>Implementation Score 3</th>
</tr>
</thead>
</table>

The immediate implementation of a measure for assessing fringing macrophytes was considered to be reasonably achievable, being developed from detailed mapping already done. It was thought that the trialling of this measure would require collation and derivation of data after the method had been refined. The measure would be collected once every six years in the IEC reporting cycle. Detailed mapping of fringing vegetation has been undertaken at 1:50,000 scale for seven estuaries in the Glenelg Hopkins CMA (Sinclair & Sutter, 2008), eight estuaries in the Corangamite CMA (Osler et al., 2010) and statewide for saltmarsh and mangroves (Victorian Saltmarsh Study*, 2010). The saltmarsh mapping was originally intended to be released in February 2010 but the report and data layer were not available at this stage of the trial. This has meant that the assessment of the saltmarsh mapping output as a measure for fringing macrophytes could not be undertaken until stage 2 of the IEC trial. This project has also revised the EVCs considered to be saltmarsh. Both mapping projects include an assessment of EVC condition. Sinclair and Sutter (2008) reviewed previous Victorian vegetation assessment such as habitat hectares and the Index of Wetland Condition. The IEC method for assessing fringing, estuary associated macrophytes has not yet been developed, a condition checklist and scoring method needs to be developed in conjunction with the measure for Lateral Connectivity. This also needs to be done in collaboration with the Climate Change component of stage 2. The checklist could note the area altered by disturbances, the presence of infrastructure likely to affect the condition of fringing vegetation, exotic vegetation, vehicle access, grazing, weirs, culverts etc. It is also likely to be informed by results from an associated MS project (conducted by James Rennie) which is examining links between hydrology, salinity regime and fringing vegetation. The application of LiDAR data for assessing riparian vegetation is currently being undertaken for the ISC. The results of this need to be considered in developing this measure for IEC. The ISC LiDAR vegetation metrics are assessed over 40m and include width of riparian vegetation, % stream toe that is shaded, fragmentation (gaps between tree canopies of greater than 10 x 10m), number of large trees, cover of Willows and Hawthorn in the tree layer (not applicable for estuaries) and cover of woody vegetation at various height intervals

Scoring is based on the percent change from historical (pre-European) condition with poor as no remaining fringing macrophytes. Good is no change in extent or condition of EVCs and no structures or activities
present likely to affect extent or condition. Intermediate scores would need to be assigned once data has
been collected, collated and analysed to determine the range of values associated with Victorian estuaries.

7.3 MICROPHYTOBENTHOS

The microphytobenthos (MPB) measure is based on determining the biomass of the live photosynthesising
MPB by measuring surface sediment chlorophyll a. The amount of degraded phytosynthetic pigments is
also assessed by determining phaeophytin a the ratio of the two phytosynthetic pigments can be used to
assess the condition of the MPB. Immediate implementation of this measure was considered hard to
achieve as the majority of the data to enable baselines and scores to be developed has to be derived. A
high level of skill is required for collection of this measure in the field and analysis in the laboratory,
although the latter can be outsourced to commercial laboratories. The majority of the work for this measure
was to refine the spatial and temporal replication required, following the work of Barton (2006). Further
work will also determine which pigments or combinations of pigments best differentiate estuary condition.
Thirty estuaries were sampled in the summer 2010 field trip (Figure 18). MPB chlorophyll concentrations
varied within and between estuaries but were reasonably consistent within sampling locations. The highest
concentrations were recorded from high-threat estuaries but high concentrations were also recorded from
low-threat systems, highlighting the need for a system of interpretation incorporating temporal variability
and system-specific context. Maximum concentrations (200-750mg/m²) were recorded in the all reaches of
the Merri estuary, the upper reach of Spring Ck estuary and the middle reach of Kennett R estuary. The
lowest concentrations were around 12mg/m².

Some difficulties arose in the lab analysis of the photosynthetic pigments due to low pigment
concentrations. This may make defining baselines from the summer 2010 fieldtrip for the IEC not viable.
Data also exists from 7 to 8 years ago in 18 estuaries (Barton 2006) which will allow some basic
assessment of change over a comparable time to the reporting cycle. The results from a selection of
Victorian estuaries (Barton 2006) could provide interim scores for further validation in a trial of the IEC.
NSW has also been assessing this measure as condition indicator and further comparison of Victorian
pigment concentrations with NSW estuaries will be made. The MPB measure will also be sampled in the
pre- incubated core monitoring and from the incubated cores in February 2011.
Figure 18. Mean microphytobenthos abundance (chl-a) at locations along estuaries by estuary type and threat level. Note differing scales on the y axes.
7.4 Phytoplankton

Chlorophyll \( a \)

| Sampling protocol E | Baseline condition PD | Scoring description PD | Implementation Score 2 |

**Cell counts of dominant species**

| Sampling protocol E | Baseline condition E | Scoring description E | Implementation Score 2 |

This measure relies on well established collection methods and analytical techniques which require a relatively high level of skill. Immediate implementation of this measure was considered to be reasonably achievable concentrating on collating existing data from other programs (GHCM, EPA & WCB studies), deriving new data to ensure a wide range of Victorian estuaries were represented and comparing similar estuaries with extremely different catchment threat levels. Another major develop needed for the measure was the review of spatial and temporal replication needed. The IEC recommended sampling design is not based on estuary sections (riverine and lagoonal) but on broad estuary zones of upper, middle and lower estuary. The IEC recommends one site per zone and three replicates (2L) per site. Samples are to be collected every six weeks over the 6 year sampling period. Immediate filtering and then freezing is recommended as per standard protocol. It was also suggested that more intensive sampling may be needed during summer. Storage of additional small samples is also recommended for the determination of cell count of dominant groups for algal blooms (high chlorophyll \( a \) concentrations). All this would pose a major resource challenge to management agencies both financially and technically. In reality it is probably more feasible to collect the samples monthly with the turbidity and dissolved oxygen samples. A fluorometer was used in a selection of the 30 estuaries to assess the consistency of the the relationship between spectrophotometric laboratory based (EPA 2000) and \textit{in situ} fluorometric chlorophyll \( a \) determination. The majority of estuaries required boating access to be able to collect the samples.

The environmental water quality guidelines (EPA 2010) provide a baseline and assist in the allocation of condition scores. Approximately half of the locations sampled in 2010 had chlorophyll concentrations above the EPA single sample preliminary guideline (6ug/L - Figure 19).This measure is also part of the Qld EPA approach and they provide scoring categories for the percentage of sites or zones that exceed their guidelines (Scheltinga and Moss 2007).
a) East-facing, open coast estuaries

b) West-facing, open coast estuaries

c) South-facing, open coast estuaries

d) Estuaries on sheltered coastlines

Figure 19. Mean phytoplankton abundance (chl-a) at locations along estuaries by estuary type and threat level. Note differing scales on the y axes.
8 RESULTS OF IMPLEMENTATION OF FAUNA THEME

The direct trialing of the implementation of the three fauna measure were not part of the initial DSE funded trial of the IEC. Melbourne Water commissioned ARI to trial the three measures in eleven estuaries in Port Phillip Bay and Western Port Bay. It is also supporting Deakin in trialling the other measures in these eleven estuaries. DSE is supporting the trial of fish and birds in 20 estuaries in stage 2, the focus in 2011 will be West and East facing functional group estuaries. ARI is concentrating on comparing and refining sampling techniques. Data from both the Melbourne Water and DSE trials will be assessed by Deakin at the end of stage 2 and baselines and scoring distribution established and response and sensitivity assessed. All three faunal measures were thought to be difficult to immediately implement due to the large amount of development needed.

8.1 FISH
Naturalness of fish, estuarine use – Observed/expected species

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Baseline condition</th>
<th>Scoring description</th>
<th>Implementation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD</td>
<td>TBD</td>
<td>TBD</td>
<td>4</td>
</tr>
</tbody>
</table>

Naturalness of fish, trophic levels – observed/expected representatives of trophic guild

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Baseline condition</th>
<th>Scoring description</th>
<th>Implementation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>5</td>
</tr>
</tbody>
</table>

To be developed following collection, collation and analysis of Victorian data. Distribution of this data will provide a contemporary baseline from which condition scores can be derived. The physical nature of individual estuaries or estuary types may need to be taken into account when allocating scores. For example, naturally turbid estuaries could support lower numbers of fish species in feeding groups requiring visual predation.

8.2 BIRDS
Naturalness of birds – observed/expected estuarine bird guilds

<table>
<thead>
<tr>
<th>Sampling protocol</th>
<th>Baseline condition</th>
<th>Scoring description</th>
<th>Implementation Score</th>
</tr>
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<td>TBD</td>
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</table>
9 REFERENCES

Arundel, HP, Pope, AJ & Quinn, GP. 2009. Victorian Index of Estuary Condition: Recommended themes and measures, School of Life & Environmental Sciences, Deakin University, Warrnambool, Vic.


## APPENDIX 1 – SAMPLING DESIGN AND DATES OF SAMPLING

Dates of sampling in statewide field program. Estuaries from the Melbourne Water extension are shown in italics and threat levels relate to a statewide sampling design rather than regional designs also planned in that extension. Subsequent tables list subestuaries and sections.

Table 7. Estuaries sampled in 2010 field campaign with functional group and threat level.

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Type, Threat level</th>
<th>Dates sampled</th>
<th>Estuary</th>
<th>Type, Threat level</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snowy R</td>
<td>South, high</td>
<td>2-3/3/10</td>
<td>Aire R</td>
<td>West, low</td>
<td>3-4/2/10</td>
</tr>
<tr>
<td>Lake Tyers</td>
<td>South, high</td>
<td>4-5/03/10</td>
<td>Glenelg R</td>
<td>West, low</td>
<td>27-28/3/10</td>
</tr>
<tr>
<td>Lake Bunga</td>
<td>South, high</td>
<td>16/02/10</td>
<td>Tidal R</td>
<td>West, low</td>
<td>22/23/3/10</td>
</tr>
<tr>
<td>Wingan Inlet</td>
<td>South, low</td>
<td>26-27/2/10</td>
<td>Kororoit Ck</td>
<td>Sheltered, high</td>
<td>22/2/10</td>
</tr>
<tr>
<td>Shipwreck Ck</td>
<td>South, low</td>
<td>26/2/10</td>
<td>Yarra R</td>
<td>Sheltered, high</td>
<td>3-1-3/10</td>
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<tr>
<td>Yeerung R</td>
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<td>17-18/2/10</td>
<td>Cardinia Ck</td>
<td>Sheltered, high</td>
<td>18-19/3/10</td>
</tr>
<tr>
<td>Merricks Ck</td>
<td>East, high</td>
<td>20/3/10</td>
<td>Bass R</td>
<td>Sheltered, low</td>
<td>7-8/2/10</td>
</tr>
<tr>
<td>Spring Ck</td>
<td>East, high</td>
<td>5-6/2/10</td>
<td>Tarra R</td>
<td>Sheltered, low</td>
<td>13/14/2/10</td>
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<tr>
<td>Barham R</td>
<td>East, high</td>
<td>6-7/3/10</td>
<td>Mitchell/Nicholson complex</td>
<td>Sheltered, low</td>
<td>17-19/2/10</td>
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<tr>
<td>Painkalac Ck</td>
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<td>24/2/10</td>
<td>Little R</td>
<td>Sheltered, low</td>
<td>22/2/10</td>
</tr>
<tr>
<td>Kennett R</td>
<td>East, low</td>
<td>6/3/10</td>
<td>Werribee R</td>
<td>Sheltered, high</td>
<td>1-2/4/10</td>
</tr>
<tr>
<td>Miranda/Smile Ck</td>
<td>East, low</td>
<td>22-27/3/10</td>
<td>Balcombe Ck</td>
<td>Sheltered, high</td>
<td>6/2/10</td>
</tr>
<tr>
<td>Merri R</td>
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<td>1-2/2,4/4/10</td>
<td>Warringine Ck</td>
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<td>18-19/3/10</td>
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<td>Anderson Inlet</td>
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<td>Bunyip R</td>
<td>Sheltered, med</td>
<td>9-10/2/10</td>
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</table>

Table 8. Subestuaries (including zonal sampling and longitudinal locations)

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Subestuary</th>
<th>Zones</th>
<th>Longitudinal profile</th>
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</thead>
<tbody>
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</tr>
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<td>U UM</td>
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<td>Brodribb R</td>
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<td>U UM M</td>
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<td>Snowy R</td>
<td>Cabbage Tree Ck</td>
<td>U</td>
<td>(U)</td>
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<tr>
<td>Lake Tyers</td>
<td>Nowa Nowa Arm</td>
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<td>U UM M ML</td>
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<td>Bunyip R</td>
<td>U M L</td>
<td>U UM M ML L</td>
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### Table 9. Sections (with three random sites sampled in each)

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Subestuary</th>
<th>Section (3 random sites)</th>
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<td>Toorloo Arm</td>
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<td>Blackfellows Arm</td>
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<tr>
<td>Bunyip R</td>
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APPENDIX 2 POTENTIAL ESTUARY DATA IDENTIFIED THROUGH CONSULTATION WITH COASTAL CMAS AND MELBOURNE WATER FOR THE IEC IMPLEMENTATION TRIAL

GH = Glenelg Hopkins CMA, CC = Corangamite CMA, MW = Melbourne Water, WG = West Gippsland CMA, EG = East Gippsland CMA.

Specific data types relate to the needs of the IEC implementation trial.

Physical form
Changed Bathymetry
Bathymetry surveys:
GH Hopkins Dan Ierodiaconou honours thesis Deakin
Glenelg ground water project Laurie Laurenson Deakin
Submerged vegetation mapping Dave Ball DPI: Lake Yambuk, Surry River, Fitzroy River, Belfast
Lough/Moyne River & Rutledges Cutting
CC Barwon, Gellibrand, Aire (transects Ford, Aire, Calder; linear GOR to mouth)
Barham from desnagging project?
MW Werribee flow assessment
Bass environmental flow using EFAM
Lower Yarra – Ports Authority
Parks Victoria Herring Island dredging
Patterson, Mordialloc, Kananook, Kororoit (occasionally) Parks Vic
Saltmarsh & mangrove mapping, used LiDAR data, therefore biased to clear water estuaries
Little, mixing zone study off Werribee, running project Greg Parry MAFRI
Yarra ARC linkage grant Peron Cook Monash, hydrodynamic modelling & bathymetric model.
Balcombe Ck
Flood studies
Western Treatment plant (WTP), Werribee flow assessment
Estuaries up top of Western Port Bay
EG Snowy
Ports for lower reaches of Gippsland Lakes tributaries & Mallacoota
Fish studies
Intrusion of saline water up Gippsland Lakes
Model of Tambo & Mitchell, mouth to road for woody structures project
ISC stream network LiDAR, Paul Wilson DSE

Historical use (changes in bathymetry):
GH Yambuk, Tales of Glenelg Wood, Hopkins Tooram Stones
Martin Boyer, collating historical data
Glenelg Nelson Pub Neil Shelton
Falthrop, Garry Millach, doing estuary management plan
CC Matt White ARI for Anglesea
MW Very old history of PPB & WPB
Contact local councils, historical societies
Older guys at PV would have an idea for PPB, Wayne Hill
Lisa Kitzen, BBW changes in land use
WG Tarra, Franklin & Powlett
EG  Snowy, John EGCMA media history & photos

Old Maps – Aerial photos
GH  Coastal board runs
  2003 GHCMA catchment
  2007 Shire, Moyne flood management, South Warrnambool, Marcus Little GHCMA
CC  Barwon: ostracods, past land use Deakin PhD Jessica Reeves
Reedy Lake, environmental water allocation
Lake Connewarre hydrological model, barrier to mouth
MW  WTP back to 1950’s
Gyrovision showing upstream barriers, camera in front of helicopters up rivers

EG  2004 imaging all private land
    Native vegetation Paul Wilson chasing
    DSE internal imagery Nicholson St
    EGCMA lots of flood imagery, Genoa, Snowy, Cann
Aerial photos at EGCMA
Mitchell, 25 July 2007 1:10400
Mallacoota, 2/2/2007 Wallagaraugh & Genoa only estuary head
  18/5/2000 most of Mallacoota 2500ft
Snowy 15/5/2000 2500ft lower Snowy. Mouth up main stem to approx above estuary
  2/2/2007 1:35000 runs: 6 Frames: 71 near Orbost, only head section of estuary
Sediment load (current vs natural)
Sediment modelling:
GH  Glenelg SKM
CC  SedNet upper Barwon & Leigh
MW  E2, entire catchment, big scale, bit like SEDNET <20km
Ports E2 model did landuse mapping, scale?
WG  Corner Inlet so presumably the estuaries flowing into it
    DPI catchment run off modelling
    SedNet, vegetated vs agricultural subcatchments,
    E2 model of Gippsland Lakes, Chris Barry Gippsland Coastal Board
EG  Sediment supply current vs pre estuaries filling up:
    Genoa (Mallacoota), Wayne Erskine early 90’s 92-94?, expert panel 2000
    Cann (Tamboon) late 90’s
    Tambo late 90’s
    Snowy
    Measured sediment loads:
CC  Review of timber harvesting in the Otways
    Water harvesting review
MW  Flow, TSS, water quality data set
Data warehouse lowest freshwater site, water quality & flow for trial estuaries
Land use mapping:
GH  Landuse erosion mapping, Dans Ierodiaconou PhD thesis, Blue gums green triangle
CC  land capability study
MW  DPI landuse & landuse change, same batch as used for Barton et al. 2008
WG  fluvial geomorphology of CI tributaries, landuse, estimated sediment loads, estimated current bed
    loads & move down system
Upstream barriers:
GH  GHCMA fish barriers
Works on waterways:
GH  Works on waterways permits, seawalls etc?
Upstream Barriers
GH  Fish barrier data base
CC  Upstream barriers: prioritisations hit list to take out, report, removal last 10 years
MW  Old Maps – Aerial photos
Gyrovision showing upstream barriers, camera in front of helicopters up rivers
Lateral Connectivity (# & type of artificial structures on foreshore)

Old Maps – Aerial photos
- WTP back to 1950’s
- CMA to list estuary aerial photo coverage. All their photos are digital and rectified

Works on waterways:
- record of last 10 years, seawalls, jetties, levees, platforms
- Development services group MW, record of what done in estuarine sections
- PV manages moorings & jetties + some construction
- Councils manage boat ramps
- Local safety & env. Management plans for local ports, Wayne Hill PV
- Werribee, council jetty, other PV
- Kororoit council
- Melbourne Port Authority, Peter Gipps Manager Env Services re Yarra & Maribyrnong
- Geoff Taylor WGCMA
- Gippsland Coastal Board
- Penny Neumann EGCMA stat planning officer for E & W: seawalls, jetties & levies.

Hydrology

Marine Exchange-
- mouth openings (AHD & number)
- EEMS records last 1.5 years description of berm height & max width,
- Balcombe, check assets report, EEMS, friends group photos point.
- since 2001

- Powlett
  - Merriman, has flow as town water supply for Seaspray
  - Wreck & Bourne Ck, council opens
- record of notification for last 2 years Snowy
- records Sydenham, Thurra, Mallacoota
  - DSE Lake Tyers

dredging:
- Falthrop want to dredge
  - Moyne Ports Board dredging
- none known

- Gippsland Port Authority

Artificial structures keeping mouth open:
- Falthrop, Moyne, Merri
- old Anglesea, old Gellibrand, rock wall Wild Dog, marina Barham
- Merricks, Patterson, Mordialloc, Kananook
- Gippsland Lakes, reinforcing/armouring silt jetties

Freshwater Flow

Farm dams:
- Southern Rural Water
  - Waterway & Wetland manager GHCMA, dams, extraction licenses
- sustainable diversion project, Statewide GIS layer 2004
- Little River & Mornington Penninsula

Sustainable diversion limit assessment
- EFLOW or Diversion grp
- Freshwater flow records
- Surrey 2 telemetric flow gauge, Statewide Thesis
- Hydrographic team, modelling
- Cardinia & Bunyip Flow studies, Werribee & Bass detailed Flow studies
EG  DPI Maffra & Gippsland Regional Water Monitoring Network contact?
Harvested coastal streams:
CC  Barham, Erskine, St George, Painkalac (Barwon Water), Gellibrand (Wannon Water)
WG  Merriman & Tarra stressed rivers flow study
Powlett, flow risk assessment
La Trobe & Avon environmental flow studies, Anderson Inlet current
Tarra, Tarwin, Powlett, Thompson, Latrobe, Avon & East Gippsland estuaries, RELM reports, SKM modelling.
Corner Inlet, hydrological model for entire catchment, Water Technology & Melbourne Uni
Southern Basins SRM, Paul Wilson DSE
Offtake upstream of estuaries Gippsland Water
Southern Rural Water & West Gippsland Water extraction licences
Extraction:
EG  East Gippsland, Gippsland and South Gippsland Water Authorities unregulated systems
   Southern Rural and Melbourne Water for regulated systems
Groundwater:
GH  Glenelg PhD Darren Herpic SA

Salinity Regime
GH  Estuary monitoring program, monthly fixed sites 7 estuaries
Darlot, salinity from Lake Conndah fish project
   Glenelg 2 telemetric EC logging (recent)
CC  Estuary Watch, plus two loggers Gellibrand & ?
MW  Yarra & Werribee fish studies
Friends of Watsons Creek, integrated catchment project
EG  Snowy, pre-opening surveys Theiss & Waterwatch
PV pre-opening monitoring

Water quality
Water Clarity (turbidity)
GH  Estuary monitoring program
CC  estuary watch (categorical data)
MW  In estuary, check which freshwater fixed sites in estuaries
Werribee WTP collected across mouth
WG  Estuary watch, Franklin surface waters
EG  Theiss, Waterwatch (Snowy) & PV pre-opening monitoring

Dissolved Oxygen (mg/L & %)
GH  Estuary monitoring program, 7 estuaries
   Telemetry stations record level, DO, temp
   EEMS records last 1.5 years
Surrey water quality, nutrients study (N&P) Deakin report
Hopkins Estuary watch
CC  Estuary watch does not do DO
MW  Check which freshwater fixed sites in estuaries
Werribee WTP collected across mouth
WG  Waterwatch Franklin surface waters, DO from 2008
EG  Theiss, Waterwatch (Snowy) & PV pre-opening monitoring

Sediment
Sediment Particle size
GH  Surrey benthic chamber work & nutrient study
CC  Connewarre, Peter Dalhouse Ballarat Uni, Aire mouth, Gellibrand (Chris Gippel)
Thompson from decommissioning sewage pipe under mouth Barwon Water
MW  EIS
DPI fisheries, MAFI fisheries, fisheries habitat assessment
Bass, Peter Dan, Phillip Island Nature Park Reserve, have an idea of studies & grey literature
WG John Hinwood & E McClaine sediment cores – mouths of CI/Nooramunga estuaries, raw data

Bank Erosion (ISC method)
Photos of best & worst bank conditions
GH Glenelg Parks Vic boat wash
Hopkins around Rowans Lane, Fitzroy mouth
Fitzroy & Darlot, Lake Condah project ARI
CC Est Watch initial condition assessment
MW Watson Creek
WG Desalination Plant EIS
EG Records of bank stability work since 2005
Shoreline erosion Gippsland Lakes report, Eric Sjerp Ethos NRM

Sediment Respiration Rate (incubated core tubes)
None

Flora and Fauna
Aquatic Macroalgae
Vegetation mapping:
GH All estuaries but Hopkins, MAFRI
MW MAFRI

Fringing Macrophyte (extent & condition)
Vegetation mapping:
Statewide fringing vegetation mapping Boon 2010
GH All estuaries but Hopkins, fringing, condition measure = weeds
Index of Wetland Condition, doesn’t do tidal wetlands does do coastal saline
Brad Harkey LIDAR coastal 0.5m contours (talk to Dan)
Flood study: Surrey inundation extent mouth closure, Moyne, South Warrnambool
Glenelg Shire Council 2m contour across all shire LIDAR
CC Curdies, Gellibrand, Aire, Barham, Painkalac, Anglesea, Spring, Thompson, like GHCMA
MW Management Plan Cardinia, Inlets, terrestrial vegetation, Jeff Yugovic study
Kororoit, bend below big bridge detailed veg mapping
Warringine park around estuary managed by council, might have management plan
WG High value rivers in Gippsland, weed mapping, spatial layers
Spartina mapping Parks Vic Dowd Morass
Wetland mapping Gippsland Lakes, Parks Vic?

Fringing veg historical photos:
CC Gellibrand, Aire (Alluvium study), Barwon, Yukovic study, RAMSAR listing
Connewarre Values Project Parks Vic
MW Management plan of WTP include broad mapping & assessment Jeff Carr 1987, 1999
Major vegetation changes, Paul Boon, Steve Sinclair, Matt White Tom Hurst projects
old land survey, pre WW2 & post WW2
WG Index of Wetland Condition, doesn’t do tidal wetlands does do coastal saline
EG EVC mapping Snowy to Bodribb
Check Sjerp report, composition changes in vegetation
PV fringing wetland Lake Wellington
Estuarine Nodes Disturbance project, weed control/revegetation with PV
Lake Tyers Eastwards, not Snowy
Coastal weed survey, finished by June 2010, single site visit
High value rivers in Gippsland, weed mapping, spatial layers
Review of the condition of the lower Snowy floodplains & wetlands, Water Technology

Microphytobenthos
None
Phytoplankton (Chlorophyll a)

Records of algal blooms, macro & b/g:
Water boards should keep records of bg blooms, have overall regional co-ordination

**GH** Phytoplankton & macroalgae, last 1.5 years GHCMA.
Wannon Water

**CC** Parks Vic keeps records for Curdies
Estuary Watch observations of macroalgal blooms

**MW** Werribee, Vicky Brown
Balcombe & Merricks councils
Patterson Lakes, B/G spiralinga

**WG** Southern Rural Water
DSE in south Gippsland

**EG** Cabbage Tree Ck has a history of algal blooms
DSE

Naturalness of Fish –
Fish surveys

**GH** Surrey (Becker) & Yambuk (Bishop) Deakin PhD thesis
Fitzroy & Darlot Lake Condah study

**CC** Environess

**WG** South Gippsland Water
Tarwin & Powlett freshwater fish
Anderson Inlet MAFRI/ARI

**EG** Nicholson Rv, EG Water. GHD survey, SKM initial study

Fish species lists:

**GH** Estuary management plans, list species found
**CC** collected for EEMSS sites
**DPI**

**MW** ARI

**WG** Powlett through EEMSS

**EG** Fisheries management plan, DPI fisheries Lake Tyers, Mallacoota & Gippsland Lakes

Naturalness of Birds
Surveys

Birds Australia has been involved in a lot of estuary surveys

**GH** Orange bellied parrot surveys
Yambuk Parks Victoria
Portland Field Naturalists

**EG** Lower Snowy, bird surveys last three years

Bird species lists:

**CC** collected for EEMSS sites
**DPI**

**MW** lots of data Birds Australia

Datasharing agreement with MW, so can get ones in their area, other need to pay for.

**WG** Powlett through EEMSS

**EG** Bairnsdale Field Naturalists
APPENDIX 3 – PROFORMA FOR FIELD TRIAL.

<table>
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<th>INDEX OF ESTUARINE CONDITION FIELD SHEET</th>
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<tr>
<td>DATE/S: ..................................</td>
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<tr>
<td>RECORDERS NAMES: ..................................</td>
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<tr>
<td>Yeocal pH checked Y/N</td>
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<tr>
<td>calibrated [ ]</td>
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<tr>
<td>VISIBLE TIDAL FLOW? YES</td>
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<td>TIDAL FLOW? IN OR OUT OR N/A</td>
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<tr>
<td>TIDE TIMES at HIGH [ ]</td>
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<tr>
<td>WATER HEIGHT FROM GAUGE BOARD: .......... (m) at ............ (time read) Located at ..........</td>
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</table>

| ESTUARY MOUTH OBSERVATIONS (circle appropriate answer or tick [ ] ) |
| PHOTOS OF MOUTH: at defined photo points [ ] or GPS points where taken [ ] |
| ESTUARY MOUTH CONDITION open to sea bar with minor outflow fully blocked, lagoon blocked with overwash Y/N |
| CONSTRUCTION OF MOUTH none L / R sand bar L / R rocky headland L / R artificial L / R (L = left bank looking downstream, R = right bank) can be more than one category |
| ARTIFICIAL STRUCTURES: rock training walls L / R wooden training wall L / R dredge L / R |
| Photograph artificial structures [ ] |
| Estimate estuary outflow depth .......... (m) width (at narrows) .......... (m) length (across beach) .......... (m) |
| OTHER COMMENTS .................................................. |

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<th>Troll or Eureka?</th>
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<td>DATE/TIME DEPLOYED: .................</td>
<td>GPS POSITION [ ]</td>
</tr>
<tr>
<td>SITE DESCRIPTION: PHOTOS TAKEN [ ]</td>
<td>CHANNEL DEPTH .......... (m) LOGGER DEPTH .......... (m)</td>
</tr>
</tbody>
</table>

| LIGHT LOGGERS DEPLOYED Y / N | TIME ............. |
| WHERE DEPLOYED: ................. |

**General observations along estuary**

**LATERAL CONNECTIVITY** — photograph & mark on map/aerial photo or GPS position

- 3009 Levee Bank 4621 Sea Wall
- 4601 Dam or Weir (on watercourse) 4622 Groyne, Breakwater, Mole
- 4802 Dam or Weir carrying Road 4823 Pier, Jetty
- 4803 Salt Evaporator 4824 Wharf
- 4807 Wreck—Bare or Awash 4825 Landing
- 4810 Channel Drain Canal Ditch, Waterway, Aqueduct 4826 Marina, Mooring Pen
- 4815 Fish Pen, Aquarium 4827 Sea Bath
- 4818 Spillway Area 4828 Boat Launching Ramp
- 4819 Dry Dock 4829 Shark Safety Net
- 4820 Look, sluice Gate
- Fishing platform Stormwater outlet

**EXAMPLE BANK EROSION:** (mark each on map/aerial photo)

- TENTATIVE RANK 0-4 [ ] (see details in site section) # PHOTOS TAKEN [ ]
- DESCRIPTION:

- TENTATIVE RANK 0-4 [ ] (see details in site section) # PHOTOS TAKEN [ ]
- DESCRIPTION:
## Longitudinal Salinity Profile

Documenting the extent of the estuary, upper <5ppt, middle 15-20ppt, lower >30ppt, 5 sites

### Upper Estuary

<table>
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<tr>
<th>Water Column Profile mid-channel:</th>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>TOP #</td>
<td>BOTTOM #</td>
<td>Total depth (m)</td>
</tr>
<tr>
<td>GPS position of site [ ]</td>
<td>photos of site [ ]</td>
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### Between Upper & Middle Estuary

<table>
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<tbody>
<tr>
<td>TOP #</td>
<td>BOTTOM #</td>
<td>Total depth (m)</td>
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### Middle Estuary

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<td>BOTTOM #</td>
<td>Total depth (m)</td>
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<td>photos of site [ ]</td>
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### Between Middle & Lower Estuary

<table>
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<td>TOP #</td>
<td>BOTTOM #</td>
<td>Total depth (m)</td>
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<tr>
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<td>photos of site [ ]</td>
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### Lower Estuary

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<tbody>
<tr>
<td>TOP #</td>
<td>BOTTOM #</td>
<td>Total depth (m)</td>
</tr>
<tr>
<td>GPS position of site [ ]</td>
<td>photos of site [ ]</td>
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</tbody>
</table>

Comments:

- 2 -
### U/M/L MEASURES

#### UPPER ESTUARY

**WATER COLUMN PROFILE** mid-channel:  
Date:  
Time:  
TOP #, BOTTOM #, Total depth (m), Secchi depth (m),  
GPS position of site [ ], photos of site [ ]  
Site description & comments:  

**PHYTOPLANKTON** 3 replicates/ site of 2 L, on ice in dark then filtered  
Fluorometer m surface 0.5 1.0 1.5 2.0 2.5 3.0 3.5 bottom  
Comments:  

**MICROPHYTOBENTHOS:** 5 small syringe cores, avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP  
Time taken [ ], Date [ ], Comments:  

**PARTICLE SIZE** in depositional area, 8 cores, large syringe corer, 10cm deep, redox in surface of 11  4 before bagging  
GPS position [ ], Photos [ ], Date [ ], Comments:  
Site & sediment description (include why chosen as depositional eg. lagoonal mud flat, fluvial delta):  

<table>
<thead>
<tr>
<th>Rep</th>
<th>Redox</th>
<th>Oxic depth</th>
<th>Rep</th>
<th>Oxic depth</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6</td>
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<tr>
<td>3</td>
<td>7</td>
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<td></td>
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</tr>
<tr>
<td>4</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### MIDDLE ESTUARY

**WATER COLUMN PROFILE** mid-channel:  
Date:  
Time:  
TOP #, BOTTOM #, Total depth (m), Secchi depth (m),  
GPS position of site [ ], photos of site [ ]  
Site description & comments:  

**PHYTOPLANKTON** 3 replicates/ site of 2 L, on ice in dark then filtered  
Fluorometer m surface 0.5 1.0 1.5 2.0 2.5 3.0 3.5 bottom  
Comments:  

**MICROPHYTOBENTHOS:** 5 small syringe cores, avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP  
Time taken [ ], Date [ ], Comments:  

**PARTICLE SIZE** in depositional area, 8 cores, large syringe corer, 10cm deep, redox in surface of 11  4 before bagging  
GPS position [ ], Photos [ ], Comments:  
Site & sediment description (include why chosen as depositional eg. lagoonal mud flat, fluvial delta):  

<table>
<thead>
<tr>
<th>Rep</th>
<th>Redox</th>
<th>Oxic depth</th>
<th>Rep</th>
<th>Oxic depth</th>
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<tr>
<td>4</td>
<td>8</td>
<td></td>
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</tbody>
</table>

CONTINUES OVER PAGE
### Water Column Profile

**Mid-channel**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Top #</th>
<th>Bottom #</th>
<th>Total Depth (m)</th>
<th>Secchi Depth (m)</th>
<th>GPS Position of Site</th>
<th>Photos of Site</th>
</tr>
</thead>
</table>

**Site Description & Comments:**

### Phytoplankton

- **Fluorometer:** 3 replicates/site of 2 L, on ice in dark then filtered
- **Units:** mg/L, ug/L

<table>
<thead>
<tr>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
</table>

### Microphytobenthos

- **5 small syringe cores,** avoid macrophyte beds, 3cm deep, dark ice ASAP, car freezer ASAP

**Date** | **Time taken** | **GPS Position** | **Photos** |
|--------|---------------|------------------|------------|

**Comments:**

### Particle Size

- **In depositional area,** 8 cores, large syringe corer, 10cm deep, redox in surface of 1\(^{1/2}\) 4 before bagging

<table>
<thead>
<tr>
<th>Date</th>
<th>GPS Position</th>
<th>Photos</th>
</tr>
</thead>
</table>

**Site & Sediment Description (Include why chosen as depositional eg. lagoonal mud flat, fluvial delta):**

<table>
<thead>
<tr>
<th>Rep</th>
<th>Redox</th>
<th>Oxic Depth</th>
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<tbody>
<tr>
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<td>7</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

**Comments:**
### 3 RANDOM SITES

<table>
<thead>
<tr>
<th>SITE 1</th>
<th>MAINSTEM</th>
</tr>
</thead>
</table>

#### WATER COLUMN PROFILE mid-channel:

- Date:
- Time:
- TOP #:
- BOTTOM #:
- Total depth (m):
- Secchi depth (m):
- GPS position of site:
- Photos of site:
- Site description & comments:

#### CHANNEL SHAPE DESCRIPTION:

- Rectangular
- Triangular
- Wedge
- Straight

#### BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

<table>
<thead>
<tr>
<th>LHB</th>
<th>RHB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Bank Profile
  - >45° & Undercut
  - >45° with Toe
  - Gentle Slope
- Exposed Roots
  - Any woody roots
  - >33% cover

<table>
<thead>
<tr>
<th>LHB</th>
<th>RHB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Bank erosion assessment overall:
- Details:
  - Veg. cont.
  - Bank movement
  - Slope >45°
  - Undercut
  - Woody roots >33%
  - Livestock damage
- Comments:
  - 1 = mostly unstable toe or >45° slope with toe, no vegetation, >33% woody roots exposed, obvious livestock damage
  - 2 = instabilities extend to toe, gentle or >45° slope, discontinuous vegetation, >33% woody roots exposed
  - 3 = isolated erosion, banks not >45° & undercut, near continuous vegetation, exposed roots <33%, gentle slope bank
  - 4 = none, banks not >45°, continuous vegetation few exposed roots, no livestock damage

#### LATERAL CONNECTIVITY — photograph

- 3099 Levee Bank
- 4801 Dam or Weir (on watercourse)
- 4802 Dam or Weir carrying Road
- 4803 Salt Evaporator
- 4807 Wreck—Bare or Awash
- 4815 Channel, Drain, Canal, Ditch, Waterway, Aqueduct
- 4815 Fish Pen, Aquarium
- 4816 Spillway Area
- 4819 Dry Dock
- 4820 Lock, Sluice Gate
- Fishing platform

Other/Comments:
3 RANDOM SITES

SITE 2 (random # )

WATER COLUMN PROFILE mid-channel:
Date: ____________________ Time: ____________________ TOP #_________ BOTTOM #_________ Total depth (m)_________ Secchi depth (m)_________
GPS position of site [_____] photos of site [_____

Site description & comments:

CHANNEL SHAPE DESCRIPTION:

- Rectangular
- Triangular
- Punched
- Vee
- Broad rectangular
- Crescent
- Sine
- Bowl

BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

<table>
<thead>
<tr>
<th>Bank Profile</th>
<th>LHB</th>
<th>RHB</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;45° &amp; Undercut</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>&gt;45° with Toe</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Gentle Slope</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
</tbody>
</table>

Exposed Roots any woody roots > 33% cover Y/N Y/N

Bank erosion assessment overall # LHB [# ] RHB [# ]

- Details:
  - Veg. cont no/min/disco/near cont./cont.
  - Bank movement Y/N Y/N
  - Slope >45° Y/N Y/N
  - Undercut Y/N Y/N
  - Woody roots >33% Y/N Y/N
  - Livestock damage Y/N Y/N

- Comments:
  - 0 = unstable toe, no vegetation, very recent bank movement, >45° slope, >33% woody roots exposed, obvious livestock damage
  - 1 = mostly unstable toe or >45° slope with toe, minimum vegetation, >33% woody roots exposed, obvious livestock damage
  - 2 = instabilities extend to toe, gentle or >45° slope, discontinuous vegetation, >33% woody roots exposed
  - 3 = isolated erosion, banks not >45° & undercut, near continuous vegetation, exposed roots <33%, gentle slope bank
  - 4 = none, banks not >45°, continuous vegetation few exposed roots, no livestock damage

LATERAL CONNECTIVITY — photograph [_____

- 6 -

3009 Levee Bank 4621 Sea Wall
4801 Dam or Weir (on watercourse) 4622 Groynes, Breakwater, Mole
4602 Dam or Weir carrying Road 4623 Pier, Jetty
4603 Salt Evaporator 4624 Wharf
4607 Wreck—Bare or Awash 4625 Landing
4610 Channel, Drain, Canal, Ditch, Waterway, Aqueduct 4626 Marina, Mooring Pen
4615 Fish Pen, Aquarium 4627 Sea Bath
4618 Spillway Area 4628 Boat Launching Ramp
4819 Dry Dock 4629 Shark Safety Net
4620 Lock, Sluice Gate Fishing platform

Other/Comments:
3 RANDOM SITES

SITE 3 (furthest from mouth random # )

WATER COLUMN PROFILE mid-channel:
Date: Time: TOP # BOTTOM # Total depth (m): Secchi depth (m):
GPS position of site [ ] photos of site [ ]
Site description & comments:

CHANNEL SHAPE DESCRIPTION:

- Rectangular
- Trapezoidal
- Peninsula
- Pointed
- Broad rectangular
- Corner
- Pointed
- Promontory

BANK EROSION 30m along left & right bank. Not assessed on outside meander bend

<table>
<thead>
<tr>
<th>Bank Profile</th>
<th>LHB</th>
<th>RHB</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;45° &amp; Undercut</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>&gt;45° with Toe</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Gentle Slope</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Exposed Roots</td>
<td>any woody roots</td>
<td>any woody roots</td>
</tr>
<tr>
<td>&gt;33% cover</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
</tbody>
</table>

Bank erosion assessment overall #

<table>
<thead>
<tr>
<th>Details</th>
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<th>RHB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veg. cont</td>
<td>no/mi/discont/near cont./cont</td>
<td>Y/N</td>
</tr>
<tr>
<td>Bank movement</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Slope &gt;45°</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Undercut</td>
<td>Y/N</td>
<td>Y/N</td>
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<tr>
<td>woody roots &gt;33%</td>
<td>Y/N</td>
<td>Y/N</td>
</tr>
<tr>
<td>Livestock damage</td>
<td>Y/N</td>
<td>Y/N</td>
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Comments:
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LATERAL CONNECTIVITY — photograph

| Levee Bank | 4621 Sea Wall |
| Dam or Weir (on watercourse) | 4622 Groyne, Breakwater, Mole |
| Dam or Weir carrying Road | 4623 Pier, Jetty |
| Salt Evaporator | 4624 Wharf |
| Wreck—Bare or Awash | 4625 Landing |
| Channel Drain, Canal, Ditch, Waterway, Aqueduct | 4626 Marina, Mooring Pen |
| Fish Pen, Aquarium | 4627 Sea Bath |
| Spillway Area | 4628 Boat Launching Ramp |
| Dry Dock | 4629 Shark Safety Net |
| Lock, Sluice Gate | Stormwater outlet |

Other/Comments:
**EVENING DATA PROCESSING**
- # sheets from fieldtrip
- # yeokal data saves
- # GPS positions
- # photos

**PHOTO IDENTIFICATION**, complete each night on download, group multiples

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<tr>
<th>Photo name</th>
<th>description</th>
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