Guideline
SCORING
ECOSYSTEM HEALTH

Part 2 – AQUATIC (FRESHWATER ECOSYSTEM)

A Procedures Manual

for

Lake Macquarie City Council

December 2015

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Document Change History

Contact for enquiries and proposed changes. If you have any questions regarding this document or if you have a suggestion for improvement, please contact:

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Version History

Version	Author	Issue Purpose	Date
1	Nigel Barton and Angela Lane	Scoring Guideline – Trim Document D07644677	December 2015

Final document approved by:

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Introduction

This document provides guidance on some of the methodologies used to monitor and score the health of aquatic ecosystems found within the Lake Macquarie Local Government Area.

Long-term monitoring programs require consistency of data collection, storage and analysis and this is achieved through clearly defined procedures. The reader should refer to the documents below for a more detailed description of the various stages of the program.

The aquatic method is based on a benchmark approach that produces a condition score. Condition scores for aquatic sites are based on three site attributes: water quality, riparian assessment and macroinvertebrates. This guideline refers primarily to scoring methods for data collected at eight sites, to provide waterway health information representative of Lake Macquarie's main catchments.

Lake Macquarie City Council's *Guideline Scoring Ecosystem Health* consists of two parts:

Part 1 – TERRESTRIAL (D01991795)

Part 2 – AQUATIC (Freshwater Ecosystem Health) (D07644677)

The Office of Environment and Heritage (OEH) publication, *Assessing estuary ecosystem health: Sampling, data analysis and reporting protocols*, provide the standardised approach to estuary ecosystem health monitoring, analysis and reporting for Lake Macquarie City Council's collaboration with OEH, to monitor freshwater and estuarine sites as part of the lake modelling program (D07468767).

References

Document Title	TRIM reference
Consultancy Reports	
Community Ecosystem Monitoring Strategy, Volume 2: Aquatic Ecosystems (prepared for Lake Macquarie City Council by Ecological Australia and BMT WBM, January 2010)	D01677388
Data	
2010 dataset used to develop freshwater guideline values	D02085712
Data Analysis – Health Grades	
Aquatic On-line Scorecard Data	D03000085
Fact Sheet 2 - Water Quality Parameters & Indicators, Hunter-Central Rivers Catchment Management Authority, 2008 www.hcr.cma.nsw.gov.au/.../Waterwatch/wwfs2_waterqualityparameters.pdf	D02976961
Site Location Map	
Distribution of freshwater catchment monitoring sites (October 2014)	D07308778

PART 2 – AQUATIC (FRESHWATER ECOSYSTEM HEALTH)

- Freshwater Waterways at site level
    - Scope and Site selection
    - Components of Waterway Health
    - Water Quality
    - Riparian Assessment
    - Macroinvertebrate monitoring

- Wetlands
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2.1 Freshwater Catchment Monitoring at Site Level

2.1.1 Scope and Site Selection

This Guideline is a reference source for scoring the health of non-estuarine (freshwater) waterway. It does not include water quality data from other external sources.

The main intended outcome is to provide a 'snapshot' report on the freshwater waterway health of Lake Macquarie's main catchments, and to use this information to inform management decisions and provide feedback to the community on the health of the City's waterways.

The following water quality parameters are collected:

- Dissolved Oxygen - measure of the amount of oxygen in the water - milligrams per litre (mg/L);
- Turbidity - measure of ability of light to pass through water - Nephelometric Turbidity Unit (NTU);
- Available Phosphates - One of the three main measures of plant nutrient - (PO_4mg/L);
- Conductivity/Salinity - measure of dissolved salts, measured by electrical conductivity (EC) – microsiemens per centimetre (µs/cm); and
- pH - a measure of acidity or alkalinity – pH scale ranges from 0 to 14 (Acidic 0 to 6.9 / Neutral 7 / Alkaline 7.1 to 14)

The sites (Table 1) were selected to represent waterway health information for Lake Macquarie's main catchments. The monitoring of eight waterway sites, is undertaken annually by Lake Macquarie City Council. See site location map (Figure 1).

Table 1: Freshwater catchment sites selected for health grade determination

SLATEY CREEK	
Site 22	Off Northville Road, Barnsley (upstream of Cherry's Bridge - eastern bank)
WINDING CREEK	
Site 69	End of Elizabeth Street, Cardiff South (upstream of concrete channel)
FLAGGY CREEK	
Site 5	Corner of Kaleen and Wakal Streets, Charlestown (along Great North Walk, under footbridge)
COCKED HAT CREEK	
Site 71	Off Oakville Road, Edgeworth
SCRUBBY CREEK	
Site 60	Off Balemo Crescent, Mount Hutton
NORTH CREEK	
Site 67	Off Martin Street, Warners Bay (above the weir)
JIGADEE CREEK	
Site 68	Off Newport Road, Cooranbong
STONY CREEK	
Site 73	Off Olney Street, Awaba

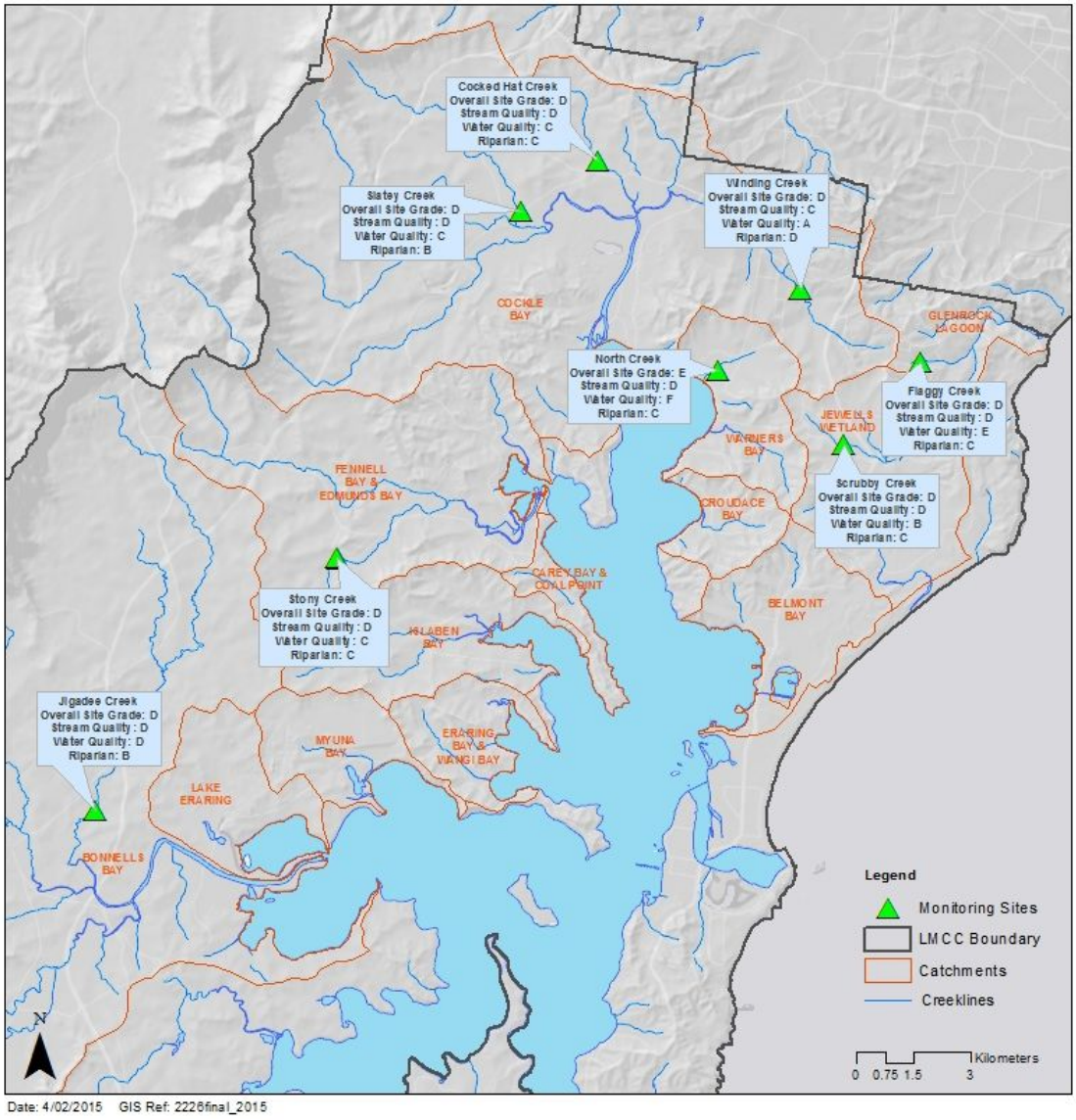

Figure 1: Distribution of freshwater ecosystem waterway monitoring sites and health scores (October 2014)

2.1.2 Components of Waterway Health (non-estuarine)

Three components of waterway health (water quality, stream pollution and riparian evaluation) have been assessed and reported in Appendix 1. Methodology for calculation of each of the health grade components (Table 2) are described in sections 2.1.3 to 2.1.5.

Table 2: Waterway health components

Measure	Health Scale
Water Quality	Graded A to F
Stream Quality Rating (Presence of Macroinvertebrates / Stream Pollution Index Rating)	Poor, Fair, Good, Excellent (Graded A-D)
Riparian assessment	Poor, Fair, Good, Excellent (Graded A-D)

Contribution to an overall site score comprises: 40% from the stream quality rating outcome, 30% from the water quality standardised score, and 30% from the riparian assessment outcome.

2.1.3 Water Quality

The methodology for calculation of standardised scores is based on *South East Queensland's Healthy Waterways Ecosystem Health Monitoring Program Annual Technical Report* (2006-2007:26-27) where the standardised score for a water quality parameter is given as:

$$\text{Standardised Score} = 1 - \left(\frac{\text{Result} - \text{Guideline}}{\text{Worst Case Scenario} - \text{Guideline}} \right)$$

The above formula:

a) makes results comparable across parameters with different scales of measure; and

b) scales the scores to the range 0.0 – 1.0.

Deriving 'Guideline Values' for Lake Macquarie waterways

Only a few of Lake Macquarie's waterways can be assumed to be minimally disturbed for use as reference sites. Benchmark or 'guideline' values for each indicator were therefore assigned (

Table 3) based on expert opinion and comparison of:

1) 20th and/or 80th percentiles of the Lake Macquarie data set (1,083 monitoring events across 34 sites generating 5,472 data points). 1st October 2010 was the cut-off point for inclusion of data to minimise seasonal effects (Spring/Summer 1st October – 31 March and Autumn/Winter 1 April – 30 September);

2) Median values for each parameter across 34 Lake Macquarie sites;

3) Waterwatch trigger values for lowland waterways <150 metres (m) (as adapted from ANZECC Guidelines 2000);

Only one set of Guideline and Worst Case Scenario (WCS) values has been calculated. There appears to be no justification in assigning the waterways found in Lake Macquarie catchments into different stream classes e.g. upland, lowland, coastal or on the basis of different soil types/geomorphology.

WCS values (expected value for each indicator for waterways in the unhealthiest condition) were assigned based on a comparison of:

4) 10th and/or 90th percentiles of the Lake Macquarie data set (1,083 monitoring events across 34 sites generating 5,472 data points)

5) Waterwatch trigger values for lowland waterways <150m in ‘poor’ condition. All Lake Macquarie sites were assigned the same Guideline and WCS values.

Table 3: Guidelines and Worst Case Scenario values calculated from Lake Macquarie dataset

	Dissolved Oxygen % (min)	**Dissolved Oxygen %** (max)	**pH** (min)	**pH** (max)	**Electrical Conductivity** (µS/cm)	**Turbidity** (NTU)	**Available Phosphate** (mg/L)
Guideline	40	100	5.5	8.5	450	15	0.1
WCS	-	-	-	-	1,000	50	0.5

WCS - worst case scenario
NTU - Nephelometric Turbidity Unit
µS/cm - microsiemens per centimetre
mg/L - (milligrams per litre)
pH - (a range of 6.5 to 8 is optimal for freshwater, a range of 8 to 9 is optimal for estuarine and seawater (HCRCMA 2008:3))

Note:

1) **WCS values are not required for calculation of pH or Dissolved Oxygen scores (see the worked example below)**
2) **Temperature is not utilised in the health score calculation but is taken into account to convert Dissolved Oxygen (mg/L) to Dissolved Oxygen (%)**
3) **Dissolved Oxygen and pH outcomes score either 1 (if recorded within guideline range) or 0 (if recorded outside guideline range)**

Worked Example:

Table 4: Site water quality data used for calculating standardised scores (working below)

DO (mg/L)	% DO	pH	Electrical Conductivity (µS/cm)	Turbidity (NTU)	Available Phosphate (mg/L)
7.1	**78**	**6**	**500**	**17.5**	**0.07**

$$\text{Standardised Score} = 1 - \left(\frac{\text{Result} - \text{Guideline}}{\text{Worst Case Scenario} - \text{Guideline}} \right)$$

Standardised scores:

1. Electrical Conductivity
   1 – (500 – 450 / 1000 – 450)
   1 – (50/550) = **0.91**

2. Turbidity
   1 – (17.5 – 15 / 50 – 15)
   1 – (2.5/35) = **0.929**

3. Available Phosphates
   1 – (0.07 – 0.1 / 0.5 – 0.1)
   1 – (-0.03/0.4) = **1**

4. Dissolved Oxygen
   %DO between 40 and 100% scores: 1
   %DO < 40 or >100% scores: 0
   Score of 78 = **1**

5. pH
   pH between 5.5 and 8 scores: 1
   pH < 5.5 or > 8 scores: 0
   Score of 6 = **1**

Average standardised score = (0.91+0.929+1+1+1)/5 = 0.97

Based on the above calculations and reference Table 5, the health grade for the water quality component at this site is A.

Table 5: Scoring Ranges for water quality health grades

A	**> 0.9**
B	**>0.85 ≤ 0.90**
C	**>0.80 ≤ 0.85**
D	**>0.75 ≤ 0.80**
E	**>0.7 ≤ 0.75**
F	**≤ 0.7**

2.1.4 Riparian Assessment

The riparian assessment methodology is a modification of the *New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual* originally developed in 2004 by the Department of Environment and Conservation (NSW). This method is designed to quickly provide a general overview of the sustainability and function of the riparian area and stream corridor. Assessment can assist in characterising the physical and ecological attributes of the waterway and evaluate trends leading to the identification of management needs and recovery strategies.

Components of the stream corridor landforms and vegetation attributes, evaluated along a 100 metre (m) reach, include:

Table 6: Parameters used in riparian assessment

SITE DETAILS	
- Elevation (metres) - Slope (metres)	- Latitude and Longitude - Stream/wetland condition (i.e. constructed, reconstructed, modified, degraded, rehabilitated, natural)
STREAM CORRIDOR	
Stream width	Visually estimate minimum, maximum and modal stream width at bank height
Topography	Choose one of four categories to provide a general idea of the shape of the river valley (Floodplain, Broad Valley, Steep Valley, or Gorge)
Water Level/Flow	Comparison of flow, at time of sampling, to base flow. Choose one of five classifications (No flow, Low, Moderate [equivalent to base flow], High, or Flood [water overtops banks])
Shading of River	Estimate percentage of water surface across whole of the site that would be shaded when the sun is directly overhead
Riparian Vegetation	Record Trees >10m as present or absent, and estimate the percentage cover of three vegetation categories (Trees <10m, Shrubs/Vines/Rushes, and Grasses/Herbs/Ferns). The edge of the riparian zone is generally identified by a change in vegetation
Streambed coverage	Percentage cover of the total streambed for algae, moss, and macrophytes

Riparian assessment scoring

The riparian score is calculated using the indicators shown in Table 7. Indicators are broad and approximate due to the subjectivity of the assessment technique. Two observers are present at each monitoring event, reducing some of the potential observer bias. Other indicators are also collected which although not a component of the score, assist in interpreting the data.

Table 7: Weighting of parameters used in scoring riparian health

Indicator		Score	Max Score
Shading	Low	5	
	Moderate	10	
	High	20	**20**
Trees >10m	present	10	**10**
	absent	0	
Trees <10m / shrubs and grasses	average >80%	20	**20**
	60-80%	15	
	40-60%	10	
	20-40%	5	
	<20%	0	
Instream vegetation			
algae	>40%	0	
	approx >25-40%	5	
	approx >15-25%	10	**10**
	Approx 5-15%	5	
	<5	0	
moss	>40%	0	
	Approx >25-40%	5	
	approx > 15-25%	10	**10**
	approx 5-15%	5	
	<5	0	
macrophytes	>60%	0	
	approx > 40-60%	10	
	approx > 30-40%	20	**20**
	approx 10-30%	10	
	<10%	0	
% native vegetation	>75%	10	**10**
	25-75%	5	
	<25%	0	
			100

Riparian health grades are assigned as follows:

Excellent	>75 and ≤ 100
Good	>50 and ≤ 75
Fair	>25 and ≤ 50
Poor	≤ 25

2.1.5 Macroinvertebrates monitoring

Most juvenile bugs are present in waterways during the Spring or Autumn. The decision was made to undertake macroinvertebrate monitoring once per year in October, based on the assumption that results will be reflective of waterway health in the months prior to bug monitoring.

The macroinvertebrate monitoring methodology is a modification of the *New South Wales Waterwatch Field Manual* originally developed by the Department of Environment and Climate Change (NSW) in 2009.

SIGNAL Score and Stream Pollution Index

Pollution Tolerance is the ability of macroinvertebrates to withstand pollution. This is reflected by a SIGNAL 2 score based on sensitivity to pollution.

SIGNAL stands for 'Stream Invertebrate Grade Number – Average Level'. It is a simple scoring system for macroinvertebrate ('water bug') samples from Australian rivers. A SIGNAL score gives an indication of water quality in the river from which the sample was collected. Rivers with high SIGNAL scores are likely to have low levels of salinity, turbidity and nutrients such as nitrogen and phosphorus. They are also likely to be high in dissolved oxygen. When considered together with macroinvertebrate richness (the number of types of macroinvertebrates), SIGNAL can provide indications of the types of pollution and other physical and chemical factors that are affecting the macroinvertebrate community.

Collecting invertebrates in a dip net and calculating a SIGNAL 2 score provides only a simple, rapid assessment, particularly if identification is taken only to order-class-phylum level. It gives some indication of what the condition of the site may be, but is not an absolute measure of how 'good' or 'healthy' the site is. A lot of information, covering the physical and chemical environment and several groups of plants and animals, is needed to make a judgement about 'health'. For this reason the methodology described here also calculates a Stream Quality Rating based on the Stream Pollution Index. This is used in combination with riparian and water quality scores to assess the health of a waterway.

The Stream Pollution Index is calculated from the abundance and diversity of bugs and their SIGNAL 2 score.

Sampling:

Use a triangular frame, fine net dip bag, to undertake a 20 minute basic sweep sampling from at least 10m of the water's edge. Identify habitat(s) sampled choosing from categories: silt and sand; stones; water plants; leaves and twigs; logs, branches, tree roots; pool; and riffle.

Sorting Sample:

To increase sensitivity of data collected, undertake a 30 minute sample sort to identify taxa to Family level and record:

- total abundance
- total number of families
- taxa richness (low or high).

Aim to collect more than 20 macroinvertebrates to enable calculation of the stream pollution index and stream quality rating set out below.

Calculating SIGNAL Score and the Stream Pollution Index:

Macroinvertebrate abundance and diversity provides an understanding of macroinvertebrate tolerance to pollution (or change in water quality), and an indication of the health of the waterway. Healthy streams have highly sensitive bugs, therefore a high SIGNAL score and a large number of bug types is indicative of a healthy waterway.

As per Waterwatch NSW, water bugs are rated according to their sensitivity to pollution. There are four grades of pollution rating, with numbers from 1 to 10:

Very sensitive:	10, 9
Sensitive:	8, 7, 6
Tolerant:	5, 4, 3
Very Tolerant:	2, 1

SIGNAL score is calculated as per NSW Waterwatch Manual

Below is a worked example of how the SIGNAL 2 score is calculated. The example is taken from the Monitoring River Health Initiative Report No. 31 – SIGNAL 2 – A Scoring System for Macroinvertebrates ('Water Bugs') in Australian Rivers, September 2003

WEIGHT TABLE	
Number of specimens	Weight factor
1 - 2	1
3 - 5	2
6 - 10	3
11 - 20	4
> 20	5

CALCULATION TABLE				
Invertebrate families collected at the site	SIGNAL 2 sensitivity grade	Number of specimens	Weight factor	Grade x weight factor
Atyidae	3	8	3	9
Baetidae	5	15	4	20
Caenidae	4	12	4	16
Chironomidae (subfamily Chironominae)	3	22	5	15
Chironomidae (subfamily Orthocladiinae)	4	16	4	16
Coenagrionidae	2	4	2	4
Corixidae	2	2	1	2
Dytiscidae	2	3	2	4
Hydrophilidae	2	5	2	4
Hydropsychidae	6	35	5	30
Leptoceridae	6	12	4	24
Notonectidae	1	7	3	3
Physidae	1	6	3	3
Planorbidae	2	1	1	2
Simuliidae	5	42	5	25
TOTALS			48	177

SIGNAL SCORE = TOTAL OF GRADE x WEIGHT FACTOR / TOTAL OF WEIGHT FACTOR = 177/48 = 3.7

Note: The above formula provides a Signal Score/Steam Pollution Index – Table 8 provides comparative assessment of a Stream Pollution Index aligned with a Stream Pollution Index Rating and Stream Quality Rating.

Table 8: Rating stream pollution

Stream Pollution Index	Steam Pollution Index Rating	Steam Quality Rating
Less than 3	Low	Poor
3 to < 4	Low	Fair
4 to 6	High	Good
More than 6	High	Excellent

Taxa richness of the benthic macroinvertebrate community is also used as a simple water quality indicator (Table 9):

Table 9: Rating taxa richness

Site Description	Taxa Richness	
	Low	**High**
Wetlands	0-14	> 14
Stream / Creek	0-15	> 15

SPI Rating and Taxa Richness Assessment

Table 10 considers the Stream Pollution Index Rating alongside Taxa Richness and indicates the types of pollution and other physical and chemical factors that are affecting a macroinvertebrate community.

Table 10: Interpreting water quality from Stream Pollution Index and Taxa Richness

Quadrant	SPI (Rating)	Taxa Richness	Site conditions based on macroinvertebrate sample
1	**High**	**High**	Good water quality and a diversity of habitats. It may be a well-managed site, natural bushland or a national park
2	**Low**	**High**	Water quality may be slightly affected by human activity or natural factors. There may be higher levels of salinity and/or nutrient levels at the site
3	**High**	**Low**	Water quality is affected by a pollution source upstream or there are few habitats due to harsh physical conditions
4	**Low**	**Low**	Water quality is affected by human use such as urban, industrial or agricultural pollution or by the downstream effects of dams

2.2 Wetland

Wetland ecosystems are highly variable, some being permanently inundated, others more closely resembling terrestrial rather than aquatic ecosystems. The following wetland types are surveyed using methods described in the terrestrial guideline Scoring Ecosystem Health Part 1 – Terrestrial and as identified by Keith Class:

- Coastal Floodplain Wetlands
- Coastal Swamp Forests
- Mangrove Swamps
- Saltmarsh
- Coastal Freshwater Lagoons

There is currently no scheduled water quality monitoring of permanently inundated wetland sites. Apart from the cost of providing resources for wetland monitoring, it is often difficult to track changes in wetland health. Water quality can vary greatly between wetlands as well as within individual wetlands. Determining wetland health scores against benchmarks can therefore be difficult.

There have been various studies on the wetlands of Lake Macquarie, most recently assessing predicted changes arising from climate change and rising water levels.

2.3 Coast

Council participates in the Beachwatch Partnership Program and samples, for Enterococci bacteria, at popular lake and beach swimming areas. Recreational water quality is assessed to a Beach Suitability Grade of either very good, good, fair, poor, or very poor.

The Beachwatch Partnership Program in Lake Macquarie currently includes recreational water quality monitoring and reporting at 7 ocean and 13 lake/lagoon sites:

Ocean Beach Sites

- Catherine Hill Bay
- Dudley Beach
- Redhead Beach
- Blacksmiths Beach
- Caves Beach
- Swansea Heads Little Beach
- Glenrock Lagoon (Beach)

Lake/Lagoon Sites

- Croudace Bay
- Arcadia Vale
- Belmont
- Swansea
- Cams Wharf
- Toronto
- Kilaben Bay
- Wangi Point
- Balcolyn
- Sunshine
- Speers Point
- Bolton Point
- Eleebana

2.4 Ocean

There is currently no formal ocean monitoring program implemented by Lake Macquarie City Council.

A preliminary review was conducted to assess current ocean monitoring systems and the availability of data applicable to ocean health in the Lake Macquarie region. It was found the Integrated Marine Observing System (IMOS) (see www.imos.org.au) provides:

- location data and mapping for Argo floats;
- accessible graphs of:
    - temperature
    - salinity (from 2000 metres to surface every 10 days), and
    - climatology
- with the float also recording oxygen, nitrate, phosphate and silicate.

The closest two Argo floats are located off the Newcastle coast.

Also operated off Newcastle, is a Slocum Ocean Glider which conducts 3 week missions / to 200m maximum depth (with attached HF Radar for surface mapping) to record temperature, salinity and velocity.

Acoustic Monitoring (AATAMS) is currently only available off Sydney and Coffs Harbour. This observes animals in coastal and continental shelf ecosystems, monitors over scales of 100's of metres to 100's of kilometres, tracking to monitor habitat use, home range size, and timing of long-term movements, migratory patterns, and biotic and abiotic factors in animal distribution and movements.

Appendix 1: Health Scores for Non-estuarine Waterways (2011 to 2014)

Site No	Location Details	Year	Riparian Score	Stream Pollution Index	Water Quality Score
COCKED HAT CREEK					
71	Off Oakville Road, Edgeworth	2011	30	2.97	0.38
			Fair	Poor	F
		2012	40	3.10	0.18
			Fair	Fair	F
		2013	35	2.60	0.72
			Fair	Poor	E
		2014	45	1.6	0.80
			Fair	Poor	C
FLAGGY CREEK					
5	Off Kaleen & Wakal Streets, Charlestown (under footbridge)	2011	75	3.15	1.06
			Good	Fair	A
		2012	75	2	0.93
			Good	Poor	A
		2013	55	2.86	0.98
			Good	Poor	A
		2014	45	2.10	0.70
			Fair	Poor	E
JIGADEE CREEK					
68	Off Newport Road, Cooranbong	2011	70	4.32	1.06
			Good	Good	A
		2012	55	4.50	0.85
			Good	Good	C
		2013	50	4.10	0.80
			Fair	Good	D
		2014	55	2.98	0.75
			Good	Poor	D
NORTH CREEK					
67	Off Martin Street, Warners Bay (above the weir)	2011	70	4.08	0.77
			Good	Good	D
		2012	30	3.40	0.78
			Fair	Fair	D
		2013	35	2.29	0.41
			Fair	Poor	F
		2014	35	1.50	0.01
			Fair	Poor	F

Site No	Location Details	Year	Riparian Score	Stream Pollution Index	Water Quality Score
SCRUBBY CREEK					
60	Off Balemo Crescent, Mount Hutton	2011	30	2	0.89
			Fair	Poor	B
		2012	40	3.03	1.17
			Fair	Fair	A
		2013	50	2.79	0.75
			Fair	Poor	E
		2014	50	2.77	0.86
			Fair	Poor	B
SLATEY CREEK					
22	Off Northville Drive, Barnsley (downstream of Cherry's Bridge)	2011	50	3.33	0.64
			Fair	Fair	F
		2012	50	3.60	1.01
			Fair	Fair	A
		2013	40	2.80	0.91
			Fair	Poor	A
		2014	55	2.80	0.81
			Good	Poor	C
STONY CREEK					
73	Off Olney Street, Awaba (new site October 2014)	2014	35	2.72	0.82
			Fair	Poor	C
WINDING CREEK					
69	End of Elizabeth Street, Cardiff South (upstream of concrete channel)	2011	45	3.09	1.02
			Fair	Fair	A
		2012	30	3.50	0.98
			Fair	Fair	A
		2013	30	2.88	0.84
			Fair	Poor	C
		2014	20	3.50	1.05
			Poor	Fair	A