TECHNICAL REPORT

for

Freshwater Monitoring Framework & Report Card

for the

Tamar Estuary and Esk Rivers Program

by:

lloyd environmental

Independent Ecological Consulting

Karoo Consulting

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Contents

Inquiries on this report can be made to:

Lance Lloyd,
Director, Lloyd Environmental Pty Ltd,
ph: 03 9884 5559, Mob: 0412 007 997,Fax: 03 9884 7405,
lance@lloydenviro.com.au, PO Box 3014, SYNDAL, Victoria 3149

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1 INTRODUCTION

This report presents the technical information supporting the Freshwater Report Card for the Tamar Estuary & Esk Rivers (TEER) Program, Freshwater Ecosystem Health Assessment Program (FEHAP) project. The report details the approach and methods used for:

- delineating reporting zones within the TEER basin;
- grading the environmental categories (streamside vegetation, water quality and instream biota) within the reporting zones; and
- combining the individual category grades into grades for each reporting zone.

The report also presents the project results, including:

- tabulated results with details of reporting zones and catchments that have insufficient data to be graded by any or all of the individual indicators; and
- final grades for the categories, reporting zones and catchments.

1.1 Background to the Technical Report

A Progress Report, dated 11 April 2012 was presented to the TEER FEHAP Workshop held on 18 April 2012. That Progress Report and the outcomes from the workshop have provided an important base for the methods and directions presented in this Technical Report. These include:

1. The ANZECC approach (ANZECC & ARMCANZ 2000a) was used as the basis for assessing water quality in the project.
2. Although the key features of the Freshwater Report Card will align with the Estuary Report Card, some features vary. These include the use of the ANZECC approach for assessing water quality trigger values, and the use of an 'A to E' grading scale, rather than the 'A to D with F for fail' grading scale.
3. Within the wide range of environmental indicators recorded across the contributing catchments, there were relatively few that met the requirements of being broad spread (i.e. sampled in all or most catchments), sampled sufficiently often (minimum of fifteen sampling events); and sampled in recent times (in the last ten years). The indicators that were selected for the report card categories were:
    - streamside condition (using TRCI streamside vegetation scores);
    - water quality (pH, EC, turbidity and nutrients); and
    - macroinvertebrate community (using AUSRIVAS outputs).
4. The TEER basin reporting was based on the six contributing catchments (Tamar, Brumbys - Lake, Meander, Macquarie, North Esk and South Esk);
5. Each of the catchments consisted of two reporting zones based on landscape features and land use. The two reporting zones in each catchment were the 'Forested Hills and Highlands' (typically above 400m ASL) and the 'Cleared Foothills and Lowland Plains' (typically below 400m ASL). The Tamar catchment did not have any land within the Forested Hills and Highlands reporting zone.

2 THE TEER BASIN AND ITS CONTRIBUTING CATCHMENTS

The Tamar Estuary and Esk Rivers basin covers approximately 10,000 km^2. It covers a range of landscapes, with altitudes ranging from over 1000 m ASL in the Central Plateau at the headwaters of the South Esk, to near sea level at the Tamar Estuary. The basin supports diverse land uses, including urban and agricultural activities, industrial operations and recreational uses.

The six catchment boundaries used in this project were based on NRM North management boundaries and do not completely align with actual watersheds (Figure 1). For example, the Brumbys - Lake catchment, which is largely a combination of the Brumbys Creek and Lake River catchments, does not end where either of these waterways join the Macquarie River. Instead it includes (approximately) 10 km of the Macquarie River from its confluence with the Lake River to its confluence with Brumbys Creek at Cressy, as well as the stretch of the Macquarie River between Cressy and its confluence with the South Esk River at Longford. Similarly, the Brumbys - Lake catchment also includes the stretch of the South Esk River from Longford, to approximately 1 km upstream of its discharge into the Tamar Estuary.

A brief description of the areas covered by the catchments used in this report is as follows:

1. The **Brumbys - Lake** catchment comprises the land that drains to Brumbys Creek from its headwaters above the town of Blackwood Creek and all its tributaries, including Back Creek, Westons Creek and Palmers Rivulet. The catchment also includes Lake River from its headwaters (inclusive of Arthurs Lake and Woods Lake and their input streams), and tributaries such as Shoobridge and Pisa Creeks. This catchment also includes Great Lake, the Macquarie River below Cressy and the South Esk River below Longford.
2. The **Macquarie** catchment includes the Macquarie River system from its headwaters to the south of Lake Leake, down to its confluence with the Lake River. The catchment also includes the Elizabeth, Tooms and Isis Rivers and all their tributaries.
3. The **Meander** catchment includes the headwaters of the Meander River in the Western Tiers down to its confluence with the South Esk River at Hadspen (in the Brumbys - Lake catchment). The catchment also includes Liffey Creek in the eastern catchment, Quamby Brook near Westbury in the central part of the catchment and Jackeys and Western Creeks in the west of the catchment.
4. The **North Esk** catchment contains the North Esk River from its headwaters near Ben Nevis down to where it discharges into the Tamar River. Tributaries to the North Esk River in the eastern and central parts of the catchment include the Ford River and Musselboro and Burns Creeks. Further west, St Patricks River is a major tributary which itself recieves tributaries such as Patersonia Rivulet, Priors Creek, Barrow Creek and Camden Rivulet.
5. The **South Esk** catchment contains the whole catchment of the South Esk and its tributaries upstream from its confluence with the Macquarie River at Longford. This includes the Nile River, St Pauls River and Break O'Day River and all their tributaries.
6. The **Tamar** catchment comprises the tributaries that drain directly to the Tamar River and Estuary, such as Middle Arm Creek, Supply River and Stony Brook from the west, and Barnards Creek, Symons Creek and Fourteen Mile Creek from the east.

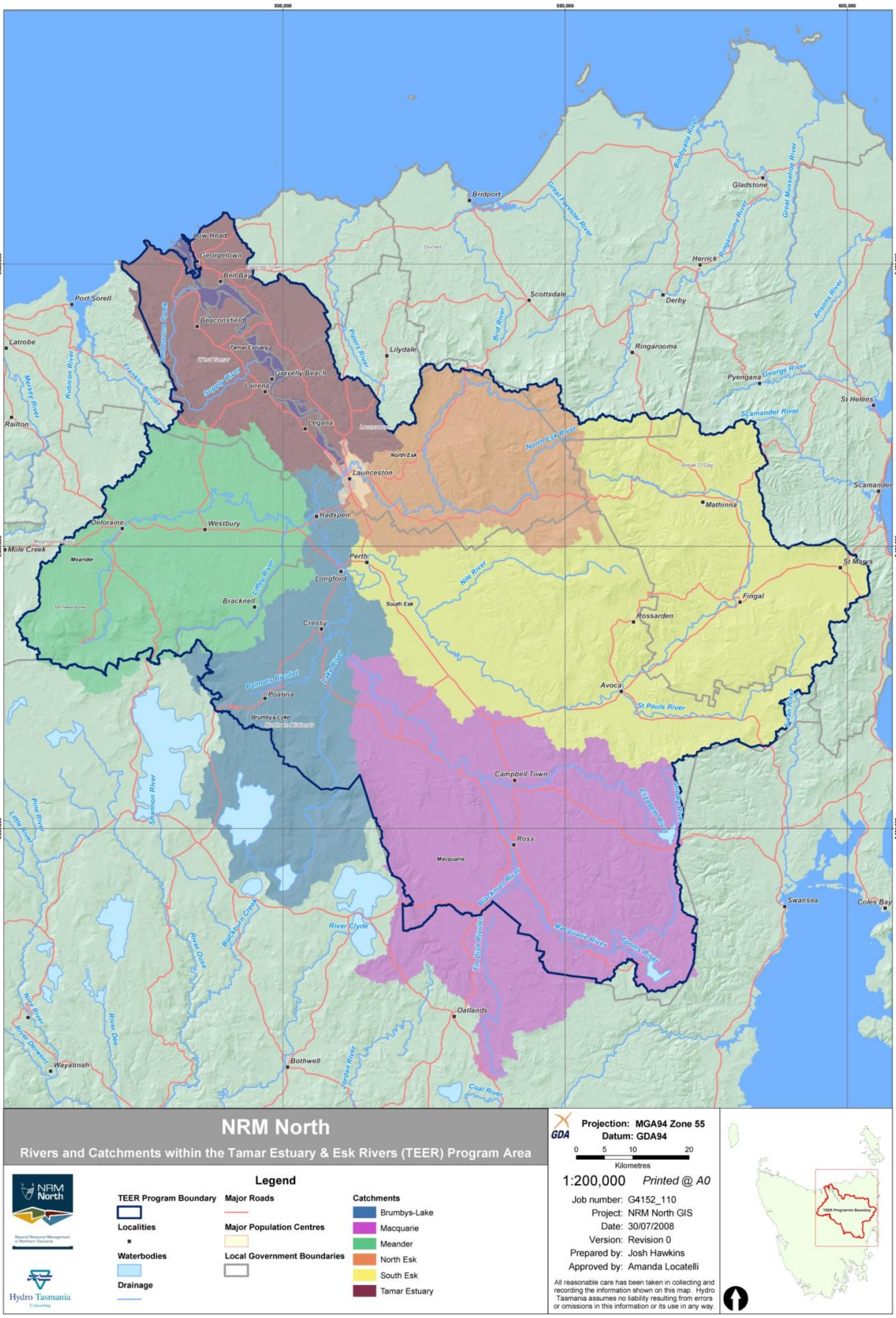


Figure 1: Catchments of the TEER Basin (note: although the TEER Program boundary does not include all of the Macquarie and Brumbys - Lake Catchments, these areas were included in the study)

3 DELINEATION OF REPORTING ZONES

The complexity of the TEER Basin meant that delineation of the basin into reporting zones will make reporting easier. The six major catchments were separated into altitude-based reporting zones (building on the fact that changes in stream ecological character are known to be associated with changes in altitude). Several options were explored, including:

- Using the ANZECC (2000a) default approach of the 150m ASL contour being the delineation line. This approach is recommended by ANZECC in the absence of existing or recommended alternatives and was initially used until an alternative was derived for the project.
- Following the DPIW (2008) approach of not applying an altitudinal delineation for trigger values "due to Tasmania's mountainous landform and relatively small catchment sizes" (DPIW 2008). Instead, in the absence of definitive data, DPIW (2008) applied the most conservative set of ANZECC default triggers [those for 'Uplands', ANZECC (2000)]. Although this approach may be readily applicable to large parts of Tasmania, members of the client-consultant team recognised a clear altitudinally-based difference in the waterways of the TEER catchments.
- Using the 400m ASL contour, based on marked changes in land character such as slope, landscape dissection and accompanying changes in land use.

The 400m contour was ultimately selected folowing examination of land features and a consensus that these features did separate at around 400m. The resulting reporting zones were named 'Cleared Foothills and Lowland Plains' (CF&LP) for the areas below 400m and 'Forested Hills and Highlands' (FH&P) for the areas above 400m (Figure 2). The delineation incorporates some flexibility, with areas higher than 400m being included in the CF&LP if they are assessed as being more similar to the lower region and, conversely, areas higher than 400m included in the FH&P if they are assessed as being more representative of that region. Each of the six TEER catchments was divided into CF&LP and FH&P reporting zones with the exception of the Tamar, which has insufficient land area above 400m.

It is important to note that any selected delineation is likely to be reviewed and refined, either as part of a Statewide classification of water quality regions or following the collection of more information in the future.

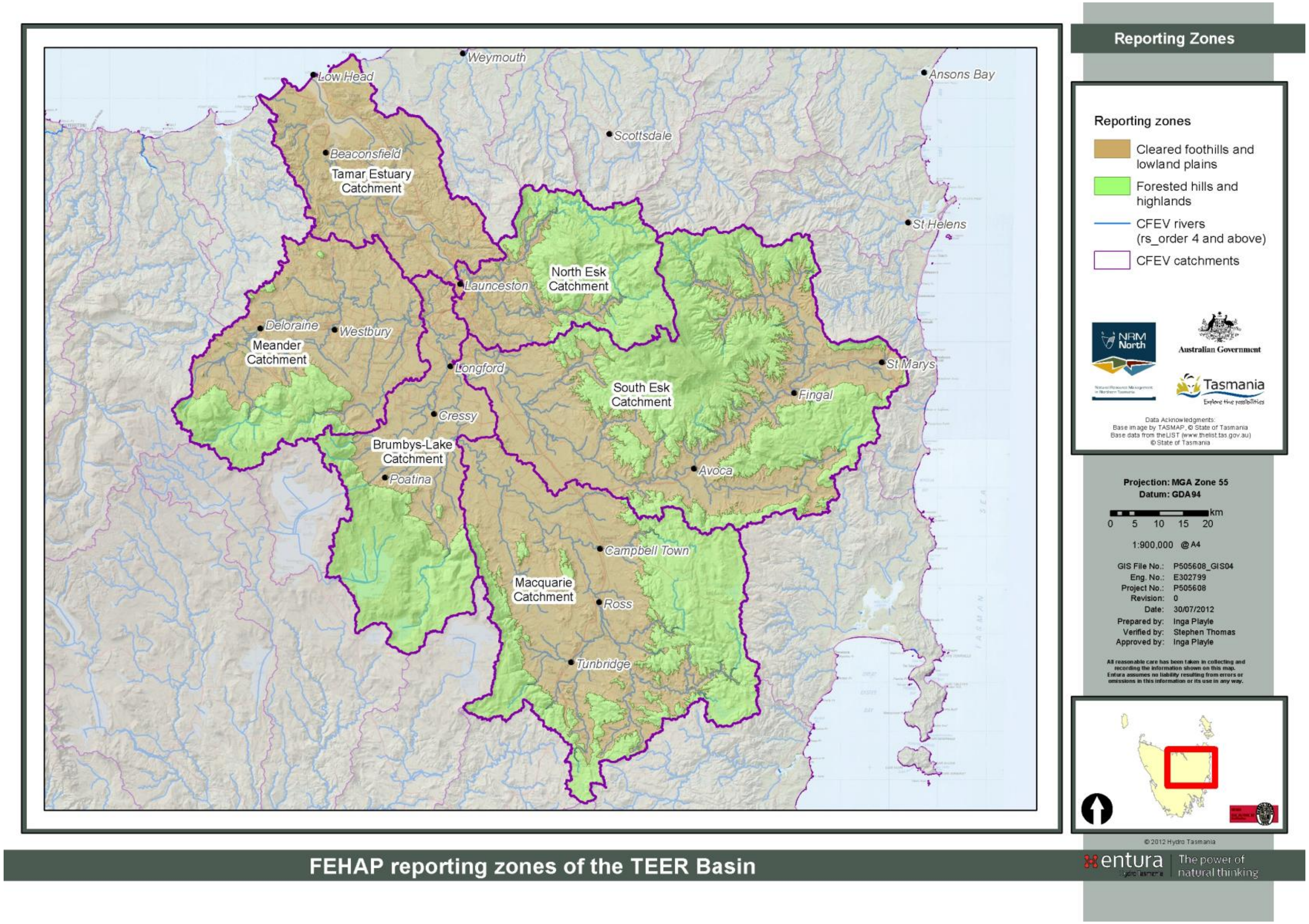


Figure 2: Reporting zones used in the TEER Basin Report Card

4 STREAMSIDE ZONE VEGETATION: APPROACH, DATA AND RESULTS

4.1 Approach

Streamside Zone Vegetation (SZV) assessment is a component of the Tasmanian River Condition Index (TRCI). The SZV data were included in the Freshwater Report Card assessment as they contribute information on an important component of freshwater ecosystems. Streamside vegetation is an important contributor to bank stability, pollutant filtering (including sediment), and in-stream habitat (through coarse woody debris and fringing vegetation). Streamside vegetation also contributes energy (as organic carbon) and essential nutrients to the aquatic ecosystem.

The overall site score from the SZV data was used to determine A to E grades for use in the Freshwater Report Card.

4.2 Data Supplied and Grade Allocations

NRM North supplied SZV data from 52 sites, collected between January 2007 and January 2012 (Table 1). The overall Site Scores for all sites were plotted on a graph against their ranking (lowest to highest) (Figure 3),allowing an assessment of the spread of the data and some identification of groupings of vegetation scores, including natural breaks in the plot. Grades from A to E were allocated for groupings of site rankings (Figure 3) and this resulted in the number of sites per grade as presented in Table 2.

The mean SZV score for each reporting zone was simply calculated by taking the mean score using all sites in each reporting zone and comparing the outcome to Table 2. For example, the Brumbys - Lake Forested Hills and Highlands reporting zone had four sites with SZV scores of, 27, 89, 83 and 87, with an average (mean) of 72, which places it in the Good (B) grade.

A confidence rating was applied to the results based on the number of sites assessed for each reporting zone (Table 3).

4.3 Results and Discussion

The Forested Hills and Highlands reporting zones were largely under-represented, with the Macquarie and South Esk each only having one TRCI site in their Forested Hills and Highlands and the Meander only having two TRCI sites. The Tamar Cleared Foothills and Lowland Plains only had one site (Table 3). In four of the five catchments that had Forested Hills and Highlands, these reporting zones received higher grades than the corresponding Cleared Foothills and Lowland Plains (Figure 4). The fifth had the same grade as its corresponding Cleared Foothills and Lowland Plains reporting zone.

Apart from the Forested Hills and Highlands of the Meander, Macquarie and South Esk catchments (with a grade of 'A', allocated with low confidence), the streamside vegetation of the TEER basin was generally rated moderate or poor. An important feature of the SZV scores within catchments is the range in grades. For example, the four sites in the Forested Hills and Highlands of Brumbys - Lake included three sites with an 'A' grading and one site with a 'D' grading, indicating that although much of the catchment's streamside zone may be in good condition, there are areas that could be substantially improved. Similarly, the four sites in the Cleared Foothills and Lowland Plains of the South Esk consisted of one site with an A grade, two with D grades and one with an E grade. The extent to which the sampling is proportionally representative of the whole catchment is unknown, but these results indicate a broad range of conditions within the catchments and reporting zones. The low number of sites assessed in several of the reporting zones gives a low confidence in the accuracy of the summary. As such, many of the grades provided below should be viewed as indicative only.

Table 1: Available SZV scores for sites in the TEER basin

WaterwayName	Location	SZV Site Score
Back Creek	Upstream of Wilmores Lane	24
Badgers Creek		87
Barrow Creek		71
Break O'Day River	At Killymoon Bridge	34
Camden Rivulet		30
Ford River	Ford River at Upper Blessington	38
Isis River	At Isis	22
Jackeys Creek	Jackeys Creek d/s Jackeys Marsh	86
Jacks Creek		27
Jones Rivulet	Gunns Marsh Rd	89
Lake River	Staunton Richard Higgins	35
Lake River	Connorville, Millers Bluff Rd	92
Lake River	Connorville	45
Lake River		81
Lake River	Macquarie Road	43
Lake River	"Rock thorpe" - Lake River Road	40
Lake River	Connorville	45
Liffey River	Upstream West Channel	20
Liffey River	Liffey River at Carrick	54
Macquarie River	Macquarie River d/s Elizabeth River	43
Macquarie River	Macquarie River at Trefusis	75
Meander River	At Strathbridge	32
Meander River	Meander River at Falls Road	96
Middle Arm Creek	Middle Arm Creek @ Beaconsfield	41
Musselboro Creek	At Burns Road	62
Nile River	Nile River at Deddington	85
North Esk River	At Ballroom	70
North Esk River	At Ben Nevis	72
Pattersonia Rivulet		65
Peddles Creek		37
Pisa Creek	Macquarie Road	33
Pisa Creek	Connorville, Connorville Road	44
Priors Creek		26
Scotch Bobs Creek	Cow Paddock Bay 25m u/s from bridge crossing.	83
Seven Time Creek		90
Shoobridge Creek	Lake River Road	89
South Esk River	Above Macquarie River at Perth	24
South Esk River	South Esk at Cokers Road	86
St Patricks River		51
St Patricks River		72
St Patricks River		74
St Patricks River	St Patricks River at Corkerys Road	63
St Patricks River		90
St Patricks River		88
St Pauls River upstream of South Esk River	Property off Royal George Road, just outside Avoca	41
Tooms River	Tooms River downstream Tooms Lake	86
Tumbledown Creek	Near Gunns Marsh Rd, close to electricity pylons	87
Unnamed	Stauntan via Andrew Dowlings property road	26
Unnamed	Unnamed tributary at Staunton	28
Unnamed creek		70
Weavers Creek		53
Western Creek	Western Creek at Bankton Road Bridge	22

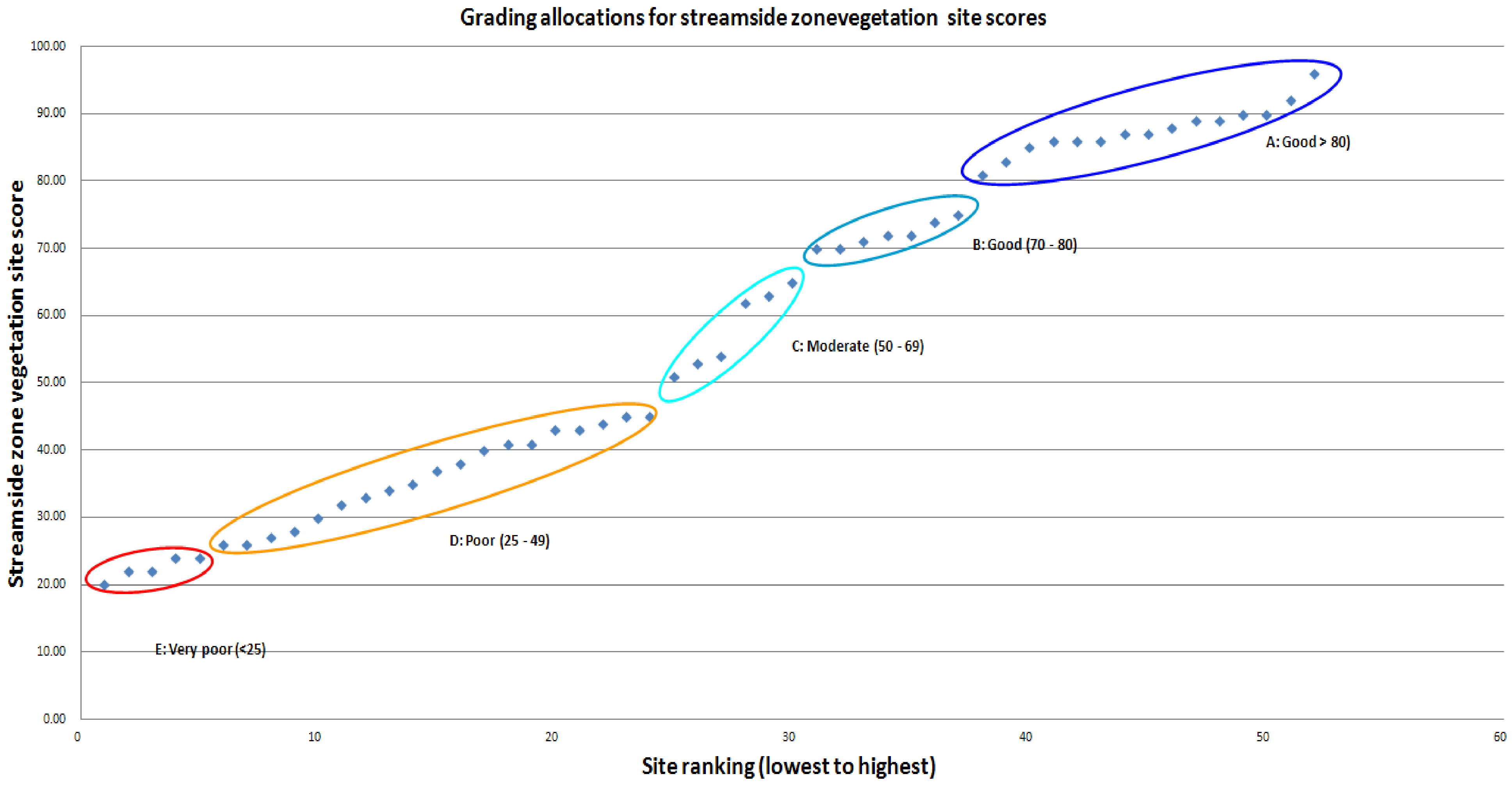


Figure 3: Grade allocation and TRCI scores for sites in the TEER basin

Table 2: Spread of TRCI sites across the grades in the TEER basin

TEER Grade		SVZ Score	No. of Sites
A	**Very good**	> 80	15
B	**Good**	70 to 80	7
C	**Moderate**	50 to 69	6
D	**Poor**	25 to 49	19
E	**Very poor**	< 25	5

Table 3: Confidence ratings used in the SZV grading table

Number of sites	Confidence rating
1-2	Low
3-5	Moderate
6 or more	High

Table 4: SZV grades and data availability for sites in the reporting zones of the TEER Basin

	Reporting zone			
	Cleared Foothils and Lowland Plains		Forested Hills and Highlands	
Catchment	No of sites	Grade	No of sites	Grade
Brumbys - Lake	**13**	**D**	**4**	**B**
Macquarie	**3**	**D**	**1**	**A**
Meander	**4**	**D**	**2**	**A**
North Esk	**7**	**C**	**12**	**C**
South Esk	**4**	**C**	**1**	**A**
Tamar	**1**	**D**		

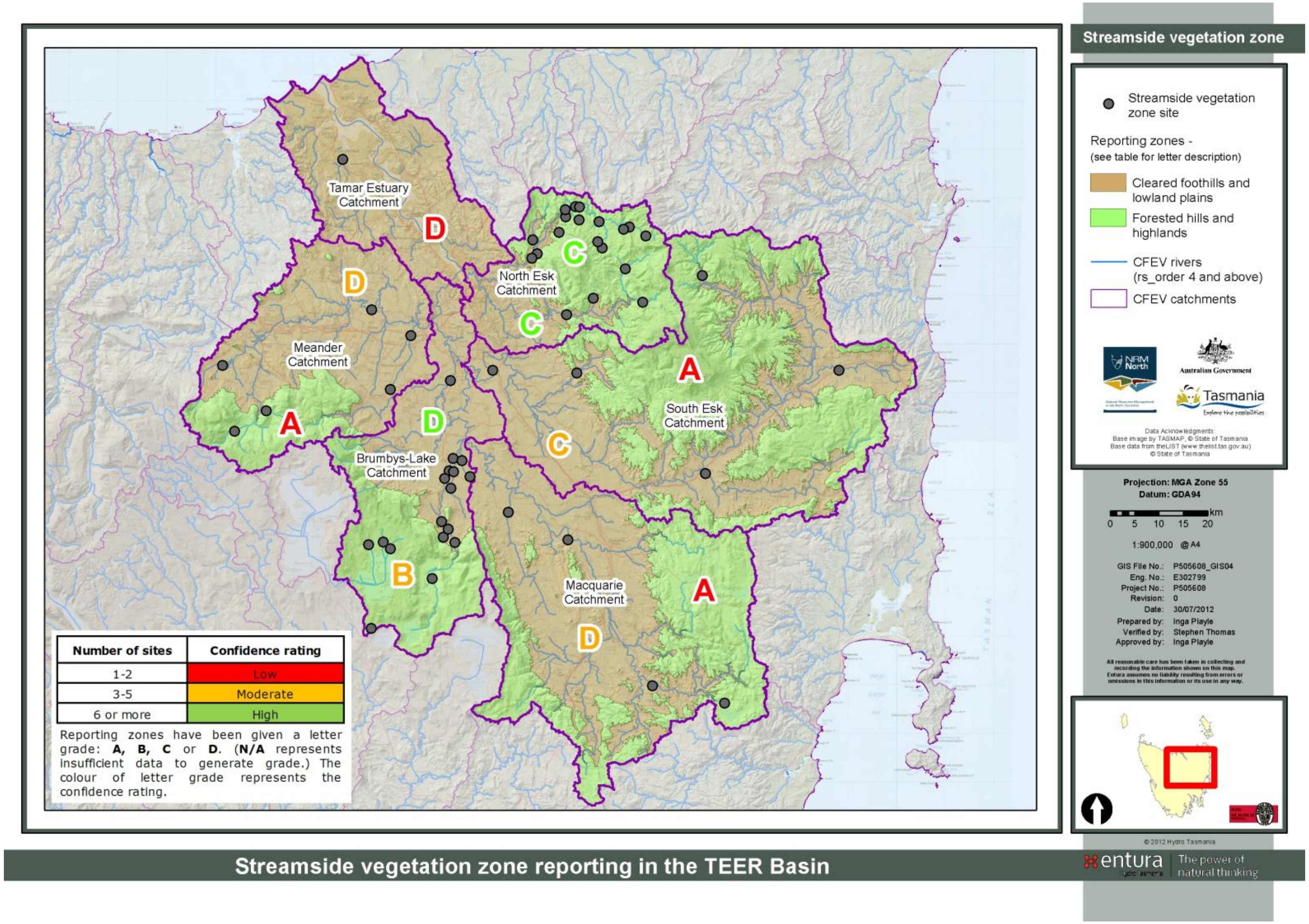


Figure 4: SZV results across the reporting zones of the TEER Basin

5 WATER QUALITY INDICATORS: APPROACH, DATA AND RESULTS

5.1 Approach

There was a large range of water quality indicators potentially available for the Freshwater Report Card. However, many of these indicators were available for a small number of sites, limited in geographic spread, sampled too infrequently, or sampled too long ago to provide confidence in their representation of current conditions. Therefore the following criteria were used to select indicators for the report card:

- all data used should be gathered within the last 10 years, to be considered 'current'
- a minimum of 15 current data points should be available for each site
- there should be a reasonable spread of current data across catchments within the TEER basin for an indicator to be selected

This resulted in the selection of two major groups of water quality data available – *in-situ* measurements, collected using meters (electrical conductivity, pH and turbidity), and laboratory analyses of water samples for nutrients (total phosphorus and total nitrogen). Similar to the streamside vegetation, water quality data was not uniformly available for all reporting zones (Table 5).

Table 5: Water quality data availability for sites in the reporting zones of the TEER Basin

Reporting zone: Catchment	**Cleared Foothills and Lowland Plains**	**Forested Hills and Highlands**
Brumbys - Lake		
Macquarie		
Meander		
North Esk		
South Esk		
Tamar		

= *In-situ* and nutrient data available for scorecard

= Only *in-situ* data available for scorecard

= Insufficient data available for scorecard

Most reporting zones had data for the *in-situ* indicators and five of the eleven reporting zones had nutrient data. The collection of consistent data sets across the catchments and reporting zones is a clear deficiency for the Freshwater Report Card and one that needs to be addressed for future reporting.

The assessment of each site's water quality was based on the ANZECC approach, which uses trigger values. A trigger value is a quantitative measure for an indicator which, if met, signifies a low risk of ecological harm being caused by that indicator. If an indicator exceeds the trigger value at a site, it is said to have 'triggered', indicating higher risk. ANZECC (2000a) provides a suite of trigger values for five geographic regions across Australia and New Zealand; Tasmania lies within the 'South East Australia' region.

Although providing regional trigger values, ANZECC refers to these as 'default' values and advocates the use of more locally derived trigger values where possible. Based on a desktop analysis of land use mapping, DPIW (2008) identified three sites within the TEER basin as potential reference sites. In the absence of further information, these sites were used as reference sites for this project. One of the sites - Jackeys Creek downstream of Jackeys Marsh - was a Forested Hills and Highlands site (above 400m). The two Cleared Foothills and Lowland Plains reference sites were Nile River at Deddington and North Esk River at Ballroom. Using the data from these sites in combination with the ANZECC default trigger values, trigger values were produced for waterways in the TEER basin (Tables 6a and 6b). The trigger values are derived from amalgamating the ANZECC default triggers with the 80th percentile values from the reference sites and are to be compared to median values of test sites. Trigger values are also provided for lakes within the TEER catchment (Table 6c).

The trigger values for the Forested Hills and Highlands have been derived for high conservation value catchments. That is, if the water quality indicators remain within the limits of these trigger values, then the risk of impact associated with these indicators is low, even for high conservation value ecosystems. The trigger values for Cleared Foothills and Lowland Plains sites and for lakes have been derived for slightly to moderately modified ecosystems, reflecting the nature of these reporting zones.

The default trigger values provided by ANZECC for turbidity and electrical conductivity are given as ranges, reflecting the broad array of stream types and sub-regions within south eastern Australia (from headwaters in the alpine areas of Tasmania and Victoria to the muddy waters of lowland plains in the Murray Darling Basin). Waters in Tasmania are likely to be at the low end of the range provided and therefore the suggested triggers for the TEER basin are at the lower end of the ANZECC default triggers.

The pH trigger is provided as a range due to the problems that low and high pH can cause an aquatic ecosystem. This means that median pH values should not be above the high trigger or below the low trigger.

For each indicator, the trigger values are set at levels that indicate increased risk to the condition of an aquatic ecosystem. Therefore, no indicator poses more or less threat if it triggers and accordingly, no indicator has been weighted with more or less value in the grading.

Table 6: Suggested trigger values for the indicators used to assess water quality in the TEER basin

(a) Forested Hills and Highlands Rivers

Site percentiles Site Name	EC (µS/cm) 80th percentile	pH 20th & 80th percentile	Turbidity (NTU) 80th percentile	TP (mg/L) 80th percentile	TN (mg/L) 80th percentile
Jackeys Creek d/s Jackeys Marsh	57	6.2 – 7.2	3	0.015	0.446
ANZECC Default trigger (for medians)	30 - 350	6.5 – 7.5	2 - 25	0.013	0.480
Suggested Triggers (for medians)	75	6.2 – 7.5	5	0.020	0.450

(b) Cleared Foothills and Lowland Plains Rivers

Site Name	EC	pH	NTU	TP	TN
Nile River at Deddington	60	6.7 – 7.5	2	0.008	0.203
North Esk River at Ballroom	76	6.4 – 7.4	7	0.021	0.430
ANZECC Default (for medians)	125 - 2200	6.5 – 8.0	6 - 50	0.050	0.500
Suggested Triggers (for medians)	125	6.5 – 8.0	10	0.025	0.500

(c) Lakes

Site Name	EC	pH	NTU	TP	TN
ANZECC Default (for medians)	20 - 30	6.5 – 8.0	1 - 20	0.010	0.350
Suggested Triggers (for medians)	20	6.5 – 8.0	4	0.010	0.350

5.2 Method

The method used in the allocation of water quality grades for the reporting zones included consideration of:

- consistency with the methods used in the TEER Estuary Report Card;
- enabling assessment with different numbers of indicators (most sites had three indicators useful for the assessment, whereas others had five);
- enabling a measure of the extent to which a site triggers (i.e. how far it exceeds a trigger value) for each indicator; and
- incorporating a measure of confidence in the final grading, based on the number of sites and indicators used in the process.

Grade Allocation

The steps followed in the grading process were:

1. For each site in each reporting zone the median of each water quality indicator was calculated and compared to the trigger value and threshold values as shown in Table 7. Using Table 7, a 'Category Value' was calculated for each indicator at each site.

Table 7: Category values for extent of triggering for the indicators used to assess water quality in the TEER basin

a) Forested Hills & Highlands

	Very low risk of impact	Increased risk of impact	Moderate risk of impact*	High risk of impact*
Category Value Indicator	**4**	**3**	**2**	**1**
Total Phosphorus (mg/L)	≤ 0.020	0.021 – 0.030	0.031 – 0.050	> 0.05
Total Nitrogen (mg/L)	≤ 0.45	0.46 – 1.1	1.0 – 1.2	> 1.2
Electrical conductivity (μS/cm)	≤ 75	76 - 300	301 - 500	> 500
Turbidity (NTU)	≤ 5	6 - 20	21 - 30	> 30
pH (pH units)	≥6.2 and ≤ 7.5	5.7 - 6.1 or 7.6 – 8.0	5.2 – 5.6 or 8.1 – 8.5	<5.2 or >8.5

*The threshold levels for impact have been derived using expert opinion and studies undertaken in similar ecosystems in Victoria (e.g. Tiller and Newall 1995; Newall and Tiller 2002, Tiller and Newall 2009).

b) Cleared Foothills and Lowland Plains

	Very low risk of impact	Increased risk of impact	Moderate risk of impact*	High risk of impact*
Category Value Indicator	**4**	**3**	**2**	**1**
Total Phosphorus (mg/L)	≤ 0.025	0.026 – 0.050	0.051 – 0.08	> 0.08
Total Nitrogen (mg/L)	≤ 0.50	0.51 – 1.2	1.3 – 1.5	> 1.5
Electrical conductivity (µS/cm)	≤ 125	126 - 500	501 – 1,500	> 1,500
Turbidity (NTU)	≤ 10	11 - 25	26 - 35	> 35
pH (pH units)	≥6.5 and ≤ 8.0	6.0 – 6.4 or 8.1 – 8.5	5.5 – 5.9 or 8.6 – 9.0	<5.5 or >9.0

*The threshold levels for impact have been derived using expert opinion and studies undertaken in similar ecosystems in Victoria (e.g. Tiller and Newall 1995; Newall and Tiller 2002, Tiller and Newall 2009).

c) Lakes*

	Very low risk of impact	Increased risk of impact	Moderate risk of impact	High risk of impact
Category Value Indicator	**4**	**3**	**2**	**1**
Total Phosphorus (mg/L)	≤ 0.010	0.011 – 0.020	0.021 – 0.030	> 0.030
Total Nitrogen (mg/L)	≤ 0.35	0.35 – 0.5	0.6 – 0.8	> 0.8
Electrical conductivity (µS/cm)	≤ 20	21 - 150	151 - 300	> 300
Turbidity (NTU)	≤ 4	5 - 10	11 - 20	> 20
pH (pH units)	≥6.5 and ≤ 8.0	6.0 – 6.4 or 8.1 – 8.5	5.5 – 5.9 or 8.6 – 9.0	5.5< or >9.0

*There are less data available for lakes in Australia and therefore these values are indicative only. In the current study there are only three lake sites in the entire study and nutrient data available for only one of these sites. Therefore the study results are not likely to be substatnially impacted by the values presented in this table.

2. For each indicator an average (mean) Category Value was calculated for all sites in the subcatchment.
3. The average Category Value for all indicators were used to calculate an average Category Value for the reporting zone.
4. A Final Score was calculated by dividing the reporting zone average Category Value by 4.
5. The Water Quality Score was calculated by dividing the Final Score by the number of indicators used. If insufficient indicators (i.e. <3) had data then no grade was given.
6. The Water Quality Score for each reporting zone was a number between 0 and 1. This was converted to a grade as follows (Table 8):

Table 8: TEER Grade for Water Quality scores

Grade		Water Quality Score
A	Very good	1
B	Good	0.950 - 0.999
C	Moderate	0.850 - 0.949
D	Poor	0.800 - 0.849
E	Very poor	< 0.800

Similar to the approach used for the TRCI site data, the assigning of grades for reporting zone water quality scores involved the plotting of the scores and determining natural breaks in the plotted data (Figure 5).

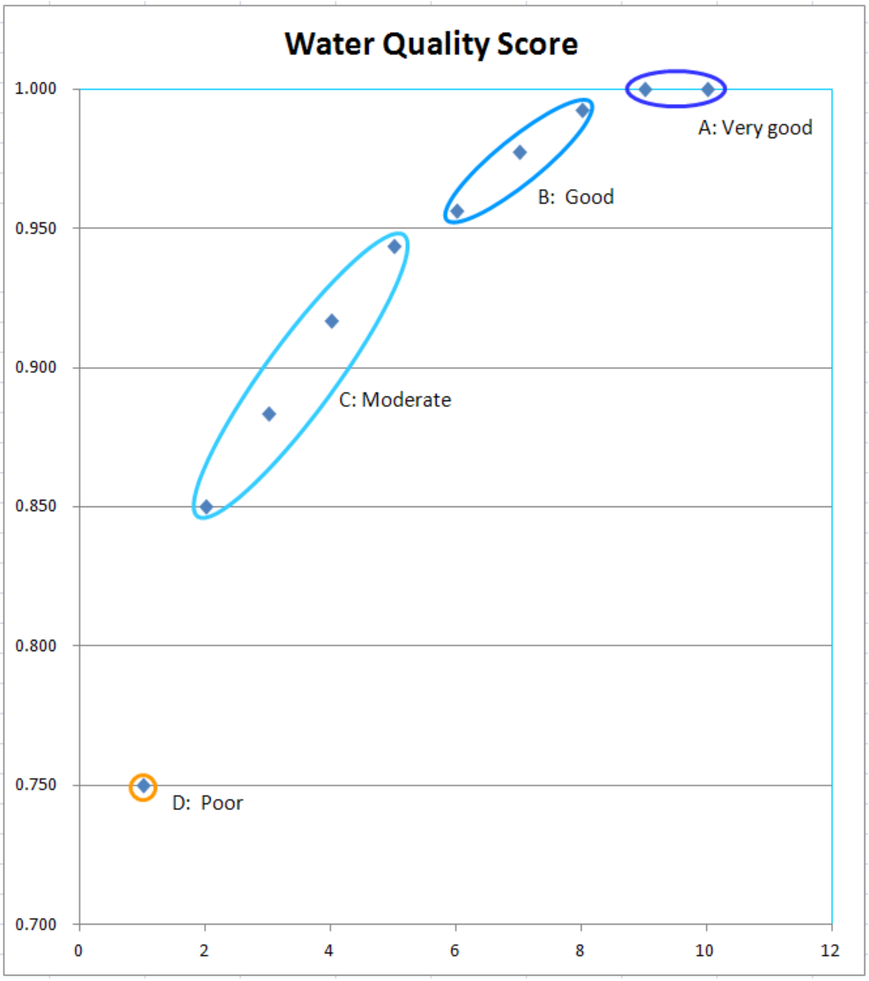


Figure 5: Grade allocation and Water Quality Scores for reporting zones in the TEER basin

Confidence Levels

Confidence in the water quality grades allocated to each of the reporting zones will be a function of the number of sites that contributed to the grade, as well as the number of water quality indicators contributing to each site's assessment. The table below provides the basis of an approach for assessing data confidence. As shown in Table 9, a reporting zone with only one or two sites produces a low confidence result. In comparison, a reporting zone with three to five sites provides a low confidence rating with only three indicators but would obtain a moderate confidence with 5 indicators. Similarly, a reporting zone with 6 or more sites would have a moderate confidence rating with 3 but a high rating with five indicators.

Table 9: Number of sites and indicators matrix for assessing confidence

Number of sites	3 indicators	5 indicators
1-2	Low	Low
3-5	Low	Moderate
≥ 6	Moderate	High

The confidence ratings in Table 9 provide a logical approach, based on the experience of the project team. However, these ratings are subjective and are designed for basin scale reporting required for the Report Card. Therefore, this approach may need modification for other studies where more intensive data is required (e.g. examination of toxicant hot spots within a single reporting zone). In the current scale of reporting, a rating of moderate is likely to provide sufficient confidence.

A complicating aspect associated with this process lies in reporting zones that have some sites with 3 indicators and some sites with 5 indicators. The proposed approach is to use the combination of site numbers and indicators that provides the highest confidence. For example, a reporting zone that has five sites with three indicators and one site with five indicators should include the single 'five indicator site' as an extra 'three indicator site' (as those three indicators are a subset of the five indicators). This would result in the reporting zone have having six sites with 3 indicators and hence a moderate confidence rating.

Highly variable reporting zones are an issue. Although the average of a highly variable catchment does not necessarily represent the condition across most of the catchment, this does not mean there is low confidence in the data, rather that they are just highly variable. High variability may be an indication that the reporting zone should be split (i.e. regionalisation).

5.3 Results and Discussion

Using the trigger and threshold values derived for the water quality indicators in the TEER basin displayed in Table 6 and the grade allocation process described in Section 5.2, grades were allocated to each of the sites in each of the reporting zones. These are displayed in Table 10, and the summary of the reporting zone grades is provided in Table 11 and Figure 6.

Vairability of Water Quality Indicators

Variability of the water quality indicators within each reporting zone can be viewed in terms of 'within-site' variability (i.e. temporal variation at a site) or 'between-site variability' (i.e. spatial variability). An analysis of temporal variability at each site is beyond the scope of a report card. However, decision making for management actions should include some review of within-site variability to provide clues regarding local site issues. For example, if a site triggers for turbidity, it may be useful to identify whether most of the results cluster around the median reading (e.g. if the 20th and 80th percentiles are reasonably close to the median readings) or whether the data are broadly spread with a lot of variation around the median. If the data are broadly spread, it could be useful to seek correlations with specific events/issues, such as storm events, land use activities or flow/discharge alterations. If the data are clusered around a median that triggers, it could suggest either that there is an ongoing disturbance to the waterbody or that the waterbody has naturally higher turbidities. For either scenario, it is likely that only minor investigations would be required to clarify the situation.

Another example of variability would be a reporting zone (or partof a zone) which tends to have intermittent flow and thus high natural variability due to climatic cycles. This occurs in the upper Macquarie catchment (David Horner, DPIPWE, personal communication) and could cause substantial fluctuations in water quality data.

Although the purpose of a report card is to summarise the information available for each reporting zone, it is important that accompanying documentation (such as this Technical Report) provide data on the variability within the reporting zones, to help resource managers analyse issues within the catchment. Table 10 (a – f) provides these data, and shows some interesting spatial variation within the reporting zones. These include the Lake sites in the Forested Hills and Highlands zone of the Brumbys - Lake catchment, with

Woods Lake 'Middle' site triggering for three of the five indicators for which it was sampled, while Great Lake at Reynolds Bay triggers for none of the three indicators for which it was sampled. Similarly, for the sites in the Forested Hills and Highlands zone of the Macquarie catchment, the Elizabeth River below Lake Leake does not trigger for any of its three indicators whereas the Tooms River downstream of Tooms Lake triggers for four of its five indicators, including a total phosphorus concentration more than two and a half times the trigger level, and high enough to pose a high risk of impact. The Tooms River site is known for problematic algal blooms (Kate Hoyle, DPIPWE, personal communication), and therefore the result does indicate a genuine water quality issue that occurred in the Forested Hills and Highlands zone of the Macquarie catchment. However, the paucity of sites in this reporting zone means that there is no data on the extent of the issue and therefore only a low confidence in the water quality grade for the zone (Tables 9 and 11).

Another aspect of the variability of water quality within the reporting zones is the difference between indicators. For example, in the Cleared Foothills and Lowland Plains of the North Esk catchment (Table 11d), five of the eight sites trigger for electrical conductivity whereas all medians for all other water quality indicators sampled are within trigger levels for all sites at which they are sampled. The Cleared Foothills and Lowland Plains of the South Esk catchment (Table 11e) provides a similar result with five of the eleven sites triggering for electrical conductivity, but no sites triggering for any other indicator.

Decision making for management of the catchments and waterbodies will require a more detailed assessment of the water quality data than that provided by a Report Card.

Table 10: Grade allocation and water quality summaries for sites in the TEER Basin

(a) Reporting zones of the Brumbys Creek and Lake River catchment

Site Name	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
Sth Esk River DS Trevallyn Dam	Cleared Foothills & Lowland Plains	82	125	4	7.3	6.5 - 8.0	4	6	10	4	ND	0.025		ND	0.5		
South Esk River at Hadspen River Reserve		55		4	7.0		4	3		4	ND			ND			
South Esk River at Pateena Road		57		4	6.6		4	2		4	ND			ND			
Macquarie River at Woolmers Lane		34		4	6.9		4	4		4	ND			ND			
Back Creek upstream Wilmores Lane		59		4	7.0		4	13		3	ND			ND			
Brumbys Creek at No.3 Weir		26		4	6.8		4	4		4	ND			ND			
Lake River at Macquarie Road		83		4	7.5		4	3		4	ND			ND			
BrumbyCreek_A/b PalmersRivulet		84		4	7.6		4	7		4	ND			ND			
Brumbys Creek b/l Palmers new site		24		4	7.2		4	5		4	ND			ND			
Lake River at Parknook		74		4	7.4		4	6		4	ND			ND			
Poatina at Re-reg Pond (Lake site)	CF&LP 'Lake'	20	20	4	6.8	6.5 - 8.0	4	1	4	4	ND	0.01		ND			
Ave Category value (CF&LP)				**4**			**4**			**3.91**							
Final Score (= Ave category value ÷ 4)				**1**			**1**			**0.98**							0.992
Woods Lake 'Middle' LAKE SITE	Forested Hills and Highlands 'Lake'	63	20	3	7.3	6.5 - 8.0	4	9	4	3	0.016	0.01	3	0.34	0.35	4	
WoodsLake_WhmsW1-ifcW1 LAKE SITE		61		3	7.4		4	5		3	ND			ND			
Great Lake at Reynolds Bay		19		4	7.0		4	1		4	ND			ND			
Ave Category value (FH&H)				**3.33**			**4.00**			**3.33**			**3.00**			**4.00**	
Final Score (= Ave category value ÷ 4)				**0.83**			**1.00**			**0.83**			**0.75**			**1.00**	0.883

(b) Reporting zones of the Macquarie River catchment

SiteName	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
Macquarie River downstream Elizabeth River	Cleared Foothills & Lowland Plains	205	125	3	7.3	6.5 - 8.0	4	8	10	4	0.030	0.025	3	0.64	0.5	3	
1.25 Km upstream Elizabeth River		274		3	7.5		4	3		4	0.024		4	0.66		3	
Macquarie River at Trefusis		134		3	7.3		4	12		3	0.027		3	0.63		3	
Ave Category value (CF&LP)				**3.00**			**4.00**			**3.67**			**3.33**			**3.00**	
Final Score (= Ave category value ÷ 4)				**0.75**			**1.00**			**0.92**			**0.83**			**0.75**	**0.850**
Tooms River downstream Tooms Lake	Forested Hills & Highlands	87	75	3	7.3	6.2 - 7.5	4	8	5	3	0.053	0.02	1	0.84	0.45	3	
Elizabeth River below Lake Leake		62		4	7.0		4	3		4	ND			ND			
Ave Category value (FH&H)				**3.50**			**4.00**			**3.50**			**1.00**			**3.00**	
Final Score (= Ave category value ÷ 4)				**0.88**			**1.00**			**0.88**			**0.25**			**0.75**	**0.750**

(c) Reporting zones of the Meander River catchment

SiteName	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
Meander River at Quamby Farm	Cleared Foothills & Lowland Plains	91	125	4	7.3	6.5 - 8.0	4	3	10	4	ND	0.025		ND	0.5		
Meander River at Strathbridge		71		4	7.0		4	6		4	0.021		4	0.58		3	
Liffey River at Carrick		60		4	6.9		4	5		4	0.013		4	0.24		4	
Quamby Brook at Roxford		171		3	7.1		4	5		4	ND			ND			
Swamp Gum Rivulet at Osmaston Road		272		3	7.1		4	16		3	ND			ND			
Meander River at Porters Bridge (Exton)		71		4	7.2		4	2		4	ND			ND			
Liffey River at Bracknell Lane		47		4	7.0		4	2		4	ND			ND			
Western Creek at Montana Road		54		4	7.3		4	6		4	ND			ND			
Ave Category value (CF&LP)				**3.75**			**4.00**			**3.88**			**4.00**			**3.50**	
Final Score (= Ave category value ÷ 4)				**0.94**			**1.00**			**0.97**			**1.00**			**0.88**	**0.956**
Jackeys Creek downstream Jackeys Marsh (DPIW 2008 Reference Site)	Forested Hills & Highlands	51	75	4	6.8	6.2 - 7.5	4	2	5	4	0.010	0.02	4	0.29	0.45	4	
Ave Category value (FH&H)				**4.00**			**4.00**			**4.00**			**4.00**			**4.00**	
Final Score (= Ave category value ÷ 4)				**1.00**			**1.00**			**1.00**			**1.00**			**1.00**	**1.000**

(d) Reporting zones of the North Esk River catchment

SiteName	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
North Esk River upstream Clarks Ford Bridge	Cleared Foothills & Lowland Plains	74	125	4	7.2	6.5 - 8.0	4	2	10	4	ND	0.025		ND	0.5		
Jinglers Creek at Glenwood Road Bridge		1123		2	7.4		4	7		4	ND			ND			
Jinglers Creek at Substation off Glenwood Road		1064		2	7.8		4	6		4	ND			ND			
Kings Meadows Rivulet at Punchbowl		1074		2	7.3		4	8		4	ND			ND			
Kings Meadows Rivulet at Kate Read Reserve		243		3	6.9		4	4		4	ND			ND			
North Esk River at Ballroom (DPIW Reference Site)		67		4	7.1		4	4		4	0.013		4	0.29		4	
Musselboro Creek at Burns Creek Road		625		2	7.2		4	2		4	ND			ND			
Ford River at Upper Blessington		59		4	7.0		4	2		4	ND			ND			
Ave Category value (CF&LP)				**2.88**			**4.00**			**4.00**			**4.00**			**4.00**	
Final Score (= Ave category value ÷ 4)				**0.72**			**1.00**			**1.00**			**1.00**			**1.00**	**0.944**
St Patricks River at Corkery Road	Forested Hills & Highlands	47	75	4	6.8	6.2 - 7.5	4	2	5	4	ND	0.02		ND	0.45		
Ave Category value (FH&H)				**4.00**			**4.00**			**4.00**							
Final Score (= Ave category value ÷ 4)				**1.00**			**1.00**			**1.00**							**1.000**

(e) Reporting zones of the South Esk River catchment

SiteName	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
South Esk at Perth	Cleared Foothills & Lowland Plains	92	125	4	6.9	6.5 - 8.0	4	4	10	4	0.012	0.025	4	0.28	0.5	4	
Nile Race at Clarendon		87		4	7.2		4	8		4	ND			ND			
Nile River at Nile		46		4	7.0		4	2		4	ND			ND			
Ben Lomond Rivulet at Nile Road*		95		4	7.3		4	3		4	ND			ND			
South Esk River at Bonneys Plains Road		89		4	7.0		4	2		4	ND			ND			
St. Pauls River Upstream South Esk		164		3	7.1		4	3		4	0.010		4	0.28		4	
Storys Creek below Aberfoyle Creek*		137		3	7.0		4	1		4	ND			ND			
Buffalo Brook at Bonneys Plains Road		223		3	7.7		4	2		4	ND			ND			
Nile River at Deddington (DPIW Reference Site)		44		4	7.1		4	1		4	0.005		4	0.12		4	
Break O"Day River at Killymoon		202		3	7.1		4	2		4	0.018		4	0.27		4	
St Marys Rivulet at Cameron Street		141		3	6.7		4	2		4	ND			ND			
Ave Category value (CF&LP)				**3.55**			**4.00**			**4.00**			**4.00**			**4.00**	
Final Score (= Ave category value ÷ 4)				**0.89**			**1.00**			**1.00**			**1.00**			**1.00**	**0.977**

(f) Reporting zones of the Tamar River catchment

SiteName	Reporting Zone	EC median	EC Trigger	Category value for EC	pH median	pH Trigger	Category value for pH	NTU median	NTU Trigger	Category value for NTU	TP median	TP Trigger	Category value for TP	TN median	TN Trigger	Category value for TN	Reporting Zone Water Quality Score (= mean of final scores)
Supply River above Falls near mill	Cleared Foothills & Lowland Plains	24	125	4	8.0	6.5 - 8.0	4	6	10	4	ND	0.025		ND	0.5		
Middle Arm Creek at West Tamar Hwy		456		3	7.8		4	7		4	ND			ND			
Stony Brook at West Tamar Highway		389		3	7.1		4	23		3	ND			ND			
Ave Category value (CF&LP)				**3.33**			**4.00**			**3.67**							
Final Score (= Ave category value ÷ 4)				**0.83**			**1.00**			**0.92**							**0.917**

Confidence Levels

All Cleared Foothills and Lowland Plains reporting zones had moderate confidence except for the Tamar, which had low confidence (Table 11). This is simply a result of the greater number of sites in the Cleared Foothills and Lowland Plains (including DPIPWE sites that sample for nutrients in addition to the *in-situ* measurements) and probably reflects the lower resourcing needs for sampling in these reporting zones. These confidence ratings suggests that the grades allocated to the Cleared Foothills and Lowland Plains of the TEER basin should be reasonably accurate.

In contrast, the low confidence for all Forested Hills and Highlands reporting zones that were sampled suggests that there is a reasonable to high chance that the Forested Hills and Highlands grades may not accurately represent the reporting zone status. One of the Forested Hills and Highlands reporting zones (Brumbys - Lake) has three sites with *in-situ* indicators only. If all of these sites had nutrient samples taken, this reporting zone would move up to having moderate confidence. Similarly, some of the Cleared Foothills and Lowland Plains reporting zones could move from moderate to high confidence by including nutrient sampling at two to four of the sites that are currently measured for *in-situ* indicators only.

Table 11: Water quality grades, numbers of sites and confidence rating in the reporting zones of the TEER Basin

	Reporting zone			
	Cleared Foothills and Lowland Plains		Forested Hills and Highlands	
Catchment	No of sites*	Grade	No of sites*	Grade
Brumbys - Lake	11 (0)	B	3 (1)	C
Macquarie	3 (3)	C	2 (1)	D
Meander	8 (2)	B	1 (1)	A
North Esk	8 (1)	C	1 (0)	A
South Esk	11 (4)	B		
Tamar	3 (0)	C		

*Number of sites with 5 indicators shown in brackets

= No data for the water quality indicators

= Moderate confidence in the water quality grade

= Low confidence in the water quality grade

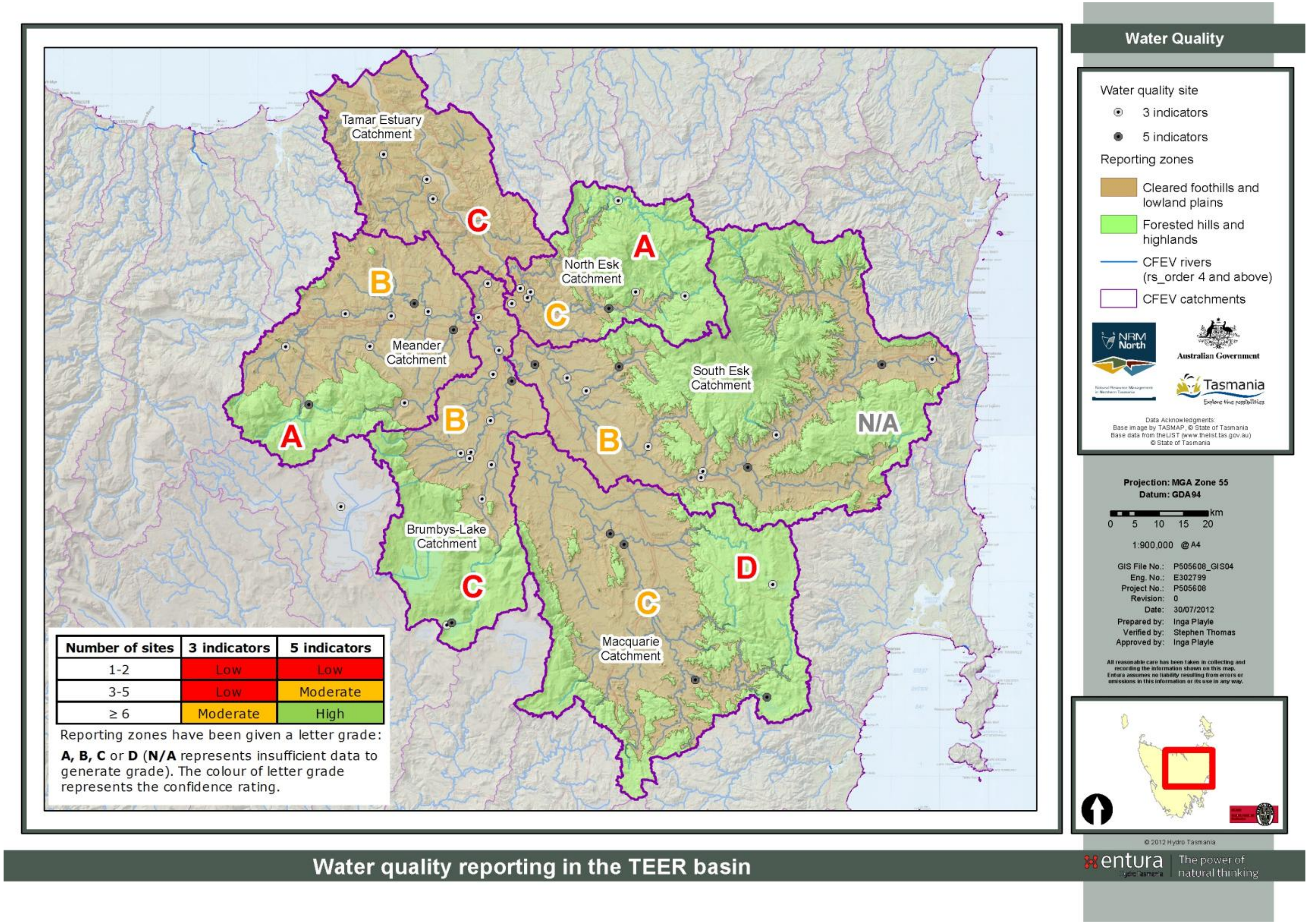


Figure 6: Water quality results across the reporting zones of the TEER Basin

6 BIOLOGICAL INDICATORS: APPROACH, DATA AND RESULTS

6.1 Approach

Biological indicators are direct measures of ecological health compared to the indirect measure represented by water quality indicators. Aquatic macroinvertebrates have been used for several decades as biological indicators of ecosystem health. The approach and the methods of collection, analysis and reporting are well developed and widely used.

The wealth of data and understanding of the relationship between the physical and chemical environment and macroinvertebrate community structure has lead to the development of models and indices that provide simple and reliable assessments of ecological health. AUSRIVAS is particularly useful as it compares a predicted macroinvertebrate community composition based on healthy un-impacted sites (usually called reference sites) to the composition at other sites. The model assesses the level of difference from the predicted reference condition, that is, the same as un-impacted (reference) sites right though to severely disturbed sites.

The use of macroinvertebrates as part of the TEER assessment is warranted as they are effective and accurate measures of ecosystem health and macroinvertebrate data are available across the TEER catchments.

6.2 Grade allocations

The AUSRIVAS model outcomes have been used as the basis for the TEER grades. The AUSRIVAS model output is the observed over expected number of macroinvertebrate families scores (or the O/E scores). These are divided into five bands; X, A, B, C and D. The description of each band is given in Table 12. Band A and X are essentially the same, that is, reference or pristine, making four "natural" grades to be had from the AUSRIVAS bands. The description for AUSRIVAS band D suggested to the authors that it could be divided into two TEER grades (Table 12). An AUSRIVAS score (O/E < 0.25) was used to delineate the TEER macroinvertebrate grade E from D. The selection of this score is arbitrary but in the view of the authors it is appropriate given data availability and the understanding of macroinvertebrate communities and their responses to environmental conditions.

The assessment is based on combined season model outputs (i.e. an autumn and spring sampling combined) for the riffle samples and, where available, also the edge samples.

To calculate the TEER grade an average of all the AUSRIVAS O/E scores for each site in a reporting zone was calculated. The average score for each reporting zone was then used to determine the grade using the TEER grade scores in Table 12. For example, if O/E scores for a site were 0.88 (AUSRIVAS A), 0.97 (AUSRIVAS A), 0.84 (AUSRIVAS B), 0.81 (AUSRIVAS B) and 0.90 (AUSRIVAS A) the average is 0.88 and the TEER grade therefore is an A.

More details concerning AUSRIVAS and how it has been applied in Tasmania can be found in the "State of the Region: Water Quality and Stream Condition in Northern Tasmania" reports and Krasnicki et al. (2001) and nationally in the "AUSRIVAS Macroinvertebrate Bioassessment Predictive Modeling Manual" (Coysh *et al.* 2000).

Table 12: TEER Grades for macroinvertebrates

AUSRIVAS Band	AUSRIVAS O/E score	TEER Grade	TEER Grade O/E score	Description
X	>1.13	A	> 0.88	Reference sites. Generally pristine and unimpacted by human activity
A	0.088 - 1.13			
B	0.63 - 0.87	B	0.63 - 0.87	Potentially mild to moderate impact on water and/or habitat quality.
C	0.38 – 0.62	C	0.38 – 0.62	Moderate to severe impact on water and/or habitat quality
D	< 0.38	D	0.25 - 0.37	Very poor water and/or habitat quality
		E	< 0.25	Extremely poor water and/or habitat quality

O/E – observed over expected number of macroinvertebrate families

6.3 Data needs and availability

At least one year of data (an autumn and a spring) have been used as the minimum. This allows the use of the combined season AUSRIVAS model.

The aim for this assessment was to combine, where possible, the AUSRIVAS combined season results for a five-year period (2005 to 2009). AUSRIVAS results were collated from the "*State of the Region: Water Quality and Stream Condition in Northern Tasmania*" for 2005, 2006, 2007 and 2008. The results of each year were then used to determine the overall reporting zone grade, which is the mean of all results for that reporting zone.

When only one year was available it was nonetheless used to grade the reporting zone. Under these circumstances, where data are limited, the resultant grade may be seen to have some or considerable uncertainty, however, the macroinvertebrate methods effectively summarise environmental conditions at a site substantially better than similar limited water quality results. Even when limited, macroinvertebrates are, therefore, much more reliable in assessing ecological conditions at a site.

6.4 Results

Where available the results for each year for each reporting zone and the mean result for each reporting zone are presented in Table 13, and are summarised in Table 15. The grades across the reporting zones are displayed in Figure 7.

Several reporting zones had no data and could not be rated. The Forested Hills and Highlands reporting zones were largely under-represented, and there were no sites for Brumbys - Lake and Macquarie Forested Hills and Highlands reporting zones.

The three Forested Hills and Highlands reporting zones, Meander, South Esk and North Esk, were indicative of catchments in very good condition. The Cleared Foothills and Lowland Plains catchments were generally in moderate to good condition, with the South Esk in very good condition.

It should be noted that as with the other measures, the low number of sites assessed in several of the reporting zones gives a low confidence in the accuracy of the summary (Tables 14 and 15). The confidence ratings in Table 14 provide a logical approach, based on the experience of the project team.

Table 13. AUSRIVAS combined season model results (Mean of 2005 to 2008 results).

Catchment	Reporting Zone	Site	Year	AUSRIVAS band		Total/n	Mean	Grade
				Riffle	Edge			
Brumbys - Lake	Cleared Foothills and Lowland Plains	Brumbys Creek at Saundridge Road	2005			9.63/ 15	0.64	B
			2006					
			2007	0.99				
			2008		0.91			
		Lake River at Macquarie Road	2005	0.73				
			2006	0.94				
			2007		0.54			
			2008	0.63				
		Macquarie River upstream of Brumbys Creek	2005		0.45			
			2006		0.42			
			2007		0.71			
			2008		0.67			
		Macquarie River downstream of Brumbys Creek	2005		0.47			
			2006		0.34			
			2007		0.45			
			2008		0.6			
		South Esk River at Hadspen River Road	2005					
			2006					
			2007	0.78				
			2008	Outside model				
South Esk	Forested Hills and Highlands	South Esk River at Cokers Road	2005	1.07		4.36/4	1.09	A
			2006	1.08				
			2007	1.13				
			2008	1.08				
	Cleared Foothills and Lowland Plains	Ben Lomond Rivulet at Nile Road	2005	0.76		19.96/ 21	0.95	A
			2006	0.7	1.13			
			2007	0.72				
			2008	0.8				
		Nile River at Nile	2005					
			2006					
			2007		0.96			
			2008	0.8				
		Nile River at Deddington	2005	1.09	1.05			
			2006	1.1	1.18			
			2007	1.01	1.09			
			2008	0.98				
		Tower Rivulet at Rossarden Road	2005	1.05				
			2006	1.0				
			2007	1.1				
			2008	0.99				
		South Esk at Perth	2005		0.72			
			2006		0.72			
			2007		1.01			
			2008	Outside model				

Catchment	Reporting Zone	Site	Year	AUSRIVAS band		Total/n	Mean	Grade
				Riffle	Riffle			
North Esk	Forested Hills and Highlands	North Esk River at Ben Nevis	2005	1.0		8.72/ 9	0.97	A
			2006	0.92				
			2007	1.0				
			2008	1.01				
		St Patricks River at Corkery Road	2005					
			2006	1.03				
			2007	0.87				
			2008	1.12				
		St Patricks River at East Diddleum Road	2005					
			2006					
			2007		0.75			
			2008	1.02				
	Cleared Foothills and Lowland Plains	Ford River at Upper Blessington	2005	0.92		22/ 27	0.82	B
			2006	0.91				
			2007	1.1				
			2008	0.89				
		Kings Meadows Rivulet at Punchbowl	2005	0.26				
			2006	0.26				
			2007	0.26				
			2008	0.26				
		Musselboro Creek at Burns Creek Road	2005	0.95				
			2006	1.01				
			2007	0.89				
			2008	1.0				
		North Esk River at Ballroom Township	2005					
			2006					
			2007	0.26				
			2008	0.96				
		Patersonia Rivulet at Scotts Road	2005					
			2006	1.04				
			2007	1.04				
			2008	1.04				
		St Patricks River at Nunamara	2005	1.13				
			2006	0.95				
			2007	0.98				
			2008	1.07				
		North Esk River upstream of Clarks Ford Bridge	2005		0.86			
			2006		0.73			
			2007		0.97			
			2008	0.7				
		North Esk at Corra Linn	2005					
			2006					
			2007	0.87				
			2008	0.71				

Catchment	Reporting zone	Site	Year	AUSRIVAS band		Total/n	Mean	Grade
				Riffle	Edge			
Macquarie	Cleared Foothills and Lowland Plains	Isis River at Isis	2005	0.91		7.25/ 9	0.81	B
			2006	0.83	0.71			
			2007	0.83				
			2008	0.68				
		Elizabeth River at Campbelltown	2005	0.85				
			2006	0.80				
			2007	0.86				
			2008	0.78				

Catchment	Reporting zone	Site	Year	AUSRIVAS band		Total/n	Mean	Grade
				Riffle	Edge			
Meander	Forested Hills and Highlands	Liffey River upstream of Liffey	2005	1.10		11.67/ 11	1.1	A
			2006	1.10				
			2007	1.12				
			2008	1.09				
		Meander River at Falls Road	2005	0.95				
			2006	1.04				
			2007	1.08				
			2008	1.04				
		Jackeys Creek downstream of Jackeys Marsh	2005	1.08				
			2006	1.02				
			2007	1.05				
			2008					
	Cleared Foothills and Lowland Plains	Meander River at Knights Bridge	2005		0.65	10.81/ 16	0.68	B
			2006		0.66			
			2007	0.63				
			2008					
		Meander River Downstream of Carrick	2005					
			2006					
			2007	0.77				
			2008	0.63				
		Western Creek at Montana Road	2005		0.79			
			2006		0.95			
			2007					
			2008	0.71				
		Meander River at Sawmill above Deloraine	2005					
			2006					
			2007					
			2008	0.71				
		Meander River at Birralee Road	2005	0.68				
			2006	0.65				
			2007	0.63				
			2008	0.68				
		Quamby Brook at Roxford	2005	0.55				
			2006	0.55				
			2007					
			2008	0.57				
Tamar	Cleared Foothills and Lowland Plains	Middle Arm Creek at Tamar Hwy	2005	0.88		5.14/ 6	0.86	B
			2006	0.78				
			2007	0.78				
			2008	0.89				

Catchment	Reporting zone	Site	Year	AUSRIVAS band		Total/n	Mean	Grade
				Riffle	Edge			
		Supply River at Winkleigh Road	2005					
			2006					
			2007	0.98				
			2008					
		Supply River upstream of old Mill	2005					
			2006					
			2007					
			2008	0.83				

Table 14: Confidence ratings used in the macroinvertebrate grading table

Number of sites	Confidence rating
1-2	Low
3-5	Moderate
6 or more	High

Table 15. Mean macroinvertebrate scores and data availability for sites in the reporting zones of the TEER Basin

	Reporting Zone			
	Cleared Foothills and Lowland Plains		Forested Hills and Highlands	
Catchment	No of sites	Grade	No of sites	Grade
Brumbys - Lake	5	B		
Macquarie	2	B		
Meander	6	B	3	A
North Esk	8	B	3	A
South Esk	5	A	1	A
Tamar	3	B		

= No data for the macroinvertebrate indicators

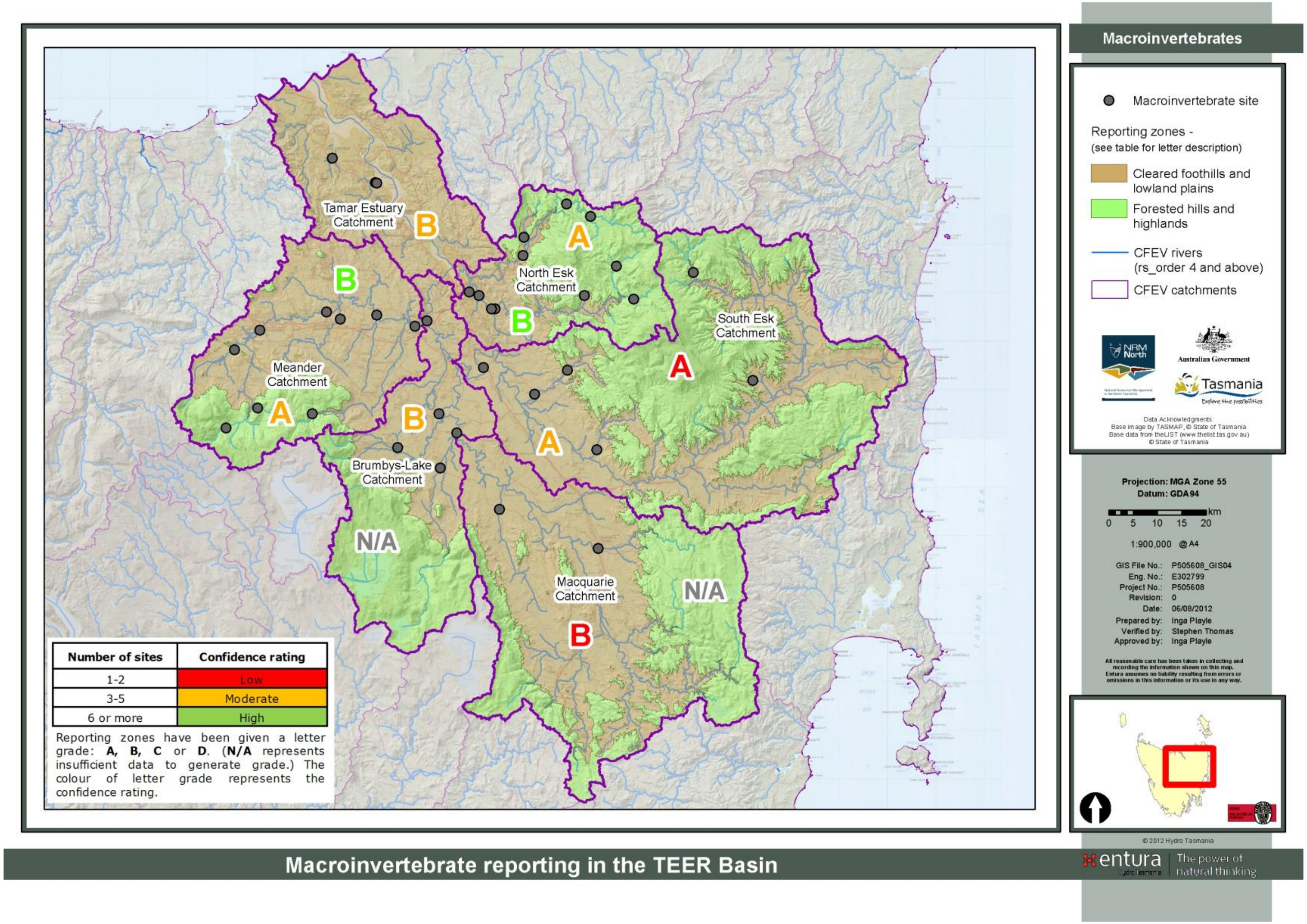


Figure 7: Macroinvertebrate results across the reporting zones of the TEER Basin

7 COMBINING STREAMSIDE VEGETATION ZONE, WATER QUALITY AND BIOLOGICAL INDICATORS: OVERALL GRADES FOR REPORTING ZONES

7.1 Approach

Combining the water quality, TRCI streamside vegetation zone and macroinvertebrate grades provides an overall grade for each reporting zone. The combined grade has only three inputs and taking the mean of these requires caution. A combined grade may obscure individual water quality, streamside zone or biological problems in the reporting zone. For example, where the individual grades are very divergent the resultant "average" combined grade smooths over these differences. Therefore, combined grades should be seen as indicative rather than completely objective and the resource managers need to be aware of the information provided in each component. Nonetheless the combined grade is useful for evaluating and depicting conditions in a reporting zone.

7.2 Grade allocations

The calculation of an overall grade, combining the water quality, streamside zone and macroinvertebrate grades for each reporting zone was achieved by allocating a numerical score for each individual site grade for each of the three measures and taking the average of the numerical results. The numerical scores used are, A = 5, B = 4, C = 3, D = 2 and E = 1. The final average score can then be converted back to an A to E grade, including "+" & "-" in each grade, as described below. Any reporting zone missing one or more of the three indicator measures was not given an overall combined grade.

Grade	Categorical score
A	4.8 – 5
A-	4.6 – 4.7
B+	4.3 – 4.5
B	3.8 – 4.2
B-	3.6 – 3.7
C+	3.3 – 3.5
C	2.8 – 3.2
C-	2.6 – 2.7
D+	2.3 – 2.5
D	1.8 – 2.2
D-	1.6 – 1.7
E+	1.3 – 1.5
E	1 – 1.2

7.3 Results

The combined water quality, SZV and macroinvertebrate reporting zone grades are listed in Table 16 and displayed in Figure 8. The results indicate that the Cleared Foothills and Lowland Plains reporting zones are all in moderate to poor condition. For the Forested Hills and Highlands catchments data are limited and assessment could only be undertaken for the North Esk and Meander, which were generally in very good condition.

Table 16. Mean of combined water quality, TRCI and macroinvertebrate scores for subcatchments of the TEER Basin*

	Cleared Foothills and Lowland Plains				Forested Hills and Highlands			
	Water Quality	SZV	Invertebrates	**Combined grade**	Water Quality	SZV	Invertebrates	**Combined grade**
Brumbys - Lake	B	D	B	**C+**	C	B		
Macquarie	C	D	B	**C**	D	A		
Meander	B	D	B	**C+**	A	A	A	**A**
North Esk	C	C	B	**C+**	A	C	A	**B+**
South Esk	B	C	A	**B**		A	A	
Tamar	C	D	B	**C**				

*These grades are indicative only. Individual components and sites within each subcatchments may be substantially better or worse than the overall mean grades presented here.

= Not enough data to determine a grade

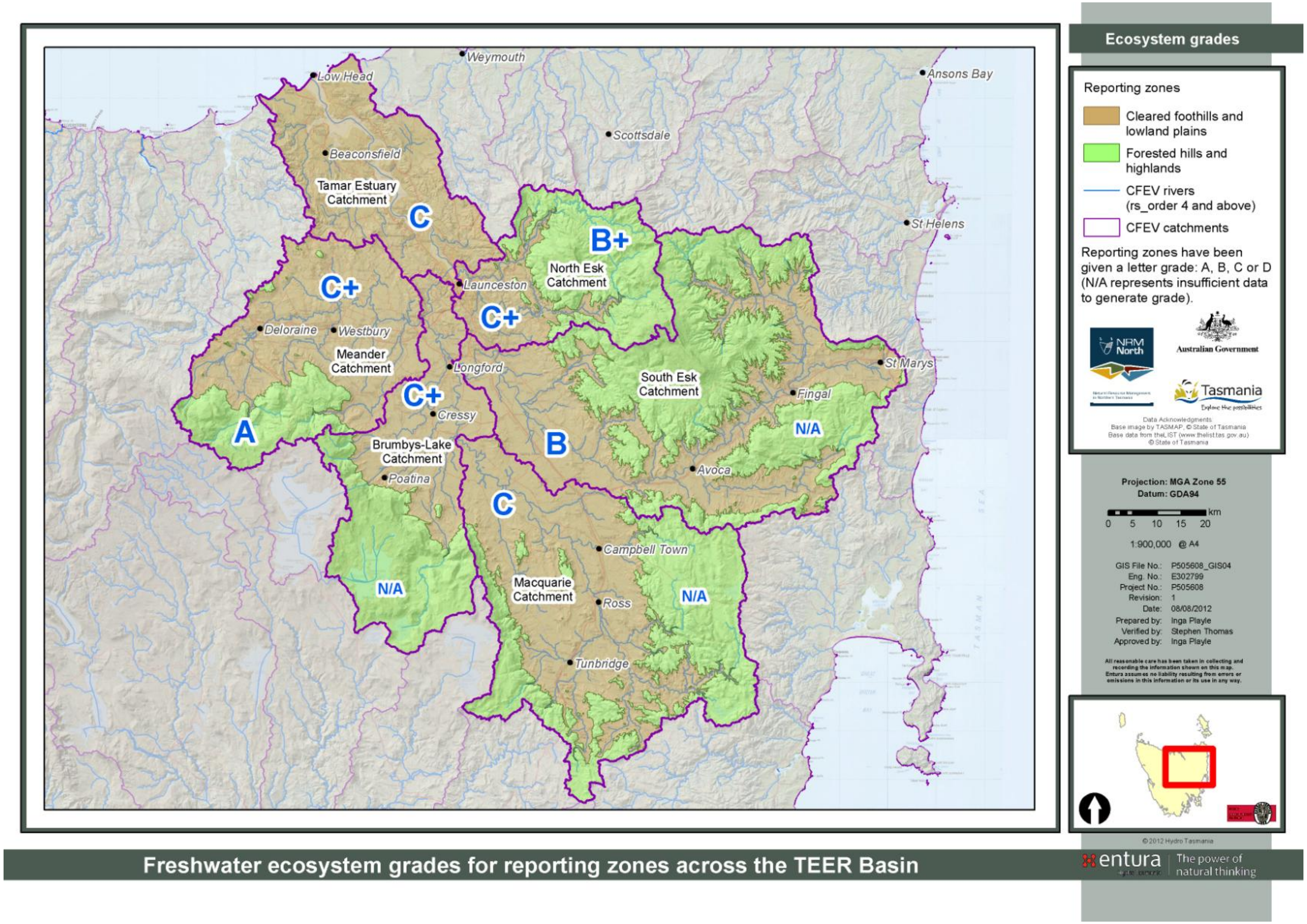


Figure 8: Combined freshwater ecosystem grades across the reporting zones of the TEER Basin

7.4 Overall interpretation

Water quality grades in the Cleared Foothills and Lowland Plains reporting zones of the TEER basin were all rated good or moderate. In the Forested Hills and Highlands, water quality was more variable, with two reporting zones being rated as very good, one as moderate and one as poor. There were no data for the Forested Hills and Highlands of the South Esk.

TRCI Streamside Zone scores were all poor or moderate across all of the Cleared Foothills and Lowland Plains reporting zones. In the Forested Hills and Highlands of the Macquarie, Meander and South Esk the SZV was rated as very good, with good and moderate ratings in the other two Forested Hills and Highlands reporting zones.

The AUSRIVAS macroinvertebrate grades indicate overall good to very good condition, that is, moderately impacted to little impact from human activities. Cleared Foothills and Lowland Plains reporting zones were all rated as being in good condition whereas the three Forested Hills and Highlands reporting zones that were assessed were rated as being in very good condition.

The AUSRIVAS macroinvertebrate results generally indicate better conditions than either the water quality or TRCI scores. Although the macroinvertebrates are generally the most direct indicator of recent historical in-stream ecosystem condition, the use of only the AUSRIVAS bands to develop the scores is a limited of the macroinvertebrate data. Further use of the data would increase the information substantially; for example, by incorporating SIGNAL scores which tend to better characterise pollution issues at a site.

The lack of macroinvertebrate results for many reporting zones lowers the confidence in the results, and there can be substantial differences in grades between sites within reporting zones, indicating environmental gradients and a patchwork of human influences.

The combined category scores generally reflect the individual grades in water quality, TRCI and macroinvertebrate grades, that is, moderate scores for the Cleared Foothills and Lowland Plains and good to very good Forested Hills and Highlands. The Macquarie and Tamar Cleared Foothills and Lowland Plains are in poor condition and are the worst reporting zones assessed.

It should be noted that the low number of sites assessed in several of the reporting zones gives low confidence in the accuracy.

8 WATER QUALITY ISSUES NOT PRESENTED IN THE FRESHWATER REPORT CARD

8.1 Water quality for recreation

Apart from aesthetic aspects such as water clarity and absence of litter, floating scums and oily sheens, the water quality indicators most used for assessing whether a site is suitable for recreation are *Escherichia coli* (*E. coli*) and enterococci. Within the TEER basin, there are 20 sites that are sampled for enterococci concentrations. These include nine in the Brumbys - Lake catchment, five of which are situated in waterways upstream and downstream of the Longford Wastewater Treatment Plant, leaving four in Brumbys - Lake (all in the South Esk River, at or below Longford) and 11 others across the TEER basin that are sampled for recreational use. These include four in the North Esk Catchment (all of which are within the urban area of Launceston except Corra Lynn, which is on the urban fringe), three in the Meander and two each in the South Esk (one near the Evandale Wastewater Treatment Plant and the other near the Perth Wastewater Treatment Plant) and Tamar catchments.

There were no sites assessed for recreational water quality in the Forested Hills and Highlands zones of any catchment and many of the sites in the Cleared Foothills and Lowland Plains zones were clustered around wastewater treatment plants, giving little information of conditions across catchments. It may be that reporting recreational water quality would be useful for the next Freshwater Report Card. If so, it would be identify to employ a site selection process designed to adequately represent the sampling zones. Some or all of the following criteria could be used:

- restrict representative sites to Cleared Foothills and Lowland Plains zones, as these contain the most used swimming areas;
- at a minimum, sample the two most popular swimming locations from each zone;
- consult a number of primary and secondary contact users of sites across the TEER basin to identify the ten (or more or less, depending on funding) most important sites for sampling.

Use of these criteria does not overcome the issue of there being reporting zones and possibly whole catchments that will not be sampled for recreational water quality. This leads to a situation where some reporting zones could be raised or lowered in the water quality assessment process, simply because they are, or are not, sampled. If there are reporting zones or catchments that are not sampled for recreational water quality, it will not be possible to determine whether the reporting zones would have received a higher or lower grade with recreational water quality sampling. Therefore, individual reporting of sites (i.e. rather than in a Report Card) may be more suitable.

Another issue for debate is the use of E. coli in the assessment of recreational water quality, particularly for primary contact in freshwaters. The USEPA recommends enterococci as the best indicator of health risk in salt water used for recreation and *E. coli* as the best indicator of health risk from water contact in freshwaters, (although enterococci is still a useful indicator in freshwater) (http://water.epa.gov/type/rsl/monitoring/vms511.cfm). The NHMRC (1990) favours the use of faecal coliforms, a sub-group of the total coliform population that is easy to measure and is present in virtually all warm-blooded animals, approximately 97% of which are E. coli in human faeces (ANZECC 2000a). However, there have been shortcomings reported in the use of faecal coliforms, with some studies suggesting that enterococci are better in marine waters and either enterococci or E. coli are better in freshwater (ANZECC 2000a).

8.2 Water quality for drinking water

The primary requirements for drinking water are that it should be safe to use and aesthetically acceptable. The NHMRC (2011) notes that the greatest risks to consumers of drinking water are posed by pathogenic microorganisms; and this would be the case in the TEER basin. However, agricultural land use within the basin increases the risk to waterways from biocides, while past and present mining within the basin could increase the risk of heavy metals and toxic chemicals.

Drinking water quality is usually dealt with by water authorities, responsible for the delivery of potable water supplies. For these authorities, the primary focus is on the quality of water they deliver from managed supply storages. However, within the TEER basin there are many residences (primarily farms) that directly take untreated water from rivers and creeks for drinking water, due to a lack of a potable water supply. In these situations, the water users need to be confident that the water in the waterways is safe from pathogens such as bacteria, protozoa, viruses and helminths [specifically parasitic 'worms' such as tapeworms, roundworms and flukes – generally of low concern in Australia (NHMRC 2011)].

Given the range of water quality indicators to be considered, the risks to be assessed and the monitoring required, it is not appropriate for a Freshwater Report Card to report on the suitability of freshwater ecosystems for drinking water supply. As well as the risks associated with identifying reporting zones as suitable for supply of drinking water, the assessment of suitability for drinking water has the same issues as assessing for recreational use: its applicability will be restricted to specific locations or reaches, limiting its use to reporting at a local scale.

9 SUGGESTED MONITORING APPROACH FOR FUTURE REPORT CARDS

To produce a report card that provides accurate assessment of catchment condition or health, a good data set is required. Information presented in this report card was based on data collected from the last 10 years of sampling and it has been just adequate to provide an assessment for some reporting zones, with other zones having little or no data for some indicators. Future report cards for the TEER basin will be reporting on current conditions (i.e. last 12 to 36 months) in contrast to this report card which reports on longer term conditions (i.e. last 10 years) and will need to consider:

1. Whether the aim of the report card and hence the aim of the monitoring program for the report card has changed – these need to be clearly defined
2. Site selection, in relation to the aim
3. Indicator selection and reporting units
4. Sampling frequency – to adequately cover seasonal influences and provide confidence in any data summaries (e.g. medians)
5. Sampling methods, including consistency of methods between organisations monitoring in the TEER region.

Each of these are discussed in individual sections below.

9.1 Aims of the report card and monitoring program

Assuming that the primary aim of future report cards remains similar to the current report card, then this will be "to communicate the current state of catchment health to catchment communities and stakeholders". Future report cards will also be able to compare results with previous report cards, allowing some assessment of changes and trends.

Regardless of whether future report cards have different aims, it is important that the aim is used in the decision making for monitoring, particularly if a monitoring framework is to be developed specifically for the report cards. This includes decisions on sites, indicators and sampling details for the monitoring program. The overriding aim of the monitoring program should be to meet the aim of the report card. All of these decsions need to be clearly documented in the report card or in the technical report accompanying the report card.

9.2 Site selection

Sites should be selected to enable an accurate assessment of catchment health. This includes selection of sites that are representative of the catchment in general or of relatively homogenous regions (reporting zones) within the catchment. Each reporting zone in each catchment should ideally have at least six sites, depending on the size and diversity of the zone. Six is the minimum number at which a confident assessment of median conditions can be made (Goudey 2007). In this report card, we have allocated moderate confidence to reporting zones that have 3 to 5 sites and although this is not ideal, this level of confidence is acceptable at a basin-wide assessment scale if resources are limiting a high confidence assessment.

An assessment of catchments or reporting zones also needs standards to compare to; these are usually supplied by measures of reference condition. For zones that are high in conservation value and largely unimpacted, the reference condition should represent that unimpacted condition. For zones that are slightly to moderately modified, and are expected to remain that way due to socio-economic uses of the catchment, then slight to moderate modification should be the reference condition for those zones.

A report card should report the general condition of the catchments and reporting zones rather than attempting to find and use reference sites. At the time of writing this Technical Report, DPIPWE is preparing a set of water quality and biological objectives for Tasmania's freshwater ecosystems (Greg Dowson, EPA Division, DPIPWE, personal communication). The water quality and biological objectives will use reference sites to set appropriate conditions and objectives for regions across Tasmania, including the region relevant to the TEER Basin. In future report cards, site conditions will need to be assessed against these objectives.

9.3 Indicator Selection

Indicators of freshwater environmental condition should be selected to represent protected environmental values (PEVs) of the catchments and reporting zones. The PEVs for the TEER catchments can be put into five major categories:

1. Protection of aquatic ecosystems
2. Recreational water quality and aesthetics
3. Raw water for drinking supply
4. Agricultural water uses
5. Industrial water supply

Aquatic ecosystems: For the majority of surface waters across the various land tenures and uses of each catchment, the most stringent water quality requirements are those needed for the protection of aquatic ecosystems. This is particularly so, since in all instances this protection is for either modified ecosystems in which fish, shellfish and/or crustaceans can be harvested for human consumption or for pristine/near pristine ecosystems. Typically, the best measure of ecosystem condition is achieved through assessing the instream biota; and in Australia the biotic group most used is the macroinvertebrate fauna. This is due to the ease of sampling and the large amount of supporting infrastructure (e.g. standard sampling methods, taxonomic keys, and interpretive indices).

Unless there are expected sources of toxicants (e.g. metals, hydrocarbons, biocides and other organic chemicals), the most informative physico-chemical indicators of water quality for ecosystem protection are the standard *in-situ* measures (electrical conductivity, dissolved oxygen, pH and temperature), turbidity (and/or suspended particulate matter), and nutrients (typically phosphorus and nitrogen).

Macroinvertebrates

Freshwater macroinvertebrates include insects, molluscs (snails and mussels), crustaceans (shrimps and yabbies) and annelids (worms). Freshwater macroinvertebrate communities are diverse and abundant and important to the functioning of a healthy aquatic ecosystem. Macroinvertebrate community health assessment is, therefore, generally a direct measure of ecosystem health. The major advantage is that macroinvertebrates respond to all environmental disturbances and toxicants and will effectively summarise water quality over weeks and months prior to sampling. On the other hand, water quality indicators such as pH, dissolved oxygen and phosphorus only suggest potential impacts and a single sample represents a moment in time rather than the situation over the past weeks, days or even hours. Indeed, the monitoring of physical and chemical indicators alone is no longer considered sufficient for the adequate protection of aquatic ecosystems. For a complete assessment of condition however, water quality and habitat conditions are important in explaining macroinvertebrate community spatial differences and changes over time.

Standard methods for the collection and processing of macroinvertebrate samples are available (e.g. EPA Victoria (2003). Data interpretation tools are also available (e.g. Coysh *et al.* 2000). For example, the community composition between sites and over time can be compared using AUSRIVAS. AUSRIVAS is a model that uses site-specific environmental variables (for example water quality, habitat and altitude) to predict the macroinvertebrates that should be expected at a site. This is compared to those actually found. The ratio of expected to observed is called the O/E score and at the best sites it should be close to 1, that is, the observed and expected lists of macroinvertebrates are almost the same. Another index of macroinvertebrate community condition is SIGNAL (Chessman 1995 and 2003). SIGNAL complements AUSRIVAS as it is more sensitive to organic and toxic chemical pollution to waterways, whereas AUSRIVAS is more likely to detect impacts to the macroinvertebrate community from physical habitat changes.

There is a need to develop ecosystem (reporting area) specific objectives based on specific ecosystem models and that the objectives reflect the expected environmental quality. Under such an approach modified catchment may not be expected to meet the same standards as near pristine ecosystems. EPA Tasmania is currently developing ecosystem specific guidelines.

<u>Electrical conductivity</u>

Salinity is the amount of salt dissolved in the water. There are many "salts" dissolved in water, most notably sodium chloride. While some dissolved salts are needed for metabolic processes by aquatic organisms, excessive amounts may be toxic. Freshwater aquatic organisms have different tolerances to salinity and most freshwater aquatic organisms will not survive in high levels of salinity. Therefore it is an important indicator of water quality. The amount of salt in the water can be measured directly by evaporating the water from a known volume of water and weighing the residual. However this is time consuming. A solution of salt will conduct electricity, and the amount it conducts depends on the concentration of the dissolved salts; the conductivity in a solution increases as the amount of salts dissolved in the water increases. "Electrical Conductivity" (EC) uses this characteristic to estimate the levels of salinity.

The major sources of salt in rivers and streams are urban and agricultural runoff, sewage and industrial effluent, and, most importantly, groundwater. Groundwater can have very high salt concentrations and rising groundwater tables can elevate surface water salinity levels substantially. Salt levels in a catchment are also affected by the geology of the catchment.

<u>Dissolved oxygen</u>

Dissolved oxygen (DO) is a measure of the concentration of the gas oxygen dissolved in water. Oxygen is essential for all aquatic plants and animals, and also for most bacteria and micro-organisms. Oxygen in water comes primarily from the atmosphere, although it can also come from plants, as it is produced during photosynthesis. The contribution of plants and, in particular algae, is generally relatively small in a healthy river but may be substantial in highly eutrophic (nutrient enriched) waterbodies where plant productivity is high.

The greatest threat to oxygen availability is usually due to oxygen-demanding substances entering water bodies. Human derived sources of oxygen-demanding substances are primarily sewage effluent, septic tanks and industrial discharges. Reduced river flows high levels of turbidity, lack of shading and heated water discharges may also reduce oxygen concentrations.

<u>Total phosphorus</u>

Total phosphorus is a measure of the amount of dissolved and bound phosphorus in the water. Phosphorus is a natural inorganic mineral essential to plants and animals. In freshwaters it generally limits plant growth. Too much may lead to excessive plant growth, which can impact dissolved oxygen concentrations through plant cell respiration and also through oxygen-demand when plant cells die and start decaying.

Natural sources include weathering of rocks and the breakdown of plant and animal material. Human derived sources include erosion depositing phosphorus rich sediment into streams, effluent from sewage treatment plants, urban stormwater runoff, intensive agriculture and dairying.

Total Nitrogen

Total nitrogen is a measure of the amount of inorganic forms (NO_2, NO_3 and NH_3) and organic forms (from the breakdown of organic matter) of nitrogen in the water.

Nitrogen is a natural inorganic mineral essential to plants and animals. Similar to phosphorus, high concentrations can contribute to excessive plant growths.

The largest natural sources of nitrogen in water are from the atmosphere and dissolved from rocks. Some bacteria can also fix nitrogen from the atmosphere. Human derived sources include erosion depositing nitrogen rich sediment into streams, effluent from sewage treatment plants, urban stormwater runoff, intensive agriculture and dairying.

Turbidity

Turbidity is a measure of the clarity of water. As suspended particulate matter including clay, silt, detritus and plankton in the water increases, the clarity decreases and the water takes on a muddy appearance. Turbidity does not measure the quantity of suspended particulate matter (SPM) in the water, just the effects it has on clarity. Turbidity reduces the amount of light entering the water, which will reduce the growth of submerged aquatic plants including most phytoplankton. Cyanobacteria ('blue-green algae'), however, may be favoured as they can float to the surface to find light, ultimately covering the surface with a thick layer of cells reducing light almost completely. Lack of light also makes it difficult for predators like fish and birds to hunt successfully.

Although not a direct measure of SPM, turbidity is indicative of SPM levels. High SPM levels interfere with the uptake of oxygen by fish and invertebrates and, when particulate matter settles, causes sedimentation. The greatest impact of sediment entering waterways is on habitat. Sediment will smother rocky bottoms, coat snags and fill deep pools, reducing the available habitat and affect the feeding and breeding of fish and aquatic macroinvertebrates.

Most of the sediment in rivers and streams comes from catchment and river streambed and bank erosion. Sediment entering waterways is a natural process, but human land use can result in excessive quantities entering these waterways. Agricultural and forestry activities and housing developments can all lead to extensive soil disturbance, erosion and sediment runoff. Unsealed roads can also contribute substantial quantities of sediment.

pH

The pH of water is a measure of its acidity or alkalinity. The pH of a water body can have serious direct and indirect impacts on the aquatic biota and on the potential uses of the water. Changes to pH may directly affect the physiological functioning of aquatic plants and animals, including enzyme functioning and membrane processes. Low pH (acidic condition) has been reported to have adverse effects on fish and aquatic macroinvertebrates, including physiological functioning, spawning failure and diminished egg hatching. Changes to pH also have indirect impacts. For example, increased pH raises toxicity of ammonia, while decreased pH can increase the toxicity of some metals. Low pH levels can also increase the solubility of toxic metals that would otherwise be bound to sediments.

Natural sources of alkalinity and acidity include geology and soils, salinity of the water body, photosynthesis and respiration (aquatic plants) and rainfall.

Human-induced changes to pH can include agricultural land practices (leading to soil acidification), waste discharges, and air pollution. Soil acidification typically occurs through a leaching of base cations from the upper soil horizons, leaving an excess of H^+ ions. Water flowing through the acidic soils enters the receiving water body with low pH. Agricultural practices can also lead to increased nutrients, which increase algal growth and consequently lead to the greater diurnal fluctuation of pH as described above.

Other indicators

As discussed above, issues and impacts specific to a site, reach or reporting zone may require sampling for additional indicators, such as biocides, heavy metals, or hydrocarbons. A difficulty with locality-specific sampling, however, is that unless the particular indicator is sampled at all sites and catchments, there is a possibility that one catchment will be marked lower simply because it had more objectives to meet. Therefore, locality-specific indicator sampling may be best reported in specific environmental studies or priority catchment studies, rather than in a basin-wide report card.

If further indicators were to be incorporated into the Report Card, then an index based on fish community would be a useful addition. Fish offer a similar benefit to water body assessment as macroinvertebrates, in that their community structure synthesises a suite of environmental variables into one or two community indices. An obstacle to this may be the specialised nature of fish sampling and the need for highly trained staff. However, like macroinvertebrates, fish sampling would be required much less frequently (possibly once per report card). Potential explanatory variables such as changes in flow and barriers to migration may be required to help explain results of the fish community index, but these are likely to be readily available.

Recreation: There are hot-spots of primary and secondary use and these should be monitored rather than catchment wide monitoring. The primary indicators currently used in the TEER basin are enterococci.

Raw water: Within the lower Macquarie and lower South Esk Rivers and also the upper Macquarie, there are some stream reaches where water (with only coarse screening) is required for drinking supply. In these stream reaches, the water quality requirements will be more stringent, particularly in terms of enterococcal measures. The issue of the Freshwater Report Card assessing waterways for drinking water quality has been discussed in Section 8.2, above.

Agriculture and industrial: Indicators assessed for aquatic ecosystems are relevant for agriculture and industrial uses.

9.4 Sampling frequency

The frequency of sampling should be based on the question, 'How many samples are required to adequately represent the catchment or reporting zone with an accepted level of confidence?'. Goudey (2007) has demonstrated that a minimum of six samples is required for sufficient confidence that the samples' median value can be used to represent the population's median value. However, the situation is complicated by the influence of seasonal variation. To be confident of representing intra-annual variation (including seasonal) monitoring programs have generally employed at least monthy sampling. Variability can, however, occur over much shorter periods of time, for example, dissolved oxygen will often vary from hour to hour and monitoring to pick up these short term changes is generally not possible. Nonetheless, monthly sampling is likley to capture the information needed to assess overall variabilty and will therfore provide an adequate assessment. Sampling frequency could be reduced to every second month if a report card covered two or three years of sampling.

For the macroinvertebrates, sampling is required twice yearly (spring and autumn samping) to enable comparison of results against the 'combined season' objectives. One year's sampling should be sufficient to cover each report card, even if the card reports on a two or three year period.

A single assessment of SZV should be sufficient for each report card, providing it is undertaken not more than two years before reporting and that there has not been significant vegetation impacts between assessment and reporting. Assessment of SZV would be most cost-effective if undertaken at concurrently with macroinvertebrate sampling at macroinvertebrate sites. The information gained should also help with interpretation of macroinvertebrate results.

9.5 Sampling methods

Sampling methods should follow those presented in ANZECC and ARMCANZ (2000b).

The most useful indicators for assessing the freshwater ecosystem condition for most of the PEVs are:

- electrical conductivity, in-situ, in µS/cm @25°C;
- dissolved oxygen, in-situ, in % saturation (required) and preferably also in mg/L;
- pH, in-situ
- turbidity, in-situ, in NTU;
- nutrients (total phosphorus and total nitrogen) sampled, stored and laboratory analysed according to NATA standards current at the time of sampling;
- macroinvertebrates, sampled according to standard Tasmanian methods; and
- SZV, using the TRCI method.

Two important features of a monitoring program operated by many partners need to be emphasised:

- Sampling approaches and methods need to be consistent within and between the TEER monitoring organisations. This is vital to enable confident comparisons between data sets gathered by the different sampling teams. Combined team sampling trips, field audits, field sampling sheets and instruction sheets are some of the approaches that could be employed to ensure sampling consistency.
- Data must be collected and reported in units that are comparable to ANZECC or any locally derived water quality objectives they are being compared against. For example, dissolved oxygen objectives are typically presented in percent saturation. Despite there being several sites used in this report card that had dissolved oxygen data, most of them were measured in mg/L instead of percent saturation. Without accompanying data on temperature, salinity, and altitude it is not possible to convert these data to percent saturation, and even with the required corollary data it is generally too time consuming to justify the expense. Similarly, electrical conductivity data encountered in this project was recorded in several different units, ranging from mS/cm to uohms/cm. Although these different units are more readily converted to a common unit, it is strongly recommended that the unit of measurement is consistent across the sampling teams and organisations, to reduce the potential for errors and increase efficiency.

9.6 Summary and recommendations for future monitoring

1. For each report card, the aim should be reviewed and defined. All aspects of sampling and reporting should be directed towards meeting the aim.
2. The recommended minimum number of sites per reporting zone are six for high confidence and three to five for moderate confidence. Ideally, most reporting zones should have at least four water quality sites for moderate confidence.
3. The most useful indicators for assessing the freshwater ecosystem condition for most of the PEVs are electrical conductivity, dissolved oxygen, pH, turbidity, nutrients (total phosphorus and total nitrogen) macroinvertebrates, and SZV.
4. Additional indicators may be useful for assessing specific impacts or localised PEVs such as contact recreation, but these may be best left to specific studies or to other monitoring programs rather than being included in a basin-wide report card. If another indicator is to be added to the report card, fish community would be useful If fish community condition is to be included, it should be explored in discussion with the Tasmanian Inland Fisheries Service.
5. Each of the regular sampling sites should be sampled monthly for water quality, in autumn and spring for macroinvertebrates, and once for SZV for an annual report card. Water quality sampling could be undertaken every second month for a report card covering two or three years of sampling.
6. Consistency of sampling methods and reporting across the TEER organisations and sampling teams is vital for meaningful comparisons between sites and catchments. Consistency should be actively pursued through the use of field sampling sheets, written sampling methods and if possible, combined sampling or field audits.

Assuming the reporting zones in this report are used in future TEER Report Cards, the priorities of future monitoring programs (in order of importance) should be:

1. To provide a grade for each reporting zone;
2. To provide at least a moderate level of confidence for each grade in each reporting zone
3. To maximise the extent to which sites within each zone are representative of the zone

The data presented in this report extends back 10 years and many of the sites used have been closed (not sampled) in the last few years. A future monitoring program should logically be based around current sampling sites for the relevant categories and indicators. The sites that are currently sampled, and the indicators they are sampled for, are presented in Table 17.

<u>1. Providing a Grade for Each Reporting Zone</u>: Pursuing the first priority requires that each indicator category (water quality, SZV and macroinvertebrates) is assessed in each reporting zone. Table 17 shows that under the current sampling regime, only three of the eleven reporting zones would be able to receive a freshwater ecosystem health grade. The remaining eight reporting zones are not currently sampled for all required categories. Three of these eight reporting zones could complete the requirements for grading simply by having SZV assessed at the sites where they are currently sampled for macroinvertebrates. These reporting zones are the Cleared Foothills and Lowland Plains of the Macquarie, North Esk and South Esk catchments. A further three reporting zones would require the establishment of a macroinvertebrate and SZV site to be able to receive a grade. These are the Forested Hills and Highlands of the Brumbys-Lake and Macquarie catchments, and the Cleared Foothills and Lowland Plains of the Tamar catchment. The remaining two reporting zones are the Forested Hills and Highlands of the North Esk and South Esk catchments, both of which currently lack water quality assessment and SZV assessment, with the South Esk Forested Hills and Highlands also lacking macroinvertebrate assessment (Table 17).

In summary, achieving grading across all reporting zones requires the following additions to the current monitoring programs:

Macquarie CF&LP North Esk CF&LP South Esk CF&LP	Assess SZV at one or more sites where macroinvertebrates are currently sampled
Brumbys-Lake FH&H Macquarie FH&H Tamar CF&LP	Establish macroinvertebrate and SZV sampling at one or more sites within the reporting zone
North Esk FH&H	Establish water quality and SZV sampling at one or more sites within the reporting zone
South Esk FH&H	Establish macroinvertebrate, water quality and SZV sampling at one or more sites within the reporting zone

Table 17. Current sites monitored for water quality, macroinvertebrates and SZV in the reporting zones of the TEER Basin

Catchment	Reporting zone*	Total Sites	Water Quality			Macro-invertebrates	SZV	Sub-catchment grading possible?
			In-situs	Nutrients	DO % sat			
Brumbys-Lake	FH&H	2	2	0	0	0	0	Missing all except in-situs
	CF&LP	20	8	0	1	12	4	Missing nutrients only
Macquarie	FH&H	2	2	0	2	0	0	Missing all except in-situs
	CF&LP	7	4	0	4	3	0	Missing Riparian (+ nutrients)
Meander	FH&H	6	1	0	1	5	2	Missing nutrients only
	CF&LP	9	5	0	4	4	3	Missing nutrients only
Nth Esk	FH&H	5	0	0	0	5	0	Missing all except Macroinvertebrates
	CF&LP	7	6	0	3	1	0	Missing Riparian (+ nutrients)
Sth Esk	FH&H	0	0	0	0	0	0	Missing all
	CF&LP	9	5	0	5	4	0	Missing Riparian (+ nutrients)
Tamar	CF&LP	2	2	0	0	0	0	Missing all except in-situs

*CF&LP = Cleared Foothills and Lowland Plains; FH&H = Forested Hills and Highlands.

= Low confidence; = Moderate confidence; = High confidence; = no sites; = Grading not possible; = Grading possible

2. Providing moderate confidence for each category grade in each reporting zone: Under the current monitoring programs, the Brumbys-Lake Cleared Foothills and Lowland Plains is the only reporting zone that returns results with moderate or higher confidence in each of the categories. The process of achieving moderate confidence in macroinvertebrate and SZV grades for each reporting zone is relatively simple to determine – sample 3 to 5 sites for each category in each reporting zone. However, the situation is more complex for water quality, where moderate confidence can be achieved by either sampling more than six sites for *in-situ* measures, or by sampling three to five sites with in-situ measures and nutrient concentrations. For example, the Cleared Foothills and Lowland Plains of the Macquarie catchment currently has four sites sampled for *in-situ* data. This reporting zone could produce a water quaity grade with moderate confidence by either adding two more *in-situ* sites, or by sampling for nutrients at three or four of the current water quality sites.

A listing of the possible permutations and combinations of *in-situ* and nutrient data required for achieving moderate confidence in water quality grading in each reporting zone would be unwieldy and can be determned for each reporting zone using the approach described for the Macquarie Cleared Foothills and Lowland Plains, described above. However, the minimum additional sampling required for each of the reporting zones to achieve moderate confidence in macroinvertebrate and SZV grades is able to be displayed more clearly and is shown in Table 18.

Table 18. Additional sites required for moderate confidence in macroinvertebrates and SZV grading of the reporting zones in the TEER Basin

Catchment	Reporting zone*	No. of additional sites needed for moderate confidence	
		Macro-invertebrates	SZV
Brumbys-Lake	FH&H	3	3
	CF&LP	0	0
Macquarie	FH&H	3	3
	CF&LP	0	3
Meander	FH&H	0	1
	CF&LP	0	0
Nth Esk	FH&H	0	3
	CF&LP	2	3
Sth Esk	FH&H	3	3
	CF&LP	0	3
Tamar	CF&LP	3	3
TOTAL		14	25

*CF&LP = Cleared Foothills and Lowland Plains; FH&H = Forested Hills and Highlands.

The most efficient approach to sampling macroinvertebrates and assessing SZV is to undertake both at the same site, assessing the SZV during a macroinvertebrate sampling event. Similarly, greater efficiency would be achieved if macroinvertebrate/SZV sites could coincide with water quality sites wherever possible, allowing macroinvertebrates and SZV data to be gathered during a water quality sampling event.

3. Maximising representativenes of sites in each reporting zone: The approach to maximising representativeness should not be prescriptive, as selection of representative sites will depend upon a suite of factors including landform, catchment geology, land use, natural vegetation cover, soil type and local climate. Selection of the most representative sites should therefore be undertaken in consultation with all TEER partners. One approach for discussion during consultation could include the applicability of 'end of valley sites'. In some reporting zones, sampling the major waterway(s) near the point where it leaves the zone could provide a useful summary of the zone's condition, particularly if much of the zone is relatively homogeneous. For example, sampling the Meander River immediately downstream of its confluence with Jackeys Creek may provide an accurate summary of the whole catchment above that site. However, each site will need to be discussed to ensure it is genuinely representative of its catchment above.

Although the above discussion is based upon the use of the current reporting zones and objectives derived in this report for those zones, the general approach can be transferred to differently drawn zones and refined objectives.

10 REFERENCES

ANZECC & ARMCANZ (2000a). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC & ARMCANZ (2000b). Australian guidelines for water quality monitoring and reporting. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Chessman, B.C. (1995). Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family-level identification, and a biotic index. *Australian Journal of Ecology,* 20, 122-129*.*

Chessman, B. C. (2003). New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research* **54**, 95–103. doi:10.1071/MF02114

Coysh, J., Nichols, S., Ransom, G., Simpson, J., Norris, R., Barmuta, L., and Chessman, B. (2000). *AUSRIVAS Macroinvertebrate Bioassessment Predictive Modelling Manual.* CRC Freshwater Ecology, Canberra.

DPIW (2008). Site-specific trigger values for physico-chemical indicators monitored under the DPIW Baseline Water Quality Monitoring Program. Water Assessment Water Quality Report Series, Report No. WA 08/52. Water Resources Division. Department of Primary Industries and Water, Hobart, Tasmania.

EPA Victoria (2003). Rapid Bioassessment Methodology for Rivers and Streams. Publication: 604.1

Goudey, R. (2007). Do statistical inferences allowing three alternative decisions give better feedback for environmentally precautionary decision-making? *Journal of Environmental Management* **85**:338–344.

Krasnicki, T., Pinto, R. and Read, M. (2001). Australia Wide Assessment of River Health; Tasmania Program Final Report. Department of Primary Industries, Water and Environment, Hobart. Technical Report No. WRA 01/2001

Newall, P. and Tiller, D. (2002). Derivation of nutrient guidelines for streams in Victoria. *Environmental Monitoring and Assessment* **74**:85-103.

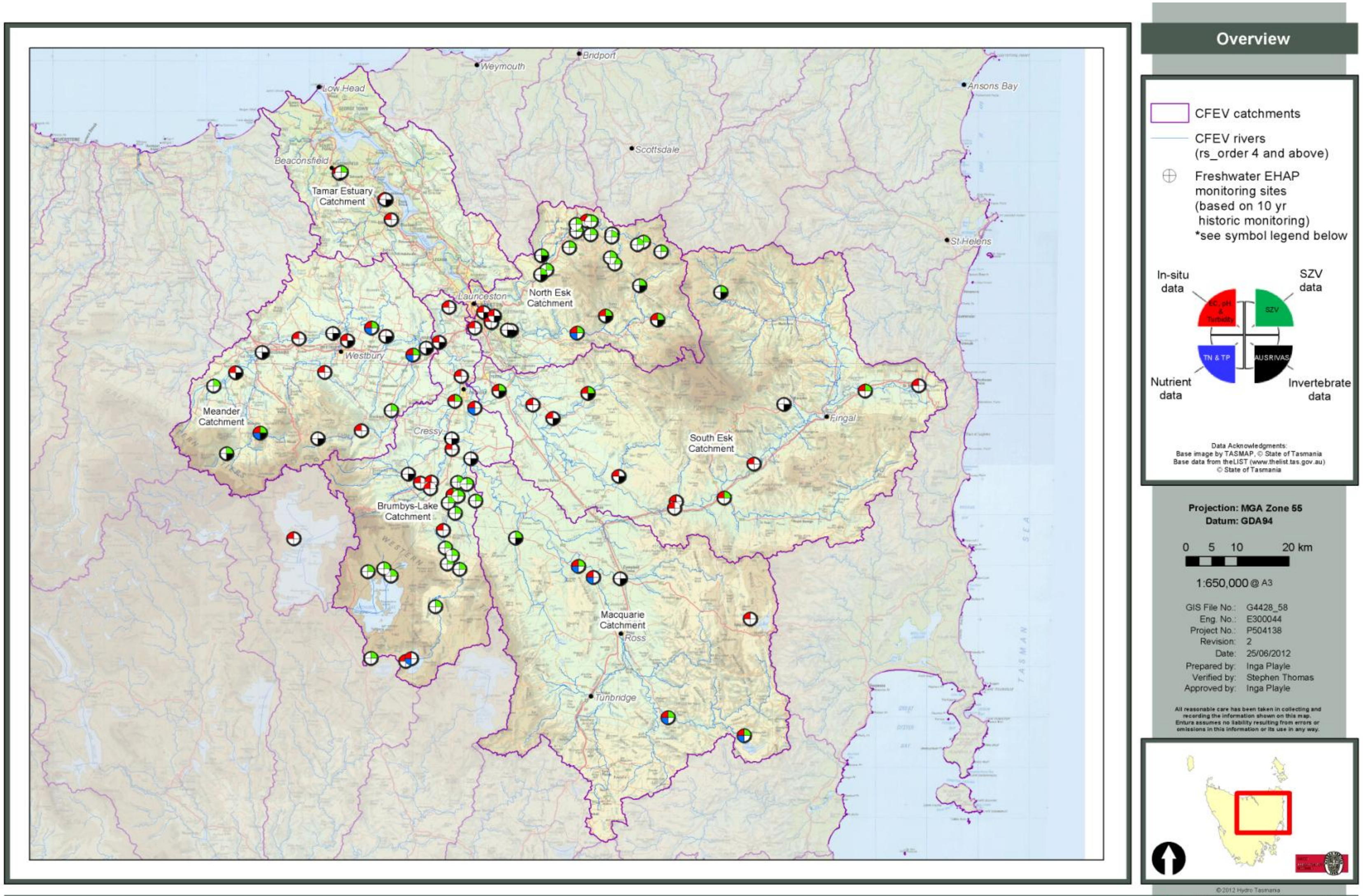
NHMRC 1990. *Australian guidelines for recreational use of water*. National Health and Medical Research Council, Canberra.

NHMRC, NRMMC (2011) *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

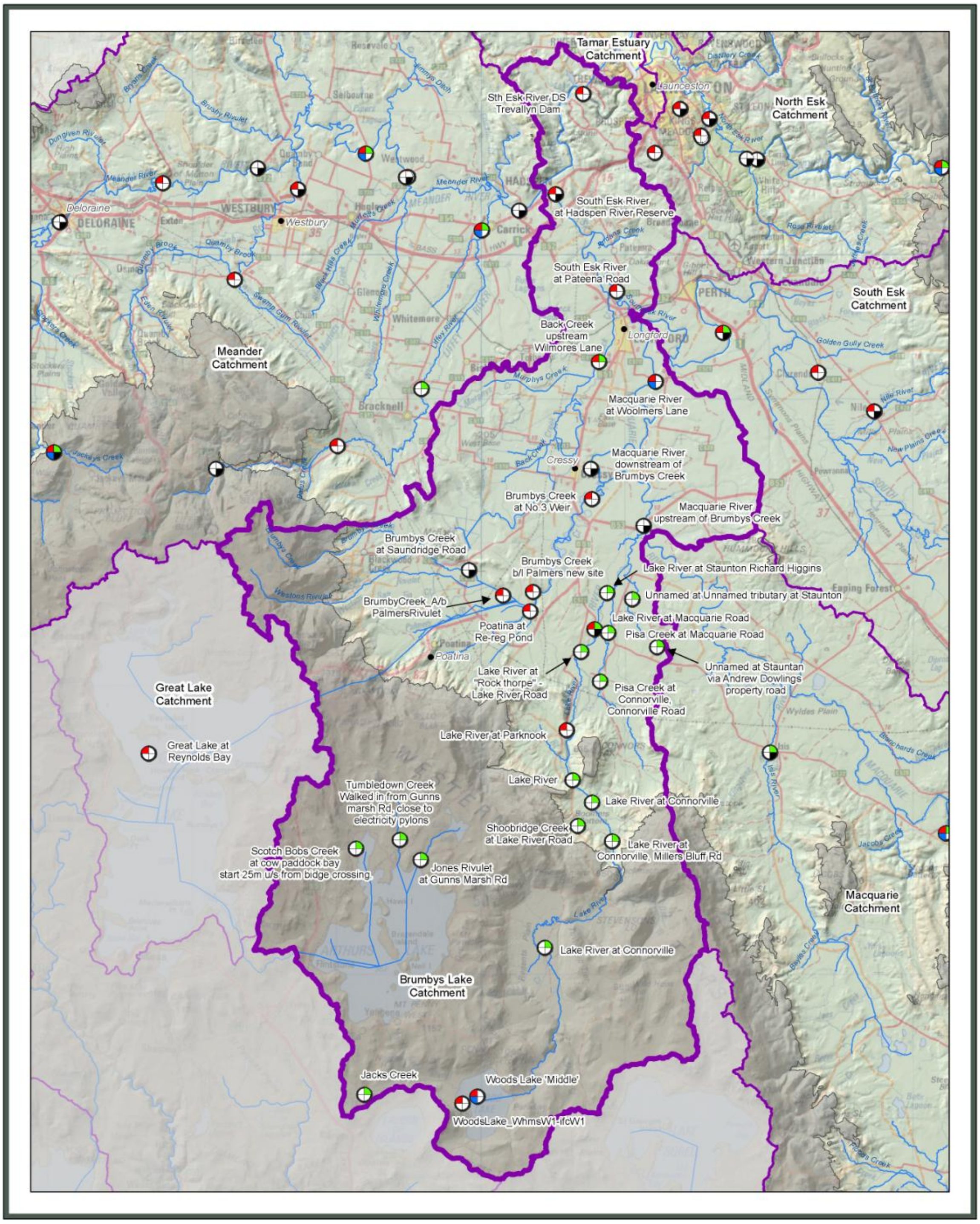
Tiller, D. and Newall, P. (1995). *Preliminary Nutrient Guidelines for Victorian Inland Streams*. Publication No. 478, EPA, Victoria.

Tiller, D. and Newall, P. (2009). Interpreting River Health Data. Water Watch Victoria.

11 APPENDIX: MONITORING SITES USED IN THE ASSESSMENT OF REPORTING ZONES ACROSS THE TEER BASIN (WHOLE BASIN, FOLLOWED BY THE SIX CATCHMENTS)



Previous monitoring sites (2001-2011) used for Report Card 2012



Previous monitoring sites (2001- 2011) used for Report Card 2012

Brumbys Lake Catchment

Projection: MGA Zone 55
Datum: GDA94

0 2.5 5 7.5 10 km
1:250,000 @ A3

GIS File No.: G4426_58
Revision: 2
Date: 04/07/2012
Prepared by: Inga Playle
Verified by: Stephen Thomas
Approved by: Inga Playle

Freshwater EHAP monitoring sites (based on 10 yr historic monitoring) *see symbol legend to right

CFEV catchments

CFEV rivers (rs_order 4 and above)

400m elevation or above (reporting boundary)

In-situ data: EC, pH, & Turbidity
SZV data: SZV
Nutrient data: TN & TP
Invertebrate data: AUSRIVAS

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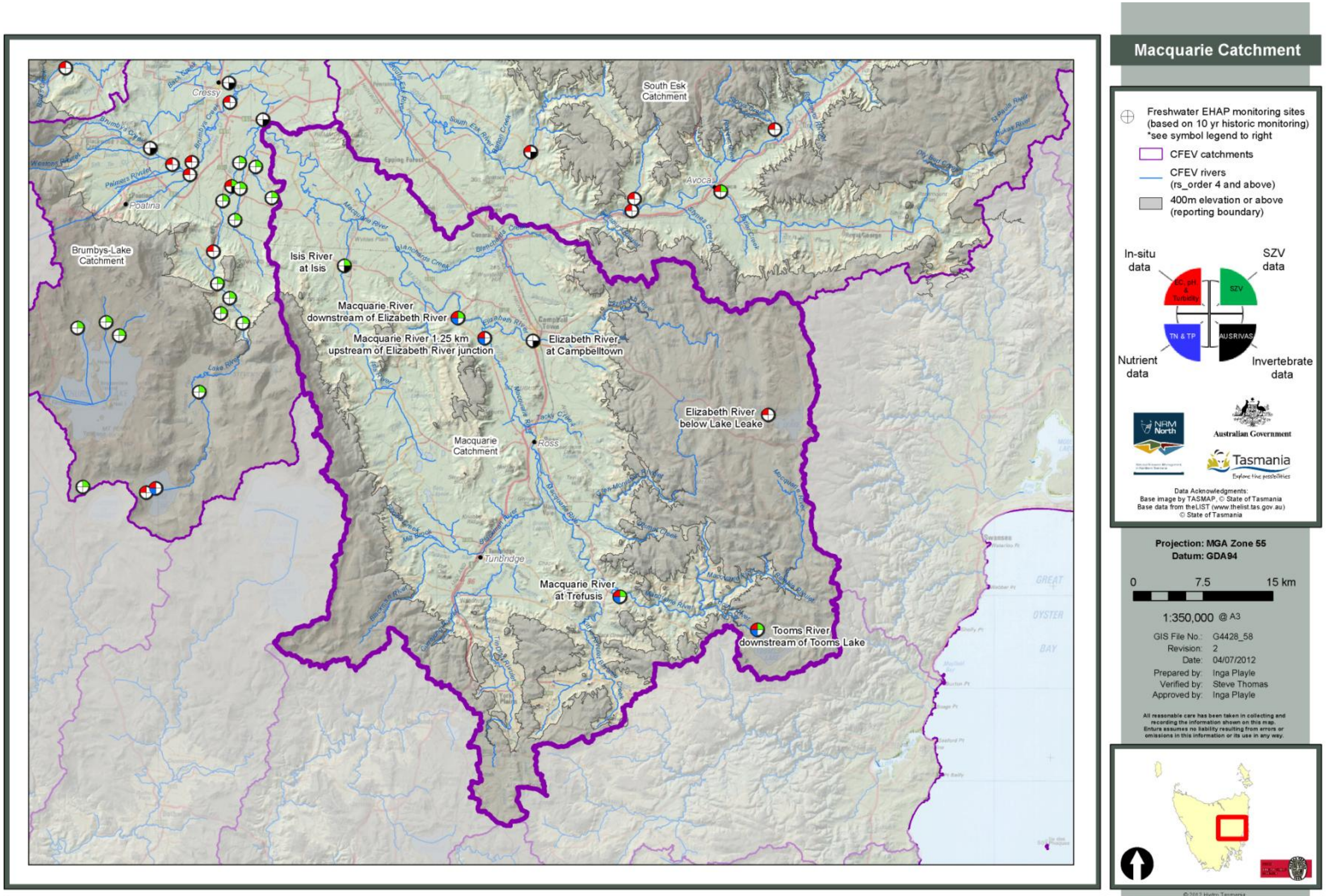
Data Acknowledgments: Base image by TASMAP, © State of Tasmania. Base data from theLIST (www.thelist.tas.gov.au), © State of Tasmania



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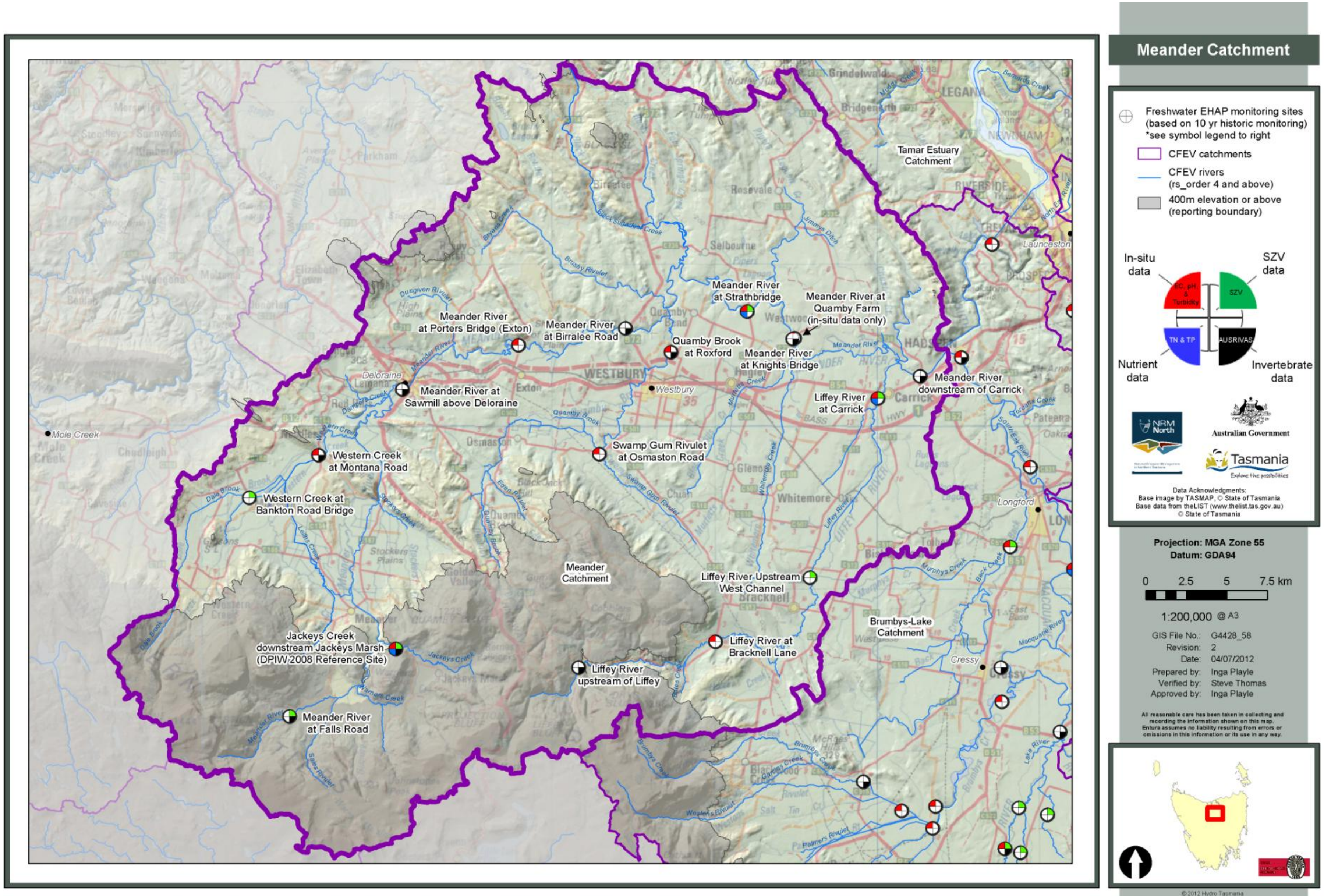

Previous monitoring sites (2001 - 2011) used for Report Card 2012

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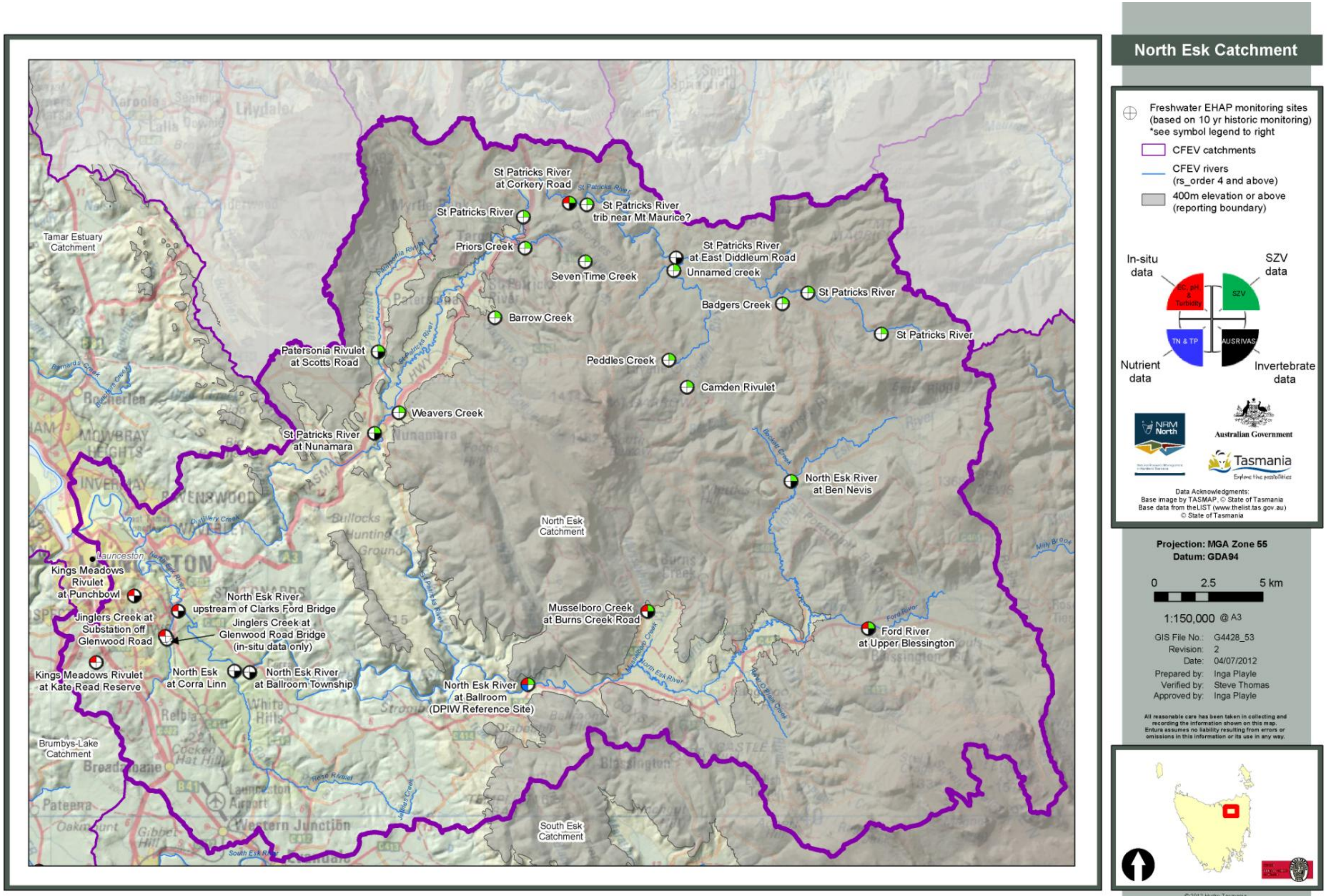

Previous monitoring sites (2001 - 2011) used for Report Card 2012

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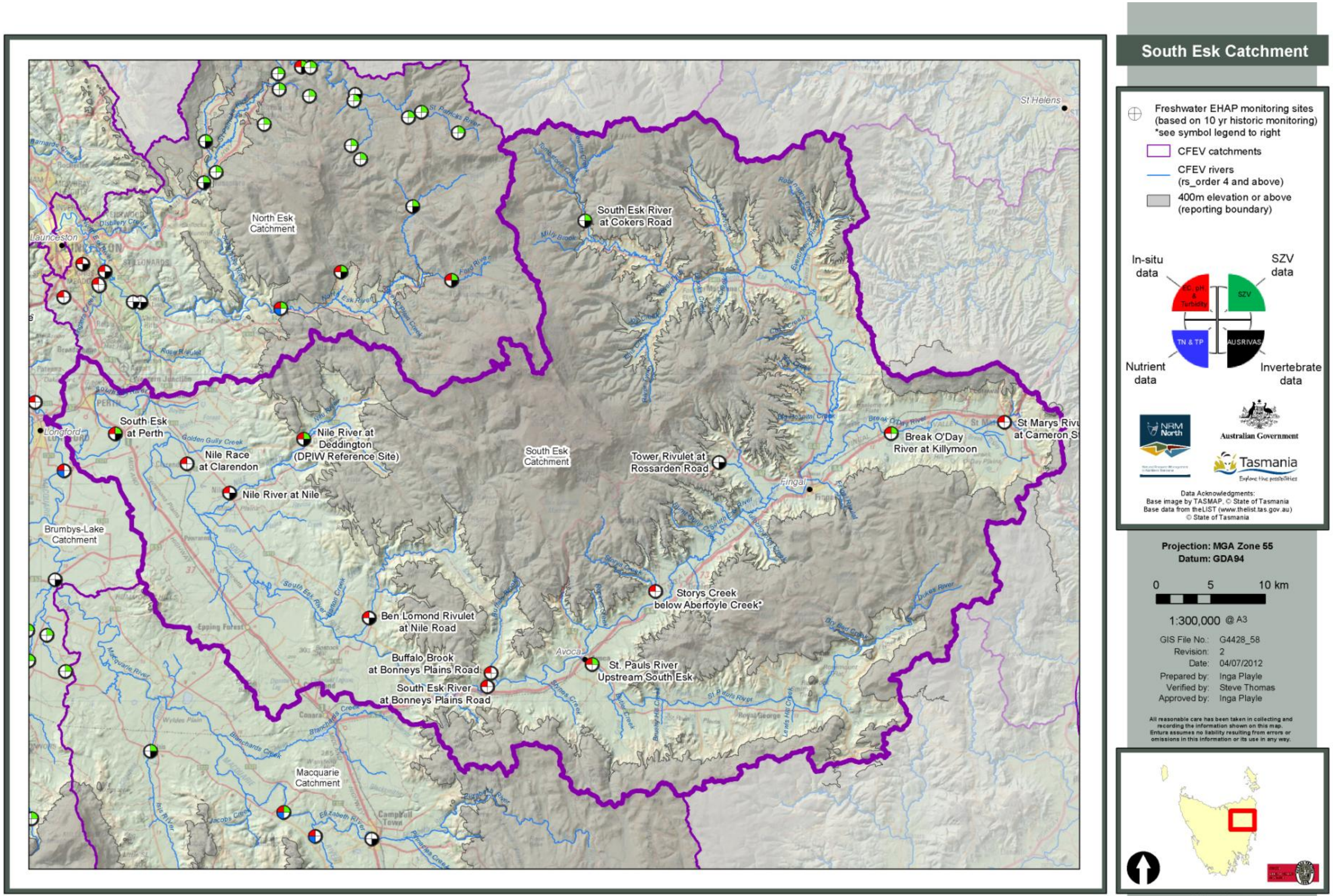
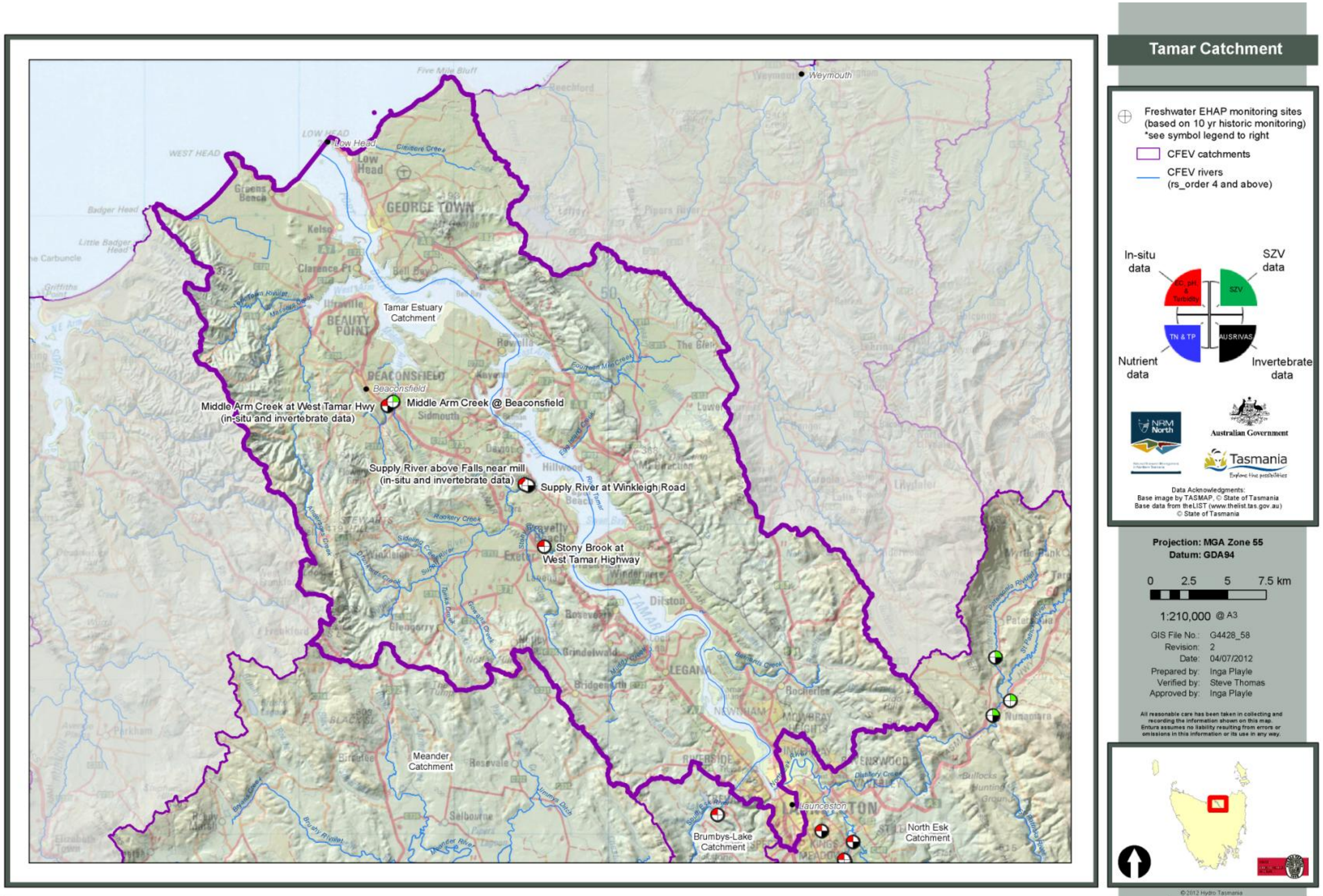


Previous monitoring sites (2001 - 2011) used for Report Card 2012



Previous monitoring sites (2001 - 2011) used for Report Card 2012