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Site-specific trigger values for physico-chemical indicators monitored under the DPIW Baseline Water Quality Monitoring Program

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Tasmania
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Contact details:

Department of Primary Industries and Water
Water Assessment
13 St Johns Avenue, New Town.
Phone: 03 6233 6833
Web: www.dpiw.tas.gov.au

The Department of Primary Industries and Water

The Department of Primary Industries and Water provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.
The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

Executive summary

The Department of Primary Industries and Water (DPIW) undertakes monthly monitoring for physico-chemical and nutrient parameters at 52 sites as part of its Baseline Water Quality Monitoring Program (BWQMP). This monitoring has been ongoing since November 2003. This document presents site-specific trigger values for each of the BWQMP sites developed by DPIW using monthly monitoring data collected from November 2003 to December 2006. A trigger value is broadly defined as a concentration that, if exceeded, alerts water managers to a potential change and thus triggers a management response.

The approach used by DPIW to develop these site-specific trigger values has been based on the framework provided by the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a). There is however an important difference in the DPIW trigger-setting process, in that the datasets used to develop the site-specific trigger values reflect site condition during 2003-2006, and as such provide a benchmark for 'current status'. The primary purpose of the DPIW site-specific triggers is to act as 'current status' trigger values which can be compared with future monitoring data to assess for stable, improving or deteriorating water quality status at each site. The current status trigger value provides a target for the protection of existing ambient water quality at BWQMP sites, recognising that existing water quality may already be influenced by varying degrees of impact. This is distinct from the ANZECC (2000a) trigger-setting process which recommends that reference condition (minimal or no impact) sites are used to derive trigger values. Under the ANZECC (2000a) framework, data from reference condition sites are used to develop 'low-risk' trigger values, where a low risk of adverse ecological effects can be inferred if trigger values are not exceeded. A subset of BWQMP sites have been identified as representative of reference condition for their catchment, and as such DPIW suggests that the site-specific trigger values for these particular sites may additionally be appropriate for use as 'low-risk' trigger values.

The DPIW site-specific trigger values should be used with consideration of information provided in this document regarding factors influencing their scope, interpretation and application.

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Glossary

The following definitions apply to terms used in this report. Many of these definitions are consistent with relevant national literature and cited where appropriate.

Current status trigger value

Concentrations of water quality indicators that reflect existing ecosystem condition, and therefore provide a target for ecosystem maintenance and a benchmark against which future water quality trends may be monitored.

Environmental value

Particular values or uses of the environment important for a healthy ecosystem or for public benefit, welfare, safety or health and requiring protection from the effects of pollution or degradation (Environment Australia 2002).

Indicator

A parameter (biological, physical or chemical) used to provide a measure of the quality of water or the condition of an ecosystem (Environment Australia 2002).

Low-risk trigger value

Concentrations (or loads) of key performance indicators [of water quality] at which if not exceeded, there is a low risk that adverse biological effects will occur (ANZECC 2000a).

Median

The middle reading, or 50th percentile, of all readings taken. i.e. of the readings 10, 13, 9, 16 and 11 (re-ordering these to read 9, 10, 11, 13 and 16), the median is 11. The mean (or average), is the sum of all values divided by the total number of readings (which in this case equals 11.8).

Reference condition

Refers to a site which is unmodified or minimally modified from 'natural' condition. Most commonly, reference sites are subject to limited disturbance from human activity. The reference condition then serves as a standard or target against which environmental change in other similar sites can be assessed.

Trigger value

A concentration that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, such as further investigation and/or remedial actions (ANZECC 2000a).

Water quality guideline

A numerical concentration level (e.g. of a contaminant) or narrative statement (e.g. visual appearance of a water body) recommended to support and maintain a designated water use (ANZECC 2000a)

1 Introduction

The physical and chemical properties of water exert significant influence on the ecological processes within aquatic ecosystems, and as such can act as indicators of ecological health. Changes in physical and chemical water quality parameters such as turbidity, salinity, pH, dissolved oxygen and nutrients often reflect changes in land use within a catchment, and these indicators can therefore be monitored to identify and assess actual or potential ecosystem degradation. Best used in conjunction with biological and habitat assessment methods, water quality indicators contribute to our understanding of the factors affecting waterway health and provide information to guide management decisions and target restoration efforts. It is widely recognised that waterways are closely linked to their catchments, and that activities within the catchment can influence the quality of these waterways (Hart 2001). The assessment of water quality is therefore a key component of effective catchment management practices.

A commonly stated goal of interstate and international water quality management programs is to "maintain or improve water quality" (e.g. Ward *et al.,* 1986; EPA Victoria, 2003). In Tasmania, one of the primary objectives of the *State Policy on Water Quality Management 1997* is to maintain and enhance water quality while allowing for sustainable development in accordance with Tasmania's Resource Management and Planning System. This objective is reiterated in other government initiatives including the *Tasmanian Surface Water Quality Monitoring Strategy* and *Tasmania Together*. The assessment of physical and chemical water quality indicators provides an efficient approach for measuring progress against this goal, and the use of water quality guidelines for these indicators provides an objective reference against which to evaluate monitoring data. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000a) define a *water quality guideline* as "a numerical concentration level (e.g. of a contaminant) or narrative statement (e.g. visual appearance of a water body) recommended to support and maintain a designated water use". ANZECC (2000a) has adopted the use of guideline trigger values for physical and chemical stressors in aquatic ecosystems, as well as for a range of other indicators. *Trigger values* are defined as "concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response", such as further investigation and/or remedial actions. ANZECC (2000a) provides default trigger values for a range of Australian waters, including regional values for Tasmania, but recommends that where possible, trigger values are refined using locally relevant data. A framework for deriving trigger values is also provided by ANZECC (2000a), and is outlined in Section 2.

The setting of guideline trigger values for physical and chemical indicators enables the evaluation of deviation of these parameters from 'natural' (or un-impacted) levels, or from some other benchmark, such as 'current status'. In relation to monitoring program goals, guideline trigger values which reflect natural levels may provide aspirational targets for the enhancement of water quality, whilst guideline trigger values which reflect current status may enable the assessment of maintenance or improvement against a benchmark that reflects existing condition. Guidelines based on natural levels may act as *low-risk triggers values*, meaning that in ecosystems where water quality parameters do not exceed these triggers there is a low risk that adverse biological effects will occur (ANZECC 2000a). Low-risk trigger values are best derived from un-impacted or 'reference' sites, as described in Section 2. *Current status trigger values*, based on existing condition, may provide interim maintenance targets for waterways which might already be significantly or moderately degraded, allowing the formulation and review of management options when restoration to 'natural' condition may be unrealistic in the short- to medium-term. This does not mean that it is acceptable to allow less rigorous environmental management in a waterway that is already impacted, just that pragmatic short term goals may be required. It is important that current status trigger values are not interpreted in the same way as low-risk trigger values – otherwise a degraded system may be judged as satisfactory because it has not deviated significantly from the previous (degraded) state (Liston and Maher 1997). As management actions improve water quality at these sites, current status trigger values may be refined using more up-to-date data or desired low-risk targets may be applied. For sites which are not significantly impacted, guidelines based on current status can still provide a locally relevant and useful comparison for the monitoring and detection of stable, improving or deteriorating water quality status.

The concept of setting trigger values based on current status underlies the approach adopted by the Department of Primary Industries and Water (DPIW) in the development of site-specific trigger values for sites monitored under the Baseline Water Quality Monitoring Program (BWQMP) in Tasmania. While the setting of DPIW site-specific trigger values has been based on the framework provided by ANZECC (2000a), the derivation of these values using 'current status' sites has certain implications for their scope and application. The purpose of this document is to provide the DPIW site-specific trigger values for BWQMP sites in Tasmania, accompanied by information on their development and recommended application.

2 National water quality guidelines

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (commonly referred to as the ANZECC guidelines) were developed as part of the National Water Quality Management Strategy to provide a national framework for assessing and managing ambient water quality in natural and semi-natural water resources. The ANZECC guidelines recognise the wide range of ecosystem types and varying condition of waterbodies in Australia and New Zealand, as well as the interdependence of all aspects of aquatic environments and the range of uses and factors that can affect them. The ANZECC framework outlines a broad strategy and set of tools that water managers can implement at a local level, enabling management actions to be tailored to suit local environmental conditions. The framework is based on the concept of identifying *environmental values* (or uses) of water resources, selecting the level of protection appropriate for these values, and determining water quality guidelines, water quality objectives and management goals necessary for sustaining each value. ANZECC (2000a) recognises environmental values including:

- aquatic ecosystems;
- primary industries;
- recreational water quality and aesthetics; and
- drinking water.

For each of these values, ANZECC (2000a) provides (or refers the reader to) information and recommended guidelines for the protection of that value. ANZECC (2000a) also recognises other environmental values such as cultural and spiritual values, but does not provide specific guidelines for management.

The ANZECC guidelines contain detailed scientific information and instructions for a comprehensive range of water quality issues, and are comprised of several volumes, chapters and external support documents. The remainder of this section relates to the ANZECC guidelines for the protection of aquatic ecosystems. Specifically, concepts relevant to the setting and application of trigger values for physical and chemical stressors will be summarised. The ANZECC (2000a) document should be referred to for more detailed background information, rationale and explanatory notes, as well as information related to the use of other indicators

2.1 Level of protection

The ANZECC guidelines for the environmental value 'aquatic ecosystem protection' specify water and sediment guidelines for sustaining the ecological health of a range of aquatic ecosystems, from freshwater to marine. The guidelines acknowledge that different levels of protection may be appropriate for different waterbodies. ANZECC (2000a) proposes three levels of ecosystem protection as a basis for applying the guidelines, corresponding to three recognised levels of ecosystem condition:

- *Condition 1: high conservation/ecological value systems* – these are largely unmodified ecosystems that have undergone minimal or no change from natural condition, and ecological integrity is regarded as intact. These systems are typically found in conservation areas or inaccessible locations. Water quality guidelines for these systems should aim to maintain no change from natural condition.
- *Condition 2: slightly to moderately disturbed systems* – these are ecosystems that may have been adversely affected to a relatively small but measurable degree by human activity, but where ecological integrity is largely intact. These systems include streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism. Water quality guidelines for these systems define an acceptable measure of change from natural condition.

- *Condition 3: highly disturbed systems* – these are measurably degraded ecosystems such as urban streams receiving road runoff or rural streams affected by intensive horticulture. Water quality guidelines for these systems may be less stringent, and are aimed at maintaining (and ideally improving) the current status of the highly modified system.

Further details on how to select the appropriate level of protection are provided in ANZECC (2000a).

2.2 Indicators

Once a level of protection has been determined for an ecosystem, the ANZECC guidelines recommend that environmental issues or pressures on that ecosystem are identified. These issues will guide the selection of relevant *indicators*, which are parameters used to provide a measure of the quality of water or the condition of an ecosystem. For the purpose of protecting the ecological health of aquatic ecosystems, ANZECC (2000a) provides guidelines for biological indicators; physical and chemical stressors; and toxicants. Sediment quality guidelines are also provided. Biological indicators are recognised as a key assessment tool as they provide information on biological and ecological changes that may result from changes in water quality or from changes in physical habitat, and as such can be used to measure the response to past or present stressors. Toxicants are chemical contaminants such as metals, aromatic hydrocarbons and pesticides that can have potentially toxic effects at certain concentrations.

Physical and chemical stressors are naturally occurring parameters that can cause serious changes in aquatic ecosystems when ambient values are too high and/or too low. These parameters include nutrients, biodegradable organic matter, dissolved oxygen, turbidity, temperature, salinity (measured as electrical conductivity), pH and changes in flow regime. Physical and chemical stressors may also modify the effects of toxicants. ANZECC (2000a) broadly classifies physical and chemical stressors into two types depending on whether they have direct or indirect effects on ecosystems. Those that have direct effects include stressors that are directly toxic to biota (e.g. heavy metals, ammonia, salinity, pH, dissolved oxygen, temperature) or stressors that are not toxic but can directly affect ecosystems and biota (e.g. nutrients can result in algal blooms; turbidity can restrict light availability for primary production). Stressors that have indirect effects act by modifying the effects of other stressors (e.g. pH can influence the release of metals).

2.3 Low-risk trigger values for physical and chemical stressors

Trigger values were described in Section 1 as concentrations that, if exceeded, would indicate a potential environmental problem, and so ‘trigger’ a management response. ANZECC (2000a) further defines *low-risk trigger values* as “concentrations (or loads) of key performance indicators below which there is a low risk that adverse biological effects will occur”. The physical and chemical trigger values are not designed to be used as ‘compliance’ or threshold values at which an environmental problem is inferred if exceeded. Rather, they should be used in conjunction with professional judgement to provide an initial assessment of the state of the waterbody (ANZECC 2000; Hart 2001). Exceedances of the low-risk trigger values are intended to provide an 'early warning' mechanism to alert managers to a potential risk. The appropriate response may be further site-specific investigation, or immediate remedial action.

The ANZECC guidelines outline a preferred approach for deriving low-risk trigger values for slightly to moderately disturbed and highly disturbed ecosystems. For physical and chemical indicators, the preferred method is to use biological and ecological effects data obtained through site- or ecosystem-specific laboratory or field testing. However, such data is not commonly available. Where there is insufficient available information on biological or ecological effects, ANZECC (2000a) recommends the use of local reference data from appropriate *reference condition* systems to determine the low-risk trigger values for each key indicator. This approach is based on the premise that some small departure from natural or reference condition is acceptable, and requires a good understanding of reference condition and a value judgement on the degree of acceptable departure (Queensland EPA, 2006).

The reference condition should provide both a target for management actions and a meaningful comparison for use in a monitoring program. Reference data for low-risk trigger values may be obtained either from the same undisturbed ecosystem (e.g. prior to or upstream of possible impacts), or from different local or regional reference systems that are relatively uninfluenced by the disturbance being assessed (ANZECC 2000). The appropriate reference condition should be chosen using information about the physical and biological characteristics of both the catchment and the waterbody to ensure it is relevant and represents suitable target conditions (ANZECC 2000). Reference systems are useful for the development of low-risk trigger values because they define the physical and chemical characteristics of essentially natural or unmodified systems (i.e. the range of conditions in which the risk of adverse ecological effects is low), while also accounting for the natural variability of the assessed indicators (Hart 2001). Where suitable high-quality reference sites cannot be found, ANZECC (2000a) recommends that modified waterbodies in the best environmental condition available can serve as useful intermediate reference targets. This may be useful for more disturbed systems, where the use of largely undisturbed reference sites may result in unrealistic or unachievable water quality targets. Further detail on the selection of appropriate reference systems is provided in Section 3.3.

Where local reference data is available, ANZECC (2000a) recommends that trigger values for slightly to moderately disturbed ecosystems are defined in terms of the 80^{th} and/or 20^{th} percentile values of data obtained from an appropriate reference system. The 80^{th} percentile of the reference data distribution is used as the low-risk value for stressors that cause problems at high levels and the 20^{th} percentile is used for stressors that cause problems at low levels. For stressors that cause problems at both high and low concentrations, the desired range for the indicator is defined by the 20th and 80th percentiles of the reference data distribution. ANZECC (2000a) recommends that a minimum of two years of contiguous monthly data (24 data points) at the reference site is required to establish a valid trigger value.

The ANZECC guidelines emphasise the principle that trigger values should be developed using local reference data. Where there is insufficient local reference data available to derive locally relevant trigger values, ANZECC (2000a) provides a set of regional default low-risk trigger values for slightly to moderately disturbed ecosystems. The default trigger values were derived from data for unmodified or slightly modified ecosystems supplied by state agencies. The default trigger values for rivers in south-east Australia are classified into two categories, based on altitude: lowland rivers are those below 150m and upland rivers are those above 150m. However, due to Tasmania's mountainous landform and relatively small catchment sizes, this definition may be less appropriate for Tasmanian rivers than for other south-eastern states. DPIW has therefore generally applied the most stringent set of default trigger values (those for upland rivers) to assist the assessment of Tasmanian rivers. The ANZECC (2000a) default low-risk trigger values for the physical and chemical stressors monitored under the BWQMP in Tasmanian rivers are provided in Table 1. Note that ANZECC (2000a) does not provide default trigger values for temperature.

Table 1. ANZECC 2000 default low-risk trigger values for slightly disturbed ecosystems in Tasmania. EC = electrical conductivity; DO = dissolved oxygen (% saturation, daytime measurements); TN = total nitrogen; NO_x = nitrate and nitrite; NH_4^+ = ammonium; TP = total phosphorus; DRP = dissolved reactive phosphorus.

Ecosystem type	Turbidity NTU	EC µS/cm	pH*	DO	TN mg/L	NO_x - N mg/L	NH_4^+ - N mg/L	TP mg/L	DRP - P mg/L
Upland river	2-25	30-350	6.5-7.5	90-110	0.480	0.190	0.013	0.013	0.005
Lowland river	6-50	125-2200	6.5-8.0	85-110	0.500	0.190	0.020	0.050	0.020

*pH values for humic rich Tasmanian rivers are 4.0 – 6.5

3 Developing site-specific trigger values for Tasmania

3.1 The Baseline Water Quality Monitoring Program

Data collected through the Baseline Water Quality Monitoring Program (BWQMP) has been used to develop site-specific trigger values for Tasmanian rivers monitored by DPIW. The BWQMP was implemented in late 2003 in response to a need identified in the *Tasmanian Surface Water Quality Monitoring Strategy* (DPIWE 2003) for a coordinated, high quality baseline water quality monitoring network for the State. The BWQMP network consists of 52 monitoring sites, shown in Figure 1. Mapping coordinates for all BWQMP sites are provided in Appendix 1. DPIW also conducts infrequent sampling at a site on Davey River in Tasmania's south west, however data for this site is not sufficient for the development of site-specific trigger values and as such it has not been considered in this document.

Monthly sampling is conducted at all sites for the following physical and chemical water quality indicators: temperature, turbidity, electrical conductivity (EC; temperature compensated at 25°C), pH, dissolved oxygen (DO), total nitrogen (TN), nitrate (NO_3 as N), nitrite (NO_2 as N), ammonia (NH_3 as N), total phosphorus (TP) and dissolved reactive phosphorus (DRP as P). Nutrients are not collected at Back Creek. Turbidity, temperature and electrical conductivity is also monitored continuously (at 15 minute intervals) at a subset of 37 sites.

The BWQMP monthly dataset is suitable for the development of 'current status' site-specific trigger values, based on the ANZECC (2000a) framework for deriving trigger values for slightly to moderately disturbed ecosystems (outlined in Section 2.3) Trigger values for each BWQMP site were derived from three years of monthly monitoring data collected between November 2003 and December 2006. Monitoring commenced later for two sites, Back Creek and Macquarie River u/s Elizabeth River, and as such trigger values for these sites have been developed from 2005-2007 and 2004-2007 datasets respectively. For each site, trigger values were defined by the 80^{th} and/or 20^{th} percentile value of the data distribution for that site. Recommended procedures and other considerations for applying the DPIW site-specific trigger values are provided in Section 5.

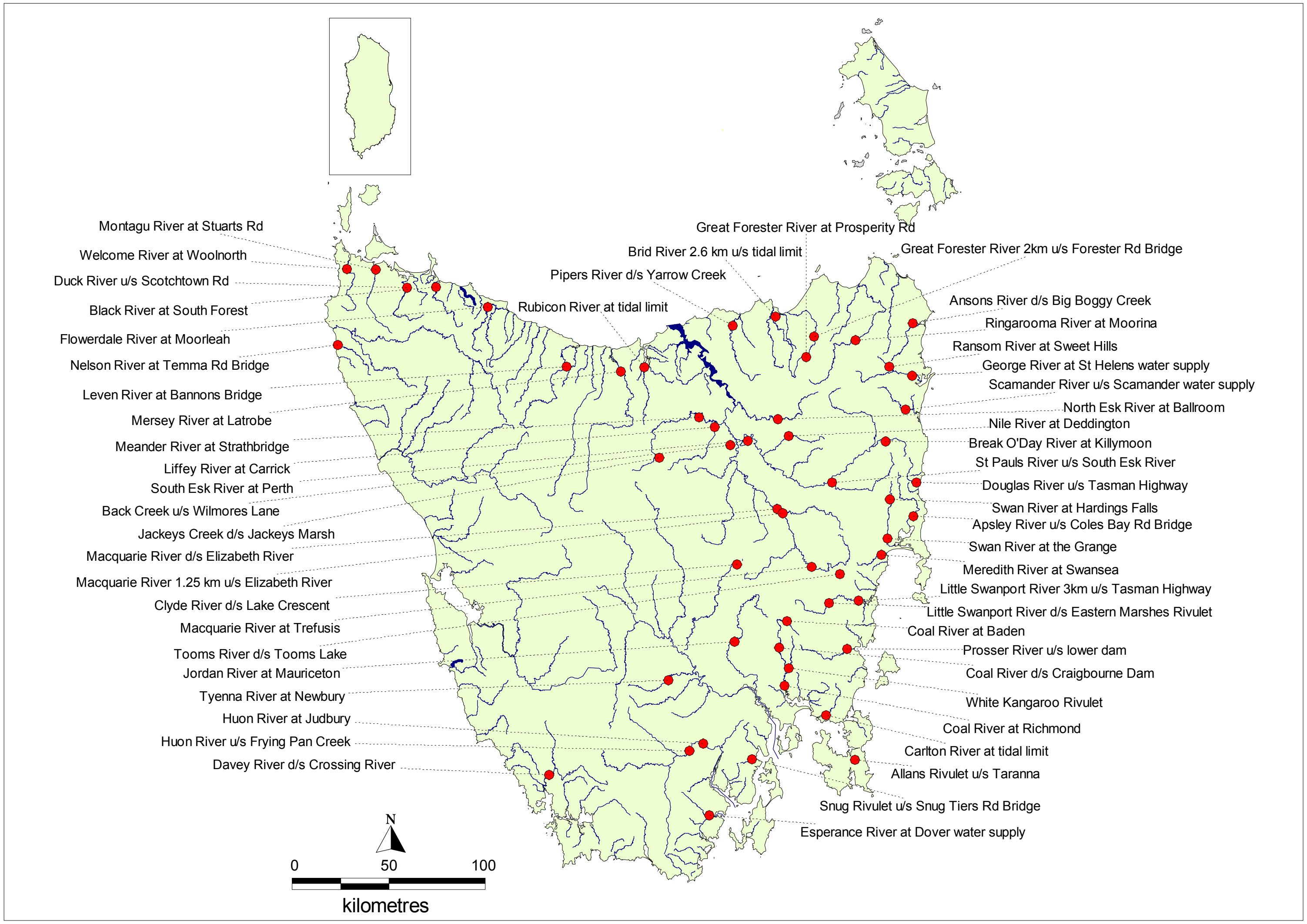

Figure 1. Sites monitored under the DPIW Baseline Water Quality Monitoring Program.

3.2 *Differentiating ANZECC low-risk trigger values from DPIW site-specific trigger values*

All BWQMP sites are located at streamflow monitoring stations, and the majority are situated near the bottom of a catchment or major catchment. The use of end-of- catchment sites in a statewide monitoring program enables the detection of broad scale impacts within a catchment and the characterisation of overall water quality status and trends (i.e. site selection is aimed at capturing the cumulative effect of upstream influences). This will generally mean that end-of-catchment sites are not representative of the best available reference condition for a catchment.

The key difference between the ANZECC low-risk trigger values and the DPIW site-specific trigger values is that sites used to define the DPIW site-specific trigger values may already be modified or impacted, and therefore it cannot be assumed that a low risk of adverse ecological effects exists if these trigger values are not exceeded. The primary purpose of the DPIW site-specific trigger values is to act as current status trigger values, providing a benchmark of site condition in 2003-2006 against which to compare future monitoring data. For sites where restoration to an essentially unmodified state is not practical in the short term, the site-specific trigger value may also serve as an intermediate target for maintenance of existing water quality.

BWQMP sites were also assessed for the possibility that they may in fact represent best available reference condition for their catchment, and that the assumption of low ecological risk for trigger values derived from these sites may then be appropriate. The following section outlines the process used by DPIW to assess BWQMP sites for suitability as reference condition sites.

3.3 *Identifying BWQMP sites in reference condition*

For the purposes of this document, *reference condition* refers to a site which is unmodified or minimally modified from ‘natural’ condition. Most commonly, reference sites are subject to limited disturbance from human activity. The reference condition then serves as a standard or target against which environmental change in other similar sites can be assessed. The reference condition concept can also be applied to more disturbed systems, and the definition of the reference condition should be consistent with the level or protection proposed. ANZECC (2000a) recommends that where no high quality reference sites are available, modified waterbodies of the best available (or least disturbed) environmental quality in the region may still provide useful reference data.

As mentioned in the previous section, although the majority of BWQMP monitoring is conducted in the lower parts of modified catchments, some BWQMP sites may be considered minimally impacted and suitable for use as reference condition sites for slightly to moderately disturbed ecosystems. Subsequently the site-specific trigger value derived for these sites may also act as a low-risk trigger value for that catchment and potentially a default low-risk trigger value for other catchments with similar geology, soil types and topography. Guidance on the application of some BWQMP site-specific trigger values as low-risk trigger values is provided in Section 5.2.

The criteria used to assess BWQMP sites for suitability as reference sites are listed below. These criteria are consistent with those used to select reference sites for physico-chemical indicators by the Queensland Water Quality Guidelines (Queensland EPA 2006), which are based in part on the approach developed under the National Monitoring River Health Initiative (CEPA, 1994). While the Queensland EPA (2006) criteria aim to identify sites that have minimal impact from human activities within 20km upstream of the site, a 10km upstream boundary is considered suitable for Tasmanian rivers, as previously adopted by (Krasnicki *et al.* 2001) for the selection of bioassessment reference sites.

Criteria used to identify reference condition sites:

1. **No intensive agriculture within 10km upstream of site.**
   Intensive agriculture involves irrigation, widespread soil disturbance and the intensive use of agrochemicals. Intensive plantation forestry is included in this category. Exceptions may be made for mature plantations composed of native species. Dryland grazing and production forestry from native forests do not fall into this category.
2. **No mining or extractive activity (current or historical) within 10km upstream of site.**
   This includes mines, quarries and sand/gravel extraction.
3. **No major urban area (>5000 population) within 10km upstream of site.**
4. **No significant point-source wastewater discharge within 10km upstream of site.**
   Exceptions may be made for small discharges into larger rivers.
5. **Seasonal flow regime not greatly altered.**
   This may be due to abstraction or regulation, and includes upstream dams or large weirs.

The land use data layer for Tasmania, developed by the GIS section of DPIW for the Bureau of Rural Science, was used to make an initial judgement about whether a BWQMP site met the above criteria. This land use layer was based on a wide range of data sources gathered between 2001-2003, and maps land use in Tasmania at the 1:25 000 scale for areas under intensive agriculture and the 1:100 000 scale for the rest of the state (Drenen 2003). The Tasmanian data layer is part of the Australian Collaborative Land Use Mapping Program, and is available at http://adl.brs.gov.au/mapserv/landuse/. The layer classifies land use across Tasmania in accordance with the Australian Land Use and Management (ALUM) Classification system (version 5), which provides a nationally consistent method for the collection and presentation of land use information across Australia. Land use categories occurring within a 10km upstream boundary of each BWQMP site are listed in Appendix 1. Category titles are reasonably self-explanatory, however more information on the ALUM Classification can be found at http://adl.brs.gov.au/mapserv/landuse/alum_info.html. For example, 'production forestry' refers to commercial production from native forests and related activities on public and private land, while 'plantation forestry' describes land on which plantations of trees or shrubs (native or exotic) have been established for production or environmental and resource protection purposes (BRS, 2006).

While some BWQMP sites may have met the above reference condition criteria based on the mapped Tasmanian land use information, further exclusions have been made based on local knowledge of site conditions (e.g. sites influenced by salinity, excessive nutrients or other local impacts). Drenen (2003) acknowledges limitations associated with the Tasmanian land use mapping project particularly related to the difficulty in distinguishing between grazing/cropping and non-irrigated/irrigated pastures from aerial mapping. Given the implications this may have for the selection of reference sites, this highlights the importance of local catchment knowledge, however it should be noted that reference site selection is based on the best available (but potentially incomplete) information. It should also be noted that a site identified as being in reference condition in 2003-2006 may not remain in this condition if future land uses change.

BWQMP sites that are considered suitable for use as reference condition sites for slightly to moderately disturbed ecosystems are indicated in Table 2. Reference data from these sites has not been pooled to define statewide low-risk trigger values (i.e. to refine the ANZECC default low-risk trigger values for Tasmania). This is because the identified reference sites represent a range of catchments with different physical, geological, vegetation and soil type characteristics. For example, Nelson River is selected as a reference site, however this is a humic rich river with a pH trigger value range of 4.0-4.8. While these trigger values may be appropriate for the Nelson River and other similar catchments, many other catchments exhibit much higher natural pH ranges. If a low-risk trigger value is required for a catchment without a reference site, it is considered preferable to select a similar catchment containing a reference site (see Section 5.2 for further information).

4 DPIW site-specific trigger values for Tasmania

Site-specific trigger values for sites monitored under the BWQMP are provided in Table 2. The 80th percentile provides an upper limit for stressors that cause problems at high values, while the 20th percentile provides a lower limit for stressors that cause problems at low values. As discussed in Section 3.2, these site-specific trigger values set a benchmark for 'current status' (2003-2006) against which future variation in water quality at these sites can be assessed. Sites which have also been identified as suitable reference condition systems for providing low-risk trigger values (see Section 3.3) have also been indicated in Table 2. Factors influencing the interpretation of the data in Table 2 are discussed below. Guidance on the application of the DPIW site-specific trigger values is provided in Section 5.

- These site-specific trigger values should be interpreted with consideration of information specific to individual physical and chemical indicators, as provided in Section 4.1.

- It is very important to note that these site-specific triggers relate to baseflow conditions and are not necessarily suitable for application during high or very low flow events. Section 5.3 provides further information.

- Some sites which have not been determined as suitable reference condition systems still have site-specific trigger values that are more conservative than ANZECC (2000a) default low-risk trigger values. It is possible that despite land uses which preclude the site from being considered suitable as a reference system, impacts on water quality may have been negligible (in 2003-2006). However, it is also possible that such a site has departed from natural condition, and the fact that it does not exceed ANZECC (2000a) low-risk trigger values may reflect the limited amount of suitable reference condition data available for Tasmanian rivers when the ANZECC (2000a) guidelines were drafted. In such a case, a site-specific trigger value that is more conservative than the ANZECC (2000a) default trigger value will provide an earlier 'flag' if conditions at that site deteriorate.

- Conversely, some site-specific trigger values are much higher (or lower) than the respective ANZECC (2000a) default low-risk trigger values. Again, this may reflect that the regional approach adopted by ANZECC for developing default low-risk trigger values may have overlooked natural variability at sites. However, the majority of sites with less conservative site-specific trigger values occur on rivers with substantially modified catchments (see Section 3.3 and Appendix 1). It is therefore more likely that the site-specific trigger value for these sites reflects the impact that catchment activities have had on these rivers. The longer-term aim for these sites would be for remedial action to improve water quality to a point that low-risk trigger can be realistically applied.

- Some sites have trigger values which may appear anomalous or trigger value ranges that are very narrow. This reflects the site-specific nature of the data, highlighting that the trigger value may be influenced by conditions or factors (both natural and/or anthropogenic) that are specific to that particular reach of river. One example is the Clyde River downstream of Lake Crescent, where a very high turbidity trigger value of 175 NTU reflects the influence that low lake levels combined with wind resuspension in Lake Crescent are having on this site.

Table 2. Site-specific trigger values for sites monitored under the DPIW Baseline Water Quality Monitoring Program. EC = electrical conductivity; DO = dissolved oxygen; TN = total nitrogen; NO_3 = nitrate; NO_2 = nitrite; NH_3 = ammonia; TP = total phosphorus; DRP = dissolved reactive phosphorus. nd = no data. See Section 4.1 for important information relating to each indicator. Sites suitable for use as 'reference condition' systems for slightly to moderately disturbed ecosystems are shaded in dark grey (see Section 3.3).

	Physical or chemical indicator and recommended site-specific trigger value																
	Temperature ° C		Turbidity NTU	EC µS/cm		pH		DO mg/L		DO % saturation		TN mg/L	NO_3 as N mg/L	NO_2 as N mg/L	NH_3 as N mg/L	TP mg/L	DRP as P mg/L
Site name	20th	80th	80th	20th	80th	20th	80th	20th	80th	20th	80th	80th	80th	80th	80th	80th	80th
Allans Rivulet u/s Taranna	7	13	2	174	217	6.7	7.4	9.5	11.5	89	102	0.206	0.082	<0.002	0.011	0.006	0.003
Ansons River d/s Big Boggy Creek	8	18	12	212	292	6.2	6.8	7.8	11.0	81	94	0.889	0.013	0.007	0.024	0.026	0.004
Apsley River u/s Coles Bay Rd bridge	9	19	9	133	176	6.7	7.4	8.7	10.7	88	101	0.424	0.005	<0.002	0.015	0.014	0.004
Back Creek u/s Wilmores Lane	8	18	20	28	506	6.6	7.6	9.5	11.8	94	107	nd	nd	nd	nd	nd	nd
Black River at South Forest	8	18	5	111	123	5.3	6.9	8.2	11.0	83	94	0.607	0.077	0.006	0.022	0.023	0.004
Break O'Day River at Killymoon	8	17	9	167	239	6.6	7.3	6.4	9.7	71	86	0.477	0.015	0.003	0.014	0.027	0.006
Brid River 2.6 km u/s tidal limit	8	17	20	134	157	6.6	7.2	9.2	11.3	89	99	1.204	0.700	0.003	0.023	0.052	0.008
Carlton River at tidal limit	8	19	14	672	1398	7.3	8.1	8.6	11.4	85	104	0.742	0.014	0.003	0.015	0.024	0.005
Clyde River d/s Lake Crescent	6	16	175	117	135	6.5	7.4	8.3	11.0	86	106	3.500	0.566	0.003	0.115	0.175	0.005
Coal River at Baden	6	16	9	274	558	6.7	7.6	6.5	9.4	61	89	0.838	0.003	<0.002	0.012	0.033	0.004
Coal River at Richmond	9	18	6	651	981	7.5	8.0	7.5	10.7	74	103	0.789	0.021	0.002	0.017	0.024	0.004
Coal River d/s Craigbourne Dam	9	17	3	436	509	7.9	8.6	9.4	11.8	94	108	0.923	0.074	0.004	0.024	0.030	0.007
Douglas River u/s Tasman Highway	9	17	5	88	121	7.0	7.6	9.4	11.2	91	104	0.267	0.172	<0.002	0.012	0.010	0.005
Duck River u/s Scotchtown Rd	10	16	23	277	512	6.8	7.8	7.0	9.2	70	83	1.684	0.557	0.022	0.153	0.260	0.074
Esperance River at Dover water supply	7	14	7	60	80	5.8	7.2	10.0	12.2	97	104	0.348	0.006	0.004	0.014	0.014	0.004
Flowerdale River at Moorleah	8	16	9	89	133	6.1	7.3	9.0	11.2	89	98	0.548	0.207	0.004	0.014	0.020	0.004
George River at St Helens water supply	7	15	5	72	80	6.2	6.9	9.0	11.5	89	99	0.508	0.272	0.002	0.022	0.022	0.005
Great Forester River 2km u/s Forester Rd bridge	8	15	11	93	99	6.3	6.9	9.1	11.0	89	95	1.036	0.595	0.004	0.022	0.046	0.010
Great Forester River at Prosperity Rd	7	15	9	90	105	6.3	7.0	9.5	11.3	92	100	1.600	1.030	0.011	0.059	0.071	0.024
Huon River at Judbury	7	14	3	59	104	6.4	7.5	9.5	12.1	92	104	0.275	0.007	0.004	0.016	0.009	0.004
Huon River u/s Frying Pan Creek	7	14	4	61	109	6.2	7.5	9.8	12.1	94	102	0.263	0.006	0.004	0.017	0.010	0.004
Jackeys Creek d/s Jackeys Marsh	6	13	3	43	57	6.2	7.2	9.0	11.7	91	101	0.446	0.214	<0.002	0.014	0.015	0.005
Jordan River at Mauriceton	8	18	7	868	1682	7.8	8.1	8.0	10.9	80	101	0.920	0.023	<0.002	0.014	0.032	0.006
Leven River at Bannons bridge	8	18	4	69	166	6.5	7.7	9.4	11.4	94	103	0.442	0.200	0.003	0.013	0.012	0.004

Site name	Physical or chemical indicator and recommended site-specific trigger value																
	Temperature ° C		Turbidity NTU	EC µS/cm		pH		DO mg/L		DO % saturation		TN mg/L	NO_3 as N mg/L	NO_2 as N mg/L	NH_3 as N mg/L	TP mg/L	DRP as P mg/L
	20th	80th	80th	20th	80th	20th	80th	20th	80th	20th	80th	80th	80th	80th	80th	80th	80th
Liffey River at Carrick	7	17	8	51	77	6.5	7.3	8.2	11.6	85	97	0.427	0.186	<0.002	0.019	0.021	0.004
Little Swanport River 3km u/s Tasman Highway	8	20	6	484	799	7.5	8.2	8.8	11.8	91	106	0.647	0.051	<0.002	0.013	0.016	0.005
Little Swanport River d/s Eastern Marshes Rivulet	7	17	6	722	1075	7.4	7.9	8.2	10.9	84	101	0.960	0.029	<0.002	0.011	0.018	0.005
Macquarie River at Trefusis	7	18	21	100	167	7.0	7.6	8.7	11.6	90	101	0.628	0.008	<0.002	0.021	0.027	0.005
Macquarie River 1.25 km u/s Elizabeth River	8	19	10	208	336	7.2	7.8	8.8	11.3	86	101	1.208	0.005	0.002	0.023	0.075	0.004
Macquarie River d/s Elizabeth River	8	20	14	124	277	6.9	7.4	8.9	11.3	91	104	0.559	0.014	0.002	0.015	0.028	0.005
Meander River at Strathbridge	7	18	7	65	128	6.6	7.4	7.5	11.2	83	96	0.587	0.256	0.003	0.020	0.024	0.007
Meredith River at Swansea	7	19	4	157	316	6.9	7.6	8.8	11.4	88	101	0.276	0.054	<0.002	0.014	0.010	0.005
Mersey River at Latrobe	8	19	5	131	170	7.1	8.1	9.6	11.6	93	105	0.638	0.393	0.003	0.014	0.014	0.005
Montagu River at Stuarts Rd	10	16	16	385	731	7.0	8.0	7.4	9.2	74	85	2.028	0.458	0.024	0.082	0.295	0.136
Nelson River at Temma Rd bridge	9	17	5	128	211	4.0	4.8	7.5	11.0	79	97	0.745	0.003	0.012	0.032	0.018	0.004
Nile River at Deddington	6	16	2	35	60	6.7	7.5	9.5	11.7	94	101	0.203	0.104	<0.002	0.011	0.008	0.003
North Esk River at Ballroom	6	14	7	60	76	6.4	7.4	9.7	11.5	91	102	0.430	0.216	<0.002	0.013	0.021	0.006
Pipers River d/s Yarrow Creek	9	17	15	145	254	6.7	7.2	8.3	11.2	86	98	0.702	0.167	0.003	0.020	0.029	0.006
Prosser River u/s lower dam	7	19	15	312	666	7.2	7.7	8.2	11.4	84	97	0.748	0.105	0.003	0.018	0.023	0.005
Ransom River at Sweet Hills	7	13	3	63	70	6.0	7.0	10.0	11.6	92	100	0.449	0.228	0.002	0.015	0.015	0.004
Ringarooma River at Moorina	8	16	4	67	74	6.1	6.9	9.5	11.3	93	100	0.892	0.614	0.002	0.017	0.018	0.004
Rubicon River at tidal limit	8	19	24	176	343	7.0	7.8	8.7	11.9	89	104	1.300	0.465	0.007	0.024	0.077	0.015
Scamander River u/s Scamander water supply	7	18	3	110	131	6.7	7.3	8.9	11.7	88	101	0.498	0.290	<0.002	0.016	0.011	0.004
Snug Rivulet u/s Snug Tiers Rd bridge	6	16	4	76	125	6.0	6.9	9.0	12.2	90	101	0.440	0.018	0.005	0.017	0.014	0.004
South Esk River at Perth	8	21	7	90	144	6.6	7.4	8.3	10.9	87	98	0.377	0.110	<0.002	0.011	0.017	0.004
St Pauls River u/s South Esk River	8	19	9	115	241	6.7	7.5	8.8	11.2	87	102	0.337	0.004	<0.002	0.012	0.014	0.004
Swan River at Hardings Falls	7	14	9	71	100	6.9	7.6	9.3	11.7	90	102	0.161	0.030	<0.002	0.010	0.009	0.004
Swan River at the Grange	9	19	4	107	185	6.8	7.5	8.9	10.9	91	103	0.456	0.281	<0.002	0.014	0.010	0.004
Tooms River d/s Tooms Lake	7	17	8	77	87	7.0	7.7	9.0	11.2	90	103	0.709	0.005	<0.002	0.017	0.045	0.003
Tyenna River at Newbury	7	11	7	95	178	7.2	8.0	10.3	12.0	93	104	0.362	0.074	0.002	0.010	0.017	0.004
Welcome River at Woolnorth	10	17	13	561	1717	7.1	7.9	6.6	8.8	68	81	1.718	0.177	0.015	0.048	0.158	0.062
White Kangaroo Rivulet	9	17	7	402	1146	7.5	7.8	8.2	10.6	81	99	0.913	0.476	0.007	0.016	0.015	0.006

4.1 *Indicator-specific considerations*

This section discusses issues specific to certain indicators which should be considered in the interpretation of the site-specific trigger values in Table 2. This report does not provide detailed indicator definitions or information on the effects of changes to water quality indicators, as this information is well-discussed elsewhere in the literature. ANZECC (2000b) provides comprehensive fact sheets on key water quality indicators, including those monitored under the BWQMP.

4.1.1 Diurnal and seasonal fluctuations

Many water quality parameters vary naturally on a diurnal (daily) or seasonal basis. Temperature and dissolved oxygen are two parameters that exhibit considerable diurnal and seasonal fluctuations at BWQMP sites, and implications for interpreting the site-specific trigger values for these indicators are considered below.

<u>Temperature</u>

In addition to natural diurnal and seasonal cycles, water temperature is also highly site-specific, and will vary depending on depth, flow, shade and other local conditions. The site-specific trigger values provided for temperature in Table 2 simply provide a range of temperatures likely to be encountered at each site as part of routine daytime monthly monitoring. This range does not take into account seasonal variation (e.g. a value recorded in winter that is significantly higher than normal winter values is unlikely to exceed the site specific trigger value due to the inclusion of summer values in the dataset). Professional judgement should be used in the interpretation of the temperature trigger values.

ANZECC (2000a) recommends the development of seasonal trigger values for indicators that exhibit seasonal variation. At the time of data analysis, the BWQMP dataset did not contain a sufficient number of data points to calculate seasonal trigger values. A discussion of sample size and percentile estimation by Goudey (1999) demonstrates that at least 14 data values are needed to derive a 95% confidence interval for the 80^{th} percentile of the data distribution. If 90^{th} percentiles are required, a minimum of 29 data values would be necessary to achieve 95% confidence intervals. This would suggest that a minimum of 5 years of monthly sampling data should be used for the derivation of seasonal trigger values based on 80^{th} percentiles. This analysis could therefore be conducted in 2009.

The Queensland EPA (2006) also suggests that in ecological terms, the most important aspects of temperature are daily maximum and daily variation in temperature, and that guidelines should be expressed in these terms. Similarly, Davies-Colley (2000) used seasonal temperature maxima to derive trigger values for temperature in New Zealand rivers. These options could be explored for the 37 BWQMP sites at which temperature is monitored continuously.

Dissolved oxygen

The level of dissolved oxygen in the water is affected by temperature, biological activity (photosynthesis, respiration, decomposition), flow, salinity and atmospheric pressure. Daily variations in dissolved oxygen are primarily related to biological activity, with lower levels typically occurring at night when photosynthesis ceases to produce oxygen and respiration and decomposition continue to consume it. The Queensland Water Quality Guidelines suggest that dissolved oxygen levels at night should not be more than 10-15% less than daytime values. (Queensland EPA 2006), however diurnal fluctuations may be substantially larger in highly productive systems (ANZECC 2000b). As with temperature, the site-specific trigger values for dissolved oxygen provided in Table 2 apply to daytime conditions.

Dissolved oxygen concentrations are also highly dependent on water temperature, which results in seasonal variations in dissolved oxygen levels. The amount of gas that can dissolve in water is inversely proportional to the water temperature. Put simply, the warmer the water, the less dissolved oxygen it can hold. A clear seasonal cycle of higher winter and lower summer dissolved oxygen concentrations (mg/L) is evident for many BWQMP sites, and as such the development of seasonal trigger values may also be appropriate for this indicator. As discussed for temperature, the development of robust seasonal trigger values may be possible once a larger dataset becomes available through ongoing monitoring.

4.1.2 Ammonium and ammonia

Confusion sometimes exists regarding the use and meaning of the terms ammonia and ammonium. Ammonium (NH_4^+) is the ionised form of the gas ammonia (NH_3). Ammonium a relatively harmless, bioavailable component of the nitrogen cycle, and is one of a range of nutrients that may indicate ecosystem stress at elevated levels. Ammonia is directly toxic to aquatic biota at high concentrations (Boulton and Brock 1999; ANZECC 2000c). ANZECC (2000a) provides a default trigger value for the physico-chemical stressor ammonium, and a separate toxicant guideline trigger value for the toxic form, ammonia.

Under ambient conditions, ammonium and ammonia shift in equilibrium with each other according to the following equation: $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$. The major factor that determines the proportion of ammonia and ammonium in water is pH, with temperature an additional influencing factor (Boulton and Brock 1999; Sawyer 2008). The relationship between pH, temperature and the proportion of ammonia and ammonium in water is illustrated in Table 3. At pH < 9 ammonium is the dominant form, with ammonia becoming more common at higher pH and higher temperatures.

Table 3. Percentage of ammonia as a proportion of total ammonium plus ammonia in freshwater at different pH and temperatures. Data sourced from American Fisheries Society (2008).

pH	Temperature (° C)					
	5	**10**	**15**	**20**	**25**	**30**
5	<0.01	<0.01	<0.01	<0.01	0.01	0.01
6	0.01	0.02	0.03	0.04	0.06	0.08
7	0.12	0.19	0.27	0.39	0.56	0.80
8	1.2	1.8	2.7	3.8	5.4	7.4
8.5	3.8	5.5	7.9	11.1	15.2	20.2
9	11.1	15.7	21.4	28.4	36.2	44.5
10	55.5	65.0	73.2	79.8	85.0	88.9
11	92.6	94.9	96.5	97.5	98.3	98.8

Nutrient samples collected under the BWQMP are analysed by the Analytical Services Laboratory of Tasmania. The laboratory method analyses the total amount of ammonium-N plus ammonia-N in the water by buffering the sample to increase pH and then testing for the ammonia form. The result is therefore reported as ammonia-N, but in fact accounts for both ammonium-N and ammonia-N. If the original pH of the water sample was < 9, ammonium would in fact have been the dominant form. Nevertheless, the DPIW site-specific trigger value is presented for the ammonia form (as a physico-chemical stressor). This is to ensure consistent terminology between the reported laboratory data and the site-specific trigger value (i.e. a reported ammonia value will be compared with a trigger value for ammonia) however it should be remembered that both the reported data and the trigger value actually refer to ammonia-N plus ammonium-N in the sample.

5 Applying the DPIW site-specific trigger values

ANZECC (2000a; 2000c) provides detailed guidance on water quality data analysis options, including a recommended approach for comparing monitoring data with trigger values. This recommended approach is summarised below, along with a discussion of other issues which should be considered in the application of the DPIW site-specific trigger values.

5.1 Assessing ongoing monitoring data against site-specific trigger values

The trigger value approach is intended to provide an alert of a *potential* or *emerging* change that should be followed up (ANZECC 2000a). Exceedances of site-specific trigger values by future monitoring data will provide DPIW with an early warning that water quality at that site is *potentially* deteriorating from 2003-2006 status, and thus trigger further investigation.

When considering exceedances of trigger values, it is important to pay attention to both the magnitude of the exceedance (how different the sample is value from the trigger value) and the frequency of exceedances (the number of times the trigger is exceeded within a given monitoring period). The Queensland Water Quality Guidelines (Queensland EPA 2006) note that trigger exceedance can occur in a variety of ways (Figure 2), and that this may guide further investigation and influence the nature of the response or management action.

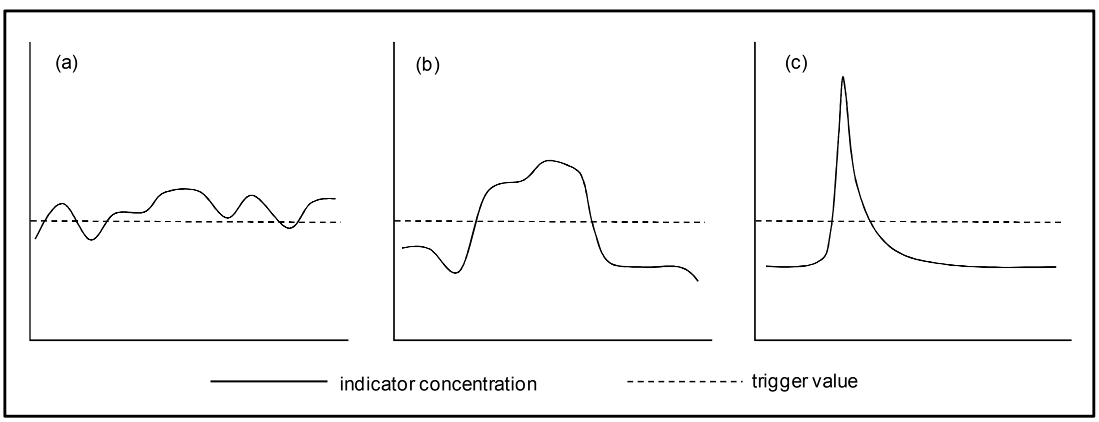

Figure 2. Three different trigger value exceedance situations (adapted from Queensland EPA 2006).

Scenario (a) illustrates a chronic long-term exceedance situation, where exceedance of the trigger value is relatively small but consistent. Scenario (b) shows a medium-term exceedance situation, in which intermittent periods or exceedance may be due to natural or anthropogenic causes. Short-term exceedance is illustrated in scenario (c), where the system has experienced stressor levels well above the trigger value for a short time. Again this may occur naturally during flood events, but may be exacerbated by human activities in catchments (Queensland EPA 2006).

It also is important to note that there are some inherent problems with comparing an individual sample value to the site-specific trigger value. It is clear that even if future monitoring data (called the test data) has an identical distribution to the 2003-2006 dataset (called the reference data, not to be confused with reference condition), the chance of a single observation exceeding the 80th percentile of the reference data is 20% (ANZECC 2000). In other words, even if water quality at a site remains stable, an individual sample from this site may be expected to exceed the site-specific trigger value 20% of the time. ANZECC (2000a) therefore recommends that for a particular parameter, the median of *n* independent samples taken at the test site should be compared to the trigger value to determine whether an exceedance has occurred. ANZECC (2000a) does not specify a fixed sample size for the test data, but notes that larger sample sizes will reduce the chance of Type I (false triggers) and Type II (false no-triggers) errors. It is therefore preferable to compare a set of *n* independent test samples against a trigger value.

The ANZECC guidelines recommend the use of control charts for comparing ongoing monitoring data with trigger values. For example, the control chart shown in Figure 3 enables a month-by-month comparison of the test site against a relevant trigger value, with associated recommended actions. For BWQMP sites, because only one sample is collected per month, the implications discussed above of comparing a single reading to a trigger value need to be kept in mind. Alternatively, the test site median could be a “rolling median” produced from a given time period of ongoing monitoring data (for example the last 12 months data), updated each month by the most recent sample value. The site-specific trigger value would remain static (defined by the 80th percentile of the 2003-2006 dataset), as the desired comparison is with the status of each site in 2003-2006. The control chart is useful in that minimal data processing is required, and the visual representation of results aides the early detection of possible trends, seasonality or other anomalies (ANZECC 2000c).

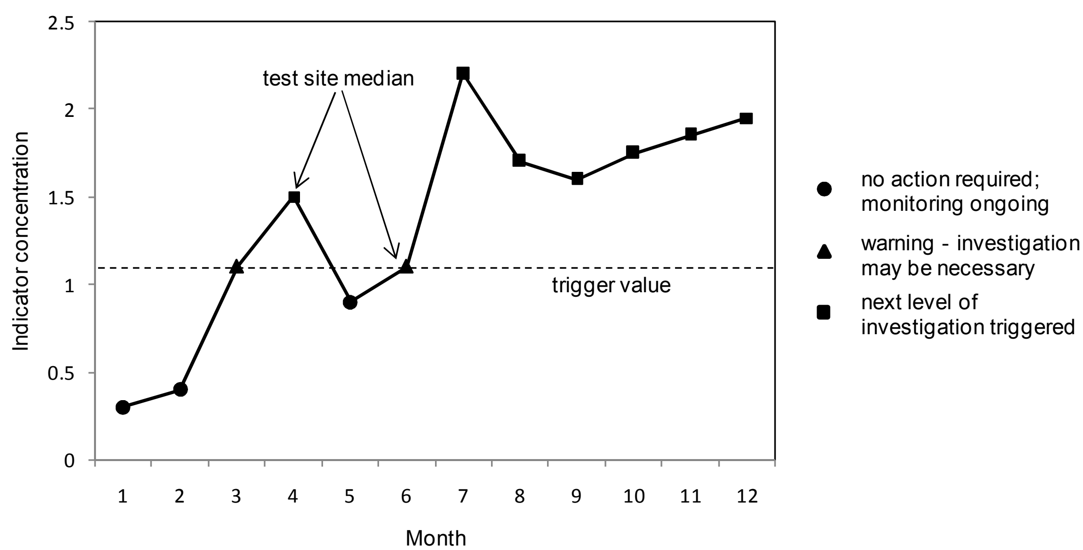

Figure 3. Control chart showing test data plotted against trigger value and time, and recommended actions (adapted from ANZECC 2000a).

An additional option for comparing future BWQMP monitoring data against site-specific trigger values is the use of box-and-whisker plots. As shown in the example provided in Figure 4, the box-and-whisker plot enables a visual assessment of the test data distribution over a set time period (e.g.12 months) against the relevant site-specific trigger value. Rather than month-by-month assessments, these plots may be useful for annual comparisons of longer-term data, allowing statistical tests to compare between annual datasets if required.

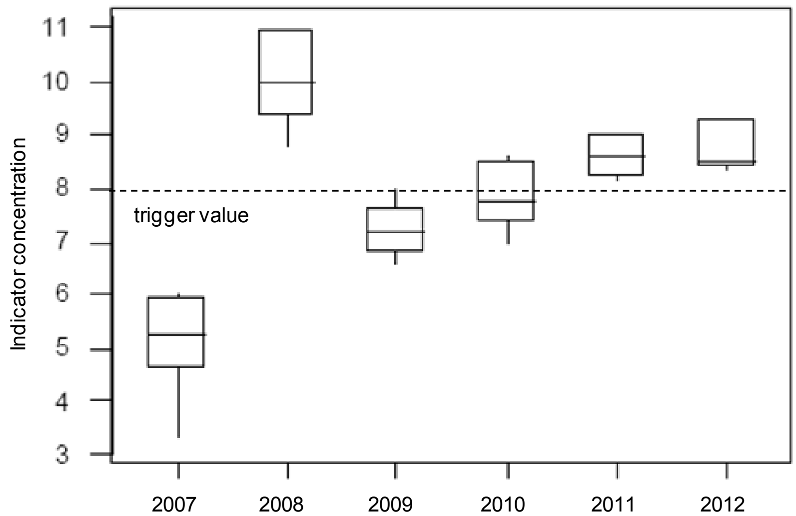

Figure 4. Example of box and whisker plot comparing test data to trigger value. Middle line represents dataset median, bottom and top edges of box represent first and third quartiles (25th and 75th percentiles) or chosen dataset percentiles (eg 20th and 80th), and vertical lines represent maximum and minimum dataset boundaries.

5.2 Using DPIW site-specific trigger values as low-risk trigger values

Section 3.3 identifies some BWQMP sites that represent reference (minimally modified) condition for slightly to moderately disturbed ecosystems, and as such the site-specific trigger value derived for these sites may also act as a low-risk trigger value for that site. While some site-specific trigger values for BWQMP reference sites may be less conservative than the default ANZECC low-risk trigger values, these levels are considered 'natural' (or as natural as possible) for those sites. Recommended data analysis methods for comparing test data with a low-risk trigger value are the same as those presented in Section 5.1.

The site-specific trigger value for a BWQMP site identified as a potential reference condition site may also be applied as a default low-risk trigger for the catchment in which that site is located. This should be done with some caution keeping in mind that the DPIW site-specific trigger value has been developed from data collected at particular point on the river and that conditions may be naturally variable elsewhere in the catchment.

If a low-risk trigger value is required for a catchment without a reference condition site, it may be possible to apply the trigger value derived for a reference condition site from a catchment with similar characteristics. The following factors should be considered before a site-specific trigger value from a BWQMP reference condition site is applied as a low-risk trigger to a different catchment (ANZECC 2000a):

- catchments should be from the same biogeographic and climatic region;
- catchments should have similar geology, soil types and topography;
- catchments should contain a similar range of habitats.

The low-risk trigger value may provide an 'aspirational' target for water quality indicators in appropriate impacted sites or catchments. In this sense, they may provide information useful for defining the water quality status to be achieved in a similar ecosystem. If a low-risk trigger value is required for a catchment for which there is no suitable DPIW site-specific trigger value from a reference condition site, the ANZECC (2000a) default low-risk trigger values for Tasmanian rivers should be applied.

5.3 High flow events

During periods when there is minimal contribution of water from overland flow (i.e. surface runoff), river flow is largely supplied by deep subsurface and groundwater sources and is termed baseflow. The DPIW site-specific trigger values were developed from monthly sample data that is generally representative of river condition under normal baseflows. While some samples may have occurred on either the rise or fall of high flow events, this data was collected as part of a monthly sampling regime and considered representative of the variation which may be expected during routine site visits by DPIW. Data collected using automated flood samplers was not included in the trigger value dataset as it is indicative of high flow events. Continuous monitoring data was also not included in the trigger value dataset, as this data is also closely correlated with flow, and requires a separate statistical approach.

Subsequently, it is recommended that the DPIW site-specific trigger values are only compared with data collected under a routine sampling regime that reflects normal baseflow conditions. Comparison of continuously recorded data with trigger values developed from a monthly dataset is inappropriate, and comparison of data collected from high flow events is also generally not recommended due to the issues discussed below.

During baseflow conditions, if there are no other directly influencing factors (e.g. point source contributions), the physical and chemical characteristics of the water remain relatively consistent (Queensland EPA 2006). Short-term but often quite large fluctuations in water quality parameter concentrations are commonly observed during flood events due to the contribution of overland flow. For some indicators (e.g. turbidity) overland flow may substantially increase concentration during flood events (see Figure 2 c), due to the large quantities of natural or anthropogenic pollutants picked up through surface runoff (Queensland EPA 2006). For other indicators (e.g. electrical conductivity), overland flow may result in a significant short-term decrease in concentration due to a diluting effect. These fluctuations occur naturally and will often be dependent on river characteristics, however the magnitude of the fluctuation is likely to be greater in a more heavily modified catchment (Queensland EPA 2006).

Although such fluctuations may still have an impact on ecosystem condition, it is clearly not appropriate to apply trigger values derived from baseflow conditions during short-term flood events. This is especially true in the case of the DPIW site-specific trigger values, where the primary purpose of the trigger value is to assess for any departure from status in 2003-2006. For some indicators, where continuously monitored or high-flow data is available, it may be appropriate to give future consideration to the development of trigger values for high-flow events. ANZECC (2000a) suggests the use of load-based guidelines, or the possibility of flow-weighted trigger values may be investigated, as have been developed by DPIW (2007) for turbidity in some catchments.

6 Review of the DPIW site-specific trigger values

This document has highlighted several areas where the DPIW site-specific trigger values may be updated or improved as new data becomes available or with additional data analyses. Some of the options that may be worth investigating are listed below:

- Statistical methods for comparing ongoing monitoring data with trigger values may be refined or modified once a process for reporting against trigger values has commenced, or as new software/methods are investigated.
- After a certain time period (e.g. 5 years) the site-specific trigger values may be reviewed in conjunction with a trend analysis. If an indicator shows an improving trend it may be appropriate to update the trigger value to reflect the improved status of the site.
- Further reference condition sites and/or data may be sourced (externally or internally) to expand the range of catchments for which a low-risk trigger value could be developed.
- Seasonal trigger-values may be developed for relevant indicators once a longer dataset becomes available.
- Load-based or flow-weighted trigger values may be developed for those sites and indicators for which high-flow and/or continuous monitoring data is available.

7 References

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Appendix 1

DPIW Baseline Water Quality Monitoring Program sites, mapping coordinates (GDA94), and land use information used to assist identification of reference sites. Land use information estimated from BRS (2006)

Site Name	Site No.	Easting	Northing	Main landuses 0-10km upstream of site (categories based on BRS (2006) landuse layer for Tasmania)	Main landuses 10-20km upstream of site (categories based on BRS (2006) landuse layer for Tasmania)
Allans Rivulet u/s Taranna	2216	572412	5230783	Production forestry; national park; other conservation.	N/A
Ansons River d/s Big Boggy Creek	2214	602312	5455383	National park; minimal use; production forestry; dryland grazing - modified pasture	Dryland grazing - modified pasture; production forestry
Apsley River u/s Coles Bay Rd Bridge	2204	602534	5356269	Dryland grazing - modified pasture; residual native cover; other conserved area; production forestry (outer catchment)	Conservation; dryland grazing - modified pasture; production forestry (outer catchment)
Back Creek u/s Wilmores Lane	18219	508285	5392874	Dryland grazing - modified pastures; irrigated cropping; intensive uses	Dryland grazing - modified pastures; irrigated cropping; intensive uses
Black River at South Forest	14213	356612	5474023	Dryland grazing - modified pastures; production forestry; plantation forestry (outer catchment)	Dryland grazing - modified pastures; production forestry; plantation forestry (outer catchment)
Break O'Day River at Killymoon	191	589261	5395024	Dryland grazing - modified pastures; irrigated cropping; residual native cove; production forestry (outer catchment)	Dryland grazing - modified pastures; irrigated cropping; residual native cover; production forestry (outer catchment).
Brid River 2.6 km u/s tidal limit	19200	531324	5458842	Dryland grazing - modified pasture; production forestry; plantation forestry; residual native cover; other conserved area; irrigated cropping (outer catchment)	Dryland grazing - modified pasture; production forestry; plantation forestry; irrigated cropping; residual native cover; other conserved area
Carlton River at tidal limit	2209	557612	5253883	Residual native cover; dryland grazing - modified pasture; plantation forestry	Production forestry; residual native cover ; dryland grazing - modified pasture; plantation forestry; conservation (buffers)
Clyde River d/s Lake Crescent	4202	511657	5331368	Residual native cover; grazing - natural vegetation; production forestry. Immediately d/s Lake Crescent. Very high turbidity and nutrient values due to resuspension issues in Lake Crescent	N/A
Coal River at Baden	3203	537327	5302121	Dryland grazing - modified pasture; dry and irrigated cropping; production forestry; plantation forestry; grazing - natural vegetation	N/A

Coal River at Richmond	3208	536139	5268297	Dryland grazing - modified pasture; residential; irrigated cropping; residual native cover and conservation (outer catchment)	Dryland grazing - modified pasture; irrigated cropping; residential; residual native cover and conservation (outer catchment)
Coal River d/s Craigbourne Dam	3206	533227	5288443	Immediately downstream large dam. Dryland grazing - modified pasture; residual native cover; conservation; irrigated cropping; production forestry; plantation forestry	Dryland grazing - modified pasture; residual native cover; conservation; irrigated cropping; production forestry; plantation forestry
Douglas River u/s Tasman Highway	2218	604106	5373717	National park; residual native cover; dryland grazing - modified pasture	National park
Duck River u/s Scotchtown Rd	14214	341556	5473776	Dryland grazing - modified pasture; residual native cover; production and plantation forestry and conservation (outer catchment)	Dryland grazing - modified pasture; residual native cover; production and plantation forestry in outer catchment
Esperance River at Dover water supply	7200	497212	5202083	Dryland grazing - modified pasture; production forestry; conservation - buffers	Production forestry; conservation (mainly buffers); national park
Flowerdale River at Moorleah	14215	382992	5463913	Dryland grazing - modified pasture; residual native cover; irrigated cropping; grazing natural vegetation; plantation forestry; production forestry; conservation	Dryland grazing - modified pasture; plantation forestry; production forestry; residual native cover; irrigated cropping; grazing natural vegetation; conservation
George River at St Helens water supply	2205	601933	5428387	Dryland grazing - modified pasture; production forestry; conservation; residual native cover	Dryland grazing - modified pasture; production forestry; plantation forestry; conservation; residual native cover
Great Forester River 2km u/s Forester Rd Bridge	19201	551446	5448685	Production forestry; irrigated modified pasture; irrigated cropping; conservation	Mix of: Production forestry; irrigated modified pasture; irrigated cropping; conservation
Great Forester River at Prosperity Rd	19224	547060	5438263	Production forestry; irrigated modified pasture; irrigated cropping; conservation; plantation forestry	Production forestry; irrigated modified pasture; irrigated cropping; conservation; plantation forestry
Huon River at Judbury	635	494126.1	5239163	Dryland grazing - modified pastures; residual native cover; plantation forestry; production forestry	Residual native cover; production forestry; other conservation (buffers)
Huon River u/s Frying Pan Creek	119	487128	5235337	Residual native cover; production forestry; other conservation (buffers)	Production forestry; other conservation (mainly buffers); national park ~20km u/s of this site
Jackeys Creek d/s Jackeys Marsh	18221	471428	5386289	Grazing - natural vegetation; conservation; production forestry	N/A
Jordan River at Mauriceton	4201	510814	5291587	Dryland grazing - modified pasture; grazing natural vegetation; plantation forestry; irrigated cropping	Dryland grazing - modified pasture; grazing natural vegetation
Leven River at Bannons Bridge	14207	382992	5463903	Dryland grazing - modified pasture; irrigated cropping; conservation; plantation forestry; residual native cover; grazing natural vegetation; production forestry (outer catchment)	Conservation; dryland plantation forestry; production forestry; dryland grazing - modified pasture

Liffey River at Carrick	164	500151	5401898	Dryland grazing - modified pasture; irrigated cropping; irrigated modified pasture; grazing - natural vegetation	Dryland grazing - modified pasture; irrigated cropping; irrigated modified pasture; grazing - natural vegetation
Little Swanport River 3km u/s Tasman Highway	2235	574385	5312673	Residual native cover; dryland grazing - modified pasture; conservation; production forestry (outer catchment)	Residual native cover; dryland grazing - modified pasture; conservation; production forestry
Little Swanport River d/s Eastern Marshes Rivulet	2212	559157	5311495	Residual native cove; dryland grazing - modified pasture; production forestry; grazing natural vegetation	Residual native cove; dryland grazing - modified pasture; production forestry; grazing natural vegetation; plantation forestry
Macquarie River 1.25 km u/s Elizabeth River	18313	535256	5357815	Grazing - natural vegetation; dryland grazing - modified pastures; irrigated cropping	Grazing - natural vegetation; dryland grazing - modified pastures; irrigated cropping; residential; plantation forestry
Macquarie River at Trefusis	18217	549760	5330003	Grazing natural vegetation; residual native cover; dryland grazing - modified pasture; production forestry	Production forestry; conservation; residual native cover; grazing natural vegetation
Macquarie River d/s Elizabeth River	18312	532357	5359990	Grazing - natural vegetation; dryland grazing - modified pastures; irrigated cropping	Grazing - natural vegetation; dryland grazing - modified pastures; irrigated cropping; residential; plantation forestry
Meander River at Strathbridge	852	492128	5407161	Dryland grazing - modified pasture; irrigated cropping	Dryland grazing - modified pasture; residual native cover; grazing natural vegetation; production forestry; plantation forestry; residential; irrigated cropping
Meredith River at Swansea	2208	585926	5336176	Residual native cover; grazing - natural vegetation; conservation; dryland grazing - modified pastures	Conservation; production forestry
Mersey River at Latrobe	447	451627	5430621	Plantation forestry; dryland grazing - modified pasture; conservation; production forestry; irrigated cropping; irrigated modified pasture; residential	Plantation forestry; dryland grazing - modified pasture; conservation; production forestry; irrigated cropping; irrigated modified pasture; residual native cover
Montagu River at Stuarts Rd	14200	325451	5483133	Dryland grazing -modified pasture; plantation forestry; residual native cover; irrigated modified pasture; conservation; production forestry (outer catchment)	Irrigated modified pasture; conservation; residual native cover; production forestry (outer catchment)
Nelson River at Temma Rd Bridge	1307	305943	5444260	Conservation; production forestry	Conservation; production forestry (outer catchment)
Nile River at Deddington	25	534200	5394264	Dryland grazing - modified pasture; residual native cover; conservation; production forestry; small amount plantation forestry (outer catchment)	Conservation/national park; production forestry
North Esk River at Ballroom	76	532086	5406166	Dryland grazing - modified pasture; production forestry; residual native cover	Dryland grazing - modified pasture; production forestry; plantation forestry; conservation
Pipers River d/s Yarrow Creek	19204	509605	5453784	Irrigated cropping; production forestry; dryland grazing - modified pasture; residual native cover; plantation forestry	Plantation forestry; dryland grazing - modified pasture; residual native cover; production forestry

Prosser River u/s lower dam	2202	568323	5288141	Residual native cover; dryland grazing - modified pasture; irrigated cropping; residential	Residual native cover; dryland grazing - modified pasture; production forestry; plantation forestry
Ransom River at Sweet Hills	2217	589940	5433067	Production forestry; dryland grazing - modified pasture; conservation; natural vegetation	N/A
Ringarooma River at Moorina	30.2	572742	5446858	Production forestry; plantation forestry; dryland grazing - modified pasture; residual native cover; irrigated modified pasture	Production forestry; plantation forestry; dryland grazing - modified pasture; irrigated modified pasture; irrigated cropping; residual native cover; residential
Rubicon River at tidal limit	17200	463562	5433606	Plantation forestry; dryland grazing - modified pasture; production forestry; irrigated cropping; residual native cover; grazing natural vegetation; conservation	Plantation forestry; dryland grazing - modified pasture; production forestry; irrigated modified pasture; grazing natural vegetation
Scamander River u/s Scamander water supply	2206	598549	5411083	Production forestry; conservation (buffer zones); dryland grazing - modified pasture	Production forestry; conservation (mainly buffers)
Snug Rivulet u/s Snug Tiers Rd Bridge	5202	519326	5231246	Protected landscape; residual native cover; dryland grazing - modified pastures; production forestry	N/A
South Esk River at Perth	181	517043	5394937	Dryland grazing - modified pasture; intensive uses; irrigated cropping	Irrigated cropping; dryland grazing - modified pasture; intensive uses
St Pauls River u/s South Esk River	18311	559682	5373269	Dryland grazing - modified pasture; residual native cover; conservation; irrigated cropping	Dryland grazing - modified pasture; residual native cover; conservation; irrigated cropping; intensive uses
Swan River at Hardings Falls	2219	591389	5366542	Conservation (inc buffers); production forestry; residual native cover	Headwaters ~ 12km upstream of site; in conservation/production forestry
Swan River at the Grange	2200	589102	5344562	Dryland grazing - modified pasture; irrigated cropping; residual native cover	Dryland grazing - modified pasture; residual native cover; conservation and production forestry (outer catchment)
Tooms River d/s Tooms Lake	18206	563988	5326227	Immediately d/s Tooms Lake. Conservation; production forestry	N/A
Tyenna River at Newbury	499	474681	5269961	Plantation forestry; production forestry; dryland grazing - modified pasture; residual native cover; residential; conservation (outer catchment)	Plantation forestry; production forestry; residual native cover; conservation (outer catchment)
Welcome River at Woolnorth	14223	310552	5483543	Irrigated modified pasture; dryland grazing - modified pasture; production forestry; residual native cover	Dryland grazing - modified pasture; production forestry
White Kangaroo Rivulet	3209	537473	5281554	Dryland grazing - modified pasture; residual native cover; conservation; irrigated cropping (outer catchment)	Residual native cover; dryland gazing; conservation; production forestry; plantation forestry