DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Tasmania

Index of River Condition for the

Montagu River Catchment

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DPIWE.

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The Department of Primary Industries, Water and Environment

The Department of Primary Industries, Water and Environment 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.

Summary

This report provides a 'snapshot' picture of river condition, in relation to riparian condition, physical in-stream habitat and in-stream structures within the Montagu River catchment. The approach adopted for this study is a derivation of the original Index of River Condition (IRC) method utilised in previous 'State of River' reports by the Department (eg: Nelson, 1999a). As the parameters of hydrology, water quality, and aquatic ecology are extensively reported in other sections of 'State of Rivers' reports, the Index of River Condition is now focused on the parameters of physical form and stream-side zone. In addition, a new element related to in-stream structures has been added to the condition assessment.

Field data collection of IRC parameters occurred at 18 representative sites within the Montagu River catchment. Eleven of these were located on the mainstream Montagu River and 7 on tributary streams. Eighteen in-stream structures were assessed separately at relevant locations throughout the catchment.

The physical form sub-index ranged in condition from excellent to very poor for both the mainstream and tributaries. Lower values were recorded for sites that occur within agricultural areas. Reduced substrate heterogeneity, reduced substrate stability, elevated erosion levels, and the lack of Coarse Woody Debris (CWD) were factors causing the lower condition scores and indicate that these issues require addressing in relation to management of in-stream integrity for the Montagu catchment.

Ratings for the stream-side zone sub-index also ranged in condition from excellent to very poor within the Montagu catchment, and were lower in agricultural areas. These findings indicate that non-vegetated or poorly vegetated riparian zones, and uncontrolled stock access to river banks are impacts that need addressing in relation to riparian zone management for the Montagu catchment.

Eight artificial structures were identified that cause some alteration of hydrological (fish passage) conditions within the mainstream and/or major tributaries. These were found to cause varying degrees of departure from 'ideal' conditions as a result of structure design. On average farm dams resulted in an extensive modification of condition, whilst bridges and culverts resulted in a partial modification of condition. The assessment suggests that fish movement may be influenced by artificial structures within the catchment, and this is important as five of the six native fish species known to occur within the catchment are migratory and require unobstructed passage between sea and river to complete their life cycle.

It is evident that riparian (stream-side) zone rehabilitation and management is a significant issue for agricultural areas of the Montagu catchment. The riparian zone was highly altered within the agricultural areas of the catchment and native species were in low proportions and in some cases completely absent. Many of these areas were also infested by weed species. Areas with poor riparian condition should be the focus of future catchment management activities to avoid further degradation, in addition to continued protection of areas that are of high conservation value or of a natural state.

Glossary of Terms

Anadromous	Fish that hatch in fresh water, then migrate to salt water to grow and mature, and inturn migrate back into fresh water to spawn and reproduce.
Catadromous	Fish that migrate from fresh water to salt water to spawn or reproduce.
Coarse Woody Debris (CWD)	Dead or living tree (branch or root system) that has fallen into or is immersed (totally or partially) in a stream. Generally with diameter greater than 10cm and length exceeding 1metre.
Diadromous	Migration between fresh and saltwater (either direction) at a regular life-history phase, but not necessarily to spawn.
Discharge	A volume of water passing a given point in unit time.
Fish passage	The directed movement of a fish past a given point in a stream. Particularly relates to the engineering and biological aspects of restoring free passage at barriers.
Fish passage device	Structure incorporated into a barrier to promote fish movement.
Fishways	Structures that allow for fish to pass barriers.
Pools	Deep, still water , usually within the main river channel.
Riffles	Areas of fast moving, broken water.
Riparian vegetation	Vegetation on the banks of streams and rivers.
Run	Unbroken, moving water.
SIGNAL	**S**tream **I**nvertebrate **G**rade **N**umber – **A**verage **L**evel. Grading based on the tolerance or intolerance of macroinvertebrates to various types of pollution and or disturbance.
Snags	In-stream fine woody debris.
Substrate	The structural elements of the river bed; boulder, cobble etc.
WIMS database	**W**ater **I**nformation **M**anagement **S**ystems database, designed for managing water usage and demand data.

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1. INTRODUCTION

This study has been conducted to provide an assessment of riverine habitat condition within the Montagu catchment. The study has been carried out in association with other studies undertaken by the DPIWE to form the basis of 'State of Rivers' reporting for the catchment.

The Index of River Condition (IRC) has been adopted in Tasmania to provide a picture of the 'overall health' of reaches within a catchment. This was originally achieved through the assessment of hydrology, water quality, aquatic ecology, physical form and stream-side zone condition. The Tasmanian IRC method provided for an index of change from a natural state and is based on similar survey approaches carried out in Victoria (CEAH, 1995) and Queensland (Anderson, 1993). Assessments have been completed for several catchments within Tasmania (Great Forester, Ringarooma, Brid, Pipers, and Mersey catchments) and the method has proven to be useful in assessing the condition of Tasmanian rivers. In addition, the results from IRC assessments in some catchments have been used by community groups to direct rehabilitation activities.

The IRC study has changed since its inception to gather information on physical form, stream-side zone and hydrological connectivity (influence of barriers) as State of River reporting already provides comprehensive assessments of hydrology, water quality and aquatic life (River Health). Previously aquatic life ratings based on SIGNAL assessments (Chessman, 1996) were incorporated into the IRC. The aquatic health of sites in terms of macroinvertebrate community composition is now reported in the Aquatic Ecology section of the "State of Rivers" report using AusRivAS outputs using Tasmanian river health models (Krasnicki *et al*., 2001).

The broad objectives of the Tasmanian Index of River condition are detailed below:

- To identify reaches that have been modified in relation to in-stream condition;
- To identify reaches where the riparian zone has undergone modification;
- To identify hydrological breaks that act as barriers to native fish migration;
- To make recommendations regarding target management areas for in-stream and riparian rehabilitation.

The current methodology is designed to identify reaches within a catchment where habitat modification has occurred. Habitat modification in this case relates to changes to in-stream and riparian vegetation parameters. The approach has been focused to provide more detail on physical river condition via detailed assessment of the riparian zone and in-stream habitat conditions and should not be viewed simply as a truncated version of previous IRC methodologies. It is a tool that is ideal for identifying areas of habitat modification and determining the source of the disturbance. From this assessment specific management issues can be identified not only for individual reaches but the catchment as a whole. The method also provides the basis for long term monitoring of changes in habitat condition as it is intended that future Index of River condition assessments would be conducted every five years. This is the review period currently identified for State of River reporting on Tasmanian catchments.

A detailed assessment of in-stream structures that have the potential to acts as barriers has been incorporated into the study. All structures have been rated on their potential to impede fish passage and their impact on the hydrological connectivity of the system. Changes in hydrological connectivity can be a result of natural features (such as waterfall, rapids) or artificial structures (such as dams, culverts and weirs). This assessment is independent of IRC ratings for physical form and streamside zone scores and therefore is discussed separately.

Fish passage is the term used to describe the ability of fish to pass a point in a stream by directed movement. Eleven of Tasmania's 25 native fish species are migratory and require free passage in order to maintain population diversity. Barriers can therefore have major implications for fish populations with the potential to cause localised extinctions, reduce fish abundance and lower genetic diversity (Thorncraft and Harris, 2000). Fish passage has been adopted as the measure of ecological integrity for this parameter.

Individual ratings for barriers can be applied to particular stream reaches and the cumulative effect of barriers on sites determined. These findings can be used as a basis for future management of development within the catchment, through the determination of the cumulative effect and location of barriers. As fish records are limited for most of the reaches in which artificial barriers occur, caution must be taken in attributing the current pattern of fish distribution to the changes in hydrological connectivity associated with these barriers. As such each individual structure has been assessed on the basis of its effect on hydrological connectivity and it is from this assessment that the likely potential for fish passage has been determined.

Assessment of river condition in this study provides a baseline of information that can be used for comparative purposes to observe changes within the Montagu catchment over time. Ideally this program should be re-run in five years using the same sites to determine if the overall condition of the catchment has improved or declined. This would be particularly useful for community groups in relation to monitoring the success of current and future restoration projects.

2. STUDY AREA

The Montagu River originates in low hills directly south of the Roger River State Reserve at an altitude of 180 metres above sea level and flows into Robbins Passage near Robbins Island. The Montagu River is approximately 42 km long and has a catchment area of approximately 357 km^2. The headwaters of the river overlie the Trowutta Land System. Parent materials of this land system are comprised of volcanic and sedimentary rocks from the Cambrian. This land system supports an open forest community dominated by stringybark (*Eucalyptus obliqua*), myrtle (*Nothofagus cunninghamii*) and sassafrass (*Atherosperma moschatum*), with an understorey of dogwood (*Pomaderris apetala*), leatherwood (*Eucryphia lucida*) and soft tree fern (*Dicksonia antarctica*). A small outcrop of Precambrian mudstones belonging to the Milshake Hills Land System occurs in the vicinity of the Roger River Road crossing and extends almost to the township of Roger River. The Milkshake Land System supports a tall open forest vegetation type, which is dominated by stringybark and Smithton peppermint (*Eucalyptus nitida*). Myrtle, sassafrass, swamp gum (*Eucalyptus ovata*) and celery top pine (*Phyllocladus asplenifolius*) are also a prominent feature of the vegetation of this land system. At Roger River Road the river is at an altitude of 50m above sea level, having descended some 130 metres over the 3 km from its source.

Downstream of Roger River Road the river passes into the Montagu River Land System. The Montagu River Land System extends for around 4 km downstream of the road crossing and is typified by level or slightly undulating plains developed on Quaternary sand deposits. This land system typically supports open eucalypt forest dominated by Smithton peppermint and swamp gum with an understorey of leatherwood, manuka (*Leptospermum scoparium*), woolly tea-tree (*Leptospermum lanigerum*) and the variable sallow wattle (*Acacia mucronata dependens*). Along drainage lines the vegetation forms a closed shrub community of leatherwood, manuka, cutting grass (*Gahnia grandis*), myrtle and celery top pine. In the vicinity of Christmas Hills Road the river passes for around 3 km through the Ekberg Creek Land System. This land system is typified by gently undulating plains of Precambrian dolomite that supports a tall open Eucalypt forest community. Smithton peppermint, stringybark, swamp gum and myrtle dominate the overstorey whilst variable sallow wattle, woolly tea-tree, lance wood (*Phebalium squameum*) and stinkwood (*Zieria arborescens*) are key elements of the understorey. The Montagu Land System outcrops again becoming the predominant land system from this point to the vicinity of Rennison Road near Togari.

The Plains Land System (comprised of Quaternary deposits) underlies the river from this point to the outlet at Robbins Passage approximately 20 km downstream. This land system forms extensive areas of flat to gently undulating plains throughout the North West corner of Tasmania. The township of Brittons Swamp also overlies the Plains Land System. The vegetation supported by this land system forms an open heath community, comprising the bottlebrush tea-tree (*Melaleuca squarrosa)*, manuka, and other tea-tree species. On better drained areas an open forest of Smithton peppermint, white gum (*Eucalyptus viminalis*) and swamp gum is common. Extensive areas of this land system have been cleared and drained for grazing and restricted cropping. In the vicinity of the river mouth patches of *Melaleuca ericifolia* swamp forest are present. This forest type is listed as a priority (endangered) vegetation type for the Tasmanian RFA and is also of conservational significance at a national level, having been proposed for listing on the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*. This community type is typically restricted to coastal or near-coastal areas particularly in the North and Northwest of the state but also in areas of the Northeast and on Flinders and King Islands.

The belts of low hills that demarcate the western (Bond Tier) and eastern extent (Christmas Hills) of the catchment to the north of the Bass Highway are comprised of Cambrian greywacke turbidite sequences belonging to the Fagans Road Land System. Fixters and Farnhams Creek also overly this land system. The Fagans Road Land System is dominated by tall open forests of stringybark, swamp gum, myrtle and blackwood (*Acacia melanoxylon*). The understorey is typically dominated by species such as dogwood, lancewood and cutting grass.

Approximately 45% of the catchment has been developed for agriculture which has resulted in the fragmentation of native vegetation within the catchment (Montagu River Catchment Management Plan - options paper, 1998). Much of the low lying areas have been converted from swamp land to pasture for grazing, including the middle reaches of the mainstream, around Brittons Swamp and near Togari. These low lying areas are naturally poorly drained and historically were extensive areas of swamp habitat. Drainage of these swampy areas has been undertaken through the development of the swale and ridge (hump and hollow) pattern drainage system, which directs flow from waterlogged areas to the river via a system of drains. The Brittons Swamp and Togari Drainage Trusts have been responsible for the development and ongoing management of these drainage systems.

Sections of the Bond Tier and Christmas Hills have been converted to eucalypt and pine plantation although native vegetation is still the dominant vegetation type through these areas (Richley, 1978, TASVEG, 2000). Weeds such as blackberries (*Rubus fruticosus*) and

Californian thistle (*Cirsium arvense*) occur throughout much of the developed zones of the catchment. Gorse (*Ulex europaeus*) and to a lesser extent Willow (*Salix fragilis*) are also present within developed areas of the catchment.

Figure 1. Longitudinal profile of the Montagu River.

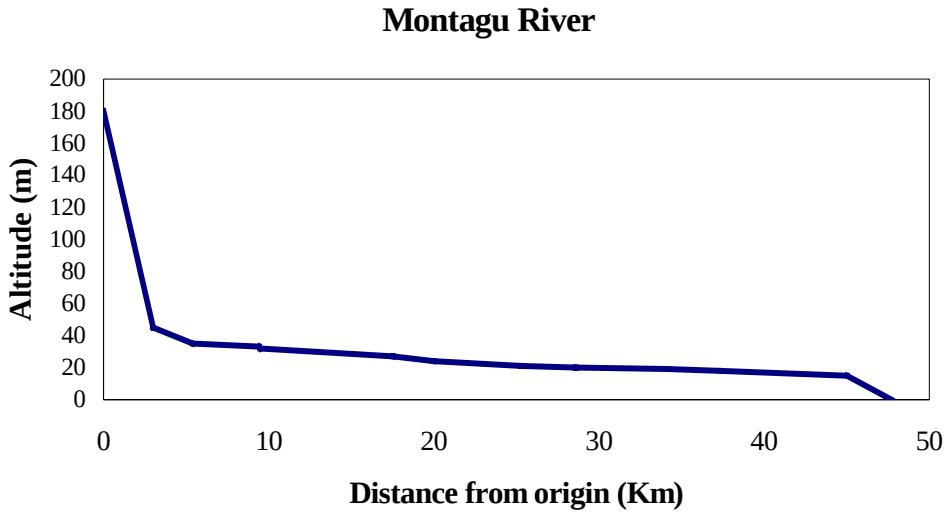
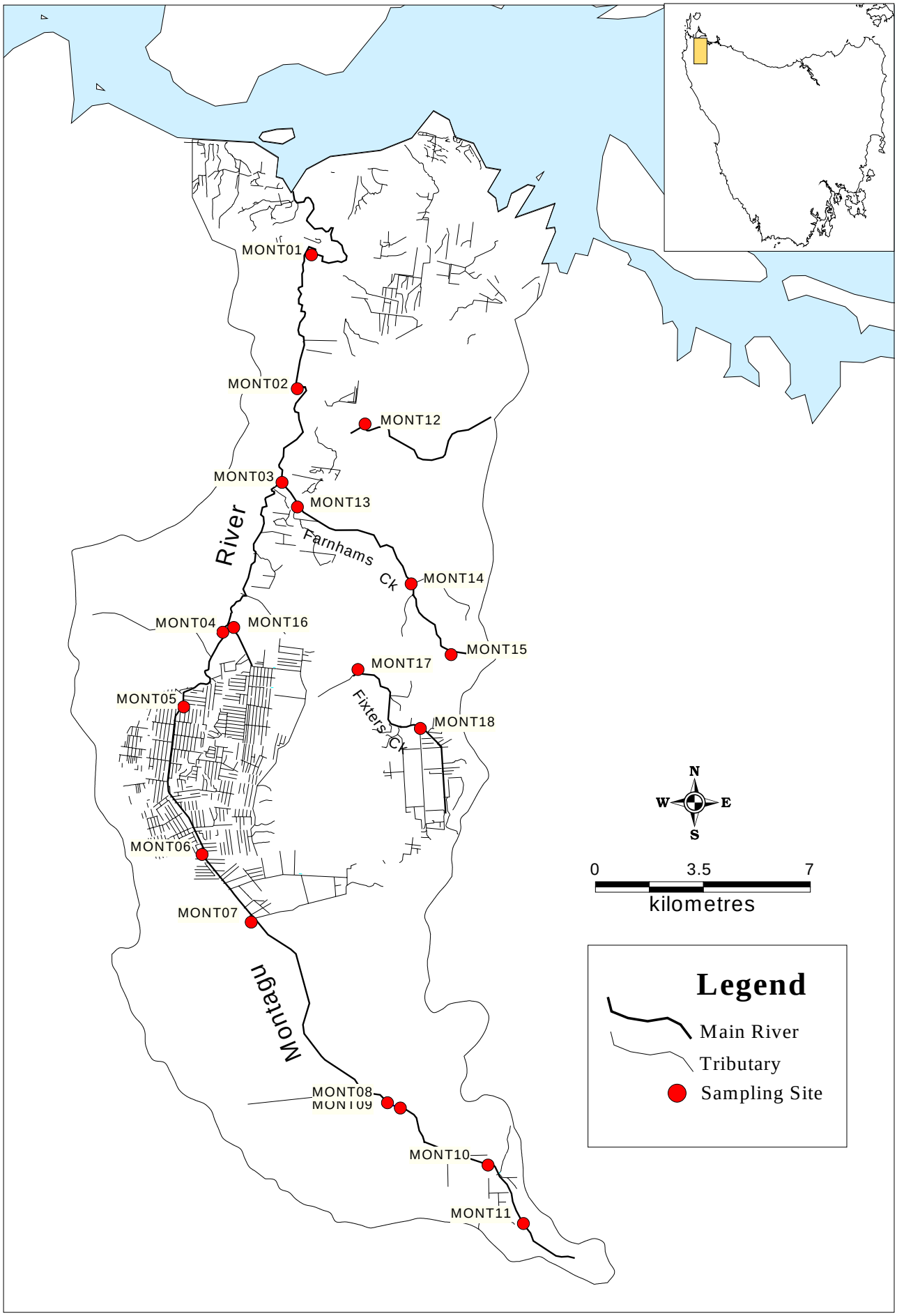


Table 1. Site Legend for Montagu IRC sites represented in Figure 2.

Site No	Site	Northing	Easting
MONT01	Montagu River at Stuarts Road	5482900	325370
MONT02	Montagu River off Quillams Road	5478500	322490
MONT03	Montagu River off Barcoo Road	5475500	324300
MONT04	Montagu River at14 Mile Plain	5470800	322820
MONT05	Montagu River at Rennison Road	5468200	321100
MONT06	Montagu River at Bass Highway	5463400	321700
MONT07	Montagu River off Eldridge Road	5461200	323300
MONT08	Montagu River downstream of Christmas Hills Road	5455300	327700
MONT09	Montagu River upstream of Christmas Hills Road	5455300	327700
MONT10	Montagu River at Donalds Road	5453300	331000
MONT11	Montagu River at Roger River Road	5451400	332150
MONT12	Un-named Tributary at Barcoo Road	5477400	327000
MONT13	Farnhams Creek at Barcoo Road	5474700	324800
MONT14	Farnhams Creek at Fagans Road	5472200	328500
MONT15	Farnhams Creek at Bass Highway	5469900	329800
MONT16	Un-named canal off Barcoo Rd	5470800	322850
MONT17	Fixters Creek at Riseborough Road	5469300	326850
MONT18	Fixters Ck at Bass Highway	5467500	328800

Figure 2: Montagu River Catchment. Index of River Condition (IRC) Sites



3. METHODOLOGY DESCRIPTION

The IRC approach has been developed to provide an assessment of current habitat condition within a catchment. This was achieved through collection of physical and ecological data from a range of reaches throughout a catchment and determining the degree of departure of physical and riparian conditions of these reaches from a natural state. The methodology is based on two sub-indices (Physical form and Stream-side zone). Each sub-index represents a rating of one or more parameters or habitat attributes (Table 3).

Parameters for each sub index are rated on a 5 point rating scale where possible rather than absolute values (Table 2). The ratings are based on the degree of divergence of the current state from a natural state. The 5 point rating scale had been developed and trialed for the Victorian IRC (CEAH, 1997b) and this has subsequently also proven to be an effective rating scale for Tasmanian catchments (Horner, 2002). According to Victorian authorities a scale with a higher or lower rating would be unrealistic given the current state of knowledge of the relationship between a change in the indicator and environmental effects (CEAH, 1997b).

Table 2. Habitat rating categories for individual sites.

Condition	**Very poor** **Highly modified**	**Poor** **Major modification**	**Moderate** **Some modification**	**Good** **Near natural**	**Excellent** **Essentially natural**
Total score	0 - 1	2 - 3	4 - 5	6 – 7	8 - 10
Habitat rating	0	1	2	3	4

3.1 Sub-index parameters

At each site a number of indicators for each sub index are assessed or rated. Descriptions of indicators for each sub-index parameter are detailed in Table 3.

Table 3. The sub-index parameters with associated indicator categories.

Sub-index	**Indicator**
Physical form	Bank type and level of stability Aquatic environment condition Meso-habitat diversity Density of coarse woody debris
Stream-side zone	Riparian vegetation condition Structural intactness Native vegetation cover Native Vegetation regeneration Vegetative regrowth Longitudinal continuity
Hydrological connectivity	Barrier effectiveness Barrier location Fish passage potential Deviation of flow Other in-stream structures Bank stability Overall disturbance

3.1.1 Physical form

Bank type and level of stability

Bank type and level of stability is an assessment of the degree to which erosion occurs at a site and/or the potential fro erosion to occur. Potential indicators of bank type and level of stability include:

- lack of vegetative cover to bind and reinforce soil;
- erosion heads;
- undermining of the toe of the banks and exposed roots;
- bank instabilities on both sides of the watercourse (this indicates bed degradation).

Aquatic environment condition

Aquatic environment condition is a measure of overall integrity of the in-stream habitat. This parameter is designed to show the influence of modification to the stream-side zone upon in-stream conditions. Potential indicators of habitat integrity include:

- overhanging indigenous riparian vegetation;
- extent of macrophyte and algal growth;
- channel alteration by exotic vegetation (typically willows);
- sediment accumulation around obstructions (typically coarse woody debris);
- elevated turbidity levels.

Mesohabitat diversity

Mesohabitat diversity is a measure of habitat availability for in-stream fauna. It relates the diversity of substrate material present to distribution of habitats with varying velocity/depth characteristics. This parameter also determines the affect of human induced modification on in-stream habitat availability within the study reach. Potential indicators for mesohabitat diversity include:

- distribution of habitats with varying velocity/depth categories;
- diversity of channel bed material;
- Human induced changes to channel sinuosity.

The rating assumes that the greater the diversity of bed material and diversity in velocity/depth categories available, the more habitat there is for in-stream fauna.

Density and origin of coarse woody debris (CWD)

In-stream coarse woody debris can represent an important habitat for aquatic animals. It provides a refuge for fish and invertebrates, food source for many macroinvertebrates, and is important for spawning for some fish species (e.g. river blackfish, *Gadopsis marmoratus*). The rating scale is based on the proportion of available CWD in the reach assessed. The rating assumes that the greater the proportion of snags available, the more habitat there is for in-stream fauna.

3.1.2 Stream-side zone

Riparian vegetation plays an important role in the maintenance of stream condition. For example, stream-side vegetation can (Skills and Pen, 1995):

- increase bank roughness thereby reducing erosion potential;
- riparian roots bind and reinforce soil (bank stabilisation);
- roots also loosen soil allowing greater infiltration of rainwater;
- vegetation filters sediment and nutrients and promotes sediment deposition;
- continuous vegetation provides ecological corridors and habitat availability for terrestrial animals and plants.

These factors directly and indirectly maintain the quality and ecological integrity of a waterway.

Riparian vegetation condition

Riparian vegetation condition is an indicator of the degree of modification that has occurred within the riparian zone as a result of disturbance to indigenous vegetation and weed encroachment. The condition of the riparian vegetation is important to determine as such zones provide a buffering effect from adjacent developed land and are important as faunal corridors and habitat.

Structural intactness

Structural intactness is an indicator of disturbance relating to the original distribution of stream-side vegetation. The ratings for structural intactness are based on a scale of continuous, patchy and sparse cover. The following definitions for the three structural layers are based on the Victorian model.

Overstorey – those woody plants greater than 5 m tall.
Understorey - those woody plants less than 5 m tall.
Ground cover - other plants without woody stems.

Proportion of native vegetation cover

This category refers to the proportion of native and introduced plant species in the reach assessed. The relative proportion of native species present provides a rating of how near to natural the reach is. The presence of exotic species may be undesirable depending on the quantity and/or the particular exotic species. Ratings are according to the percentage cover that is present and is determined separately for each structural layer.

Presence of regeneration of native plant species

Regeneration of native vegetation is an important indicator of current condition. Due to the difficulty in assessing the regeneration of ground cover species, it has been applied to overstorey and understorey species only.

Overstorey stream-side vegetation regeneration

The regeneration of indigenous species within the stream-side zone is an important rating of its current condition. A well-developed overstorey suggests long term stability of the area from previous disturbance events such as clearing, logging and fire.

Vegetative regrowth categories

This rating is based on the assumption that natural succession in vegetation culminates in the formation of a climactic community. Such an end point community receives the highest rating. The nature of the climax communities varies and is determined by environmental conditions within an area. For example high rainfall areas of the state support temperate rainforest as a climax community, whilst low rainfall areas may culminate in a sclerophyll community.

Longitudinal continuity

In essence, longitudinal continuity is simply a measure of how continuous stream-side vegetation is. Any gap that exists in a vegetation corridor has the potential to act as a barrier to terrestrial fauna movement or increase physical and ecological disturbance via erosion/ sedimentation/ runoff. The parameter specifications adopted here are the result of expert panel discussions in Victoria (CEAH, 1997a). A significant discontinuity is defined as a gap in the stream-side vegetation greater than 10 m long and that has a width of 5 metres or less. The two factors applied are:

- proportion of bank length with vegetation greater than 5 m wide;
- the number of significant discontinuities per unit length.

3.1.3 Hydrological connectivity

Hydrological connectivity, or the ability of water to move between river reaches has been identified as an important factor in assessing riverine condition. This index has been incorporated to highlight which indicators of hydrological connectivity have undergone modification within the catchment. As with the previously mentioned sub indices there are a number of parameters that have been identified that allow the formation of a rating scale for hydrological connectivity. A 5 point rating system has been developed for each parameter and details are given under each parameter heading below. The term "ideal" is used in preference to the term "natural" used in stream side zone and physical form assessment. Hydrological connectivity parameters are as follows:

1. Barrier effectiveness

This parameter determines the ability of an in-stream structure to influence the seasonal availability of water within the downstream reach. It takes into account the design of the structure and the frequency at which the structure drowns out throughout the year.

2. Barrier location (subcatchment ratios)

It is important to consider both the effectiveness of the barrier to influence hydrological connectivity and also its position within the catchment. The degree of naturalness for this parameter is related to the relative catchment areas upstream and downstream of the structure.

3. Fish passage potential

This parameter assesses the potential for changes to in-stream condition to affect the rate of fish passage across an in-stream structure. The degree to which in-stream conditions depart from a natural condition is influenced through structure design. The presence of fish passage devices that aid movement is important in evaluating this parameter.

4. Deviation of flow

Barriers alter the natural flow regime within the area they are located. The degree to which the flow is modified from natural conditions can be viewed in terms of upstream and downstream alterations. Typically upstream of a barrier water is impounded whilst downstream flow is restricted. This parameter provides an indication of the extent of impoundment upstream and the availability of water downstream. It also provides an indication of the velocity of the downstream flow in addition to water quantity.

5. Other in-stream barriers

This parameter relates the ability of other in-stream structures to affect the barrier being reviewed and highlights the impact of multiple developments for particular reaches. An in-stream structure would receive a lower score for this parameter if it were to occur within a reach with multiple hydrological breaks rather than a reach with no other barriers.

6. Bank stability

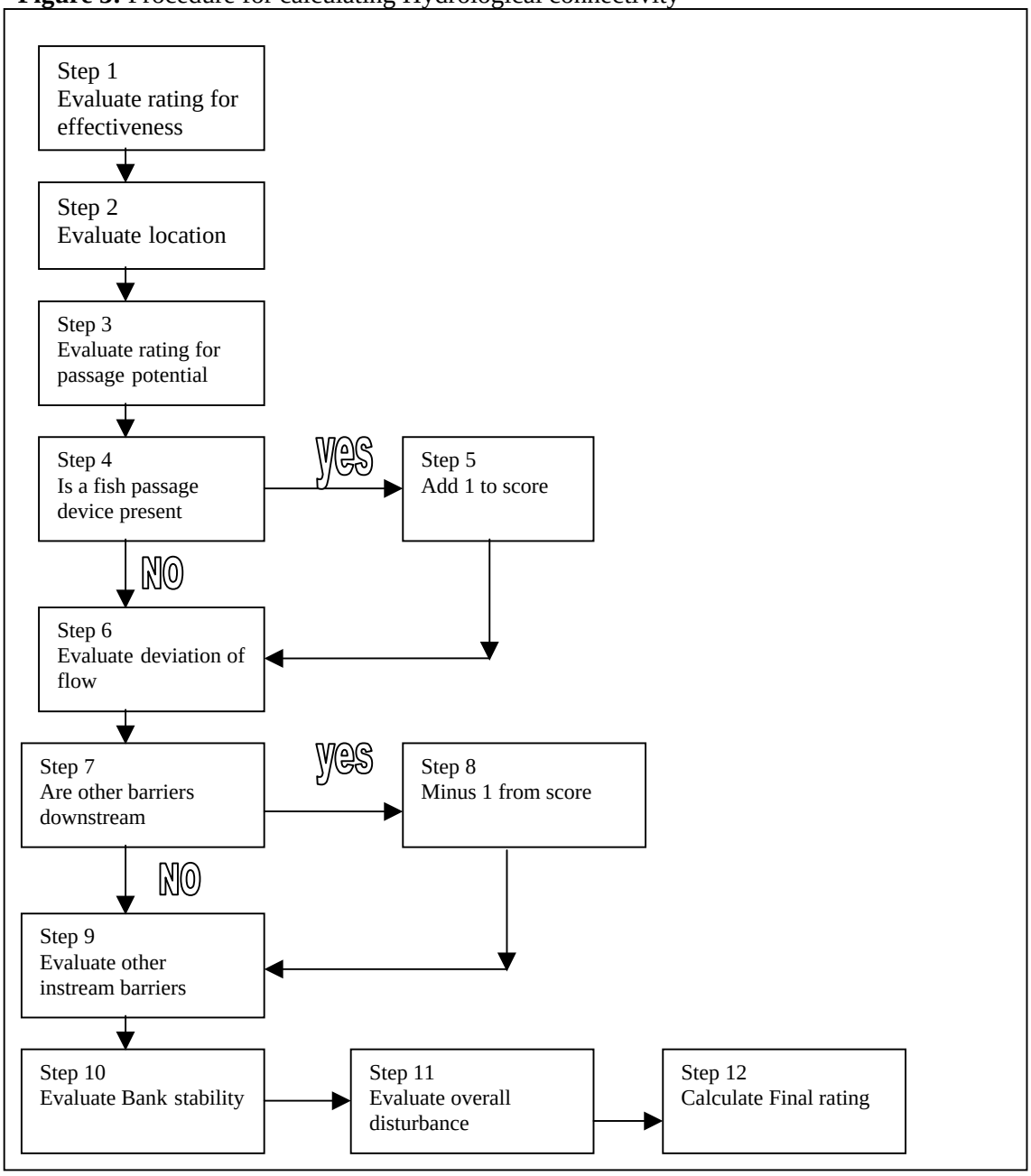
The stability of the surrounding stream banks is an important factor to determine in relation to hydrological connectivity. Stable conditions have been set as the standard for "ideal". High rates of bank erosion are known to result in increased sediment loads within waterways and reduced water quality. These are important factors to consider as they have a negative impact on native fish communities (Richardson and Jowett, 2002).

7. Overall disturbance

For this parameter five disturbance categories were selected being, extreme, major, moderate, minor, and very low. As riparian habitat plays an important role in maintaining the quality and ecological integrity of a waterway the categories are largely based on physical aspects of stream-side vegetation such as the degree of weed infestation, cover provided by native species and native species richness. Details of the disturbance categories utilised in determining this parameter are provided in Appendix 3.

Analysis of all parameters provides an overall rating of how an individual barrier effects hydrological connectivity. In order to determine the effects of multiple barriers upon the system a decision tree was developed based on the above parameters. An overview of the decision tree is provided in Figure 3.

Figure 3: Procedure for calculating Hydrological connectivity



3.2 Site selection and survey methods

Site assessments were conducted during February 1999. A total of 18 sites were surveyed within the catchment (Figure 2 and Appendix 1a). Eleven sites were located on the mainstream and 7 on major tributaries within the catchment. Each site was selected as being representative of the reach (length of river) where it occurs. Site selection was based on examination of maps and extensive ground 'truthing' prior to the survey. Selection of study sites overlapped with the sites used in the assessment of water quality and aquatic ecology. This allowed for the incorporation of existing long term water information for the catchment into this 'snapshot' assessment. During August and December 2002 an additional survey of parameters related to hydrological connectivity was undertaken. This allowed for the direct assessment of 18 artificial in-stream structures that have the potential to act as barriers to fish migration or movement (see Appendix 1b).

4. RESULTS

4.1 IRC results for mainstream sites

A total of 11 sites were sampled on the mainstream (Figure 2) and IRC ratings for the mainstream Montagu River are provided in Figure 5. Parameters that suggest major or extreme modification from a natural or ideal condition are presented in Table 6 along with any data gaps. Condition maps for the physical form and stream-side zone sub-indices are provided in Figures 7 and 8 respectively. Management issues for each mainstream site are identified in Table 9.

For the mainstream the rating for physical condition ranged from excellent to very poor condition with the values for individual sites being influenced by the degree of development around the site (Figure 5). Two of the mainstream sites rated as in excellent condition, (Montagu River off Quillams Rd (MONT02), and Montagu River at Roger River Rd (MONT11). Both sites occur in areas of the catchment that have been subject to minimal development. With increasing levels of development, in-stream conditions were found to deteriorate (Figure 5). The physical form index for two reaches of the Montagu mainstream rated as in good condition (Montagu R at Stuarts Rd (MONT01), and Montagu River at Thorpes Plains (MONT03). Two sites rated as being in moderate condition (Montagu River upstream canal off Barcoo Rd. (MONT04), Montagu River downstream of Christmas Hills Rd. (MONT08). Poor conditions for physical form occurred at three sites (Montagu River at Rennison Rd. (MONT05), Montagu River off Eldridges Rd. (MONT07), and Montagu River upstream of Christmas Hills Rd. (MONT09). Physical form condition was found to be very poor (Highly modified) at two sites, (Montagu River at Bass Highway (MONT06), and Montagu River at Donalds Rd. (MONT10). Both of these sites occur in reaches that have been extensively developed for agriculture (Figure 7).

From Table 6 it is evident that major or extreme modification of individual physical form indicators occurs within reaches of the mainstream Montagu River adjacent to agricultural land. Three mainstream sites (Montagu River at Rennison Rd. (MONT05), Montagu River at Bass Highway (MONT06), and Montagu River at Donalds Rd. (MONT10) display major or extreme modification to all four parameters of physical form. These 3 sites occur within agricultural reaches of the mainstream that have been subject to in-stream modification through channelisation. From Table 6 it is evident that the indicators for mesohabitat diversity and coarse woody debris (CWD) are most influenced by land usage and drainage development within the catchment.

Condition of the stream-side zone ranged from essentially natural to highly modified. One site, Montagu River at Roger River Rd (MONT11) rated as in excellent condition. Three of the mainstream sites rated as in good (near natural) condition, (Montagu River off Quillams Rd (MONT02), Montagu River off Eldridges Rd. (MONT07), and Montagu River downstream of Christmas Hills Rd. (MONT08). Two sites rated as being in moderate condition, (Montagu R at Stuarts Rd (MONT01), and Montagu River at Thorpes Plains (MONT03)). Two sites were found to have been subject to major modification and were in poor condition, (Montagu River upstream canal off Barcoo Rd. (MONT04), and Montagu River upstream of Christmas Hills Rd. (MONT09)). The stream-side zone for three sites (Montagu River at Rennison Rd. (MONT05), Montagu River at Bass Highway (MONT06), and Montagu River at Donalds Rd. (MONT10) rated as in very poor condition. The condition of stream-side vegetation in the mainstream varied between reaches and like physical form ratings reflected adjacent land use practices. In agricultural areas there was a trend for reduced ratings, indicating a higher degree of modification as illustrated in Figure 5 and Table 6. From Table 6 it is evident that major or extreme modification to all six parameters of this sub-index has occurred within agricultural reaches of the mainstream. These findings reflect the discontinuous nature of existing vegetation, the low proportion of native species present, and the lack or regeneration by native species within these reaches.

Figure 5. IRC results for the Montagu River mainstream sites

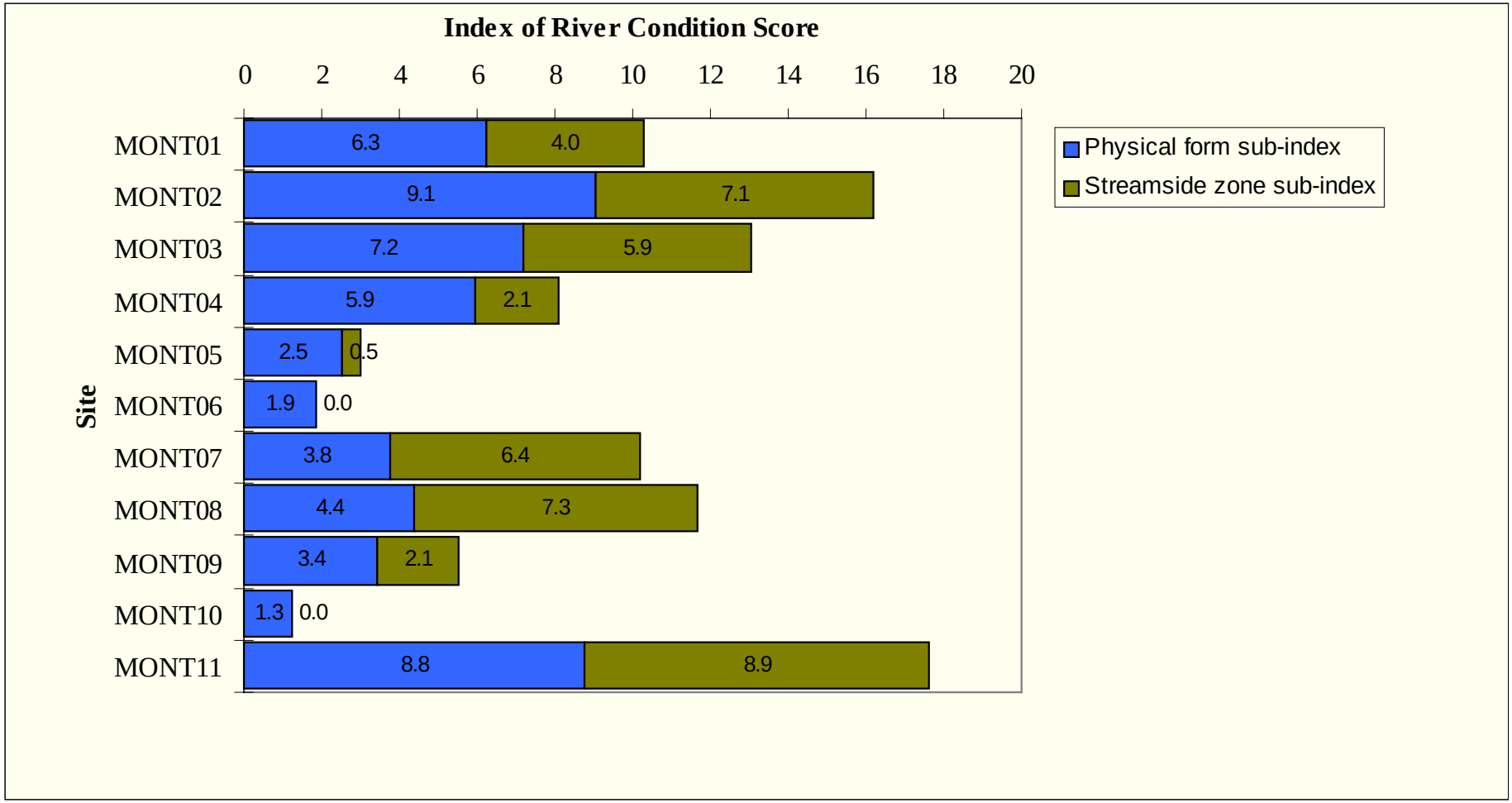


Table 6: IRC Sub-index ratings and indicator values for the Montagu River catchment sites.

		Physical form					Stream-side zone						
Site	Morphology	Physical form rating	Bank stability	Aquatic environ	Mesohabitat	CWD	Stream-side rating	Riparian condition	Struct. int.	% indig.	Regen.	Overst regen.	LC
Montagu R at Stuarts Rd	floodplain	6.3					4.0						
Montagu R off Quillams Rd	floodplain	9.1					7.1						
Montaqu R off Barcoo Rd	floodplain	7.2					5.9						
Montagu R at 14 Mile Plain	floodplain	5.9					2.1						
Montagu R at Rennison Rd	floodplain	2.5					0.5						
Montagu R at Bass H'way	floodplain	1.9					0.0						
Montagu R off Eldridge Rd	floodplain	3.8					6.4						
Montagu R d/s Christmas Hills Rd	valley	4.4					7.3						
Montagu R u/s Christmas Hills Rd	valley	3.4					2.1						
Montagu R at Donalds Rd	floodplain	1.3					0.0						
Montagu R at Roger River Rd	valley	8.8					8.9						
Un-named Tributary at Barcoo Rd	floodplain	6.9					8.7						
Farnhams Ck at Barcoo Rd	floodplain	5.0					7.7						
Farnhams Ck at Fagans Rd	valley	8.1					8.0						
Farnhams Ck at Bass H'way	valley	7.8					9.4						
Un-named canal off Barcoo Rd	floodplain	0.6					0.2						
Fixters Ck at Riseborough Rd	valley	8.1					8.5						
Fixters Ck at Bass H'way	valley	1.3					0.2						

Indicator suggests major or extreme. difference from natural or ideal conditions	CWD = Coarse woody debris
	Regen = regeneration of indigenous species.
Inadequate data to evaluate sub-index.	LC = Longitudinal continuity
Adequate data to evaluate indicator and ratings suggest changes have not been extreme or major.	

4.2 IRC results for tributary sites

IRC ratings for the tributary streams of the Montagu catchment are provided in Figure 6. A total of 7 sites were sampled on 4 tributaries (Figure 2). Parameters that suggest major or extreme modification from a natural condition are highlighted in Table 6 along with data gaps. Descriptive maps for Physical form and Stream-side sub-indices values are provided in Figures 7 and 8 respectively.

The Physical form sub-index of two tributary sites, Farnhams Ck at Fagans Rd (MONT14), and Fixters Ck at Riseborough Rd (MONT17), rated as in excellent (essentially natural) condition. The physical form sub-index rated as in good condition for two tributary sites (un-named tributary off Barcoo Rd (MONT12), and Farnhams Creek at Bass Highway (MONT15)). One site rated as in moderate condition (Farnhams Creek at Barcoo Rd (MONT13)). No sites rated as in poor condition for this sub-index, however two sites rated as in very poor condition, (un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18)).

As with the mainstream, physical form condition deteriorated for the tributary sites within agricultural areas. This is clearly reflected in the low ratings of (un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18)), when compared with tributary sites that occur in less developed zones, such as Farnhams Ck at Fagans Rd (MONT14) and Fixters Creek at Riseborough Rd (MONT17). From Table 6 it is evident that all 4 indicators of in-stream condition (bank type and stability, aquatic environment condition, mesohabitat diversity and, CWD) have been highly modified for un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18), both of which occur within agricultural areas. The un-named canal off Barcoo Rd (MONT16) is a man made canal and therefore would be expected to display a certain degree of departure from natural conditions. Fixters Creek at Bass Highway (MONT18) has been subject to extensive modification as a result of development of the Brittons Swamp drainage district (see Figure 2).

The stream-side zone sub-index of four tributary sites, (un-named tributary off Barcco Rd (MONT12), Farnhams Ck at Fagans Rd (MONT14), Farnhams Creek at Bass Highway (MONT15), and Fixters Ck at Riseborough Rd (MONT17)), rated as in excellent (essentially natural) condition. Farnhams Creek at Barcoo Rd (MONT13), rated as in good condition, with a value of 7.7 (bordering on excellent condition). No tributary sites rated as in moderate or poor condition. Two tributary sites rated as in very poor condition for the stream-side zone sub-index, (un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18)). As with the physical form sub-index general trends were noted that related site condition to surrounding land usage. From Table 6 it is evident that the very poor ratings for the un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18) are in response to major or extreme modification to all of the indicators of the Stream-side zone sub-index. These ratings reflect the absence of a woody riparian zone and the lack of native vegetation at these sites.

Index ratings clearly illustrate a trend between the condition of stream reaches and adjacent land use with those sites rated with the greater degree of departure from a natural state occurring within agricultural areas (Figure 6). Ratings were generally found to improve in sections of the tributaries where development is low.

Figure 6. IRC results for the Montagu River tributaries.

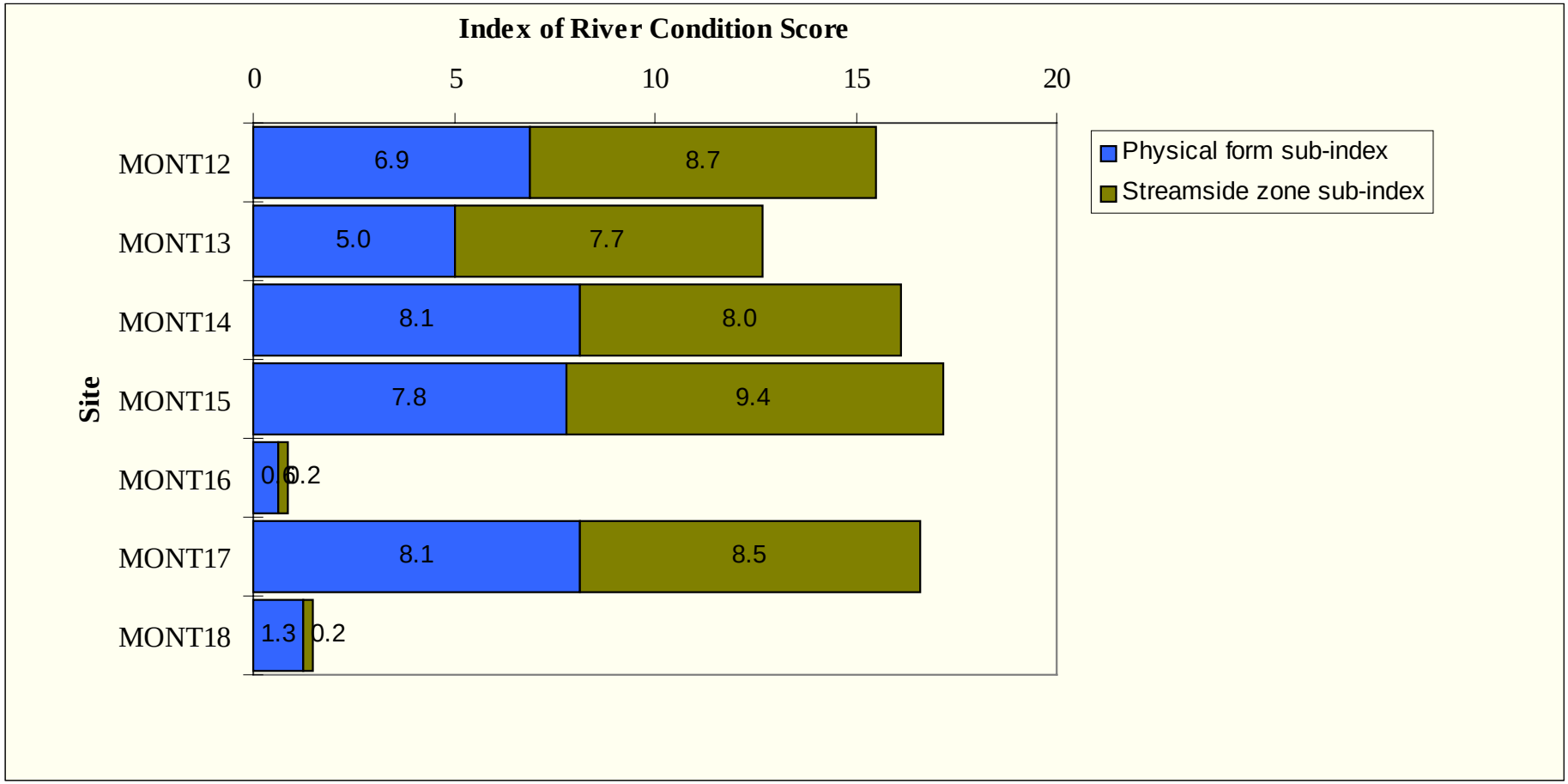


Figure 7: Montagu Catchment. Physical form sub-index ratings.

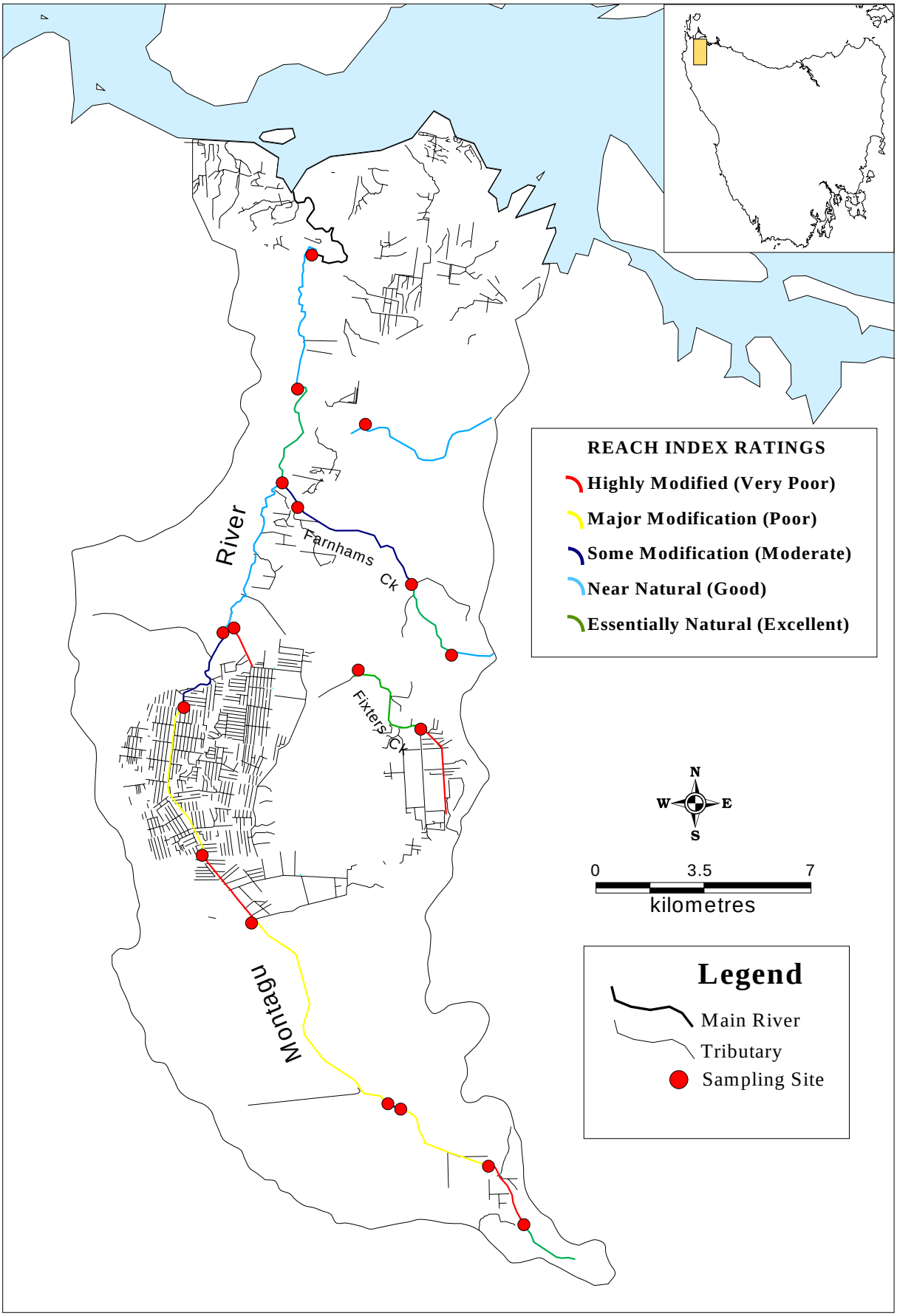


Figure 8: Montagu Catchment. Stream-side zone sub-index ratings.

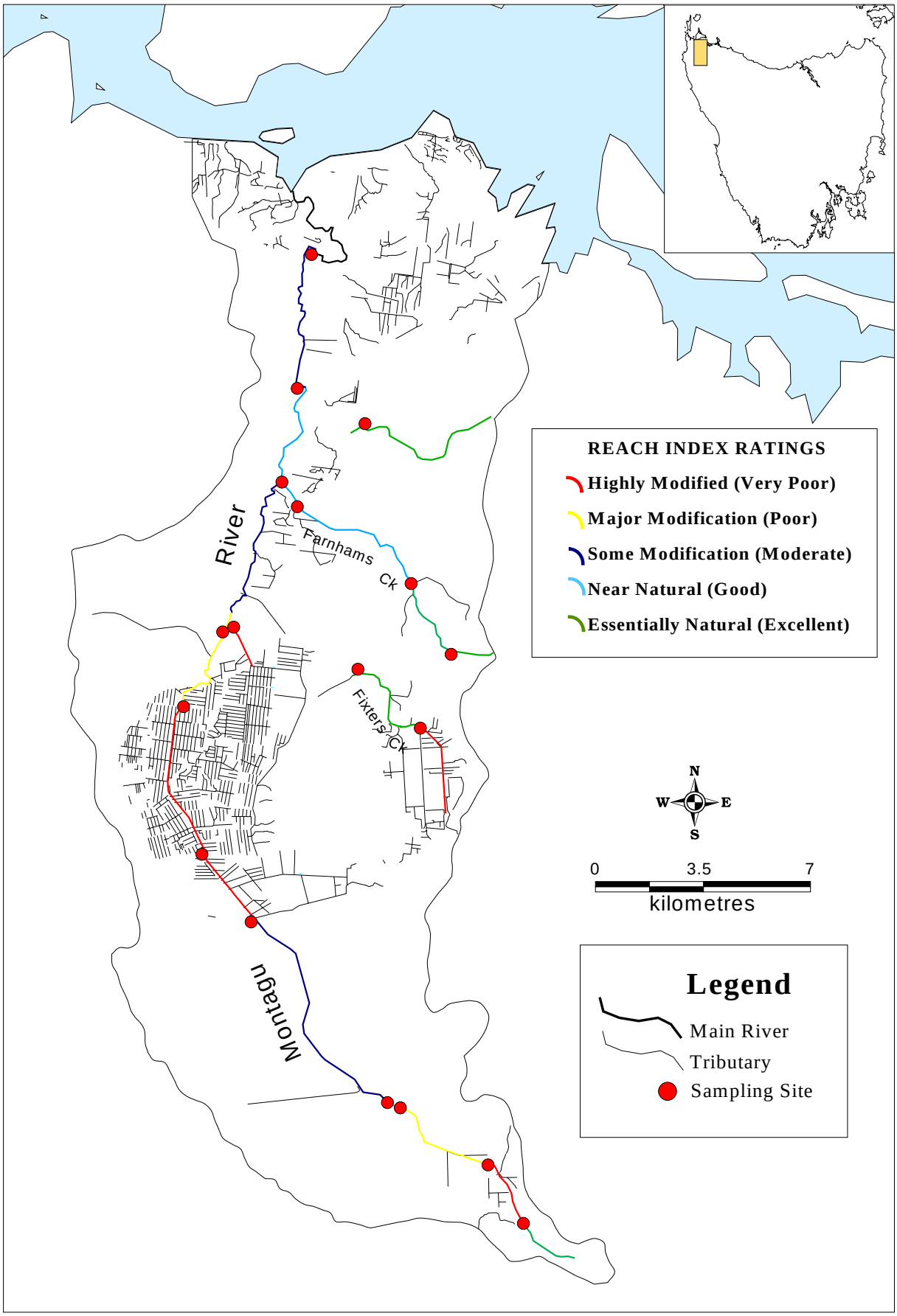
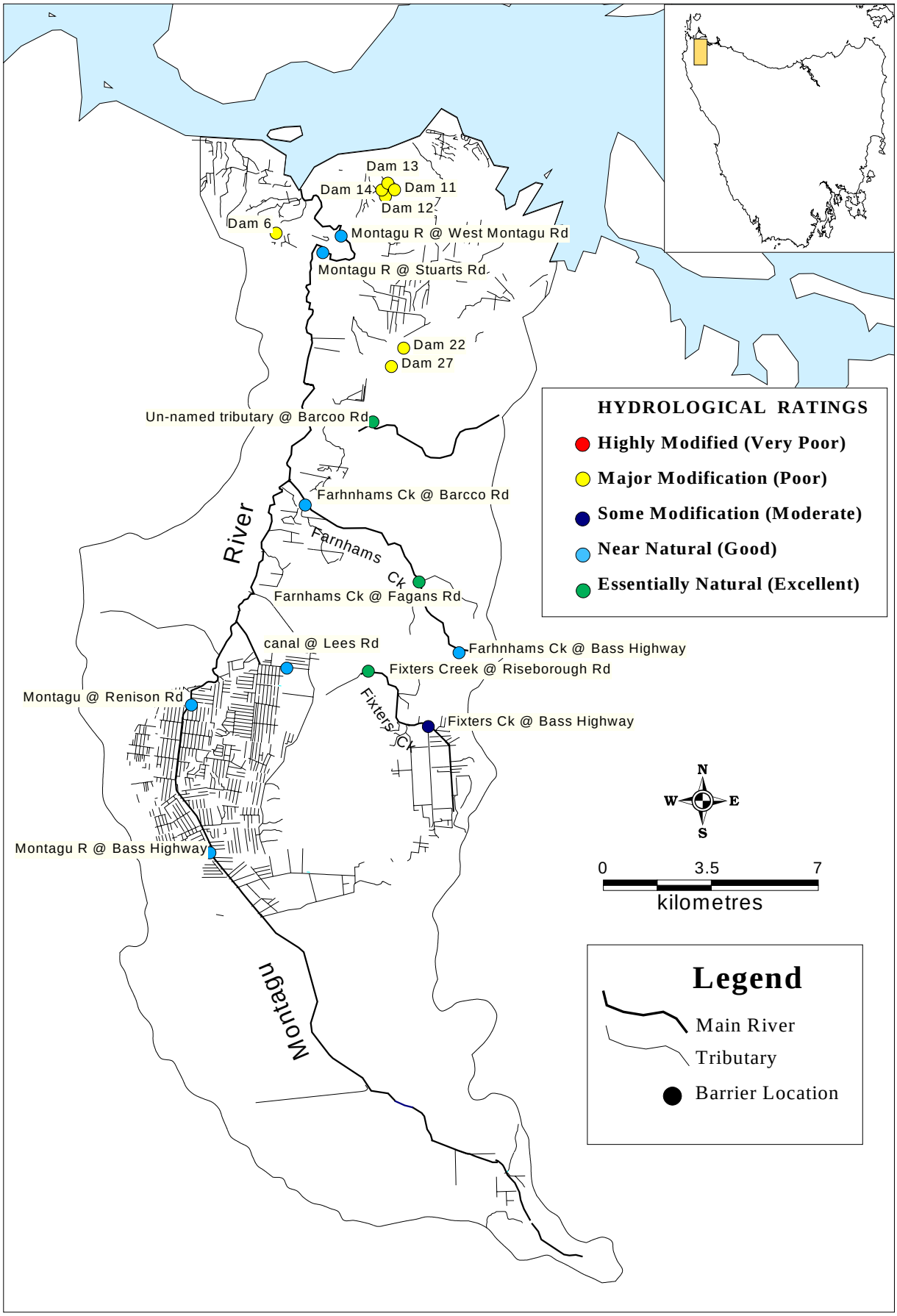


Figure 9: Montagu Catchment. Barrier locations and Hydrological ratings.



4.3 Hydrological Connectivity

Table 7. Median rating values for barrier types assessed within the Montagu catchment.

Structure type	Number assessed	Hydrological rating (median)	Hydrological condition
Bridge	10	7.5	Near ideal
Culvert	1	6.4	Near ideal
Farm dam	7	3.2	Poor

Table 7 presents ratings for various types of structures in relation to hydrological connectivity. For the Montagu catchment, bridges (n=10) and culverts (n=1) result in partially modified conditions and farm dams (n=7) result in poor conditions for fish passage. Figure 9 shows the distribution of structures and related fish passage values of structures that were surveyed within the catchment. From Figure 9 it is evident that hydrological connectivity within the mainstream is influenced by bridges that provide for near ideal passage conditions. Figure 9 shows that for each tributary a low proportion of the overall stream length is affected by in-stream structures that alter hydrological connectivity to a moderate or extreme degree.

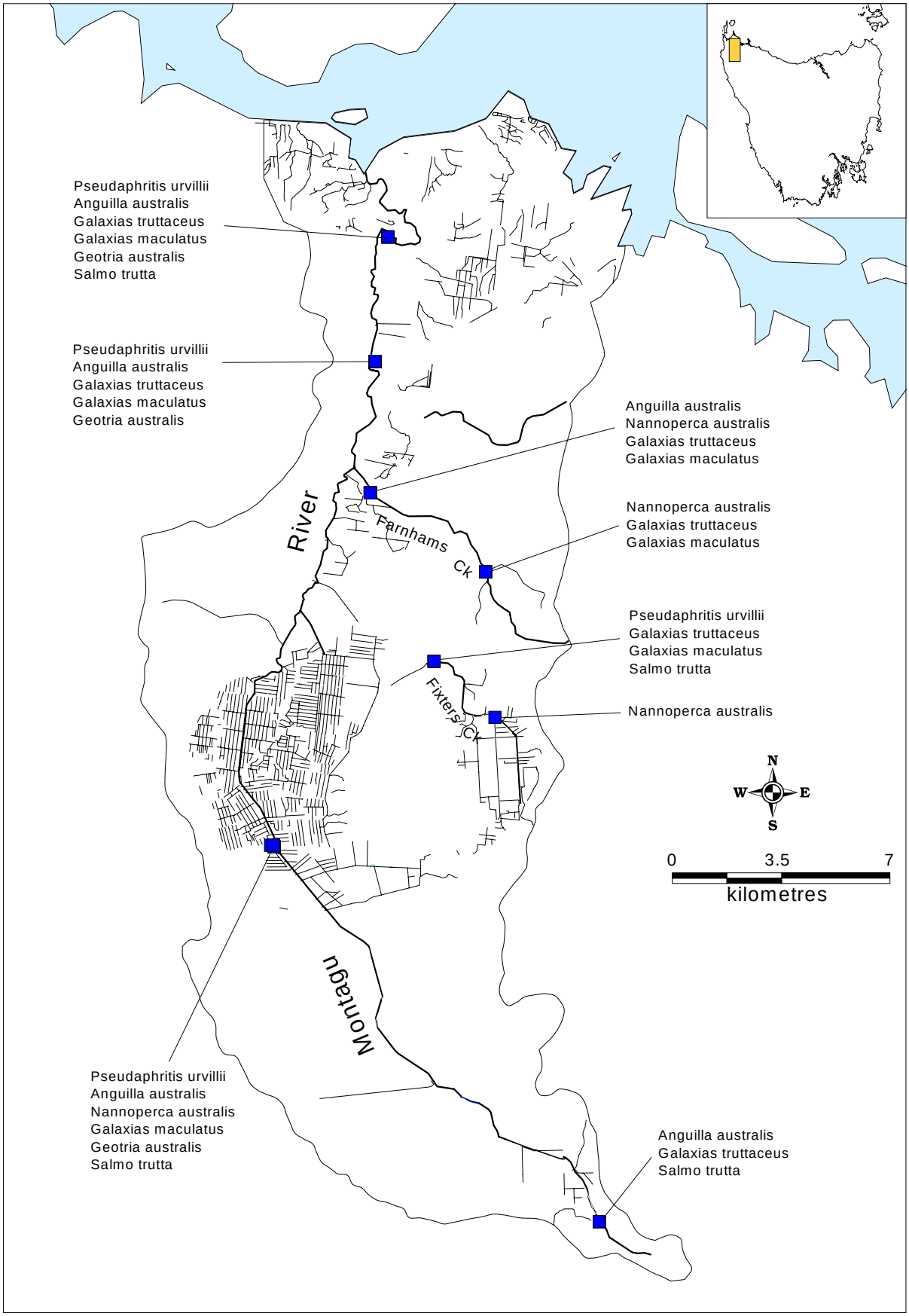
Records of fish locations have been reviewed for the Montagu catchment. Table 8 provides a summary of which native and introduced species are known from the catchment, the fishes movement habit and the number of verified records, based on RFA data and DPIWE electrofishing data. Figure 10 provides distribution details of fish species within the Montagu catchment.

From Figure 10 it is evident that many migratory native fish species occur throughout the catchment including the uppermost reaches. Electrofishing surveys carried out by DPIWE in 2002 and location data from the RFA database suggest that the distribution of most migratory species is widespread and therefore passage conditions particularly in the mainstream are adequate. Electrofishing surveys for the Montagu indicate that brown trout (*Salmo trutta*) population density is low and this is consistent with the findings of Davies (1999) for the Welcome River. Davies (1999) suggests that the low abundances of *S. trutta* in the Welcome catchment can be attributed to unfavourable habitat conditions (low velocities, predominantly fine sand/silt substrates and lack of suitable spawning sites). Given that these habitats also are characteristic of the Montagu River the reasons for low *S. trutta* abundances are likely to be the same as for the Welcome River. In addition electrofishing surveys indicate that the Montagu River supports a diverse native fish assemblage which is also consistent with Davies's (1999) study of the Welcome River.

Table 8. Inventory of fish species for the Montagu catchment (IFS database).

Scientific Name	Common Name	Movement	Number of records
Native Fish			
Geotria australis	Pouched lamprey	Anadromous	3
Anguilla australis	Short-finned eel	Catadromous	5
Galaxias maculatus	Jollytail	Diadromous	6
Galaxias truttaceus	Spotted galaxias	Diadromous	7
Nannoperca australis	Pygmy perch	Non-migratory	7
Pseudaphritis urvillii	Sandy flathead	Diadromous	4
Introduced Fish			
Salmo trutta	Brown Trout	Non-migratory	4

Figure 10: Fish distribution map for the Montagu catchment.



Of the 36 records listed in Table 8, 89% relate to native fish whilst 11% are from the introduced brown trout (*Salmo trutta*). *Nannoperca australis* (pygmy perch) is the only native fish recorded for the catchment that is non-migratory.

In addition to the species listed in Table 8, a further three freshwater fish species are highly likely to occur within the Montagu catchment based on known distribution records and habitat requirements. These are; the dwarf galaxias (*Galaxiella pusilla)*, the Australian grayling (*Prototroctes maraena*) and the Tasmanian smelt *(Retropinna tasmanica)*. Further information on these species is provided in the Aquatic ecology report.

As part of the IRC assessment of the Montagu catchment various types of barriers were assessed for their effect on hydrological connectivity. Surveys of in-stream structures focused primarily on the hydrological changes that are associated with each artificial structure type and how these changes alter the potential for fish passage. For the North Esk catchment these were found to cause varying degrees of departure from naturalness as a result of structure design (Horner, 2002). The same trends were shown for structures of similar design within the Montagu catchment, with bridges and culverts resulting in partial modification to condition, and farm dams resulting in a major modification to condition. One would expect that structures of similar design would have similar effects on hydrological connectivity in other catchments throughout the state.

Existing and proposed dam sites for the Montagu system were identified from the WIMS (Water Information Management System) database and are outlined in Appendices 3a and 3b and their positions within the catchment are provided in Appendix 2c. Appendix 2c clearly illustrates that the majority of dams (existing and proposed) occur on tributaries within the catchment. The small sub-catchment areas upstream of these structures represents a small proportion of the overall habitat available within the catchment and as such are likely to have little effect on fish passage in relation to the catchment as a whole. This means dams will exert the greatest effect on tributaries rather than the mainstream. The pattern of development has implications for the catchment in terms of fish movement management as the headwaters of the two largest tributary systems (Fixters and Farnhams Creek) have the potential to become hydrologically disconnected from the remainder of the catchment.

5. DISCUSSION

Physical River Condition and Stream Side Zones

The IRC ratings for both in-stream physical condition and stream-side zone condition for reaches surveyed reflects the influence of land use in the Montagu River catchment on stream integrity. The comparatively undisturbed condition of the physical form and stream-side zone sub-indices of reaches within non-agricultural areas of the Montagu River catchment strongly contrasts with the reduced ratings for these indices within agricultural areas. Specific management issues have been identified in relation to poor ratings for physical form and stream-side zone (refer to Figure 8) for the mainstream and tributary sites and are provided in Tables 9 and 10, respectively.

The IRC clearly illustrates a trend between the condition of stream reaches and adjacent land use with those sites rated with the greater degree of departure from a natural state occurring within agricultural areas. The IRC ratings indicate that reduced substrate heterogeneity, reduced substrate stability, elevated erosion levels, and the lack of Coarse Woody Debris (CWD) are impacts that require addressing in relation to management of in-stream integrity for agricultural areas of the Montagu catchment.

Typically ratings for the stream-side zone sub-index were lower in agricultural areas than for non-developed zones. This assessment indicates that extensive clearing of native vegetation has resulted in non-vegetated or poorly vegetated riparian zones, enabled encroachment by weed species and allowed stock access to the river banks. The stream-side zone is the interface between the aquatic and terrestrial environment and acts as an important buffer to any activities that may occur in the adjacent land zone. Riparian vegetation of appropriate buffer widths and complexity can provide significant protection for streams via the mechanisms below:

- Protection from sediment runoff from forestry, farming or roading activities (Collier *et al.*, 1995);
- It may act as a filter to chemical spray from intensive agriculture or forestry (Davies *et al.*, 1994);
- It provides bankside stability and inhibits erosion (Abernethy and Rutherford, 1999);
- It forms an important relationship with aquatic systems by providing in-stream and bankside habitat for fauna. It is the source of nutrient inputs through snags and leaf fall (Stevens and Cummins, 1999);
- It reduces water temperature through shading effects (Collier *et al.*, 1995);
- Continuous vegetation is important as faunal corridors and in maintaining suitable habitat (Stevens and Cummins, 1999).

Hydrological Connectivity

The location of a barrier within a catchment can influence its impact on fish populations. Where the catchment area upstream of a barrier is small, the proportion of upstream habitat in relation to the whole catchment is low. In such instances even a complete barrier may isolate only a small proportion of a catchment and prevent fish populations from travelling past it. As a result, the impacts in relation to the whole catchment are comparatively small. In contrast, barriers to fish migration in the lower reaches of a system have the potential to cause the greatest effect on fish recruitment and distribution upstream. The cumulative effect of barriers along a river may result in populations becoming reduced, even when individual barriers have a low effect on movement.

Dissimilarities often occur in relation to fish community composition on either side of a physical structure and the degree of dissimilarity is largely a function of how effective a barrier is to preventing passage. Recent assessment of in-stream structures within the North Esk catchment found that on average farm dams resulted in an extensive modification of condition, weirs and culverts a moderate modification and bridges a partial modification of condition (Horner, 2002). Similarly for the Montagu catchment farm dams resulted in an extensive modification of condition whilst bridges and culverts resulted in a moderate change in condition. Barrier effectiveness is also partly determined by the ability of each fish species to migrate past it. For example, species such as the short-finned eel (*Anquilla australis*) which can move across land and the Climbing galaxias (*Galaxias brevipinnis*) which can climb steep gradients are able to negotiate barriers more easily than those species that rely purely on swimming, such as the Jollytail (*Galaxias maculatus*).

Of the 25 species of native freshwater fish in Tasmania, 11 are known to have migratory components to their lifecycles (Fulton, 1990). However, all fish species require access to preferred habitat that requires movement and colonisation over varying distances depending on territoriality and this varies between species. Five native fish species have been recorded from the Montagu catchment that require unimpeded passage between the lower reaches and headwaters. Fish are frequently denied access to areas upstream of physical barriers (Walker, 1999) and in many instances habitat present in these upstream reaches (eg; spawning sites on gravel beds) are essential for the completion of the fishes life history. If passage across a barrier is not favourable for different species, there is the potential for genetically distinct populations to arise. This has ramifications for genetic diversity with the potential to lower the populations ability to adapt to changes in environmental conditions (Walker, 1999).

A limited number of in-stream structures are located within the Montagu catchment. Bridges associated with road crossings have been identified as the most common structure type that has the potential to alter hydrological connectivity. As indicated by Table 8, this type of structure has only a partial impact on hydrological connectivity. Existing in-stream dams are located on minor tributaries and as a result little of the overall catchment area occurs upstream of these structures. Fish distribution records (see Appendix. 5) suggest that influence of artificial in-stream barriers on overall hydrological connectivity in the Montagu catchment has been minimal on a catchment scale.

In addition to artificial structures such as weirs, farm dams, and culverts that have the potential to act as physical barriers, less tangible physical and behavioural barriers are also likely to affect fish movement within the system. Behavioural barriers to fish passage can result from changes to the aquatic environment that affect fish physiology (Thorncraft and Harris, 2000).

Various water quality parameters are important in this context, especially dissolved oxygen (DO), pH, faecal coliform levels and turbidity. Poor quality for individual parameters or a combination of parameters can disrupt environmental cues responsible for triggering fish movement (Thorncraft and Harris, 2000).

Recent investigations of the effects of sediment on fish communities have shown that fish abundance and diversity in New Zealand streams reduced as sediment load within a stream increased and also that in-stream habitat availability declined as sediment load increased (Richardson and Jowett, 2002). It has been suggested that turbidity may interfere with the obligatory journeys between the sea and freshwater for diadromous fish species (Richardson and Jowett, 2002). Upstream migration rates have been found to vary for individual species in response to turbidity. *Galaxias brevipinnis* and *Galaxias maculatus* have been found in field experiments to display 50% avoidance response to turbidities of 69 and 419 Nephelometric Turbidity Units (NTU), respectively. Fixters Creek at Bass Highway (MONT18) had the highest median and extreme values for turbidity of all the sites surveyed within the catchment (see Water Quality report). On 4 occasions turbidity levels were recorded (1999 to 2001 data - Water Quality Section) in excess of those levels known to evoke avoidance responses in *G. brevipinnis* and *G. maculatus*.

In addition to suspended sediment, deposited sediment also has a biological effect. Deposition of sediment can reduce the availability of physical habitat for bottom dwelling species through the filling of interstitial spaces with fine sediment, which results in a decrease in hydraulic roughness. Water velocity has also been shown to increase with increasing deposition of fine sediment (Thorncraft and Harris, 2000). The consequence of this to fish is that there is less habitat available for use as shelter and that which is available is more important for avoiding flows.

Geology, rainfall, and topography are the main controls on sediment export, however land use can exert an important influence (Quinn and Stroud, 2002). Siltation has been identified as a key issue for the Montagu catchment where silt has accumulated as a result of agricultural activities and road runoff within the catchment (Montagu Rivercare Plan, 2002). The incorporation of sediment transportation basins has been identified as a means of reducing sediment load entering the main river channel. This does not however address the cause of sediment mobilisation within the catchment.

Unfortunately desilting works may have the undesirable effect of reducing water quality and thus influencing fish movement patterns. As adverse conditions may be inadvertently created during in-stream rehabilitation works, the timing of river management activities taking into the requirements of migrating fish species and periods of peak fish movement (e.g. migration) is an important consideration when planning river restoration activities.

Hydrological connectivity of the mainstream and individual tributaries is dealt with in the following sections.

Mainstream Montagu River

The IRC assessment indicates that the sites on the mainstream Montagu River display varying degrees of departure from a natural condition. It is evident that some impacts are related to adjacent agricultural land use practices. In-stream conditions at sites within agricultural areas are primarily influenced by low habitat diversity, dominance of fine substrate, lack of CWD, and high levels of overall disturbance. Stream-side zone conditions at each site are primarily influenced by this in the reduced presence of native vegetation and the low proportion of riparian cover.

Specific management issues identified for the mainstream Montagu River sites are provided in Table 9. Management issues that may be considered as a whole include the presence of understorey weed species, limited riparian zone integrity, limited regeneration of native vegetation and lack of vegetation providing bank stability. In summary, most of the critical problems for the mainstream occur in response to the removal of riparian vegetation and subsequent bank instability.

There has been limited development of in-stream structures for the mainstream Montagu River. Five road crossings have been identified that have the potential to alter hydrological connectivity. In a recent assessment of hydrological connectivity within the North Esk catchment, bridges were found to have a partial effect on fish passage potential (Horner, 2002). No existing in-stream dams were identified from the WIMS database for the main channel. One in-stream dam is however proposed near Roger River Road. As this would be within the upper reaches of the mainstream the overall impact upon fish passage would be low as the proportion of stream being effected is small. Fish distribution records (Figure 10) infer that overall hydrological connectivity within the Montagu River has been little effected to date by the presence of artificial in-stream barriers.

Table 9. Management issues identified for the main stream Montagu River sites.

Reach	Management issues
Montagu River at Stuarts Rd.	Weeds – Blackberries (*Rubus fruticosus*), gorse (*Ulex europaeus*) and bracken fern (*Pteridium esculentum*). Limited riparian zone. Limited CWD cover. Unrestricted stock access to river banks and some minor erosion.
Montagu River off Quillams Rd.	Weeds - Minor cover of Stinging nettles (*Cirsium vulgare*),. Limited stock access to river bank.
Montagu River off Barcoo Rd.	Weeds - Minor cover of thistles (*Cirsium arvense*). Some evidence of recent erosion from flood event. No obvious management issues.
Montagu River at 14 Mile Plain	Weeds - Minor cover of thistles and cumbungi (*Typha spp.*). Potential for erosion due to soft banks. No obvious stock access points. Poor riparian cover for left bank (facing upstream).
Montagu River at Rennison Rd.	Weeds - Minor cover of thistles and Cumbungi. Sparse riparian cover dominated by Poplar trees (*Populus spp*.). Native vegetation cover absent. Limited CWD cover. Poor bank stability. No stock access issues due to appropriate fencing.
Montagu River at Bass H'way.	Weeds - Minor cover of thistles. Absence of riparian cover and no indigenous plant regeneration. Limited CWD cover. Potential stock access to left bank of river. Poor bank stability.

Table 9. continued.

Montagu River off Eldridge Rd.	Weeds - Minor cover of thistles and cumbungi. Unrestricted stock access to river banks. Limited CWD cover.
Montagu River downstream of Christmas Hills Rd.	Weeds - Nil. No obvious management issues. Forestry coupes nearby - need to ensure that adequate buffer zones are provided.
Montagu River upstream Christmas Hills Rd.	Weeds - Moderate cover of thistles and bracken fern. Riparian zone cleared by 10 metre width on left bank of river with limited indigenous plant regeneration. Limited CWD cover. Forestry operations adjacent to site. Poor bank stability
Montagu River at Donalds Rd.	Weeds - Moderate cover of thistles. Riparian zone absent. No indigenous plant regeneration. Limited CWD cover. Extensive aquatic macrophyte cover. Unrestricted stock access to river banks resulting in evidence of bank instability.
Montagu River at Roger River Rd.	No obvious management issues.

Tributaries of the Montagu River

As with the mainstream, sites on tributaries that occur within agricultural areas displayed reduced ratings for physical form and stream-side zone condition. The predominant impacts identified for the tributary sites are as follows:

- stream bank erosion due to the lack of stream-side vegetation;
- uncontrolled stock access to stream banks in agricultural zones;
- limited indigenous plant regeneration;
- agricultural practices that limit riparian zones;
- channelisation.

The most common disturbances to the riparian zones on tributaries were related to extensive clearing of native vegetation that has resulted in limited to no riparian vegetation. Stock access to stream banks was also identified as a potential impact for sites within agricultural areas. Channelisation has been identified as a key factor influencing physical river condition for tributary sites within agricultural areas. Specific management issues for each tributary study reach are provided in Table 10.

Hydrological connectivity for the tributaries of the Montagu catchment is more influenced by the presence of in-stream structures than is the mainstream (Figure 9). Farm dam development within the catchment has to date been limited to the upper tributaries (Appendix 2c). As a result hydrological connectivity for the lower tributaries in general has been little influenced by farm dam development.

Given the particular nature of disturbance to physical river condition at each tributary site, details on site condition in relation to ratings for physical in-stream condition, stream-side zone and hydrological connectivity ratings are discussed below.

Un-named tributary off Barcoo Rd. (MONT12)

MONT12 is the lowest tributary site sampled and rates as in good condition in respect to physical form and in excellent condition in relation to the stream-side zone. In general, riparian vegetation health for the tributary is excellent, with vigorous indigenous plant regeneration and riparian zones in excess of 30 metres in width.

No obvious management issues were identified for this tributary. Hydrological connectivity has been directly assessed at one point for this tributary, at the bridge crossing at Barcoo Rd. This bridge is an open structure and has little effect on hydrological connectivity. Fish passage within the mainstream up to the confluence of this tributary is influenced by one in-stream structure, being the bridge at West Montagu Road. This structure rates as 'near ideal' for fish passage conditions.

Farnhams Creek (MONT13, MONT14 and MONT15)

Three sites were assessed along the length of this tributary and these display various degrees of departure from natural condition for both sub-indices. The physical-form sub-indices for these sites ranged from excellent to moderate condition and varied in respect to the degree of adjacent development of the site. Farnhams Ck at Fagans Road (MONT14) occurs in native forest and the condition rating is excellent. Farnhams Creek at the Bass Highway (MONT15) which occurs in remnant native vegetation surrounded by agriculture was rated as in good condition. The lowermost site on Farnhams Creek (at Barcoo Rd (MONT13)) occurs in the most developed section of the tributary and was assessed as having a moderate departure from natural in relation to physical form condition. This primarily results from the meso-habitat diversity indicator from the physical form sub-index which has been modified to a major or extreme degree for this site (Table 6). This reach also has undergone channel straightening and modification, has poor substrate availability given the dominance of clay and poor distribution of habitats with varying velocity/depth categories (dominated by run habitat).

The stream-side zone sub index follows a similar trend to that of the physical form index with conditions being influenced by surrounding land usage. Farnhams Ck at Fagans Rd (MONT14) and Farnhams Creek at Bass Highway (MONT15) both rated as in excellent condition (essentially natural). Farnhams Creek at Barcoo Rd (MONT13) rated as in good condition (near natural). The final score of 7.7 for this sub-index for Farnhams Creek at Barcoo Rd (MONT13) borders the excellent (essentially natural) category. For this tributary no indicators for the stream-side zone index depart from natural condition by a major or extreme degree (Table 6). Bracken fern (*Pteridium esculentum*) is the only exotic plant species to have been identified for this tributary and it is generally sparse. Native vegetation dominates this subcatchment and provides a woody riparian zone, which is in most instances over 40 metres in width.

The hydrological connectivity of this tributary is potentially influenced by eight artificial structures (4 bridges, 1 culvert and 3 in-stream dams). Examination of the road crossings at which bridges were present revealed that these structures were of adequate design to minimise impacts on hydrological connectivity. Previous assessment of various artificial barriers types, similarly found that structures of an open construction have a limited effect on hydrological connectivity within the North Esk catchment (Horner, 2002). The culvert at the Bass Highway rated as 6.4 (near ideal) from the current assessment although this rating borders on being in moderate condition. The crossing has been well designed with the culvert being placed at the level of the stream bed thus maintaining hydrological connectivity.

The in-stream dams in Farnhams Creek have the potential to alter hydrological connectivity by a major degree, resulting in poor fish passage conditions within the tributary. The existing in-stream dams occur within the headwaters of this tributary (on Farnhams Ck and Greys Ck) and have minor catchment areas upstream (WIMS database). One further in-stream dam is currently proposed for Farnhams Creek (Appendix 2b - Dam No.34). Its position is located upstream of the largest existing dam (Appendix 2a - Dam No.1) and as such has little impact on current passage up Farnhams Creek. However the proposed dam will further fragment passage upstream of the lowermost impoundment. Nevertheless, fish distribution records (see Appendix 5) infer that overall hydrological connectivity within this tributary has been little affected by the presence of artificial in-stream barriers.

Un-named canal off Barcoo Rd at 14 Mile Plain (MONT16)

This site is representative of the highly artificial watercourses within the catchment that have been altered for drainage purposes. Both physical form and stream-side zone subindex indicate that river condition at this site is very poor and is similar in condition to mainstream sites adjacent to agricultural landuse.

All four of the indicators for physical form have been modified to a major or extreme degree (Table 6). Of the seven tributary sites surveyed, this site (MONT16) received the lowest rating for in-stream condition and is more similar in condition to the poorly rated mainstream sites adjacent to agricultural landuse (Montagu River at Bass Highway (MONT06) and Montagu River at Donalds Rd. (MONT10)). These sites have been subject to extensive channel modification, which has reduced stream integrity.

The stream-side zone sub index also rates as very poor for this site. All 6 indicators for this index display major or extreme modification from the natural condition (Table 6). The poor stream-side zone rating is reflects the absence of woody plant species from the riparian zone which is dominated by grass and weed species, such as blackberries and thistles.

While the in-stream environment has been highly modified through the channelisation of the canal itself and extensive drainage systems, hydrological connectivity is essentially natural and has not been fragmented by artificial structures. One only potential barrier assessed for this tributary (the Lees Road Bridge) was found to provide near ideal conditions for fish passage. Fixters Creek joins the Montagu mainstream via a canal and a number of drainage lines in the vicinity of Lees Rd. The artificial and complex nature of these drainage lines mauy have implications for fish passage from the mainstream into the middle to upper reaches of Fixters Creek which is a natural watercourse.

Fixters Creek (MONT17 and MONT18)

Fixters Creek is the second largest tributary in the Montagu River catchment with the lower and upper reaches of this tributary bordering significant agricultural development. In IRC assessments for other Tasmanian catchments, the upper reaches of major tributaries are commonly in better riverine condition than downstream reaches and this generally reflects the trend of increased development in a downstream direction (Nelson 1999a, 1999b, and Horner, 2002). This tributary however displays the converse with lower conidition ratings for both sub-indices at the upper site in response to increasing departure from natural conditions.

Physical form condition was assessed as excellent (essentially natural) for Fixters Creek at Riseborough Rd (MONT17) and as in very poor condition (highly modified) upstream for Fixters Creek at Bass Highway (MONT18). From Table 6 it is evident that all of the physical form indicators have departed from a natural state by a major or extreme degree for the Bass Highway site.

Condition of the stream side zone varied from essentially natural (excellent condition) at Fixters Creek at Riseborough Rd (MONT17) to extremely modified (very poor condition) at Fixters Creek at Bass Highway (MONT18). All six indicators of stream-side condition departed from a natural state by a major or extreme degree at Fixters Creek at Bass Highway (MONT18). These findings directly reflect riparian clearing, which have resulted in the loss of riparian zone integrity (see Table 6).

Hydrological connectivity is near ideal for this tributary from Barcoo Rd to the Bass Highway. Near ideal conditions were recorded for the bridge crossings at Riseborough Road and Barcoo Road. However, an assessment of the road crossing at the Bass Highway revealed that hydrological connectivity is impaired to a moderate degree (value of 4.6) given the outlet for the bridge is perched some 40 centimetres above the stream bed and the resultant critical outflow provides very poor potential for passage. Fish distribution records (see Figure 10) support this given that diadromous native species occur in the lower sections of the tributary but are absent from the upper reaches. As hydrological connectivity is near ideal up to the Bass Highway crossing, it would be expected that *G. truttaceus* and *G. maculatus* would be present up to this point. This is in fact the case for Farnhams Creek, where both galaxiid species have been recorded near the Bass Highway. High turbidity levels within the upper section of Fixters Creek may account for the difference in fish species between these tributaries (see Water Quality report).

The rate of fish movement into this tributary is dependent on passage conditions within the un-named canal off Barcoo Rd. Though physical barriers within the canal have not been identified that will alter passage potential, extreme modification to in-stream and streamside conditions are likely to be important factors in determining passage rates, as these have the potential to evoke behavioural avoidance responses.

Examination of physical form and stream-side zone ratings suggest that the greatest loss of condition for tributary streams occurs as a result of disturbance from surrounding land usage practices. Clearance of riparian vegetation adjacent to agricultural areas have the greatest impact on river condition resulting in very poor condition at 2 sites (un-named canal off Barcoo Rd (MONT16) and Fixters Creek at Bass Highway (MONT18)). The most common elements associated with poor tributary condition were the absence of riparian cover, the presence of exotic species, lack of vegetation that aids bank stability and limited indigenous vegetation regeneration and streambank erosion. Management issues identified for individual sites are provided in Table 10.

Table 10. Management issues identified for the Montagu River tributary sites.

Reach	Management issues
Un-named tributary at Barcoo Rd.	Weeds- Minor cover by bracken fern. No obvious management issues.
Farnhams Creek at Barcoo Rd.	Weeds- Minor bracken fern cover. No obvious management issues.
Farnhams Creek at Fagans Rd.	Weeds- Minor cover by bracken fern. No management issues.
Farnhams Creek at Bass Highway.	Weeds - Nil. No management issues identified.
Un-named canal off Barcoo Rd.	Weeds - Blackberries and thistles (moderate cover). Absence of riparian cover. No indigenous plant regeneration. Artificial channel. Absence of CWD. Poor bank stability.
Fixters Creek at Riseborough Rd.	Weeds - Bracken fern (sparse cover). Potential issues associated with reductions in riparian width from forestry operations.
Fixters Creek at Bass Highway.	Weeds - Blackberry, thistles (low cover). Extensive water fern (*Azolla spp*.) growth. Unrestricted stock access to river banks. Limited riparian zone dominated by non woody (grass) species. No indigenous plant regeneration. Poor bank stability. Absence of CWD.

6. CONCLUSION

Previously the IRC has proven to be a viable tool to assess the deviation of a reach away from a natural condition both in terms of physical form and the condition of the stream-side zone for Tasmanian catchments (Nelson, 1999a and Horner, 2002). For the Montagu catchment the Index of River Condition has had limitations in assessing the deviation of some reaches away from a natural condition in terms of physical form condition. In some instances reaches that have been altered from a natural state by channelisation fail to indicate major or extreme differences in indicator condition. Despite this the IRC does illustrate that in-stream and stream-side zone condition for the Montagu catchment is most influenced by land usage and drainage development associated with intensive agricultural development.

The IRC identifies potential degradation issues for each reach within the Montagu catchment, which are currently, or have the potential to reduce riverine quality. Using the ratings generated from this study it is possible for river managers and community groups to target areas for river rehabilitation activities with management options aimed at improving the overall condition of impacted areas. These may include:

- Better stream-side zone management to allow the re-establishment of an appropriate buffer strip of native species.
- Reduction of sediment input from artificial drainage channels.
- Stream bank protection by limiting stock access and control of stream bank erosion.
- Weed reduction and long term control programs.

The hydrological connectivity component of the study has effectively demonstrated that it has the potential to identify the ability of in-stream structures to act as barriers to fish migration. It has proven to be a robust means of indicating the potential for free movement from headwaters to the lower reaches. The interpretation of ratings has identified areas in the catchment that may restrict fish passage at present and should provide a basis for the planning of future in-stream storage development for the catchment. Future operations should aim to maintain and or preferably improve hydrological connectivity within the system and ideally protect tributaries that have unrestricted fish passage.

The IRC has provided a baseline of information that can be used for comparative purposes to observe changes within the catchment over time. With a management plan in place for the catchment, it would be possible to repeat the IRC survey in 5 years using the same sites to determine if the overall condition of the catchment has improved or declined.

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8. APPENDICES

APPENDIX 1: Artificial barriers - dam and bridge locations for the Montagu River.

Site	Northing	Easting	Type	Hydrological rating
Fixters Creek at Bass Highway	5467500	328800	Bridge	2
Farnhams Creek at Barcoo Rd	5474700	324800	Bridge	3
Un-named tributary at Barcoo Rd	5477400	327000	Bridge	4
Farnhams Creek at Bass Highway	5469900	329800	culvert	3
Montagu River at West Montagu Rd	5483650	325960	Bridge	3
Montagu River at Stuarts Rd	5482900	325370	Bridge	3
Montagu River at Bass Highway	5463400	321700	Bridge	3
Dam 11	5485100	327800	Dam	1
Dam 12	5484900	327900	Dam	1
Dam 13	5485200	327700	Dam	1
Dam 14	5485000	327600	Dam	1
Montagu River at Renison Rd	5468200	321100	Bridge	3
Dam 6	5483100	323700	Dam	1
Dam 22	5479800	328000	Dam	1
Dam 27	5479200	327600	Dam	1
Farnhams Creek at Fagans Rd	5472200	328500	Bridge	4
Fixters Creek at Riseborough Rd	5469300	326850	Bridge	4
Un-named canal at Lees Rd	5469400	324200	Bridge	3

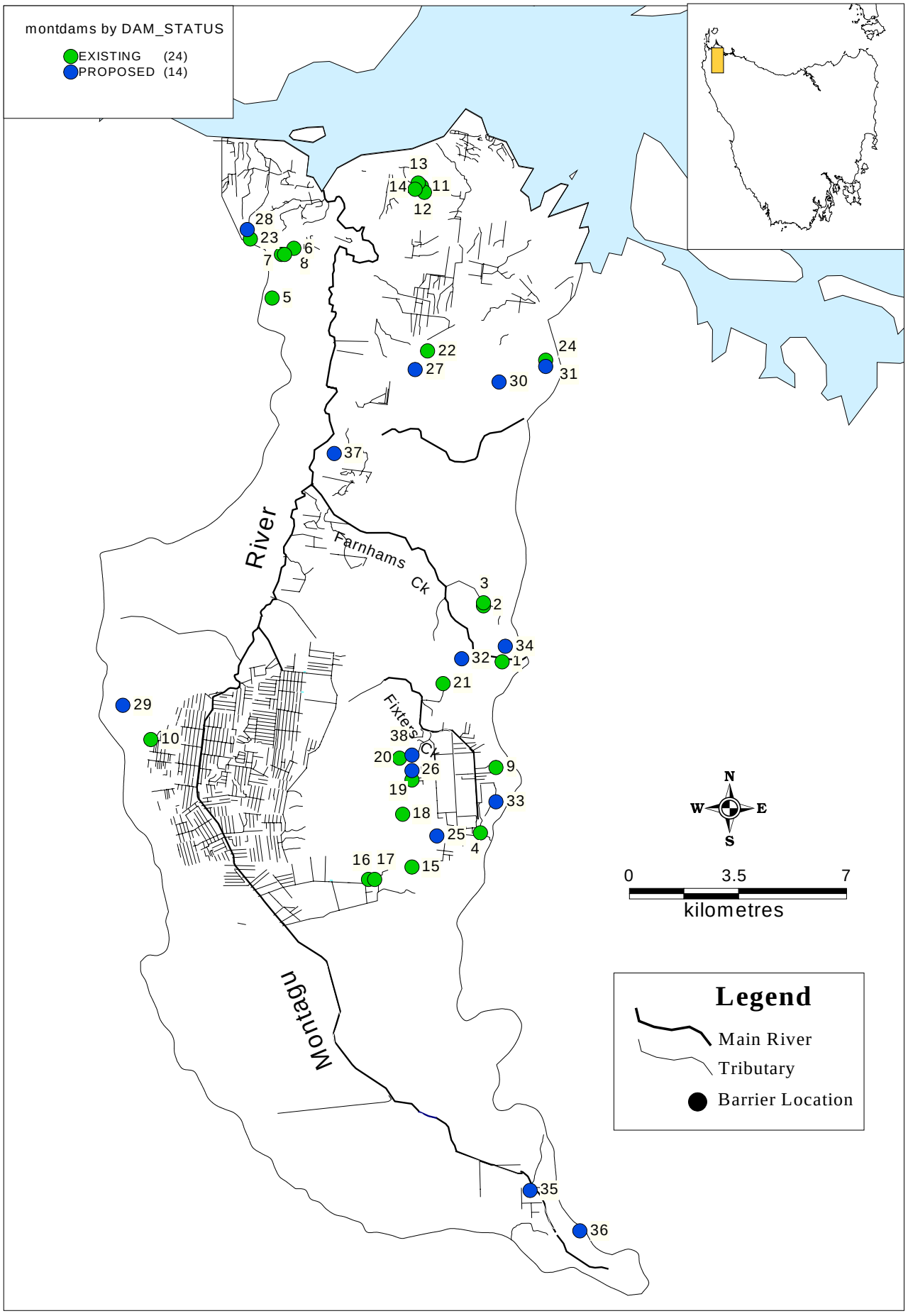
Appendix 2a: Existing in-stream dam location details for the Montagu Catchment.

Dam number	Northing	Easting	Purpose
1	5469800	330400	IRRIGATION
2	5471600	329800	IRRIGATION
3	5471700	329800	IRRIGATION
4	5464300	329700	IRRIGATION
5	5481500	323000	IRRIGATION
6	5483100	323700	IRRIGATION
7	5482900	323300	IRRIGATION
8	5482900	323400	IRRIGATION
9	5466400	330200	IRRIGATION
10	5467300	319100	STOCK
11	5485100	327800	IRRIGATION
12	5484900	327900	IRRIGATION
13	5485200	327700	IRRIGATION
14	5485000	327600	IRRIGATION
15	5463200	327500	IRRIGATION
16	5462800	326100	IRRIGATION
17	5462800	326300	IRRIGATION
18	5464900	327200	IRRIGATION
19	5466000	327500	IRRIGATION
20	5466700	327100	IRRIGATION
21	5469100	328500	STOCK
22	5479800	328000	STOCK
23	5483400	322300	IRRIGATION
24	5479500	331800	STOCK

Appendix 2b: Proposed in-stream dam location details for the Montagu Catchment.

Dam number	Northing	Easting	Purpose
25	5464200	328300	STOCK
26	5466300	327500	STOCK
27	5479200	327600	STOCK
28	5483700	322200	IRRIGATION
29	5468400	318200	OTHER
30	5478800	330300	STOCK
31	5479300	331800	STOCK
32	5469900	329100	STOCK
33	5465300	330200	STOCK
34	5470300	330500	IRRIGATION
35	5452800	331300	IRRIGATION
36	5451500	332900	AESTHETIC
37	5476500	325000	IRRIGATION
38	5466800	327500	IRRIGATION

APPENDIX2C: Existing and proposed dam locations for the Montagu catchment



APPENDIX 3: Overall site disturbance indicator categories for the Hydrological Connectivity sub-index

1. EXTREME DISTURBANCE	
Riparian vegetation	**Absent or severely reduced. Vegetation present is severely disturbed - i.e.**
dominated by exotic	**species. Native species are rare or absent.**
Surrounding vegetation	**Agriculture and/or cleared BOTH sides. Plants present are virtually all exotic**
species (pines,	**willows, etc.)**
2. MAJOR DISTURBANCE	
Riparian vegetation	**Some native vegetation present, but it is severely modified BOTH sides by**
grazing	**or the intrusion of introduced species. Native species severely reduced in numbers**
(species richness) and cover.	
Surrounding vegetation	**Agriculture and/or cleared BOTH sides. Plants present are virtually all exotic**
species (pines,	**willows, etc.).**
3. MODERATE DISTURBANCE	
Riparian vegetation	**Moderately disturbed by stock or through the intrusion of introduced species,**
though native species	**remain in reasonable numbers and abundance.**
Surrounding vegetation	**Agricultural land and/or cleared on ONE side; native vegetation on the other**
clearly disturbed or	**with a high percentage of introduced species.**
4. MINOR DISTURBANCE	
Riparian vegetation	**Native vegetation on BOTH sides of the river in generally good condition with few**
introduced species	**present. Any disturbance is minor.**
Surrounding vegetation	**Native vegetation present on BOTH sides of the river with a virtually intact**
canopy. Minor	**disturbance present through introduced species.**
5. VERY LOW DISTURBANCE	
Riparian vegetation	**Native vegetation on both sides of the river in an undisturbed state. Introduced**
species are rare or	**insignificant. Representative of pristine condition.**
Surrounding vegetation	**Native vegetation on both sides of the river with an intact canopy. Introduced**
species are rare or	**insignificant. Representative of pristine condition.**