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

Tasmania

Index of River Condition for the Jordan River Catchment

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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.

Executive 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 Jordan 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).

Previous applications of the IRC methodology provide an overall condition rating based on five subindices (Nelson, 1999a). The sub-indices that were previously used to detect changes in condition from a natural state included aquatic ecology, hydrology, water quality, stream-side zone and physical form. These sub-indices were taken from the Victorian Index of River Condition and adapted to Tasmanian conditions (CEAH, 1997a). 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 streamside zone. In addition, a new element has been added to condition assessment in relation to in-stream structures. Assessment of in-stream structures does not necessarily correspond to sites where riparian and physical in-stream habitat was assessed, as they are location specific. This sub-index has proven successful in determining the potential of artificial structures of varying design to influence fish passage within the North Esk Catchment (Horner, 2002).

Field data collection of IRC parameters occurred at 42 representative sites within the Jordan River catchment. Thirteen of these were located on the mainstream Jordan River and 29 on tributary streams. One hundred and twenty nine (129) in-stream structures were assessed separately at relevant locations throughout the catchment.

The physical form sub-index ranged in condition from moderate to very poor for the mainstream sites and from excellent to very poor for the tributary sites. Lower values were recorded for sites that occur within agricultural areas. These findings 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 the Jordan catchment.

The stream-side zone sub-index ranged in condition from excellent to very poor within the Jordan catchment. Typically ratings for this sub-index were lower in agricultural areas than for non-developed zones. These findings indicate that non-vegetated or poorly vegetated riparian zones, and uncontrolled stock access to riverbanks are impacts that need addressing in relation to riparian zone management for the Jordan catchment.

Surveys of in-stream structures focused primarily on the hydrological changes that are associated with each artificial structure and how these changes alter the potential for fish passage. Eighty-four artificial structures were identified that cause alteration of hydrological (fish passage) conditions within the mainstream and/or major tributaries by a moderate to extensive degree. 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, culverts and weirs a moderate modification of condition whilst bridges resulted in a partial modification of condition. These findings indicate that fish movement patterns may be influenced by artificial structures within the Jordan catchment. This is of particular importance as the five 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 Jordan catchment. Within agricultural areas of the catchment it was found that the riparian zone was highly altered and that native species were in low proportions and in some cases completely absent. Typically agricultural zones also displayed varying degrees of infestation 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	Water Information Management Systems 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 Jordan 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 to assess river condition for Tasmanian rivers. In addition, community groups to target rehabilitation activities have used IRC assessments on previous catchments.

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, 1995) 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 useful 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 can provide the basis for long term monitoring of changes in habitat condition as future Index of River condition assessments could be conducted every five years.

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 waterfalls and 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 Jordan catchment over time. Ideally this program could 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 Jordan catchment occupies an area of approximately 124,600 hectares (North, 1999) and the river emerges from Lake Tiberias. From Lake Tiberias, it flows in a northwesterly direction until Burnt Log Gully where it then flows in a southerly direction for about 80 km through Melton Mowbray, Broadmarsh and Brighton to enter the Derwent Estuary near Bridgewater (Figure 1). Hughes (1988) classifies the Jordan River as a Group 2 river in terms of hydrology. This group includes rivers in the drier regions of the south-east of the state and the hydrological characteristics of these rivers are comparable with semi arid rivers of mainland Australia. Rivers in this group are characterised by low mean annual runoff, low annual rainfall and the greatest variability in terms of monthly flows.

The Jordan catchment is characterised by an upper catchment that consists predominantly of native forest and a lower catchment that has a long history of agricultural use (North, 1999). In the lower reaches, North (1999) found that the riverbanks of the Jordan river and major tributaries are substantially degraded with few sections retaining intact native riparian vegetation with the extent of weed infestation, notably willows posing a significant management problem. The riparian vegetation of the middle to lower reaches of the catchment consists mainly of crack willow (*Salix fragilis*), gorse (*Ulex europaeus*) with some remnant native vegetation. Many sections of the river are cleared of riparian vegetation with pasture grass adjacent to the riverbanks.

Table 1. Site Legend for Jordan IRC sites represented in Figure 1.

Site Code	Site	Northing	Easting
JORD01	Jordan u/s tidal limit at old SG station	5269500	519700
JORD02	Jordan at Pontville Ford	5273150	521800
JORD03	Jordan at Elderslie Road	5274100	514800
JORD04	Jordan at Andersons Road	5279950	508950
JORD05	Jordan at Roydon Road 300m d/s of Bridge	5283900	506600
JORD06	Jordan at Clifton Vale Road	5289400	507200
JORD07	Jordan at Mauriceton	5291500	510100
JORD08	Jordan u/s Donnybrook Rivulet	5299450	511850
JORD09	Jordan at Apsley	5303000	512000
JORD10	Jordan at Glenmore Sugarloaf	5309600	513950
JORD11	Jordan at Black Bridge	5311900	515800
JORD12	Jordan at Burnt Log Gully	5315800	521900
JORD13	Jordan at Jericho	5308100	524100
JORD14	Bagdad Rivulet u/s Golf Course	5273850	522400
JORD15	Bagdad Rivulet at Eddington Road	5281100	518300
JORD16	Bagdad Rivulet off Harbach's Road	5284500	519450
JORD17	Strathallan Rivulet u/s Golf Course	5273600	522600
JORD18	Strathallan Rivulet at Tea Tree	5273450	526300
JORD19	Tea Tree Rivulet at Back Tea Tree Road	5271300	525825
JORD20	Woodlands Creek u/s Tea tree	5273760	528370
JORD21	Brown Cave Creek / Chauncy Vale Road	5282870	519350
JORD22	Mangalore Creek / Black Brush Road	5276380	517200
JORD23	Stoneyhurst Creek off Storeys Road	5275900	508450
JORD24	Grahams Creek at Elderslie Road	5279400	509400
JORD25	Grahams Creek off Grahams Creek Road	5278490	506730
JORD26	Green Valley Rivulet at Cockatoo Valley Rd	5281400	508600
JORD27	Green Valley Rivulet at Green Valley Road	5280300	513400
JORD28	Espies Creek off Pelham Road	5284000	503920
JORD29	Green Ponds Rivulet at Wilderness Lane	5292300	514500
JORD30	Quoin Rivulet at Midlands Highway	5296650	514600
JORD31	Quoin Rivulet at Colebrook Heights	5294450	521390
JORD32	Donnybrook Rivulet at Den Road	5299100	511600
JORD33	Donnybrook Rivulet upper at Den Road	5299450	507800
JORD34	Little Den Creek at Lake Highway	5302700	511400
JORD35	Little Den Creek at Bisdees Road	5302780	509430
JORD36	Spring Hill Creek at Lower Marshes Road	5307550	513750
JORD37	Exe Rivulet at Exe Sugarloaf	5314700	518300
JORD38	Green Hill Rivulet off track at Bowhill Road	5316200	521500
JORD39	Green Hill Rivulet at Bowhill Road	5318300	519900
JORD40	Petherton Creek at Bowhill Road	5316400	524200
JORD41	Dulverton Rivulet at Bowhill Road	5315500	525500
JORD42	Huntworth Creek at Stonor Road	5309200	525850

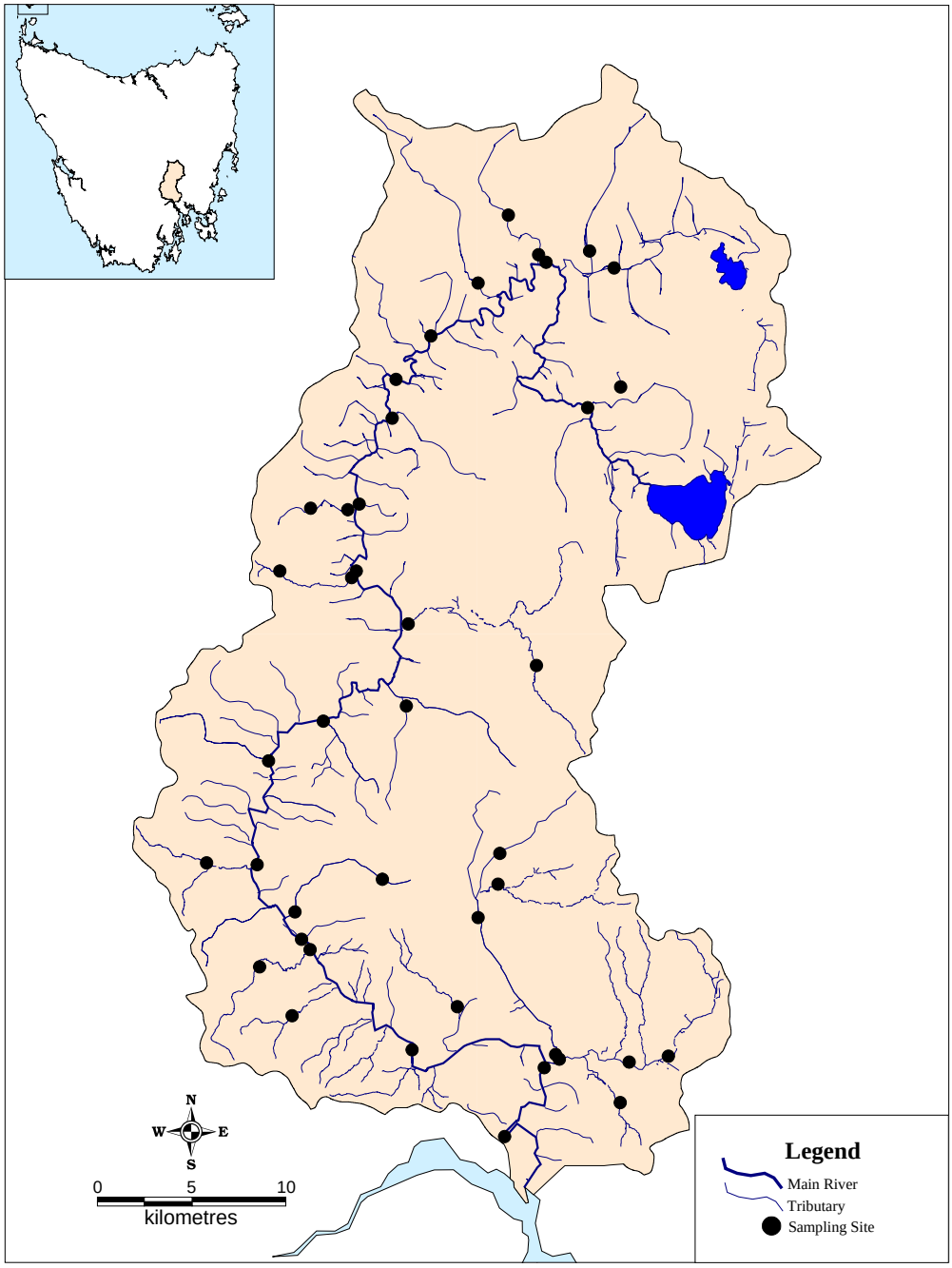


Figure 1: Jordan River Catchment. Index of River Condition (IRC) sites.

3. METHODOLOGY DESCRIPTION

The IRC approach has been developed to provide an assessment of current habitat condition within a given 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 for the Victorian IRC (CEAH, 1997b) after rigorous trial of the original Index for Victorian conditions and this has subsequently 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 Mesohabitat 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 instability 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 is available 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 or 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 metres long and that has a width of 5 metres or less. The two factors applied are:

- the 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 above sub indices for streamside zone and physical form condition 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 condition departs 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

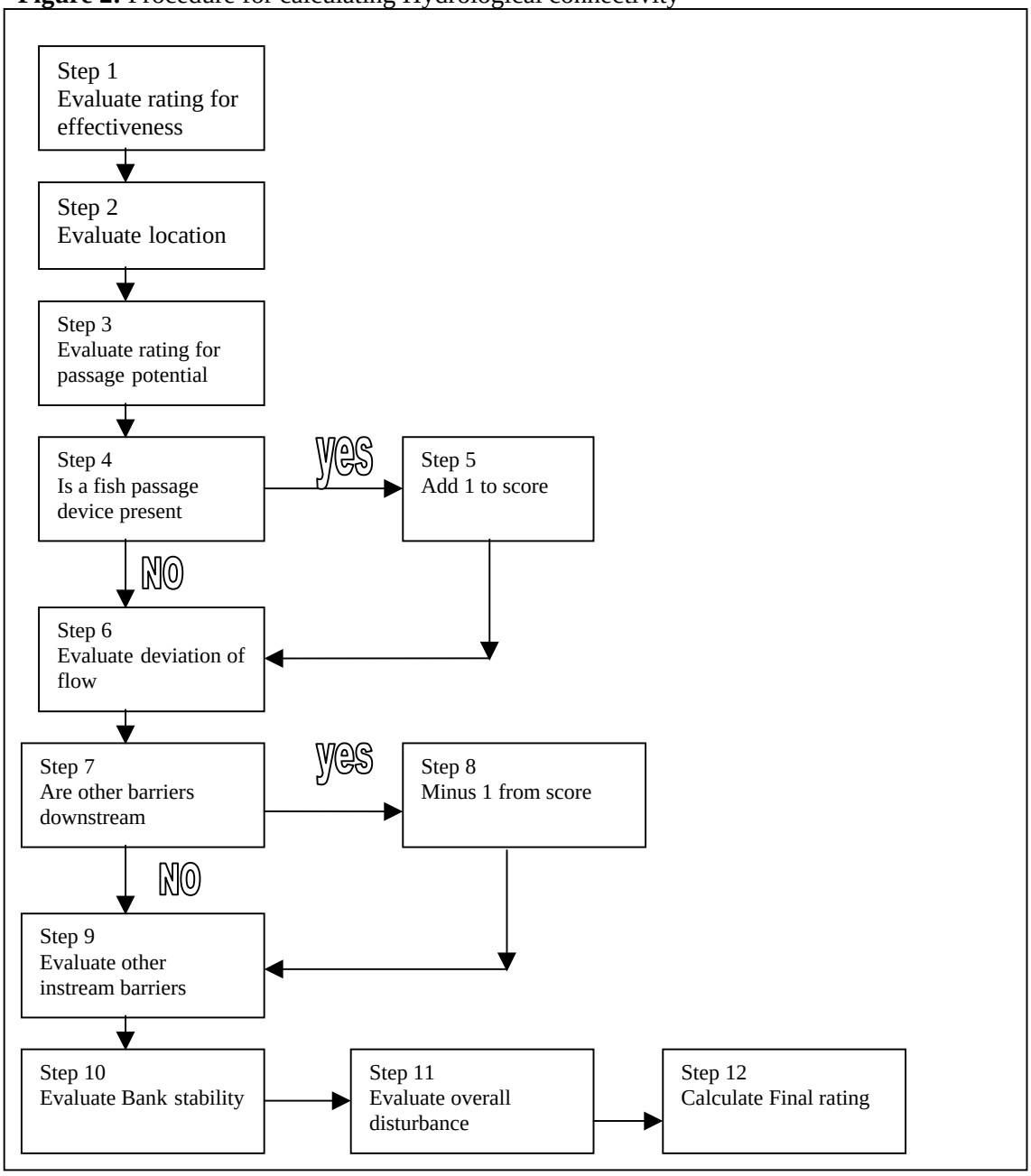
The stability of the surrounding stream banks is an important factor to determine in relation to hydrological connectivity. Stable conditions have been set as the standard for "ideal". High rates of bank erosion are known to result in increased sediment loads within waterways and reduced water quality. 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 2.

Figure 2: Procedure for calculating Hydrological connectivity



3.2 Site selection and survey methods

Site assessments were conducted during February, 2002. A total of 42 sites were surveyed within the catchment (Figure 1 and Appendix 1a). Thirteen sites were located on the mainstream and 20 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 was where possible consistent with those 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 and added interpretation at a given site. During January 2002 an additional survey of parameters related to hydrological connectivity was undertaken. This allowed for the direct assessment of 130 artificial in-stream structures that have the potential to act as barriers to fish migration or movement (Appendix 1b). An additional 17 farm dams were assessed that were found to be off stream structures.

4. RESULTS

4.1 IRC results for mainstream sites

A total of 13 sites were sampled on the mainstream (Figure 1) and IRC ratings for the mainstream Jordan River are provided in Figure 3. Parameters that suggest major or extreme modification from a natural or ideal condition are presented in Table 4 along with any data gaps. Condition maps for the physical form and stream-side zone sub-indices are provided in Figures 6 and 7 respectively. Management issues for each mainstream site are identified in Table 8.

For the mainstream the rating for physical condition ranged from moderate to very poor condition with the values for individual sites being influenced by the degree of development around the site (Figure 3). The physical form sub-index for two reaches of the Jordan mainstream rated as in moderate condition (Jordan River upstream Donnybrook Rivulet (JORD08), and Jordan River at Glenmore Sugarloaf (JORD10). The physical form subindex was found to be in poor condition for six mainstream sites (Jordan River at old gauging station (JORD01), Jordan River at Andersons Road (JORD04), Jordan River at Clifton Vale Road (JORD06), Jordan River at Mauriceton (JORD07), Jordan River at Apsley (JORD09) and Jordan River at Burnt Log Gully (JORD12)). The physical form sub-index rated as in very poor condition for five mainstream sites (Jordan River at Pontville Ford (JORD02), Jordan River at Elderslie Road (JORD03), Jordan River at Roydon Road (JORD05), Jordan River at Black Bridge (JORD11), and Jordan River at Jericho (JORD13)). Sub-index rating values of 1.9 for Jordan River at Pontville Ford (JORD02), Jordan River at Roydon Road (JORD05) and Jordan River at Black Bridge (JORD11) indicate that in-stream conditions for these sites border on poor (major modification). Jordan River at Jericho (JORD13) was the most altered of the mainstream sites with a physical form sub-index value of 0.0.

From Table 4 it is evident that major or extreme modification of individual physical form indicators occurs within reaches of the mainstream Jordan River adjacent to agricultural land. Six mainstream sites (Jordan River at Pontville Ford (JORD02), Jordan River at Elderslie Road (JORD03), Jordan River at Roydon Road (JORD05), Jordan River at Black Bridge (JORD11), Jordan River at Burnt Log Gully (JORD12), and Jordan River at Jericho (JORD13)) display major or extreme modification to all four parameters of physical form. From Table 4 it is evident that the indicator for coarse woody debris (CWD) is subject to major or extreme disturbance for all mainstream sites.

Condition of the stream-side zone ranged from poor to very poor for the mainstream sites. Three sites (Jordan River at old gauging station (JORD01), Jordan River upstream Donnybrook Rivulet (JORD08) and Jordan River at Glenmore Sugarloaf (JORD10)) rated as in poor condition. The remaining 10 mainstream sites (Jordan River at Pontville Ford (JORD02), Jordan River at Elderslie Road (JORD03), Jordan River at Andersons Road (JORD04), Jordan River at Roydon Road (JORD05), Jordan River at Clifton Vale Road (JORD06), Jordan River at Mauriceton (JORD07), Jordan River at Apsley (JORD09), Jordan River at Black Bridge (JORD11), Jordan River at Burnt Log Gully (JORD12) and Jordan River at Jericho (JORD13) were 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 3 and Table 4. From Table 4 it is evident that major or extreme modification to parameters of this sub-index has occurred most frequently 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.

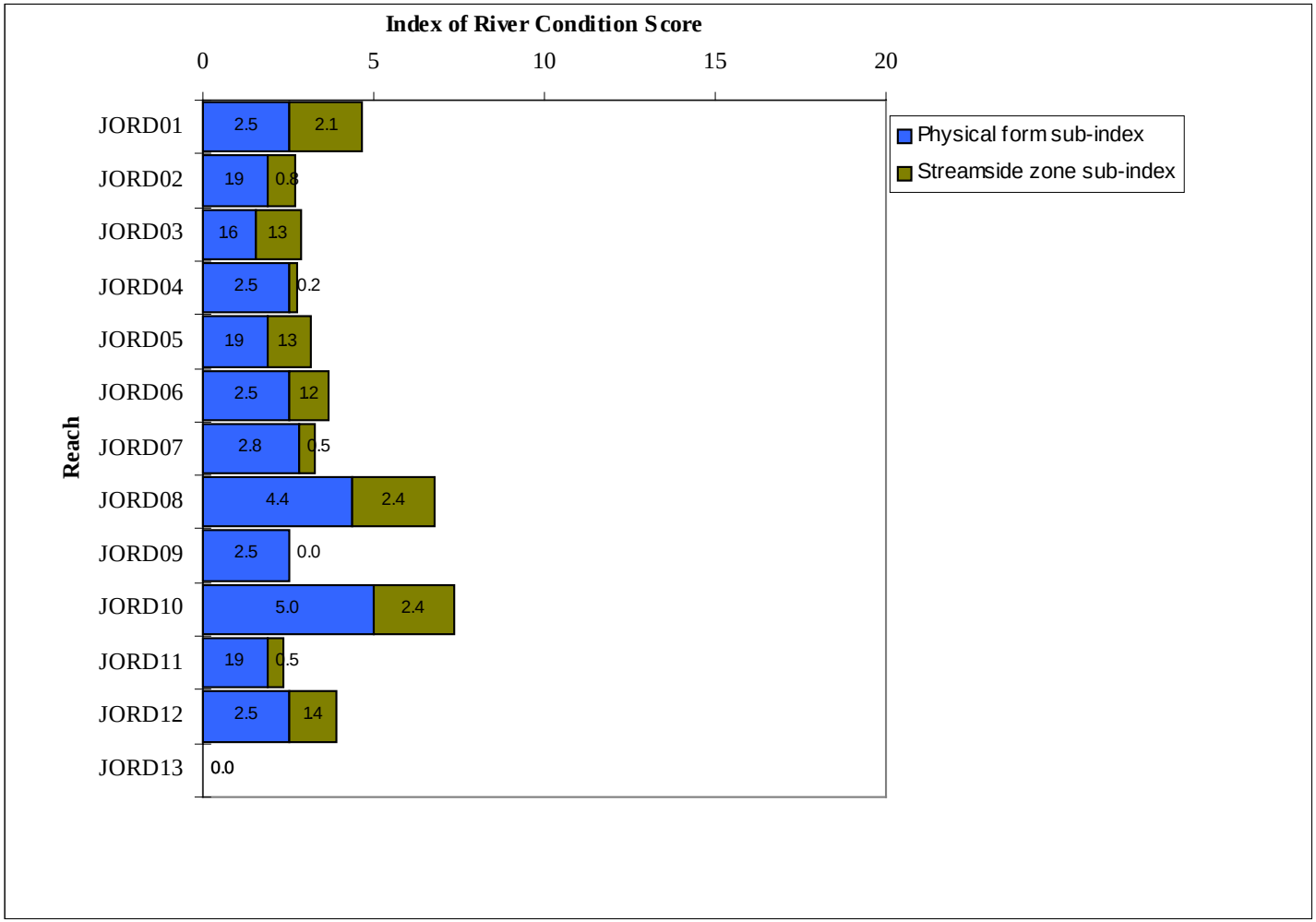


Figure 3. IRC results for the Jordan River mainstream sites.

Table 4: IRC Sub-index ratings and indicator values for the Jordan River mainstream 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
JORD01 Jordan River at old gauging station.	Valley	2.5					2.1						
JORD02 Jordan River at Pontville Ford.	Valley	1.9					0.8						
JORD03 Jordan River at Elderslie Road.	Valley	1.6					1.3						
JORD04 Jordan River at Andersons Road.	Valley	2.5					0.2						
JORD05 Jordan River at Roydon Road.	Valley	1.9					1.3						
JORD06 Jordan River at Clifton Vale Road.	Valley	2.5					1.2						
JORD07 Jordan River at Mauriceton.	valley	2.8					0.5						
JORD08 Jordan River upstream Donnybrook Rivulet.	valley	4.4					2.4						
JORD09 Jordan River at Apsley.	valley	2.5					0.0						
JORD10 Jordan River at Glenmore Sugarloaf.	valley	5.0					2.4						
JORD11 Jordan River at Black Bridge.	Valley	1.9					0.5						
JORD12 Jordan River at Burnt Log Gully.	Valley	2.5					1.4						
JORD13 Jordan River at Jericho.	Valley	0.0					0.0						

Indicator suggests major or extreme. difference from natural or ideal conditions

Inadequate data to evaluate sub-index.

Adequate data to evaluate indicator and ratings suggest changes have not been extreme or major.

CWD = Coarse woody debris

Regen = regeneration of indigenous species.

LC = Longitudinal continuity

4.2 IRC results for tributary sites

IRC ratings for the tributary streams of the Jordan catchment are provided in Figure 4. A total of 29 sites were sampled on 20 tributaries (Figure 1). Parameters that suggest major or extreme modification from a natural condition are highlighted in Table 5 along with data gaps. Maps for Physical form and Stream-side sub-indices values are provided in Figures 6 and 7 respectively.

Four tributary sites were found to be in essentially natural (excellent) condition for Physical form (Bagdad Rivulet off Harbach's Road (JORD16), Quoin Rivulet at Colebrook Heights (JORD31), Little Den Creek at Lake Highway (JORD34), and Little Den Creek at Bisdees Road (JORD35)). The Physical form sub-index of three tributary sites (Brown Cave Creek at Chauncy Vale Road (JORD21), Grahams Creek at Elderslie Road (JORD24), and Donnybrook Rivulet at Den Road (JORD32)), rated as in good (near natural) condition. Four tributary sites rated as in moderate condition (Bagdad Rivulet at Eddington Road (JORD15), Strathallan Rivulet at Tea Tree (JORD18), Stoneyhurst Creek off Storeys Road (JORD23), and Grahams Creek off Grahams Creek Road (JORD25)). Eleven tributary sites rated as in poor condition for this sub-index (Bagdad Rivulet upstream of Golf Course (JORD14), Strathallan Rivulet upstream of Golf Course (JORD17), Woodlands Creek upstream of Tea Tree (JORD20), Mangalore Creek at Black Brush Road (JORD22), Espies Creek off Pelham Road (JORD28), Quoin Rivulet at Midlands Highway (JORD30), Donnybrook Rivulet upper at Den Road (JORD33), Springhill Creek at Lower Marshes Road (JORD36), Exe Rivulet at Exe Sugarloaf (JORD37), Green Hill Rivulet off Bowhill Road (JORD38), and Green Hill Rivulet at Bowhill Road (JORD39)). Seven sites rated as in very poor (highly modified) condition for physical form (Tea Tree Rivulet at Back Tea Tree Road (JORD19), Green Valley Rivulet at Cockatoo Valley Road (JORD26), Green Valley Rivulet at Green Valley Road (JORD27), Green Ponds Rivulet at Wilderness Lane (JORD29), Petherton Creek at Bowhill Road (JORD40), Dulverton Rivulet at Bowhill Road (JORD41), and Huntworth Creek at Stonor Road (JORD42)).

Like the mainstream, physical form condition deteriorated for the tributary sites within agricultural or urbanised areas. This is clearly reflected in the low ratings of Quoin Rivulet at Midlands Highway (JORD30) and Bagdad Rivulet upstream of Golf Course (JORD14), when compared with tributary sites that occur in less developed zones, such as Quoin Rivulet at Colebrook Heights (JORD31) and Bagdad Rivulet off Harbach's Road (JORD16).

The stream-side zone sub-index of two tributary site (Bagdad Rivulet off Harbach's Road (JORD16) and Little Den Creek at Bisdees Road (JORD35)), rated as in excellent (essentially natural) condition. Two sites rated as in good (near natural) condition for this sub-index (Quoin Rivulet at Colebrook Heights (JORD31) and Little Den Creek at Lake Highway (JORD34)). A single tributary site rated as in moderate condition (Brown Cave Creek at Chauncy Vale Road (JORD21). Five tributary sites rated as in poor condition for the stream-side zone sub-index (Stoneyhurst Creek off Storeys Road (JORD23), Grahams Creek at Elderslie Road (JORD24), Grahams Creek off Grahams Creek Road (JORD25), Donnybrook Rivulet at Den Road (JORD32), and Green Hill Rivulet off Bowhill Road (JORD38)).

Very poor conditions were assessed for the stream-side zone sub-index at 19 tributary sites (Bagdad Rivulet upstream of Golf Course (JORD14), Bagdad Rivulet at Eddington Road (JORD15), Strathallan Rivulet upstream of Golf Course (JORD17), Strathallan Rivulet at Tea Tree (JORD18), Tea Tree Rivulet at Back Tea Tree Road (JORD19), Woodlands Creek upstream of Tea Tree (JORD20), Mangalore Creek at Black Brush Road (JORD22), Green Valley Rivulet at Cockatoo Valley Road (JORD26), Green Valley Rivulet at Green Valley Road (JORD27), Espies Creek off Pelham Road (JORD28), Green Ponds Rivulet at Wilderness Lane (JORD29), Quoin Rivulet at Midlands Highway (JORD30), Donnybrook Rivulet upper at Den Road (JORD33), Springhill Creek at Lower Marshes Road (JORD36), Exe Rivulet at Exe Sugarloaf (JORD37), Green Hill Rivulet at Bowhill Road (JORD39), Petherton Creek at Bowhill Road (JORD40), Dulverton Rivulet at Bowhill Road (JORD41), and Huntworth Creek at Stonor Road (JORD42)).

In a similar fashion to physical form sub-index assessments, the general trends suggested a relationship between site condition and adjacent land use or development. From Table 5 it is evident that the very poor ratings for 9 of the tributary sites is indicative of 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 and or urban areas (Figure 4). Ratings were generally found to improve in sections of the tributaries where development is low.

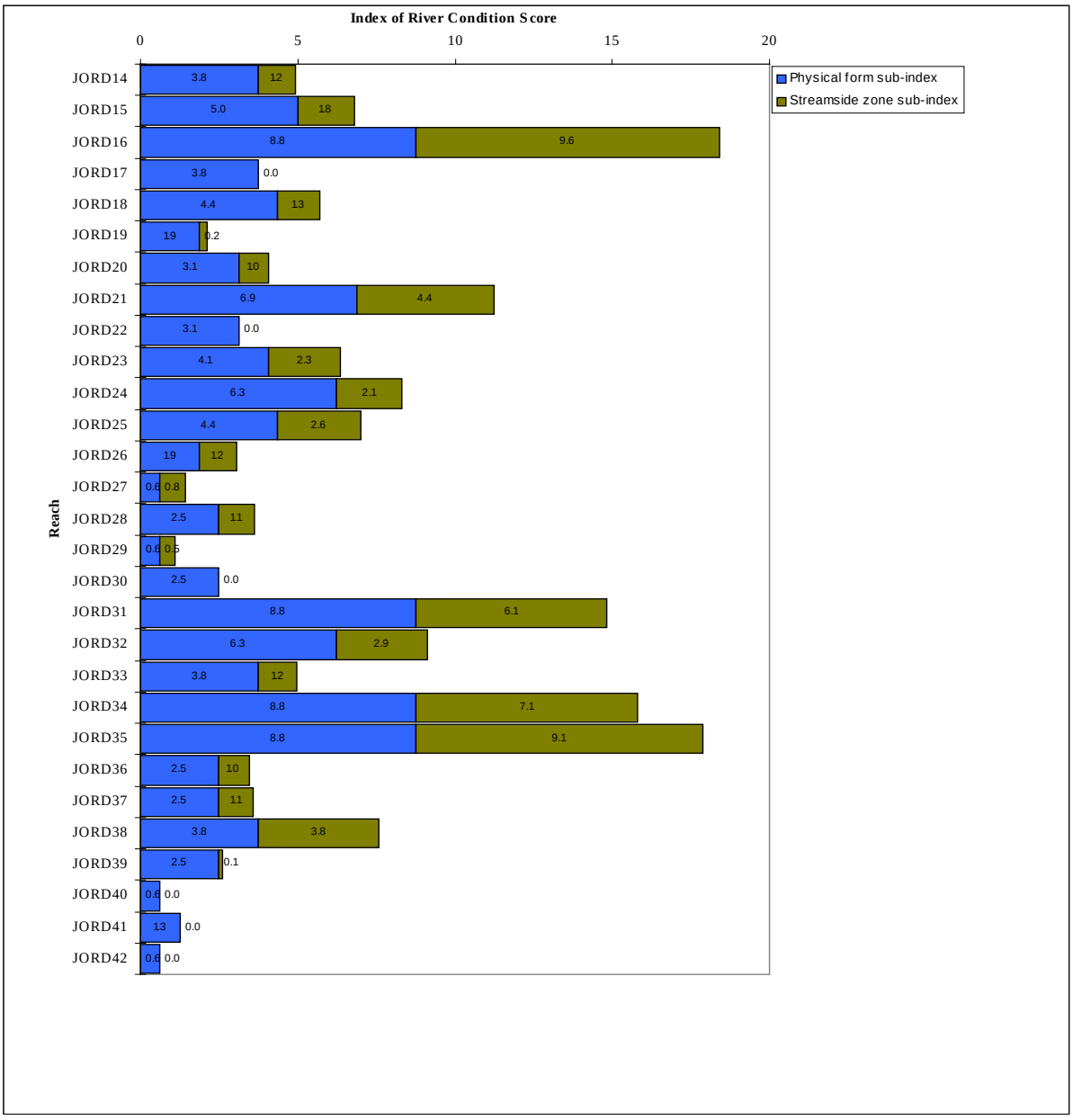


Figure 4. IRC results for the Jordan River tributary sites.

Table 5: IRC Sub-index ratings and indicator values for the Jordan River tributary 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
JORD14 Bagdad Rivulet upstream of Golf Course.	Valley	3.8					1.2						
JORD15 Bagdad Rivulet at Eddington Road.	Valley	5.0					1.8						
JORD16 Bagdad Rivulet off Harbach's Road	Valley	8.8					9.6						
JORD17 Strathallan Rivulet upstream of Golf Course	Valley	3.8					0.0						
JORD18 Strathallan Rivulet at Tea Tree	Valley	4.4					1.3						
JORD19 Tea Tree Rivulet at Back Tea Tree Road	Valley	1.9					0.2						
JORD20 Woodlands Creek upstream of Tea Tree	Valley	3.1					1.0						
JORD21 Brown Cave Creek at Chauncy Vale Road	Valley	6.9					4.4						
JORD22 Mangalore Creek at Black Brush Road	Valley	3.1					0.0						
JORD23 Stoneyhurst Creek off Storeys Road	Valley	4.1					2.3						
JORD24 Grahams Creek at Elderslie Road	Valley	6.3					2.1						
JORD25 Grahams Creek off Grahams Creek Road	Valley	4.4					2.6						
JORD26 Green Valley Rivulet at Cockatoo Valley Road	Valley	1.9					1.2						
JORD27 Green Valley Rivulet at Green Valley Road	Valley	0.6					0.8						
JORD28 Espies Creek off Pelham Road	Valley	2.5					1.1						
JORD29 Green Ponds Rivulet at Wilderness Lane	Valley	0.6					0.5						
JORD30 Quoin Rivulet at Midlands Highway	Valley	2.5					0.0						
JORD31 Quoin Rivulet at Colebrook Heights	Valley	8.8					6.1						
JORD32 Donnybrook Rivulet at Den	Valley	6.3					2.9						

Road													
JORD33 Donnybrook Rivulet upper at Den Road	Valley	3.8					1.2						
JORD34 Little Den Creek at Lake Highway	Valley	8.8					7.1						
JORD35 Little Den Creek at Bisdees Road	Valley	8.8					9.1						
JORD36 Springhill Creek at Lower Marshes Road	Valley	2.5					1.0						
JORD37 Exe Rivulet at Exe Sugarloaf	Valley	2.5					1.1						
JORD38 Green Hill Rivulet off Bowhill Road	Valley	3.8					3.8						
JORD39 Green Hill Rivulet at Bowhill Road	Valley	2.5					0.1						
JORD40 Petherton Creek at Bowhill Road	Valley	0.6					0.0						
JORD41 Dulverton Rivulet at Bowhill Road	Valley	1.3					0.0						
JORD42 Huntworth Creek at Stonor Road	Valley	0.6					0.0						

Indicator suggests major or extreme. difference from natural or ideal conditions

Inadequate data to evaluate sub-index.

Adequate data to evaluate indicator and ratings
Suggest changes have not been extreme or major.

CWD = Coarse woody debris
Regen = regeneration of indigenous species.
LC = Longitudinal continuity

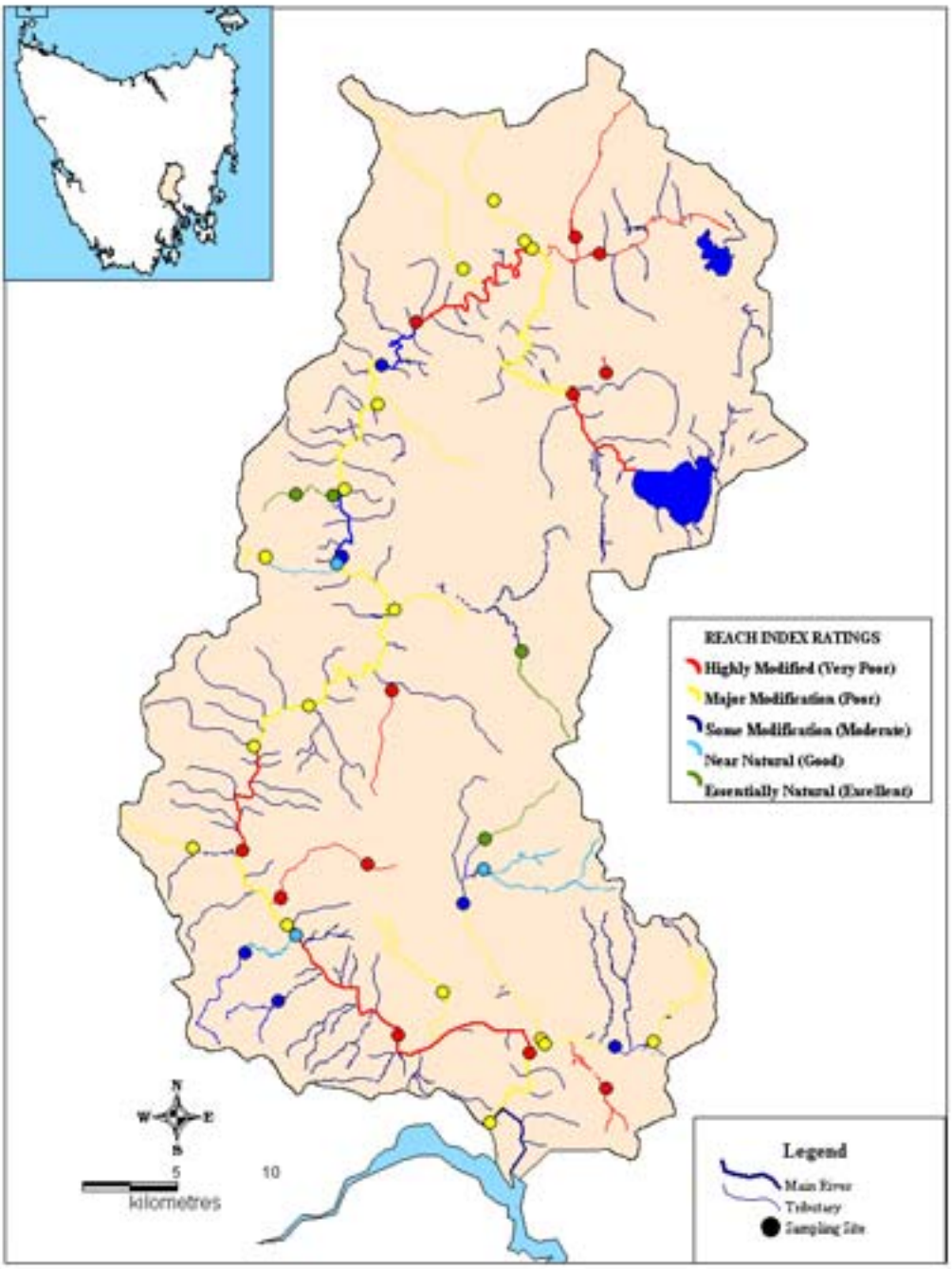


Figure 5: Jordan Catchment. Physical form sub-index ratings.

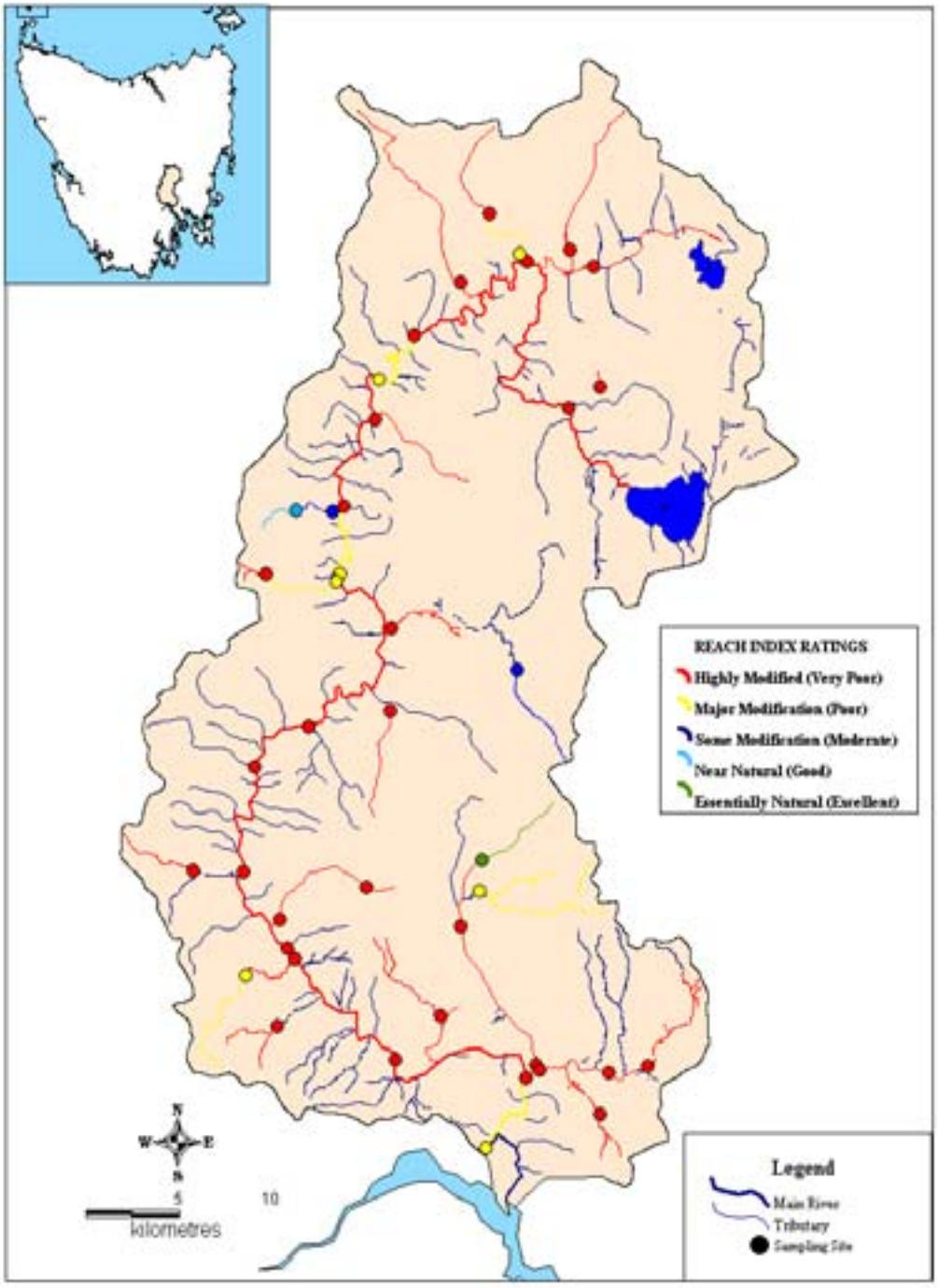


Figure 6: Jordan Catchment. Stream-side zone sub-index ratings.

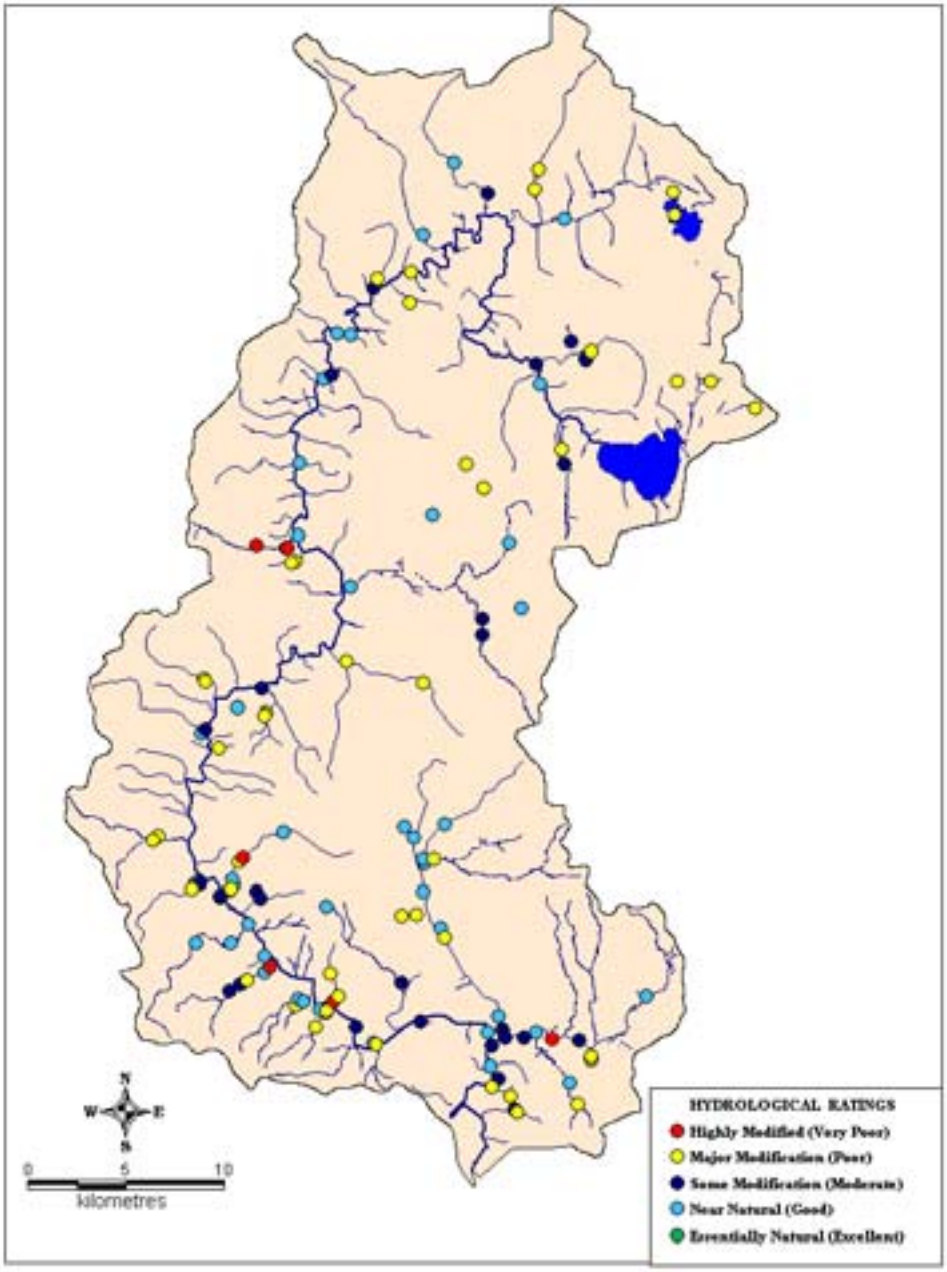


Figure 7: Jordan Catchment. Barrier locations and hydrological connectivity ratings.

4.3 Hydrological Connectivity

Table 6 presents ratings for various types of structures in relation to hydrological connectivity. In the Jordan catchment, bridges (n=42) result in partially modified conditions, culverts (n=19) and weirs (n=2) result in moderately modified conditions, whilst dams (n=67) result in poor conditions for fish passage. Figure 7 shows the distribution of structures and related fish passage values of structures that were surveyed within the catchment. Of the structures assessed, eighty-four result in moderate to extreme modification for fish passage.

Table 6. Median rating values for barrier types assessed within the Jordan catchment.

Structure type	Number assessed	Hydrological rating (median)	Hydrological condition
Bridge	42	6.8	Near Ideal
Culvert	19	5.4	Moderate
Weir	2	4.3	Moderate
Dam	67	3.2	Poor

Of the barriers assessed, the Elderslie Road weir has the greatest potential to affect fish passage within the Jordan River. This is due in part to the design of the weir and its location on the mainstream within the lower catchment. Improvement of hydrological conditions across the weir should be considered in relation to native fish management within the Jordan catchment.

One hundred and twenty three existing and forty four proposed dam sites for the Jordan system were identified from the WIMS (Water Information Management System) database and are outlined in Appendices 2a and 2b 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 each represent 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.

Records of fish locations have been reviewed for the Jordan catchment. Table 7 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 8 provides distribution details of fish species within the Jordan catchment.
Electrofishing surveys carried out by DPIWE in 2002 and location data from the RFA database indicate that native fish diversity is greater within the lower reaches of the Jordan catchment than in the upper reaches (Figure 8). The short-finned eel (*Anguilla australis*) is the only migratory native fish species that has been recorded within the upper catchment. Tasmanian smelt (*Retropinna tasmanica*) has also been recorded within the mid to upper catchment. This pattern of species distribution is likely to result to a large extent from the seasonal changes in surface water availability and hence successful passage upstream (Magalhaes *et al*., 2002). Recent investigations of fish assemblage variation by Magalhaes *et al*. (2002) within catchments subject to seasonally predictable drying indicate that the summer shortage of surface water limits fish occurrence in headwaters and that fish concentrate in downstream reaches of streams where surface waters persist. The natural flow regime of the Jordan River displays similar seasonal trends in water availability to that of the streams studied by Magalhaes *et al*. (2002) with many tributaries experiencing drying over the summer months. It is likely that fish distribution within the Jordan catchment historically is a response to the seasonal variation in surface water availability with many species avoiding ephemeral reaches.

Species richness of native fish at each site was higher for the lower mainstream and Bagdad Rivulet than other sites throughout the catchment. Fish numbers for migratory species were also higher within the lower catchment. This pattern of distribution is consistent with the findings of Magalhaes *et al*. (2002) for streams that show strong seasonal variation in surface water availability.

Table 7. Inventory of fish species for the Jordan catchment (IFS database).

Scientific Name	Common Name	Movement	Number of records

Native Fish			
Anguilla australis	Short-finned eel	Catadromous	47
Galaxias maculatus	Jollytail	Diadromous	231
Pseudaphritis urvillii	Freshwater flathead	Diadromous	21
Retropinna tasmanica	Tasmanian smelt	Anadromous	16
Introduced Fish			
Oncorhynchus mykiss	Rainbow trout	Non-migratory	1
Salmo trutta	Brown trout	Non-migratory/ Amphidromous	17
Perca fluviatilis	Red-finned perch	Non-migratory	245
Tinca tinca	Tench	Non-migratory	71

Of the 649 records listed in Table 7, 48% relate to native fish whilst 52% are from introduced species. Introduced species within the system are likely to have the greatest influence on native fish populations through predation and competition. The Inland Fisheries Service views redfin perch as an introduced 'pest fish'. This is due to its ability to out compete native fish, and in some cases seriously reduce or even eradicate populations. It has also been shown to prey on juvenile trout. Similarly, Tench are believed to directly compete with trout and native fish for food and habitat resources. Bryant and Jackson (1999) recognise introduced fish species, such as redfin, as a major potential threat to native fish populations. The prevalence of Tench and Redfin within the catchment is likely to be a key factor influencing native fish abundance and distribution within the Jordan catchment.

At the majority of mainstream sites *T.tinca* (tench) and/or *P.fluviatalis* (redfin) dominate fish assemblages. In the lower mainstream the converse is the case where *G.maculatus* and *A.australis* dominate the assemblages (JORD01 and JORD02). For all sites surveyed on Bagdad Rivulet, *G.maculatus* are the dominant species. Exotic species account for 14% (redfin and tench) and 18% (brown trout) of the fish numbers at JORD14 and JORD16, respectively with no exotics captured at JORD15. Surveys suggest that Bagdad Rivulet is an important tributary for maintaining native fish populations within the Jordan catchment.

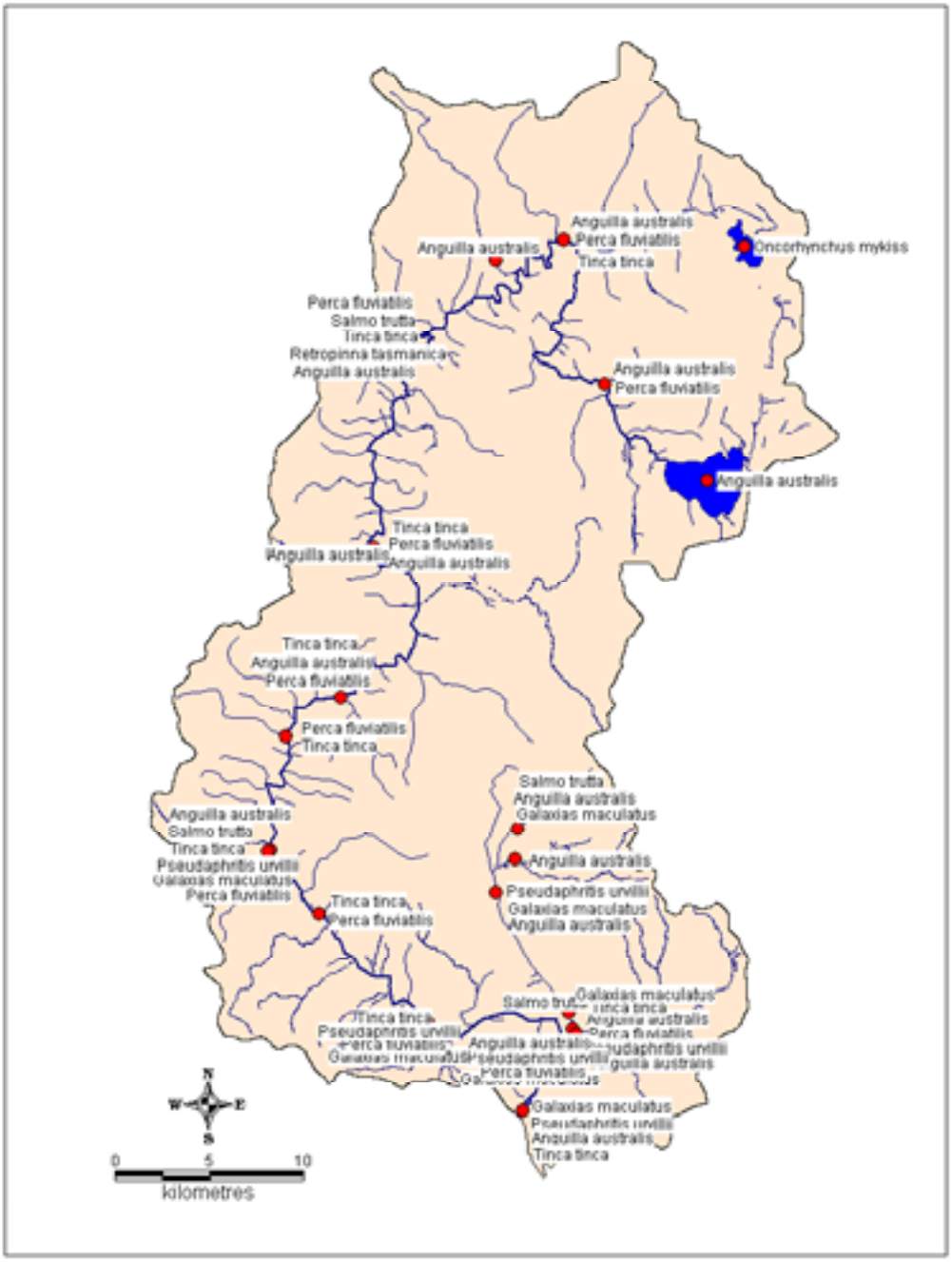


Figure 8: Fish distribution map for the Jordan catchment.

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 Jordan 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 Jordan River catchment strongly contrasts 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 Figures 4 and 5) for the mainstream and tributary sites and these are provided in Tables 8 and 9, 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 management in relation to in-stream integrity for agricultural areas of the Jordan 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 promoted 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. 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). For the Jordan catchment dams resulted in a major modification of condition whilst weirs and culverts resulted in a moderate change in condition and bridges a partial modification of condition. Barrier effectiveness is also partly determined by each fish species ability 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. Four native fish species have been recorded from the Jordan 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).

Within the Jordan catchment farm dams have been identified as the most common structure type that has the potential to alter hydrological connectivity. As indicated by Table 6, this type of structure results in poor conditions for 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.

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 have the potential 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 (Richardson and Jowett, 2002). Turbidity levels were found to exceed 69 NTU at numerous sites within the lower catchment with individual values reaching up to 235 NTU (see Water Quality report).

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).

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

Mainstream Jordan River

The IRC assessment indicates that sites on the mainstream Jordan 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 Jordan River sites are provided in Table 8. 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.

Twenty in-stream structures were assessed for the mainstream Jordan River, of which nine were identified to result in a moderate to extreme change in hydrological connectivity conditions. Two weirs were assessed for the mainstream. The Elderslie Road weir was rated as having poor fish passage conditions and the Mauriceton weir as having moderate fish passage conditions. Seven culverts were assessed of which one was found to provide near ideal passage conditions, five were found to provide for moderate passage conditions and one poor passage conditions. Of the 12 bridges assessed, nine were found to provide for near ideal fish passage conditions and two for moderate passage conditions (those at Jericho and Cockatoo Gully Road). Of the structures assessed the Elderslie Road weir is likely to have the greatest impact on fish movement, as hydrological connectivity across the weir is poor and location within the lower catchment on the mainstream.

Table 8. Management issues identified for the main stream Jordan River sites.

Reach	Management issues
Jordan River upstream tidal limit at old stream gauging station.	Weeds – Extensive cover byWillow (*Salix fragilis*), Hawthorn (*Crataegus monogyna*), and Blackberries (*Rubus fruticosus*). Minor cover by thistles, Gorse (*Ulex europaeus*) and sweet briar (*Rosa rubiginosa*). Poor riparian zone intactness and low cover by native woody elements. Absence of native CWD cover. Potential for erosion during high flow events due to low bank instability. Potential for stock induced bank erosion. Limited diversity of substrate material (dominated by silt) and dominance of single habitat type.
Jordan River at Pontville Ford.	Weeds – Abundant cover by Willows and Blackberries. Minor cover by Gorse, bullrushes and *Azolla*. Absence of indigenous overstorey regeneration and reduced riparian width. Absence of native CWD cover. Reduced habitat and substrate diversity due to impoundment behind culvert. Evidence of previous willow control/removal for some areas.
Jordan River at Elderslie Road.	Weeds – Abundant cover by thistles. Minor cover of willow, gorse and bullrushes. Limited indigenous overstorey regeneration and reduced riparian width. Absence of native CWD cover. Potential for erosion during high flow events due to low bank instability. Evidence of stock induced bank erosion. Limited diversity of substrate material (dominated by silt) and dominance of two habitat types (pool and run).

Table 8. Contd.

Jordan River at Andersons Road.	Weeds – Extensive cover by Gorse, thistles, willow, blackberry and hawthorn. Minor cover by cumbungi. Heavy erosion at stock access points commonly encountered. Poor riparian zone integrity for both banks with native species being essentially absent. Absence of native CWD cover. Limited diversity of substrate material and dominance of two habitat types (pool and run).
Jordan River at Roydon Road.	Weeds - Abundant cover of willow, blackberries, thistles, gorse and hawthorn. Minor cover by cumbungi. Absence of native species from the overstorey and understorey of right bank (facing upstream). Moderate stock access to unfenced sections of river banks. . Low habitat diversity and limited substrate heterogeneity.
Jordan River at Clifton Vale Road.	Weeds - Low cover by gorse, blackberry, willow, hawthorn, and thistles. Native vegetation cover severely reduced within understorey and absent from overstorey. Limited CWD cover. Minor erosion encountered in areas with poor bank stability. Potential for stock access though no stock induced erosion was noted. Low habitat diversity and limited substrate heterogeneity.
Jordan River at Mauriceton.	Weeds – Moderate cover of gorse, thistles, blackberry, hawthorn and willows. Minor cover by cumbungi. Highly reduced cover by native woody species within the overstorey and understorey. Absence of indigenous plant regeneration. Absence of native CWD cover. Low habitat diversity and limited substrate diversity.
Jordan River upstream Donnybrook Rivulet	Weeds – Moderate cover by gorse and thistles. Minor cover by willow, blackberry, hawthorn and bracken. Limited riparian cover and width with very low proportion of indigenous woody plants within overstorey and understorey. Limited CWD cover. Moderate growth of cumbungi.
Jordan River at Apsley	Weeds – Moderate cover by willow, blackberry, thistles and gorse. Absence of indigenous plant regeneration. Limited CWD cover and that whish is present is of exotic origin. Evidence of bank erosion due to lack of binding vegetation to hold fine materials in place. Evidence of minor erosion associated with stock access points.
Jordan River at Lower Marshes Road (Glenmore Sugarloaf).	Weeds - Extensive cover of gorse and willows with minor cover by thistles. Limited cover by native woody species within the overstorey and understorey. Limited indigenous plant regeneration. Limited native CWD cover. Limited diversity of substrate material and dominance of two habitat types (pool and run).
Jordan River at Black Bridge.	Weeds – Extensive cover of willows, gorse and thistles. Absence of cover by native woody species within the overstorey and understorey. Riparian width reduced to less than 5 metres. No native CWD cover. Fencing excludes stock access for most of the reach, with potential access being limited to discrete sections of the right bank (facing upstream) due to lack of fencing. Evidence of channel downcutting through bank erosion at channel constrictions. Low diversity of instream habitat types and substrate material. Extensive Cumbungi within pools.

Table 8. Contd.

Jordan River at Burnt Log Gully.	Weeds – Abundant cover of willows and gorse. Overstorey essentially absent with understorey vegetation dominated by willow and gorse. No indigenous plant regeneration. Limited native CWD cover. Poor bank stability with channel downcutting evident at several points. Potential stock access to right bank (facing upstream). Topography likely to limit stock access to river. Moderate cover of cumbungi and *Azolla* in pools.
Jordan River at Jericho.	Weeds – Minor cover of thistles, gorse, and willows. Poplar and pine trees have also been planted. Riparian zone lacks structural integrity and is dominated by introduced grasses. Indigenous woody species are essentially absent. Moderate levels of bank erosion are evident at stock access points. Current fencing limits stock access to a limited area of stream bank. Very poor mesohabitat diversity and instream integrity. Absence of native CWD. Low cover of aquatic macrophytes. Ephemeral at upstream end of reach with poorly defined channel. Land care revegetation program on right side (facing upstream).

Tributaries of the Jordan River

As with the mainstream, sites on tributaries that occur within agricultural and urban areas had 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.

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. Specific management issues for each tributary study reach are provided in Table 9.

Hydrological connectivity for the tributaries of the Jordan catchment is more influenced by the presence of in-stream structures than is the mainstream (Figure 7). Farm dam development within the catchment has to date been limited to the tributaries, with the majority being within the upper reaches (Appendix 2c). As a result hydrological connectivity for the 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.

Bagdad Rivulet (JORD14, JORD15 and JORD16)

Bagdad Rivulet is the largest stream within the Jordan River catchment. Three sites were assessed along the length of this tributary and these display varying degrees of departure from natural condition for both sub-indices. As with the Jordan River mainstream the greatest departure form natural condition was noted for the streamside zone subindex in response to surrounding land usage. Surrounding land usage for this tributary is predominantly for agriculture. In previous IRC assessments (Nelson 1999a, 1999b, and Horner, 2002) major tributaries have shown a general trend of improved condition in the upper catchment as the degree of development has decreased. Bagdad Rivulet displays a similar trend of improved condition within the upper catchment where development has been limited.

The physical form sub-index rated as in excellent (essentially natural) condition for Bagdad Rivulet off Harbach's Road (JORD16), moderate condition for Bagdad Rivulet at Eddington Road (JORD15), and in poor condition for Bagdad Rivulet upstream of Golf Course (JORD14). From Table 5 it is evident that major or extreme disturbance to the indicator of CWD has occurred at Bagdad Rivulet upstream of the Golf Course (JORD14) and Bagdad Rivulet at Eddington Road (JORD15). CWD is essentially absent from Bagdad Rivulet upstream of Golf Course (JORD14), whilst the low levels of CWD at Bagdad Rivulet at Eddington Road (JORD15) is predominantly exotic in origin.

Like the physical form sub-index, the streamside zone displayed varying degrees of departure from natural conditions in response to land usage. Bagdad Rivulet off Harbach's Road (JORD16) rated as in excellent (essentially natural) condition for this sub-index, whilst Bagdad Rivulet upstream of the Golf Course (JORD14) and Bagdad Rivulet at Eddington Road (JORD15) rated as in very poor (highly modified) condition. The riparian zone of Bagdad Rivulet off Harbach's Road (JORD16) is predominantly native (96%), continuous and for most of the reach exceeds 40 metres in width. At Bagdad Rivulet at Eddington Road (JORD15) the riparian zone has been reduced to less than 5 metres width, is discontinuous and up to 95% of the streamside vegetation is exotic (willow, hawthorn and gorse). The riparian zone of Bagdad Rivulet upstream of the Golf Course (JORD14) has been subject to high levels of disturbance, is severely reduced and is dominated by exotic species (blackberries, hawthorn, willow and gorse). These findings clearly illustrate the increasing influence of land clearing on riparian integrity.

Hydrological connectivity has been directly assessed at 13 locations within this tributary (6 dams, 6 bridges, and 1 culvert). At five of these locations (all dams) hydrological connectivity is influenced by a moderate to extreme degree. The potential affect of these in-stream structures on hydrological connectivity was found to vary in relation to their design. On average farm dams were found to result in poor hydrological conditions, culverts moderate conditions and bridges good conditions. Interestingly, one dam was found to provide for moderate hydrological conditions and another for near ideal hydrological conditions. Both are small barriers with low wall heights that provide for flow for the majority of the year. One barrier (Pontville Ford) has been identified for the Jordan River downstream of the confluence with Bagdad Rivulet that influences passage conditions to a moderate degree.

Strathallan Rivulet (JORD17 and JORD18)

The physical form sub-index of Strathallan Rivulet at Tea Tree (JORD18) rated as in moderate condition (value of 4.4) and that of Strathallan Rivulet upstream of the Golf Course (JORD17) in poor condition (value of 3.8). From figure 5 it is evident that both sites display major or extreme modification to the indicator of CWD which is a common for sites within developed areas of the catchment.

The stream-side zone sub-index rated as in very poor (highly modified) condition for Strathallan Rivulet upstream of Golf Course (JORD17) and for Strathallan Rivulet at Tea Tree (JORD18). Strathallan Rivulet upstream of the Golf Course (JORD17) received a rating value of 0.0, which reflects the extreme modification to all 6 indicators for this sub-index. From Figure 5 it is evident that all 6 indicators for this sub-index have been subject to major to extreme modification at Strathallan Rivulet upstream of the Golf Course (JORD17), and 4 of the 6 indicators at Strathallan Rivulet at Tea Tree (JORD18).

The hydrological connectivity of this tributary is potentially affected by seven artificial structures (1 culvert, 1 bridge and 5 in-stream dams). The culvert assessed was found to provide moderate hydrological conditions, the bridge near ideal conditions and dams moderate to very poor conditions. From Figure 7 it is evident that hydrological connectivity is altered by the presence of in-stream barriers along most of the length of this tributary. Poor hydrological conditions coupled with 'drying' often results in the loss of surface water from much of the tributary during the summer months.

Tea Tree Rivulet at Tea Tree Back Road (JORD19)

Tea Tree Rivulet has been subject to substantial development and condition ratings for both sub-indices are very poor in response to extreme departure from natural conditions at this site. From Table 5 it is evident that all 4 indicators of physical form have been subject to major or extreme modification. Sections of this reach had been subject to erosion as a result of uncontrolled stock access. The absence of woody vegetation from the riparian zone limits bank stability within this reach. The lack of woody riparian vegetation has most likely resulted in the low cover of CWD within this reach.

The streamside zone sub-index rating has been highly influenced by riparian vegetation modification at this site and was found to be in very poor condition. From Table 5 it is evident that at each site all 6 indicators for this sub-index have been subject to major or extreme modification from natural conditions. Overstorey and understorey elements are essentially absent from the riparian zone, whilst the ground cover is dominated by pasture grasses. Stock access to stream banks has resulted in areas of bank destabilisation and erosion. The re-establishment of riparian vegetation and the control of stock access are management issues that have been identified for this site.

Hydrological connectivity was assessed at two locations within this tributary and was found to vary dependant on the structure design at each location. Poor conditions were assessed for the farm dam surveyed and "near ideal" conditions for the bridge crossing of Back Tea Tree Road (Figure 7). As the dam is within the upper reach of the tributary it is likely to have a limited influence on the overall hydrological connectivity of Tea Tree Rivulet. The bridge crossing of Back Tea Tree Road is of an open construction allowing for good (near ideal) fish passage conditions. From the WIMS data it is evident that dam development for this tributary has been limited and that existing dams occur on small streams rather than the main channel.

Fish movement into Tea Tree Rivulet is dependent on passage conditions within Strathallan Rivulet. Passage conditions within Strathallan Rivulet are influenced to a moderate degree at one location downstream of the confluence with this tributary (Figure 7). Very poor in-stream and streamside zone integrity may also influence fish movement within this tributary. As this tributary is ephemeral, surface water availability is also an influence on fish distribution.

Woodlands Creek upstream of Tea Tree (JORD20)

Woodlands Creek upstream of Tea Tree (JORD20) rated as in poor condition for physical form and very poor condition for the streamside zone sub-index. Table 5 indicates that the indicators for Bank Stability, Aquatic Environment and CWD have been subject to major or extreme modification at this site. These findings reflect the clearing of the riparian zone, which reduces bank stability, increases light penetration to the stream and reduces the source of CWD.

The streamside zone subindex for this site received a rating value of 1.0 (Figure 5) which indicates very poor streamside integrity. Table 5 indicates that 5 of the 6 indicators for this sub-index have been subject to major or extreme modification. The riparian zone has been reduced to less than 5 metres in width, is discontinuous, lacks overstorey elements, and has a patchy understorey dominated by gorse and hawthorn. Native understorey species are present throughout the reach but provide little overall cover.

A single instream structure was assessed for this tributary (the bridge crossing of Grices Road). The bridge was of an open design and found to provide for near ideal fish passage conditions. A dam on Strathallan Rivulet downstream of the confluence with Woodlands Creek has resulted in extreme modification to hydrological connectivity. The very poor passage conditions within Strathallan Rivulet are likely to limit fish recruitment into this tributary.

Brown Cave Creek at Chauncy Vale Road (JORD21)

The single site assessed on this creek rates as in good condition in relation to physical form (value of 6.9) and poor condition (value of 3.1) for streamside integrity. From Table 5 it is evident that no indicators of physical form have been subject to major or extreme modification whilst 3 indicators for streamside integrity were found to be modified. Sections of this reach exhibit erosion as a result of uncontrolled stock access. CWD levels within this reach are likely to be indicative of natural inputs for the catchment.

The moderate condition assessed for the streamside zone subindex reflects native vegetation clearing and weed encroachment within the riparian zone. Major modification has occurred to the riparian zone within this reach. Clearing of vegetation along the right bank has lead to a discontinuous overstorey with reduced cover by indigenous species and limited regeneration by overstorey species. Weed species recorded at this site include willow, gorse, blackberries, and bracken fern.

The bridge crossing at Chauncy Vale Road and the farm dam upstream of the confluence with Bagdad Rivulet were assessed in relation to hydrological connectivity for this tributary. The bridge was of an open design and was found to provide good (near ideal) hydrological connectivity. Poor conditions for hydrological connectivity were noted for the dam in response to the absence of free surface water across the structure for most of the year. Fish movement into Brown Cave Creek is influenced by passage conditions within Bagdad Rivulet, particularly at the in-stream dam downstream of Roberts Road (Dam 53).

Mangalore Creek at Black Brush Road (JORD22)

JORDAN22 was the only site assessed for this tributary and rates as in poor condition for physical form and as in very poor (highly modified) condition for the streamside zone sub-index (Figure 4). As with the majority of sites within the Jordan catchment CWD is sparse at this site (essentially absent) resulting in extreme modification (Table 5). From Table 5 it is evident that bank stability has also been subject to major or extreme disturbance. The indicators of aquatic environment condition and mesohabitat diversity display moderate modification to condition and are influenced by reduced habitat as a consequence of low water levels at the time of assessment.

The streamside zone sub-index rated as in very poor condition for this reach and streamside integrity has been influenced by riparian vegetation alteration at this site. From Table 5 it is evident that 5 of the 6 indicators for this sub-index have been subject to major or extreme modification from natural conditions. The riparian zone within this reach is dominated by gorse, which forms a patchy understorey layer. Indigenous plant species are absent from the overstorey and understorey and provide a low proportion of ground cover present. Blackberries and thistles have also been identified as weed species that require management at this site.

Hydrological connectivity was assessed for the culvert at Black Brush Road and found to be in moderate condition (Figure 7). WIMS data indicates that no in-stream dams have been developed on this tributary. Fish movement into this tributary is influenced by passage conditions with the mainstream Jordan River. Passage conditions from the Jordan River mouth to the confluence of Mangalore Creek are influenced to a moderate degree at the Pontville Ford.

Stoneyhurst Creek off Storeys Road (JORDAN23)

This site rates as in moderate condition (value of 4.1) for the physical form sub-index and very poor (highly modified) condition (value of 1.9) for the streamside zone sub-index. The indicators for bank stability and CWD have been subject to major or extreme disturbance reducing in-stream integrity. A rating value of 2.3 indicates that the condition of the streamside zone is poor and overall borders on very poor condition. From Table 5 it is evident that the level of clearing of native plant species in the riparian zone has resulted in major or extreme modification to 4 of the 6 indicators for riparian condition. The indicators of structural intactness and native vegetation regeneration have been subject to moderate levels of modification.

Five structures were assessed for this tributary in relation to hydrological connectivity. The open structure of the bridge at Elderslie Road allows for near ideal (good) passage condition. The culvert at the study site was found to provide for moderate passage conditions. Three in-stream dams have modified hydrological connectivity within this tributary to varying degrees. From Figure 7 it is evident that passage conditions are very poor directly upstream of the Jordan River confluence, this is due to the presence of an in-stream dam. Poor conditions were assessed for Dam 97 and moderate conditions for Dam 60. Two in-stream dams were assessed within the upper reaches of the tributary and found to provide poor (highly modified) hydrological connectivity. Fish recruitment into this tributary is influenced by passage conditions within the lower Jordan River particularly by passage past the Elderslie Road weir.

Grahams Creek (JORD24 and JORD25)

Grahams Creek at Elderslie Road (JORD24) and Grahams Creek off Grahams Creek Road (JORD25) have been subject to varying degrees of adjacent development for agriculture. The physical form sub-index for Grahams Creek at Elderslie Road (JORD24) rates as in good (near natural) condition and Grahams Creek off Grahams Creek Road (JORD25) as in moderate condition.

The streamside zone sub-index for both sites rate as in poor condition. For both sites the indicators for proportion of native cover, regeneration of overstorey species and longitudinal continuity have been subject to major or extreme modification to condition.

The riparian zone present at Grahams Creek at Elderslie Road (JORD24) is less than 5 metres in width, discontinuous, and subject to weed encroachment over 30% of the reach (primarily hawthorn and blackberries).

Hawthorn accounts for 10 to 15% of ovestorey cover, blackberries up to 60% of cover within the understorey and introduced grasses and thistles 100% of cover within the ground layer. The riparian zone of Grahams Creek off Grahams Creek Road (JORD25) as with Grahams Creek at Elderslie Road (JORD24) has been highly reduced in width, continuity, and structural intactness. Blackberries account for approximately 30% of the patchy understorey cover present at Grahams Creek off Grahams Creek Road (JORD25), whilst introduced grasses and thistles account for up to 85% of the ground layer vegetation. Weeds at Grahams Creek off Grahams Creek Road (JORD25) account for up to 40% of the vegetation present. Blackberries and thistles have been identified as weed species within both reaches that require future management.

Three bridges were assessed on Grahams Creek and these were found to provide good (near ideal) conditions for hydrological connectivity. From Figure 7 it is evident that hydrological connectivity within this tributary is little influenced by in-stream structures. A single dam was identified for the tributary from the WIMS database, however this potential barrier was not directly assessed. From the ratings derived for other dams within the catchment this structure is likely to provide for poor passage conditions. As with Stoneyhurst Creek, fish passage into this tributary is influenced by hydrological conditions across the Elderslie Road weir.

Green Valley Rivulet (JORD26 and JORD27)

Two sites were assessed for this tributary, which were found show extreme departure from natural condition (highly modified) for both sub-indices in response to surrounding land usage. Green Valley Rivulet at Cockatoo Valley Road (JORD26) displays a lower degree of disturbance than does Green Valley Rivulet at Green Valley Road (JORD27), the sites having physical form sub-index values of 1.9 and 0.6 respectively. A sub-index value of 1.9 indicates that instream integrity at Green Valley Rivulet at Cockatoo Valley Road (JORD26) borders on the poor category. From Table 5 it is evident that all four indicators for this sub-index have been subject to major or extreme modification to condition at both sites. The data shows that the indicators of bank type and stability, mesohabitat diversity, and CWD depart from natural to an extreme degree and for aquatic environment to a major degree at Green Valley Rivulet at Green Valley Road (JORD27). This reflects extensive erosion resulting in channel down cutting, limited vegetation cover, and the dominance of fine substrate material (silt). For Green Valley Rivulet at Cockatoo Valley Road (JORD26) the indicator of CWD displays extreme modification, whilst those of bank type and stability, mesohabitat diversity, and aquatic environment display major modification. The difference noted between sites is also influenced by the reduced habitat as a consequence of low water levels at JORD27 at the time of assessment.

Like the physical form sub-index, the streamside zone at both reaches was found to be in a highly modified (very poor) condition reflecting surrounding land usage. From Table 5 it is evident that the degree of disturbance to stream side integrity increases from Green Valley Rivulet at Cockatoo Valley Road (JORD26) to Green Valley Rivulet at Green Valley Road (JORD27). At Green Valley Rivulet at Cockatoo Valley Road (JORD26) the riparian zone has been reduced to less than 5 metres width, provides sparse cover with up to 95% of the streamside vegetation present being exotic (willow and gorse). The riparian zone of Green Valley Rivulet at Green Valley Road (JORD27) has been severely reduced along both banks providing only sparse cover for less than 15% of the reach. Silver Wattle (*Acacia dealbata*) provides the only overstorey and understorey present, whilst introduced grasses dominate the ground layer. Thistles and blackberries have been identified as weed species within this reach that require future management considerations.

Four farm dams and 4 bridges were assessed for this tributary and were found to have varying impacts on hydrological connectivity. The farm dams assessed were found to provide poor to very poor conditions for hydrological connectivity and the bridges good to moderate conditions (Figure 7). From Figure 7 it is evident that poor conditions for connectivity occur within the lower section of the tributary due to the presence of two in-stream dams.

Espies Creek off Pelham Road (JORD28)

One site was assessed for this tributary which occurs within an agriculturally developed reach. The physical form subindex of this site rates as in poor condition with 3 of the 4 indicators for in-stream integrity displaying major or extreme modification to condition. This reach was essentially dry at the time of assessment. This reduction in flow and hence habitat account for the poor rating for the mesohabitat diversity indicator. Areas of moderate erosion were noted within the reach, with unrestricted stock access occurring at a number of these points.

Extensive clearing of the riparian zone has resulted in very poor streamside condition for this reach. From Table 5 it is evident that all 6 indicators for stream side zone condition display major or extreme modification to condition. The riparian zone of Espies Creek off Pelham Road (JORD28) contains few indigenous species, has a discontinuous overstorey and understorey, and is highly reduced in width. Bracken and thistles are common weeds at this site, whilst blackberries are present at low levels.

Two dams and one culvert were assessed in relation to hydrological connectivity for this tributary. All 3 structures were found to provide for poor hydrological connectivity. The culvert was partially blocked on either end by debris and water levels within the pipe were very low. Under higher flow conditions the culvert is likely to allow for moderate passage conditions.

Green Ponds Rivulet at Wilderness Lane (JORD29)

The physical form and streamside zone subindex for Green Ponds Rivulet at Wilderness Lane (JORD29) were rated as in very poor condition. The highly modified nature of this site is in response to land usage for agriculture. In-stream conditions are very poor due to low substrate heterogeneity, the dominance of fine sediment, and the absence of surface water.

The streamside zone at this site has been subject to extreme modification for the development of agricultural land for grazing and rates as in very poor condition. From Table 5 it is evident that all six indicators for this sub-index have been subject to major or extreme modification from natural condition. Native woody species have been extensively cleared from the riparian zone, which has resulted in the absence of native elements from the overstorey and understorey layers. Willow and hawthorn provide riparian cover for up to 50% of the reach but the zone does not exceed 5 metres in width. Introduced grass species are the dominant vegetation type present, with extensive cover also by thistles throughout the reach.

Two dams were assessed on this tributary and both provide for poor conditions in relation to hydrological connectivity. Fish occurrence within this tributary is to a large extent limited by seasonal drying, which reduces surface water availability.

Quoin Rivulet (JORD30 and JORD31)

Two sites were assessed for this tributary, which were found to display varying degrees of departure from a natural condition for both sub-indices. The Physical form subindex for Quoin Rivulet at Colebrook Heights (JORD31) rates as in excellent (essentially natural) condition and poor condition for Quoin Rivulet at Midlands Highway (JORD30). No individual indicators display major or extreme modification for Quoin Rivulet at Colebrook Heights (JORD31), whilst 3 of the 4 indicators do so for Quoin Rivulet at Midlands Highway (JORD30) (Table 5).

The streamside zone sub-index rates as in good (near natural) condition for Quoin Rivulet at Colebrook Heights (JORD31) and as in very poor condition for Quoin Rivulet at Midlands Highway (JORD30). Native overstorey and understorey elements are essentially absent from the riparian zone of Quoin Rivulet at Midlands Highway (JORD30). The occasional hawthorn is present within the reach, which provides limited structural diversity. The ground layer for this reach is dominated by pasture grasses and thistles. In contrast, the riparian zone of Quoin Rivulet at Colebrook Heights (JORD31) supports a well developed overstorey and understorey that is comprised entirely of indigenous species. From Table 5 it is evident that the indicator of longitudinal continuity has been subject to major or extreme modification for this reach. This is due to the presence of 3 areas of vegetation clearance within the reach.

Four dams, two culverts and two bridges were assessed in relation to hydrological connectivity for this tributary. The farm dams were found to provide either poor or very poor fish passage conditions. Each culvert and bridge was found to provide for near ideal (good) passage potential. As with Green Ponds Rivulet, seasonal variation in surface water availability is likely to be a key factor in determining fish occurrence within this tributary.

Donnybrook Rivulet (JORD32 and JORD33)

Two sites were assessed for this tributary and were found to display varying degrees of departure from natural condition for each sub-index in response to land usage. For this tributary, in-stream condition decreases within the upper reach. Donnybrook Rivulet at Den Road (JORD32) rates as in good (near natural) condition for physical form and Donnybrook Rivulet upper at Den Road (JORD33) as in poor condition. A rating value of 3.8 for this subindex for Donnybrook Rivulet upper at Den Road (JORD33) indicates that site condition borders on moderate. From table 5 it is evident that the indicators of CWD and mesohabitat diversity have been subject to major or extreme modification to condition for Donnybrook Rivulet upper at Den Road (JORD33).

As with physical form condition, the stream-side zone deteriorated within the upper reach. Donnybrook Rivulet at Den Road (JORD32) rates as in poor condition for streamside integrity and Donnybrook Rivulet upper at Den Road (JORD33) in very poor condition. From Table 5 it is evident that the degree of disturbance to indicators for this sub-index increases between these sites.

Three dams, two bridges and one culvert were assessed for this tributary in relation to hydrological connectivity (Figure 7). All three dams were found to provide for very poor hydrological connectivity, whilst both bridges and the culvert provided for good hydrological connectivity. DAM 102 (Stockman No1) and DAM 103 (Stockman No2) are the tallest dams within the catchment, with wall heights of 16.5 and 21 metres respectively. As these are large structures they are unlikely to drown out on a regular basis, limiting potential for fish movement across them. Water availability and thus fish passage within the lower reach of this tributary is governed by discharge from DAM 102a. *Anguilla australis* (the short-finned eel) is the only native species to have been found within Donnybrook Rivulet and nearby sections of the mainstream.

Little Den Creek (JORD34 and JORD35)

The physical form sub-index for Little Den Creek at Lake Highway (JORD34) and Little Den Creek at Bisdees Road (JORD35) rate as in excellent (essentially natural) condition in this assessment. No individual indicators for this sub-index have been subject to major or extreme modification at either location due to the limited degree of land usage. Other tributary sites that occur in areas of limited land usage such as, Bagdad Rivulet off Harbach's Road (JORD16) and Quoin Rivulet at 'Colebrook Heights' (JORD31) also rate as in excellent condition.

The streamside zone sub-index for Little Den Creek at Bisdees Road (JORD35) rates as in excellent (essentially natural) condition and that of Little Den Creek at Lake Highway (JORD34) as in good (near natural) condition. No individual indicators of streamside integrity display major of extreme modification for Little Den Creek at Bisdees Road (JORD35), whilst that of longitudinal continuity displays major modification for Little Den Creek at Lake Highway (JORD34). The disturbance noted for this indicator is in response to vegetation clearing within the vicinity of the road crossing.

Two structures were assessed for this tributary in relation to hydrological connectivity. These are the culvert crossing of the Lake Highway and the bridge at Bisdees Road. The culvert and bridge were found to provide for near ideal (good) fish passage potential. The culvert results in essentially natural passage conditions, as its position and placement has a negligible effect on instream integrity. The bridge crossing of Bisdees Road is of an open design allowing for essentially unaltered flow and passage conditions. The presence of additional instream barriers and stock access disturbance result in the near ideal (good) rating for this structure. Fish passage within the mainstream Jordan is influenced to a moderate degree at four locations and by a major degree at one location between the confluence of this tributary to the river mouth.

Springhill Creek at Lower Marshes Road (JORD36)

A single site was assessed for this tributary and was found to be in poor condition in relation to physical form and very poor (highly modified) condition in relation to streamside integrity. As with other tributary sites that occur within agricultural reaches the reduced ratings for both sub-indices reflect the surrounding land usage.

A single culvert was assessed in relation to hydrological connectivity for this tributary and was found to provide for moderate conditions. Passage for this culvert is highly dependent on flow levels through the structure, with passage being limited to periods of higher flow. As with many of the tributaries within the Jordan catchment the seasonal variation in flow levels through potential barriers governs fish occurrence to a large extent.

Exe Rivulet at Exe Sugarloaf (JORD37)

Exe Rivulet at Exe Sugarloaf (JORD37) occurs within a reach subject to agricultural development and the influence of land usage is clearly reflected in this assessment. The physical form sub-index for this site rated as in poor condition and all four indicators display major or extreme modification to condition. The Streamside zone sub-index rates as in very poor condition and 5 of the 6 indicators display major or extreme modification to condition.

The bridge at the lower end of the study reach was found to provide for near ideal (good) passage conditions by this assessment. The structure was of an open design which allow for essentially natural in-stream conditions.

Green Hill Rivulet (JORD38 and JORD39)

Two sites were assessed along the length of this tributary and these show varying degrees of departure from natural condition for both sub-indices. The physical form sub-index for both sites (Greenhill Rivulet off Bowhill Road (JORD38) and Greenhill Rivulet at Bowhill Road (JORD39)) rate as in poor condition. A rating value of 3.8 for Greenhill Rivulet off Bowhill Road (JORD38) indicates that in-stream condition borders on the moderate category. From Table 5 it is evident that major or extreme modification to condition has occurred for all 4 indicators of in-stream integrity for Greenhill Rivulet at Bowhill Road (JORD39).

Like physical form condition, the condition of the streamside zone reflects the influence of land usage at each site. The streamside zone sub-index for Greenhill Rivulet off Bowhill Road (JORD38) rates as in poor condition and Greenhill Rivulet at Bowhill Road (JORD39) as in very poor (highly modified) condition. Like physical form, streamside condition for Greenhill Rivulet off Bowhill Road (JORD38) with a rating value of 3.8 borders on the moderate category. Table 5 clearly illustrates the impact of vegetation clearing at Greenhill Rivulet at Bowhill Road (JORD39), where all 6 indicators for this sub-index have been subject to major or extreme modification to condition. The indicator of structural intactness has been subject to major modification whilst the remaining indicators display extreme modification to condition.

Two structures were assessed for this tributary in relation to hydrological connectivity, being the culvert crossing of Greenhill Rivulet at Bowhill Road (JORD39) and the culvert crossing of Greenhill Rivulet off Bowhill Road (JORD38). These structures were found to provide for moderate and near ideal fish passage conditions, respectively. A critical outflow of approximately 20 centimetres was noted for the culvert at Greenhill Rivulet off Bowhill Road (JORD38). The three concrete pipes overall provide for poor ratings for the indicators for fish passage potential and deviation of flow, and have a moderate influence on the indicator for barrier effectiveness. Assessment of the culvert at Bowhill Road revealed that the structure provides for essentially natural in-stream conditions, resulting in little change in hydrological condition or fish passage potential. The single metal pipe is approximately 1.5 metres in diameter and at the time of assessment provided water to a depth of 30 centimetres. As with many of the tributaries within the Jordan catchment the seasonal variation in flow levels through potential barriers governs fish occurrence to a large extent within this particular tributary.

Petherton Creek at Bowhill Road (JORD40)

Petherton Creek at Bowhill Road (JORD40) rates as in very poor (highly modified) condition in relation to physical form and streamside zone integrity. The reach occurs within an area extensively developed for agriculture which has resulted in major or extreme modification to all indicators for both sub-indices.

Two in-stream dams were assessed in relation to hydrological connectivity for this tributary and theses were found to provide poor fish passage conditions. DAM 82 is approximately 3 metres in height, and provides an obvious barrier to flow. DAM 83 is in the order of 7 metres in height and acts as a complete barrier to flow. Sections of Petherton Creek upstream of DAM 82 are essentially isolated from lower reaches of Petherton Creek.

Dulverton Rivulet at Bowhill Road (JORD41)

Like Petherton Creek, Dulverton Rivulet occurs within an area of the catchment that has been extensively developed for agriculture and this is reflected in the very poor ratings for physical form and streamside integrity at this site. Table 5 indicates that all of the indicators for each sub-index have been subject to major or extreme modification from natural condition.

The bridge crossing of Dulverton Rivulet at Bowhill Road was found to provide for near ideal fish passage conditions. The bridge allows for essentially natural in-stream conditions with little influence on hydrological condition. Fish passage rates at this point are more likely to be influenced by the very poor streamside condition than the presence of this structure. Observations by the property owner of the land adjacent to the reach assessed suggest that groundwater fed springs around the 'Waverley' property may maintain summer flows within this section of the tributary.

Huntworth Creek at Stonor Road (JORD42)

Huntworth Creek at Stonor Road (JORD42) is the upper most tributary site assessed on the Jordan River and overall condition is likely to be influenced by adjacent agricultural land usage. Like the mainstream and other tributary sites within the upper catchment, in-stream and streamside condition was found to be very poor (highly modified).

Two in-stream dams and a bridge were assessed for this tributary in relation to hydrological connectivity. The bridge at Park Farm was found to provide for near ideal (good) fish passage conditions, DAM115 for moderate passage conditions, and DAM116 for poor fish passage conditions. The effectiveness of the culvert crossing of Stonor Road was difficult to identify, as it was overgrown by thistles and grasses. Culverts have in this assessment shown to result in a moderate modification of hydrological condition. Fish distribution within this tributary is likely to be limited by the influence of seasonal flows on successful fish passage between permanent pool habitats and surrounding land use impacts on water quality.

As with the mainstream of the Jordan River, the tributary sites are subject to impacts resulting from adjacent land use practices such as farming and to a lesser extent urbanisation. These small streams have been found to be influenced by riparian practices. General issues and impacts for tributaries overall include the following:

- lack of riparian vegetation;
- limited indigenous plant regeneration;
- presence of exotic plant species;
- erosion due to destruction of stream-side zones;
- Agricultural land use practices;
- Unrestricted stock access.

Comparisons of physical form and stream side zone ratings indicate that the greatest loss of condition for tributary streams occurs as a result of disturbance from surrounding land use practices. Agricultural practices have the greatest impact on river condition resulting in very poor conditions for physical form and stream side zone ratings at 7 sites (Tea Tree Rivulet at Back Tea Tree Road (JORD19), Green Valley Rivulet at Cockatoo Valley Road (JORD26), Green Valley Rivulet at Green Valley Road (JORD27), Green Ponds Rivulet at wilderness lane (JORD29), Petherton Creek at Bowhill Road (JORD40), Dulverton Rivulet at Bowhill Road (JORD41), and Huntworth Creek at Stonor Road (JORD42). The most common contributors to poor condition at the tributary sites were the absence of riparian cover, lack of vegetation that aids bank stability and limited indigenous vegetation regeneration. Management issues identified for individual sites are provided in Table 9.

Table 9. Management issues identified for the Jordan River tributary sites.

Reach	Management issues
Bagdad Rivulet upstream of golf course.	Weeds- Extensive cover by hawthorn, gorse, willow, blackberry and thistles. Minor cover by broom. Extensive cover by Cumbungi (aquatic macrophyte) within pools. Limited riparian cover by indigenous woody species within overstorey and understorey. No indigenous plant regeneration. Absence of indigenous CWD.
Bagdad Rivulet at Eddington Road.	Weeds- Extensive cover by hawthorn and broom (*Cytisus scoparius*). Minor cover by willow, blackberry, and thistles. Indigenous plant species are a minor element of the overstorey and understorey. Riparian zone reduced to a width not exceeding 10 metres. Moderate willow root mat development. Potential for stock access to banks.
Bagdad Rivulet off Harbach's Road.	Weeds- Minor cover by willow, blackberry and bracken. No management issues identified.
Strathallan Rivulet upstream of golf course.	Weeds – Extensive cover by Hawthorn, blackberry, thistles and gorse. Minor cover by broom. Extensive growth of Cumbungi and *Azolla* within pools of the lower section of reach. Riparian zone highly modified, lacking indigenous elements from the overstorey and understorey layers. Sparse exotics provide element of structural diversity (Sparse overstorey and understorey cover). Moderate levels of erosion. Absence of CWD.
Strathallan Rivulet at Tea Tree.	Weeds – Abundant willow, sweet briar and gorse, with minor cover by thistles and blackberries. Riparian width reduced to less than 5 metres and dominated by introduced species. Limited indigenous plant regeneration. Absence of CWD cover. Minor infestation of Cumbungi. Limited erosion.
Tea Tree Rivulet at Back Tea Tree Road.	Weeds – Minor cover by thistles and hawthorn. Riparian zone essentially absent. Poor in-stream habitat availability during periods of low flow. Potential issues associated with unrestricted stock access to entire right bank (facing upstream) and lower sections of the left bank. Evidence of stock damage to banks directly upstream of Back Tea Tree Road.
Woodlands Creek upstream of Tea Tree.	Weeds – Abundant cover by gorse, thistles and hawthorn. Minor cover by willow and Cumbungi. Limited cover by CWD. Indigenous species are rare within the overstorey and understorey, resulting in very poor structural intactness and reduced riparian width. Limited regeneration by indigenous species. Moderate levels of bank erosion.
Brown Cave creek at Chauncy Vale Road.	Weeds – Minor cover by hawthorn, blackberries, thistles, and bracken. Evidence of stock access to two discrete sections of stream bank. Low levels of erosion. No further management issues identified.
Mangalore Creek at Black Brush Road.	Weeds – Abundant cover by gorse and minor cover by blackberries and bracken. Potential for stock access to stream banks due to absence of fencing. Absence of indigenous woody elements from the riparian zone. Poor mesohabitat diversity during periods of low flow. Absence of CWD. Prolific algal growth within channel.
Stoneyhurst Creek off Storeys Road.	Weeds – Extensive cover by blackberries, thistles, bracken, and minor cover by gorse. Evidence of stock damage to banks at a number of access points.

Table 9. Contd.

Grahams Creek at Elderslie Road.	Weeds – Extensive cover by blackberries and hawthorn and minor cover by thistles. Reduced riparian width and structural intactness. Limited regeneration by indigenous plant species. Sections of both banks subject to moderate erosion.
Grahams Creek off Grahams Creek Road.	Weeds – Abundant blackberry, thistle, and bracken cover. Indigenous woody species offer patchy overstorey and understorey cover providing a degree of structural diversity within the riparian zone. Limited cover by CWD. Unrestricted stock access to banks with evidence of associated erosion.
Green Valley Rivulet at Cockatoo Valley Road.	Weeds – Abundant thistle cover and minor cover by willow, gorse, and blackberries. Highly modified riparian zone lacking native overstorey and understorey elements. Increased structural diversity provided by willows at upstream extent of study reach. Absence of CWD. Poor mesohabitat diversity and poor in-stream integrity. Minor levels of bank erosion. Stock access restricted from lower section (100 metres) of reach by bank profile and fencing.
Green Valley Rivulet at Green Valley Road.	Weeds – Abundant cover by thistles and minor cover by blackberries. Sparse riparian zone with limited discontinuous cover by silver wattle. Unrestricted stock access to left bank (facing upstream). Extensive channel downcutting and bank erosion. Low water availability and very poor mesohabitat diversity.
Espies Creek off Pelham Road.	Weeds – Abundant thistles and bracken cover. Emergent native woody species provide limited structural diversity to riparian zone. Very poor mesohabitat diversity. Unrestricted stock access to stream banks with evidence of associated erosion. Poor in-stream habitat availability during periods of low flow.
Green Ponds Rivulet at Wilderness Lane.	Weeds – Abundant cover by willow, hawthorn and thistles. Unrestricted stock access to stream banks. Channel subject to drying during periods of low flow. Willow and hawthorn provide overstorey cover that is patchy up to 5 metres in width for half of the study reach.
Quoin Rivulet at Midlands Highway.	Weeds – Abundant cover by hawthorn and thistles. Reduced riparian integrity due to loss of structural layers. Absence of cover and or regeneration by indigenous plant species. Unrestricted stock access to left stream bank (facing upstream). Absence of CWD. Poor mesohabitat diversity and poor in-stream integrity. Extensive cover by aquatic macrophytes (Cumbungi). Channel subject to drying during periods of low flow.
Quoin Rivulet at Colebrook Heights.	No management issues identified.
Donnybrook Rivulet at Den Road.	Weeds – Extensive cover by blackberries and thistles, with minor covers by gorse, hawthorn, willow and sweet briar. Minor areas of unchecked erosion. The stream is unfenced though steep sides limit access by stock.
Donnybrook Rivulet upper at Den Road.	Weeds – Minor cover by willow, thistles and bracken. Highly reduced riparian integrity with only a few emergent woody natives present. Unrestricted stock access to stream banks with the extent of erosion at access points being limited.
Little Den Creek at Lake Highway.	No management issues
Little Den Creek at Bisdees Road.	Evidence of minor stock access. No additional management issues identified.

Table 9. Contd.

Springhill Creek at Lower Marshes	Weeds – Abundant cover by gorse and minor cover by thistles.

Road.	Native woody elements are absent from the streamside zone. Absence of CWD. Stock access to left bank (facing downstream) is restricted by fencing for over 300 metres. Stock usage at time of assessment was not evident. The course of the stream appears to have been subject to alteration with the current channel being of an artificial nature.
Exe Rivulet at Exe Sugarloaf.	Weeds – Extensive cover by hawthorn and gorse, and minor cover by willow and blackberries. Stock access restricted for right bank (facing downstream) whilst the left bank is unfenced. Evidence of bank erosion at stock access points. Some evidence of channel downcutting and meandering.
Green Hill Rivulet off track off Bowhill Road.	Weeds – Abundant cover by thistles and gorse, with minor cover by bracken fern. Riparian zone lacking overstorey and understorey elements. Native grasses and sedges provide groundcover. Evidence of moderate levels of bank erosion. Potential for stock access to both banks due to absence of fencing.
Green Hill Rivulet at Bowhill Road.	Weeds – Abundant cover by gorse, with minor cover by thistles and rosehip. Native woody elements are essentially absent from the riparian zone. Gorse provides some shading for small sections of the stream. Stock access is unrestricted to both banks. Evidence of erosion and bank undercutting at stock access points.
Petherton Creek at Bowhill Road.	Weeds – Abundant cover by thistles and gorse, with minor cover by willows. Site displays evidence of mechanical gorse control. Potential for stock access to left bank (facing downstream) whilst to the right bank access is restricted by fencing. Woody elements absent from riparian zone.
Dulverton Rivulet at Bowhill Road.	Weeds – Abundant cover by thistles and minor cover by gorse. Woody elements absent from riparian zone. Unrestricted stock access to stream banks with evidence of associated erosion. Very poor in-stream conditions with extensive algal and azolla growth. Moderate levels of bank erosion and channel meandering.
Huntworth Creek at Stonor Road.	Weeds -. Abundant cover by thistles. Elevated algal growth indicating nutrient enrichment. Woody elements are absent from the riparian zone. Evidence of unrestricted stock access to river banks and unchecked erosion

6. CONCLUSION

The Index of River Condition 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. The technique also identifies potential degradation issues for each reach within the Jordan River 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.
- 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 and mainstream reaches 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 could 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 1a: Jordan River site list with grid references for each study location.

Site Code	Site	Northing	Easting	Altitude(m)	Area(Km2)
JORD01	Jordan u/s tidal limit at old SG station	5269500	519700	20	
JORD02	Jordan at Pontville Ford	5273150	521800	40	1262.3
JORD03	Jordan at Elderslie Road	5274100	514800	89	1005.8
JORD04	Jordan at Andersons Road	5279950	508950	90	925.7
JORD05	Jordan at Roydon Road 300m d/s of Br	5283900	506600	100	
JORD06	Jordan at Clifton Vale Road	5289400	507200	120	731.2
JORD07	Jordan at Mauriceton	5291500	510100	150	752.9
JORD08	Jordan u/s Donnybrook Rivulet	5299450	511850	200	
JORD09	Jordan at Apsley	5303000	512000	220	529.5
JORD10	Jordan at Glenmore Sugarloaf	5309600	513950		
JORD11	Jordan at Black Bridge	5311900	515800	280	391
JORD12	Jordan at Burnt Log Gully	5315800	521900	320	299
JORD13	Jordan at Jericho	5308100	524100	380	79
JORD14	Bagdad Rivulet u/s Golf Course	5273850	522400	40	117.6
JORD15	Bagdad Rivulet at Eddington Road	5281100	518300	115	
JORD16	Bagdad Rivulet off Harbach's Road	5284500	519450	200	
JORD17	Strathallan Rivulet u/s Golf Course	5273600	522600	40	74.8
JORD18	Strathallan Rivulet at Tea Tree	5273450	526300	70	43.8
JORD19	Tea Tree Rivulet at Back Tea Tree Road	5271300	525825	100	9.2
JORD20	Woodlands Creek u/s Tea tree	5273760	528370		
JORD21	Brown Cave Creek / Chauncy Vale Road	5282870	519350	150	
JORD22	Mangalore Ck / Black Brush Road	5276380	517200	100	
JORD23	Stoneyhurst Creek off Storeys Road	5275900	508450	180	
JORD24	Grahams Creek at Elderslie Road	5279400	509400	110	18.2
JORD25	Grahams Creek off Grahams Creek Rd	5278490	506730	230	
JORD26	Green Valley Rt at Cockatoo Valley Rd	5281400	508600	105	14.6
JORD27	Green Valley Rivulet at Green Valley Rd	5280300	513400	260	
JORD28	Espies Ck of Pelham Rd	5284000	503920	160	
JORD29	Green Ponds Rivulet / Wilderness Lane	5292300	514500	260	
JORD30	Quoin Rivulet at Midlands Hwy	5296650	514600	190	103.3
JORD31	Quoin Rivulet at Colebrook Heights	5294450	521390		
JORD32	Donnybrook Rivulet at Den Road	5299100	511600	230	9.2
JORD33	Donnybrook Rt upper / Den Rd	5299450	507800	520	
JORD34	Little Den Creek at Lake Highway	5302700	511400	260	15
JORD35	Little Den Creek at Bisdees Road	5302780	509430		
JORD36	Spring Hill Creek at Lower Marshes Rd	5307550	513750		
JORD37	Exe Rivulet at Exe Sugarloaf	5314700	518300	330	45.1
JORD38	Green Hill Rivulet off Track of Bowhill Road	5316200	521500		
JORD39	Green Hill Rivulet at Bowhill Road	5318300	519900	430	15.8
JORD40	Petherton Creek at Bowhill Road	5316400	524200	360	37.1
JORD41	Dulverton Rivulet at Bowhill Road	5315500	525500	370	68.8
JORD42	Huntworth Creek / Stonor Road	5309200	525850	430	

APPENDIX 1b: Artificial barriers – dam, weir, culvert, and bridge locations for the Jordan River.

Location	Easting	Northing	Type	Rating
Jordan River at Elderslie Road	515787	5273283	bridge	3
JORD3	514900	5274100	bridge	3
Jordan at Black Brush Road	513000	5275000	bridge	3
Stoneyhurst Creek at Elderslie Road	510300	5276800	bridge	3
Jordan River at track off Elderslie Road	510200	5277800	bridge	3
Unnamed tributary at Clifton Vale Road	508850	5290460	bridge	3
Woodlands Creek at Grice's Road	529710	5275690	bridge	3
Strathallan Rivulet at Maiden Erleigh	524090	5273880	bridge	3
Strathallan Rivulet at Strathallan	524900	5273500	bridge	3
Jordan at Tea Tree Road	526800	5272090	bridge	3
Jordan at Pontville Bridge	521650	5273860	bridge	3
Bagdad Rivulet at Rifle Range Road	522180	5274700	bridge	3
JORD19	525825	5271300	bridge	3
Jordan River at Jones Road	506740	5281580	bridge	3
JORD27	513400	5280300	bridge	3
JORD26	508600	5281400	bridge	3
Green Valley Rivulet at Cockatoo gully Rd(2)	508550	5281700	bridge	3
Green Valley Rivulet at Cockatoo gully Rd(3)	511200	5284080	bridge	3
Horfield Creek at Green Valley Road	517350	5284350	bridge	3
Dysart Creek at Green Valley Road	517850	5283830	bridge	3
JORD15	518300	5281100	bridge	3
Bagdad Rivulet at Chauncy Vale Road	518400	5282500	bridge	3
Jordan at Den Road	511950	5299300	bridge	3
JORD30	514600	5296650	bridge	3
JORD11	515800	5311900	bridge	3
JORD37 (Exe Rivulet)	518300	5314700	bridge	3
JORD9 (Apsley)	512000	5303000	bridge	3
JORD10 (Glenmore SL)	513950	5309600	bridge	3
Jordan at Lower Marshes Road	514630	5309530	bridge	3
Jordan at Glen Iris	513200	5307350	bridge	3
Serpentine Valley Creek at Lovely Banks Rd.	518800	5300300	bridge	3
Jordan River at Midlands Highway	524300	5307030	bridge	3
Huntworth Creek at Park Farm	526600	5308400	bridge	3
Bagdad Rivulet at Roberts Road	519210	5279200	bridge	3
JORD24	509400	5279400	bridge	3
Grahams Creek at Grahams Creek Road	508470	5278450	bridge	3
JORD25	506730	5278490	bridge	3
JORD41	525500	5315500	bridge	3
Limekiln Creek at Strathelie	511900	5275600	bridge	3
Unnamed Tributary off Church Road	512200	5275400	culvert	3
Bagdad Rivulet off Harbach's Road (JORD16)	519450	5284500	culvert	3
Jordan at Clifton Vale Road	506994	5289207	culvert	3
Stonyhut Creek at Lovely banks Road	522694	5298913	culvert	3
Unnamed tributary at Beards Road	523350	5295550	culvert	3
Green Hill Rivulet at Bowhill Road(JORD39)	519892	5318312	culvert	3
89	518300	5282700	dam	3
Green Valley Rivulet at Cockatoo Gully Road	507970	5280800	bridge	2
JORD13	524100	5308100	bridge	2
Jordan at Cockatoo Valley Road	507950	5280850	bridge	2

APPENDIX 1b Contd.

JORD3	514900	5274100	culvert	2
JORD22	517200	5276380	culvert	2
JORD29	508450	5275950	culvert	2
Green Hill Rivulet off track of Bowhill Road	521629	5316842	culvert	2
Huntworth Creek / Stonor Road (JORD42)	525850	5309200	culvert	2
Strathallan Rivulet at Tea tree (JORD18)	526300	5273450	culvert	2
Jordan at Clifton Vale Road (JORD6)	507200	5289400	culvert	2
Springhill Creek at Lower Marshes Road (JORD36)	513635	5307565	culvert	2
Mudwalls Road	525537	5302954	culvert	2
Lower Marshes Road (JORD36)	515800	5311900	culvert	2
Jordan at Pontville ford JORD02)	521800	5273150	culvert	2
Mauriceton weir	510045	5291471	weir	2
3	521325	5295000	dam	2
3B	521336	5294171	dam	2
20	506900	5281500	dam	2
46	523500	5273600	dam	2
57	522400	5274000	dam	2
58	522500	5273600	dam	2
60	509000	5276300	dam	2
66	509800	5281100	dam	2
67	510000	5280700	dam	2
74	522200	5271500	dam	2
79	523000	5269900	dam	2
96	518200	5274400	dam	2
115	526600	5308300	dam	2
Snake Gully Creek at Elderslie Road	513400	5274950	culvert	1
Jordan at Belle Vale Road	517700	5312750	culvert	1
Elderslie Rd weir	515890	5273200	weir	1
4	531100	5316900	dam	1
19	506500	5281200	dam	1
30	521800	5271100	dam	1
31	514400	5292800	dam	1
33	508900	5282600	dam	1
34a	508400	5281150	dam	1
34b	508470	5281200	dam	1
35	514000	5275700	dam	1
37	513600	5276900	dam	1
38	516000	5312400	dam	1
40	517600	5311200	dam	1
42	507100	5291900	dam	1
48	535300	5305800	dam	1
50	504800	5283900	dam	1
51	504500	5283700	dam	1
53	519400	5278700	dam	1
55	517200	5279800	dam	1
56	518000	5279900	dam	1
68	526900	5272500	dam	1
69	526900	5272600	dam	1
70	526200	5270200	dam	1
71	522800	5270600	dam	1
77	531300	5307200	dam	1
78	523100	5269800	dam	1

APPENDIX 1b Contd.

82	524000	5317000	dam	1

83	524200	5318000	dam	1
84	525400	5303700	dam	1
87	511800	5275200	dam	1
91	521400	5301700	dam	1
94	520500	5302900	dam	1
95	520500	5302900	dam	1
97	509300	5276500	dam	1
100	511800	5298000	dam	1
101	511600	5297900	dam	1
108	518900	5282700	dam	1
109	510300	5290200	dam	1
110	510200	5290100	dam	1
112	512800	5274100	dam	1
113	533000	5307200	dam	1
116	526900	5308700	dam	1
118	531200	5315700	dam	1
120	507200	5291800	dam	1
121	506600	5281400	dam	1
122	518300	5291750	dam	1
124	507850	5288450	dam	1
9	510500	5277200	dam	0
28	513400	5274900	dam	0
29	513700	5275400	dam	0
34	509100	5282800	dam	0
43	524900	5273500	dam	0
102	511300	5298700	dam	0
102a	511400	5298700	dam	0
103	509800	5298800	dam	0

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

Number	DAM NAME	EASTING	NORTHING	TASMAP	PURPOSE
1		534850	5306000	Stonor	IRRIGATION
2		533900	5307400	Stonor	IRRIGATION
3		521325	5295000	Colebrook	IRRIGATION
4		531100	5316900	Oatlands	RECREATION
5		517500	5273000	Broadmarsh	IRRIGATION
6		517500	5273000	Broadmarsh	IRRIGATION
7		507300	5278700	Broadmarsh	IRRIGATION
8		517800	5281600	Elderslie	AESTHETIC
9		510500	5277200	Elderslie	IRRIGATION
10		510500	5277300	Elderslie	IRRIGATION
11		510500	5277400	Elderslie	IRRIGATION
12		527800	5273300	Tea Tree	IRRIGATION
13		528300	5273500	Tea Tree	IRRIGATION
14		528100	5273500	Tea Tree	IRRIGATION
15		527500	5273700	Tea Tree	IRRIGATION
16		527200	5273800	Tea Tree	IRRIGATION
17		528800	5273400	Tea Tree	IRRIGATION
18		528100	5273200	Tea Tree	IRRIGATION
19		506500	5281200	Elderslie	IRRIGATION
20		506900	5281500	Elderslie	IRRIGATION
21		516300	5274500	Broadmarsh	IRRIGATION
22		516600	5274300	Broadmarsh	IRRIGATION
23		511500	5273200	Broadmarsh	COMMERCIAL
24		502700	5284200	Elderslie	IRRIGATION
25		516600	5286800	Elderslie	IRRIGATION
26		517000	5284700	Elderslie	STOCK
27		513000	5274400	Broadmarsh	IRRIGATION
28		513400	5274900	Broadmarsh	IRRIGATION
29		513700	5275400	Broadmarsh	IRRIGATION
30		521800	5271100	Tea Tree	IRRIGATION
31		514400	5292800	Kempton	STOCK
32		520900	5307500	Stonor	IRRIGATION
33	JONES NO 3	508900	5282600	Elderslie	IRRIGATION
34		509100	5282800	Elderslie	IRRIGATION
35		514000	5275700	Broadmarsh	IRRIGATION
36		513500	5276400	Broadmarsh	IRRIGATION
37		513600	5276900	Broadmarsh	IRRIGATION
38		516000	5312400	Bothwell	IRRIGATION
39		518800	5310000	Bothwell	IRRIGATION
40		517600	5311200	Bothwell	IRRIGATION
41		519000	5309000	Bothwell	IRRIGATION
42	TIMSBURY NO 1	507100	5291900	Kempton	IRRIGATION
43		524900	5273500	Tea Tree	IRRIGATION

Appendix 2a Contd.

44		524800	5273800	Tea Tree	IRRIGATION
45		524400	5274000	Tea Tree	IRRIGATION
46		523500	5273600	Tea Tree	IRRIGATION
47	STRATHALLAN	524900	5274600	Tea Tree	IRRIGATION
48		535300	5305800	Stonor	IRRIGATION
49		535400	5305800	Stonor	IRRIGATION
50		504800	5283900	Elderslie	IRRIGATION
51	TAYLOR NO 2	504500	5283700	Elderslie	IRRIGATION
52		519500	5278800	Broadmarsh	IRRIGATION
53		519400	5278700	Broadmarsh	IRRIGATION
54		519300	5278900	Broadmarsh	IRRIGATION
55	BROWNLOW	517200	5279800	Broadmarsh	STOCK
56		518000	5279900	Broadmarsh	STOCK
57		522400	5274000	Tea Tree	IRRIGATION
58		522500	5273600	Tea Tree	IRRIGATION
59		522400	5273400	Tea Tree	IRRIGATION
60		509000	5276300	Broadmarsh	IRRIGATION
61		510000	5275700	Broadmarsh	IRRIGATION
62	GEARD	510600	5275500	Broadmarsh	IRRIGATION
63		508200	5275600	Broadmarsh	OTHER
64		518600	5281800	Elderslie	IRRIGATION
65		505300	5286500	Elderslie	IRRIGATION
66	NORTH NO 1	509800	5281100	Elderslie	IRRIGATION
67	NORTH NO 2	510000	5280700	Elderslie	IRRIGATION
68		526900	5272500	Tea Tree	IRRIGATION
69		526900	5272600	Tea Tree	IRRIGATION
70	GLEN QUOIN	526200	5270200	Tea Tree	IRRIGATION
71		522800	5270600	Tea Tree	IRRIGATION
72		518500	5278300	Broadmarsh	IRRIGATION
73		519200	5302000	Bothwell	STOCK
74		522200	5271500	Tea Tree	STOCK
75		516200	5284000	Broadmarsh	IRRIGATION
76		519300	5271900	Broadmarsh	IRRIGATION
77	SALMON	531300	5307200	Stonor	STOCK
78		523100	5269800	Richmond	AESTHETIC
79		523000	5269900	Richmond	AESTHETIC
80		505400	5280600	Elderslie	STOCK
81		528700	5271600	Tea Tree	IRRIGATION
82		524000	5317000	Oatlands	IRRIGATION
83	AGNEW	524200	5318000	Oatlands	IRRIGATION
84	TAYLOR NO 1	525400	5303700	Oatlands	IRRIGATION
85	MCSHANE	511400	5274700	Broadmarsh	IRRIGATION
86		511000	5274900	Broadmarsh	IRRIGATION
87		511800	5275200	Broadmarsh	IRRIGATION
88		518300	5282500	Broadmarsh	IRRIGATION

Appendix 2a Contd.

89		518300	5282700	Broadmarsh	IRRIGATION
90		521800	5301600	Stonor	STOCK
91		521400	5301700	Stonor	STOCK
92		521000	5301000	Stonor	STOCK
93		521000	5301000	Stonor	STOCK
94		520500	5302900	Stonor	STOCK
95		520500	5302900	Stonor	STOCK
96		518200	5274400	Broadmarsh	IRRIGATION
97		509300	5276500	Broadmarsh	IRRIGATION
98		510100	5276700	Broadmarsh	IRRIGATION
99		535200	5305000	Stonor	IRRIGATION
100		511800	5298000	Kempton	STOCK
101		511600	5297900	Kempton	STOCK
102	STOCKMAN NO 1	511300	5298700	Kempton	IRRIGATION
103	STOCKMAN NO 2	509800	5298800	Kempton	IRRIGATION
104		523300	5295500	Colebrook	IRRIGATION
105		524000	5272700	Tea Tree	STOCK
106		533600	5307400	Stonor	IRRIGATION
107		533700	5307900	Stonor	IRRIGATION
108		518900	5282700	Elderslie	IRRIGATION
109	ALLWRIGHT NO 4	510300	5290200	Kempton	IRRIGATION
110		510200	5290100	Kempton	IRRIGATION
111	ALLWRIGHT NO 3	510500	5289100	Kempton	IRRIGATION
112		512800	5274100	Broadmarsh	IRRIGATION
113		533000	5307200	Stonor	STOCK
114		532700	5305500	Stonor	STOCK
115		526600	5308300	Stonor	STOCK
116		526900	5308700	Stonor	STOCK
117		513500	5295300	Kempton	IRRIGATION
118		531200	5315700	Oatlands	RECREATION
119	INVERCARRON	510800	5279300	Broadmarsh	IRRIGATION
120	TIMSBURY NO 2	507200	5291800	Elderslie	IRRIGATION
121		506600	5281400	Elderslie	IRRIGATION
122	GRANGE	518300	5291750	Kempton	IRRIGATION
123		526125	5275050	Tea Tree	IRRIGATION

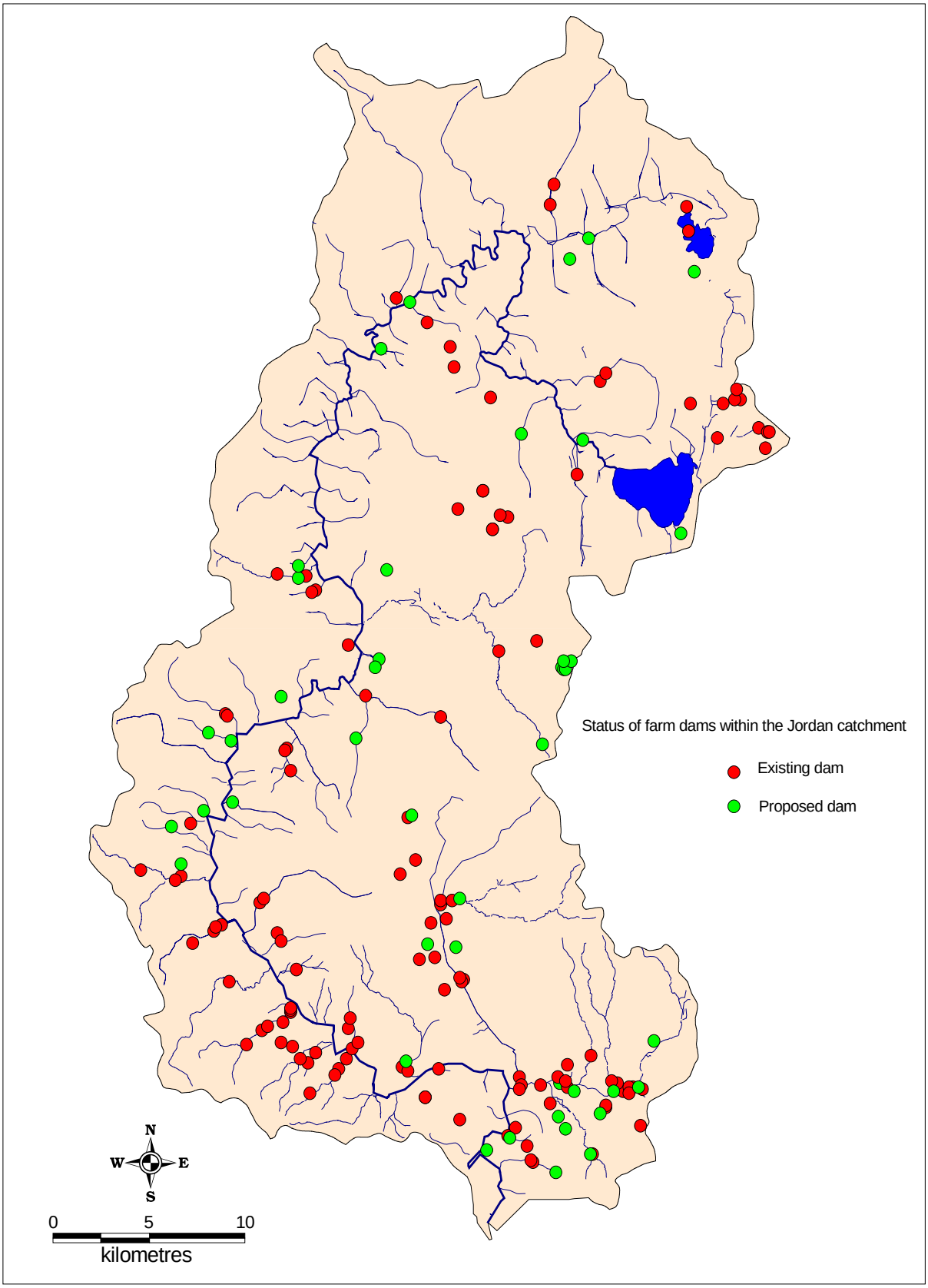
Appendix 2b: Proposed in-stream dam location details for the Jordan Catchment.

Number	DAM NAME	EASTING	NORTHING	TASMAP	PURPOSE
124		527300	5273300		IRRIGATION
125	BLACKWELL	504800	5284500		IRRIGATION
126		516500	5274775		IRRIGATION
127		515200	5309900		IRRIGATION
128	JONES NO 5	516700	5312200		IRRIGATION
129		524500	5273700		IRRIGATION
130		515500	5299000		STOCK

Appendix 2b Contd.

131		521900	5271000	STOCK
132	STOCKMAN NO 3	510900	5298600	IRRIGATION
133		510900	5299200	STOCK
134		519300	5282800	STOCK
135		531500	5313700	STOCK
136		523600	5290400	STOCK
137		528600	5273500	STOCK
138		513900	5290700	STOCK
139		530800	5300800	IRRIGATION
140		522500	5305700	STOCK & DOMESTIC
141		529400	5275775	IRRIGATION
142		524600	5294200	STOCK & DOMESTIC
143		524700	5294100	STOCK & DOMESTIC
144		524800	5294100	STOCK & DOMESTIC
145		525100	5294500	STOCK & DOMESTIC
146		524700	5294500	STOCK & DOMESTIC
147		507475	5287550	IRRIGATION
148		525250	5273300	IRRIGATION
149	THOMPSON	524425	5272050	IRRIGATION
150		524800	5271450	IRRIGATION
151		526600	5272200	IRRIGATION
152		526100	5270200	IRRIGATION
153		519100	5280400	IRRIGATION
154		517625	5280550	IRRIGATION
155		524300	5269300	STOCK
156		504300	5286350	IRRIGATION
157		505975	5287125	IRRIGATION
158		516800	5286900	IRRIGATION
159		520700	5270400	IRRIGATION
160	ISLES NO 1	526000	5315350	IRRIGATION
161	ISLES NO 2	525025	5314325	IRRIGATION
162		507400	5290575	IRRIGATION
163		506225	5290975	IRRIGATION
164	COX JC & LP	510000	5292750	IRRIGATION
165		525700	5305400	IRRIGATION
166		514900	5294200	IRRIGATION
167		515100	5294600	IRRIGATION

Appendix 2c: Existing and proposed dam locations for the Jordan 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.**