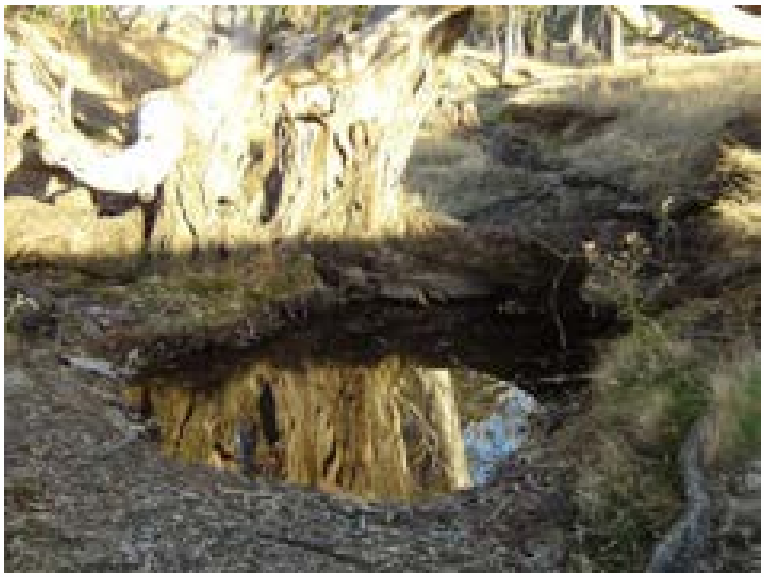
SKM

Wimmera Catchment Management Authority

Waterways for Life.

Wattle Creek Waterway Action Plan



- Final
- 29 September 2005

action Salinity & Water AUSTRALIA

Victoria The Place To Be

Wattle Creek
Waterway Action Plan

- Final
- 29 September 2005

Sinclair Knight Merz
ABN 37 001 024 095
590 Orrong Road, Armadale 3143
PO Box 2500
Malvern VIC 3144 Australia
Tel: +61 3 9248 3100
Fax: +61 3 9248 3400
Web: www.skmconsulting.com

Glossary

Term	Definition
aggradation	The process of raising the bed level of a stream through deposition of sediment
alluvial	Sediment deposited by flowing water, in a riverbed, flood plain, or delta
bedrock	Exposed solid rock that underlies loose material, such as soil, sand, clay, or gravel
bench	A level elevation of deposited material attached to a stream bank that exists between the streambed and the floodplain
degradation	A decline or lowering of the condition/quality, of the stream or floodpain
erosion	Processes, such as weathering, dissolution, abrasion, , and transportation, by which material is worn away from a surface
geomorphology (morphology)	The branch of geology that studies the characteristics and configuration and evolution of rocks, land forms
headcut	Vertical or near vertical drop in channel elevation greater than 300mm
incision	Lowering of a waterways bed level r
reach	A stream management unit i.e. a segment of a waterway
riparian	Of, on, or relating to the banks of a natural water course.

Executive Summary

The Wattle Creek Waterway Action Plan is one of many such plans being prepared by Wimmera Catchment Management Authority (Wimmera CMA) as part of a program to identify site-specific actions to ensure the health and stability of waterways in the Wimmera catchment.

This Waterway Action Plan focuses on key waterway management issues for which the Wimmera CMA is responsible, and it outlines recommended initiatives to improve the health of the waterways located within the Wattle Creek catchment over the next five to ten years. The initiatives and priorities have been set in line with the objectives of the Wimmera Regional River Health Strategy (2005).

The plan provides a readily accessible form of information and analysis of the key waterway issues that have been identified and prioritised. Information contained within the plan aims to provide an understanding of the management approaches the Wimmera CMA encourage.

Wattle (Heifer Station) Creek is a small seasonally flowing tributary of the Wimmera River which has a catchment area of approximately 433 km^2. Rising from the predominantly sedimentary slopes of the north-western end of the Pyrenees ranges and draining to the lowland valley plains of the Wimmera River floodplain near Greens Creek, the stream system rapidly descends from the foothill areas onto broad lowland valley plains with low rises. The catchment has undergone widespread clearance since European settlement, triggering a range of degradation processes, including incision, tunnelling and gullying.

Due to the historically poor drainage characteristics of the area, many drainage channels appear to have been constructed to drain the landscape to enhance cropping and grazing opportunities. Many of these channels have triggered gully and headward erosion and although the primary erosion processes have finished, there are still many instances of active bed and bank erosion in the catchment, particularly in the foothill regions. The soil profile in the area typically consists of a thin layer of topsoil beneath which lies soils that are extremely slakey in nature. Once exposed, the slakey soils are extremely vulnerable to the effects of flowing water and offer little resistance to erosion. A feature of the drainage system is the presence of many depositional or seasonal swamp areas where drainage systems terminate and drop sediment before connection to the main stem waterways. Some of these sediment stores have been drained to allow for agricultural use, while others remain in place but are under threat.

The investigation process undertaken for this study included a review of the relevant previous studies, aerial photography analysis, an information collection process with local landholders and stakeholders and a field inspection of the catchment. The investigation process determined that the main stems of Wattle (Heifer Station) and Howard Creeks are relatively stable despite disturbances,

modifications and land management pressures. However, the tributaries showed marked indications of disturbances and despite an apparent extensive set of interventions by the former SCA, there are still many areas of bed and bank erosion and/or reworking of historical incision areas and lateral movement in streams.

The major issues for erosion remain within the sedimentary reaches of the foothills, this generally being associated with either channelisation of streams, a loss of robust and continuous riparian vegetation community, evidence of saline discharges and impacts of stock.

The resultant impact on water quality and instream values of the mainstem waterways is marked The impacts of salinity and high turbid waters exiting the catchment are evident on the receiving waters of the Wimmera River.

The key issues identified in the Wattle (Heifer Station) Creek and Howard Creek catchment that the Wimmera CMA needs to address include:

- The protection and enhancement of areas of higher fauna and flora quality;
- The reconnection of key riparian linkages along the streams;
- The rehabilitation of areas of serious stream erosion in the tributaries through stabilisation and revegetation programs, with particular attention to those streams directly connected to the mainstems;
- The rehabilitation of many former SCA works to secure the function and integrity of those works;
- Degradation of riparian vegetation and streams banks and verges due to impacts of stock access through fencing and revegetation programs;
- The need to negotiate improved offstream stock watering arrangements;
- The study of, protection and enhancement of seasonal wetlands and sediment stores along the tributary streams and in the floodplains for intrinsic habitat values and water quality management roles;
- The support of interagency programs, including management of widespread salinity discharge and production issues;
- The support of weed management programs along all streams;
- An expanded monitoring of the water quality and instream fauna across the system;
- A refined study of flood management for the Navarre Township and the floodplain downstream; and
- The support for interagency programs to improve sustainable land use practices.

Many beneficial projects have already been undertaken by individuals in conjunction with the Wimmera CMA and other agencies. Whilst this work is commended, a lot more remains to be done.

A detailed and prioritised set of activities for the CMA to concentrate on to achieve the above objectives are identified in this report.

Contents

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
Draft A	16/06/05	M. Hillemacher	T. Dando	16/06/05	First Draft
Draft B	21/06/05	T. Dando	T. Dando	21/06/05	Minor Edits
Draft C	12/07/05	T. Dando	T. Dando	12/07/05	WCMA comments
Final	29/09/05	M. Hillemacher	M. Hillemacher	29/09/05	Final comments

Distribution of copies

Revision	Copy no	Quantity	Issued to
Draft B	One	3 Hardcopy, 1 electronic	WCMA – M. Tilgner
Draft B	Two	1 Hardcopy	File
Draft C	Three	Electronic	WCMA – M. Tilgner
Final	Four	Electronic	WCMA – M. Tilgner

Printed:	21 July 2008
Last saved:	29 September 2005 11:06 PM
File name:	I:\WCMS\Projects\WC03232\Deliverables\Wattle Creek\Wattle_Creek_WAP_Draft_130705.doc
Author:	Martin Hillemacher, Scott Semour, Bruce Abernethy, David Endersby
Project manager:	Trevor Dando
Name of organisation:	Wimmera CMA
Name of project:	Wattle Creek Waterway Action Plan
Name of document:	Wattle Creek Waterway Action Plan
Document version:	Draft
Project number:	WC03232

1. Introduction

1.1 What is a Waterway Action Plan

A Waterway Action Plan (WAP) examines catchments and individual reaches of waterways and identifies site-specific actions to ensure the health and stability of the waterway.

The intention of Waterway Action Plans is to provide information in an easily accessible form for users. Waterway Action Plans set out strategic directions and outline actions to address key issues associated with specific reaches of the waterway. They set a framework from which Wimmera Catchment Management Authority (Wimmera CMA) is able to prioritise rehabilitation works for the next five to ten years. However, while Waterway Action Plans are predominantly works oriented, they only define the outline of projects and do not contain detailed project prescriptions or detailed costing estimates. These are additional tasks that need to be undertaken at the project implementation stage.

1.2 Objectives of the Wimmera Waterway Action Plans

This plan focuses on key waterway issues for which Wimmera is responsible, namely:

- Progressive reduction in the amount of sediment, suspended solids and turbidity originating from the Heifer Station Creek and tributaries to the Wimmera River;
- Protection of the existing floodplains and wetlands for their water quality treatment role;
- Rehabilitation of unstable waterways and gullies through tackling bed and bank erosion and rehabilitation of old structures;
- Protect and enhance existing high value riparian areas and achieve the improvement of riparian vegetation condition along the waterways with a key focus of regional biodiversity connection;
- Protect and rehabilitate existing high value and critical instream habitat areas; and
- Support the attainment of the Regional Salinity Management Plan.

It sets out a framework by which the Wimmera CMA is able to prioritise rehabilitation works for the next five to ten years.

Wimmera CMA will address the following aims through the development of Waterway Action Plans:

i) establish a set of objectives for the management of the stream systems with a view to improving the river health over time;

ii) produce a plan that focuses on key waterway management issues in the Wimmera CMA's scope of responsibilities and priorities as outlined in the Wimmera Regional River Health

Plan, such that an outline works program for the stream can be identified for the next five to ten years;

iii) provide an accessible form of information and analysis of key waterway issues so that other agencies organisations and community groups are aware of those issues and the plan's prioritisation of works; and

iv) encourage landowners and community groups to be aware of the plan's contents, which provides a framework for undertaking additional planning or works along the stream corridors, and addressing their responsibilities in the areas of land management. Waterway Action Plans thus present an opportunity to assist coordination between management authorities and have the potential to promote a shared vision for the waterways between Councils, DPI, DSE, Wimmera CMA the community and other stakeholders.

1.3 Project Scope

The scope of this project is to:

i) Develop a report that documents appropriate management techniques for waterways within the Wattle Creek catchment over the next five to ten years; and

ii) Facilitate the implementation of waterway action works where required.

1.4 Key Tasks

The following key tasks are outlined in the project brief and have been completed to achieve the above:

- Review of available information including relevant state and regional strategies, reports, aerial photography, longtitudinal profiles, water quality information etc.
- Consultation with stakeholders, ie department organisations.
- Consultation with the community i.e. landholders.
- Inspection of the catchment.
- Division of the catchment into smaller 'sub-catchments' or 'reaches'.
- Development of detailed sub-catchment management plans that detail the risks and opportunities within each sub-catchment.
- Prioritisation of management actions.
- Development of detailed sub-catchment maps showing the location of proposed management actions.
- Identification of bed and bank instabilities.
- Identification of pest plant and animal species that may pose a threat to waterway health at a sub reach scale.

- Assessment of the extent and condition of riparian vegetation and fencing at a sub reach scale.
- Identification of high value assets and detail any risks and opportunities associated with these assets.
- Provision of an indicative budget to undertake management actions.
- Development of the WAPs with a “Landscape” or whole of catchment approach to natural resource management (NRM), giving consideration for other natural resource management (NRM) programs and projects planned or underway within the catchment.

1.5 Catchment Location

The Wattle Creek catchment is located in Western Victoria and covers an area of approximately 433 km^2, shown in Figure 1.1 below. Major towns located near the catchment include Stawell and Ararat. The largest towns that are located within the catchment include Landsborough, Navarre and Barkly.

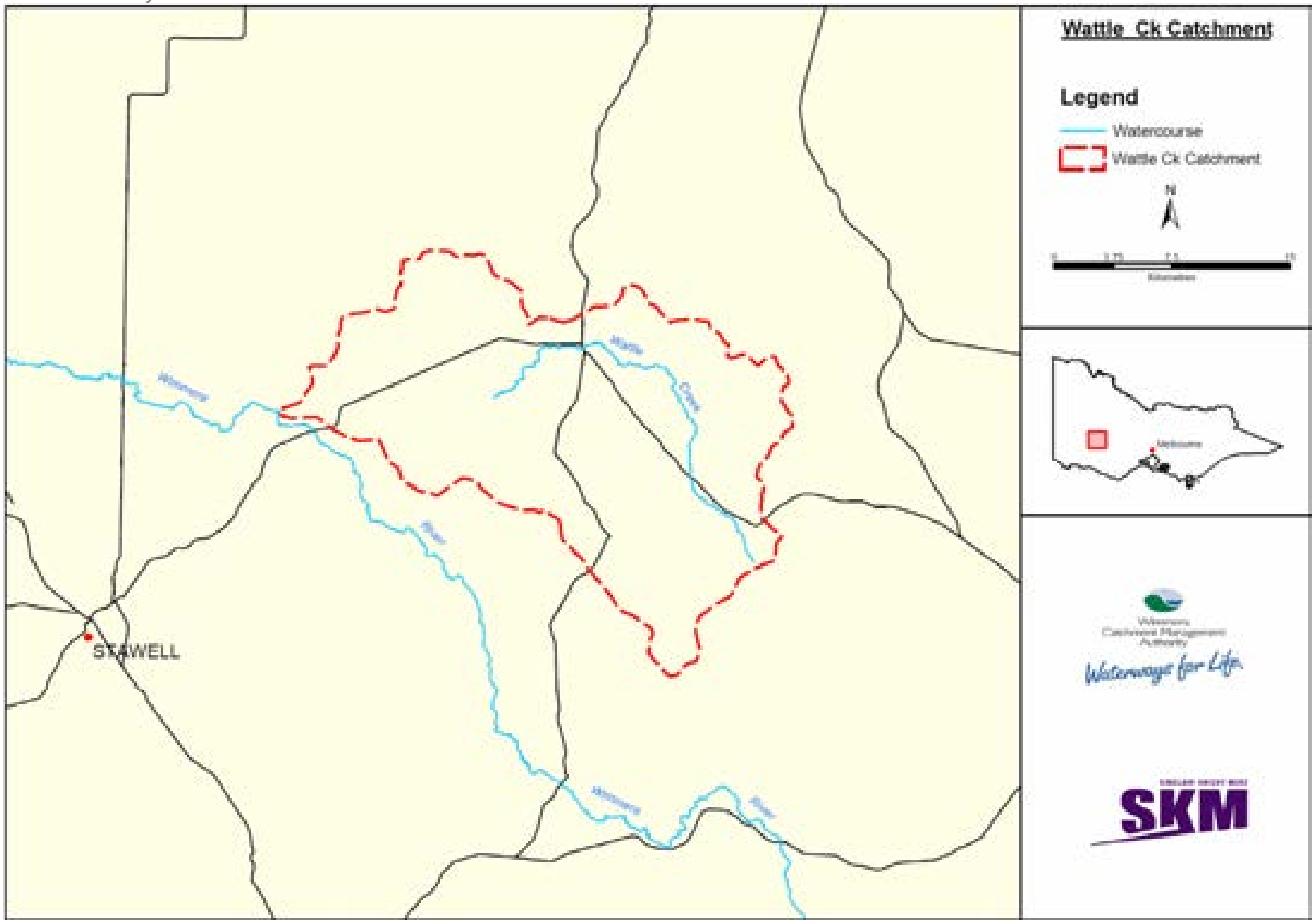


Figure 1.1 – Wattle Creek Catchment Location.

1.6 Major waterways in the Catchment

The major waterways in the Wattle Creek catchment are all identifiable by name including:

- Heifer Station (Wattle) Creek;
- Howard Creek;
- Greens Creek;
- Friends Creek; and
- Morl Morl Creek.

There are numerous other named and unnamed tributaries throughout the system.

1.7 Relevant Reports and Background Information

The Wattle Creek catchment system is part of the upper Wimmera River catchment. Regional strategies and policies that are relevant to this WAP include:

- Victorian River Health Strategy (2002)
- Wimmera Regional Catchment Strategy (2004)
- Draft Wimmera Waterway Health Strategy (2005)
- Wimmera Water Quality Strategy (2002)
- Wimmera River Geomorphic Investigation (2001)
- Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment (2003).

This Waterway Action Plan has been compiled in line with the key management actions, objectives, goals and recommendations made in these documents.

1.8 Supporting Programs

Wimmera CMA, together with DSE and DPI are the principle authorities responsible for delivering the recommendations of these strategies and policies on a regional basis. Collaborative programs that play a vital role in supporting these objectives include:

- Wimmera Weed Action Plan
- Wimmera Salinity Management Plan
- Steep Hill Country Management Plan
- Whole Farm Planning
- Wimmera Rabbit Management Action Plan
- Victorian pest management framework (DSE)
- Victorian Biodiversity Strategy
- Shire Planning Schemes

2. Catchment Description

2.1 Whole of Catchment Overview

This section provides an overview of the catchment generally. A more detailed analysis on a reach by reach basis is provided in Sections 4 to 11.

2.1.1 Water Quality

Water quality in the Wattle Creek catchment is very much a reflection of the climate, land use and geology. The catchment is based on a predominantly sedimentary rises, low hills and undulating areas with some metamorphic ridges and steeper hills on the northern ends of the Pyrenees and as a result is prone to the production of saline and moderately turbid waters under event flow conditions.

The dominant issues for the catchment with respect to water quality are:

- Transport of high loads of very finely suspended solids (turbidity) to the main stem reaches and the Wimmera River;
- The transport of soluble nutrients either through leaching or runoff from broad acre farming an/or township sewage at Navarre and Landsborough; and
- The transport of salt loads to the Wimmera River impacting on the residual and refuge values of the lower Heifer Station Creek and Greens Swamp. Saline discharges are likely to enter the catchments waterways through the porous gravel seams that are present in the foothill regions. Flows discharging from the deeply fractured sedimentary and metamorphic regions in the upper catchments (i.e. upstream of Barkly) were observed to have high salinity levels. Flows in the lower reaches (Reach 1 downstream of Werenda Lane) were observed to be brackish.

Rainfall records indicate that the predominant rainfall in the catchment is likely to occur in late autumn, winter and in early spring. During this period, ground cover is generally low and major rainfall events are likely to result in sheet, gully and channel erosion, adversely impacting on water quality by increasing turbidity levels and transporting sediments to lower reaches.

Unfortunately there is no reported data on suspended solids, turbidity or nutrients in the Water Quality Data Warehouse (DSE 2005) to enable an appraisal of the loads to the Wimmera River. Given the observed mitigation of suspended solids loads in the floodplain wetlands and swamps, it is likely that only low loads of settleable solids will be experienced in the downstream reaches. However there is a high probability of high turbidity levels throughout the whole of the stream system across the catchment despite some mitigation by the swamp systems in the lowland plains.

A search of the Victorian Resource Data Warehouse (http://www.vicwaterdata.net/

vicwaterdata/home.aspx) revealed that limited water quality data is available for the catchment. No specific conclusions on this data alone were therefore drawn. Rather, this information together with observations from field inspections were used. In assessing the data and observations it is important to take into account the extended dry sequences of the 1996-2001 and 2003-2005 period into consideration. The field inspection stage of this study was undertaken at the end of an extended dry period, with no flow being encountered at most sites.

Towards the lower end of the catchment downstream of Woodlands Road and Werenda Lane, a small brackish flow was noted, however the pools further upstream were dry. This indicates the presence of springs and old sand lenses throughout the catchment along with the known discharge areas. Many observations were also made of salt fluorescence in banks of the weathered and incised streams during field assessments. It is understood that a study of salinity levels in the lower catchment is currently underway (R Carter WCMA *pers comm*.).

2.1.2 Stream Ecology

With respect to instream fauna, Doeg (2000) undertook an assessment of the values of the area as part of the preparation of the Upper Wimmera River Water Resources Management Plan (Environmental Flows, Avoca, Glenelg and Wimmera River) 2003. This data showed that some fish species of significance existed in the region. These include the following:

- Mountain Galaxias (*Galaxias olidus)*
- River Blackfish (*Gadopsis maroratus)*
- Flat headed Gudgeon (*Phylipnodon gradiceps)*

Platypus studies were undertaken in the catchment over a period of three years (Holwell *et al*. 1998; Serena and Williams 1998, 1999; Worley and Serena 2000) without any reported captures in Heifer Station Creek, and Howard Creek systems.

Generally, little information on the instream fauna in the catchment was able to be obtained. Further biological monitoring investigations of the seasonal streams or the more permanent pools would reveal more insight into the abundance or other wise of both indigenous and exotic species. In particular, detailed studies of the permanent pools in Reaches 1 and 2 would help confirm the existence of species and reinforce the importance of these pools as refuges in drier periods.

2.1.3 Vegetation

The Wattle Creek catchment has been highly modified and disturbed as a result of European settlement. Little in the way of natural vegetation remains in the catchment, and that tends to be highly disturbed as a result of past management issues, particularly as a result of livestock damage.

This situation is particularly apparent within the remaining riparian vegetation, where stock access further exacerbates other issues of land degradation such as erosion.

Large scale land clearance associated with the development of the area post European settlement has removed a great deal of the original vegetation cover, while a large number of introduced species have been added to the vegetation in the region during this time. The main assets of remnant vegetation are currently restricted to areas of relief in the upper portions of the catchment, generally associated with areas of steep terrain. The Landsborough Ridge and Mt Separation retain the main component of remnant vegetation in the catchment. Some small isolated pockets of remnant vegetation do remain on the lower slopes, but tend to be subject to further pressures as a result of this. A significant amount of roadside vegetation does exist throughout the catchment, which, although not remnant vegetation in the strict definition, does present some vegetation resources that may be incorporated into wider vegetation management approaches.

The following table lists the remaining remnant vegetation of the Wattle Creek Catchment and lists the reaches in which they occur. As evident from the list, the two main Ecological Vegetation Classes associated with the riparian environment (Creekline Grassy Woodland and Creekline Sedgy Woodland) have been completely removed from the catchment (as intact remnant stands).

Table 2-1 - Remaining EVC's of the Wattle Creek Catchment (DSE, 2005a, b & c)

Current EVC Remaining in Catchment (DSE, 2005)	Reach	Remaining Character	Location
6 - Sand Heathland	1, 2, 3, 4, 8	Small isolated remnants in lower catchment.	Lower Floodplain
20 - Heathy Dry Forest	4, 6	Relatively continuous along the lower western slopes of the Landsborough Ridge.	Mid to upper slopes with skeletal soils
22 - Grassy Dry Forest	4, 6, 8, 9	Relatively continuous along the upper western slopes of the Landsborough Ridge.	Lower slopes and alluvial plain outside riparian influence
23 - Herb-rich Foothills Forest	6	Upper portion of the southern slopes of the catchment.	Lower slopes and alluvial plain outside riparian influence
47 - Valley Grassy Forest	9	Isolated patches of the drainage line south of Landsborough.	Lower slopes and alluvial plain outside riparian influence
61 - Box Ironbark Forest	3, 4, 5, 6, 8, 9	Isolated patches of the mid slope across the northern portion of the catchment, including the northern slopes of the Landsborough ridge.	Upper Slopes

67 - Alluvial Terrace Herb- rich Woodland	9	Small patches along the break of slope on the western side of the Landsborough Ridge.	Riparian zone
70 - Hill Crest Herb-rich Woodland	3, 4, 8, 9	Upper slopes of the Landsborough Ridge and small isloated patches across the northern slopes of the catchment.	Upper Slopes and Crests
76 - Low Rises Grassy Woodland	3, 4, 7, 9	Isolated patches on lower slopes.	Lower slopes on alluvium
175 - Grassy Woodland	4, 5	Isolated patches on lower slopes.	Slopes

Aside from remnant vegetation, portions of the water courses (particularly the main stem) still retain some native vegetation cover, particularly the River Red Gum overstorey, although stock damage in particular has destroyed the understorey and ground cover character, hence removing the EVC character.

Overall, vegetation management in the Wattle Creek catchment should focus upon securing the existing vegetated areas along the drainage lines through stock exclusion and conservation fencing. Areas where vegetation needs to be re-established should similarly be reserved, allowing natural regeneration to begin. A strategic focus, linking areas of existing vegetation and biodiversity value should then be observed, initiating a revegetation focus on overstorey components where necessary.

Weed control within the catchment is also an issue in relation to overall vegetation management. A large number of introduced species have been recorded within the catchment, the most recent of which was a detailed weed mapping project commissioned by WCMA in 2005.

2.1.4 A model of catchment change

The gullies and broader-scale hillslope erosion that are now apparent in the Wattle Creek catchment are likely to have been initiated in the middle of the Nineteenth Century when valley floor vegetation was cleared for agriculture (and later more extensive fuel wood cutting) along with the introduction of hoofed stock. These changes in landuse have resulted in increased runoff and decreased erosion resistance (Prosser and Slade, 1994). When runoff is concentrated in hillslope hollows, the ability of flows to erode waterways increases, sometimes incising gullies into the valley floor. Once initiated, gullies spread at an exponentially declining rate with much of the networks being formed within the first few decades (Graf, 1977). This model of landscape change has been widely used to explain the occurrence of gully erosion (Prosser and Slade, 1994).

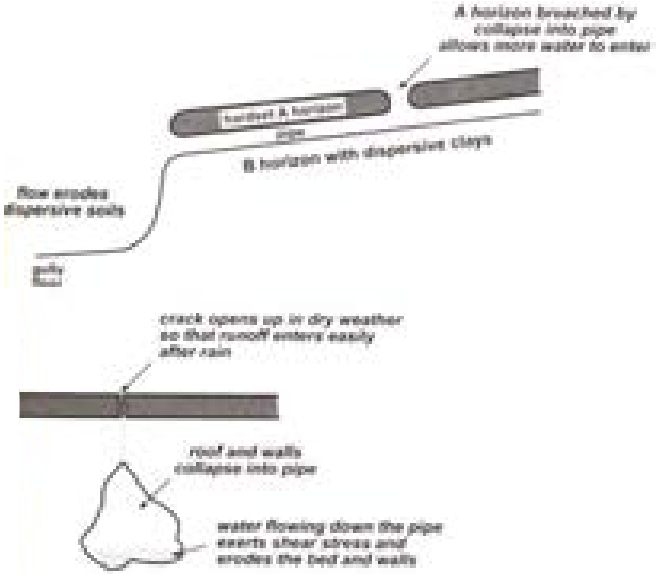
Channel initiation by overland flow has been viewed as a threshold phenomenon related to the size of the contributing area and its slope (Horton, 1945). The relationships between source area and slope have been explored in a number of environments to predict the onset and the stable extent of

gully networks (e.g. Dietrich *et al.*, 1992; Prosser and Abernethy, 1996; Morgan and Mngomezulu, 2003). Once incision occurs, gully heads migrate upslope until some threshold of contributing area and/or slope is met. At this point runoff, capable of further incision, cannot be generated and the gully stabilises in its headward extent. This topographic threshold is also influenced by vegetation. The loss of groundcover and enhanced runoff results in an increase in the erosivity of flows on the valley floor. The effect of this is to reduce the critical area/slope required for gully initiation and stabilisation.

The other dimensions of gully networks are gully width and depth. Gullies often continue to incise down to bedrock or until some stable gradient is achieved from the baselevel of the downstream drainage network (see Schumm *et al.*, 1984). After the gully floor has stabilised the gully walls tend to lay back under the influence of water and gravity until they are reduced to relatively stable slopes (Crouch, 1987). As gully floor elevation and sidewall slopes stabilise, vegetation is able to colonise the surfaces, further damping the effects of erosion processes.

Relating gully morphology to erosion process provides a useful field technique to assess gully stability. The further a gully head from its upstream drainage divide the more potential there is for continued headward extension. Secondary nickpoints in gully floors indicate that some change in baselevel has renewed the incision process and that the gullies will continue to deepen (sometimes to bedrock). Deepening gullies will promote sidewall instability and maintain the walls at steep angles. Lower angles on the sidewalls indicate general gully stability. Overtime, with the establishment of vegetation, the gully will begin to infill and begin the process of landscape recovery.

Much of the gully erosion in southeast Australia, occurred only after valley floor vegetation had been disturbed (Prosser and Slade, 1994). However, other factors, such as the strength and hydraulic properties of valley-floor soils, also influence erosion processes. Many Australian soils have hard-setting A-horizons, and more clayey sodic B-horizons (Young and Young, 2001). The B-horizon often has a lower permeability and water is forced laterally and moves as throughflow downslope. If the clays in the B-horizon are dispersive, fine soil particles can be carried in suspension in the throughflow (Figure 2.1). The transport of clay-sized particles by subsurface water leads to piping, tunnelling and seepage erosion (Young and Young, 2001). While the removal of vegetation has increased runoff rates, the characteristics of the underlying soils can have a strong influence on the potential for gullying to occur.



- **Figure 2.1 - Gullies and seepage flow (from Young and Young, 2001).**

These principles and geomorphic processes, provide an appreciation of the setting in which the processes of erosion and deposition operate within the catchment. The potential to misinterpret the natural instability which can exist in a catchment, as simply being a result of human impact, or to exaggerate the human impact, has been recognised as a consistent problem in geomorphic studies (Dollar, 2000). Recognition of the different factors that have contributed to the development of the erosion problem, and the role that subsurface and overland flow paths have in driving the erosion processes is important as a precursor to recommending appropriate rehabilitation options.

In assessing the stability of the waterways within the catchment, it is important to consider the natural characteristics of the area such as the geology, soil types, topography, and type and extent of vegetation cover.

2.1.5 Flooding

The information on flooding is derived from in field observations of the terrain and provision of flood information obtained from DSE (Department of Natural Resources. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources).

Site observations and the presence of flood level markers provided an indication of where floodwaters from tributaries is likely to cause some dislocation to low level road crossings. Reach specific observations are discussed in detail in the relevant Reach chapters below.

2.2 Management Reaches

To describe the condition, issues and recommended actions in the Wattle Creek catchment, the waterway system has been divided into nine primary reaches. Being such a large catchment, the delineation has been based on geographic units that uses recognisable factors such as stream junctions or roads to define reaches.

As a large proportion of the main stems were observed as exhibiting similar form and condition, it was decided against delineating by geomorphic boundaries, as this would have resulted in significantly less reaches being identified. The tributaries connected to the nine primary reaches have been described as 'sub reaches'.

2.2.1 Reach, sub reach and tributary labelling convention

For the purposes of this report, a naming convention has been applied that identifies the reach, sub-reach and tributary. This has been used to help identify individual waterways within the catchment for the purposes of discussion in the report and identification on the respective reach maps. An example of the convention that has been applied is R1/2/4. This example refers to Reach 1, sub-reach 2, tributary 4 and are notated on the relevant waterways in the individual reach maps.

The location and extent of the nine reaches are shown in Figure 2.2 with the detail of the main stems listed in Table 2-2 below.

- **Table 2-2– Reach delineation of the Wattle Creek catchment**

Reach	Location description	Easting and Northing
Reach 1	Reach 1 - Heifer Station Creek – Greens Creek Junction to the Wimmera River including Greens Creek	D/S - 668882 5909865 U/S - 679000 5904300
Reach 2	Reach 2 - Heifer Station Creek - Tributary Junction at Werenda Lane to Greens Creek Junction	D/S - 672404 5909733 U/S - 676915 5912522
Reach 3	Reach 3 - Heifer Station Creek - Woodlands Road to Werenda Lane	D/S - 676915 5912522 U/S - 681204 5911039
Reach 4	Reach 4 - Wattle Creek, Navarre to Woodlands Road	D/S - 681204 5911039 U/S - 688723 5914018
Reach 5	Reach 5 –Wattle Creek – Bibby's Road at Barkly and Tributaries to Navarre	D/S - 688723 5914018 U/S - 694876 5909899
Reach 6	Reach 6 Wattle Creek – Headwaters and tributaries to Bibby's Road at Barkly	D/S - 694876 5909899 U/S - 698432 5899209
Reach 7	Reach 7 – Howards Creek - Tulkara Railway Road including Friends Creek and tributaries to Heifer Station Creek junction	D/S - 678973 5911346 U/S - 685734 5903501
Reach 8	Reach 8 – Harlows Lane, Landsborough to Howard Creek at Tulkara Railway Road	D/S - 683338 5907616 U/S - 688342 5903660
Reach 9	Reach 9 – Howards Creek - Upstream Headwaters including Tributaries to the Junction of Native Youth Creek, Landsborough	D/S - 688342 5903660 U/S - 694273 5892993

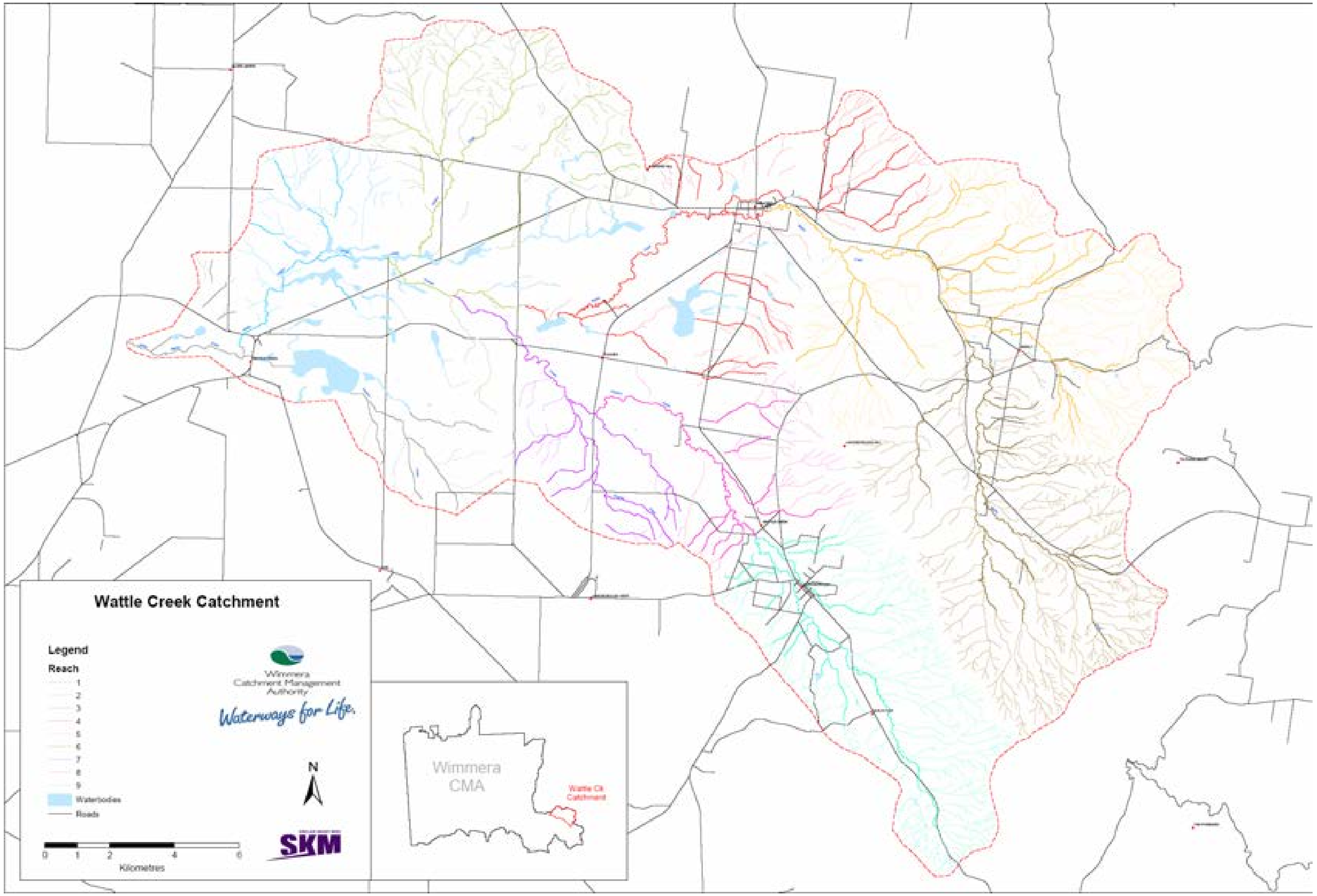


Figure 2.2 – Geographic delineation of the catchment reaches

3. Method for assessing the Catchment

3.1 Information Collection

The following information sources were used to compile the information, which forms the basis of this plan:

- A desktop review of available information and documents;
- A meeting with respective stakeholders was held on 6th April 2005. Stakeholders include (but is not limited to) DSE, DPI, Wotjobaluk Traditional Land Council and the Pyrenees Shire Council;
- A community consultation meeting was held on 6th April 2005. Advertising means included the distribution of an information sheet via a letterbox drop, advertising in the local paper, and the placement of information sheets at various community centres/locations in the catchment;
- The study team undertook an inspection of the catchment over a 5-day period over the period 18-22 April 2005; and
- The study team also undertook an aerial inspection of the catchment on 21 April 2005.

3.2 Risk Assessment and Priority Setting

To help rank the recommendations made as part of this project, a risk assessment approach has been used to determine the priority of the relative importance of actions within the catchments of the Activity Plan.

Priority has been established through an assessment of the condition (based on ISC scoring 1-5), then an assessment as to its Consequence (via a Risk Threat matrix with a score of 1-5) and then an assessment of the urgency or need to intervene quickly or over time with the action (score 1-10). These are multiplied together to get an overall numeric ranking score which determines the priority. This has then been translated into one of a five descriptor that brackets the scores from Urgent, Very High, High, Moderate through to Low according to the following bands:

- **Table 3-1 Priority ranking scores**

Priority	Ranking Score
Urgent	>150
Very High	120-149
High	90-119
Moderate	60-89
Low	30-59

3.3 Reach Activity Spreadsheets (Summary of Issues and Actions)

Activity spreadsheets have been compiled to document important site-specific issues identified in each of the nine reaches, refer to Appendix A through to Appendix I. The spreadsheets offer an overview of the extent of expenditure required to achieve the vision of this Plan in the next five to ten years. The spreadsheets detail the issues, location, recommended actions, cost estimate and assign a priority to each respective issue. The issues for each reach have been grouped into the following activity headings:

- Stream systems and ecology (E)
- Stability (S)
- Water quality (W)
- Vegetation management (V) and
- Flood management (F)

3.3.1 Issue – Naming convention

Issues have been identified using a naming convention that refers to 1) the activity heading, 2) the issue number, and 3) the respective reach. For example E1/1, refers to the first stream systems and ecology issue identified in reach one. Similarly, S6/1 refers to a sixth stability issue identified in reach one. The issue number is used to identify specific issues only and is not related to a priority. Priorities are set in another part of the spreadsheets (refer to Section 3.2above)

3.3.2 Location of issues

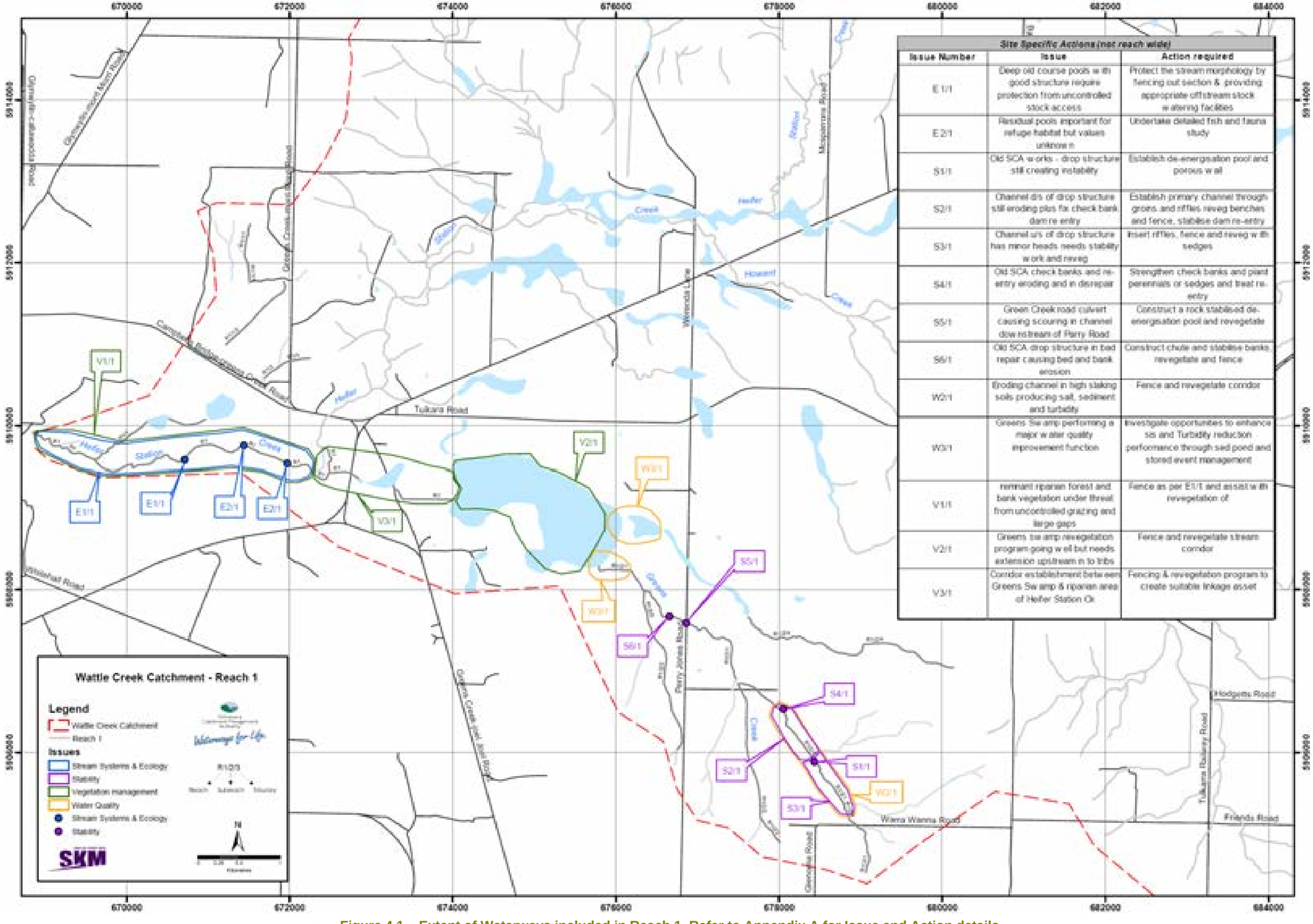
Where possible a GPS location has been provided (Easting and Northing) in the MGA datum (GDA94) to identify site specific locations. Reach maps have also been compiled with an overlying grid to help identify where the respective issues are located. Further, each activity is distinguishable by colour i.e. Stream system and stability issues are represented by a different colour to Vegetation issues.

3.4 Catchment Analysis by Reach

To enable a comprehensive assessment of the catchment to be undertaken, the study area has been divided into nine individual management reaches that covers the entire Wattle Creek catchment.

The following nine sections provide reach specific detail including a plan of the reach, discussion of morphology, vegetation, habitat, water quality and flooding. Key threats and risks are also presented in tables for each reach.

4. Reach 1 - Heifer Station Creek – Greens Creek Junction to the Wimmera River including Greens Creek



Site Specific Actions (not reach wide)		
Issue Number	Issue	Action required
E1/1	Deep old course pools with good structure require protection from uncontrolled stock access	Protect the stream morphology by fencing out section & providing appropriate offstream stock watering facilities
E2/1	Residual pools important for refuge habitat but values unknown	Undertake detailed fish and fauna study
S1/1	Old SCA works - drop structure still creating instability	Establish de-energisation pool and porous wall
S2/1	Channel d/s of drop structure still eroding plus fix check bank dam re entry	Establish primary channel through groins and riffles reveg benches and fence, stabilise dam re-entry
S3/1	Channel u/s of drop structure has minor heads needs stability work and reveg	Insert riffles, fence and reveg with sedges
S4/1	Old SCA check banks and re-entry eroding and in disrepair	Strengthen check banks and plant perennials or sedges and treat re-entry
S5/1	Green Creek road culvert causing scouring in channel downstream of Perry Road	Construct a rock stabilised de-energisation pool and revegetate
S6/1	Old SCA drop structure in bad repair causing bed and bank erosion	Construct chute and stabilise banks revegetate and fence
W2/1	Eroding channel in high slaking soils producing salt, sediment and turbidity	Fence and revegetate corridor
W3/1	Greens Sw amp performing a major water quality improvement function	Investigate opportunities to enhance sis and Turbidity reduction performance through sed pond and stored event management
V1/1	remnant riparian forest and bank vegetation under threat from uncontrolled grazing and large gaps	Fence as per E1/1 and assist with revegetation of
V2/1	Greens Sw amp revegetation program going well but needs extension upstream in to tribs	Fence and revegetate stream corridor
V3/1	Corridor establishment between Greens Sw amp & riparian area of Heifer Station Ck	Fencing & revegetation program to create suitable linkage asset

- **Figure 4.1 – Extent of Waterways included in Reach 1. Refer to Appendix A for Issue and Action details.**

4.1 Reach Location

This reach extends from the Greens Creek junction to the Wimmera River and includes Greens Creek, refer to Figure 4.1 for more detail.

4.2 Morphological description

This portion of the catchment consists mainly of cleared low foothill rises from the Navarre Range and floodplains associated with the old courses of Heifer Station Creek and the Wimmera River. Much of the area is utilised for cropping and sheep grazing, with mostly uncontrolled stock access to the waterway.

Heifer Station Creek is generally 'U' shaped with permanent pools (possibly fed from flows through the deep sand and gravel sequences that occur in the valley floor). However, no flow was observed during field inspections. The bed and banks are basically stable except for areas where excessive stock access has denuded the bank and verge vegetation and is causing erosion of the banks. Bed materials are generally alluvial clay and silt deposits with some sand and gravels. Velocities through the reach will be low due to the flat grades and hence the area is likely to accumulate organic matter. The deep pools are broken up in sequence by silt and sandy benches with organic layers.

The main tributary of Heifer Station Creek in this reach is Greens Creek (that rises from the low hills of Joel Joel). The tributaries of this reach are generally relatively short and fall from low sedimentary hill rises with moderately slaking and dispersive silty clay soils overlaying gravel layers. The northern streams are small and show no significant signs of deep erosion. Seasonal swamp areas are likely to be important mitigation assets for attenuation of catchment borne sediments and contaminants.

The upper segments of this reach have undergone past incision and despite extensive works by the former Soil Conservation Authority (SCA), many of the waterways are in danger of reactivation of erosion. The channel is deeply incised and showing signs of insidious erosion contributing to the poor water quality of the catchment. A number of old SCA structures and works along Greens Creek require repair and/or replacement to stabilise the reach.

4.3 Vegetation

Along the Heifer Station Creek, a narrow and discontinuous strip of riparian vegetation was observed, but still displayed a healthy cover of mature River Red Gums and Buloke interspersed with an understorey that includes Hedge Wattle.

The tributaries all showed very poor vegetation characteristics with only a few remnant River Red Gums existing within the riparian zone. Along with the long drought, stock access to the riparian zone of the tributaries is contributing to loss of vegetation and stream condition decline.

The condition of the seasonally dry wetlands is important for water quality management and habitat and these should be the focus of a detailed mapping and protection program. This would entail identification of all swamp areas and establishment of fencing and vegetation management arrangements to protect the function and integrity of the wetlands. The rehabilitation works undertaken for the seasonal /permanent Greens Swamp needs to be continued and supported.

Little remnant vegetation was apparent within this reach. The vegetation that is present is largely confined to road reserves, which provide the only means for lateral connectivity beyond the riparian environment. Small patches of Sand Heathland are the only remnant vegetation mapped within the reach (DSE, 2005).

As can be seen, the only EVC that remains (DSE 2005) is small patches of Sand Heathland.

Table 4-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 1.

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
6 – Sand Heathland	6 - Sand Heathland	Lower Floodplain
	68 - Creekline Grassy Woodland	Banks of Heifer Station Creek.
	76 - Low Rises Grassy Woodland	Upper areas of tributaries
	132 - Plains Grassland	Floodplain with minor elevation
	175 - Grassy Woodland	Slopes

Key actions required to maintain and restore a healthy vegetation character within the reach revolve around the relief of stock pressure through riparian fencing programs and the establishment of decentralised watering features, as well as strategic revegetation within the established corridor. This would focus around the restoration of a canopy layer (River Red Gum, Buloke).

4.4 Habitat

The habitat complexity of the reach was generally high, particularly in those areas where stock access has been restricted. Contributing attributes include good bank and verge cover and instream large woody debris and macrophytes. However, the overstorey tended to be depleted towards both the lower and upper Campbell's Bridge Road ends where cropping and grazing activities encroached right to the top of the batter and into the stream zone. The presence of a Crown reserve over the lower portions of the reach downstream of the former Greens Creek Primary School site gives rise to opportunities to secure the highest values in the reach.

The permanent pools of the reach are likely to provide important refuges for fish and mammal species. Whilst no site specific data is available for this reach, species such as flat headed gudgeon, mountain galaxias, blackfish, yabbies and freshwater shrimp are known to frequent reaches both upstream and downstream (SKM 2002), and it is therefore likely that they are also present in this

reach. The pools may also provide habitat for species such as Platypus and Water Rat that would readily feed off the abundant yabbies and freshwater shrimp.

The upper end of the main stem of Heifer Station Creek in this reach is fairly degraded with lower complexity and minimal permanent pools apparent at the time of the site inspections. The creek bed was occupied by phragmites, which indicates a saturated summer substrate is likely to exist. The phragmites bands provide important bird habitat in light of the few areas of habitat off the stream corridor.

Unfortunately the habitat condition of most of the ephemeral tributaries is extremely poor with no appreciable significance. Greens Swamp is the exception to this where significant effort is being made to counter high saline levels and reintroduce appropriate vegetation.

4.5 Water Quality

Numerous permanent pools were observed along the main stem of Heifer Station Creek. These were clear at the time of inspection and no sign of algal blooms were evident and the substrate showed little sign of gross aggradation. This suggests that there is little transport of gross or settleable sediment through to the main stem. From this observation, it may be reasonable to deduce that transportable sediments are being attenuated in either foothill fans or swamplands outside of the main stem.

Some finely divided silts were however observed as being present in the sediments. This indicates that very fine silts and colloids are being transported under event conditions.

Areas of high salinity through the reach are identified in Wimmera Regional Salinity Management Plan. The major areas of concern that have been identified in this reach are at Greens Swamp. The higher levels of salinity are likely to occur from a combination of seepage and surcharging from groundwater storages, and the leaching of known sources of salt in the silurian based soils from the upper catchment areas into base and subsurface flows. In upstream reaches, base flows were estimated to have a salt concentration of approximately 5000 uS/m at the time of inspection.

4.6 Flooding

Flood mapping (DSE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources) shows that the whole of the main stem of Heifer Station Creek in Reach 1 will break out beyond the top of bank in a major flood event. Field observations of the terrain indicate that floodwaters from the main stem will inundate adjacent cropping lands, but no infrastructure is likely to be affected.

The Greens Creek crossing of Stawell Avoca Road downstream of Greens Swamp is likely to be subject to broad sheet flooding despite the obvious retarding influence of Greens Swamp. Due to

both the flows in Greens Creek itself and tailwater effects from Heifer Station Creek, flooding of the road is likely to occur for lengthy periods following medium to large events i.e. greater than a 1 in 10 year ARI flood event. The likely area of inundation over the Stawell Avoca Road occurs immediately after a bend in the road and is not marked with any warning signs. For this reason, the location is considered to be potentially unsafe.

Crossings that are likely to be inundated in minor events occur along Greens Creek at Warra Wanna and Perry Jones Road. As these are minor local roads no major dislocation is expected. Further these crossing points are not expected to stay inundated for long periods as downstream conditions will facilitate free flowing outfalls, particularly in minor events.

4.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 1. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix A – Reach 1 Summary of Issues and Actions.

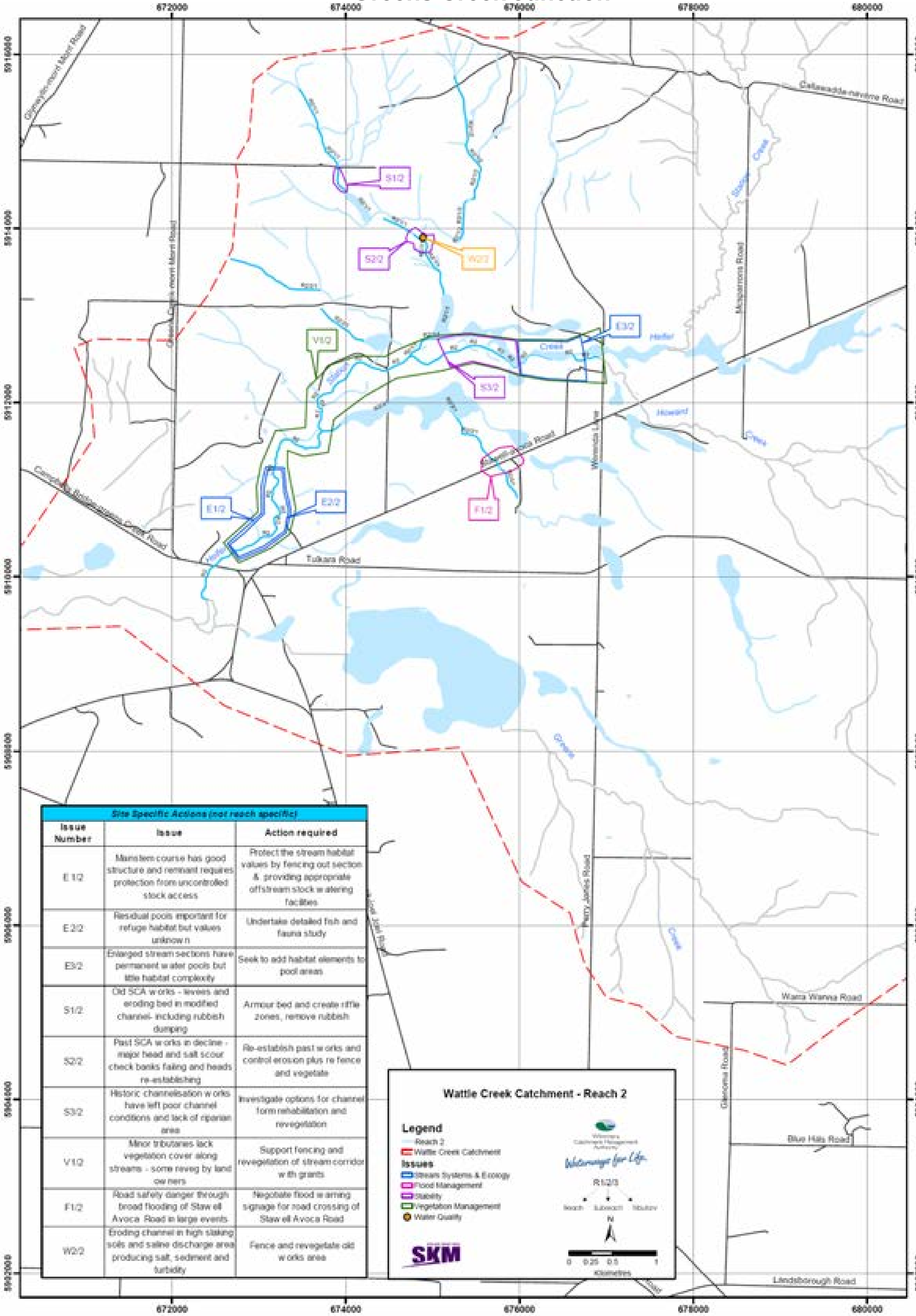
Table 4-2 – Threats and Priorities identified in Reach 1

Threat	Priority
Decline of high value habitat and riparian vegetation along Heifer Station Creek mainstem	Very High
Stock access to stream zones in both Mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline due to lack of maintenance and have potential to fail	Very High
Active erosion in old incised tributary streams with the potential to generate and transport sediment	Very High
Road safety danger at Greens Creek crossing for in major ARI events	High
Loss of key ephemeral swamps to mitigate suspended solids and turbidity	High
No data on significant water quality values to guide best management requirements	High
Nutrient transport from catchment due to land use patterns and loss of mitigation systems	Moderate
Salinity production in denuded catchment leading to saline discharges and higher salinity	Moderate

- **Figure 4.2 – high value pools at the downstream end of Heifer Station Creek in Reach 1.**

Figure 4.3 – Active erosion in Reach 1

5. Reach 2 - Heifer Station Creek - Tributary Junction at Werenda Lane to Greens Creek Junction



Site Specific Actions (not reach specific)		
Issue Number	Issue	Action required
E1/2	Mainstem course has good structure and remnant requires protection from uncontrolled stock access	Protect the stream habitat values by fencing out section & providing appropriate offstream stock watering facilities
E2/2	Residual pools important for refuge habitat but values unknown	Undertake detailed fish and fauna study
E3/2	Enlarged stream sections have permanent water pools but little habitat complexity	Seek to add habitat elements to pool areas
S1/2	Old SCA works - levees and eroding bed in modified channel- including rubbish dumping	Armour bed and create riffle zones, remove rubbish
S2/2	Past SCA works in decline - major head and salt scour check banks failing and heads re-establishing	Re-establish past works and control erosion plus re fence and vegetate
S3/2	Historic channelisation works have left poor channel conditions and lack of riparian area	Investigate options for channel form rehabilitation and revegetation
V1/2	Minor tributaries lack vegetation cover along streams - some reveg by land owners	Support fencing and revegetation of stream corridor with grants
F1/2	Road safety danger through broad flooding of Stawell Avoca Road in large events	Negotiate flood warning signage for road crossing of Stawell Avoca Road
W2/2	Eroding channel in high slaking soils and saline discharge area producing salt, sediment and turbidity	Fence and revegetate old works area

- **Figure 5.1 - Extent of Waterways included in Reach 2. Refer to Appendix B for Issue and Action details.**

5.1 Reach Location

This reach extends from Tributary Junction at Werenda Lane to Greens Creek Junction, refer to Figure 5.1 for more detail.

Much of the area in this reach is utilised for cropping and sheep grazing, with mostly uncontrolled stock access to the waterway. A crown reserve exists over the lower half of the main stem, but no crown reserve is evident along upper main stem towards Werenda Lane.

5.2 Morphological Description

This reach reflects the different nature of the catchment, as it is situated in the transition from the deep pooled segment of Reach 1 to the broad alluvial floodplain. Again the tributaries rise from the cleared low foothill rises from the Navarre Range to the floodplains associated with the old courses of Heifer Station Creek. The topography in this reach is very flat, with expansive floodplain areas. It appears that the upper sections of Heifer Station Creek have been channelised. Compared to the narrow shallow sections of Reach 1 (downstream), the main stem in this reach is quite wide with many pools. This channelised section appears to run for nearly 3.0 km back towards Werenda Lane. Bed materials observed were generally alluvial clay and silt deposits combined with some sand and gravel. Velocities through this reach are likely to be very low due to the flat grades.

At the time of inspection, a small flow was evident at the upper ford on Werenda Lane in Heifer Station Creek indicating that subsurface flows pass through the gravel seams near this location.

The bed and banks appear to be relatively stable along the main stem through this reach, most likely a consequence of the flat grade of the waterway and surrounding topography. Exceptions to this are where excessive stock access has resulted in erosion and denuding of the scant banks and verge vegetation.

The tributaries of this reach are relatively short and fall from the low sedimentary rises. The soil profile consists of slaking and dispersive silty clay soils overlaying gravel layers. The northern streams are small and show significant signs of active deep erosion and salinisation. The tributary R2/1/1 has had extensive SCA works done in the past to arrest headward erosion and incision. The installation of diversion banks and overland flow paths is also quite extensive in this region and has proven to be quite successful. The integrity of many of these structures is declining due to a lack of maintenance. In some instances, breaches in diversion banks were observed (Figure 5.2). Ageing structures combined with a poor vegetative cover increases the potential for erosion processes to be reinitiated. Further, the area is highly vulnerable to episodic flood events.

Evidence of rubbish dumping in areas where bank and bed erosion has occurred in upstream tributaries in this reach was observed (Figure 5.3).

5.3 Vegetation

The vegetation along the main stem of Heifer Station Creek was generally present as a narrow and discontinuous riparian zone, lacking significant overstorey. Groundcover consisted of a few saline tolerant species**.**

The tributaries all showed very poor vegetation characteristics with only a few remnant River Red Gums remaining along the stream lines. Along with the long drought, open access to the stream lines of the tributaries for grazing is contributing to loss of vegetation and stream condition decline. Some owner intervention of riparian revegetation was evident on some of the minor sub tributaries, which is to be supported.

The condition of the ephemeral wetlands is important for water quality management and habitat and these should be the focus of a detailed mapping and protection program. This would entail identification of all swamp areas and establishment of fencing and vegetation management arrangements to protect the function and integrity of the wetlands.

Small patches of Sand Heathland (EVC 6) have been recorded within Reach 2 (DSE, 2005), which is the only remnant vegetation mapped within the reach.

The deep pools were observed to be very clear and were surrounded by saline tolerant species indicating that salinity levels are likely to be high. No appreciable overstorey or midstorey vegetation left in this reach.

Table 5-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 2

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
6 – Sand Heathland	6 – Sand Heathland	Lower Floodplain
	61 – Box Ironbark Forest	Upper Slopes
	60 – Creekline Sedgy Woodland	Lower banks of main tributary
	68 – Creekline Grassy Woodland	Banks of main channel.
	175 – Grassy Woodland	Slopes

5.4 Habitat

The habitat of the main stem is very poor due to the loss of the riparian forest and modification to the stream channel. The main pool has little to offer as habitat as they are cleared pools with little complexity. The presence of a Crown Reserve over the lower portions of the reach gives rise to opportunities to secure the some higher values through revegetation and fencing. Again there will be a need to address stock watering access.

The permanent pools of the upper portion of the main stem reach could form an important refuge for fish and other species if they were rehabilitated. Based on the data previously referred to (SKM 2002), it may be possible to establish a habitat capable of supporting a range of fish and mammal species. The portion near Werenda Lane has some remnant River Red Gums that could provide a focus point to work from.

As with Reach 1, the habitat condition of most of the ephemeral tributaries is extremely poor with no appreciable significance.

5.5 Water Quality

The water in the pools were clear at the time of inspection with no sign of algal blooms and the substrate showing little sign of gross aggradation. Again this reinforces that there is little transport of gross or settleable sediment through to the main stems, this being attenuated in either foothill fans or a series of ephemeral swamps across the catchment. However the presence of finely divided silts in the sediments indicates that very fine silts and colloids will be transported under event conditions along with elevated nutrients from catchment sources. The higher salinity regime can be expected given the leachable country and known sources of salt in the Silurian based soils of the upper catchment areas. Base flows upstream were noted to be about 5000 uS/m at an upstream location.

5.6 Flooding

Mainstem flooding is to be expected along the whole of the Reach 2 but appears to only affect adjacent cropping lands. The information on flooding is derived from in field observations of the terrain and provision of flood information from DSE (DSE. *Flood Data Transfer Project,* www.dse.vic.gov.au/Interactive maps/Victorian Water Resources).

Flooding is broad scale in Reach 2 and affects a significant length of the Stawell Avoca Road west of the Heifer Station Creek Crossing as the flood waters break across the broad floodplain west of Werenda Lane and Stawell.

The main Avoca Stawell Road may stay inundated for lengthy periods following an event greater than 1 in 10 year event due to Heifer Station Creek flooding break out via series of flood distributaries on the south side of the mainstem.

This area of the Stawell Avoca Road is not marked with any warning signs and is hence potentially unsafe.

5.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 2. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix B – Reach 2 Summary of Issues and Actions.

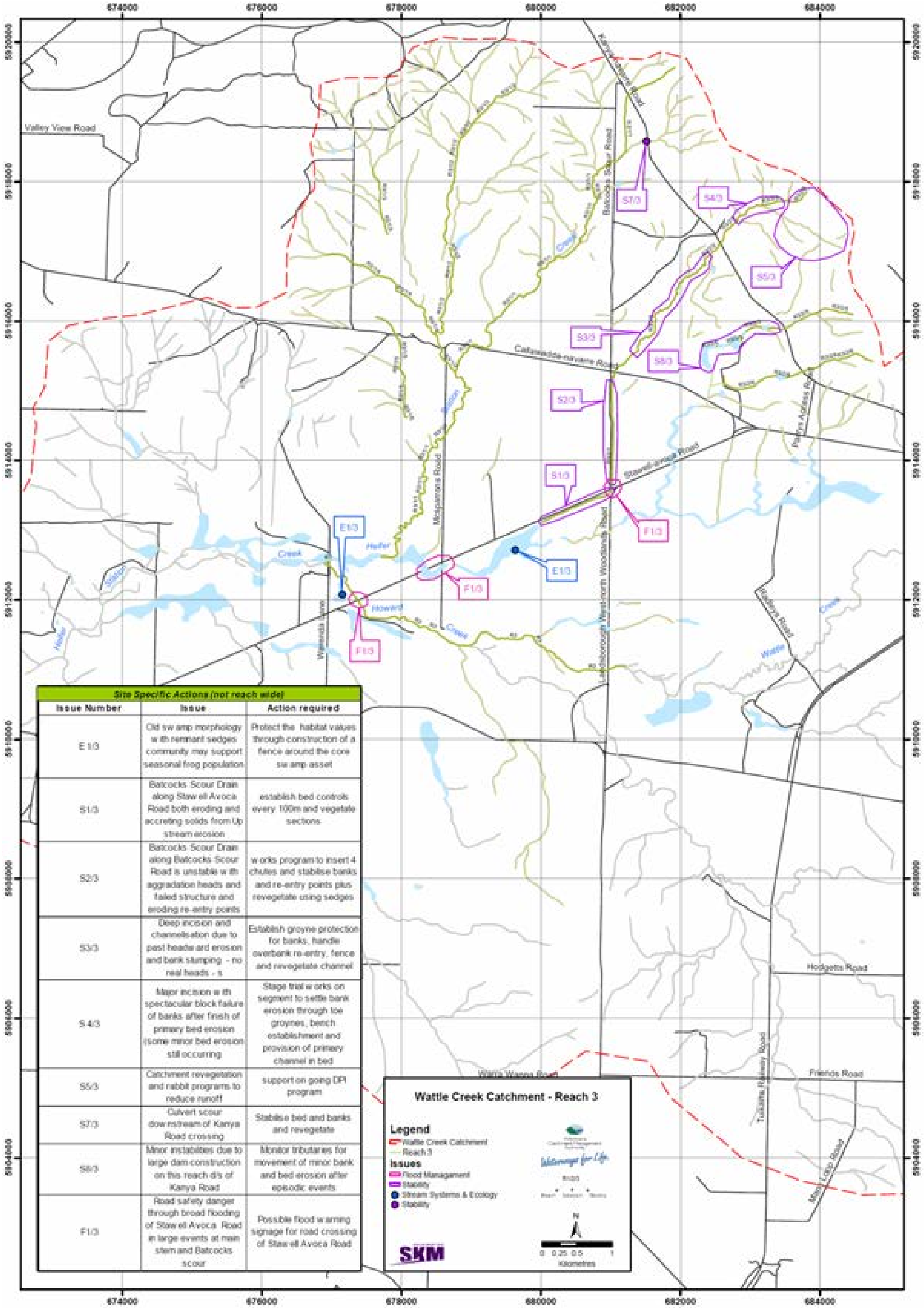
- **Table 5-2 – Threats and Priorities identified in Reach 2**

Threat	Priority
Loss of habitat and riparian vegetation along Heifer Station Creek mainstem	Very High
Stock access to stream zones in both mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline on tributary due to no maintenance and has the potential to fail.	Very High
Small amounts of active erosion in upper tributary streams with the potential to generate and transport sediment	Very High
Road safety of Stawell Avoca Road under flood conditions	High
Loss of key ephemeral swamps and floodplains to mitigate suspended solids and turbidity	High
Nutrient transport from catchment due to land use and loss of mitigation systems	Moderate
Salinity production in denuded catchment leading to saline discharge areas and higher salinity	Moderate
Rubbish dumping in eroding Waterways	Moderate

- **Figure 5.2 – Breached levee bank (old SCA works)**

Figure 5.3 – Rubbish dumping in eroded tributary

6. Reach 3 - Heifer Station Creek - Woodlands Road to Werenda Lane



Site Specific Actions (not reach wide)		
Issue Number	Issue	Action required
E1/3	Old sw amp morphology w ith remnant sedges community may support seasonal frog population	Protect the habitat values through construction of a fence around the core sw amp asset
S1/3	Batcocks Scour Drain along Staw ell Avoca Road both eroding and accreting solids from Up stream erosion	establish bed controls every 100m and vegetate sections
S2/3	Batcocks Scour Drain along Batcocks Scour Road is unstable w ith aggradation heads and failed structure and eroding re-entry points	w orks program to insert 4 chutes and stabilise banks and re-entry points plus revegetate using sedges
S3/3	Deep incision and channelisation due to past headw ard erosion and bank slumping - no real heads - s	Establish groyne protection for banks, handle overbank re-entry, fence and revegetate channel
S 4/3	Major incision w ith spectacular block failure of banks after finish of primary bed erosion (some minor bed erosion still occurring	Stage trial w orks on segment to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed
S5/3	Catchment revegetation and rabbit programs to reduce runoff	support on going DPI program
S7/3	Culvert scour dow nstream of Kanya Road crossing	Stabilise bed and banks and revegetate
S6/3	Minor instabilities due to large dam construction on this reach d/s of Kanya Road	Monitor tributaries for movement of minor bank and bed erosion after episodic events
F1/3	Road safety danger through broad flooding of Staw ell Avoca Road in large events at main stem and Batcocks scour	Possible flood w arning signage for road crossing of Staw ell Avoca Road

- **Figure 6.1– Extent of Waterways included in Reach 3.Refer to Appendix C for Issue and Action details.**

6.1 Reach Location

This reach includes that of the mainstem of Heifer Station Creek from Woodlands Rd to Werenda Lane and also the tributary of Morl Morl Creek (sometimes locally known as Smiths Creek) and Batcocks Scour (refer to Figure 6.1 for more detail).

6.2 Morphological Description

The main stream channel exists in a broad floodplain used for cropping and sheep grazing. Mapping indicates that a Crown Reserve exists over the whole of the mainstream reach, but no Crown Reserve is evident along any of the tributary streams.

This reach is well defined and appears to be located in its original alignment. Key features are that the mainstem waterway has a relatively shallow form with a chain of pools located within a broad flat alluvial floodplain. Again the tributaries rise from the cleared low foothill rises from the Navarre Range to the floodplains. No channelisation has occurred and the old channel is stable and surrounded by a narrow line of mature River Red Gums. There is no appreciable midstorey vegetation left in this area due to the grazing by stock.

The mainstem is generally a shallow 'U' shaped with laid-back upper banks. The reach is composed of semi-permanent pools that were connected by a small salty flow at the time of our inspection. Indeed, the residual deep pools are very clear indicating a higher salinity. The bed and banks appear basically stable due to the flat grade except for areas where excessive stock access is eroding the banks and denuding the scant bank and verge vegetation. Bed materials are generally alluvial clay and silt deposits with some sand and gravel deposits.

The tributaries of this reach are extensive. Morl Morl Creek is a small channel within a broad gently sloping valley floor. Its condition is basically stable due to a significant investment by the SCA and landowners in remediation works and, from appearances, reasonably good maintenance to retain the works. Only some minor channel bank erosion is evident on some of the upper foothill tributaries.

Batcocks Scour is an example of a catchment diversion undertaken many years ago with the current generation still trying to arrest the problems caused by the disturbances and erosion arising. What is apparent is that the upper section of this tributary (R3/2/2) was diverted from its natural course to run parallel to Batcocks Scour Road. This created a shorter and steeper waterway, which triggered headward erosion in the upstream segments. Today, the diversion is still eroding and transporting large quantifies of sediment into the drains on the south side of the Stawell Avoca Road, which eventually discharges into an ephemeral swamp where the fines tend to settle out. This system is still unstable and is in need of major works right back into the foothills where the erosion is now five metres deep. Whilst it is apparent that the headward erosion is essentially finished the lateral

movement of flows in the deeply incised channel is resulting in severe bank erosion by undercutting and subsequent cantilever failure of the overhang.

The incision problems have been exacerbated by the loss of deep rooted perennial grasses and trees, giving rise to increased surface runoff. A DPI rehabilitation project using deep ripping, seeding and tree planting on the boney slopes has partially succeeded in lowering runoff. Much work needs to be done over a period of time to reduce the overall impact of this area. Similar problems exist in the adjacent tributary to the east where a series of large checkbank dams have been installed. Channel erosion is still occurring upstream of these dams. All the upper foothill streams are vulnerable to the impacts of episodic erosion.

6.3 Vegetation

The vegetation along the main stem of Heifer Station Creek is continuous but narrow, without any significant understorey. Groundcover consists of a few sedges and native grasses, with the majority of components having been trampled out.

Except for Morl Morl Creek, which has had some revegetation programs, the tributaries all showed very poor vegetation characteristics with only a few remnant River Red Gums existing along the stream lines. Along with the long drought, open access to the stream lines of the tributaries for grazing is contributing to loss of vegetation and stream condition decline. Some CMA and landowner intervention of riparian revegetation was evident on some of the minor sub tributaries. These works should be supported and extended.

The condition of the ephemeral wetlands is important for water quality management and habitat value and these should be the focus of a detailed mapping and protection program. In particular the swamp at the end of Batcocks Scour is critical to the retention of erosion products in the catchment.

Little remnant vegetation remains in the catchment. The following table details the remnant vegetation that is currently mapped within the catchment (DSE, 2005a & b) and that which is thought to have occurred within the catchment prior to European Settlement (DSE, 2003).

- **Table 6-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 3**

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
6 – Sand Heathland	6 – Sand Heathland	Lower Floodplain
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper Slopes
70 – Hill Crest Herb-rich Woodland	70 – Hill Crest Herb-rich Woodland	Upper Slopes and Crests
76 – Low Rises Grassy Woodland	76 – Low Rises Grassy Woodland	Lower slopes on alluvium
	60 – Creekline Sedgy Woodland	Lower banks of main tributary
	68 – Creekline Grassy Woodland	Banks of main channel.
	175 – Grassy Woodland	Slopes

Although the majority of EVC's previously found within the reach are still present (excluding riparian associations) their distribution is patchy and their abundance minimal. Those remaining should be secured where possible with fencing programs and revegetation undertaken to secure their presence. The riparian landscape requires suitable stock control and revegetation to retain some natural character within these areas.

6.4 Habitat

The habitat of the mainstem is relatively poor due to the loss of a wide riparian forest and access of stock to the stream channel. Some of the deeper pools along the mainstem show some habitat complexity but a program of riparian fencing, revegetation and targeted habitat insertion would greatly lift the overall value of the segment. An area of remnant Red Gum Swamp exists immediately upstream of Werenda Lane and the Stawell Avoca Road. The presence of a Crown reserve over the lower portions of the mainstem reach gives rise to opportunities to secure the some higher values. Again there will be a need to address stock watering access.

The more permanent pools of the upper portion of the main stem reach could form an important refuge for fish and other species if they were rehabilitated. Based on the data previously referred to (SKM 2002), it may be possible to establish a habitat capable of supporting a range of fish and mammal species.

As with previous reaches, the habitat condition of most of the ephemeral tributaries is extremely poor with no appreciable significance.

6.5 Water Quality

The water quality of the mainstem pools was observed to be brackish to sub saline and showed no sign of algal blooms. The substrate showed little sign of gross aggradation but the chain of pools is broken up by sediment banks. The lack of appreciable and noticeable sediment in the lower

mainstem segments, reinforces that there is little transport of gross or settleable sediment through to the mainstem, this being attenuated in either foothill fans or a series of ephemeral swamps across the catchment. However the presence of finely divided silts in the sediments indicates that very fine silts and colloids will be transported under event conditions along with elevated nutrients from catchment sources. In the case of Batcocks Scour the transport of significant erosion product loads needs to be tackled with a long term stabilisation and revegetation program. The higher salinity regime can be expected given the leachable country and known sources of salt in the Silurian based soils of the upper catchment areas. Base flows upstream were estimated to be about 5000 uS/m.

Another issue to do with water quality is that of high suspended solids and turbidity loads arising from runoff from gravel roads under rainfall conditions. Roads can contribute substantially to the over all suspended solids problem of a catchment along with the erosion of roadside drains.

6.6 Flooding

Mainstem flooding is to be expected along the whole of the Reach 3 particularly downstream of the Howard Creek junction. There is no mapping of the floodplain in this area. An analysis of the risk should be undertaken in the future.

Flooding along Batcocks Scour Road is also likely as is also the lower segments of Morl Morl Creek. Again no mapping is available to predict any impacts. However it is likely that the Stawell Avoca Road will be seriously impacted at the Heifer Station Creek Crossing as is the Batcocks Scour crossing.

The main Avoca Stawell Road may stay inundated for lengthy periods during large ARI flow events due to Heifer Station Creek flooding break out via a series of flood distributaries on both sides of the mainstem. This area of the Stawell Avoca Road is not marked with any warning signs and is hence potentially unsafe.

6.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 3. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix C – Reach 3 Summary of Issues and Actions.

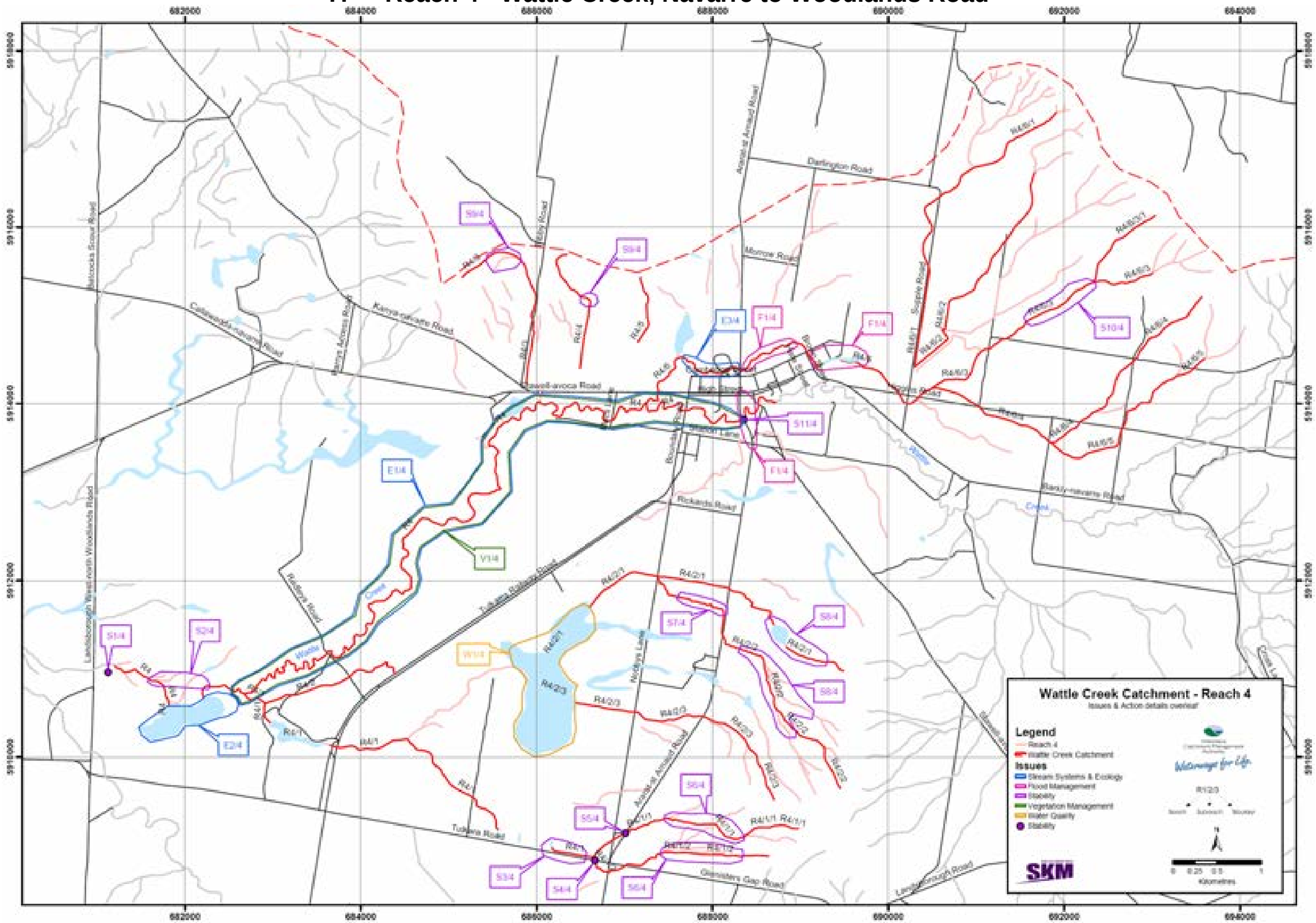
- **Table 6-2 – Threats and Priorities identified in Reach 3**

Threat	Priority
Further loss of habitat and riparian vegetation along Heifer Station Creek mainstem	Very High
Stock access to stream zones in both mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline on upper Batcocks Scour tributary due to no maintenance which is leading to the production of significant loads of sediment downstream	Very High
Significant amounts of active erosion in upper tributary streams with the potential to generate and transport sediment	Very High
Loss of key ephemeral swamps and floodplains to mitigate suspended solids and turbidity	Very High
Road safety of Stawell Avoca Road under flood conditions at both Batcocks Scour and Heifer Station Creek crossings	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Nutrient transport from catchment due to land use and loss of mitigation systems	Moderate
Salinity production in denuded catchment leading to saline discharge areas and higher salinity	Moderate
Rabbit infestations in upper catchments reducing ground cover on drier hills	Moderate

- **Figure 6.2 – Active Bank Erosion**

Figure 6.3 – Oversized Channel

7. Reach 4 - Wattle Creek, Navarre to Woodlands Road



- **Figure 7.1– Extent of Waterways included in Reach 4. Refer to Appendix D for Issues and Actions details.**

Table 7-1 Reach 4 Issues and Actions Details

Site Specific Actions (not reach wide)		
Issue Number	**Issue**	**Action required**
S3/4	Channel scour and heads due to high flow energy in area subject to significant historic aggradation arising from upstream erosion	Stabilise heads and re-establish flood distributary system in consultation with landowner
S4/4	Culvert Scour d/s of Tulkara Road	Stabilise scour hole and de-energise with a chute
S5/4	Deep incision and channelisation due to past headward erosion and bank slumping leading to destabilisation of Ararat St Arnaud road	Establish de-energisation pool, chutes, groyne protection for banks, handle overbank re-entry, fence and revegetate channel
S 6/4	Major incision with spectacular block failure of banks after finish of primary bed erosion (some minor bed erosion still occurring) and further disturbance by a developer on four tributaries	Stabilise headward erosion in all 4 tributaries - Stage trial works on segment to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed
S7/4	Deep incision of channelised drain with old SCA drop structure at Ararat StArnaud Road.	Establish de-energisation pool, chutes, groyne protection for banks, handle overbank re-entry, fence and revegetate channel
S8/4	Deep incision of channelised drain through property into multiple gullies in foothills.	Establish chutes, groyne protection for banks, handle overbank re-entries, fence and revegetate channels
S9/4	Minor instabilities in foothill tributary channels from Navarre Hill - some past SCA works	Monitor minor foothill tributaries for movement of minor bank and bed erosion after episodic events
S10/4	Minor instabilities in stabilised channels of plain area and foothill tributary channels from Pyrenees of Blind Creek catchment - some past DPI/SCA works	Monitor minor foothill tributaries for movement of minor bank and bed erosion after episodic events. Revegetate the stabilised works areas
S11/4	Old weir d/s of Escor St Navarre in disrepair	Investigate purpose of weir and either remove or refurbish if weir has a significant role
E1/4	Mainstem vegetation and numerous waterholes along mainstem with aged RRG and pool habitats need stronger protection	Negotiate stock access control and fencing with adjoining landowners and revegetate, with a view to providing appropriate offstream stock watering facilities.
E 2/4	Old swamp morphology with remnant sedges and Buloke community may support seasonal frog population and be floristically significant	Protect the habitat values through construction of a fence around the core swamp asset in cooperation with the landowner
E3/4	Old course s of Blind Creek through reserve have good vegetation and old wetland morphology	Protect in an work and seek cooperative effort with Reserve management to rehabilitate
V1/4	Thin , discontinuous, remnant riparian forest and bank vegetation along mainstem under threat from uncontrolled grazing and large gaps breaking wildlife and riparian corridor	Provide for controlled stock access, fence and assist with revegetation of corridor
W1/4	High suspended solids and turbidity in Tributaries being attenuated by old swamp and could be improved	Investigate opportunities to improve wq treatment performance of swamp through insertion of wall and orifices
F1/4	Road safety danger through broad flooding of Stawell Avoca Road and Navarre from Blind Creek in large events	Negotiate flood warning signage for road crossing of Stawell Avoca Road and review flood management options for Navarre township
S1/4	Bank laybacks and disturbances upstream of Woodlands Road	Establish bank controls and revegetate
S2/4	Excavated meander cut created to drain area under flood is badly scoured and eroding in both bed and banks	Insert flow chokes, grade controls and stabilise banks and re-entry points plus revegetate using sedges.

7.1 Reach Location

This reach includes the mainstem of Wattle Creek upstream of Woodlands Road and also the many tributaries to the north to Navarre Hill, north east of Navarre and east on to the northern end of the Landsborough Hill Range (refer to Figure 7.1 for more detail).

7.2 Morphological Description

The main stream of this reach has a has a well established channel form that sits slightly perched in a broad floodplain used for cropping and sheep grazing. The stream is ephemeral although large pools may remain for extended periods. It is interesting to note that although the pools near Radleys Road were dry there was a small flow at Woodlands Road. No significant Crown Reserves exist over much of the mainstream reach, except for a small area near Navarre and an old stock watering reserve immediately upstream of Woodlands Road. There are no Crown Reserves on any of the tributaries either north or south of the mainstem.

The mainstem channel is a relatively large stable channel with very old River Red Gums lining the banks. It has a deep 'U' section with alluvial deposits that separate numerous well defined pools. The pools have a strong organic layer overlying old silt sand and gravel layers. The plan form of the stream is far more sinuous than that of the downstream segments indicating a relatively flat grade. The mainstem appears to have had a bypass channel (meander cut) diversion at the western end of the Woodlands Property, that has drained a large Buloke swamp meander. The bypass is approximately 1.0 km long and alienates approximately 2.5 km of waterway. The bypass is still eroding and will need bed stabilisation works to prevent further incision in upstream reaches and along the bypass. A significant concrete and sheet pile weir immediately downstream of the Escor Street has failed and is not ponding water, as intended. It is likely that flows are passing underneath this structure in the deep sands and gravel seams. A small residual pool was evident downstream in an otherwise dry channel.

The tributaries rise on the cleared low foothill rises from the Navarre Range to the north-northeast and the foothill extension of the Landsborough Hill range to the east. The northern segments of the foothill streams off Navarre Hill have had been straightened historically and been subject to past stabilisation activities. These still have apparent minor and insidious erosion that needs to be monitored. Some of the upper ends on the hillslope are still eroding and are unstable.

The streams to the east which drain to the mainstem via a series of large ephemeral wetlands have a very poor condition with deeply eroded beds and banks arising from past channelisation and diversion activities. There is evidence of past SCA intervention on some of these with large drop structures and check banks to divert the flows. Unfortunately these streams are still actively eroding and transporting sediment to the wetland areas. In particular the tributaries R4/1/1, R4/1/2 and R4/1/1 in the foothills east of the Ararat-St. Arnard Rd are particularly deep and have active rill, undercutting, tunnelling and block failure at depths of up to 4m. The two outlet streams of R4/1 have had past intervention but this appears to have only exacerbated the erosion, resulting in

sediment filling the valley line above the fences further downstream towards Tulkara Road. Further, some of the road crossings are in threat of being undermined. Whilst these are significant sediment sources, the bulk of the eroded material is stored locally in dams and swamps and does not appear to reach the main stem.

The incision problems have been exacerbated by the loss of deep rooted perennial grasses and trees, giving rise to increased surface runoff from the foothill ranges. Much work needs to be done to reduce the overall impact of these issues.

The streams and catchments to the east of Navarre on the (locally termed) Blind Creek system (R4/6) have had a lot of remedial works undertaken through SCA, DPI and CMA programs. Most of these streams seem relatively stable but there needs to be a follow up program of revegetation and stock control. The very upper reaches of these streams are displaying minor erosion as in the case of the Navarre Hill tributaries and should be monitored for significant changes.

All the upper foothill streams are open to the impacts of episodic erosion under high intensity events.

7.3 Vegetation

The vegetation along the main stem of Wattle Creek is continuous but narrow in places except where the remnant Buloke Swamp exists on the alienated course of the Woodlands property. Stock access seems to be basically uncontrolled except by the steep banks along the deeper sections. There is no appreciable recruitment to the overstorey or midstorey vegetation left in this area due to the grazing by stock. Groundcover consisted of a few sedges and native grasses.

The tributaries are essentially without overstorey and or midstorey vegetation.

Table 7-2 lists a reasonably diverse assemblage of remnant vegetation mapped in Reach 4. Little remnant vegetation remains in the reach, although, within the small patches of remaining vegetation that do remain, good diversity is evident.

- **Table 7-2 - Current and Pre-European Vegetation Attributes (EVC) Reach 4**

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
6 – Sand Heathland	6 – Sand Heathland	Lower Floodplain
20 – Heathy Dry Forest	20 – Heathy Dry Forest	Upper slopes, skeletal soils
22 – Grassy Dry Forest	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper Slopes
70 – Hill Crest Herb-rich Woodland	70 – Hill Crest Herb-rich Woodland	Upper Slopes and Crests
76 – Low Rises Grassy Woodland	76 – Low Rises Grassy Woodland	Mid slopes
	67 – Alluvial Terrace Herb-rich Woodland	Alluvial terraces
	70 – Hill Crest Herb-rich Woodland	Upper slopes with skeletal soils
175 – Grassy Woodland	175 - Grassy Woodland	Slopes

The conservation and revegetation of the Buloke Swamp area should be considered a major objective in relation to vegetation management within the catchment. Although the majority of EVC's previously found within the reach are still present (excluding riparian associations) their distribution is patchy and their abundance minimal. Those remaining should be secured where possible with fencing programs and revegetation undertaken to secure their presence. The riparian landscape requires suitable stock control and revegetation to retain some natural character to these areas.

7.4 Habitat

The habitat of the main stem is relatively good with some remnant pools providing for a range of native and introduced fish species. In particular Flat Headed Gudgeon, Mountain Galaxias and Blackfish frequent the pools at the lower end of the reach. These more permanent pools could be enhanced as high value refuges for fish and other species if they were rehabilitated. Based on the data previously referred to (SKM 2002), it may be possible to establish a habitat capable of supporting a wider range of fish and mammal species.

As with previous reaches, the habitat condition of most of the ephemeral tributaries is extremely poor with no appreciable significance.

7.5 Water Quality

The water quality of the mainstem pools is brackish to sub saline and shows no sign of algal blooms. The substrate shows little sign of gross aggradation, but the chain of pools is broken up by sediment banks indicating historic mass sediment movement and or episodic scouring to form the deeper pools. The lack of appreciable and noticeable sediment in the lower mainstem segments,

reinforces that there is currently little transport of gross or settleable sediment through to the mainstem reach, this being attenuated in either foothill fans or a series of ephemeral swamps across the catchment. However the presence of finely divided silts in the sediments indicates that very fine silts and colloids will be transported under event conditions along with elevated nutrients from catchment sources. A separate study into the importance of the attenuation capability of these swamps and wetlands is required to evaluate there ability to sustain and improve the sedimentation retention function.

The higher salinity regime can be expected given the leachable country and known sources of salt in the Silurian based soils of the upper catchment areas. As well as the small base flows noted at the downstream end with an estimated salinity of 5000- 6000 uS/cm, it is likely that there are deeper gravel and sand leads that transport flows and or provide springs along the mainstem. This would explain why some of the waterholes have water and others not in extended dry periods.

Along with the abundance of suspended solids and turbidity from eroding tributaries another source of these contaminants is likely to be from rural roads under rainfall conditions. Roads can contribute substantially to the overall suspended solids export from a catchment along with the erosion of roadside drains. In particular the Tulkara Road would contribute greatly to the solids load.

7.6 Flooding

Mainstem flooding is to be expected along the whole of the Reach 4 and particularly east of Tulkara Road and along Blind Creek at Navarre. There is incomplete mapping of the floodplain in the area downstream of Navarre and a flood study should be undertaken to establish the extent and the assets at risk.

Whilst no mapping exists of flooding for the eastern tributaries and mainstem, it is expected to be extensive given the flat terrain and perched nature of the mainstem. Broad sheet flows and the formation of large ephemeral wetlands are particularly likely in the Tulkara Railway Road area.

The flooding of Navarre is also recorded due to the large catchment of north and east of the town. Town planning maps and DSE maps (DSE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources) show extensive flooding from this system. It is interesting to note the floodwall at the eastern end of the town on Blind Creek, presumably to stop break out across the Barkly Road towards Wattle Creek and also along the main street. It is likely that many houses in Navarre are flooded, as floor levels seem close to the ground throughout the town.

This flood management system should be reviewed for its performance, as it appears that the levee may only transfer the problem to elsewhere in the town.

It is also apparent that both the Stawell-Avoca and Ararat-St Arnaud Roads will become impassable and may stay inundated for lengthy periods following large ARI rainfall events due to Wattle Creek flooding and breaking out via series of flood distributaries on both sides of the mainstem.

These areas are not well marked with any warning signs indicating the potential for flooding and are therefore considered to be potentially unsafe.

7.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 4. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix D – Reach 4 Summary of Issues and Actions.

- **Table 7-3 – Threats and Priorities identified in Reach 4**

Threat	Priority
Further loss of habitat and riparian vegetation along Wattle Creek mainstem	Very High
Stock access to stream zones in both mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline on tributaries to the east (R4/1 system) due to no maintenance and is producing significant loads of sediment downstream.	Very High
Significant amounts of active bed and bank erosion in the eastern tributary streams with the potential to generate and transport large loads of sediment	Very High
Loss or decline in performance of key ephemeral swamps and floodplains to mitigate suspended solids and turbidity arising from the tributaries	Very High
Road safety of Stawell Avoca, Ararat St Arnaud Roads and Tulkara and Tulkara Railway Roads under flood conditions at creek and floodplain crossings	High
Flooding in Navarre likely to involve private assets and flood mitigation strategies need to be reviewed	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products.	High
Nutrient transport from catchment due to land use and loss of mitigation systems	Moderate
Salinity production in denuded catchment leading to saline discharge areas and higher salinity	Moderate

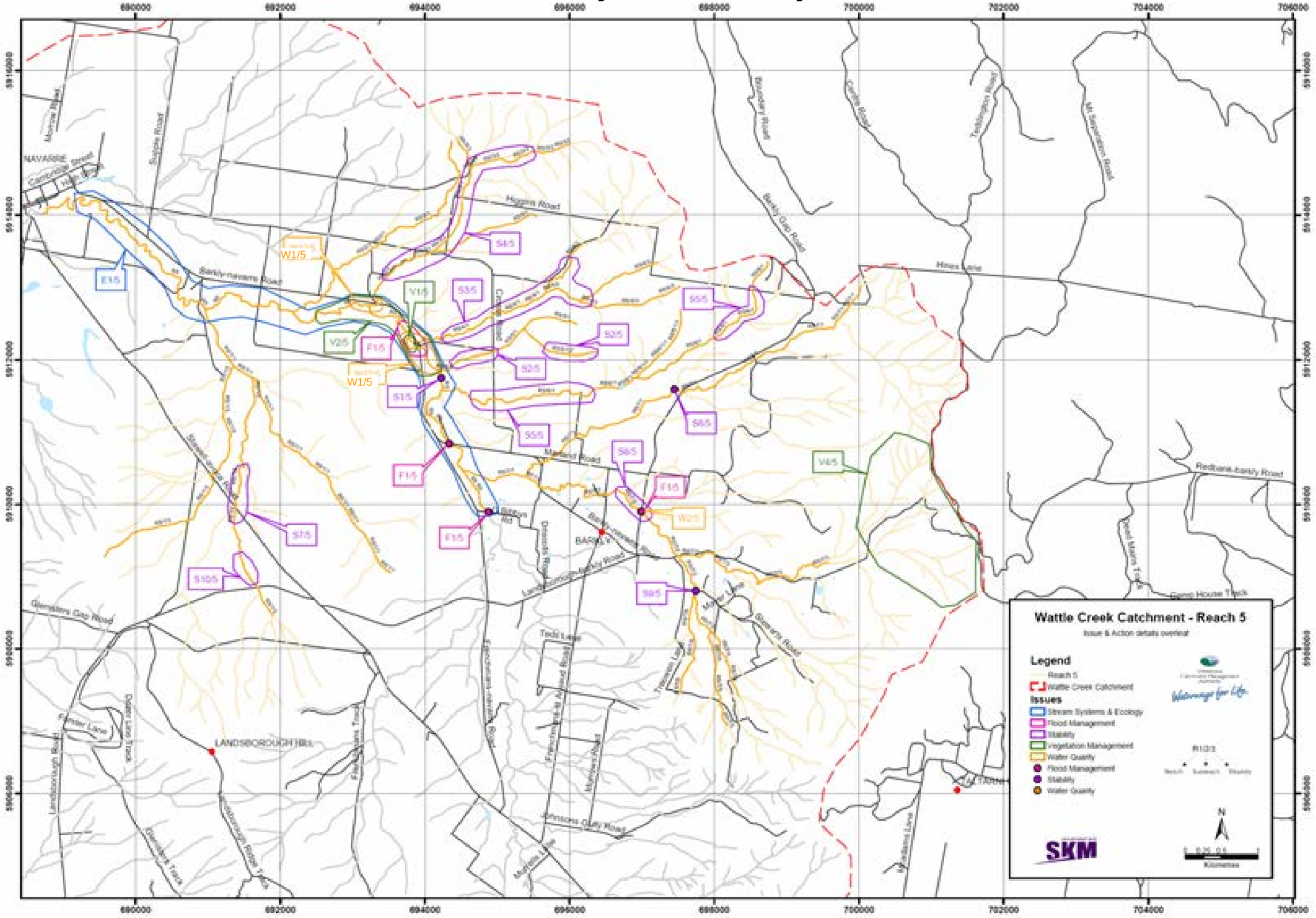
Rabbit infestations in upper catchments reducing catchment cover on drier hills	Moderate

- **Figure 7.2 – Block bank failure downstream of Stawell-Avoca Road**

Figure 7.3 – Erosion head in drain along Tulkara Road

- **Figure 7.4 – Major sediment deposition is Evidenced by buried fence posts**

8. Reach 5 –Wattle Creek – Bibby's Road at Barkly and Tributaries to Navarre



- **Figure 8.1– Extent of Waterways included in Reach 5. Refer to Appendix E for Issues and Actions details.**

Table 8-1 Reach 5 Issues and Actions Details

Site Specific Actions (not reach wide)		
Issue Number	**Issue**	**Action required**
E1/5	Mainstem vegetation and numerous waterholes along mainstem with aged RRG and pool habitats need stronger protection	Negotiate stock access control and fencing with adjoining landowners and revegetate, with a view to providing appropriate off stream stock watering facilities.
V1/5	Sediment saturation levels and salt affecting the riparian community at the junction of R5/4/1 and downstream	Investigate techniques to lower the saturation levels in the riparian areas
V2/5	Thin , discontinuous, remnant riparian forest and bank vegetation along mainstem under threat from uncontrolled grazing and large gaps breaking wildlife and riparian corridor	Provide for controlled stock access, fence and assist with revegetation of corridor
V4/5	Secure remnant vegetation in upper catchment	Protect vegetation through fencing & other support programs i.e. Land for Wildlife
W 1/5	High bed load, suspended solids and turbidity in lateral tributaries having direct impact on the mainstem of Wattle Creek	Investigate opportunities to improve sediment and water quality treatment performance through the establishment of formal sediment traps on the tributaries upstream of the mainstem
W2/5	Old mining area and signs of battery discharges to stream may indicate heavy metal contamination in sediments	Undertake sediment testing for heavy metals
S1/5	Bank laybacks and minor channelisation on the mainstem upstream of Barkly Road	Establish bank controls and revegetate
S 2/5	Major incision with block failure of banks after finish of primary bed erosion (some minor bed erosion still occurring) direct impact on Wattle Creek. Upstream segment eroding in foothills forming gullies	Undertake staged bed and bank works on whole of tributary over 5 years to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed, fence and plant. (Council to repair black brute culvert under road.)
S 3/5	Major incision with block failure of banks after finish of primary bed erosion (some minor bed erosion still occurring) direct impact on Wattle Creek	Undertake staged bed and bank works on segment to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed, fence and plant
S 4/5	Major incision with bank erosion after finish of primary bed erosion in upper reaches (some minor bed erosion still occurring) direct impact on Heifer Wattle Creek. Some old SCA structures to re-establish	Undertake staged bed and bank works on segment to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed, fence and plant
S 5/5	Major incision with active bed erosion in upper segments and bank erosion after finish of primary bed erosion in lower reaches (some minor bed erosion still occurring) direct impact on Heifer Wattle Creek. Old Check bank dams breached	Undertake staged bed and bank works on segment to settle bank erosion through toe groynes, bench establishment and provision of primary channel in bed, fence and plant. Concentrate on upper reach heads first
S6/5	Scour hole d/s of Barkly Gap Road threatening to undermine the road culvert and head drop creating erosion d/s	Establish a de-energisation chute and stablise channel downstream

S7/5	Deep incision and channelisation and headward erosion and bank slumping leading to destabilisation of tributaries d/s of Stawell Avoca Road	Establish de-energisation pool, chutes, groyne protection for banks, handle overbank re-entry, fence and revegetate channel
S8/5	Marshall Lane ford unstable and impacted on by high energy and large bed loads of gravel derived from disturbances of old mining areas	Stabilise the road ford and 500m d/s
S9/5	Stewarts Road Ford has a very deep active erosion head at the road which has been stabilised many times	Provide grade control d/s of the road and provide a chute for the ford to ensure its integrity. (provide safety Signage)
S10/5	Incision of channelised drain through steep foothill property into multiple gullies in foothill fans	Establish channel armour and form low chutes, re-entries, fence and revegetate channels
F1/5	Road safety danger through broad flooding of Barkly Navarre road, Marland Road, Bibby's Road and Marshalls Lane in large events	Negotiate with Council for improved flood warning signage for road crossings

8.1 Reach Location

This reach includes that of the mainstem of Wattle Creek upstream of Navarre through to Bibby's Road at Barkly, including the many tributaries to the east that rise from the Pentland Range and also those from the eastern slopes of the Landsborough Hill Range (refer to Figure 8.1 for more detail).

8.2 Morphological Description

The main stream throughout this reach is incised within a narrow floodplain. River Red Gums line the banks while the floodplain has been cleared for cereal cropping and sheep grazing. The stream in this reach is ephemeral with some residual pools seen as far upstream as Marland Road. Interpool runs are colonised by *Phragmites spp*. The plan form of the stream is mildly more sinuous than that of the tight sinuous form in Reach 4 indicating a slightly steeper grade.

Except for the large crown reserve south of Navarre, no significant Crown Reserves exist along approximately 50% of the streams upstream of Navarre, to the Navarre Barkly Road where the Crown Reserve restarts. This is proably due the original settlement pattern where Heifer Station was occupied prior to the *Crown Lands Act* in the 1880's. There are no Crown Reserves on any of the tributaries either east or west of the mainstem.

The eastern-most tributaries are relatively steep and rise on the cleared low foothill rises of the Pyrenees Ranges. In contrast to the previously described reaches, these tributaries have direct connectivity to the mainstem without the benefit of a floodplain or wetland system to trap sediments. As a result of the steep grades most of these streams have undergone incision that has left some segments with 3.5 m deep vertically sided channels. Whilst the head cutting appears to have declined, the lateral bank undercutting and cantilever failure is very evident. Some past works have been undertaken with some old gully plug dams and walling evident. Attempts at rock chutes have failed; a culvert installed by the Council on T Driscolls and Cross's Road corner is collapsing due to lack of maintenance. The headwaters of the five tributaries R5/2, R5/3, R5/4, R5/5, and R5/6 all have active bed and bank erosion that will need to be addressed through a rehabilitation program. As these tributaries have direct connectivity with the mainstem, their rehabilitation should attract higher priority than those tributaries (in other reaches) that are poorly connected via floodplain wetlands.

The tributary R5/7 is interesting in as much as its erosion has ceased and there are signs that the natural process of channel stabilisation is well advanced. The only site on this tributary that needs attention is the crossing at the Barkly Gap Road where a headcut has formed on the downstream side of the road. The tributary R5/7/2 has some very active areas with the ford at Marshalls Lane showing scouring problems with both aggradation and degradation obvious in large banks of Quartz pebbles downstream and upstream of the ford. It is obvious from the mullock heaps

throughout the district that the area has been significantly disturbed through historic gold mining. One area of interest was the location of a stamping mill wash out area with bands of many colours of silts in the banks.

The headward erosion is basically finished in the area but the banks remain unstable. A ford crossing at Stewarts Road R5/7/2 is in need of urgent repair to overcome past attempts of repairing a serious safety problem. Insidious erosion is occurring further up the catchment of this reach with channel and bank erosion occurring due to loss of vegetation cover. Rabbits appear to be a problem in this area.

The Redbank Barkly Road crossing on R5/7/3 has a large concrete drop structure on the downstream side and some repair works are needed to secure this asset.

The streams to the west side of the mainstem are similar to those on the discussed in Reach 4 for the Landsborough Hill Range country. These can bee seen to have eroded in to the upper reaches with these areas still active. Active heads and incision processes are evident in R5/1/2, R5/1/3 and R5/1/4 in particular, upstream of the Stawell Avoca Road. Culvert erosion was also noted at each of these tributaries along the Stawell Avoca Road.

All the upper foothill streams are open to the impacts of episodic erosion under high intensity events and will start another round of bank instability that gives rise to transport of erosion products and bed loads of gravels and silt.

8.3 Vegetation

The vegetation along the main stem of WattleCreek is generally continuous but narrow to non-existent in places and shows some signs of salinity stress. This is particularly evident where the five tributaries deliver sediment and solutes to the mainstem valley around T Driscolls Road. Sedimentation is also causing stress in this area. Large areas of phragmites are colonising the flood plain and stream indicating the elevated saturation through the accumulated sediments.

Most of the tributaries are essentially without overstorey and or midstorey vegetation. Erosion is evident as is uncontrolled stock access where the banks are not vertical. The upper slopes retain some remnant vegetation, as listed in Table 8-2 below, however these have been degraded through past landscape disturbance, most likely grazing, firewood collection and mining operations. Very little remnant vegetation remains intact, and the diversity of this vegetation is low, when compared with pre-European settlement distribution.

- **Table 8-2 - Current and Pre-European Vegetation Attributes (EVC) Reach 5**

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
	6 – Sand Heathland	Lower Floodplain
	20 – Heathy Dry Forest	Upper slopes, skeletal soils
	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper Slopes
	67 – Alluvial Terrace Herb-rich Woodland	Alluvial terraces
	70 – Hill Crest Herb-rich Woodland	Upper Slopes and Crests
	76 – Low Rises Grassy Woodland	Upper areas of tributaries
	83 – Swampy Riparian Woodland	Banks of Wattle Creek.
	86 – Creekline Grassy Woodland	Banks of Wattle Creek.
175 – Grassy Woodland	175 – Grassy Woodland	Slopes

The control of stock access and initiation of a revegetation program, focusing on over storey species should be a priority for Reach 5. With the general scarcity of vegetation on the whole within the reach, revegetation programs should have the initial focus of establishing some smaller patches of vegetation in the upper tributaries which can form the basis of future linkage and corridor development programs. It is anticipated that such an approach would enable species to spread down the catchment, once the riparian zone has been secured in relation to livestock access.

8.4 Habitat

Despite the sedimentation occurring in the mid reaches, the habitat of the main stem is relatively good with some remnant pools providing some refuge. It is likely that species found downstream will also be present in the pools including Flat Headed Gudgeon, Mountain Galaxias and Blackfish. A full study of all fish and mammals needs to be undertaken to get a better understanding to aid management in the future.

These more permanent pools could be enhanced as high value refuges for fish and other species if they stock access is removed. Depending on the flow patterns, it may be possible to establish a habitat capable of supporting a wider range of fish and mammal species.

As with previous reaches, the habitat condition of most of the ephemeral and lateral tributaries is extremely poor with no appreciable significance.

8.5 Water Quality

The water quality of the remnant mainstem pools is brackish to sub saline and show no sign of algal blooms. As mentioned aggradation is evident mid reach and the associated increase in suspended solids and turbidity will be impacting on downstream values.

The higher salinity regime can be expected given the leachable country and known sources of salt discharge upstream. As well as the small base flows noted at the downstream end with an estimated salinity range of salinity of 1200 to 10,000 uS/cm over the year. As with downstream reaches, it is likely that there are deeper gravel and sand leads that transport flows and or provide springs along the mainstem.

Although no data exists, there is potentially the likelihood of heavy metal contaminants arising from the former gold mining areas around Barkly. It would be worthwhile to check for arsenic and mercury compounds in the sediments of the tributaries as a minimum.

The seriously eroding tributaries will see the elevation of both suspended solids and turbidity in this reach. Without the mitigating influences of off-stream wetlands the stream receives untreated flows another source of these contaminants is likely be from rural roads under rainfall conditions. This will be added to via road runoff from the many unmade roads in the reach.

8.6 Flooding

Flooding is major issue where the Barkly Road traverses the floodplain between R5/3/1 and R5/6/1. The DSE mapping (DSE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources) confirms the field observations and the depth of flood is expected to inundate the road by 1.0m. Some areas of excessively high velocities are likely to occur across the road.

Mainstem flooding is to be expected along the whole of the Reach 5, but is more confined by the confined flat valley floor in this reach. Marland and Bibbys Road crossings will also be inundated in major ARI rainfall events as the cross sectional area beneath the bridge is limited.

Some of the road culverts inspected along the Stawell Avoca Road are prone to debris blockage and may also have over road flows in larger events.

Many of these potential flood points are either unmarked or inadequately marked and as such present a potential safety hazard.

8.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 5. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix E – Reach 5 Summary of Issues and Actions.

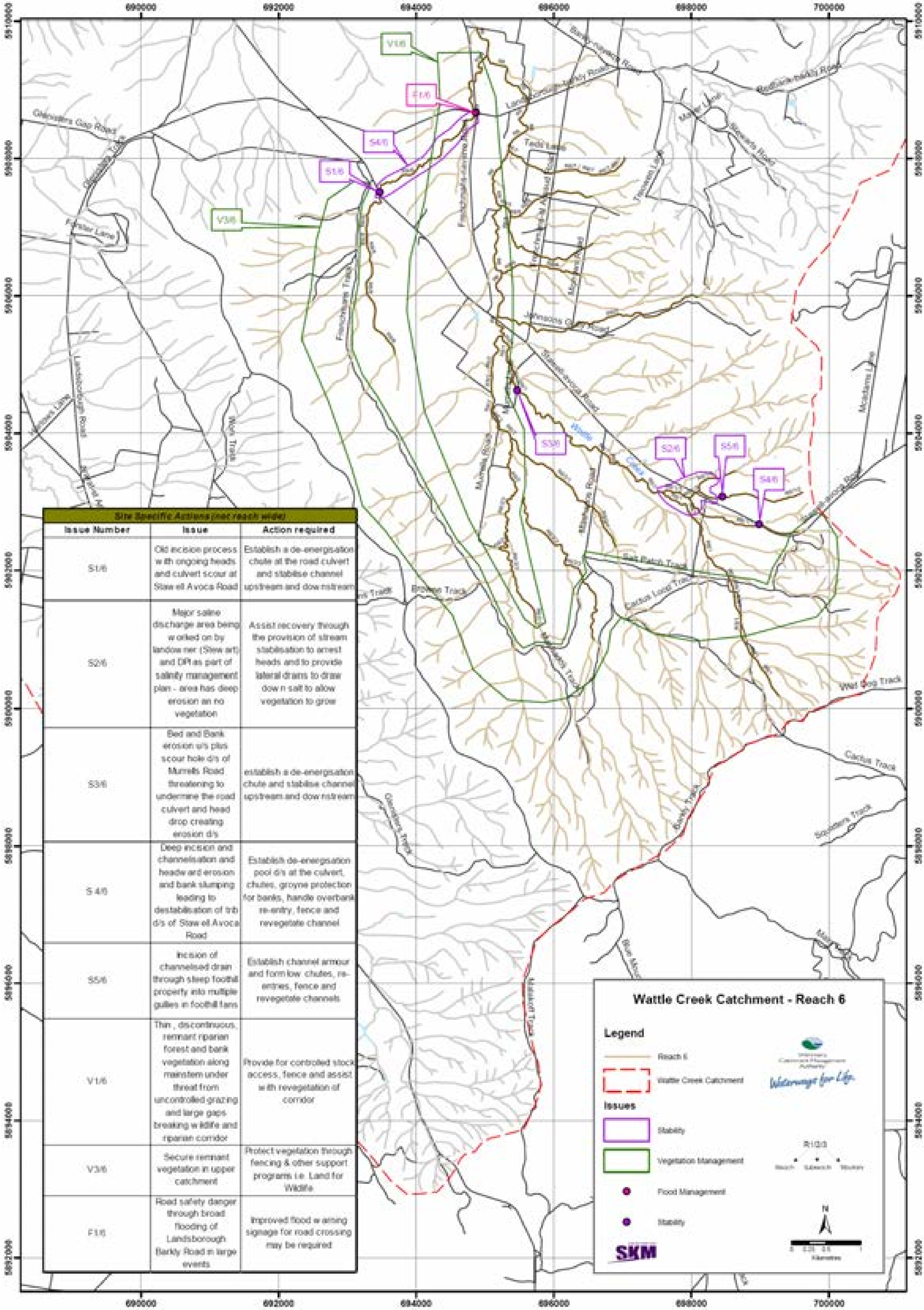
- **Table 8-3 – Threats and Priorities identified in Reach 5**

Threat	Priority
Further loss of habitat and riparian vegetation along Wattle Creek mainstem	Very High
Stock access to stream zones in both mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline on tributaries to the east (R 5/3/1, R5/4/1 and R5/5/1 systems) due to no maintenance and is producing significant loads of sediment downstream	Very High
Significant amounts of active bed and bank erosion in the eastern tributary streams with the potential to generate and transport large loads of sediment directly to the mainstem of Wattle Creek due to no ephemeral swamps and floodplains to mitigate suspended solids and turbidity arising from the tributaries	Urgent
Road safety of Navarre Barkly and Stawell Avoca Roads under flood conditions at creek and floodplain crossings	High
Road safety at tributary fords on Marshall Lane and Stewarts Road	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Nutrient transport from catchment due to land use and loss of mitigation systems	Moderate
Salinity production in denuded catchment leading to saline discharge areas and higher salinity	Moderate
Rabbit infestations in upper catchments reducing catchment cover on drier hills	Moderate

- **Figure 8.2 – Failed Chute**

Figure 8.3 – Maintenance required on SCA Structures

9. Reach 6 Wattle Creek – Headwaters and tributaries to Bibby's Road at Barkly



Site Specific Actions (not reach wide)		
Issue Number	**Issue**	**Action required**
S1/6	Old incision process with ongoing heads and culvert scour at Stawell Avoca Road	Establish a de-energisation chute at the road culvert and stabilise channel upstream and downstream
S2/6	Major saline discharge area being worked on by landowner (Stewart) and DPI as part of salinity management plan - area has deep erosion an no vegetation	Assist recovery through the provision of stream stabilisation to arrest heads and to provide lateral drains to draw down salt to allow vegetation to grow
S3/6	Bed and Bank erosion u/s plus scour hole d/s of Murrells Road threatening to undermine the road culvert and head drop creating erosion d/s	establish a de-energisation chute and stabilise channel upstream and downstream
S 4/6	Deep incision and channelisation and headward erosion and bank slumping leading to destabilisation of trib d/s of Stawell Avoca Road	Establish de-energisation pool d/s at the culvert, chutes, groyne protection for banks, handle overbank re-entry, fence and revegetate channel
S5/6	Incision of channelised drain through steep foothill property into multiple gullies in foothill fans	Establish channel armour and form low chutes, re-entries, fence and revegetate channels
V1/6	Thin , discontinuous, remnant riparian forest and bank vegetation along mainstem under threat from uncontrolled grazing and large gaps breaking wildlife and riparian corridor	Provide for controlled stock access, fence and assist with revegetation of corridor
V3/6	Secure remnant vegetation in upper catchment	Protect vegetation through fencing & other support programs i.e. Land for Wildlife
F1/6	Road safety danger through broad flooding of Landsborough Barkly Road in large events	Improved flood warning signage for road crossing may be required

- **Figure 9.1– Extent of Waterways included in Reach 6. Refer to Appendix F for Issue and Action details.**

9.1 Reach Location

This reach includes that of the mainstem of Wattle Creek upstream of Barkly to the forested headwaters of the Pyrenes and Landsborough Ranges, including the many tributaries to the east that rise from the foothills and ranges (refer to Figure 9.1 for more detail and extent).

9.2 Morphological Description

The main channel through this reach is a stable but slightly incised waterway that flows within a floodplain used for grazing. The plan form of the stream has a low sinuosity and some areas may have been subject to historic channelisation works. The stream in this reach is ephemeral but tends to retain permanent pools as the catchment size increases downstream. Some residual pools could still be seen as far upstream as Murrells Lane. Stands of *Phragmites spp*. exist in the interpool runs.

Discontinuous Crown Reserve exists over approximately 50 % of the mainstem. However, except for one tributary to the west, there are no Crown Reserves along the tributary waterways. Unrestricted stock access has degraded affected areas of the riparian zone and has led to historic bank erosion.

The eastern-most tributaries are relatively steep and rise on the cleared low foothill rises at the end of Pyrenees Ranges. As with Reach 5 these tributaries have direct connectivity to the mainstem without the benefit of a floodplain or wetlands system to trap sediments. However as most of these streams have smaller catchments compared to those in Reach 5, the degree of incision is less and most are basically stable.

The headwater streams of tributaries R6/1 have serious salinity problems as well as incision. Whilst a lot of work has been undertaken by the property owner in a collaborative effort with DSE to tackle this problematic area of severe salinity, spiny rush and erosion, a supportive effort by the WCMA for the eroded waterways would aid the project. Upstream a road culvert treatment is causing scouring in downstream sections due to the high velocities created by the culvert arrangement. Erosion is also evident in tributaries R6/1/4 and R6/1/5, probably due to a combined impact of channelisation to culverts and salinity problems.

The waterway downstream of this area is showing the impacts of increased runoff from the denuded areas, bank erosion and subsequent increased gravel bedload. The erosion downstream of Murrells Lane Ford is serious.

The western tributary R6/9 arising near Frenchmans Track has had past works done on it by the SCA, but is in need of follow up works to repair more recent damage, particularly downstream of the Stawell Avoca Road culvert. Tributary R6/9 is also showing signs of classic headward erosion immediately upstream of the mainstem.

The rest of the tributaries, although bare, are relatively stable. However, with limited vegetation present there is little protection of the current stream form and future floods may well rejuvenate bed incision and consequent bank erosion.

9.3 Vegetation

The vegetation along the main stem of Wattle Creek is discontinuous and narrow to non existent in places. The upper slopes retain a good remnant vegetation cover in places, with much of the vegetation having regenerated since the conclusion of mining operations.

Most of the tributaries are essentially without overstorey and or midstorey vegetation. Erosion is evident as is uncontrolled stock access where the banks are not vertical. The occurrence of Spiny Rush was noted as being more prevalent in the tributaries from the east indicating a salt issue.

Table 9-1 below indicates the present and former distribution of remnant vegetation within the catchment. The remaining remnant vegetation is generally found in the upper reach to the south, in areas that were too steep for the initial development of the landscape.

Table 9-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 6

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
	6 – Sand Heathland	Lower Floodplain
20 – Heathy Dry Forest	20 – Heathy Dry Forest	Upper slopes, skeletal soils
22 – Grassy Dry Forest	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
23 – Herb-rich Foothills Forest	23 – Herb-rich Foothills Forest	Lower slopes
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper Slopes
	67 – Alluvial Terrace Herb-rich Woodland	Alluvial terraces
	70 – Hill Crest Herb-rich Woodland	Upper Slopes and Crests
	76 – Low Rises Grassy Woodland	Lower slopes on alluvium
	86 – Creekline Grassy Woodland	Lower tributaries and main stem
	175 - Grassy Woodland	Slopes

Control of stock access and the initiation of revegetation programs through the establishment of a canopy cover within designated patches of the riparian zone in the first instance would be advisable. Stock control over the entire riparian zone is required, but within the scope of that undertaking, the revegetation of small areas of the drainage line, allowing species to spread into adjoining areas with time, once pressure from stock access is dealt with.

9.4 Habitat

Despite the stream getting smaller and residual pools becoming less prominent, the habitat values of the main stem pools is relatively good with some remnant pools providing refuge. Salinity is likely to be an issue in limiting the diversity but some native species may be found on closer examination.

As with previous reaches a comprehensive study of the instream ecosystem needs to be undertaken to get a better understanding of the system and aid management in the future.

These more permanent pools could be enhanced as high value refuges for fish and other species if they were rehabilitated. Depending on the flow patterns, it may be possible to establish a habitat capable of supporting a wider range of fish and mammal species.

There are very limited habitat values in most of the ephemeral and lateral tributaries.

9.5 Water Quality

The water quality of the remnant mainstem pools is impacted by rising salinity. As mentioned earlier, aggradation is evident in the mainstem downstream of the eroding lateral tributaries, although this is not to the same scale as in Reach 5.

The higher salinity regime can be expected given the problematic salinity discharge area in reach R6/1. As well as the small base flows noted at the downstream end of this reach it is likely that stronger saline flows occur at depth in the gravel seams of the valley.

The seriously eroding tributaries will see the elevation of both suspended solids and turbidity in this reach. Further the historic grazing of the forests will also give rise to sheet erosion and high suspended solids and turbidity under high intensity rainfall events. This will be added to from road runoff from the many unsealed roads in the reach.

9.6 Flooding

Flooding is major issue where the Barkly Road traverses the flood plain between R5/3/1 and R5/6/1. The DSE mapping (DSE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources) confirms the field observations and the depth of flooding could reach a depth of over 1.0 m along the road. Some areas of high velocity across the road may also be experienced.

Mainstem flooding is to be expected along the whole of the mainstem of Reach 6, but is confined by the narrow flat valley floor in this reach. It is likely that the Landsborough Barkly Road and the main Stawell Avoca Road is likely to be inundated in major events as the bridge cross sections are limited.

Some of the road culverts inspected along the Stawell Avoca Road are prone to debris blockage and may also have over road flows in larger events.

The ford at Murrells Lane is potentially dangerous under flood conditions due to the expected high velocity of the stream.

Many of these potential flood points are either unmarked or inadequately marked and as such present a potential safety hazard.

9.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 6. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix F – Reach 6 Summary of Issues and Actions.

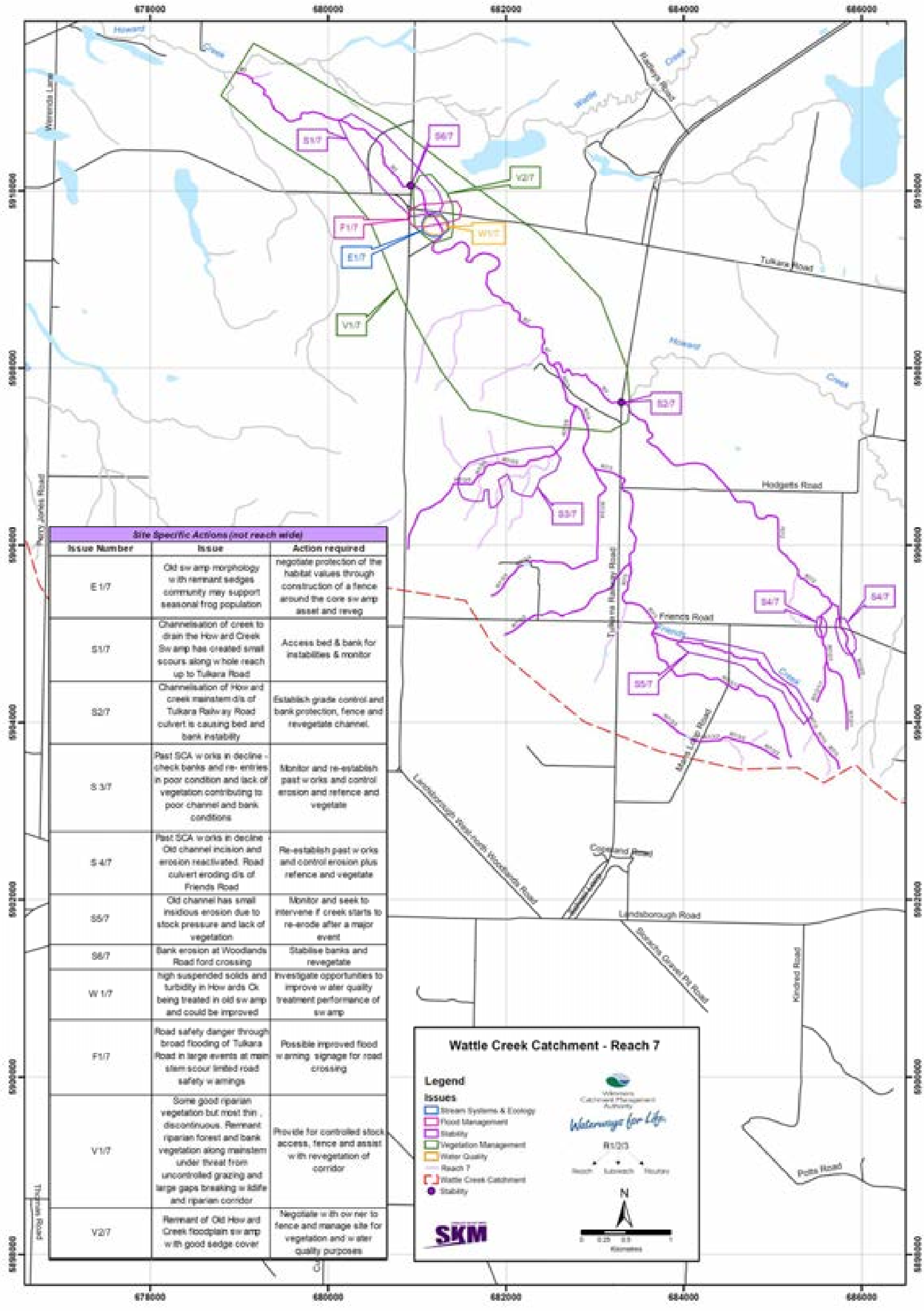
Table 9-2 – Threats and Priorities identified in Reach 6

Threat	Priority
Further loss of habitat and riparian vegetation along Wattle Creek mainstem	Very High
Stock access to stream zones in both mainstem and eroding areas of tributaries	Very High
Old SCA stabilisation works in decline on tributaries to the east (R 6/8) due to no maintenance and recent damage.	Very High
Salinity production in denuded catchment areas and forests leading to saline discharge areas and higher salinity	High
Active bed and bank erosion in reach R6/1, R6/8 and R6/9, with the potential to generate and transport large loads of sediment directly to the mainstem of W Creek due to no ephemeral swamps and floodplains to mitigate suspended solids and turbidity arising from the tributaries	High
Road safety of Landsborough Barkly, Stawell Avoca Roads an Murrells Lane under flood conditions at creek and floodplain crossings	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Nutrient transport from catchment due to land use and lack of mitigation systems	Moderate
Rabbit infestations in upper catchments reducing catchment cover on drier hills	Moderate

Figure 9.2 – Active hillslope erosion

Figure 9.3 – Severely salt affected area requires collaborative rehabilitation

10. Reach 7 – Howards Creek - Tulkara Railway Road including Friends Creek and tributaries to Heifer Station Creek junction



Site Specific Actions (not reach wide)		
Issue Number	Issue	Action required
E 1/7	Old sw amp morphology w ith remnant sedges community may support seasonal frog population	negotiate protection of the habitat values through construction of a fence around the core sw amp asset and reveg
S1/7	Channelisation of creek to drain the How ard Creek Sw amp has created small scours along w hole reach up to Tulkara Road	Access bed & bank for instabilities & monitor
S2/7	Channelisation of How ard creek mainstem d/s of Tulkara Railw ay Road culvert is causing bed and bank instability	Establish grade control and bank protection, fence and revegetate channel.
S 3/7	Past SCA w orks in decline - check banks and re- entries in poor condition and lack of vegetation contributing to poor channel and bank conditions	Monitor and re-establish past w orks and control erosion and refence and vegetate
S 4/7	Past SCA w orks in decline Old channel incision and erosion reactivated. Road culvert eroding d/s of Friends Road	Re-establish past w orks and control erosion plus refence and vegetate
S5/7	Old channel has small insidious erosion due to stock pressure and lack of vegetation	Monitor and seek to intervene if creek starts to re-erode after a major event
S6/7	Bank erosion at Woodlands Road ford crossing	Stabilise banks and revegetate
W 1/7	high suspended solids and turbidity in How ards Ck being treated in old sw amp and could be improved	Investigate opportunities to improve w ater quality treatment performance of sw amp
F1/7	Road safety danger through broad flooding of Tulkara Road in large events at main stem scour limited road safety w arnings	Possible improved flood w arning signage for road crossing
V1/7	Some good riparian vegetation but most thin , discontinuous. Remnant riparian forest and bank vegetation along mainstem under threat from uncontrolled grazing and large gaps breaking w ildlife and riparian corridor	Provide for controlled stock access, fence and assist w ith revegetation of corridor
V2/7	Remnant of Old How ard Creek floodplain sw amp w ith good sedge cover	Negotiate w ith ow ner to fence and manage site for vegetation and w ater quality purposes

- **Figure 10.1– Extent of Waterways included in Reach 7. Refer to Appendix G for Issue and Action details.**

10.1 Reach Location

This reach includes the mainstem of Howard Creek upstream of the Junction with Heifer Station Creek west of Woodlands Road through to the Tulkara Railway Road. There are a number of tributaries of Friends Creek all within low rolling hill country (refer to Figure 10.1 for more detail).

10.2 Morphological Description

The main stream of this reach varies in capacity dramatically. The channel at the downstream end towards Heifer Station Creek is almost non existent and appears to have been formed as a drain, to drain what looks like a large terminal swamp similar to Greens Swamp. Remnants of this formerly extensive swamp still exist immediately north and south of the Tulkara Road crossing. Further upstream at the Tulkara Road crossing, a culvert has been built, along with a channel to direct the flood waters into a larger channel. This latter channel has eroded due to the concentration of flood waters that previously would have been conveyed over a broad floodplain. Apparently, these works occurred in the 1970's as part of the road works to upgrade the Tulkara Road to an all-season road. Breakaway floodwaters along Tulkara Road are directed by Andersons Scour back into Howard Creek approximately 2 km west of Tulkara Railway Road. This channel is essentially stable due to the rapid break out onto the floodplain.

There are few Crown Reserves in this entire reach and no Crown Reserves along the tributary waterways. Elsewhere, Howard Creek Swamp and associated floodplain retains a remnant swamp vegetation community. The swamp probably also acts as a sediment trap.

The tributaries do not appear to be actively eroding at present. However, historic erosion seems to have been arrested by SCA works in the past. However, as with other areas, lack of maintenance has seen these works fall into disrepair. The construction of a new dam on Friends Creek is coincidental with a series of erosion heads that have established due to downstream channelisation. The Tulkara Railway Road crossing of Friends Creek has a deep scour pool and an old SCA drop structure 100 m downstream that needs repair (and possibly the addition of energy dissipators). The bed and bank erosion in the channels should also be addressed in this exercise. It is interesting to note that up to 0.5 m of post settlement alluvium PSA has been deposited on the banks at this location indicating the extent of sediment mobilised since settlement.

Erosion is still going on in both Friends Creek upstream of Friends Road and tributary R7/3/5. Both these areas have been subjected to past SCA works. Headward and bank erosion are still occurring in R7/2 an R7/2/1, particularly at the road culverts and downstream. A diversion at the upper end of R7/2/2 is causing concern, with the activation of new bed and bank erosion.

10.3 Vegetation

Small areas of well developed remnant vegetation exist along the main stem of Howard's Creek, however, the majority of the reach contains a discontinuous and narrow corridor of riparian vegetation. The remnant vegetation along the main stem is a very important wildlife corridor and needs to be rehabilitated along with that of the swamplands. The remnant Carex swamp south of Tulkara Road shows the components of the ground cover that existed in these swamps prior to landscape modification. Its retention is critical to the capture of sediments from the catchments.

Most of the tributaries are essentially without overstorey and or midstorey vegetation. Erosion is evident as uncontrolled stock access where the banks are not vertical. Some older SCA plantings need revisiting for inclusion of a sedge groundcover and understorey to help arrest erosion processes.

Very little remnant vegetation exists in Reach 7. Only one small patch of remnant vegetation remains. Table 10-1 below lists the remnant vegetation remaining within the reach and that which is believed to have occurred prior to European settlement.

Table 10-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 7

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
	6 - Sand Heathland	Lower Floodplain
	20 – Heathy Dry Forest	Upper slopes, skeletal soils
	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
	48 – Heathy Woodland	Mid-upper slopes, thin, infertile soils
76 – Low Rises Grassy Woodland	76 – Low Rises Grassy Woodland	Upper areas of tributaries
	175 – Grassy Woodland	Slopes

The future focus for vegetation management within the reach needs to focus on revegetation, controlling stock access from the riparian environment and strategic revegetation in the upper catchment to control the erosion currently present in the area.

10.4 Habitat

Howard Creek is seasonal and there was no evidence that any residual pools form in the lower reaches. Hence, the presence of significant instream communities is unlikely to occur. There has not been a definitive study of the instream fauna in this area. As with previous reaches a comprehensive study of the instream ecosystem needs to be undertaken to get a better understanding of the system and aid management in the future.

There are very limited habitat values in most of the ephemeral and lateral tributaries.

10.5 Water Quality

The water quality of this reach is hard to discuss, due to the complete lack of historical data as well as the whole creek system being dry at the time of inspection. However the occurrence of a large PSA in areas, indicates that sediment transport and high turbidities is still likely to be an issue.

The eroding tributaries, the lack of vegetation along the streams and unfettered stock access will see the elevation of both suspended solids and turbidity in this reach.

10.6 Flooding

Whilst there is no flood mapping for this portion of the reach it is likely that flooding will, be extensive given the relatively small channel capacities, very flat grades and broad floodplains. The flood crossings of Friends Creek and tributaries are likely to cause damage and inconvenience through flooding along Friends Road. The Friends Creek crossing at Tulkara Road is likely to break across the road as the culvert size is restricted.

Flooding is a regular and major issue where Tulkara Road traverses the floodplain east of Woodlands Road. This area has been sealed to form a broad flat and shallow ford. Flood depth may get to 0.5 m in this location but velocities are likely to be relatively low due the flat grade. Flood depth markers are present in this location.

10.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 7. For specific details on issues, actions, locations, priorities and cost estimates, refer Appendix G – Reach 7 Summary of Issues and Actions.

- **Table 10-2 – Threats and Priorities identified in Reach 7**

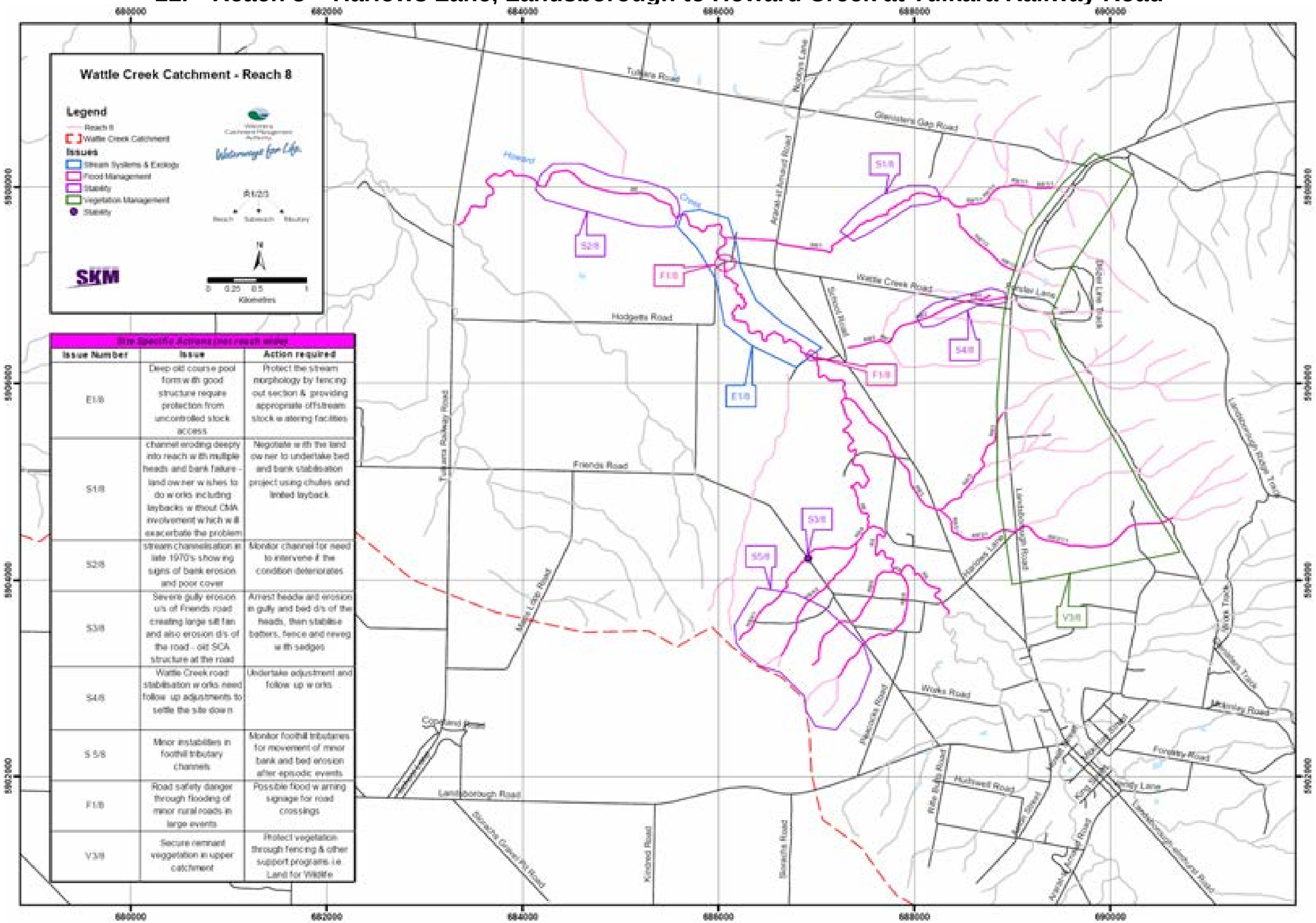
Threat	Priority
Further loss of habitat and riparian vegetation along lower Howards Creek mainstem	Very High
Loss of and need for retention and rehabilitation of the former Howards Creek floodplain swamp is critical to treatment of water quality for suspended solids and turbidity	Very High
Old SCA stabilisation works and Council works in decline on Howards Creek and Friends Creek downstream of Tulkara Railway Road	Very High
Old SCA stabilisation works in decline on Friends Creek and	High

tributaries R 7/3/5, R7/2/1and R7/2/2 due to no maintenance and recent damage	
Active bed and bank erosion in reaches R7/3, R7/2/2 and R7/3/5, with the potential to generate and transport loads of sediment directly to the mainstem of Howards Creek	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Stock access to stream zones in both mainstem and eroding areas of tributaries	High
Road safety at Friends Creek crossing of Tulkara Railway Road and also Howards Creek crossing of Tulkara Road under flood conditions	Moderate
Rabbit infestations in upper catchments reducing catchment cover on drier hills	Moderate

Figure 10.2 The remnant Carex swamp south of Tulkara Road (near the intersection of woodlands Road)

Figure 10.3 –– The remnant Carex swamp south of Tulkara Road (near the intersection of woodlands Road)

11. Reach 8 – Harlows Lane, Landsborough to Howard Creek at Tulkara Railway Road



- **Figure 11.1– Extent of Waterways included in Reach 8. Refer to Appendix H for Issues and Action details.**

11.1 Reach Location

This reach includes the mainstem of Howard Creek upstream of the Tulkara Road culvert through to the junction with Native Youth Creek upstream of Friends Road, Landsborough and includes the directly connected tributaries (refer to Figure 11.1 for more detail).

11.2 Morphological Description

The main channel in this reach is stable with a series of deep interconnected pools (dry at the time of inspection) lined by mature River Red Gums.

Some channelisation work appears to have been undertaken in sections of the channel upstream of the Tulkara Road crossing. This is evidenced by the straighter channel form when compared to the more sinuous upstream segments and the batter of the right bank. We assume that the works were undertaken by the former Avoca Shire as part of a program to increase the trafficability of the Tulkara Road to an all-seasons road. Prior to these works the channel verges probably flooded regularly. Indeed the floodplain to the south of the broad loop of the channel would most likely have been an ephemeral swamp. The current channel is basically stable but there has been a loss of some of the trees along the stream as a result of the works. The channelised section may be prone to future adjustment and should be monitored for erosion activity from time to time. However, the whole of the mainstem is within a Crown Reserve that will assist the negotiation of revegetation along the reach.

The Wattle Creek Road tributaries of R8/1 and R8/2 have undergone significant incision processes. R8/2 has been subject to a WCMA works program designed to arrest the erosion and stop transport of sediment onto the downstream golf course. These works are new and there are signs of early failure of some elements, including bank toe groynes and levy incision where stream powers remain high. It is likely that follow up works will be required (the area needs close monitoring). Tributary R8/1 has a very deep incision and a series of advancing erosion heads that could only be viewed from the air as access was denied for inspection. Some initial layback works appear to have been undertaken by the landowner but this is unlikely to resolve the headward erosion. Sediment is accumulating in the downstream waterway indicating that the CMA should establish a working dialogue with landowners in the area at an early stage to ensure appropriate actions are taken. Similar insidious erosion is appearing in tributary R8/3 and needs monitoring.

The western tributaries are relatively steep and are eroding badly as they move into the upper slopes beyond Friends Road. Extensive debris and sediment deposits across the fences are evident (perhaps from the February 2005 storm) indicating active erosion. The road crossings are causing scouring on the downstream side in all cases. Works will be required to arrest the erosion heads and settle the channels down, plus repair the scours downstream of the road culverts.

11.3 Vegetation

Vegetation present along the main stem of Howards Creek occurs in sizeable patches in a few locations but is discontinuous and narrow where present. The remnant vegetation along the main stem is a very important wildlife corridor and needs to be secured and rehabilitated to provide connectivity in a generally cleared landscape. Revegetation should be undertaken along the mainstem in a cooperative program with the adjacent landowners.

Most of the tributaries are essentially without overstorey and or midstorey vegetation. Erosion is evident as is uncontrolled stock access where the banks steepness permits. Again the introduction of a sedge groundcover and understorey to would help arrest erosion processes contributing to the lowering of erosion and transport of solids and turbidity from the catchment.

Remnant vegetation is largely confined to the upper slopes of the northern portion of the Landsborough Ridge, with remnant vegetation having been largely removed from the lower slopes and valley floor. Table 11-1 below lists the remnant vegetation that currently remains and the EVC's thought to have occurred in the area prior to European settlement.

Table 11-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 8

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
6 – Sand Heathland	6 – Sand Heathland	Lower Floodplain
22 – Grassy Dry Forest	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
	48 – Heathy Woodland	
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper Slopes
	67 – Alluvial Terrace Herb-rich Woodland	Alluvial terraces
70 – Hill Crest Herb-rich Woodland	70 – Hill Crest Herb-rich Woodland	Upper Slopes and Crests
	76 – Low Rises Grassy Woodland	Lower slopes on alluvium

The scarcity of suitably intact vegetation within the floodplain and lower slopes is an issue of vegetation management that requires attention. The control of livestock within the riparian zone would help foster a greater natural regeneration, with species from the upper catchment able to spread down watercourses. The targeted revegetation of the riparian zone through the re establishment of over storey species would facilitate a greater regeneration capacity.

11.4 Habitat

As with the downstream reach (Reach 7), Howard Creek is seasonal and there was no evidence that any permanent residual pools form in the mainstem except maybe in a wet year. Hence, the presence of significant instream communities is unlikely to occur. There has not been a definitive study of the instream fauna in this area. As with previous reaches a comprehensive study of the instream ecosystem needs to be undertaken to get a better understanding of the system and aid management in the future.

There are very limited habitat values in most of the ephemeral and lateral tributaries as they are ephemeral.

11.5 Water Quality

The water quality of this reach is hard to discuss due to the lack of historical data and the whole creek system was dry at the time of inspection. However there are indications that sediment transport and high turbidity will occur in rainfall events. The erosion product impacting on the Golf Course is a good indicator of this fact.

The eroding tributaries, the lack of vegetation along the streams and unfettered stock access will see the elevation of both suspended solids and turbidity in this reach.

11.6 Flooding

Flood mapping for this reach is incomplete with the lower segment upstream of Tulkara Railway Road unmapped. It is however likely flooding will be extensive given the relatively small channel capacities, very flat grades and broad floodplains. The flood crossings of Friends Road tributaries are likely to cause damage to the road and create inconvenience through flooding. Flooding is also likely at the Hodgetts and Hallows Lane crossings on the mainstem, plus segments of the Navarre Landsborough Road where it traverses the floodplain or intersects the tributaries arising from the Landsborough Hill catchments.

No flood warning depth indicators were noted in any of these locations.

11.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 8. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix H – Reach 8 Summary of Issues and Actions.

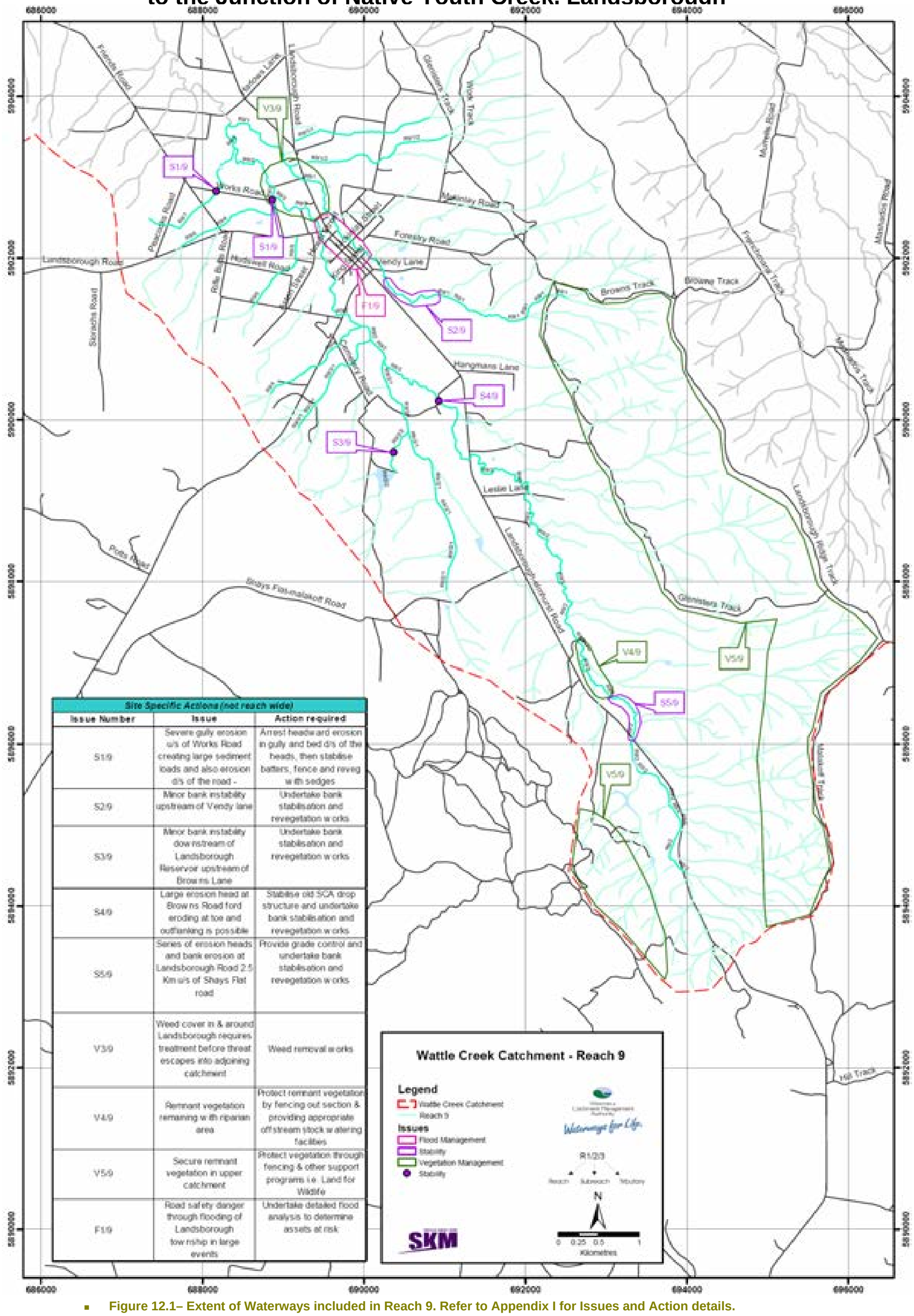
- **Table 11-2 – Threats and Priorities identified in Reach 8**

Threat	Priority
Further loss of habitat and riparian vegetation along lower Howards Creek mainstem	Very High
Active bed and bank erosion in reaches R8/1, R8/4, R8/5, R8/6, with the potential to generate and transport loads of sediment directly to the mainstem of Howards Creek	Very High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Stock access to stream zones in both mainstem and eroding areas of tributaries	High
Road safety at Hodgetts Lane and Hallows Lane crossings and at tributary crossings along the Landsborough Navarre Road under flood conditions	Moderate
Old Council works along Howards Creek and CMA works on R8/2 require monitoring for potential follow up works	Moderate

- **Figure 11.2 – Active erosion**

Figure 11.3 – Site requires monitoring and partnership program with landholders

12. Reach 9 – Howards Creek - Upstream Headwaters including Tributaries to the Junction of Native Youth Creek. Landsborough



Site Specific Actions (not reach wide)		
Issue Number	Issue	Action required
S1/9	Severe gully erosion u/s of Works Road creating large sediment loads and also erosion d/s of the road -	Arrest headward erosion in gully and bed d/s of the heads, then stabilise batters, fence and reveg with sedges
S2/9	Minor bank instability upstream of Vendy lane	Undertake bank stabilisation and revegetation works
S3/9	Minor bank instability downstream of Landsborough Reservoir upstream of Browns Lane	Undertake bank stabilisation and revegetation works
S4/9	Large erosion head at Browns Road ford eroding at toe and outflanking is possible	Stabilise old SCA drop structure and undertake bank stabilisation and revegetation works
S5/9	Series of erosion heads and bank erosion at Landsborough Road 2.5 Km u/s of Shays Flat road	Provide grade control and undertake bank stabilisation and revegetation works
V3/9	Weed cover in & around Landsborough requires treatment before threat escapes into adjoining catchment	Weed removal works
V4/9	Remnant vegetation remaining with riparian area	Protect remnant vegetation by fencing out section & providing appropriate off stream stock watering facilities
V5/9	Secure remnant vegetation in upper catchment	Protect vegetation through fencing & other support programs i.e. Land for Wildlife
F1/9	Road safety danger through flooding of Landsborough low m/hp in large events	Undertake detailed flood analysis to determine assets at risk

- **Figure 12.1– Extent of Waterways included in Reach 9. Refer to Appendix I for Issues and Action details.**

12.1 Reach Location

This reach includes the mainstem of Howard Creek upstream of its junction with Native Youth Creek at Landsborough through to the headwaters and includes the directly connected tributaries (refer to Figure 12.1 for more detail).

12.2 Morphological Description

The mainstem of this reach is a relatively small 'U' shaped channel that has undergone some incision probably during the gold mining days. The channel is characterised by a continuous graded bed with occasional gravel bar riffles rather than the pool and run form noted downstream.

Flow is ephemeral and likely to be impacted by large diversions and dams throughout this upper catchment area. The tributary streams of R9/2/1 and R92/2 are diverted into the Landsborough Reservoir which is used to supply both Landsborough and Navarre. A bore near Wattle Creek Road north of Landsborough is used to supplement supply in dry years.

Reach 9/2/1 is showing some signs of degradation due to land disturbance and high energy of the reservoir overflow. Historic sluice mining in the upper catchment has left a legacy of a highly eroded and disturbed channel that is still showing signs of bank and bed erosion, particularly near the road crossing upstream of Shays Flat Road. Investigation of a series of grade controls in this reach is warranted.

Most of the eastern tributaries forming part of the Native Youth Creek are relatively short and do not show any significant sign of serious erosion. A series of existing large on-stream dams will mitigate any heavy sediment loads to the creeks. Native Youth Creek was seen to be basically stable except for a small segment upstream of Vendy Lane which has minor bank erosion and a weed management problem. Only the lower segment of R8/1/2 is showing signs of erosion that should be monitored.

Erosion and gully formation in the western tributaries of the sedimentary foothills are pronounced with serious erosion in R9/6 and R9/7. These streams transport large loads of sediment that discharge directly to the streams without any mitigation. Remediation works should be undertaken to arrest the advance of the erosion. An old drop structure and ford on Howards Creek at Browns Lane needs some remedial works and grade control.

12.3 Vegetation

The vegetation along the main stem of Howards Creek is fairly extensive and wide but becomes narrow and discontinuous upstream of Browns Lane through the upper catchment before it goes back into the old Crown Reserve south Shays Flat Road. The encroachment of vineyards into the stream riparian zone limits the re-establishment of a good riparian vegetation community.

Most of the tributaries are without significant overstorey and or midstorey vegetation before the start of the State Forests of the Landsborough Range. Erosion is evident where uncontrolled stock access occurs. The introduction of a sedge groundcover and understorey to would help arrest erosion processes, and contribute to the lowering of erosion and transport of solids and turbidity from the catchment.

Reasonable reserves of remnant vegetation are present within the reach, largely due to the presence of the State Forests of the Landsborough Ridge. Vegetation of the lower slopes and valley floor, and particularly the drainage line is scarce. The majority of EVC's that are likely to have occurred prior to European settlement are still present within the reach (although largely restricted to the upper slopes). Of note is one patch of remnant vegetation mapped within the riparian zone in the southern portion of the catchment. Table 12-1 below lists the remant vegetation currently present and thought to have occurred prior to European Settlement.

- **Table 12-1 - Current and Pre-European Vegetation Attributes (EVC) Reach 9**

Current EVC Remaining in Reach (DSE, 2005)	Pre 1750 EVC's in reach (DSE, 2003)	Location
	20 – Heathy Dry Forest	Upper slopes, skeletal soils
22 – Grassy Dry Forest	22 – Grassy Dry Forest	Lower slopes and alluvial plain outside riparian influence
	23 – Herb-rich foothills Forest	Lower slopes on fertile soils
47 – Valley Grassy Forest	47 – Valley Grassy Forest	Alluvial terrace and lower slopes outside of riparian influence
61 – Box Ironbark Forest	61 – Box Ironbark Forest	Upper slopes of the lower ridges
67 – Alluvial Terrace Herb-rich Woodland	67 – Alluvial Terrace Herb-rich Woodland	Alluvial terraces
70 – Hill Crest Herb-rich Woodland	70 – Hill Crest Herb-rich Woodland	Upper slopes with skeletal soils
76 – Low Rises Grassy Woodland	76 – Low Rises Grassy Woodland	
	175 – Grassy Woodland	

The patch of Valley Grassy Forest remaining within the drainage line in the southern portion of the reach requires urgent attention to secure the area form stock pressure. As the only remaining EVC listed within the riparian zone of the catchment, this should be undertaken as a matter of urgency. The remaining riparian zone should also be fenced allowing the natural regeneration to follow down catchment once stock pressures have been removed. The re-establishment of overstorey species in secured areas would increase the rate of natural regeneration.

12.4 Habitat

As with the whole of the Howard Creek system which is a seasonal stream at best, there was no evidence of any permanent residual pools in the mainstem except maybe in a wet year, which would maintain any significant instream fauna. Hence, the presence of any permanent instream communities is unlikely to occur, but the normal range of ephemeral life forms may occur. There has not been a definitive study of the instream fauna in this area. As with previous reaches a comprehensive study of the instream ecosystem needs to be undertaken to get a better understanding of the system and aid management in the future.

There are very limited habitat values in most of the ephemeral and lateral tributaries as they are ephemeral.

12.5 Water Quality

Again the water quality of this reach is hard to discuss due to a lack of historical data as well as the whole creek system being dry at the time of inspection. However there are indications that sediment transport and high turbidities will occur in rainfall events. There are signs of erosion product transport along the mainstem with some gravel banks appearing.

It is likely that the streams will be high in suspended solids and turbidities under rainfall conditions given the degree of historic catchment disturbance due to gold mining and also the more recent impacts arising from vineyards and grazing.

Interestingly the runoff from the forested catchments is likely to be high in suspended solids and turbidity due to the allowance of grazing in the forest until relatively recently. This has seen the forest groundcover depleted and exposure of the erodible substrate to occur.

The township of Landsborough is unsewered and it is likely that the residual products from septic and sullage will find their way to the creek via the gravel seams of the valley floor. No data is available to make comment on the seriousness of this issue.

12.6 Flooding

Flood mapping for this reach (DSE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources) indicates that flooding will occur down the narrow flat floors of the valleys. The most significant flooding issue is within the Landsborough Township, where flood breakaway is likely between Native Youth Creek and Howards Creek in several locations. The extent of flooding ad threat to commercial of private assets has not been studied in detail but anecdotal information indicates that several lower lying properties may be threatened. The flooding is mainly due to limited channel and or culvert capacities. Obviously under this situation flood safety on road crossings may be an issue.

No flood warning depth indicators are located within the town in any of the likely problem locations.

12.7 Threats and Priorities

The following table summarises the major threats that have been identified in Reach 9. For specific details on issues, actions, locations, priorities and cost estimates, refer to Appendix I – Reach 9 Summary of Issues and Actions.

Table 12-2 – Threats and Priorities identified in Reach 9

Threat	Priority
Further loss of habitat and riparian vegetation along Howards Creek mainstem	Very High
Very Active head and gully erosion in streams R9/6 and R9.7 leading to sediment transport to the mainstem	Very High
Active stream erosion at Browns Lane ford and drop structure crossing	Very High
Active bed and bank erosion on mainstem upstream of Shays Flat Road junction	Very High
Minor bed and bank erosion in reaches R9/1 and R9/2 downstream of the reservoir	High
Lack of riparian vegetation along most tributaries impacting on long term stability and production of erosion products	High
Stock access to stream zones in both mainstem and eroding areas of tributaries	High
Road safety at Browns Lane crossing under flood events	Moderate
Flooding in Landsborough township associated with Breakaway flows from Native Youth Creek could threaten private and commercial assets	Moderate

- **Figure 12.2 – Active erosion**

Figure 12.3 – Active erosion

13. Summary

Specific issues and actions for the **nine** individual reaches are shown in the following reach activity spreadsheets (Appendix A to Appendix I). These sheets detail the recommended actions and have been grouped according to activity headings, namely:

- Stream systems and ecology (E);
- Stability (S);
- Water quality (W);
- Vegetation management (V); and
- Flood management (F).

A catchment wide summary of each of the above activity headings has also been compiled. These sheets (Appendix J through to Appendix N) combine the data previously presented by reach, in a single table and have been ranked by priority.

A list of Wimmera CMA incentive rates is shown in Appendix O. for more information on incentives, refer to Wimmera CMA '*Healthy Waterways Incentive Scheme*'.

A whole of catchment map that includes aerial photography, site specific issues and actions is shown in Appendix P. Note: It is recommended that this map be printed at A0 scale for best results.

14. References

Coffeys, 1997a. Iron Pot Creek project hydrological investigation, Crowlands, Victoria. Coffey Partners International Pty Ltd, August 1997.

Coffeys, 1997b. Iron Pot Creek project permeability testing and additional field observations, Crowlands, Victoria. Coffey Partners International Pty Ltd, November 1997.

Crouch, R.J., 1987. The relationship of gully sidewall shape to sediment production. Australian Journal of Soil Research, 25: 531-9.

DNRE. *Flood Data Transfer Project*, www.dse.vic.gov.au/Interactive maps/Victorian Water Resources

DNRE, 2002. Victorian River Health Strategy. www.nre.vic.gov.au/vrhs

DSE, 2005 1:100,000 Biomap Beaufort (7523). Department of Sustainability and Environment, Melbourne.

DSE, 2005. Victorian Bioregions, Flora and Fauna Program.

Dietrich, W.E., C.J. Wilson, D.R. Montgomery, J. McKean and R. Bauer, 1992. Erosion thresholds and landsurface morphology. Geology, 20: 675-9.

Doeg, T. J. (2000). Phase 1 Environmental assessment for the project "Regionaldevelopment and water resource management plan for the upper Wimmera and Avoca catchments: Upper Wimmera case study". Timothy J. Doeg Environmental Consultant, Northcote.

Dollar, E.J.S., 2000. Fluvial Geomorphology. Progress in Physical Geography, 24(3): 385-406.

Graf, W.L., 1977. The rate law in fluvial geomorphology. American Journal of Science, 277: 178-91.

Holwell, G., Serena, M and Williams, G.A, 1998. Ecology and conservation of platypus in the Wimmera River catchment. II. Results of radio-tracking and habitat studies, winter 1998. (Report to Earthwatch Australia and Rio Tinto Project Platypus). Australian Platypus Conservancy, Whittlesea.

Horton, R.E., 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geological Society of America Bulletin, 56: 275-370.

Morgan, R.P.C. and D. Mngomezulu, 2003. Threshold conditions for initiation of valley-side gullies in the Middle Veld of Swaziland. Catena, 50: 401-14.

Prosser, I.P. and C.J. Slade, 1994. Gully formation and the role of valley-floor vegetation, southeastern Australia. Geology, 22(1127-1130).

Prosser, I.P. and B. Abernethy, 1996. Predicting the topographic limits to a gully network using a digital terrain model and process thresholds. Water Resources Research, 32(7): 2289-98.

R Carter, *pers comm*, Salinity Levels in the Lower Wimmera Catchment (On-going), WCMA 2005.

Schumm, S.A., M.D. Harvey and C.C. Watson, 1984. Incised Channels: Morphology, Dynamics and Control. Water Resources Publications, Littleton, Colorado.

Serena , M and Williams, GA, 1998. Ecology and conservation of platypus in the Wimmera River catchment. I. Results of population surveys, 1997 - 1998. (Report to Earthwatch Australia and Rio Tinto Project Platypus). Australian Platypus Conservancy, Whittlesea.

Serena , M and Williams, GA, 1999. Ecology and conservation of platypus in the Wimmera River catchment. III. Results of population surveys, April-November 1999. (Report to Earthwatch Australia and Rio Tinto Project Platypus). Australian Platypus Conservancy, Whittlesea.

Serena , M and Williams, GA, 2002. Ecology and conservation of platypus in the Wimmera River catchment. V. Results of population surveys, March 2000-April 2002. (Report to Rio Tinto Project Platypus). Australian Platypus Conservancy, Whittlesea.

SKM, 2003. Environmental Flows, Avoca, Glenelg and Wimmera River. Wimmera Catchment Management Authority, Vic.

Victorian Resource Data Warehouse (http://www.vicwaterdata.net/ vicwaterdata/home.aspx)

Young, A. and R. Young (eds.), 2001. Soils in the Australian Landscape. Oxford University Press, Melbourne.

Wimmera CMA, May 2005. Draft Wimmera Waterway Health Strategy.

Wimmera CMA, April 2003. Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment.

Wimmera CMA, 2002. Wimmera River Geomorphic Investigation, Sediment Sources Transport and Fate.

Wimmera CMA, 2003. Wimmera Regional Catchment Strategy.

Wimmera CMA, August 2003. Wimmera Salinity Action Plan.

Wimmera CMA, October 2002. Wimmera Water Quality Strategy.

Worley, M and Serena, M, 2000. Ecology and conservation of platypus in the Wimmera River catchment. IV. Results of habitat studies, Summer 1999. (Report to Rio Tinto Project Platypus). Australian Platypus Conservancy, Whittlesea.