



River Action Plan for the Upper Collie Catchment



Centre of Excellence in Natural Resource Management,
University of Western Australia

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River Action Plan for the Upper Collie Catchment

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by

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The University of Western Australia



Government of **Western Australia**
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Water for the Future

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HOW TO USE THIS RIVER ACTION PLAN

This River Action Plan (RAP) was prepared by the Centre of Excellence in Natural Resource Management (CENRM), The University of Western Australia, with cooperation the of landholders within the Upper Collie River Catchment. It contains a detailed description of the current ecological health of the waterways, provides information on current management issues, and recommends strategies to address these issues.

Landholders may find this a useful tool to help manage their waterways, while community groups may find it helpful to prioritise actions to make the best use of limited resources. For others, it will provide background information to aid decision-making.

For Landholders

Landholders should turn to their relevant map in Section 5 and read the associated management issues and recommendations. They should then read Section 6 to determine why these issues are considered to be a priority for remediation, and Section 7 to determine the most appropriate actions to address these issues. Information on the general study area and methodology used to develop this Action Plan can be found in Sections 1, 2, 3, 4 and 6.

For State Government and Regional & Sub-regional NRM groups

Section 5 contains detailed information on management issues for each segment of the waterway ('reach'). The Appendices provide technical advice on how to best address and practically 'deal' with these management issues and relevant pages should be read carefully prior to implementation.

The Appendices provide further information that may be useful to landholders and community groups:

- Native vegetation of the Collie River Catchment;
- Common weeds found in the study area;
- Planning advice;
- Permits required prior to commencing river works;
- Landcare Project time line;
- Best Management Practice (BMP); and,
- Useful contacts and phone numbers.

Acronyms used in the Report

RAP	River Action Plan
NHT	Natural Heritage Trust
CfOC	Caring for Our Country
DEC	Department of Environment and Conservation (previously CALM)
WRC	Water and Rivers Commission (now DoW)
DoW	Department of Water (previously DoE)
CALM	Department of Conservation and Land Management (now DEC)
DoE	Department of Environment (previously CALM)
DAFWA	Department of Agriculture and Food, Western Australia

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The Shire of Collie provided information on land tenure, vesting and property owners.

This River Action Plan (RAP) has drawn extensively from the RAP work of Leigh Taylor (Brunswick River), Cathie Derrington (Upper Preston) and Leigh Shinde-Taylor (Lower Collie Catchment). The effort these authors have put in to these RAPs is gratefully acknowledged.

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SUMMARY

The study area is generally referred to as the Upper Collie River Catchment (the section above the Wellington Dam) and the Lower Collie River (below the Wellington Dam). This study is of the Upper Collie River and is concerned with approximately 81 kms of major river, consisting of Collie River Central, Collie River South, Collie River East and the Harris River.

The aim of this River Action Plan (RAP) is to provide information to landholders, interested community members, and organisations on the ecological health and current condition of the Upper Collie River System and make general, and in some situations, specific recommendations on how to improve the management into the future.

Foreshore assessments were carried out during April and May 2009 using the Foreshore Condition Assessment method developed by Dr Luke Pen and Margaret Scott for rivers in the South-West of Western Australia (Pen and Scott 1995). The survey sites were taken at approx. 300 meter intervals.

A summary of the foreshore condition ratings (Pen-Scott) and length of fencing of the main river channels in the catchment is presented in Tables 1 and 2.

Table 1: Summary of foreshore condition rating of Upper Collie Rivers.

Foreshore condition	Total length (kms)*	Total %
A1	3.7	2.3
A2	17.7	10.9
A3	12.4	7.7
B1	8.3	5.1
B2	7.2	4.4
B3	23.2	14.3
C1	75.0	46.4
C2	12.9	8.0
C3	1.4	0.9

* Both banks combined i.e. 161.8kms

Further explanation about the Pen-Scott survey methodology and categories (as foreshore condition) is presented in Section 3.

Table 2: Length of fenced embankments on Upper Collie Rivers.

Fencing category (meters)	Total length (kms)*	% of length
0 (zero)	106.4	65.8
1 – 75	2.1	1.3
76 – 150	9.4	5.8
151 – 225	5.1	3.2
226 - 300	38.8	24.0

* Both banks combined i.e. 161.8kms

Section 7 of this Report provides an overview of the State-wide Waterways Management Framework methodology (see Macgregor et al. 2009) along with the major findings from the study area. In short, the methodology used a values-threats approach where the high values – high threats sites are considered a priority over medium value and low value sites. As will become apparent in the reach descriptions (Section 5), the Waterways Framework has been used to draw attention to the higher priority sections of each reach. Responsible landholders and government agencies that may be considering management actions are encouraged to tackle the higher value sections before the medium and low value sections.

Table 3 summarises the management priority rankings found for the rivers in the study area, which was divided into 217 individual survey sites.

Table 3: Site management priority rankings

Sub-priority ranking	No of survey sites	Total %
High value – high threat	1	0.5
High value – medium threat	8	3.7
High value – low threat	11	5.1
Medium value – high threat	5	2.3
Medium value – medium threat	40	18.4
Medium value – low threat	12	5.5
Low value – high threat	21	9.7
Low value – medium threat	82	37.8
Low value – low threat	37	17.0

Further discussion about the Waterways Management Framework and the values-threats criteria is presented in Section 3.

Key issues identified

The key issues of concern identified during the foreshore assessments and detailed community consultations were:

- *Loss of native fringing vegetation and degradation of remaining vegetation;*
- *Weed invasion;*
- *Erosion and sedimentation of the waterways;*
- *Water extraction and regulation;*
- *Water quality issues, including nutrient enrichment, pollution and salinity; and,*
- *Need for technical assistance for landholders planning to protect and enhance the foreshore by fencing revegetating.*

General recommendations to improve the health of the Upper Collie Catchment

It is recommended that the Upper Collie River stakeholders, both government and private, consider the following:

- Landholders are encouraged to fence the river to restrict/control stock access;
- Government agencies and landholders are encouraged to apply for further funding to continue to subsidise the cost of revegetation projects including fencing;
- The protection of remnant areas of the river still retaining native fringing vegetation (especially those identified as ‘high-value’) should be protected and enhanced as a priority. It is far more cost-effective to protect these areas now than to attempt to restore them later after further degradation has occurred;
- Wherever possible landholders and weed action groups should undertake revegetation using a diverse suite of local (provenance) native species (including trees, shrubs, sedges, rushes, herbs and native grasses);
- Seek to expand and support weed and feral animal control projects in the catchment;
- Utilise best management practice (BMP) techniques that minimise soil erosion and nutrient loss to waterways such as buffer strips, soil testing and fertiliser management plans, and maximising vegetation cover on the soil;
- Landholders should work with engineers from the Department of Environment and Conservation (DEC) to address serious erosion and sedimentation problems;
- DEC should expand their water monitoring program of the Upper Collie Rivers to address community concerns in regards to nutrient levels, contamination and salinity;
- Water Sensitive Urban Design (WSUD) principles should be utilised in any new and existing residential developments;
- Use ‘clean site’ building techniques to reduce the impact of urban development on the water quality of the Upper Collie River;
- Local government and developers in the Upper Collie River should seek to implement Foreshore Management Plans in a timely and effective manner;
- Landholders are encouraged to use Best Management Practices on rural drains.

1. INTRODUCTION

Background

The rivers of south-western Australia are characterised by varying levels of degradation. The larger river systems with headwaters to the east of the Darling Scarp (Swan-Avon, Blackwood and Murray) are influenced by secondary salinisation and, as a consequence, are not impounded for water supply (Bunn and Davies 1992). In contrast, the shorter (e.g. first and second order) streams arising on the west of the Darling Scarp are fresh and consequently almost all have been regulated for water supply (Kite et al. 1997).

The Collie River is a major river system in the south-west of Western Australia flowing through the town of Collie in south-western Australia. The river has been impacted by a range of land-uses and substantial levels of regulation (e.g. Harris River Dam, Wellington Dam). Since the catchment was cleared, salt from the soil has flowed into the river systems causing parts of the river to become saline – saline water flows into Collie River East and Collie River South (DoW 2007). DoW is diverting saline water from Collie River East to prevent it flowing downstream and entering Wellington Reservoir. Diverted water is pumped to a coalmine void for storage. The salinity recovery program is on target to restore fresh water quality water to the reservoir by 2015 (DoW 2008).

Coal mining is a very important economic activity within the catchment and Collie Coal Basin is declared a Groundwater Management Area. Groundwater is withdrawn from the Collie Coal Basin for a variety of reasons but especially power generation and mine dewatering. Dewatering takes place to ensure mine workings are more stable and this has the potential to reduce flow in Collie River South resulting in less water in the pools (Beckwith 2007). Long-term and large-scale abstraction for power station water supply, particularly from the Cardiff sub-area, has also modified the groundwater system (DoW 2007). Abstraction in excess of annual recharge has led to a basin-wide decline in groundwater levels by approx. one metre across the basin but in some parts the water table is more than 50 metres below its estimated natural state (DoW 2008).

The river is considered a major environmental asset in the area and for Collie Town. The condition of the main rivers in the catchment, especially the presence of the aquatic plant Nardoo (*Marsilea mutica*) in the 8km stretch of the Collie River through the town of Collie, has been a contentious issue for many years (Davies et al. 2008).

Upper Collie River Action Plan – Study Aims

The primary aim of this study was to:

- Develop a River Action Plan (RAP) for waterways within the Upper Collie River Catchment that will provide clarity and direction for government and community stakeholders to cooperatively maintain and improve the ecological health of the catchment waterways.

There were five objectives devised to meet this stated aim:

1. Identify, collate and describe the known ecological, cultural and social values of the Upper Collie waterways;
2. Assess the condition of distinct foreshore reaches within the project area, against recognised condition grading methodology supported by weed and erosion mapping assessments;
3. Assess risk, threats and conflicts associated with adjacent land use to the foreshore;
4. Review and amend as necessary the South West Catchment Council's Waterways Decision Support System for the reaches within the project area; and,
5. Review and assess current waterways management practices and make recommendations for management, practical restoration and protection.

2. STUDY AREA

The study area is defined by Figures 1a and 1b. The project includes the reaches of the upper Collie River extending upstream from the Mungalup Tower gauging station on Collie River Central, to Lake Kepwari on the South Branch, the old Griggs Road Bridge on the East Branch and up-stream to the Harris Dam and Harris River.

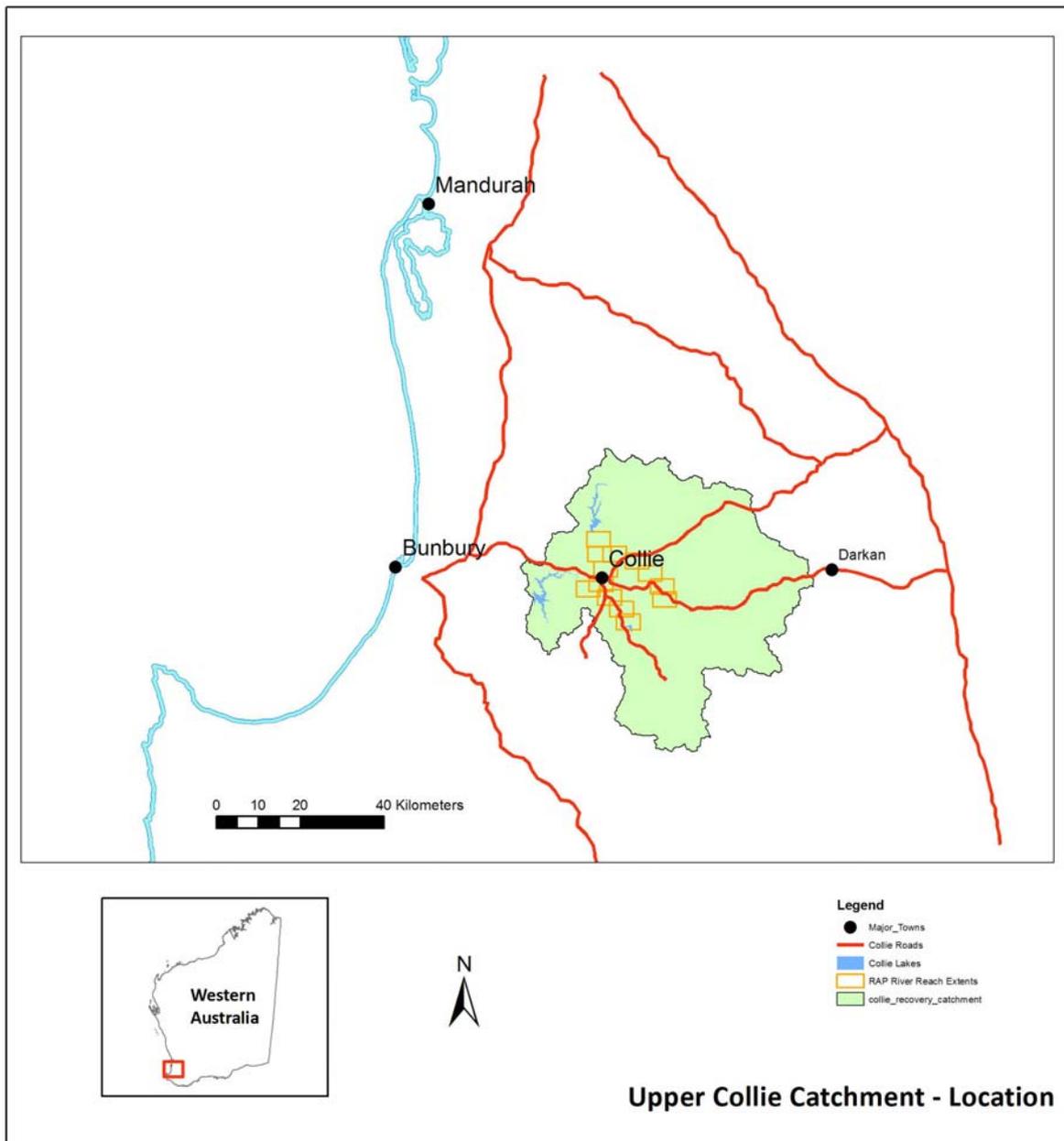


Figure 1a: The location of the Upper Collie Catchment study area

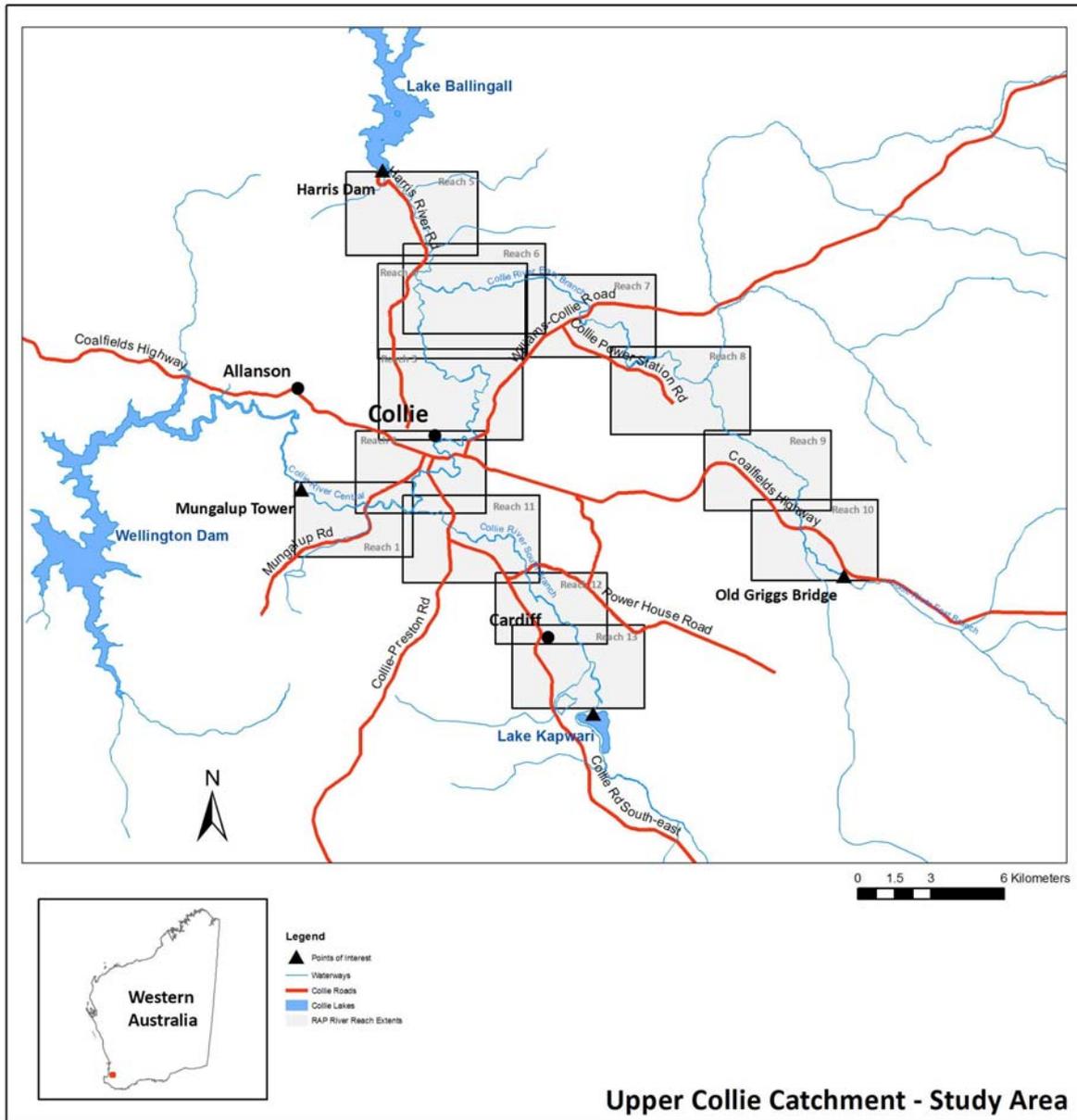


Figure 1b: The location of the Upper Collie Catchment study area

Catchment Description

The Collie River upstream from the Wellington Dam is a Water Resource Recovery Catchment described in the Western Australian State Salinity Strategy and covers an area of 2827km² (Mauger et al. 2001). The Collie River is affected by secondary salinisation in the upper reaches but becomes less saline as tributaries input fresh water from higher rainfall and forested areas (Davies 2003).

The major mining activity in the catchment is the extraction of coal. The Collie Coal Basin is a declared Groundwater Management Area and the groundwater from this basin discharges into the Collie River and tributaries. A stakeholder consultation (Beckwith 2007) found stakeholders recognised the necessity for abstraction of groundwater, the rate of withdrawal was of concern, including the potential for reduction in flow in the Collie River South, less water in river pools and bank subsidence (Beckwith 2007).

The majority of the upper catchment is forested and in the 2002 National Land and Water Resources Audit (NLWRA 2002) the catchment is described as in a 'moderate' condition compared with other catchments in Australia.

The river system

The Upper Collie River Catchment is the section above the Wellington Dam (the Lower Collie River lies below the Wellington Dam). This study is concerned with the Upper Collie Catchment that is approximately 81km in length, consisting of portions of the Collie River South, Collie River East and Harris River.

Climate

The climate of the Collie region is Mediterranean with hot, dry summers and cool, wet winters (Seddon 1972). Average annual rainfall is approximately 1200mm. Maximum rainfall generally occurs between May and September. Average annual evaporation rates for the catchment area vary from 1200mm to 1600mm, with monthly rates between 50mm in June and 300mm in January (Welker and Davies 2001). Rainfall is both seasonal and predictable; however, the Harvey region has received below average rainfall for the preceding 20 years (Welker and Davies 2001).

Climate change

The southwest of Western Australia has experienced a significant decline in rainfall since the 1960s (CSIRO 2001). Based on current models for global warming, CSIRO (2001) has predicted (by 2030) an increase in temperature for the southwest and a decreasing trend (-20% to +5%) in winter and spring rainfall and a $\pm 10\%$ change in summer/autumn rainfall. While the intensity of specific winter rainfall events may increase, their duration is expected to decrease. Correspondingly, the duration of drought events and rates of evaporation is also predicted to increase. The 20% decrease in southwest rainfall over the last 30-40 years has resulted in a 40% decrease in annual stream flow (CSIRO 1996).

Landforms and soils

The primary soils and subsystems of the Upper Collie are presented in Figure 2.

The Darling Range is the uplifted edge of the Yilgarn Block, part of the Precambrian Western Plateau which extends to the Goldfields. The Darling Range is an area of ancient, weathered rock (Mulcahy and Bettanay 1972) which has resulted in the very low nutrient status of upland streams (Bunn and Davies 1990). The Swan Coastal Plain is a deep sedimentary trough consisting of sandy aeolian soils with a sequence of alluvial clay soils along its eastern part. Soils of the Coastal Plain and the foothills are Pleistocene-Holocene in age while the Darling Range is dominated by Tertiary laterites over Achaean granites and metamorphic rock (Marchant et al. 1987).

The Upper Collie Catchment can be described by considering the description of the Lowden Valleys landform. The landform is made up of deeply incised valleys. The dominant geology is colluvium over metasediments and granite rocks. The soils are friable red/brown loam earths, brown loamy earths, loamy gravels, brown deep loamy duplexes, duplex sandy gravels and stony soils (Department of Agriculture 2005).

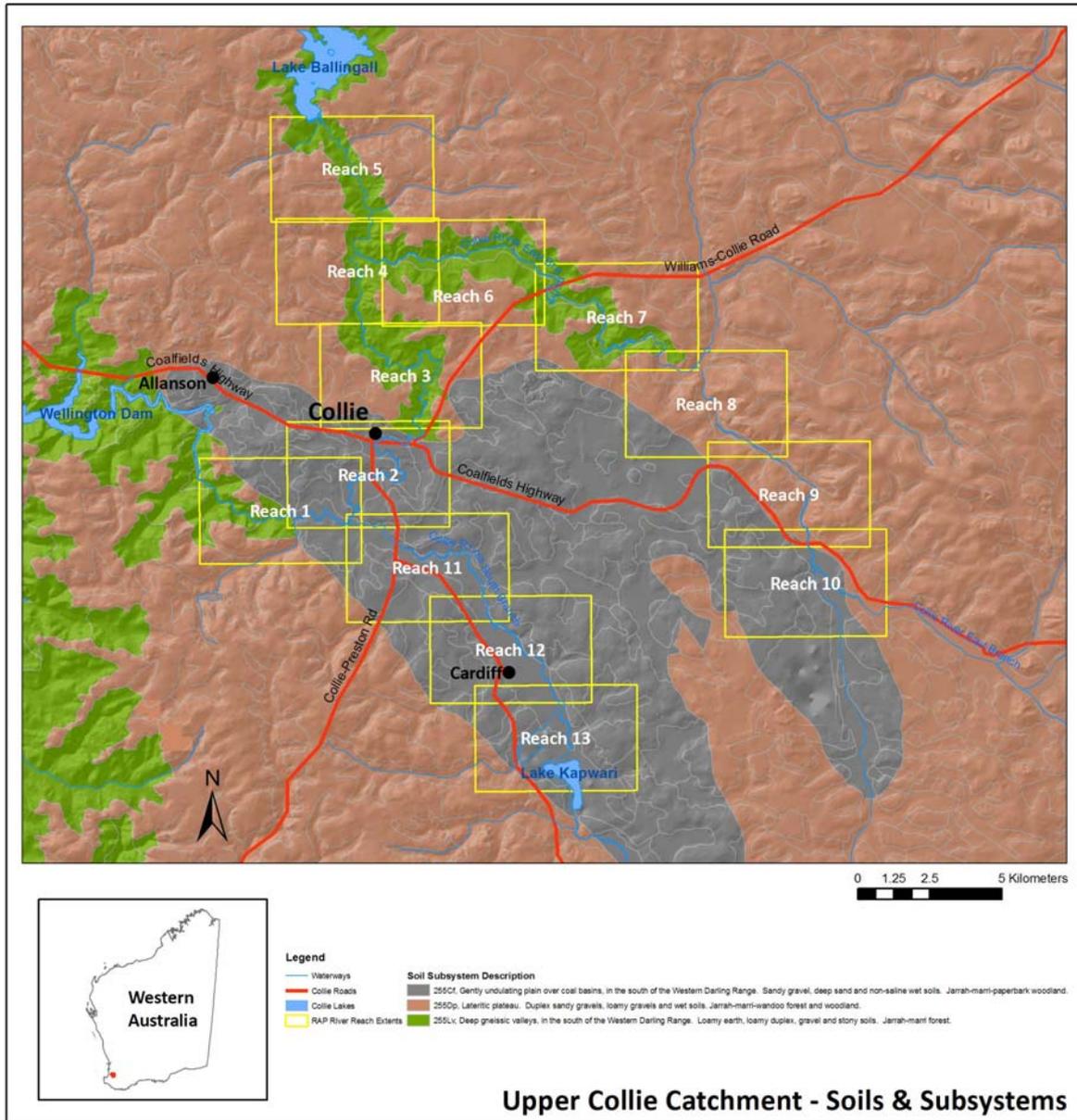


Figure 2: Upper Collie Catchment: primary soil subsystems

Vegetation communities

The primary vegetation communities (derived from Bell and Heddle 1989) of the Upper Collie are presented in Figure 3.

The lateritic soils of the Collie River catchment region of the Darling Range overlie granitic bed-rock and support a dry sclerophyll forest which is dominated by jarrah (*Eucalyptus marginata*), with marri (*Corymbia calophylla*) in some valleys (Shea et al. 1975). This over-story is occasionally replaced by other eucalyptus species including blackbutt (*E. patens*), bullich (*E. megacarpa*) and flooded-gum (*E. rudis*) (Bell and Heddle 1989). Some woodland areas are severely affected by jarrah dieback (*Phytophthora cinnamomi*). Blackbutt and flooded-gum are common along less degraded watercourses.

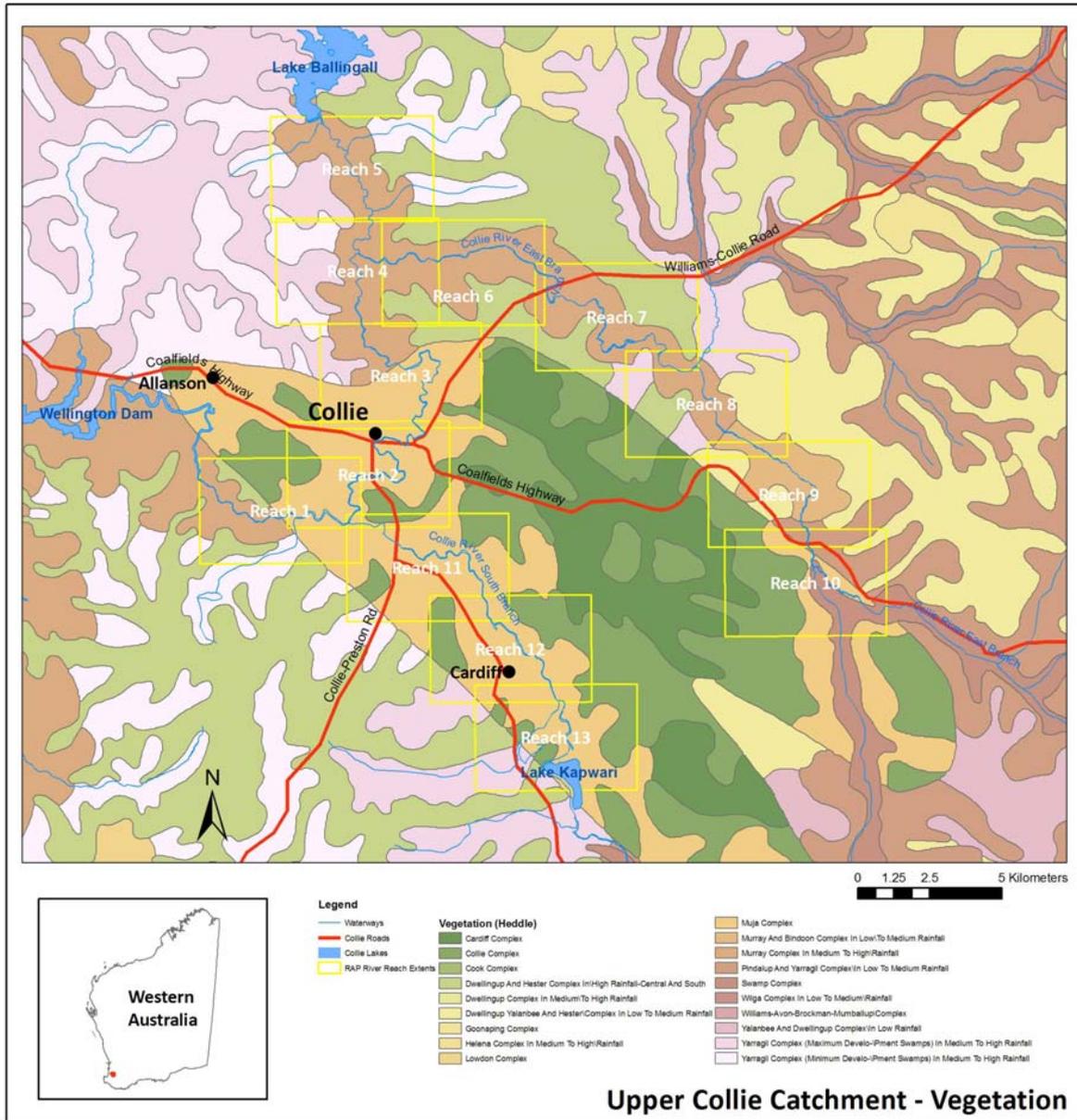


Figure 3: Upper Collie Catchment: vegetation communities (after Bell and Hedde 1989)

Historically, the understorey plants would have been dominated by white myrtle (*Hypocalymma angustifolium*), *Trymalium ledifolium* and *Astartea fascicularis*. However, very little of this understorey remains and the riparian understorey was characterised by dense sclerophyllous shrubs (e.g. *Taxandria linearifolia*, *H. angustifolium*, *Calytrix glutinosa* and *Hakea costata*) and sedges. Wetland and riparian vegetation on the Coastal Plain usually include flooded-gum (*Eucalyptus rudis*), *Melaleuca preissiana* and *M. raphiophylla* over heath (e.g. *A. fascicularis*, *Pericalymma ellipticum* var. *ellipticum*, *Regelia ciliata*, *H. angustifolium*) and sedgelands.

Aquatic fauna

A literature review undertaken by Sinclair Knight Mertz (2010) that considered aquatic fauna for the study area found a number of unpublished and published reports associated with aquatic fauna for the Upper Collie. The majority of these studies were undertaken as part of Environmental Water Requirement (EWR) and Environmental Water Provision (EWP) assessments, conducted between 1998 and 2009. The Department of Environment and Conservation (DEC) also surveyed aquatic macroinvertebrates at sites throughout the Collie Basin, between 1994 and 1999. These surveys were

part of the Australia-Wide Assessment of River Health (AWARH) program, the aim of which was to develop a standardised biomonitoring system for rivers (the AusRivAS models) (Halse 1999, 2002; Kay et al. 2000). In January 2009, the Upper and Lower Collie were sampled under a project aimed at assessing the *Framework for the Assessment of River and Wetland Health* (FARWH) to the flowing waters of the south-west of Western Australia (van Looij et al. 2009). Results from the 2009 sampling were made available for inclusion in this RAP by the Department of Water (DoW).

Table 4 summarises aquatic fauna (aquatic macroinvertebrates, crayfish, fish, tadpoles, tortoise and mammals) found in the primary branches of the Upper Collie.

River Action Plan for the Upper Collie River, 2010

Table 4: Values of known Upper Collie aquatic fauna with potential dependence on river-baseflow

Upper Collie Zones	Location	Aquatic Macroinvertebrates	Crayfish	Fish	Tadpoles*	Tortoise	Mammals	Potential River-Baseflow GDE
East Branch	Wargyl Pool, upstream of salinity diversion	10 Families, 14 Species (WRM 2007, SW FARWH 2009)	Koonacs (SW FARWH 2009). Gilgies may occur based on presence in adjacent reaches	Western minnow (WRM 2007, SW FARWH 2009)	Not surveyed	Absent during survey. Long-necked tortoise likely to occur based on anecdotal evidence	Water rats (DoW staff observation 2007)	Low to Medium
	Chicken Creek, Centaur Road	11 Families (SW FARWH 2009)	Gilgies, Koonacs (SW FARWH 2009)	Nightfish, Western minnow (SW FARWH 2009)	Not surveyed	'as above'	Not surveyed	Low to Medium
	Duderling Pool	28 Families, 66 Species (DEC 1994-99, WRM 2007)	Gilgies (DEC 1994-99, WRM 2007)	Nightfish, Western minnow, Pygmy perch (WRM 2007)	Absent during survey	Long-necked tortoise (DoW staff observation 2007, WRM 2007)	Water rats (DoW staff observation 2007)	Low to Medium
	Buckingham Bridge Pool	16 Families (DEC 1998-99)	Gilgies, Marron (DEC 1998-99)	Nightfish, Western minnow, Pygmy perch (WRM 2007)	Not surveyed	Long-necked tortoise (DoW staff observation 2007, WRM 2007)	Absent during survey	Medium to High
	Buckingham Town (Pumphouse) Pool	18 Families (DEC 1999)	Gilgies, Marron (DEC 1999)	Nightfish, Western minnow, Pygmy perch (WRM 2007)	Not surveyed	Long-necked tortoise (WRM 2007)	Absent during survey	Medium to High
	Pilatti's Pool	20 Families (DEC 1998-99)	Absent during survey. Gilgies and Marron may occur based on presence in adjacent upstream & downstream pools	Nightfish, Western minnow & Pygmy perch likely to occur based on presence in upstream pools	Not surveyed	Absent during survey. Long-necked tortoise likely to occur based on anecdotal evidence	Not surveyed	Medium to High
	Coolangatta Pool	27 Familie, 52 Species (WRM 2007, SW FARWH 2009)	Gilgies, Marron (WRM 2007, SW FARWH 2009)	Cobbler, Nightfish, Western minnow (WRM 2007, SW FARWH2009)	Absent during survey	'as above'	Water rat (P4) (WRM 2007)	Medium to High
	Collie River East Branch, Quinn's Road	6 Families (SW FARWH 2009)	Gilgies, Marron (SW FARWH 2009)	Cobbler, Nightfish, Western pygmy perch, Western minnow (SW FARWH 2009)	Not surveyed	Long-necked tortoise (SW FARWH 2009)	Not surveyed	Medium to High
	Sanctuary Pool	21 Families; Freshwater Mussel (P4) (DEC 1994-99)	Gilgies, Marron (DEC 1994-99)	Not surveyed. Nightfish, Western minnow & Pygmy perch likely to occur based on presence in upstream pools	Not surveyed	'as above'	Not surveyed	Medium to High
Harris River	Above Norm Road (below Harris Dam)	28 Families, 44 Species; <i>Glacidorbis</i> ¹ (IUCN VUN), Freshwater mussels ² (P4) (Streamtec 1997 ¹ , SW FARWH 2009 ²)	Gilgies, Marron (Streamtec 1997, SW FARWH 2009)	Nightfish, Western minnow, Western pygmy perch (Streamtec 1997, SW FARWH 2009)	Tadpoles - species unknown (DoW staff mid-1990s)	Absent during survey Long-necked tortoise may occur based on the known geographic range, but likely limited by lack of suitable habitat	Not surveyed	Medium to High
	Below Norm Road	33 Families, 69 Species (WRM 2009)	Gilgies, Marron (Beatty & Morgan 2005, WRM 2009)	Nightfish, Western minnow (WRM 2009)	Absent during survey	'as above'	Absent during survey	Medium to High
	Collie River confluence (Stubbs Farm)	25 Families, 43 Species; Freshwater mussels (P4) (DEC 1994-1999, Streamtec 1997)	Gilgies, Marron (Beatty & Morgan 2005)	Nightfish, Western minnow (Beatty & Morgan 2005)	Not surveyed	'as above'	Not surveyed	Medium to High
South Branch	Collie River South Branch, upstream of Lake Kepwari	12 Families (SW FARWH 2009)	Gilgies, Marron (SW FARWH 2009)	Nightfish, Western pygmy perch, Western minnow (SW FARWH 2009)	Not surveyed	Long-necked tortoise (SW FARWH 2009)	Not surveyed	Medium to High

River Action Plan for the Upper Collie River, 2010

Upper Collie Zones	Location	Aquatic Macroinvertebrates	Crayfish	Fish	Tadpoles*	Tortoise	Mammals	Potential River-Baseflow GDE
gilgies, long-necked tortoise and water rats noted as being present in 1999, along with fresh-water mussels (WEC 2001). Cobbler have also been previously identified in South Branch (WEC 2001) Tadpoles observed by DoW in mid-1990s	Long Pool	18 Families; Aeshnidae ¹ , Paramelitidae ² , Gomphidae ² (DEC 1998-1999 ¹ , Current study ²)	Gilgies, Marron (WEC 2001, Current study)	Nightfish, Western pygmy perch, Western minnow, (Morgan <i>et al.</i> 1996, Current study)	Glauert's froglet (Current study); Tadpoles (species unknown) (DoW staff observation mid-1990s)	Long-necked tortoise (Current study)	Absent during survey. Anecdotal evidence that water rats (P4) occur through-out the South Branch pools (WEC 2001)	Very High
	Walker's Pool	14 Families; Aeshnidae ¹ , Gomphidae ² (DEC 1998-1999 ¹ , Current study ²)	Gilgies, Marron (DEC 1998-1999, Current study)	Nightfish, Western pygmy perch, Western minnow, (Morgan <i>et al.</i> 1996, Current study)	Absent during survey	Absent during survey. Long-necked tortoise likely to occur based on anecdotal evidence (WEC 2001)	'as above'	High
	Cox Pool	10 Families (DEC 1998-1999)	Gilgies, Marron (DEC 1998-1999, Morgan <i>et al.</i> 1995)	Nightfish, Western pygmy perch, Western minnows (Morgan <i>et al.</i> 1998)	Not surveyed	'as above'	'as above'	Medium to High
	Townsend's Pool	13 Families (Current study)	Gilgies, Marron (Current study)	Nightfish, Western pygmy perch, Western minnows (Morgan <i>et al.</i> 1996, 1998, Current study)	Absent during survey	'as above'	'as above'	Medium to High
	Town (Cardiff) Pool	16 Families; Aeshnidae ¹ , Paramelitidae ² (DEC 1999 ¹ , Current Study ²)	Gilgies, Marron (DEC 1999, Current study)	Nightfish, Western pygmy perch, Western minnows (Morgan <i>et al.</i> 1996, Current study)	Glauert's froglet (Current study)	'as above'	'as above'	Very High
	Graham's Pool	16 Families ¹ ; Aeshnidae ¹ , Gomphidae ² (DEC 1999 ¹ , Current Study ²)	Gilgies, Marron (Current study)	Nightfish, Western minnows (Morgan <i>et al.</i> 1996, Current study)	Glauert's froglet (Current study)	'as above'	'as above'	High
	Piavinni's Pool	10 Families (DEC 1999)	Crayfish (unidentified) observed by DoW mid-1990s	Not surveyed. Nightfish and Western minnows likely to occur based on presence in adjacent upstream and downstream pools	Not surveyed	'as above'	'as above'	Low to Medium
	Chinaman's Pool	20 Families;Paramelitidae (DEC 1988-1999, Current study)	Gilgies, Marron (DEC 1988-1999, Current study)	Nightfish, Western minnows (Morgan <i>et al.</i> 1996, Current study); Cobbler (DoW staff observation 2010, downstream side of v-notch Shulz's weir)	Glauert's froglet (Current study)	'as above'	'as above'	Very High
	Mungulup Pool	16 Families ¹ ; Gomphidae ² (DEC 1998) ¹ , Current study ²)	Gilgies, Marron (DEC 1998, Current study)	Nightfish, Western minnows (Current study)	Absent during survey	'as above'	'as above'	Medium to High
	Collie River South Branch upstream of Minninup Pool	17 Families (SW FARWH 2009)	Gilgies, Marron (SW FARWH 2009)	Cobbler, Nightfish (SW FARWH 2009)	Not surveyed	'as above'	Not surveyed	Medium to High
	Minninup Pool	9 Families (Current study)	Gilgies, Marron (Current study)	Nightfish, Western minnows (Current study)	Absent during survey	'as above'	Not surveyed	Medium to High
	Collie River South Branch upstream of South Branch gauging station	10 Families; Gomphidae (SW FARWH 2009)	Gilgies, Marron (SW FARWH 2009)	Cobbler, Nightfish, Western pygmy perch (SW FARWH 2009)	Not surveyed	'as above'	Not surveyed	Medium to High
	Collie River	Collie River, down-	20 Families; Gomphidae	Gilgies, Marron	Cobbler, Nightfish,	Not surveyed	Long-necked tortoise	Not surveyed

River Action Plan for the Upper Collie River, 2010

Upper Collie Zones	Location	Aquatic Macroinvertebrates	Crayfish	Fish	Tadpoles*	Tortoise	Mammals	Potential River-Baseflow GDE
	stream of Mungulup Tower gauging station	(SW FARWH 2009)	(SW FARWH 2009)	Western pygmy perch (SW FARWH 2009)		(SW FARWH 2009)		

*There are additional species of frogs likely to occur at all sites, based on the known geographic range of the species and the availability of suitable habitat (Bamford & Watkins 1983, Watkins 1983, Cogger 1992). However, the extent to which these species rely on river pools and base-flows for breeding, is unknown. Species that may breed in river pools and still shallow backwaters and which may be at risk from groundwater drawdown include, the western banjo frog, Lea's frog, Gunther's Toadlet and the motorbike frog. It is considered that the risk to these species will low in reaches with higher than historic water tables *e.g.* across the Swan Coastal Plain. Though tadpoles of these species are often encountered in river pools and small, shallow creeklines, the majority breed in off-channel wetlands, swamps and bogs, and as long as these habitats continue to be available, local populations will be at low risk from reductions in river baseflow.

Heritage

The Upper Collie River Catchment has significant Indigenous and non-Indigenous cultural values.

Indigenous heritage

The Aboriginal peoples of the South West Region, prior to European contact, formed a distinctive socio-cultural group collectively known as Nyungar (O'Connor et al. 1995). A painting by John Sara tells the story of how the Ngarngungudditj Wargul, or Hairy-Faced snake, came down from the north of Collie a long time ago, to form the rivers within the Leschenault Catchment.

“The snake came down through Collie creating the hills and rivers down to Turkey Point and Eelaap. He pushed his big body and turned to form the estuary and Koombana Bay. He then came back up the Collie River to a place called Minninup Pool. When the moon is high in the sky you can see his spirit resting there. Koombana Bay was a beautiful sea bay and Turkey Point was an Aboriginal ceremony camping ground. The Wargul (note initial spelling) is the great mythical snake that controls the lives, actions, totems and beliefs of the Nyungar people.” This story was told by John Sara with special thanks to George E. Webb (dec), elder Wardandi Tribe, Busselton and Joseph Northover, Collie Nyungar.

A study carried out by Beckwith Environmental Planning (2009) is reported as *Nyungar Values of the Collie River*. The findings of this study, as they relate to the Upper Collie Catchment, are included in this report and are as follows. The study identified 14 specific sites of significance to Aboriginal people alongside the main rivers in the study area (Table 5). In fact, the entire Collie River and its tributaries including the Harris River (are considered sacred) and it is a registered mythological site under the *Aboriginal Heritage act 1972* (site ID 16713), not only as a water source, but also because of its significance in relation to the Waugal. But as Table 14 reveals there are other more specific sites within the rivers themselves, or within the riparian zone, which are also important. However, as the Beckwith (2009) study demonstrated, not all known Aboriginal sites are registered in the Department of Indigenous Affairs' WA Register of Aboriginal Sites.

Table 5: Registered & important Indigenous sites located on rivers of the Upper Collie

Site name	Site ID	Site type	Additional information	Reach Map ref
Collie Spring	4699	Mythological, historical	Water source	Reach 2 AH 01
Minninup Pool	15330	Mythological; swimming, picnicking, fishing, gathering		Reach 1 AH 02
Shotts Graves	15331	Skeletal material/burial, modified tree		Reach 9 AH 03
Telfer Pool	4579	Ceremonial; corroboree ground		Reach 3 AH 04
Eight Mile Pool	4690	Ceremonial, mythological	Camp	Reach 3 AH 05
Ewington Spring	15333	Not identified in register	Water source	Reach 2 AH 06
High Chaparral Camps	15335	Not identified in register; permanent camp, marron, fish	Camp	Reach 2 AH 07
White City Camp	16003	Not identified in register; residential housing	Camp	Reach 2 AH 08
Mungalup Tower	N/A*	Swimming, marroning		Reach 1 AH 09
Duderling Pool	N/A*	Camping, fishing, swimming, marroning, hunting		Reach 10 AH 10
Buckingham Pool	N/A*	Camping, fishing, swimming, marroning, permanent camp		Reach 10 AH 11
Monong	N/A*	Camping, fishing, swimming, marroning		Reach 8 AH 12

Railway bridge/Jum's Pool	N/A*	Fishing, swimming, marroning	Reach 13 AH 13
Long Pool	N/A*	Fishing, swimming, marroning	Reach 13 AH 14

* These sites have not been registered in the WA Register of Aboriginal Sites (Dept of Indigenous Affairs) but are identified in *Nyungar Values of the Collie River* report (Beckwith Environmental Planning 2009).

For ease of reference the sites contained in Table 14 are identified on the reach maps by way of an orange triangle symbol with a reach map reference number (e.g. Reach 2, AH 07).

Under the *Aboriginal Heritage act 1972* approval must be obtained from the Minister for Indigenous Affairs for works on Aboriginal sites. These include activities such as river restoration (Bucktin 2002). Anyone intending to carry out river restoration activities on Aboriginal sites should be aware of their obligation under the *Commonwealth Native Titles Act 1993* and the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*. The Department of Water had developed a Pilot Study for anyone considering carrying out on-ground works at Aboriginal sites, available from:

<http://swcatchmentscouncil.com/uploads/File/ACEG-D-04-a%20Mar%2008.pdf>

European heritage

In 1829, Dr Alexander Collie and Lieutenant William Preston jointly discovered the Collie and Preston rivers, giving their surnames to the respective rivers. Dr Alexander Collie could hardly have foreseen that a town, some 40km upstream from his nearest contact would also take his name (Williams 1979).

Further exploration of the river occurred a year later when Lieutenant Governor Sir James Stirling's expedition recognised the potential of the land for agricultural use. The Collie River Valley was later used for beef and sheep grazing. In the early 1880's, coal was found near the river and by the late 1880's the area around Collie was recognised for its coal resources (CALM 2005).

Collie has grown to be one of the most important mining towns in the state, supplying coal from 1961, for the generation of electricity (CALM 2005). Following the discovery of coal and the development of transport facilities the increased infrastructure stimulated the timber industry (Williams 1979). The mills provided timber to the mining industry and the railways. Two of these mills that began operation in the 1940's are still in operation today (CALM 2005).

In 1931, the Wellington Dam was constructed for the Collie Irrigation Scheme; at the time of its construction it was the largest in Western Australia (CALM 2005).

Many sites along the rivers of the Upper Collie can be regarded as having value; examples would include river pools (most of which are also sites of special significance to Aboriginal people), parks, camping areas, walking tracks, swimming areas, fishing sites etc. But other sites of value are indicative of historical use e.g. old bridges and jetties. Many of these sites have also been identified on the reach maps (as yellow triangles). While these sites may not be protected by law in the same manner as Aboriginal sites, anyone carrying out river restoration activities should be cognisant of their social value and make every effort not to cause any unnecessary damage.

A full list of the ecological, social and economic value parameters considered important to waterways (values) is provided in the following section (Section 3).

3. STUDY METHODOLOGY

The approach used in this study incorporated two methodologies: the WA Waterway Values-Threats Assessment Framework developed by Macgregor et al. (2009) and the River Foreshore Condition Assessment methodology developed by Pen and Scott (1995). The Pen-Scott (1995) methodology was enhanced by considering additional river erosion and sedimentation criteria (as discussed below).

Waterways values-threats framework

The State-wide Waterways Management Framework was designed to provide State Government agencies and others involved in river management with an objective and systematic method for prioritising management. The Framework uses a values-threats approach adopted by the State for all Natural Resource Management (NRM) contexts and is similar to the Department of Environment’s *Salinity Investment Framework*.

Waterway values

Waterway values are classified across three dimensions in the Framework (ecological, social and economic) and for each dimension values criteria are identified (Table 6).

Table 6: Values criteria for waterways management

Ecological values	Social values	Economic values
- Naturalness/condition	- Visual amenity	- Water & mineral extraction
- Representativeness	- Recreational	- Commercial
- Diversity or richness	- Non-Indigenous heritage	- Infrastructural
- Rarity	- Educational	
- Special features	- Indigenous jurisdiction	
	- Spiritual	
	- Hunting/gathering	

(Macgregor et al. 2009)

To develop a holistic prioritisation for management actions for the Upper Collie, this study collected data to represent all three dimensions and these determined the prioritisation classification (e.g. medium value/high threat (MV/HT)) displayed in the maps in Section 5.

The values criteria considered during the prioritisation classification procedures were as follows:

Ecological:

- *Naturalness* (channel modifications; Pen-Scott (1995) rating – left & right banks; riparian cover (%) – left & right banks)
- *Diversity* (species in riparian zone; submerged vegetation; emergent vegetation; woody debris)
- *Special features* (land use e.g. reserves, forestry, agriculture, urban)

Social:

- *Visual amenity* (aesthetic appeal; picnic sites; lookouts)
- *Recreational* (fishing; camping; walking; horse riding; swimming; golfing; boating)
- *Spiritual* (Aboriginal sites)

Economic:

- *Water extraction* (dams, weirs, diversions)
- *Infrastructural* (road & rail crossings)

Waterway threats

Figure 4 demonstrates all the potential threats that can impact on waterway values. Waterway threats

are nearly always anthropogenic in origin e.g. bank erosion and sedimentation as a result of excessive stock grazing. Not all of these activities may be problematic however – it is only when they exceed ecological thresholds that problems arise.

Some threatening activities are capable of causing many threatening processes while others are likely to only cause a few; for example, inappropriate agriculture is capable of causing most of the threatening processes identified in Figure 4 whereas inappropriate bicycling is likely to cause only minor erosion.

In a similar manner to values, threats may be considered under criteria, indicators and measures. While actual threats are associated with human activities (causes), the immediate management concern is likely to be threatening processes (effects).

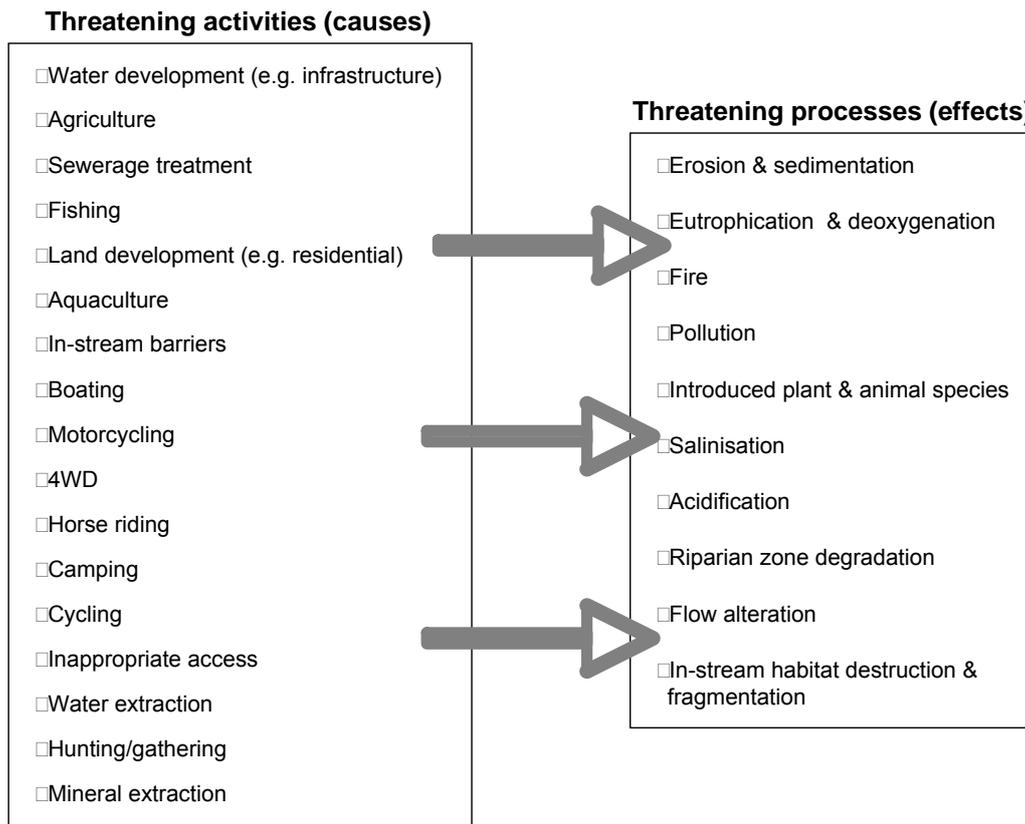


Figure 4: Threatening activities and processes impacting on waterway values (Macgregor et al. 2009).

The threats considered during the prioritisation classification procedures were:

- *Riparian zone degradation* (endemic vegetation health/vigour; riparian width; plant recruitment)
- *Livestock access* (presence/condition fencing – left & right banks; cattle pudging/trampling)
- *Introduced plants* (No. of weed species; % of weed cover – left & right banks)
- *Eutrophication* (filamentous algae)
- *Erosion* (bank undercutting & slumping – left & right banks)
- *Sedimentation* (water turbidity; sediment bars)

Prioritising according to values and threats

By utilising suitable indicators to represent the selected values and threats criteria, scores are generated and plotted in two-dimensional space (Figure 5).

		VALUES		
		High	Medium	Low
THREATENING PROCESSES	High	High value, high threat (HV/HT) (Priority 1a)	Medium value, high threat (MV/HT) (Priority 2a)	Low value, high threat (LV/HT) (Priority 3b)
	Medium	High value, medium threat (HV/MT) (Priority 1b)	Medium value, medium threat (MV/MT) (Priority 2b)	Low value, medium threat (LV/MT) (Priority 3c)
	Low	High value, low threat (HV/LT) (Priority 1c)	Medium value, low threat (MV/LT) (Priority 3a)	Low value, low threat (LV/LT) (Priority 3d)

Figure 5: Waterway values-threats prioritisation matrix (Macgregor et al. 2009).

Figure 5 demonstrates three primary priorities for management action: Priority 1, Priority 2 and Priority 3 (Note: these are highlighted in three colours on the reach maps). Priority 1 reaches or sub-catchments should be considered the highest priority and consequently should receive primary attention for management. Priority 2 reaches or waterways would receive attention secondarily with those classed Priority 3 being considered last. In this framework waterway assets or values take precedence over threats. However, a simple three-tier system does not consider how management should be prioritised within each of the three primary categories. For example, for Priority 1, there are three further categories or ‘sub-priorities’: high-value, high-threat (HV/HT); high-value, medium-threat (HV/MT); and, high-value, low-threat (HV/LT). Similarly, there are two sub-priorities for Priority 2 and four sub-priorities for Priority 3. By considering these sub-priority categories, further attention can be given to the institutional, social and economic constraints and limitations that are present in every NRM circumstance. In other words, the feasibility or practicality of management can be considered. For example, it is quite likely that management will be most effective if the less challenging threats are managed first. Once specific river sites are classified general management responses can be considered based on each reaches classification (see Section 7 for site-specific details).

River foreshore condition assessment

The Pen-Scott (1995) method of riparian zone assessment was used for the foreshore assessment. This system provides a graded description of the river foreshore from pristine (A grade) through to ditch (D grade). A summary of the grades of the Pen-Scott (1995), are illustrated in Figure 6 and photos on following pages. This method allows comparisons of waterway health across the south west of Western Australia, and can be used to prioritise actions.

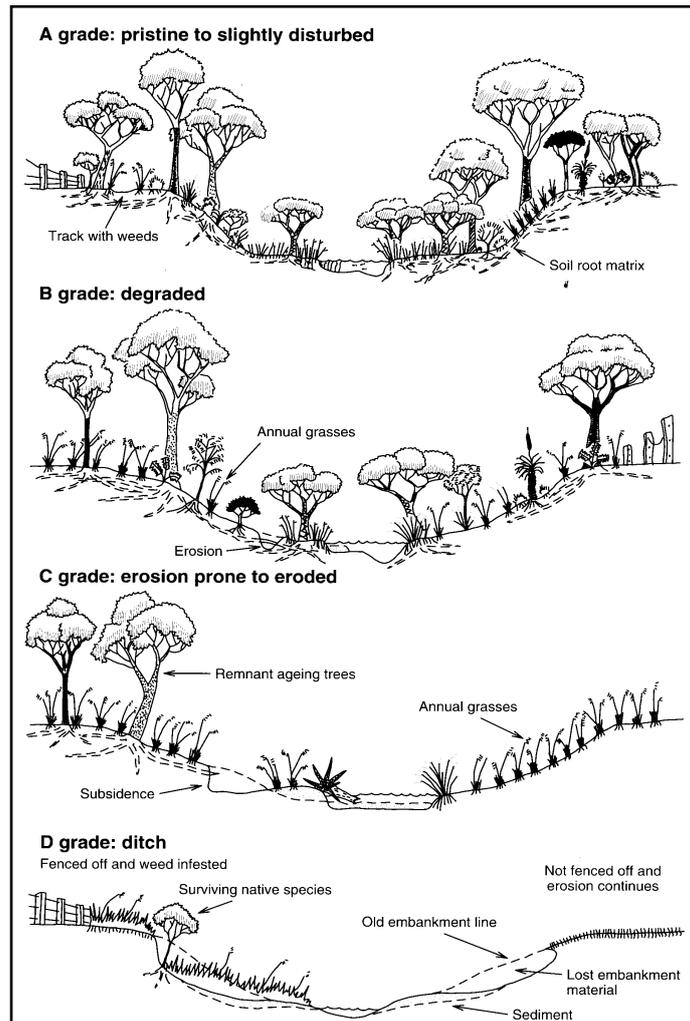


Figure 6: The four grades of river foreshore condition (A) pristine to (D) ditch (after Pen and Scott 1995)

A grade foreshore: Pristine – near pristine

A1 Pristine – embankment and floodway are entirely vegetated with native species and there is no evidence of human activity or livestock damage.



Figure 7: Pen-Scott grade A1
Pristine with embankment and floodway entirely vegetated with native species.
(Collie River South 200m up-stream from confluence with Collie River Central)

A2 Near pristine – native vegetation dominates but introduced weeds are occasionally present in the understorey, though not to the extent that they displace native species.

A3 Slightly disturbed – areas of localized human disturbance where the soil may be exposed and weed density is relatively heavy, such as along walking or vehicle tracks. Otherwise, native plants dominate and would quickly regenerate in disturbed areas should human activity decline.

B grade foreshore: Weed infested but tree covers still largely present

B1 Degraded, understorey mainly natives – weeds have become a significant component of the understorey vegetation. Although native species remain dominant, a few have probably been replaced or are being replaced by weeds.

B2 Degraded, understorey 50% weeds – understorey weeds are about as abundant as native species. The regeneration of some tree and large shrub species may have declined.

B3 Degraded, understorey weed dominated – weeds dominate the understorey, but many native species remain. Some tree and large shrub species may have declined or have disappeared.



Figure 8: Pen-Scott grade B3
Degraded, weeds dominate the understorey, but many native species remain.
Some tree and large shrub species have disappeared
(Collie River East adjacent to lot WELLIL 02315)

C grade foreshore: Erosion prone to eroded

C1 Erosion prone – trees remain, possibly with some large shrubs or grass trees, but the understorey consists entirely of weeds, mainly annual grasses. Most of the trees will be of only a few resilient or long-lived species and their regeneration will be almost negligible. In this state, where short-lived weeds support the soil, a small increase in physical disturbance will expose the soil and render the river valley vulnerable to serious erosion.

C2 Soil exposed – annual grasses and weeds have been removed through heavy livestock damage and grazing, or other impacts such as a result of recreational activities. Low-level soil erosion has begun, by the action of either wind or water.



Figure 9: Pen-Scott grade C2
Soil is exposed through heavy livestock damage.
The far shore is graded A3, slightly disturbed with local infestation of weeds
(Collie River East adjacent to lot WELLIL 02980)

C3 Eroded – soil is being washed away from between tree roots, trees are being undermined and unsupported embankments are subsiding into the river valley.

D grade foreshore: Ditch to drain

D1 Ditch eroding – fringing vegetation no longer acts to control erosion. Some trees and shrubs remain and act to retard erosion in certain spots, but all are vulnerable to undermining.

D2 ditch, freely eroding – no significant fringing vegetation remains, and erosion is completely out of control. Undermined and subsided embankments are common, as are large sediment plumes along the river channel.

D3 Drain, weed dominated – the highly eroded river valley may have been fenced off enabling colonisation by perennial weeds. The river has become a simple drain, similar to a typical major urban drain.

Note: no part of the Upper Collie study area was found to be in D grade condition.

Additional bank erosion and sedimentation assessment

Additional bank erosion and sedimentation criteria were considered during the foreshore condition assessments to supplement the methodology of Penn-Scott (1995). This considered the following: bank undercutting (outside bends), bank slumping, point bars, pool aggradation (particularly inside meander bends) and large woody debris (LWD) (Table 7).

Table 7: Field assessment method for river erosion and sedimentation.

Erosion/deposition process	Class	Assessment criteria
Bank undercutting	A	Nil
	B	0-50cm
	C	50-100cm
	D	> 100cm
Bank slumping	A	Nil
	B	Occupies 5% of active channel
	C	5-20% active channel
	D	20-50% active channel
	E	>50% active channel
Point bars	A	Nil
	B	0-10% encroachment to active channel
	C	10-25% active channel
	D	25-50% active channel
	E	>50% active channel
Pool aggradation (depth determined by 'point of first refusal')	A	Nil
	B	0-10cm
	C	10-50cm
	D	50-100cm
	E	>100cm
Large woody debris (quantity of individual pieces >40cm diameter & at >40 degrees to angle of flow)	A	Nil
	B	1
	C	1-5
	D	>5

The second map associated with each of the 13 reaches (Section 5) provides an indication of the erosion and sedimentation features found during the foreshore assessment. The degree of severity is also indicated (according to class A, B, C, D, E). A key is also provided in the site description text associated with each reach (Section 5).

Community involvement

Community involvement is an integral component for the development of River Action Plans. In this case, every effort was made to involve the community at all stages of the foreshore assessment process.

Many survey site assessments were conducted in the company of landholders and they provided invaluable historical and anecdotal information about the catchment. Importantly they expressed their views, explained what their concerns were, and how they considered the waterways should be managed.

While foreshore assessments were being conducted, local community workshops were also held to present initial findings and seek feedback about the project and management recommendations. In all, three workshops accompanied the research process. The first workshop was held in Collie on the 25th March 2009; the second was held in Cardiff on the 29th April 2009, and a third and final workshop was held on 31st March 2010 in Collie. Stakeholders and community representatives at the workshop were asked to provide information about what they considered were the major issues for the Upper Collie rivers.

Other consultation processes included individual phone calls with landholders and State agency and local government personnel with responsibilities for the Upper Collie Rivers.

The following points (in order of priority) were raised by the community. *(Please note that the views expressed are those from the consulted community and do not necessarily reflect those of the author, the Centre of Excellence in Natural Resource Management, nor the Department of Water).*

- Over extraction of water for mining and power generation purposes at the expense of environmental flows, especially to retain water in the pools.
- Reduction in water quality (especially salinity) as a result of over extraction – associated fish kills.
- Weeds – especially Blackberry and Watsonia.
- Loss of native vegetation and native animals.
- Erosion of river banks.
- Sedimentation – the result of bank erosion, which is susceptible to weed encroachment e.g. couch grass.

These community concerns and management issues are discussed further in the next Section.

Foreshore data availability

Data collected during the Upper Collie Rivers foreshore assessment were organised into Excel spreadsheets for statistical and Geographic Information Systems (GIS) analyses. As part of the River Action Plan project, these data, together with the GIS shape and attribute files, and the complete photo library (containing aprox. 1,070 photographs) have been provided to the South West Catchments Council (SWCC) for integration with SWCC's Waterways Decision-Support System. Other datasets provided to SWCC include the values-threat assessment data along with the derived scores.

Enquiries concerning access to any of these data may be directed to:

South West Catchments Council
PO Box 5066 □ Bunbury DC WA 6230
Phone: (08) 9780 6193
Web: www.swcatchmentscouncil.com/

4. MANAGEMENT ISSUES

There are a number of management issues in the Upper Collie River Catchment. They vary according to landform and soils, past and current land use and management practices. These interrelated issues are summarised below.

Water extraction, allocation & environmental flows

In discussions about water extraction and environmental flows there are a number terms and definitions that may appear ambiguous to some readers so to aid the following discussion the following definitions may be useful:

- Ecological Water Requirements (EWRs) describe water regimes (spatial and temporal) needed to sustain the ecological values of water dependent ecosystems at a low level of risk.
- Environmental Water Provisions (EWPs) are that part of the ecological water requirements that can actually be met after consideration of social and economic factors.

The need to mitigate ecological impacts of flow regulation and diversion has also occurred through a number of Federal policies:

- Principles of Ecologically Sustainable Development (1992);
- Intergovernmental Agreement on the Environment (1992);
- COAG (1994) recommended fundamental water reforms, including the need to provide water for the environment as part of the introduction of comprehensive systems of water allocations;
- Draft National Water Quality Management Strategy (1994); and,
- Draft State-wide Policy – Environmental Water Provisions Policy for Western Australia. Water and Rivers Commission (2000).

The *Rights in Water and Irrigation Act 1914* was the major water legislation in Western Australia. In June 1999, amendments to the Act were proposed to bring water resource management in line with the Council of Australian Government (COAG) water reform agenda. Proposed amendments to the *Rights in Water and Irrigation Act 1914* went before Parliament in October 1999 for implementation in 2000. The Water Reform Agreement states that EWRs are met and not endangered by other consumptive users. These form major elements of the revised *Water and Irrigation Amendment Bill 1999*.

A major outcome of the revision was the issue of water allocation to the environment. The goal of environmental allocation was ‘to sustain and where necessary, restore ecological processes and biodiversity of water dependent ecosystems’. As a framework, ARMCANZ/ANZECC (1996) provided a set of National Principles for the Provision of Water for Ecosystems. Although the National Principles (Principle 2) stated that environmental water requirements (EWRs) should be determined using the ‘best scientific information available’, many approaches are still based on a subjective and/or expert panel approach (Arthington and Zalucki 1998).

The Department of Water (DoW) has had the role of custodian, independent arbiter and regulator of the water industry of Western Australia. The DoW has stated its role is to ensure the State’s water resources are managed to support sustainable development, conservation of the environment and for the long-term benefit of the community (see Water and Rivers Commission 2000).

The major groundwater system in Collie is the Collie Coal Basin. This is made up of the Premier and Cardiff sub-basins. Coal is mined from the Collie Coal Basin through open-cut mining, which results in the need to dewater large volumes of groundwater. There is a high demand for surplus mine dewater as third parties can use it, such as for cooling purposes by the local power industry.

As noted in the previous Section, the Upper Collie community is deeply concerned about the amount of water extracted from the Upper Collie for industrial purposes. In particular, the future of the river

pool supplementation programs along the Collie River south and east branches is of concern to local landowners. The Department of Water has recently released the *Upper Collie Water Allocation Plan* (DoW 2009) and this plan sets out a clear direction for allocating and managing the Collie water resources under current demand. Current demand and environmental flows in the Collie River will be maintained by limiting the amount of water that can be pumped from the river and from groundwater.

Maintaining ecological values

Water is released from the Harris Reservoir according to a regime defined in the Water Corporation's operating strategy for the reservoir. In addition to releases made for environmental needs, water has been released from the Harris Reservoir to manage salinity in the Wellington Reservoir. This release is referred to as a 'salinity mitigation release' and has occurred in 1998, 1999 and 2003.

Water licensing and use implications

Under the *Rights in Water and Irrigation Act, 1914* 'riparian rights' allow landholders to take water for specific non-commercial purposes such as domestic use or non-intensive stock watering (Water and Rivers Commission 2001). Riparian rights only occur where there is a stream flowing through a property or the property abuts the watercourse, and there is no publicly reserved land between the watercourse and the private property. Extracting water for commercial purposes or in excess of riparian rights may require a licence from the Department of Water (DoW). Riparian rights only give access to what water is available, and are not a guarantee of supply (Cape to Cape Catchments Group 2005). A number of landholders extract water directly from the Upper Collie rivers for commercial purposes, some of which hold DoW licences.

The State Government has committed to coal mining under the Griffin Coal and Wesfarmers Premier Coal state agreement Acts. The department has issued each of the mining companies a licence to abstract enough groundwater (mine dewater) from their mining operations to facilitate a safe mining environment. There is currently a total of 49GL/yr allocated for mine dewatering (DoW 2009). With an allocation limit (based on annual recharge) of 2.2GL/yr this means the Premier subarea's licence total is over 2000% of the allocation limit (DoW 2009). This indicates that dewatering activity in the Premier is highly unsustainable abstraction.

The Department of Water expects major water users to identify and mitigate the impacts of their water use. This includes pool supplementation of groundwater-fed pools that are affected by groundwater drawdown. The Department of Water supports the supplementation of Cardiff Town Pool (Collie R. South Branch) and Duderling Pool and Buckingham Bridge / Town Pool (Collie R. East Branch).

According to the *Upper Collie Water Allocation Plan* (DoW 2009) the Department of Water will not allow any consumptive groundwater abstractions in the Premier above the 2.2GL allocation limit. This will ensure that, as in the Cardiff sub-area, groundwater levels in the Premier will begin to recover once dewatering ceases. When dewatering operations cease, the allocation associated with the dewatering licence will not be available for consumptive use. The licensed entitlement will be returned to the Department. The previously allocated dewater will then provide recharge to the aquifer.

Stock and domestic bores abstracting from the confined aquifers will be licensed. Where there is no access to scheme water, the Department of Water will not refuse any licences for stock and domestic purposes.

Future new industries in Collie will not be able to rely on groundwater production bores or on taking additional water directly from the river.

Water quality issues

There is community concern about water quality in the rivers of the Upper Collie Catchment. Issues such as salinity, nutrient levels, eutrophication and fish kills were raised during the workshops and foreshore surveys. While fish kills have not been formally recorded in the Upper Collie there is strong anecdotal evidence to suggest this happened on at least one occasion. Those landholders reporting

fish kills were concerned about the cause and there is concern it is connected with over-extraction and that has combined with increasing salinity and nutrient levels, which has adversely impacted the ecological integrity of the rivers.

Salinity levels

Land clearing in the eastern and southern portion of the catchment has led to dryland salinity, with increased saline water inflow to streams. As a result, water quality in the Collie River and in the Wellington Reservoir has deteriorated. The Collie R. East Branch contributes the highest salt load to the Wellington Reservoir (DoW 2009). A salinity recovery program is underway, to improve water quality in the Wellington Reservoir, by diverting saline inflows from the Collie R. East Branch. The Harris and Bingham rivers provide a valuable, seasonal input of fresh water to the Collie River system. Land clearing has also increased flows compared to fully forested catchments. Higher flows have resulted in river channel erosion and the sedimentation of downstream river pools. This is particularly evident along the Collie R. East Branch (DoW 2009).

The Resource Science Division of the Water and Rivers Commission produced a report, the *Collie Salinity Situation Statement* (WRC 2001), which provides details of salinity levels in the major tributaries of the Collie Catchment. Some of the findings of this report are noteworthy.

Trend analysis shows that by 1990 the Wellington inflows, Mungilup Tower and Collie R. East may have reached a maximum salinity of 870mg/L, 1130mg/L, and 1990mg/L respectively at mean annual flow. Collie R. South, James Crossing and James Well reached 920mg/L, 5900mg/L and 2400mg/L respectively by 1993, and prior to that showed increasing trends of 9mg/L/year, 157mg/L/year and 34mg/L/year respectively. The salinity of Bingham River continues to be less than 300mg/L.

A number of land use changes were modelled to determine their effect on salinity levels. The options considered were: tree plantations on land already committed for such use; alley farming using commercial trees on other suitable land; other suitable tree-species on land not suitable for commercial trees or plantations; lucerne on suitable land; shallow drainage on pasture land; groundwater pumping; and, partial or total diversion of stream flow from up-stream tributaries.

It was found that no single option could achieve the target; however, the target could be met, or substantially met, by adding separately to any of a variety of options, assuming the committed tree plantations are in place.

The authors of the *Collie Salinity Situation Statement* (Water and Rivers Commission 2001) concluded that since 1990 there has been no trend of increasing salinity of water inflow to Wellington Dam. (The salinity target for Wellington inflow has been set at 500mg/L as an annual flow-weighted mean when rainfall equals the 1980 to 1995 average. In 1995, Wellington inflow salinity was 885mg/L.) This is thought to be due in part to the rises in groundwater following clearing being substantially complete, and in part to the effects of tree plantations established by them.

Further reduction in salinity is expected once all existing and planned tree plantations have been fully established. However, this is not thought to be sufficient to meet the inflow salinity targets. Continuing protection of remnant native vegetation is important to maintain its water-use functions, loss of which negates efforts to reduce salinity by other means.

Nutrient levels

It should be noted that there is a general absence of data on nutrient levels in the Upper Collie (McKenna 2010 pers. comm.) so the following comments must remain generic rather than specific to the Upper Collie. Nitrogen (N) and phosphorus (P) are two of the most important plant nutrients that are commonly found in a wide range of fertilisers. Fertiliser runoff from rural and urban land can lead to increased amounts of N and P in rivers resulting in nutrient enrichment (eutrophication). Excessive nutrients levels can cause algal blooms and episodic fish kills in the pools of the rivers. Algal blooms predominate in summer and autumn, including non-toxic and potentially fish-killing species of

phytoplankton have been recorded in other similar situations (e.g. the Brunswick River) (Rose 2004). The rapid breakdown of algal blooms can strip oxygen from the water also resulting in fish kills.

Rural drains

The water quality of rural drains depends upon the various activities that occur within the catchment area of the drainage system. If best agricultural practices are not used then various nutrients, pesticides and sediment can 'leak' from the property and enter the drainage system (Water Corporation 2002).

Urban stormwater

Rural drains are not the only drainage system that can have an impact on the water quality of the Upper Collie River. Urban stormwater drains into the river often contain a number of contaminants, such as street litter, fertiliser loss from lawns, animal wastes, sediments, petrol, oil and heavy metals from vehicles.

Untreated stormwater can greatly reduce the water quality of rivers and waterways, which can then lead to adverse impacts on the aquatic animals, plants and ecosystems (Department of Environment 2005).

Water Sensitive Urban Design (WSUD) promotes the treatment of water prior to discharge from a stormwater outlet. The Leschenault Catchment Council, local governments and the DoW are encouraging developers to utilise the principles of WSUD in new residential developments. For more information on WSUD contact the Department of Water.

Erosion and sedimentation

While some level of erosion and deposition is natural in any waterway, the acceleration of these processes can cause management problems. Wide-scale clearing of native vegetation in the catchment, especially in the riparian zone, has increased surface runoff causing significant erosion including bank undercutting and slumping. Typical issues associated with erosion include:

- Loss of valuable soil;
- Loss of fences as the water course deviates;
- Poor water quality resulting from increased turbidity and nutrients;
- Increased flood potential due to the silting up of the channel;
- Filling of summer pools;
- Increased channel width and loss of agricultural land;
- Reduced visual amenity and recreational sites associated with the waterways; and,
- Further loss of native vegetation as severe erosion problems cause subsidence.

Stock access

Much of the grazing land in the Upper Collie River is unfenced, allowing stock access to riparian vegetation and the river. A number of problems discussed above can be exacerbated as a result of unrestricted stock access. These include:

- Loss of native fringing vegetation;
- Weed invasion;
- Compacted soils;
- Nutrient enrichment;
- Erosion; and,
- Poor water quality.

Loss of native fringing vegetation

Many parts of the river foreshores in the Upper Collie have a healthy and complete vegetation structure. However, for the rest of the river foreshores, most of the vegetation is degraded to some degree – clearing, stock access, erosion and weed invasion. In many areas there is a healthy overstorey of mature trees but little understorey, while in a few highly degraded parts there is no native vegetation of any kind. It is important to retain and enhance native riparian vegetation as it has many functions including erosion control, dissipating flow, sediment and nutrient retention and providing habitat for many species.

Weed invasion

A large number of weeds were found in the foreshore surveys. The dominant species are identified in the Foreshore Reach maps in Section 5. Disturbance through clearing, grazing, erosion and modification of the channel provides ideal conditions for weed recruitment, growth and spread. The main weeds of concern in the study area were Blackberry, *Watsonia* and grasses such as Kikuyu and Couch.

Weeds often compete with native vegetation and restrict natural regeneration. They are a significant source of degradation of remnant vegetation and are a major economic cost to society. According to a study by Sinden et al. (2004), the economic cost of weeds in Australia is approximately \$4,000m annually. This includes the costs of control and losses in output in agricultural land (\$3,927m), the cost of control in the natural and built environment (\$104m) and the amount spent on research and development (\$8m). It does not include the considerable amount of volunteer time and labour donated by community groups and landholders in controlling weeds (Cape to Cape Catchments Group 2005).

All revegetation activities need to include strategic weed management actions to increase the survival rate of plantings and to reduce long-term management activities. If grassy weeds infest a revegetation site, they will out-compete the native vegetation, and may cause a fire hazard. For more information on specific weed control, see Section 6.

5. RIVER FORESHORE CONDITION AND RECOMMENDATIONS FOR MANAGEMENT

Using the maps

The following pages provide an index for the maps, and an overview of the condition of the river of the Upper Collie Catchment. For a summary of the condition rating and percentage of the rivers that are fenced to exclude stock, please see Table 1 and Table 2 in the Summary.

The maps are organised into 13 pairs (Reaches). The first map in each pair shows the foreshore condition (as assessed using the Pen-Scott method) along with weeds and the adjoining land titles. The second map shows provides an indication of fencing (left and right banks) and the degree of erosion and sedimentation of the banks. (Note: the definition of left and right banks is based on the assumption that the map reader is looking downstream.) The second map also indicates sites of value to Aboriginal and non-Aboriginal peoples. Both maps provide an indication of the value-threat classification for prioritising management actions. Legends are provided on both map types.

The background aerial imagery of the map was taken in 2006 and these are available for purchase from Landgate.

Management recommendations

The notes accompanying each map pair summarises each reach with background information, the current condition of the survey sites along with action response recommendations in terms of weeds, erosion and fencing. It is intended that these management recommendations may be used by a range of organisations as well as landholders.

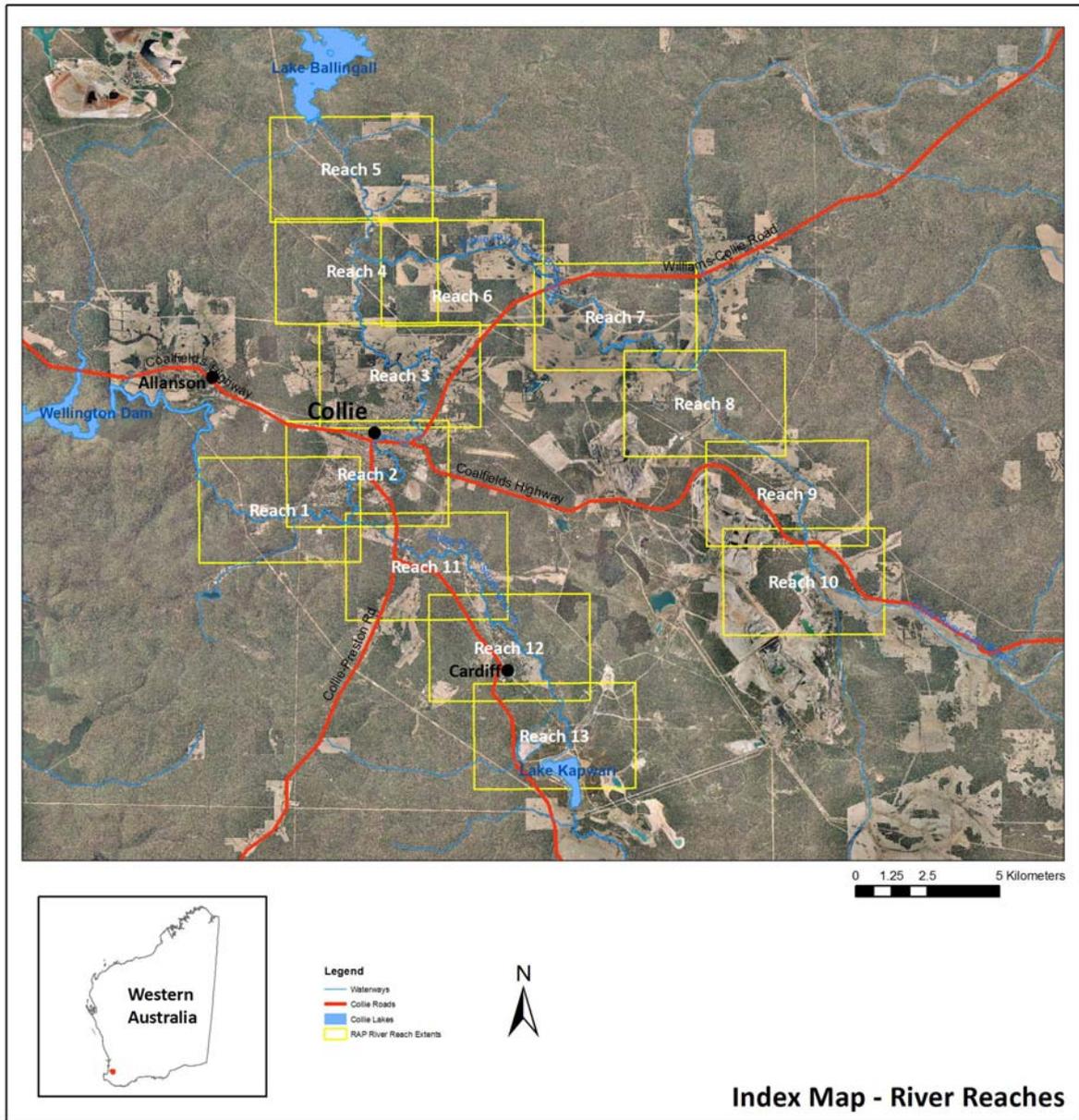


Figure 10: Index map: Upper Collie Catchment river reaches

REACH 1

Reach 1 begins at Mungalup Tower gauging station (site CRC001) on Collie R. Central (CRC) and extends approx. 7.2kms upstream to site CRC013 (a total of 13 individual survey sites).

Description

Feature	Comments
Landuse	Forest and nature reserves dominate both foreshores but there are small hobby farms on lots WELLIL 01346 (south shore) and D084144 (north shore).
Land tenure	With the exception of the hobby farms, all lots are forest reserves or uncleared reserves.
Fencing	The northern foreshore has approx. 500-600m of fencing (lot D084144) but otherwise both foreshores are unfenced; however, since most lots are forest reserves or vacant crown land, fencing is not a major management concern.

Condition

Feature	Comments
Vegetation	Native vegetation is largely intact. Species evident during survey: Dominant trees & shrubs: River banksias (<i>Banksia littoralis/seminuda</i>), marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), Astartea (<i>Astartea fascicularis</i>), sickle hakea (<i>Hakea falcata</i>), swamp paperbark (<i>Melaleuca rhapsiophylla</i>), mohan (<i>Melaleuca viminea</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Jointed twig rush (<i>Baumea articulata</i>), bare twigrush (<i>Baumea juncea</i>) and marsh club rush (<i>Bolboschoenus caldwellii</i>) Aquatic plants: Nardoo (<i>Marsilea mutica</i>) – regarded locally as a weed.
Weeds	Occasional patches of pasture grasses, cootamundra wattle (<i>Acacia baileyana</i>), blackberry (<i>Rubus</i> spp.), green fat hen (<i>Chenopodium murale</i>) radiata pine (<i>Pinus radiata</i>), silver wattle (<i>Acacia podalyriifolia</i>) and watsonia (<i>Watsonia meriana</i>).
Bank stability and erosion	Banks are largely stable with little obvious erosion although there is evidence of minor undercutting in places and there is some erosion as a result of human access (see photo PP62). Large woody debris is also evident in places but this is causing only minor erosion.
Special features, other comments	Mungalup Tower (AH 03) and Minningup Pool (AH 02) are sites of Indigenous significance. There is a weir with boards in place at the fence line between lots D084144 and R34343 (see photo PP63). There is good potential for rehabilitation since most of the landuse in the reach is forest reserve and free from stock access.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1b	HV/MT (1 site)	Site CRC011.	Weeds found at this site were Silver wattle, Watsonia and pasture grasses. There is minor bank undercutting on the right bank. No fencing but given the land use this is not regarded as a threat.
1c	HV/LT (6 sites)	Sites CRC001, CRC002, CRC007, CRC008, CRC009, and CRC010.	Weeds found were Cootamundra wattle, Radiata pine, Fat hen green, Paspalum, Watsonia, Silver wattle and Pasture grasses. There is minor undercutting at the start of CRC002 – caused by

			human access (see photo PP62) and at sites CRC007, CRC009 and CRC010. There is also minor erosion potential as a result of LWD at most of these sites.
3a	MV/LT (3 sites)	Sites CRC005, CRC006 and CRC012	Just one weed of concern found at sites CRC005 and CRC006 – Cootamundra wattle – but there is also Radiata pine, Watsonia and pasture grass at CRC012. There is minor bank undercutting of both banks at all sites with further erosion potential from LWD at CRC005. Fencing is considered adequate.
3c	LV/MT (1 site)	Site CRC004.	Two weeds were found at this site – Blackberry and Cootamundra wattle. There is minor undercutting on both banks. If stock occupies lots D084144 (north bank) and/or WELLIL 01346 then the fencing on both banks should be completed.
3d	LV/LT (2 sites)	Sites CRC003 and CRC013	At CRC013 the weeds Radiata pine, Watsonia and pasture grasses were found. There is minor undercutting on both banks at site CRC003 and LWD. There is currently no fencing on either bank and if stock occupy lot D084144 (north bank) then fencing should be installed.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Weeds	Encourage landholders (local government and DEC), local community groups and weed action groups in weed management. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target blackberry, Cootamundra wattle, Silver wattle and Watsonia in this area. Assist regeneration of native vegetation through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fencing/loss of native vegetation	While very little of the foreshores are fenced, this is not regarded as a concern since there is no stock accessing the river from reserved land. However, landholders of lots D084144 and WELLIL 01346 are encouraged to extend fencing where stock is present.
Fish	Fish habitat is generally quite good but some erosion control using large woody debris at sites where there is undercutting, or planting with emergent vegetation such as rushes and sedges, would enhance habitat further.
Declining water quality	With almost no agriculture along the foreshores, water quality is not being negatively influence by immediate landuse. However, encouraging the use of Best Management Practices (BMPs) on farms up-stream to increase water quality would be beneficial to the reach. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a comprehensive list of BMPs.

Please note ‘encourage’ and ‘support’ can mean to: provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 1:



PP62: Pen-Scott A1 – Bank erosion from human access



PP63: 'Robert's Rocks' Weir with boards in place



PP65: Current road crossing



PP66: Looking over Minningup Pool (AH 02) to south bank (Pen-Scott B1)



PP64: Remains of old river crossing



Pen-Scott A1 example, north bank, up-stream from PP62



Pen-Scott A2 example, north bank, down-stream from PP64

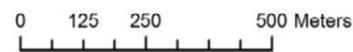
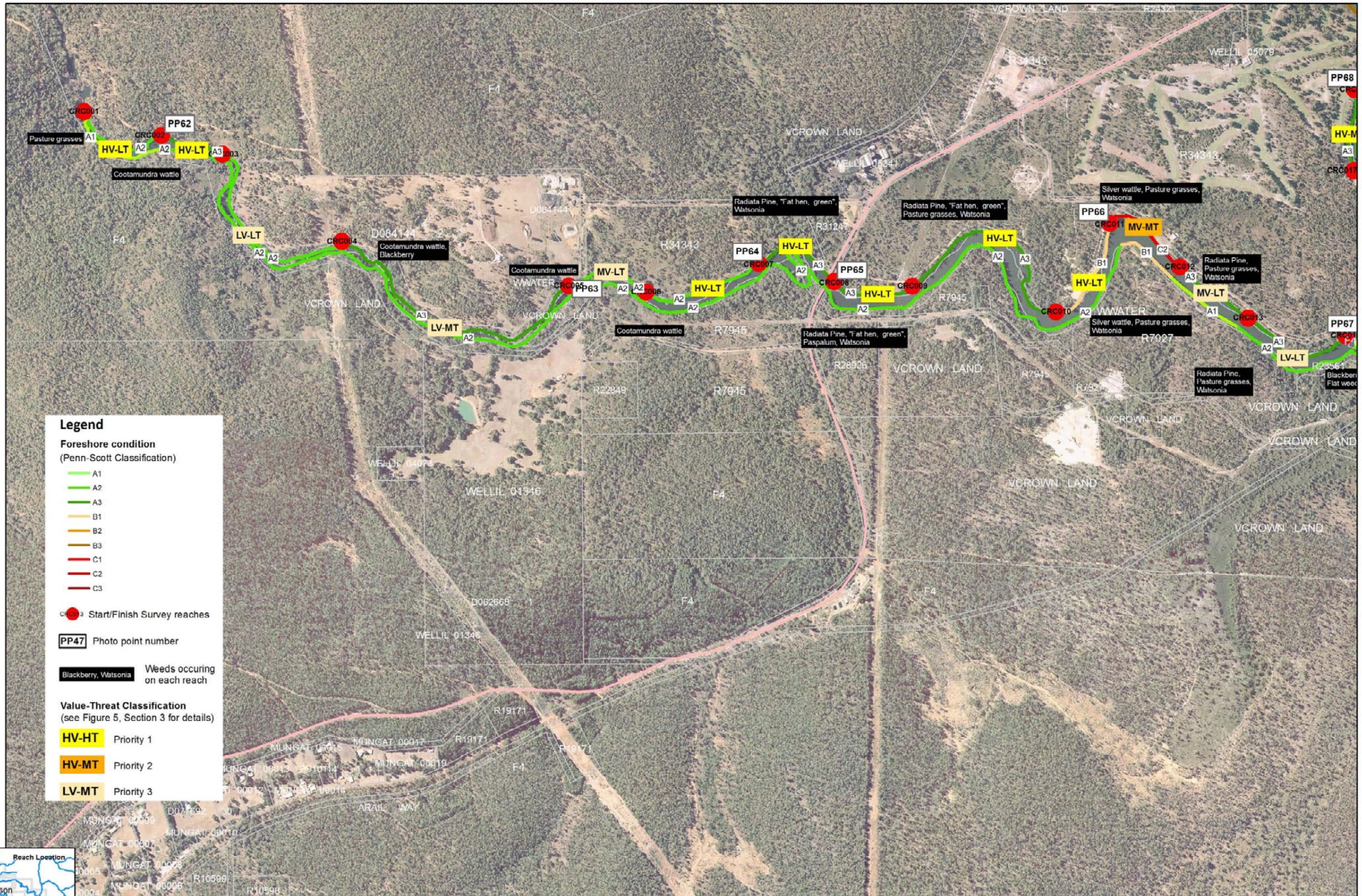


Pen-Scott C2 – Minningup Pool (AH 02), north bank, up-stream from PP66

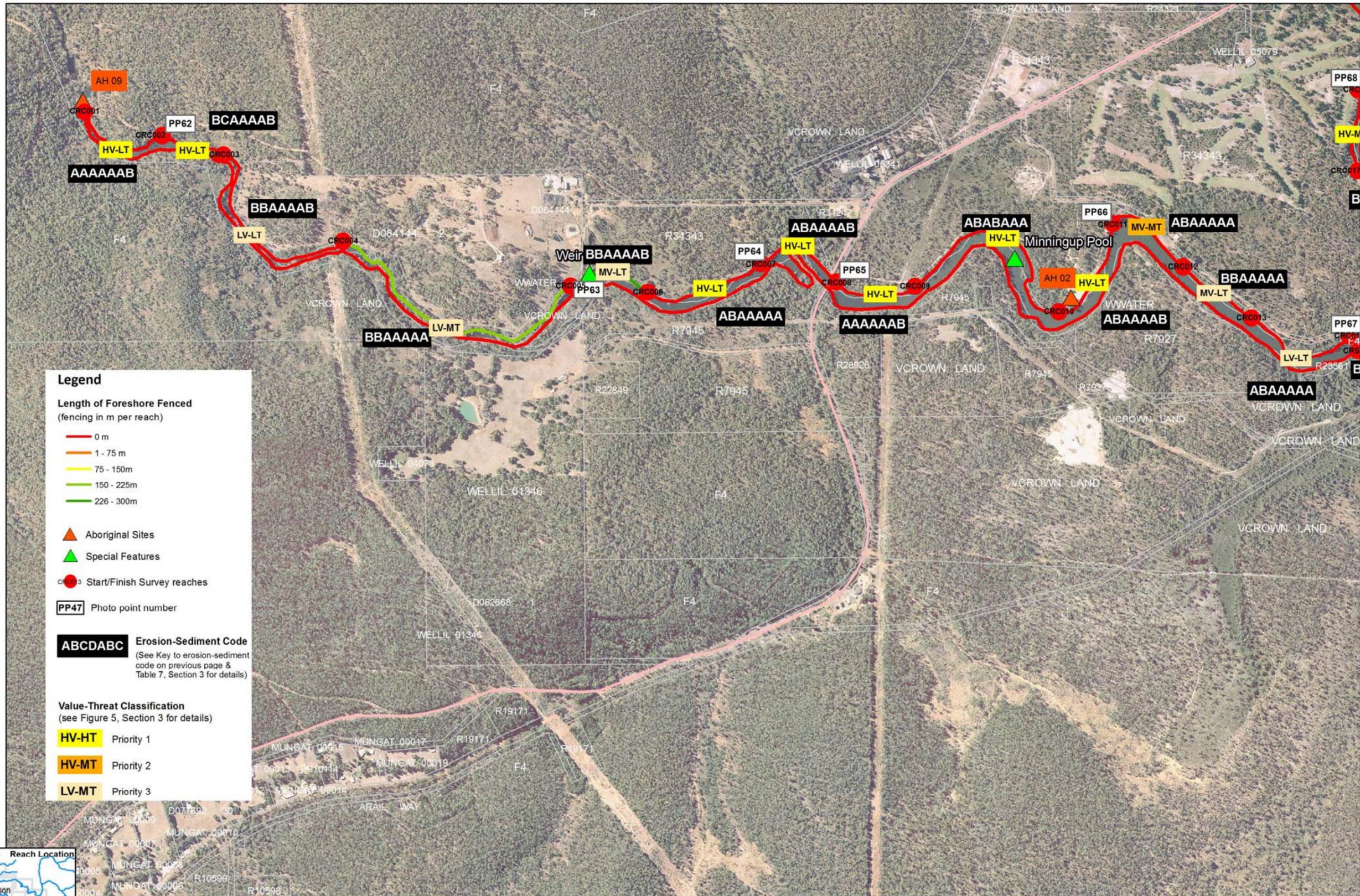
Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



Foreshore Condition & Weed Mapping
Upper Collie RAP: Reach 1



Legend

Length of Foreshore Fenced
(fencing in m per reach)

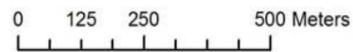
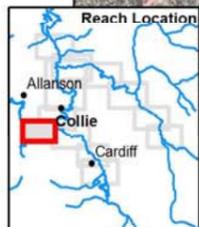
- 0 m
- 1 - 75 m
- 75 - 150m
- 150 - 225m
- 226 - 300m

▲ Aboriginal Sites
▲ Special Features
● Start/Finish Survey reaches
PP47 Photo point number

ABCDABC Erosion-Sediment Code
(See Key to erosion-sediment code on previous page & Table 7, Section 3 for details)

Value-Threat Classification
(see Figure 5, Section 3 for details)

- HV-HT Priority 1
- HV-MT Priority 2
- LV-MT Priority 3



**Erosion-Sediment Mapping
Upper Collie RAP: Reach 1**

REACH 2

Reach 2 continues upstream with site CRC014 to CRC038 of Collie R. Central (CRC) for another 8.8kms. It contains 25 individual survey sites most of which pass through the town of Collie.

Description

Feature	Comments
Landuse	The southern part of Reach 2 is adjacent to the local golf course and there are local parks and some reserved land. Residential landuse dominates adjacent land in the wester part.
Land tenure	Primarily managed reserves (Shire, DEC) and Vacant Crown Land throughout with some urban freehold (including the golf course).
Fencing	Both foreshores of the entire length of Reach 2 are completely unfenced.

Condition

Feature	Comments
Vegetation	Native vegetation is largely intact in reserve sections but riparian zone is largely cleared in urban sections. Dominant trees & shrubs: River banksias (<i>Banksia littoralis/seminuda</i>), marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), Astartea (<i>Astartea fascicularis</i>), sickle hakea (<i>Hakea falcata</i>), swamp paperbark (<i>Melaleuca rhapsiophylla</i>), mohan (<i>Melaleuca viminea</i>), bracken fern (<i>Pteridium esculentum</i>), wandoo (<i>E. wandoo</i>), peppermint (<i>Agonis flexuosa</i>), two leaved hakea (<i>Hakea trifurcata</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), semaphore sedge (<i>Mesomelaena tetragona</i>), spreading sword-sedge (<i>Lepidosperma effusum</i>) and Pale rush (<i>Juncus pallidus</i>). Herbs, creepers & bulbs: Button weed (<i>Cotula</i> spp.) Aquatic plants: Nardoo (<i>Marsilea mutica</i>) – regarded locally as a weed.
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), radiata pine (<i>Pinus radiata</i>), silver wattle (<i>Acacia podalyriifolia</i>), bulrush (<i>Typha orientalis</i>), African lovegrass (<i>Eragrostis curvula</i>), paspalum (<i>Paspalum dilatatum</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> sp.) and watsonia (<i>Watsonia meriana</i>).
Bank stability and erosion	The river along this reach was ‘trained’ in the 1960s following the 1964 flood. Banks are largely stable but there is some minor undercutting in places.
Special features, other comments	There are a number of weirs with boards over the 8 km urban stretch of the river (CRC025 (see photo PP71) and Ewington Weir at CRC038). Also, a constructed riffle at site CRC038. The main purpose of these weirs is to ensure water is retained behind them in pools; however, as Davies et al.’s (2008) report highlights, these are largely responsible for the presence of the aquatic weed Nardoo which is regarded by most Collie residents as an ‘eyesore’. There are four sites of Aboriginal significance: Collie Spring (AH01); High Chaparral Camps (AH07); White City Camp (AH08); and, Ewington Spring (AH06).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1b	HV/MT (2 sites)	Sites CRC016 and CRC017.	Weeds are not a concern but there is some minor bank undercutting and slumping especially on the right bank. There is no fencing at any part of this reach but this not regarded as an issue in this reach.

2b	MV/MT (11 sites)	Sites CRC018, CRC019, CRC020, CRC021, CRC022, CRC026, CRC028, CRC029, CRC032, CRC034 and CRC035.	The aquatic weed Nardoo is common throughout this reach but especially up-stream of the weir at site CRC025, PP71 (see photo PP72). Weeds identified at these sites were Blackberry, Watsonia, Silver wattle, African lovegrass, Paspalum, Bulrush, Flat weed, Phalaris, Radiata pine and pasture grasses. A drain on the right bank and a stormwater entry point are promoting localised erosion at the golf course (CRC017) and at Jack Mears Park (CRC021) (see photos PP68 and PP69). Other than these very localised erosion, there is only minor bank undercutting at sites CRC018, CRC019, CRC021 (right bank), CRC032, CRC033, CRC034 and CRC035 (mainly the left bank).
3a	MV/LT (1 site)	Site CRC014.	No obvious weeds and only minor bank undercutting on right bank.
3c	LV/MT (10 sites)	Sites CRC023, CRC024, CRC025, CRC027, CRC030, CRC031, CRC033, CRC036, CRC037 and CRC038.	As noted above, Nardoo is common throughout many of these sites but also present is Blackberry, Watsonia, Silver wattle, Radiata pine, Flat weed, Paspalum, Blowfly grass, Bulrush, African lovegrass, and pasture grasses. There is some minor sedimentation (point bar) and LWD at site CRC031, and minor bank undercutting (both banks) at CRC036, CRC037 and CRC038.
3d	LV/LT (1 site)	Site CRC015.	Little evidence of weeds and no obvious erosion or sedimentation.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Weeds	Encourage landholders (local government and DEC), local community groups and weed action groups in weed management. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target blackberry and watsonia in this area. Assist regeneration of native vegetation through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Urban development	Sub-division and on-site developments should utilise site management BMPs to ensure sediment from sites is not washed into stormwater drains and consequently into the river.
Fencing/loss of native vegetation	While very little of the foreshores are fenced, this is not regarded as a concern in this reach.
Fish	There is little natural habitat for fish although the presence of the weirs ensures water remains in the pools throughout the year. Given the urban nature of the surrounding landuse there would seem little opportunity to enhance the habitat further.
Declining water quality	No agriculture along the foreshores, water quality is not being negatively influenced by immediate landuse. However, the golf course should minimise the risk of nutrients entering the river by ensuring the use of Best Management Practices (BMPs) for fertiliser use on the course. Likewise, BMPs on farms up-stream should be practiced to enhance the water quality of this reach. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient

inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a comprehensive list of BMPs.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 2:



PP68: Bank erosion caused by drain



PP69: Bank damage as a result of storm water entry



PP71: Venn St Weir with boards in place



View up-stream from PP71: extensive Nardoo in river & pasture grasses on east bank (Pen-Scott C1)



PP73: View downstream from jetty on left bank (Pen-Scott B3)

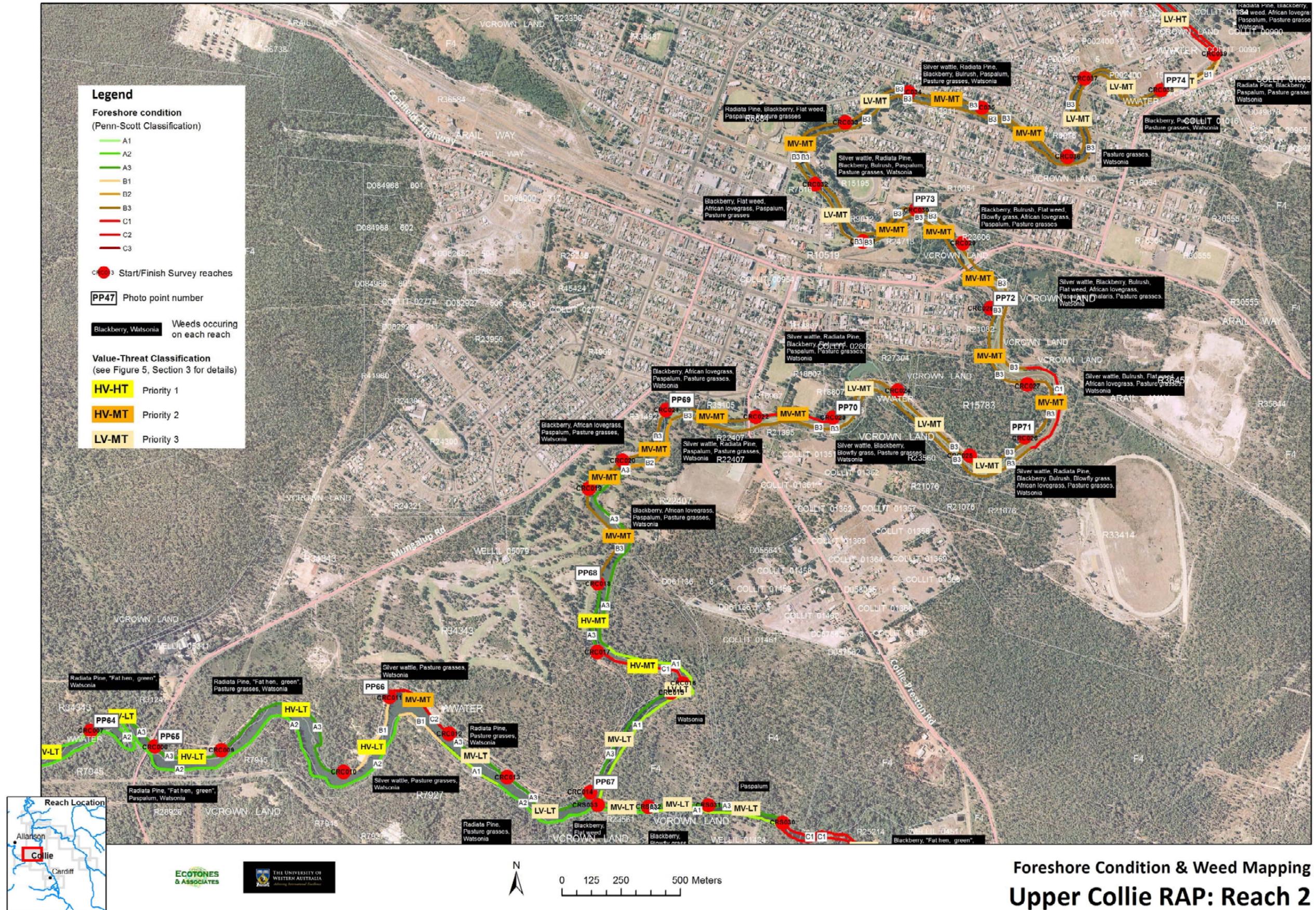


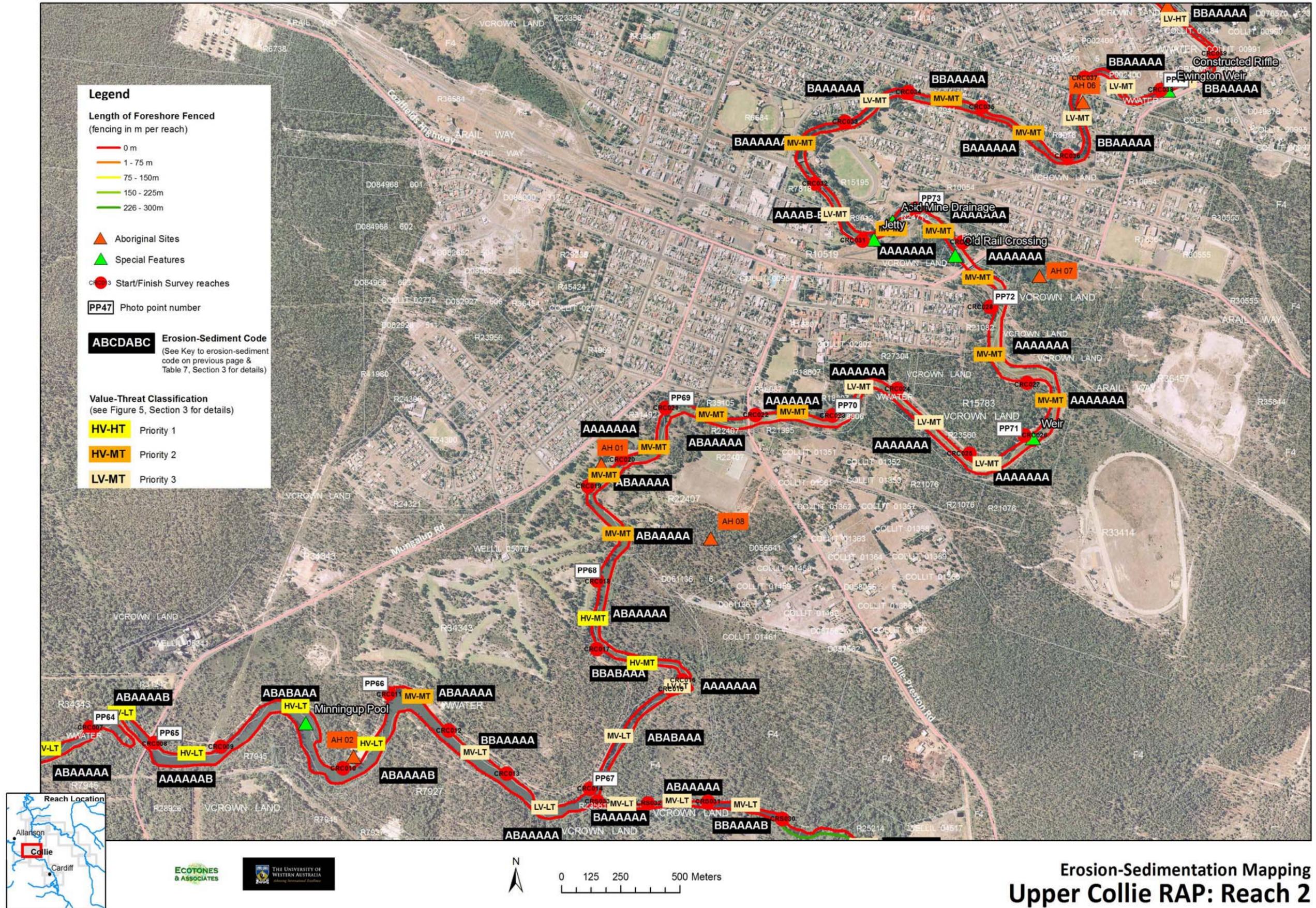
PP74: Constructed riffle near Ewington Weir (looking downstream)

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)





REACH 3

Reach 3 continues upstream on Collie R. Central (CRC) from Reach 2 for about 8.5kms. The first survey site was CRC039 and the last CRC062. It contains 24 individual survey sites, mostly in cleared agricultural land to the north of Collie.

Description

Feature	Comments
Landuse	The southern part of the reach lies within the rural urban fringe of Collie (north). Lot P014975 remains uncleared but the lots on the western side (lots COLLIT 01076 and COLLIT 00356 can be described as semi-rural (hobby farms). Most of the remaining lots (in the northern part of the reach) have been cleared for agriculture and are grazed.
Land tenure	Reserves are the responsibility of the Shire, other lots are freehold.
Fencing	Lot PO14975 is unfenced. Most other lots are fully fenced but lots upstream of Eight Mile Pool (AH005) are approx 50% fenced. Lots PO22213 and WELLIL 01222 are mostly unfenced.

Condition

Feature	Comments
Vegetation	Dominant trees & shrubs: River banksias (<i>Banksia littoralis/seminuda</i>), marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), mohan (<i>Melaleuca viminea</i>), swish bush (<i>Viminaria juncea</i>), grey honey myrtle (<i>Melaleuca incana</i>), coojong (<i>Acacia saligna</i>), bracken fern (<i>Pteridium esculentum</i>), wandoo (<i>E. wandoo</i>), swamp sheoak (<i>Casuarina obesa</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), broad leaved hakea (<i>Hakea amplexicaulis</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), semaphore sedge (<i>Mesomelaena tetragona</i>) and pithy sword sedge (<i>Lepidosperma longitudinale</i>). Herbs, creepers & bulbs: Button weed (<i>Cotula</i> spp.)
Weeds	Pasture grasses, blackberry (<i>rubus</i> spp.), radiata pine (<i>Pinus radiata</i>), silver wattle (<i>Acacia podalyriifolia</i>), bulrush (<i>Typha orientalis</i>), African lovegrass (<i>Eragrostis curvula</i>), paspalum (<i>Paspalum dilatatum</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> spp.), phalaris (<i>Phalaris aquatica</i>), green fat hen (<i>Chenopodium murale</i>), dock (<i>rumex</i> sp.), fleabane (<i>Conyza</i> sp.), blackberry nightshade (<i>Solanum nigrum</i>) and watsonia (<i>Watsonia meriana</i>).
Bank stability and erosion	Most of this reach has only minor erosion; however, there is evidence of more severe erosion (mainly undercutting) at site CRC041 and lot COLLIT 01076. Large woody debris can be found at this and other sites in the reach and this may be partially responsible for the bank erosion.
Special features, other comments	There are two sites with Aboriginal significance: Telfer Pool (AH04) and Eight Mile Pool (AH05). There are two human-made rock riffles at site CRC041.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
2b	MV/MT (2 sites)	Sites CRC042 and CRC044.	The main weed concerns are Pasture grasses but there is some Blackberry at CRC042. There is minor undercutting along both banks. Fencing is generally good at the sites although there is no

			fencing along lot PO14975 (left bank); however, since this lot is uncleared and not grazed, this is not regarded as a concern.
3b	LV/HT (2 sites)	Sites CRC039 and CRC062.	There are a number of weeds present of concern at site CRC039, especially Blackberry and Watsonia but there is also Radiata pine, African lovegrass, Paspalum and Pasture grasses. Blackberry and Pasture grasses are also found at CRC062. Active bank undercutting is taking place on the right bank (west side) at site CRC039 (see photo CRC039). The banks on both sides of the river at both sites are currently unfenced, which is a concern given that land use at these sites is pasture for grazing.
3c	LV/MT (12 sites)	Sites CRC040, CRC041, CRC045, CRC047, CRC050, CRC051, CRC052, CRC056, CRC057, CRC059, CRC060 and CRC061	The weed of most concern is Blackberry which is found throughout many sites in this reach but especially at CRC040, CRC045, CRC050, CRC051, CRC052, CRC057, CRC059 and CRC060. Watsonia is also present at CRC040. Other weeds found include African lovegrass, Fat hen green, Fleabane, Flat weed, Dock, Deadly nightshade, Paspalum and pasture grasses. There is severe bank undercutting on right bank at site CRC041. LWD is also evident at CRC041 but also at CRC050, CRC051, CRC056 and CRC061. LWD may be partially responsible for the severe bank erosion at CRC041. There is no fencing on right bank CRC040, left bank CRC056 and right bank at CRC061, only partial fencing on right bank CRC047, CRC050, left bank CRC059.
3d	LV/LT (8 sites)	Sites CRC043, CRC046, CRC048, CRC049, CRC053, CRC054, CRC055 and CRC058	Blackberry is present at CRC046, CRC049, and CRC058. Other weeds include Fat hen green, Fleabane, Flat weed, Blowfly grass, Paspalum, Dock, Ribbon weed and pasture grasses. Active but minor undercutting is taking place at sites CRC043 and this may be being encouraged by the presence of LWD at the site. LWD is also at site CRC053 and CRC055. The left bank of site CRC048 is only partially fenced, similarly the right bank at CRC049 and CRC058. Since it appears the adjacent land use to these sites is grazing, landholders should complete the fencing to control stock access.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Encourage local landholders and the Shire to work with engineers from the Department of Water (DoW) to address the more serious erosion problems in the reach. Implement erosion control measures at sites CRC039 and CRC041 as a priority (see Section 6 for detailed erosion control techniques).
Weeds	Significant numbers of weeds are evident in this reach. Encourage landholders (local government and DEC), local community groups and weed action groups in weed management. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target Blackberry, Silver wattle and Watsonia in this area. Assist regeneration of native vegetation through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and

	information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Urban development	Sub-division and on-site developments should utilise site management BMPs to ensure sediment from sites is not washed into stormwater drains and consequently into the river.
Fencing/loss of native vegetation	Loss of native riparian vegetation is a significant issue in this reach, especially in the northern section. Much of the river in this reach is bound by UCL so landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Where stock are present fence off the river to restrict stock access and provide off-river watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.
Fish	Use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.
Declining water quality	Encourage the Shire Council to realign large woody debris to ensure it does not encourage erosion. Encourage use of Best Management Practices (BMPs) on adjacent farms to increase water quality locally and downstream. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a comprehensive list of appropriate BMPs.

Please note ‘encourage’ and ‘support’ can mean to: provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 3:



Pen-Scott C1 example: severe undercutting on west bank (CRC039)



Pen Scott B3 example: Telfer's Pool, AH 04 (CRC040)



Pen Scott B1 example: pasture grasses dominate understorey (CRC041)



Pen Scott B1 example (CRC052)



Pen Scott C2 example: heavily grazed foreshore with old crossing in background (CRC054)



Pen Scott C1 example: south bank, limited riparian vegetation (CRC055)



Pen Scott C2 example: bank damage from stock access (CRC059)

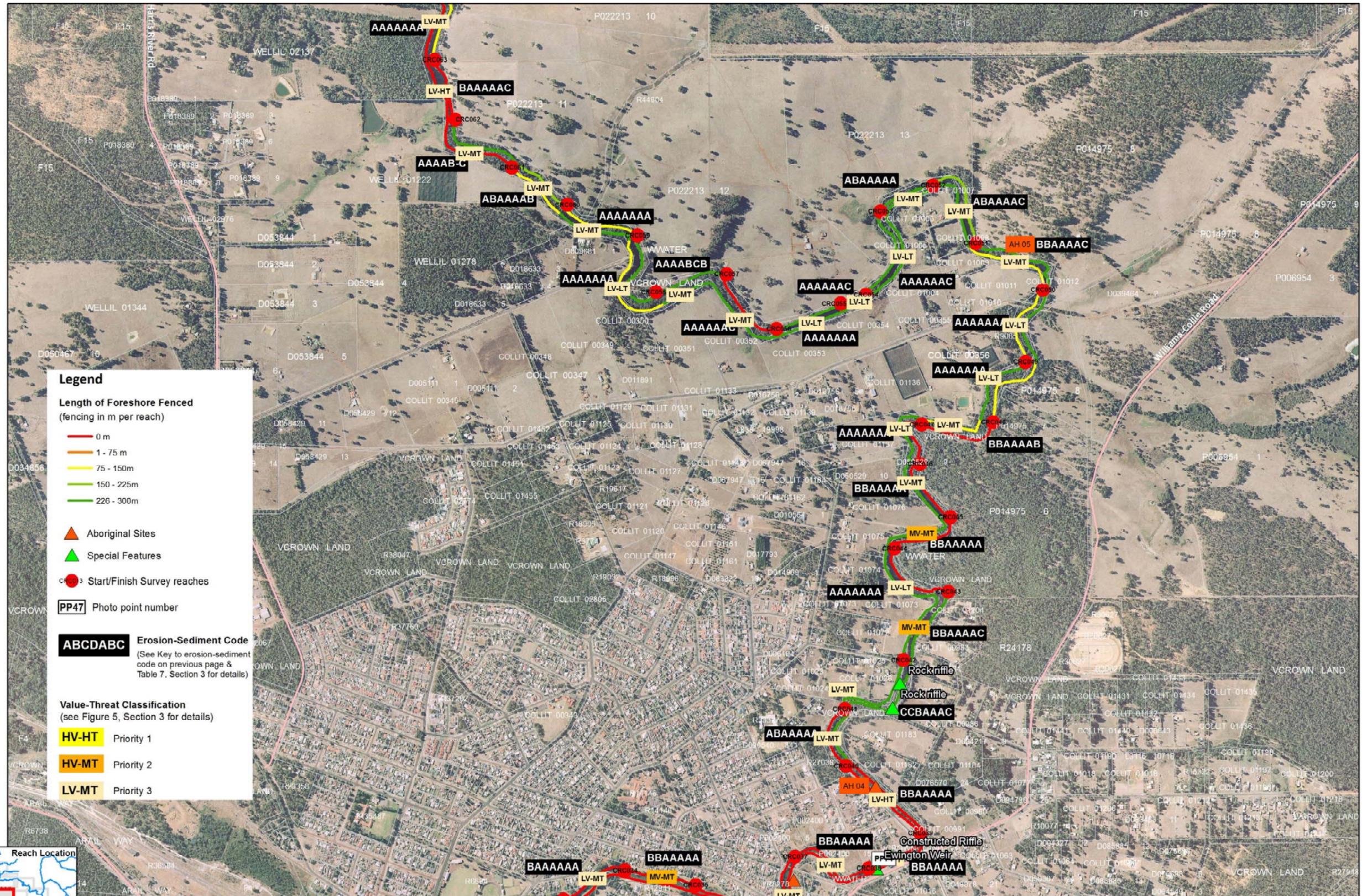


Pen Scott C1 example: minimal riparian vegetation & algae in water (CRC061)

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



Legend

Length of Foreshore Fenced (fencing in m per reach)

- 0 m
- 1 - 75 m
- 75 - 150m
- 150 - 225m
- 226 - 300m

▲ Aboriginal Sites

▲ Special Features

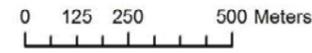
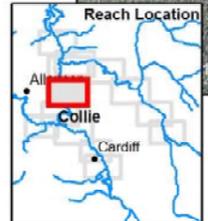
● Start/Finish Survey reaches

PP47 Photo point number

ABCDABC Erosion-Sediment Code
(See Key to erosion-sediment code on previous page & Table 7, Section 3 for details)

Value-Threat Classification
(see Figure 5, Section 3 for details)

- HV-HT Priority 1
- HV-MT Priority 2
- LV-MT Priority 3



**Erosion-Sedimentation Mapping
Upper Collie RAP: Reach 3**

REACH 4

Reach 4 considers the last three survey sites on Collie R. Central (CRC) but also the last three survey sites on the Harris R. (HR). It continues up CRC from site CRC063 for about 4.1kms ending with site CRC073 at the confluence with the Harris and Collie R. East (CRE) rivers. There are 11 survey sites on CRC, mostly in plantation forested and reserved land, and the last three sites of the Harris (1.9kms).

Description

Feature	Comments
Landuse	Most lots west of the river have been cleared for grazing. A large portion on the east side is plantation forest but there is a lot, P017495 that remains uncleared.
Land tenure	A single landholder owns many lots in the southern part of this reach. Reserves are crown land and managed by DEC.
Fencing	Fencing on the western side of the river is mostly complete. There is no fencing at lot P017495 or along the plantation forest but lack of fencing on lots in the southern part of the reach is a concern as these lots are grazed.

Condition

Feature	Comments
Vegetation	Dominant trees & shrubs: Marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), bracken fern (<i>Pteridium esculentum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), swish bush (<i>Viminaria juncea</i>), zamia palm (<i>Macrozamia riedlei</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), marsh club rush (<i>Bolboschoenus caldwollii</i>), jointed twig rush (<i>Baumea articulata</i>) and spreading sword-sedge (<i>Lepidosperma effusum</i>). Herbs, creepers & bulbs: Button weed (<i>Cotula</i> spp.) and dodder (<i>Cassytha flava</i>). Aquatic plants: Nardoo (<i>Marsilea mutica</i>) – regarded locally as a weed, water ribbons (<i>Triglochin</i> spp.)
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), paspalum (<i>Paspalum dilatatum</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> spp.), dock (<i>Rumex</i> spp.), cotton bush (<i>Gomphocarpus fruiticosus</i>), fleabane (<i>Conyza</i> sp.), green fat hen (<i>Chenopodium murale</i>), pennyroyal (<i>Mentha pulegium</i>), parrot's feather (<i>Myriophyllum aquaticum</i>) and watsonia (<i>Watsonia meriana</i>).
Bank stability and erosion	Most of this reach has only minor erosion; however, there is evidence of minor undercutting at 8 sites. Large woody debris is also found at some of these sites.
Special features, other comments	There are two river crossings on Collie R. East at sites CRE091 and CRE093, and another on the Harris R. at HR016. There is also a V-notch weir on the Harris R at HR014.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
2b	MV/MT (1 site)	The last survey site on Collie R. Central (CRC073).	The main weeds of concern are Blackberry and pasture grasses (see photo) but Cotton bush is also present. Minor bank undercutting on the right bank (west side). The right bank remains completely unfenced and stock access may be responsible for the undercutting.
3b	LV/HT	This site is located	Again, Blackberry and pasture grasses are present

	(1 site)	on the Harris R. (HR016).	as is minor bank undercutting on the left bank. The left bank is unfenced but land use here is forestry.
3c	LV/MT (10 sites)	These sites are common throughout the reach: CRC063, CRC064, CRC066, CRC067, CRC068, CRC069, CRC070, CRC071, CRC072 and HR015.	Blackberry is the main weed that is of concern and this is common to almost all sites in the category. Pasture grasses are also common throughout. Other weeds found were Fleabane, Flat weed, Paspalum and Dock. Minor bank undercutting is evident on both banks at CRC064 and CRC072, also the right bank of CRC066 and CRC071. LWD is also common at these sites: CRC064, CRC067, CRC069, CRC070, CRC071 and CRC072 (most concern at CRC067, CRC069 and CRC071. Where stock are present, fencing is inadequate on the left bank of CRC063 (photo), CRC064 and HR015.
3d	LV/LT (2 sites)	The sites in this category are CRC065 and HR017.	Blackberry does not appear to be evident at these sites however there are extensive pasture grasses and other weeds (i.e. Fleabane, Fat hen green, Blowfly grass, Parrot feather, Ribbon weed and Paspalum). Minor bank undercutting (left bank) is found at CRC065 but there is significant LWD at bot sites – especially HR017.

* See Table 12 in Section 7 to identify dominant management approaches. NB: 11 sites are associated with Collie R. Central and 3 with the Harris R.

Issue	Management Action/Advice
Erosion	Encourage landholders to protect banks from stock by fencing where necessary and then stabilise banks through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	Significant numbers of weeds are evident in this reach. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Encourage landholders (local government and DEC), local community groups and weed action groups in weed management. Target Blackberry in this area. Assist regeneration of native vegetation through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fencing/loss of native vegetation	Loss of native riparian vegetation is a significant issue in this reach, especially on the western bank. Most lots are well fenced except lots in the southern part – at sites CRC063 and CRC064. Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Where stock are present fence off the river to restrict stock access and provide off-river watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.
Fish	Use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.
Declining water quality	Encourage landholders to stabilise bank erosion by planting local native species (see above) and where necessary align large woody debris so that it does not cause

erosion. Encourage use of Best Management Practices (BMPs) on adjacent farms to increase water quality locally and downstream. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a comprehensive list of BMPs.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 4:



Pen-Scott C2 example: exposed bank (CRC063)



Pen-Scott C1 example at CRC064



Pen-Scott B3 example at CRC065



Pen-Scott B3 example: pasture grasses occupying bank (CRC073)



Pen-Scott C2 example, Harris R. (HR015)

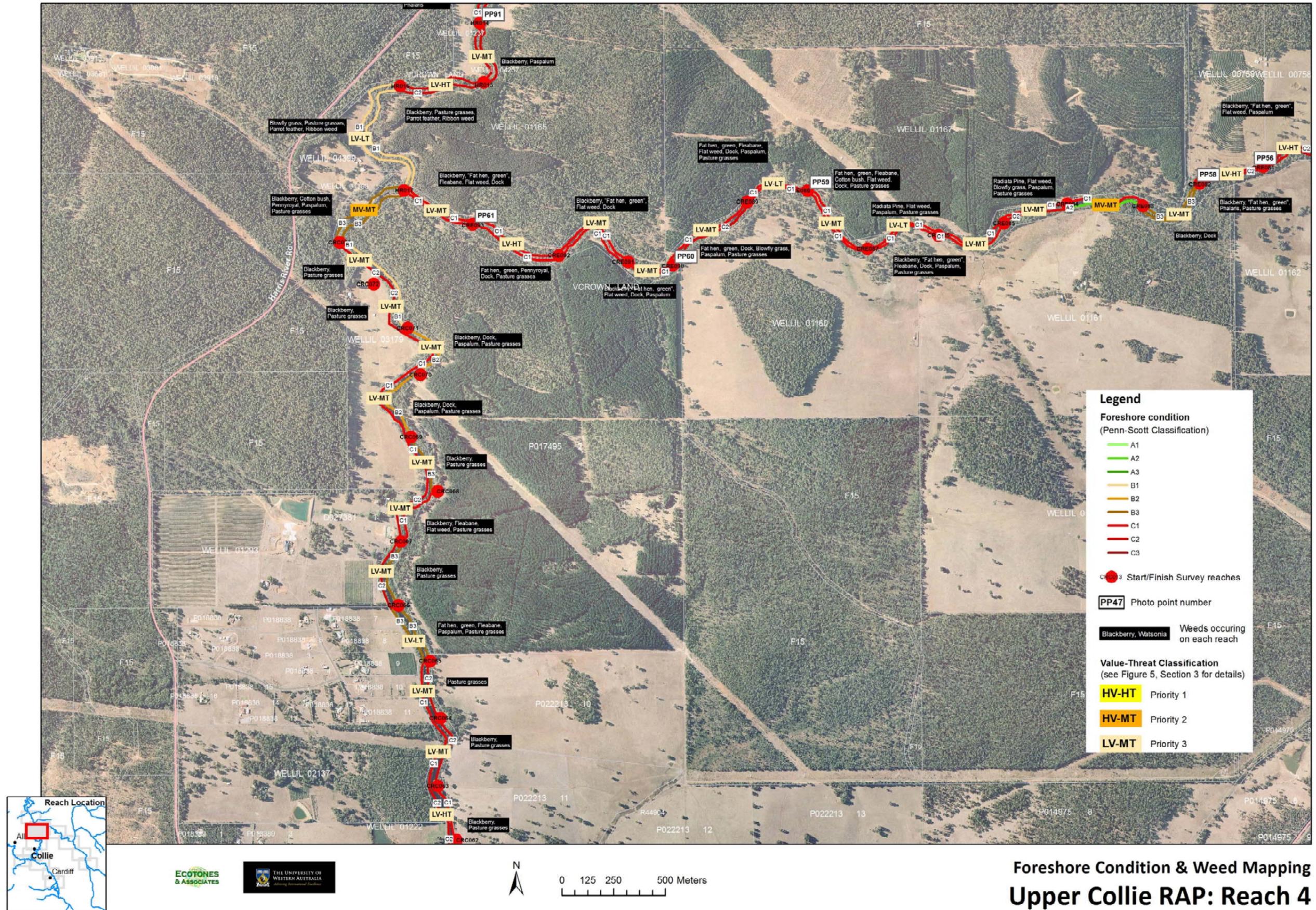


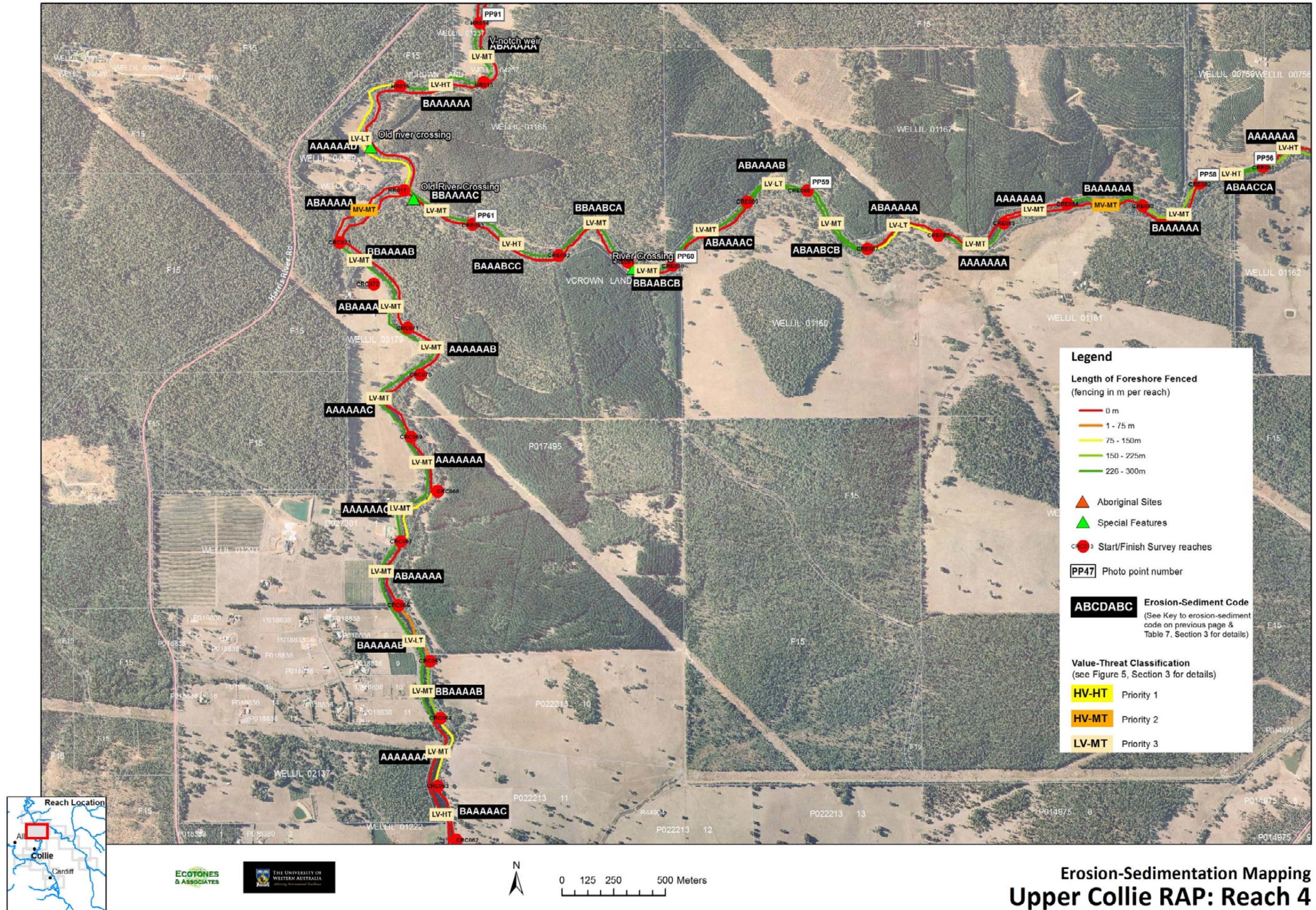
Pen-Scott B1 example, Harris R. (HR017)

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)





REACH 5

Reach 5 features the Harris R. (HR). The start (HR001) is just south of the Harris Dam and the reach extends downstream for approx. 5.1kms to site HR012. The first seven of the 12 survey sites of the Harris R. run through forest-reserved land.

Description

Feature	Comments
Landuse	Lots in the northern part of the reach (F15) are reserved crown land. Lots WELLIL 04503 and WELLIL 00985 have been cleared for agriculture and are under grazing pasture – most of the threats to the river are associated with this landuse.
Land tenure	The forest reserves are managed by DEC. Agricultural lots are freehold and owned by a single landholder.
Fencing	There is little fencing on either bank of this reach. The forest reserve lots are completely unfenced, lots WELLIL 04503 and WELLIL 00985 are both only partially fenced.

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: River banksia (<i>Banksia littoralis/seminuda</i>), marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), mohan (<i>Melaleuca viminea</i>), bracken fern (<i>Pteridium esculentum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), Swamp sheoak (<i>Casuarina obesa</i>), swish bush (<i>Viminaria juncea</i>), zamia palm (<i>Macrozamia reidleyi</i>), sickle hakea (<i>Hakea falcata</i>), two leaved hakea (<i>Hakea trifurcata</i>), swamp peppermint (<i>Taxandria linearifolia</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), semaphore sedge (<i>Mesomelaena tetragona</i>), tall clumped sedge (<i>Restionaceae</i>), pithy sword sedge (<i>Lepidosperma longitudinale</i>), jointed twig rush (<i>Baumea articulata</i>), spreading sword-sedge (<i>Lepidosperma effusum</i>) and pale rush (<i>Juncus pallidus</i>).</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>) and angled lobelia (<i>Lobelia anceps</i>).</p> <p>Aquatic plants: Nardoo (<i>Marsilea mutica</i>) – regarded locally as a weed, Water ribbons (<i>Triglochin</i> spp.)</p>
Weeds	Pasture grasses, paspalum (<i>Paspalum dilatatum</i>), parrot's feather (<i>Myriophyllum aquaticum</i>) and phalaris (<i>Phalaris aquatica</i>).
Bank stability and erosion	Bank stability is good between the dam and the agricultural lots but there is evidence of erosion on banks through the agricultural lots.
Special features, other comments	There are farm crossings and a stock access point between lots WELLIL 04503 and WELLIL 00985. There is a V-notch weir at site HR014 (see photo).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
3a	MV/LT (1 site)	Site HR001 at the top of the reach (just below the Harris Dam).	The only weed found at this site was Parrott feather. There is no erosion or LWD that may be regarded as a concern and while the river is unfenced on both banks this is not regarded as a threat given the current landuse (forest reserve).

3b	LV/HT (1 site)	Between lots WELLIL 04503 and WELLIL 00985 (HR010).	Two weeds were found here: Phalaris and Duckweed; however, the main concerns are associated with active bank erosion (undercutting on both banks and sedimentation). There is no fencing to prevent stock access on the right bank and only limited fencing on the left.
3c	LV/MT (2 sites)	Between lots WELLIL 04503 and WELLIL 00985 (HR011 and HR012).	Phalaris is the only weed found at these sites. Again, there is active sedimentation (probably the result of active erosion at sites HR008 and HR009 up-stream) and fencing is completely inadequate to prevent stock access.
3d	LV/LT (8 sites)	All the sites between (and including) HR002 and HR009.	Parrott feather is the most common weed found in these sites but Paspalum and Ribbon weed can also be found at sites HR008 and HR009. There is very little evident erosion at these sites except some very minor undercutting of the right bank at HR008. LWD can also be found at sites HR004 and HR007 but this is not regarded as a concern.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Stock are accessing the river at lots WELLIL 04503 and WELLIL 00985 and this is causing erosion at these sites and sedimentation downstream. Encourage the landholder to fence off the river to restrict stock access and provide off-river watering points to minimise bank damage and protect water quality.
Weeds	Significant numbers of weeds are evident in this reach. Encourage the landholder (local government and DEC), local community groups and weed action groups in weed management. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target phalaris and paspalum in this area. Assist regeneration of native vegetation along foreshores of agricultural lots through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority when weeds are removed.
Fencing/loss of native vegetation	Native vegetation is a good condition in the north of the reach in the reserved lots. Loss of native riparian vegetation is a significant issue in the southern part where agriculture dominates. Most agricultural lots have little or inadequate fencing to protect banks from stock. Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Where stock are present fence off the river to restrict stock access and provide off-river watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.
Fish	Encourage the landholder of the agricultural lots to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.
Declining water quality	Encourage the landholder in the use of Best Management Practices (BMPs) to increase water quality locally and downstream. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a list of BMPs.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 5:



Pen-Scott B1 example: (HR001)



Pen-Scott A2 example: (HR005)



Pen-Scott A2 example: (HR006)



PP90: Farm crossing at HR009



Pen-Scott A3 example: stock access damage
(HR009)



Pen-Scott C1 example: (HR010)



Pen-Scott C2 example: (HR012)

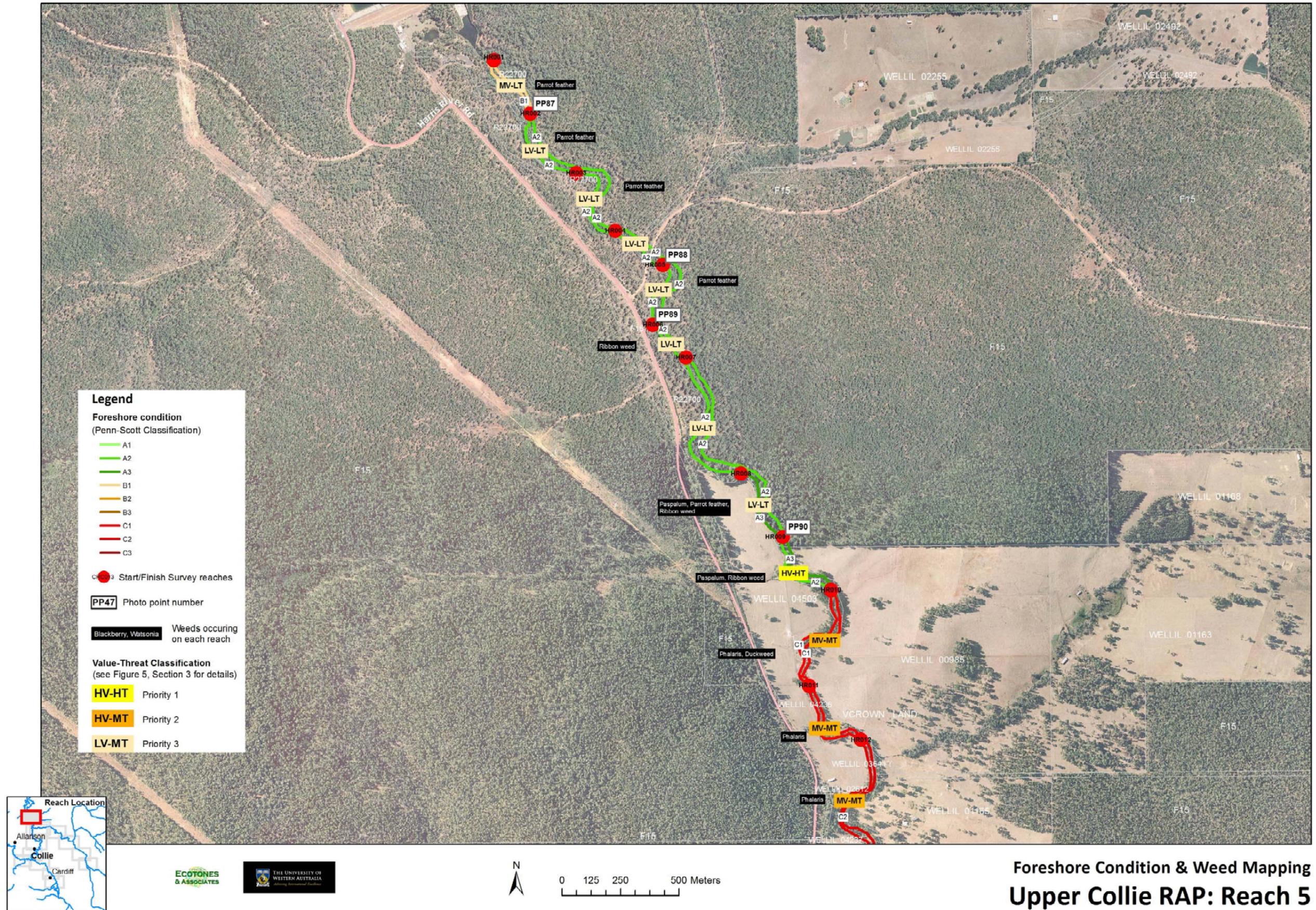


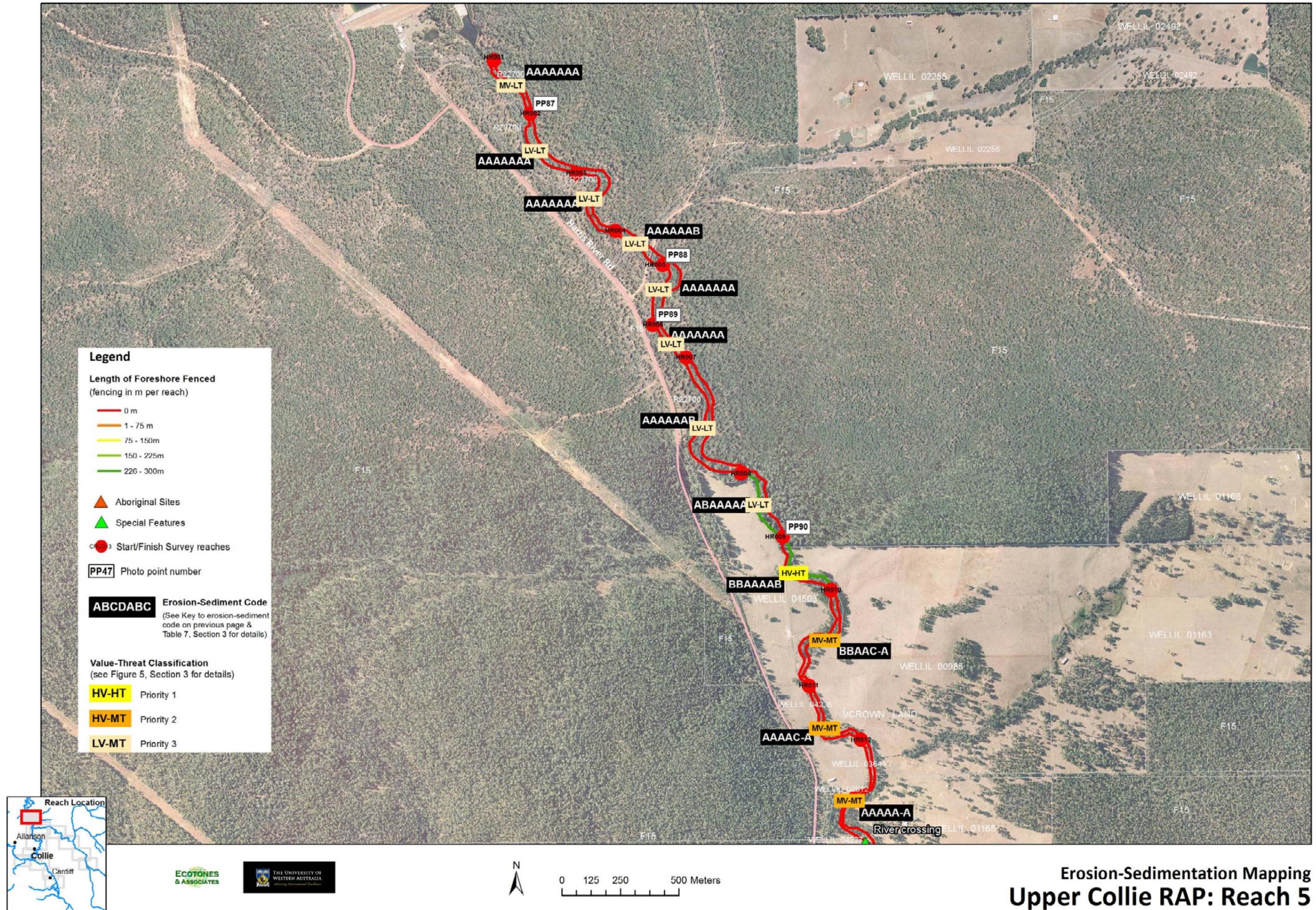
V-notch weir at HR014

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)





REACH 6

This reach is the last on Collie R. East (CRE). It continues downstream for 6.0kms from the last surveyed site in Reach 7 and includes sites from CRE079 to CRE093 – 15 sites. The last site is where CRE meets the Harris R. (three sites associated with the Harris R. can also be seen on the maps).

Description

Feature	Comments
Landuse	Dominant land use at this reach is agricultural but lots WELLIL 01165 and P017495 are uncleared and the majority of lot WELLIL 01167, immediately north of Collie R. East, has been planted with plantation forest (<i>E. globulus</i>).
Land tenure	The majority of lots are freehold farmland but the uncleared reserved land (WELLIL 01165) is managed by DEC.
Fencing	The eastern side of the Harris R. is unfenced although this lot is fenced where it meets the northern bank of Collie R. East. Lot WELLIL 01167 (plantation forest) is partially fenced (western half) but there are parts unfenced or where fencing is in poor condition. Lot WELLIL 00759 is fenced but WELLIL 00758 is unfenced. On the south bank of Collie R. East, fencing is intermittent – lots WELLIL 01160, WELLIL 01161 and WELLIL 01162 are partially fenced.

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: River banksia (<i>Banksia littoralis/seminuda</i>), marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. Rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), mohan (<i>Melaleuca viminea</i>), bracken fern (<i>Pteridium esculentum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), swish bush (<i>Viminaria juncea</i>), zamia palm (<i>Macrozamia riedlei</i>), sickle hakea (<i>Hakea falcata</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), jointed twig rush (<i>Baumea articulata</i>), spreading sword-sedge (<i>Lepidosperma effusum</i>), marsh club grass (<i>Bolboschoenus caldwellii</i>) and pale rush (<i>Juncus pallidus</i>).</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), angled lobelia (<i>Lobelia anceps</i>) and button weed (<i>Cotula</i> spp.)</p> <p>Aquatic plants: Parrot feather (<i>Myrophyllum aquaticum</i>) and water ribbons (<i>Triglochin</i> spp.)</p>
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), radiata pine (<i>Pinus radiata</i>), paspalum (<i>Paspalum dilatatum</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> spp.), dock (<i>Rumex</i> spp.), cotton bush (<i>Cortaderia selloana</i>), fleabane (<i>Conyza</i> spp.), green fat hen (<i>Chenopodium murale</i>), pennyroyal (<i>Mentha pulegium</i>) and parrot feather (<i>Myrophyllum aquaticum</i>).
Bank stability and erosion	Relatively minor bank undercutting and large woody is evident in the western part of the reach and sedimentation can be found at the western end of lot 20183640.
Special features, other comments	Water Corp. gauging station/weir 2.1 kms upstream from confluence). Concrete road crossing on Collie R. east about 1.5 kms upstream from Harris R. confluence.

Management

Priority ranking of Collie R. East sites (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
2b	MV/MT (2 sites)	Sites CRE083 and CRE090.	Blackberry and Dock are present at both sites. Minor undercutting on left bank of CRE083 and both banks of CRE090. There is also pool aggradation and LWD at CRE090. No fencing on left bank of CRE083 or CRE090; however, land use at CRE090 is plantation forest so stock access is not currently a concern at this site.
3b	LV/HT (3 sites)	Sites CRE080, CRE081 and CRE092.	Sites CRE080 and CRE081 both contain Blackberry and Fat hen green but Flat weed and Paspalum are also found at CRE080 while Phalaris and pasture grasses are at CRE081. It was evident during survey that some Blackberry had been sprayed (PP58). Fat head green, Pennyroyal, Dock and pasture grasses are found at CRE092. CRE080 is free from erosion concerns however both CRE081 and CRE090 have bank undercutting, point bars and pool aggradation. CRE090 also has significant LWD. Fencing is inadequate at CRE080 (no fencing on right bank and partial on left) and stock was seen accessing the river at this site.
3c	LV/MT (8 sites)	Sites CRE079, CRE082, CRE084, CRE085, CRE087, CRE089, CRE091 and CRE093.	These sites are distributed evenly across the reach. Blackberry is common to most of these sites and is the weed of most concern. Other common weeds found at these sites include Fat hen green, Flat weed, Paspalum, Fleabane, Dock and pasture grasses. Cotton bush was also found at CRE087. There is a large obstructing log at CRE089 and other significant LWD at CRE093. CRE091 and CRE093 also have minor bank undercutting on both banks and this occurs on the right banks of CRE087 and CRE089 and on the left bank of CRE082. Sites where fencing is inadequate to prevent stock access are CRE079, CRE084 and CRE089 all along the southern (left) bank.
3d	LV/LT (2 sites)	Sites CRE086 and CRE088.	Blackberry is at CRE086 while Fat hen green, Fleabane, Dock, Paspalum and pasture grasses are common to both sites. Minor undercutting is taking place on the right banks of both these sites and LWD is at site CRE088. Fencing is good at CRE088 but at CRE086 the right bank is unfenced and the left is only partially fenced; it is the left bank which is of most concern since WELLIL 01160 is a grazed lot.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Landholders and DEC should consider re-aligning large woody debris to minimise bank disturbance. Especially for lots WELLIL 01160, 01161 01162, encourage the landholder to protect banks from stock by fencing where necessary and then stabilise banks through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	Significant numbers of weeds are evident in this reach. Encourage landholders (local government and DEC), local community groups and weed action groups in weed management. Information regarding weed management may be obtained

	<p>from: http://www.agric.wa.gov.au/PC_92738.html</p> <p>Target blackberry, phalaris and paspalum in this area. Assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.</p>
Fencing/loss of native vegetation	<p>Loss of native riparian vegetation is a significant issue to the south of Collie R. East (lots WELLIL 01160, 01161 01162). Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Fencing should be repaired where in poor condition and installed where stock are accessing the river. Install watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.</p>
Fish	<p>Encourage the landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.</p>
Declining water quality	<p>Encourage the landholders in the use of Best Management Practices (BMPs) to increase water quality. The Department of Agriculture and Food WA (DAFWA) water management BMPs includes the management of important on-farm issues such as erosion, nutrient inputs, vegetation, grazing and water sources (see Appendix 6). Contact DAFWA for a comprehensive list of BMPs.</p>

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 6:



PP57: river crossing



PP58: Pen-Scott C2 example, sprayed blackberry



Pen-Scott B3 example (CRE083)



Pen-Scott C1 example (CRE085)



Pen-Scott C1 example (CRE085)



PP59: Pen-Scott C1 example, large log has erosion potential



PP60: currently used river crossing

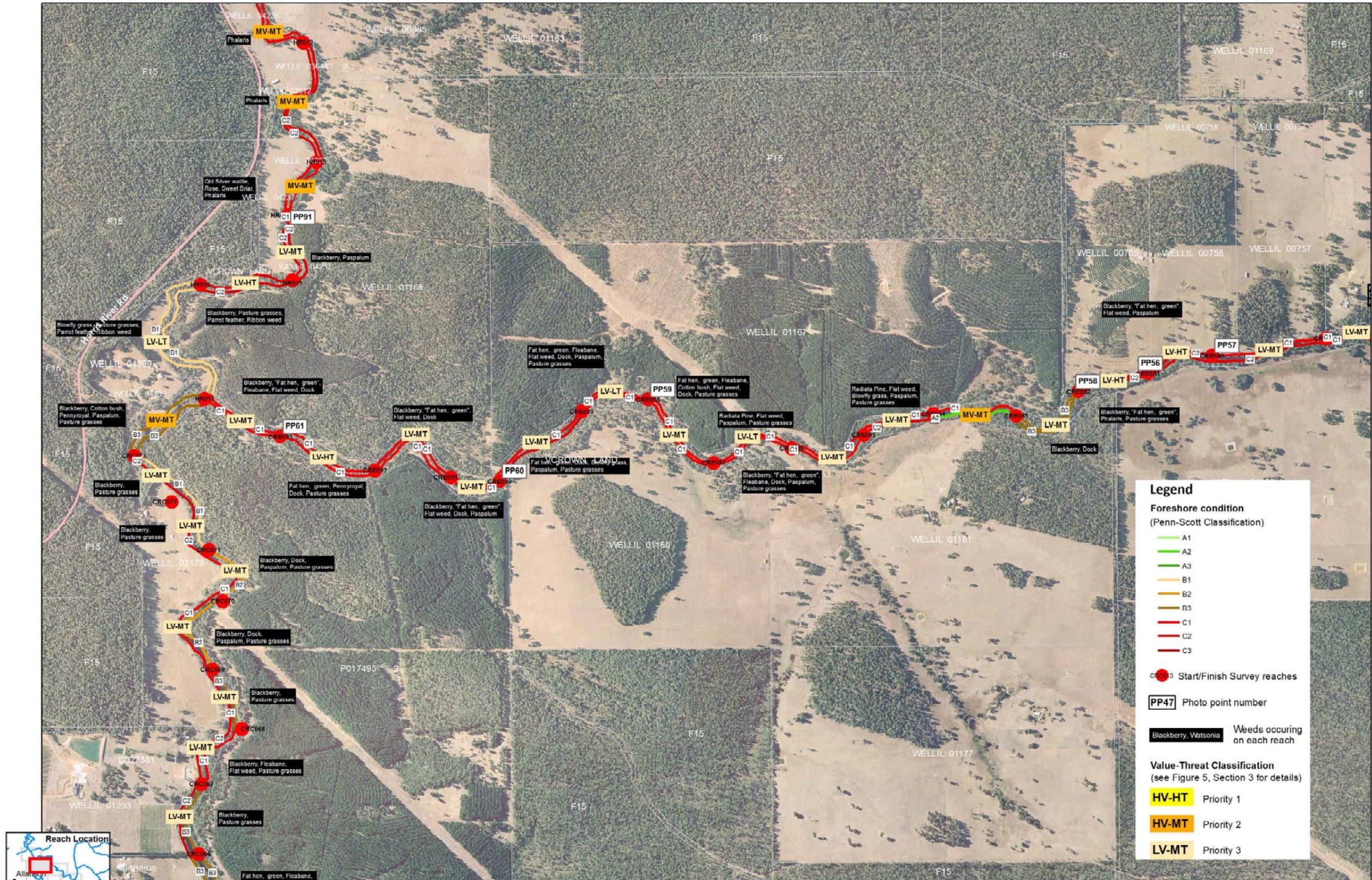


PP61: remains of old river crossing

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)

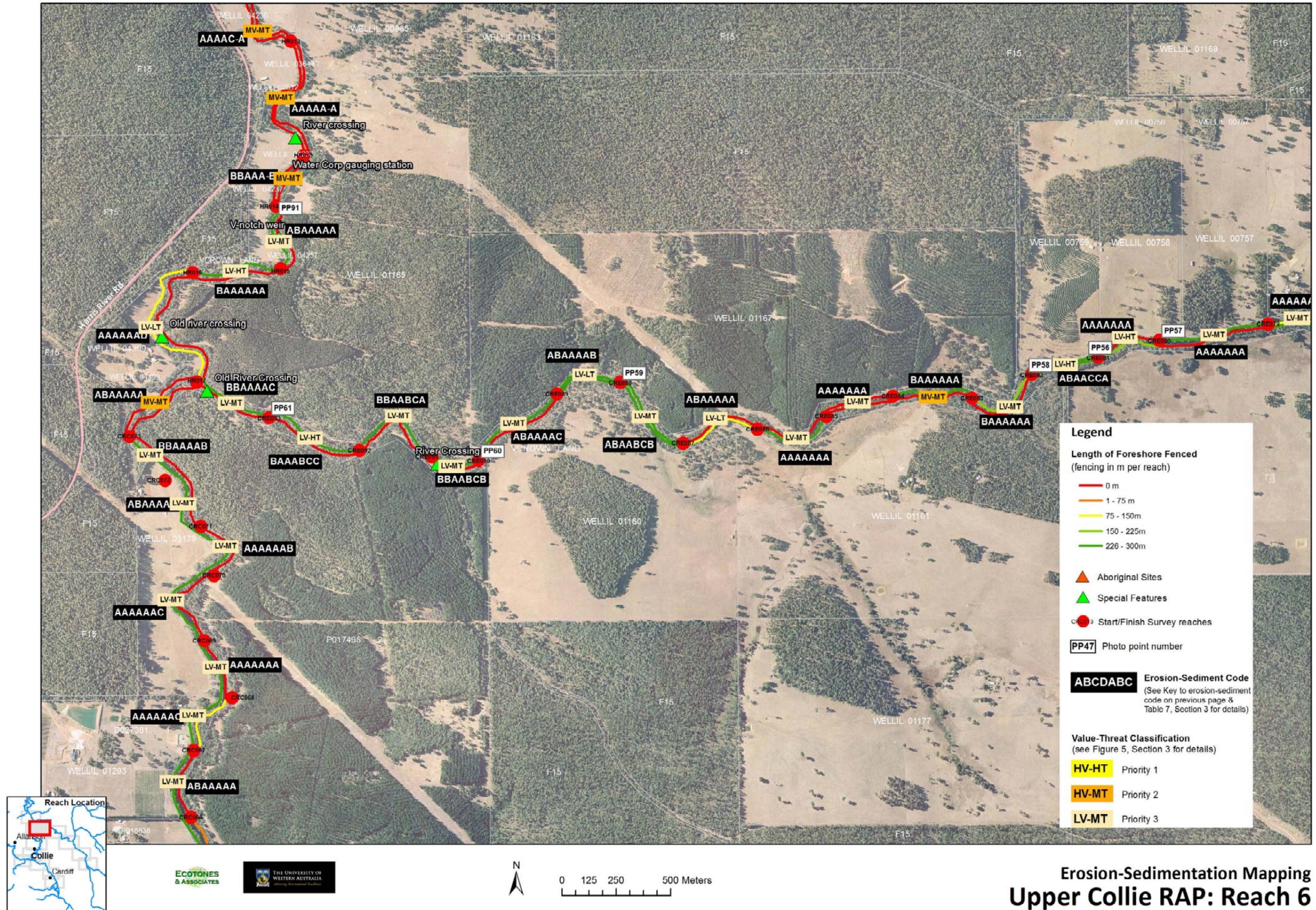


ECOTONES & ASSOCIATES



0 125 250 500 Meters

**Foreshore Condition & Weed Mapping
Upper Collie RAP: Reach 6**



REACH 7

This reach continues downstream on Collie R. East for approx. 7.3 kms. There are 21 individual survey sites beginning with CRE058 and ending with CRE078.

Description

Feature	Comments
Landuse	The reach passes through predominantly agricultural land which is under pasture. A 1 km stretch of the riparian zone, between lot F15 and PO20236, is largely uncleared. Lots in the south-east of the reach are planted for timber.
Land tenure	Predominantly freehold farms with plantation timber in southern part of reach.
Fencing	Most of the reach, especially in the southern half, remains unfenced.

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: Marri (<i>C. calophylla</i>), Jarrah (<i>E. marginata</i>), flooded gum (<i>E. Rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), coojong (<i>Acacia saligna</i>), Astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), sickle hakea (<i>Hakea falcata</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), jointed twig rush (<i>Baumea articulata</i>), marsh club grass (<i>Bolboschoenus caldwellii</i>) and pale rush (<i>Juncus pallidus</i>).</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), angled lobelia (<i>Lobelia anceps</i>) and samphires (<i>Halosarcia</i> spp.)</p> <p>Aquatic plants: Water ribbons (<i>Triglochin</i> spp.)</p>
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), paspalum (<i>Paspalum dilatatum</i>), phalaris (<i>Phalaris aquatica</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> spp.), fleabane (<i>Conyza</i> sp.), stinkwort (<i>Dittrichia graveolens</i>), green fat hen (<i>Chenopodium murale</i>), toad rush (<i>Juncus bufonis</i>), dock (<i>Rumex</i> sp.), black berry nightshade (<i>Solanum nigrum</i>), sweet briar (<i>Rosa rubiginosa</i>), birds' foot trefoil (<i>Lotus corniculatus</i>) and silver wattle (<i>Acacia podalyriifolia</i>)
Bank stability and erosion	Significant sedimentation, pot holing, LWD and, to a lesser extent, bank erosion is common throughout the reach.
Special features, other comments	Old river crossing 200 meters downstream of Williams Road bridge (PP49); spring at site CRE078 (see photo PP55); old river crossings at sites CRE068 (PP49) and CRE066.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
2a	MV/HT (1 site)	Site CRE065.	A number of weed species were identified at this site including: Blackberry, Sweet briar, Fat hen green, Fleabane, Flat weed, Blowfly grass, Paspalum, Phalaris and pasture grasses. There is minor undercutting on the right bank but of more concern is sedimentation in the form of point bars and pool aggradation. Both banks remain completely unfenced but since the landuse here is forestry, this is not a concern.
2b	MV/MT	Sites CRE066,	Weed species identified at this site include:

	(3 sites)	CRE068 and CRE069.	Blackberry, Sweet briar, Fat hen green, Fleabane, Flat weed, Birdsfoot trefoil, Dock, Blowfly grass and pasture grasses. There is minor undercutting or the right bank but of more concern is sedimentation in the form of point bars. Only the left bank is partially fenced – the right is completely unfenced; again not a concern at this time.
3b	LV/HT (5 sites)	Sites CRE064, CRE072, CRE073, CRE074 and CRE076.	Weeds observed at these sites include Blackberry, Sweet briar, Fat hen green, Fleabane, Dock, Paspalum and pasture grasses. There is minor undercutting on right bank (CRE064), large point bar at CRE072, CRE073 and CRE074 (this may be the result of extensive overland flow and rill erosion, see photos from PP52) but also pool aggradation and LWD. LWD only at site CRE076. No fencing on either bank at CRE064. Left bank appears fully fenced at CRE072 but none on right bank. Partial fencing on both banks at sites CRE073 and CRE074. Site CRE076 is fully fenced on left bank but there is none on the right. Improving fencing would significantly reduce threats.
3c	LV/MT (10 sites)	CRE059, CRE060, CRE061, CRE062, CRE063, CRE067, CRE070, CRE071, CRE077 and CRE078.	Weeds found at these sites include Blackberry, Sweet briar, Very small toad rush, Fat hen green, Fleabane, Dock, Stink wort/weed, Flat weed, Birdsfoot trefoil, Deadly nightshade, Blowfly grass, Paspalum, Phalaris and pasture grasses. Also Silver wattle at CRE070. Site CRE067 appears free from erosion/sedimentation problems; however, there is minor undercutting at sites CRE060, CRE061, CRE063, CRE070 and CRE071. Some pot holing at CRE071 (see photo PP50). Point bars and pool aggradation are both evident at CRE063 and CRE071. LWD was found at five sites: CRE059, CRE063, CRE070, CRE077 and CRE078. Very few of the banks at these sites have been fenced. Neither bank at sites CRE059, CRE060, CRE061, CRE062, CRE063 and CRE067 are fenced. The left banks of sites 70, 71, 77 and 78 are fully fenced but only CRE078 has partial fencing on the right bank – all other right banks have no fencing.
3d	LV/LT (2 sites)	CRE058 and CRE075.	Weeds identified at these sites include: Blackberry, Sweet briar, Fat hen green, Flat weed, Dock, Stink wort/weed, Birdsfoot trefoil, Phalaris, Flat weed, Blowfly grass and pasture grasses. Bank erosion is not a concern at either site but there are point bars and pool aggradation and LWD at both sites. There is no fencing on either bank at CRE058 but both banks at CRE075 appear fully fenced.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Especially for lots in the north-west of this reach, encourage the landholders to protect banks from stock by fencing where necessary and then stabilise banks through planting of local native species – especially lot WELLIL 00760, 00761, 00763 and 00794. Appendix 1 contains a list of local species suitable for planting.

Weeds	Many species of weeds are evident in this reach. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target blackberry, sweet briar, phalaris and paspalum in this area.
Fencing/loss of native vegetation	Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Fencing should be installed where necessary to protect the river from stock. Significant numbers of weeds are evident in this reach. Encourage landholders, Western Power, local community groups and weed action groups in weed management. Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Loss of native riparian vegetation is a significant issue in the north-western part of this reach. Fencing should be repaired where it is in poor condition and installed where stock are accessing the river. Install watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.
Declining water quality	Encourage the landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.

Please note ‘encourage’ and ‘support’ can mean to provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 7:



PP48: Pen-Scott C1 example



PP49: remains of old river crossing



PP50: Pen-Scott C1 example, pot holing



PP51: Pen-Scott C2, cattle accessing streambed



PP52: Pen-Scott C3 example, rilling & overland flow erosion



PP52: Pen-Scott C3 example, large bank undercutting



PP53: Pen-Scott C1 example, bank damaged by stock



PP55: Spring

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)

REACH 8

This reach continues downstream on Collie R. East from Reach 9. It begins at site CRE031 and ends at site CRE057 (27 sites in all) – a river distance of approx. 8.4 kms.

Description

Feature	Comments
Landuse	Landuse is predominantly uncleared reserves and plantation forest. The only notable exception is a portion of lot P020236 (at sites CRE040, CRE041 and CRE042) which has been cleared and is under pasture.
Land tenure	Land tenure is freehold and Western Power is the dominant owner of lots in the reach. Most other lots are a combination of crown land (DEC managed) but timber lots will be privately owned.
Fencing	There is almost no fencing on the entire northern bank of the reach. On the southern bank, again, most is unfenced however part of lot P020236 is fully fenced at sites CRE037, CRE038, CRE039, CRE040 and CRE041.

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: Marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), coojong (<i>Acacia saligna</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), wandoo (<i>E. wandoo</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), sickle hakea (<i>Hakea falcata</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Marsh club rush (<i>Bolboschoenus caldwellii</i>), pale rush (<i>Juncus pallidus</i>) and sedges (<i>Carex</i> spp.).</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), angled lobelia (<i>Lobelia anceps</i>) and samphires (<i>Halosarcia</i> spp.)</p> <p>Aquatic plants: Water ribbons (<i>Triglochin</i> spp.).</p>
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), paspalum (<i>Paspalum dilatatum</i>), phalaris (<i>Phalaris aquatica</i>), blowfly grass (<i>Briza maxima</i>), fleabane (<i>Conyza</i> sp.), stinkwort (<i>Dittrichia graveolens</i>), flat weed (<i>Hypochaeris</i> spp.), green fat hen (<i>Chenopodium murale</i>), lotus (<i>Lotus</i> sp.), dock (<i>Rumex</i> sp.), blackberry nightshade (<i>Solanum nigrum</i>), pennyroyal (<i>Mentha pulegium</i>) and parrot's feather (<i>Myriophyllum aquaticum</i>).
Bank stability and erosion	There is significant sedimentation in the form of point bars and pool aggradation just before and after the confluence with the Bingham River (sites CRE038, CRE039, CRE040 and CRE041). Large woody debris can also be found at a number of sites in the reach.
Special features, other comments	V-notch weir at site CRE044. Monong (close to site CRE038) is a site of Aboriginal significance (AH 12).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1b	HV/MT (1 site)	Site CRE044.	Weeds found at this site were Fat hen green, Blowfly grass, Paspalum and pasture grasses. There was no erosion or sedimentation of concern at the time of survey. There is no fencing on either bank however since landuse is now agro-forestry this is not a concern.

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2a	MV/HT (1 site)	Site CRE031.	Weeds found at this site were Fat hen green, Stink wort/weed, Paspalum and pasture grasses. There is some minor undercutting on right bank and there is some LWD. There is no fencing on either bank but again landuse is now agro-forestry so this is not a concern.
2b	MV/MT (7 sites)	Sites CRE043, CRE045, CRE047, CRE051, CRE054, CRE055 and CRE056.	Weeds found were Fat hen green, Fleabane, Stink wort/weed, Phalaris, Dock, Paspalum, Parrot feather and pasture grasses. There is minor undercutting (both banks) at CRE045 and right banks at CRE047 and CRE051. Sedimentation (point bars and pool aggradation) is occurring at CRE047, CRE054, CRE055 and CRE056. LWD can be found at sites CRE047, CRE051 and CRE055. All sites are unfenced with the exception of CRE047 where the left bank fully fenced however this is not a concern since adjacent landuse is predominantly agro-forestry.
3a	MV/LT (2 sites)	Sites CRE052 and CRE053.	Weeds found were Fat hen green, Fleabane, Dock, Paspalum and pasture grasses. There is some minor undercutting on both banks (CRE053) and the left bank (CRE052). Neither site is fenced on either bank but landuse is now agro-forestry.
3b	LV/HT (2 sites)	Sites CRE033 and CRE034.	Weeds found at these sites included Fat hen green, Stink wort/weed, Pennyroyal, Dock, Paspalum and pasture grasses. Minor bank undercutting can be seen on both banks at both sites. Bank slumping is also evident at CRE034 and there is significant sedimentation in the form of point bars and pool aggradation at CRE033. LWD is also present at this site. There is no fencing at either site (not a concern).
3c	LV/MT (12 sites)	Sites CRE032, CRE035, CRE036, CRE039, CRE040, CRE041, CRE042, CRE046, CRE048, CRE049, CRE050 and CRE057.	Weeds found at these sites included Golden dodder (see photo PP39), Fat hen green, Fleabane, Stink wort/weed, Pennyroyal, Dock, Blowfly grass, Paspalum, Freesia, Parrot feather and pasture grasses (PP37). Sites CRE042 and CRE049 are unusual in that there is no evidence of erosion or sedimentation; however, all the other 10 sites are badly affected. Bank undercutting was found at sites CRE032, CRE035, CRE041 (PP39), CRE046, CRE048, CRE050 and CRE057; bank slumping (both banks) is occurring at CRE032; point bars and pool aggradation is found at CRE032, CRE036 (PP33), CRE039, CRE040, CRE041, CRE048, and CRE057; and, LWD is present at all sites except CRE035, CRE033, CRE042 and CRE049 (e.g. PP36 at site CRE039; PP45 at site CRE046). Sites CRE036, CRE037, CRE039, CRE040, CRE041, CRE049 and CRE050 are all completely or partially fenced on the left bank but all but one site (CRE057) are completely unfenced on the right bank. There's evidence of heavy grazing (e.g. see PP46). Given the current landuse in this reach, fencing of most concern is at sites CRE040 and CRE041 because stock occupy the adjacent lot.

3d	LV/LT (2 sites)	Sites CRE037 and CRE038.	Weeds found at these sites included Fat hen green, Fleabane, Stink wort/weed, Dock, Paspalum and pasture grasses. There was no noticeable erosion at either site but there is a point bar and pool aggradation at site CRE038. The right bank of both sites is entirely unfenced (not a concern at this time) while the left is fully fenced.
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* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Encourage landholders to remove and/or re-align large woody debris causing erosion at sites the confluence of the Bingham River. Encourage the landholder of lot P020709 (CRE041) to protect banks from stock by fencing where necessary and then stabilise banks through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	Many species of weeds are evident in this reach. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html Target blackberry, phalaris and paspalum in this area.
Fencing/loss of native vegetation	Since most of the landuse in this reach is reserve or under forest, fencing is not a concern for most of the reach. However, where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Since lot P020709 is cleared, the landholder should be encouraged to complete fencing. Encourage landholders, Western Power, local community groups and weed action groups in weed management. Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Loss of native riparian vegetation is a significant issue on the south bank at lot P020236. Fencing should be repaired where it is in poor condition and installed where stock are accessing the river. Install watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.
Declining water quality	Encourage the landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.

Please note 'encourage' and 'support' can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 8:



PP33: Pen-Scott C1, sediment bar & erosion



PP36: Pen-Scott B3 example, log induced scour



PP37: Pen-Scott C1 example, widespread pasture grasses



PP39: Pen-Scott C1 example, golden dodder infested tree



PP39: Pen-Scott C1 example, bank undercutting



PP43: Pen-Scott C1 example



PP45: Pen-Scott C1 example, large woody debris pile-up

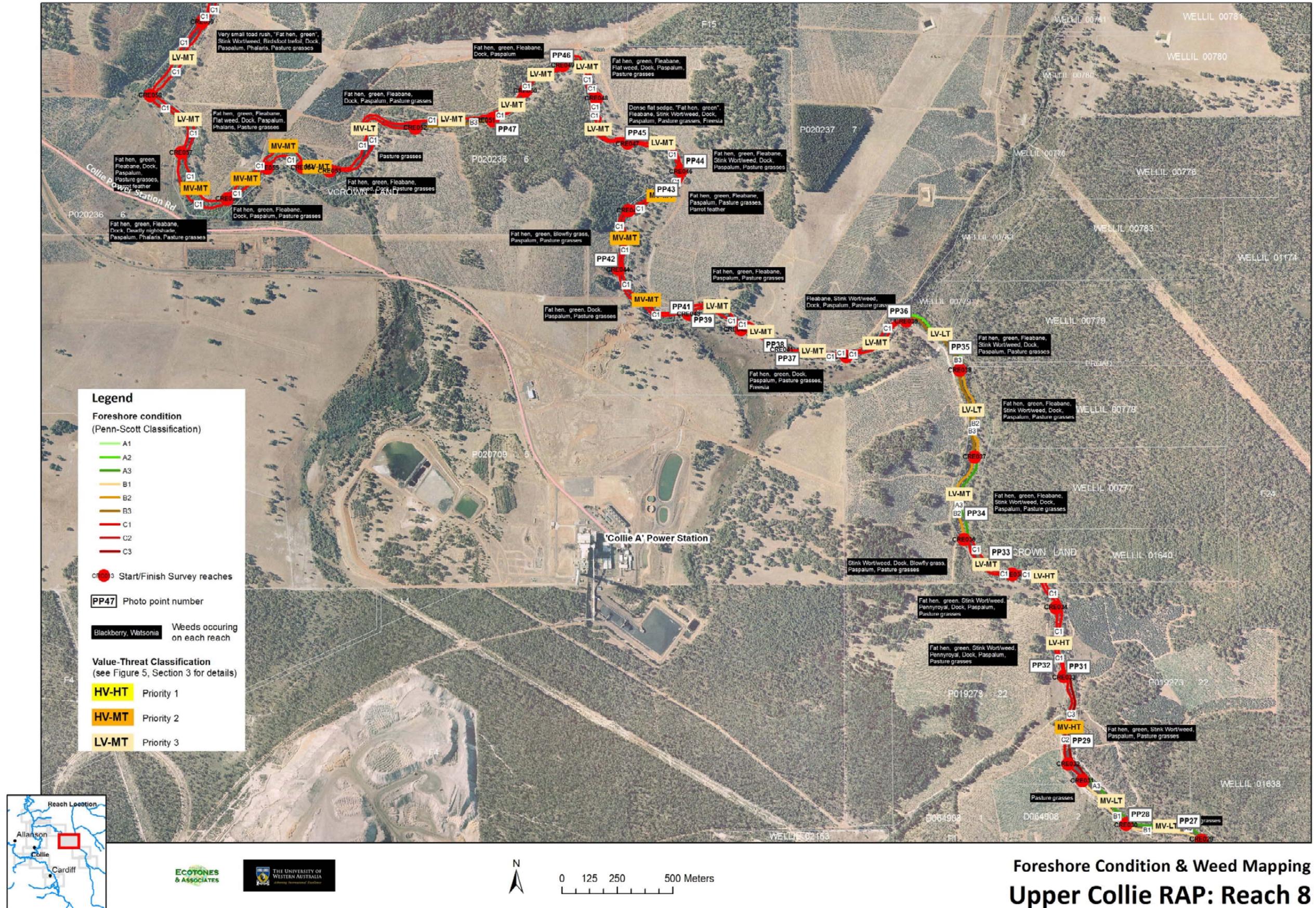


PP46: Pen-Scott C1 example, heavily grazed banks

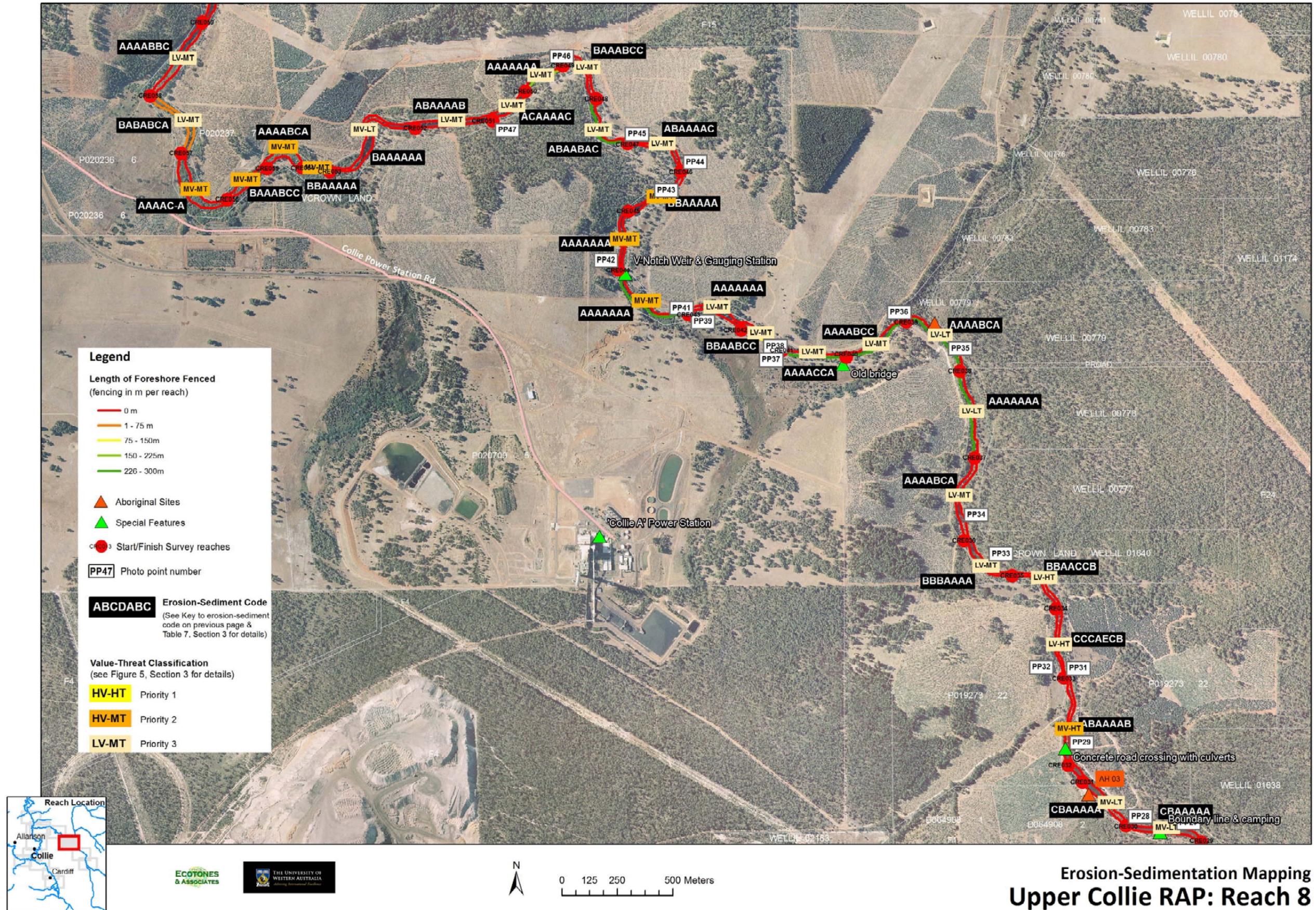
Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



Foreshore Condition & Weed Mapping
Upper Collie RAP: Reach 8



REACH 9

This reach is the second downstream on Collie R. East (CRE). It begins at site CRE015 and continues to site CRE030 (16 sites in all) for a river distance of approx. 5.7kms. There are 16 individual survey sites associated with this part of Collie R. East.

Description

Feature	Comments
Landuse	Lots in the north-west of the reach (P019273, D064908, WELLIL 01638, F4, F24) are either forest reserves or vacant crown land and so are forested or uncleared. The remaining lots in the south-east (WELLIL 02322, WELLIL 02696, WELLIL 01639, WELLIL 02173, WELLIL 02315, WELLIL 02886, WELLIL 02980, WELLIL 03046, WELLIL 01715, WELLIL 03119) are mostly cleared for agriculture and are grazed. There is a road reserve between the river and lots WELLIL 01639 and WELLIL 02315.
Land tenure	The forest reserves and vacant crown land fall under the management of DEC; the other land is freehold farmland. The Shire manages the road reserve.
Fencing	Uncleared lots in the north-east of the reach are unfenced. The majority of the cleared lots are fully fenced although there are some short sections of the road reserve (adjacent to lots WELLIL 02322 and 21553540) are unfenced. Part of lot WELLIL 02980 in the south of the reach is unfenced.

Condition

Feature	Comments
Vegetation	Dominant trees & shrubs: Marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), christmas tree (<i>Nuytsia floribunda</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), wandoo (<i>E. wandoo</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), sickle hakea (<i>Hakea falcata</i>), two leaved hakea (<i>Hakea trifurcata</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Pithy sword sedge (<i>Lepidosperma longitudinale</i>), marsh club rush (<i>Bolboschoenus caldwellii</i>) and sedges (<i>Carex</i> spp.). Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>) and samphires (<i>Halosarcia</i> spp.)
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), tagasaste (<i>Chamaecytisus palmensis</i>), Yorkshire fog (<i>Holcus lanatus</i>), paspalum (<i>Paspalum dilatatum</i>), phalaris (<i>Phalaris aquatica</i>), blowfly grass (<i>Briza maxima</i>), fleabane (<i>Conyza</i> sp.), stinkwort (<i>Dittrichia graveolens</i>), green fat hen (<i>Chenopodium murale</i>), dock (<i>Rumex</i> sp.), sweet briar (<i>Rosa rubiginosa</i>), Easter lily (<i>Amaryllis belladonna</i>), freesia (<i>Sparaxis bulbifera</i>) and pennyroyal (<i>Mentha pulegium</i>).
Bank stability and erosion	Bank undercutting is significant on a number of sites in the north-west e.g. CRE027, CRE028 and CRE029 and some sites in the south (CRE015, CRE016, CRE017 and CRE018) contain LWD.
Special features, other comments	Shotts Graves, an important Aboriginal site (AH 03), is located at site CRE030 (lot D064908).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1b	HV/MT (1 site)	Site CRE026.	Weeds found at this site were Fat hen green, Paspalum and pasture grasses. There is some minor undercutting on both banks and while there is no

			fencing on either bank this isn't regarded as problematic since stock do not occupy adjacent lots.
2a	MV/HT (2 sites)	Sites CRE018 and CRE027.	Weeds present at these sites include Fat hen green, Yorkshire frog, Paspalum and pasture grasses. Active bank undercutting (PP26) and scouring is taking place (see PP21, site CRE018) at both sites and there is quite severe sedimentation in the form of point bars and pool aggradation.
2b	MV/MT (2 sites)	Sites CRE016 and CRE028.	Weeds present at these sites include Tagasaste, Sweet briar, Fat hen green, Fleabane, Pennyroyal, Blowfly grass, Paspalum, Eastern lily and pasture grasses. Erosion: There is quite severe bank undercutting at CRE028 (see PP28) and LWD can be found at CRE016. Only a small portion of the left bank is fenced and this should be completed to prevent stock accessing the river (see cattle pudging, PP16).
3a	MV/LT (2 sites)	Sites CRE029 and CRE030.	The weeds of concern at these two sites are pasture grasses. There is bank undercutting on both banks but it is more severe on the left bank.
3b	LV/HT (4 sites)	Sites CRE017, CRE019, CRE021 and CRE025.	Weeds found include Blackberry, Tagasaste, Sweet briar, Fat hen green, Fleabane, Pennyroyal, Blowfly grass, Paspalum, Eastern lily and pasture grasses. There is significant undercutting at sites CRE017 and CRE019 (see PP19) especially the right bank of CRE019, but sedimentation is also present at CRE021 and CRE025. The fencing on the left bank of CRE017 is incomplete.
3c	LV/MT (3 sites)	Sites CRE020, CRE022, and CRE023	Weeds found include Blackberry, Tagasaste, Sweet briar, Fat hen green, Fleabane, Pennyroyal, Blowfly grass, Paspalum, Eastern lily and pasture grasses. At CRE023 there is minor undercutting and slumping on both banks. There is no fencing on the right bank of CRE023 (lot WELLIL 02322). At site CRE020 the fencing is complete but the gate was left open to allow cattle to access the river (PP22).
3d	LV/LT (2 sites)	Sites CRE015 and CRE024.	Weeds present at these sites include Tagasaste, Sweet briar, Fat hen green, Stink wort/weed, Fleabane, Pennyroyal, Blowfly grass, Paspalum, Eastern lily and pasture grasses. There is no evidence of erosion or sedimentation but there is some LWD at CRE015.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Encourage the landholders of lots WELLIL 02315 and WELLIL 02980 to protect banks from stock by fencing where necessary and then stabilise banks through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	There are many species of weeds in this reach but landholders and others should be encouraged to target blackberry, tagasaste, sweet briar, pennyroyal, phalaris and paspalum. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html
Fencing/loss of native vegetation	Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. Fencing is currently being

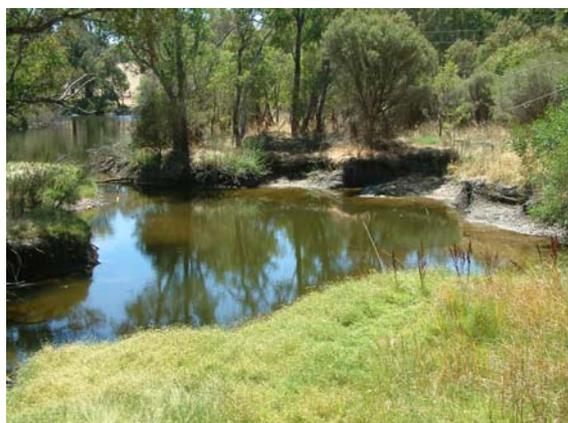
	<p>installed/repared in some places but where there is a lack of fencing combined with grazing landholders should be encouraged to install. Also, encourage landholders, Western Power, local community groups and weed action groups in weed management (as above). Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.</p>
Fish	<p>Loss of native riparian vegetation is significant on most lots in the reach. Fish habitat can be improved by enhancing the riparian zone. Fencing should be repaired where it is in poor condition and installed where stock are accessing the river. Install watering points to minimise bank damage and protect water quality. Where native riparian vegetation has been cleared, assist regeneration and expand riparian zone through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access.</p>
Declining water quality	<p>Encourage landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.</p>

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 9:



PP16: Pen-Scott C1 example, cattle pudging



PP19: Pen-Scott C1 example, river crossing causing bank undercutting



PP21: Pen-Scott C1 example, floodplain scour



PP22: Pen-Scott C1 example, cattle accessing the river bed



PP23: Pen-Scott C1 example, graded track crossing



Pen-Scott C1 example, bank undercut with exposed tree roots (CRE025)



PP26: Pen-Scott B3 example, bank undercutting

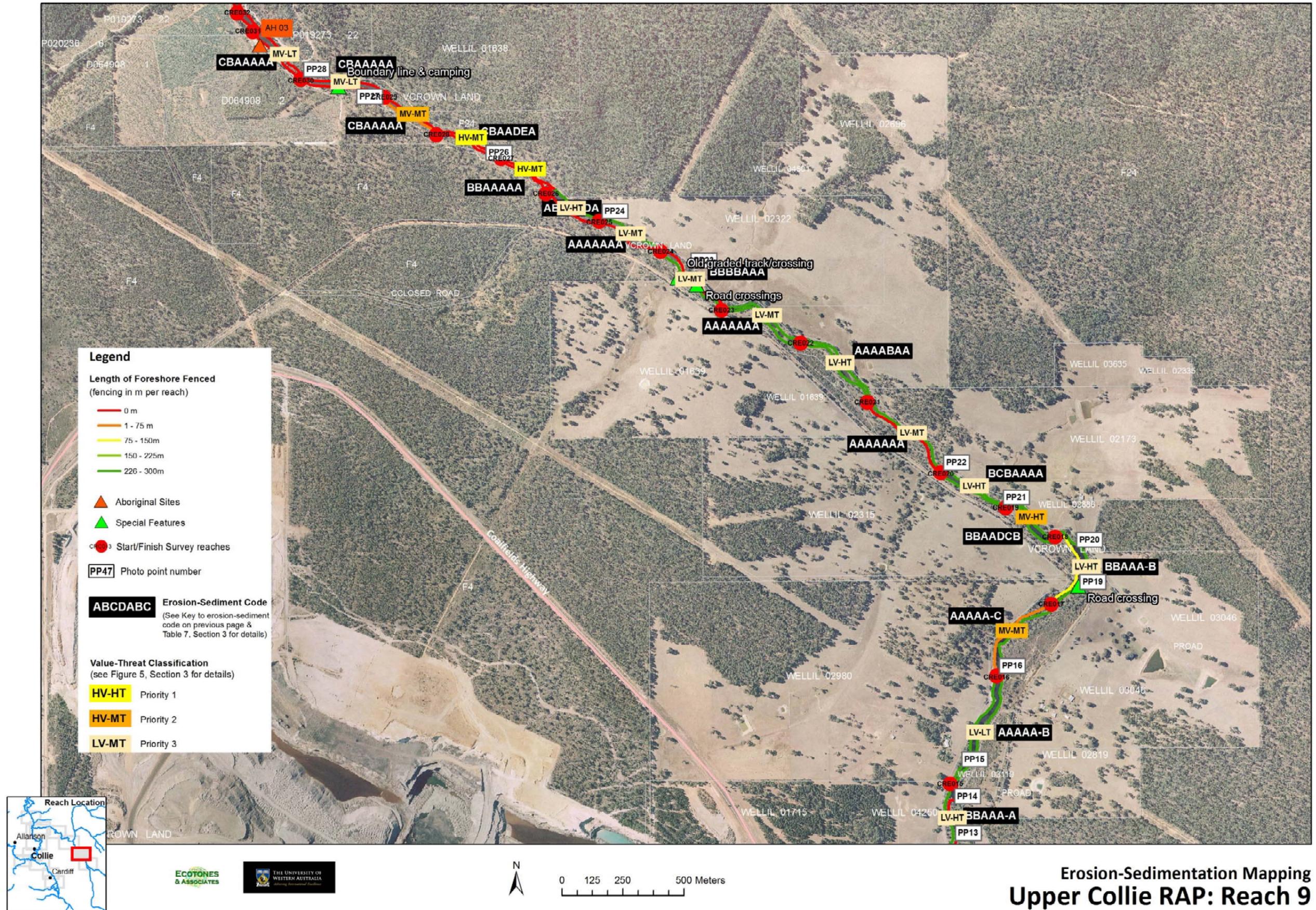


PP28: Pen-Scott B1 example, meander undercutting

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



REACH 10

This reach is the first of five that make up Collie R. East (CRE). This reach starts at the Old Griggs Road bridge (CRE001) and extends downstream approx. 4.5kms to site CRE014 so there are 14 individual survey sites associated with this part of Collie R. East. All lots along this reach are pasture although the lot at the far north of the reach is partially uncleared.

Description

Feature	Comments
Landuse	All lots have been cleared and are grazed.
Land tenure	Freehold farmland for the majority of the reach although WELLIL 04250 is under farm forestry but there is a forest reserve in the north-east (R24) and two small reserved lots identified as R17723.
Fencing	The extent and standard of fencing varies considerably over the length of the reach but the majority of the grazed lots are fully fenced, the exception being the right bank close to Dunderling Pool, which is unfenced.

Condition

Feature	Comments
Vegetation	Dominant trees & shrubs: Marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), modong (<i>Melaleuca preissiana</i>), coojong (<i>Acacia saligna</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), wandoo (<i>E. wandoo</i>), narrow leaved oxlyobium (<i>Oxylobium ebracteolatum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Pithy sword sedge (<i>Lepidosperma longitudinale</i>), marsh club rush (<i>Bolboschoenus caldwellii</i>), finger rush (<i>Juncus subsecundus</i>) and pale rush (<i>Juncus pallidus</i>) and <i>Cyperus</i> spp. Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), Samphires (<i>Halosarcia</i> spp.)
Weeds	Pasture grasses, paspalum (<i>Paspalum dilatatum</i>), fleabane (<i>Conyza</i> sp.), green fat hen (<i>Chenopodium murale</i>), dock (<i>Rumex</i> sp.), radiata pine (<i>Pinus radiata</i>), tagasaste (<i>Chamaecytisus palmensis</i>), blowfly grass (<i>Briza maxima</i>), gladiolus (<i>Gladiolus</i> spp.), sweet briar (<i>Rosa rubiginosa</i>), Easter lily (<i>Amaryllis belladonna</i>), freesia (<i>Sparaxis bulbifera</i>), pennyroyal (<i>Mentha pulegium</i>) and arum lily (<i>Zantedeschia aethiopica</i>).
Bank stability and erosion	Stock have damaged the bank at sites CRE012 and CRE014 and stock and LWD are encouraging undercutting at lot sites CRE001 to CRE004.
Special features, other comments	Dunderling Pool, AH 10, CRE010 (see photos below) and Buckingham Pool (AH 11, CRE012) are both significant Aboriginal sites. Old rail and road crossings at lots R17723 and there is dewatering inflow at CRE008.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1c	HV/LT (1 site)	Site CRE011.	Weeds found at this site were Fat hen green, Fleabane, Dock, Paspalum and pasture grasses. There is minor undercutting, pool aggradation on right bank with some LWD. Lack of fencing, especially on the right bank, is allowing stock access damage to take place.
2b	MV/MT (4 sites)	Sites CRE001, CRE004, CRE009 and CRE012.	Weeds: Sweet briar, Fat hen green, Fleabane, Dock, Paspalum, Arum lily, Gladiolus and pasture grasses. Very significant sedimentation in the form of point

			bars and pool aggradation at all sites except CRE012; however, stock access is causing bank damage at CRE012 (PP11). There is very significant slumping on both banks at CRE004. Fencing should be installed at CRE001 (both banks), and at least the right bank of CRE009 and CRE012.
3b	LV/HT (2 sites)	Sites CRE007 and CRE014.	Weeds present at site CRE007 were Fat hen green, Fleabane, Dock, Paspalum, Arum lily, Eastern lily and pasture grasses. Black berry, Radiata pine, Tagasaste, Freesia and Gladiolus were also found at CRE014. Minor erosion takes the form of minor undercutting – both banks at both sites. The left banks of both sites are fenced but neither on the right side is.
3c	LV/MT (6 sites)	Sites CRE002, CRE003, CRE005, CRE006, CRE008 and CRE013.	Weeds found at these sites were Dense flat sedge, Fat hen green, Fleabane, Dock, Paspalum, Arum lily, Eastern lily, Gladiolus and pasture grasses. The dewatering site at CRE008 (PP6) is encouraging excessive pasture grasses. There is severe pot holing at CRE002 (see photos) and LWD causing severe scouring at CRE005 (PP3). Point bars and pool aggradation is found at all sites except CRE008. Fencing should be improved at CRE002, installed on the right bank of CRE008 and CRE013 if stock occupy adjacent lots.
3d	LV/LT (1 site)	Site CRE010.	Weeds: Fat hen green, Fleabane, Dock, Paspalum, Arum lily, Eastern lily and pasture grasses. There is quite severe sedimentation evident by point bars and pool aggradation. Fencing should be completed where there are gaps.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Remove and/or re-align large woody debris causing erosion, specially for site CRE005, encourage the landholder to stabilise banks through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	There are many species of weeds in this reach but landholders and others should be encouraged to target cotton bush, tagasaste, phalaris, paspalum, gladiolus spp. and arum lily. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html
Fencing/loss of native vegetation	Where the river is bound by UCL landowners do not have riparian rights to water. Access to water may be through negotiated easement with the Department of Planning as the vested authority for UCL. There significant stretches of the river that lack fencing. Where this combines with grazing landholders should be encouraged to complete fencing. Encourage landholders, local community groups and weed action groups in weed management (as above). Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Loss of native riparian vegetation is significant on almost all lots in this reach. Fish habitat can be improved by establishing and enhancing the riparian zone. Plant with local native species. Appendix 1 contains a list of local species suitable

for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access. As noted above, landholders should also be encouraged to install fences where stock are accessing the river. Install watering points to minimise bank damage and protect water quality.

Declining water quality	Encourage landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.
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Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 10:



Pen Scott C1 example (CRE002)



PP3: Pen-Scott C1 example, large log induced scour



Pen Scott C1 example, LWD and erosion (CRE005)



PP6: Mine dewater inflow site (CRE008)



PP6: Pen-Scott C1 example, pasture grasses encouraged by dewatering inflow



Pen-Scott B2 example, Dunderling Pool, AH 10 (CRE010)



Pen-Scott B3 example, LWD and pasture grasses

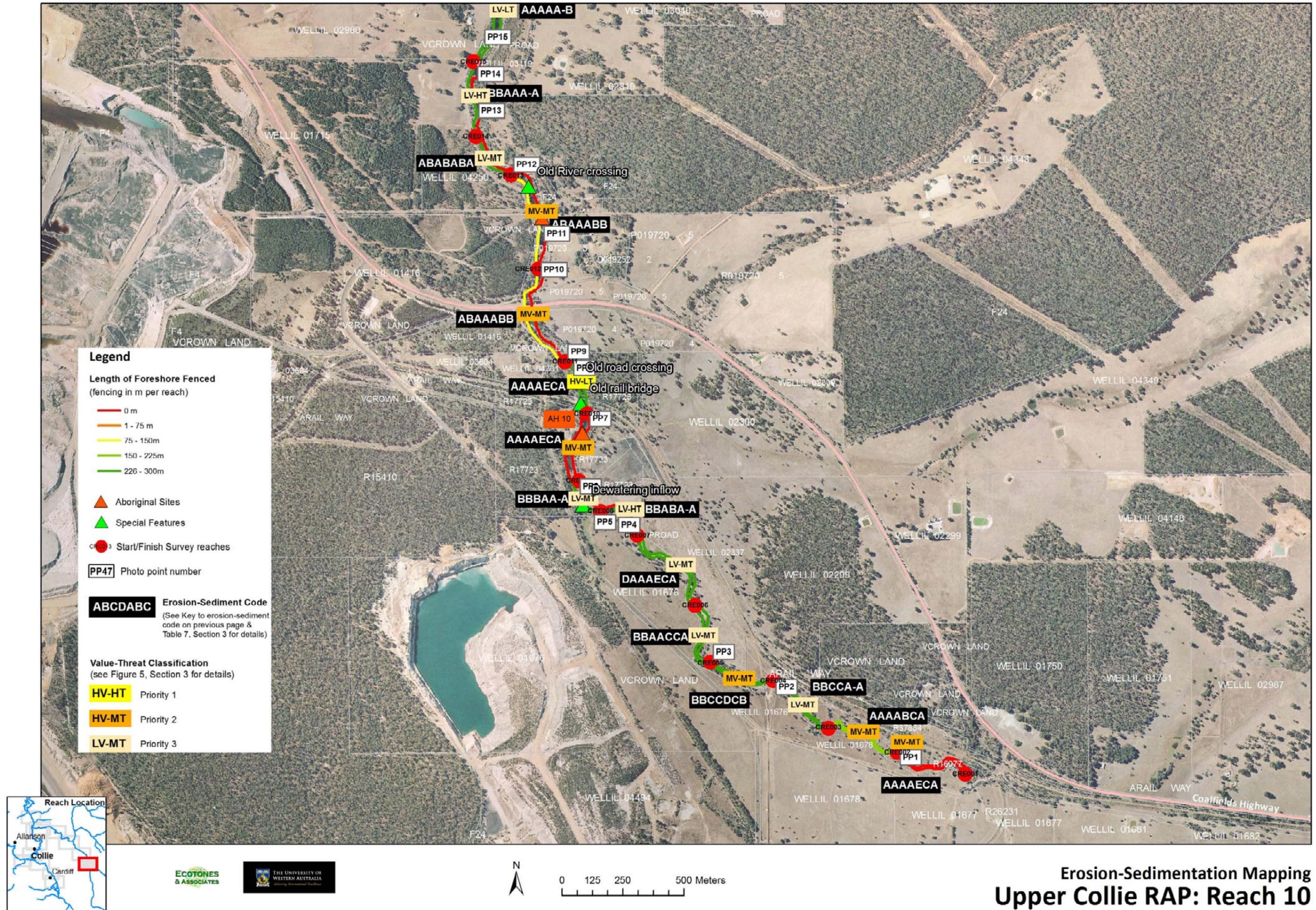


PP11: Pen-Scott B3 example, stock damage

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



REACH 11

Reach 11 is the last of three representing Collie R. South (CRS). The reach starts at survey site CRS016 (from where Reach 12 ends) and extends downstream to site CRS034 for approx. 7.2kms to the confluence with Collie River Central. There are 20 individual survey sites associated with this part of Collie R. South.

Description

Feature	Comments
Landuse	Most land is uncleared forest reserve but there are a few small cleared (semi-rural) lots.
Land tenure	Forest reserves are managed by DEC and cleared lots are freehold.
Fencing	Most of this reach remains unfenced but there are stretches of fencing on the left bank (south-east lots: D043362, COLLET 00131, 00134, 00135, 00146; north-west lots: R25214, WELLIL 01427).

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: Marri (<i>C. calophylla</i>), jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), prickly Moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), wandoo (<i>E. wandoo</i>), bracken fern (<i>Pteridium esculentum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), swish bush (<i>Viminaria juncea</i>), sickle hakea (<i>Hakea falcata</i>), broad leaved hakea (<i>Hakea amplexicaulis</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), pithy sword sedge (<i>Lepidosperma longitudinale</i>), marsh club rush (<i>Bolboschoenus caldwellii</i>) and semaphore sedge (<i>Mesomelaena tetragona</i>)</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), angled lobelia (<i>Lobelia anceps</i>) and button weed (<i>Cotula</i> spp.)</p>
Weeds	Pasture grasses, blackberry (<i>Rubus</i> spp.), radiata pine (<i>Pinus radiata</i>), paspalum (<i>Paspalum dilatatum</i>), phalaris (<i>Phalaris aquatica</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> spp.), Fleabane (<i>Conyza</i> sp.), stinkwort (<i>Dittrichia graveolens</i>), green fat hen (<i>Chenopodium murale</i>), African lovegrass (<i>Eragrostis curvula</i>), Black berry nightshade (<i>Solanum nigrum</i>), birds' foot trefoil (<i>Lotus corniculatus</i>), Yorkshire fog (<i>Holcus lanatus</i>) and watsonia (<i>Watsonia</i> spp.).
Bank stability and erosion	Most bank erosion is limited to minor bank undercutting and there are only two sites where there is significant sedimentation (CRS016 and CRS029).
Special features, other comments	Old railway crossing at site CRS020 (see photo PP81). V-notch weir at site CRS028 (see photo PP85).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1a	HV/HT (1 site)	CRS018.	Weeds present are Blackberry, Flat weed, Deadly nightshade and pasture grasses. There is minor bank undercutting and slumping on left bank. Neither bank is fenced and this should be installed if stock occupies adjacent lots.
1b	HV/MT (1 site)	CRS025.	Weeds found were Blackberry, Flat weed and Blowfly grass. There is minor bank undercutting on both banks.

1c	HV/LT (3 sites)	CRS022, CRS023 and CRS024.	Weeds are Stink wort/weed, Flat weed and pasture grasses. Erosion concerns are mostly minor bank undercutting but this is more severe at CRS024 on left bank.
2b	MV/MT (5 sites)	CRS016, CRS026, CRS027, CRS028 and CRS031.	Weeds found were Blackberry, Radiata pine, Fat hen green, Stink wort/weed, Birdsfoot trefoil, Fleabane, Dock and pasture grasses. Severe sedimentation at CRS016 (point bar and pool aggradation) but otherwise there is only minor bank undercutting (predominantly on the left bank). Fencing on the left bank of CRS016 and the right bank of CRS028 should be completed.
3a	MV/LT (2 sites)	CRS020 and CRS030.	Weeds found were Blackberry, Flat weed and Paspalum. There is minor bank undercutting on both banks of CRS030 and LWD at both sites.
3c	LV/MT (5 sites)	CRS015, CRS017, CRS019, CRS029 and CRS032.	Weeds found were Blackberry, Fat hen green, Fleabane, Stink wort/weed, Flat weed, Birdsfoot trefoil, Dock, Deadly nightshade, Yorkshire fog, Phalaris, Blowfly grass, African lovegrass, Watsonia (CRS019) and pasture grasses. There is minor undercutting on left bank of CRS015 and CRS029; also, sedimentation at CRS029 and LWD at CRS015. Fencing should be completed on left bank at CRS015 and right bank of CRS017 if adjacent lots are grazed. Lot WELLIL 01433 may also require fencing (CRS029).
3d	LV/LT (3 sites)	CRS021, CRS033 and CRS034.	Weeds found include Blackberry, Flat weed and Blowfly grass. There is dead (sprayed) Watsonia at CRS034. Some minor undercutting (both banks) at CRS033 and CRS034.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Encourage DEC and landholders to stabilise banks through planting of local native species (especially sites CRS018 and CRS024). Appendix 1 contains a list of local species suitable for planting.
Weeds	The landholder of lot WELLIL 01461 should be encouraged to spray the Watsonia at site CRS019 and the DEC should be encouraged to monitor Watsonia at CRS034 to ensure there is no recovery. Generally, landholders and others should be encouraged to target blackberry, watsonia, radiate pine, deadly nightshade and pasture grasses. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html
Fencing/loss of native vegetation	Landholders of grazed lots should be encouraged to complete fencing if stock are occupying adjacent lots (CRS015, CRS016, CRS017, CRS018, CRS028 and CRS029). Encourage landholders, local community groups and weed action groups in weed management (as above). Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Fish habitat can be improved by establishing and enhancing the riparian zone where cleared. Plant with local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock

	access. As noted above, landholders should also be encouraged to install fences where stock are accessing the river. Install watering points to minimise bank damage and protect water quality.
Declining water quality	Encourage landholders to use large woody debris at sites where there is undercutting and planting with emergent vegetation such as rushes and sedges will enhance habitat.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 11:



Pen-Scott C1 example with LWD (CRS015)



Pen-Scott C1 Chinaman’s Pool (CRS18)



PP81: Old railway bridge with numerous access tracks



PP82: Pen-Scott A2 example



PP83: Pen-Scott A1 example



PP84: Pen-Scott A3 example



PP85: V-notch weir and bridge

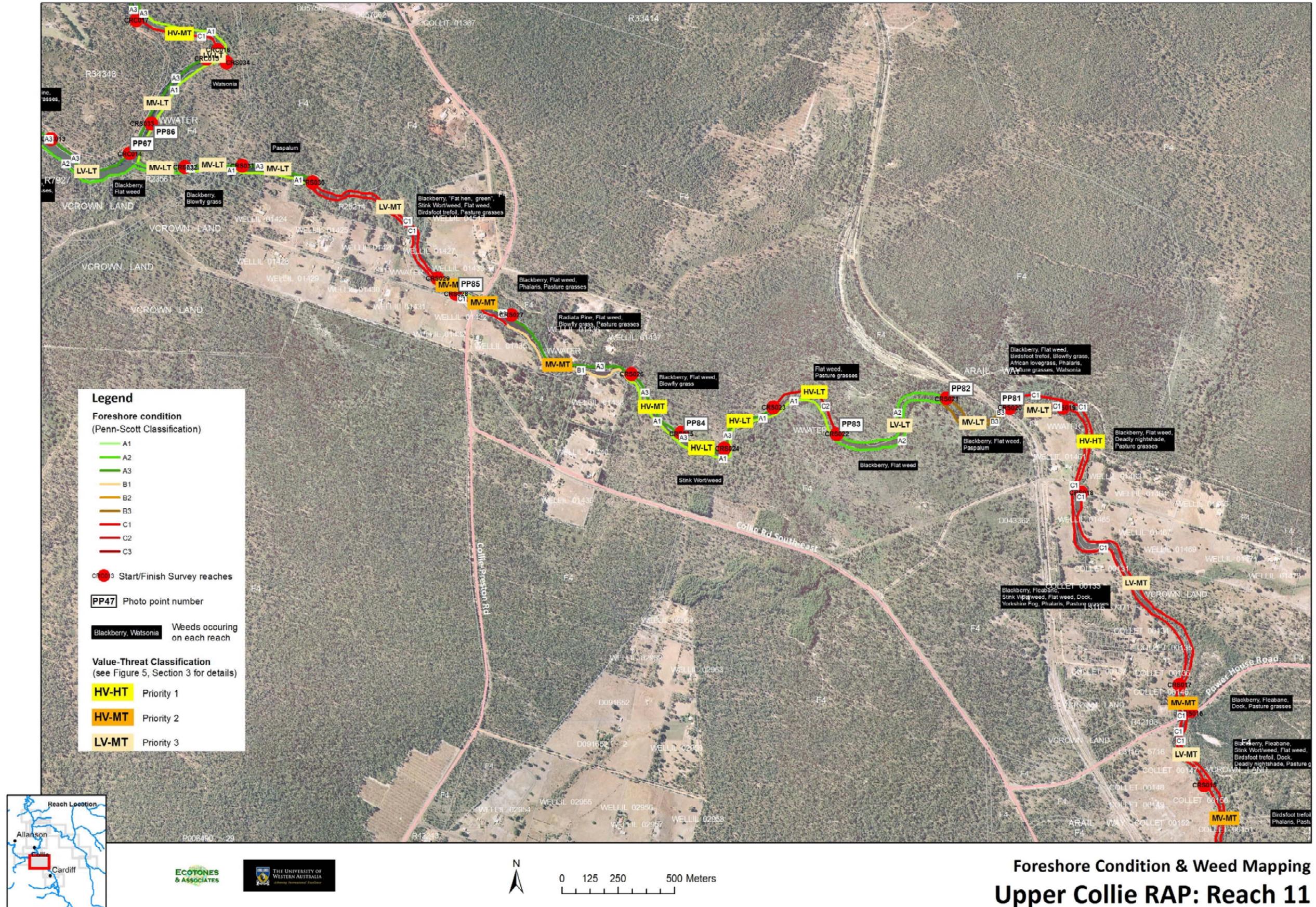


Pen-Scott A2 example, confluence with Collie R. Central (CRS034)

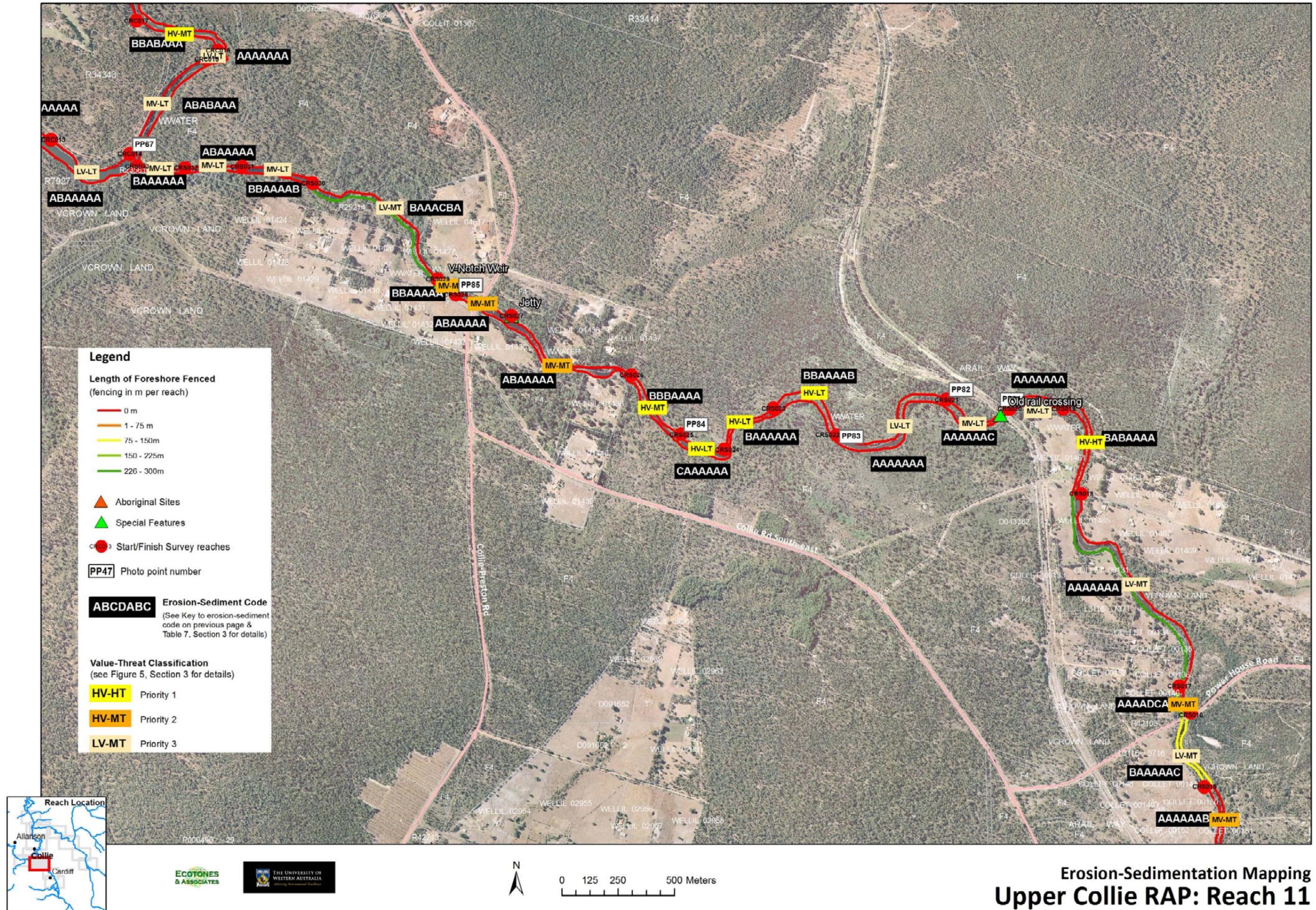
Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



Foreshore Condition & Weed Mapping
Upper Collie RAP: Reach 11



REACH 12

Reach 12 continues down-stream on Collie R. South (CRS) from Reach 13 – from site CRS006 to site CRS014 – a total of nine survey sites (approx. 3.6kms). All lots east of the river are uncleared but most lots on the west side are cleared.

Description

Feature	Comments
Landuse	The eastern side of the river is dominated by forest reserve – lot F4. The western side is made up of semi-rural lots associated with Cardiff townsite. Most of these have been cleared for hobby farming purposes but lot D042758 is notable as the only lot of uncleared vacant crown land.
Land tenure	Forest reserve (F4) eastern side of river and the vacant crown land lot on the western side are managed by DEC. Freehold semi-rural lots are freehold.
Fencing	No part of the western foreshore is fenced in the defined reach. Fencing on lots on the east bank is patchy. The vacant crown land lot on the west side is also unfenced. Cleared freehold lots COLLET 00147, 00150, 00151 and D042469 are unfenced and lots COLLCT 00287 and 00288 are partially fenced.

Condition

Feature	Comments
Vegetation	<p>Dominant trees & shrubs: Marri (<i>C. calophylla</i>), flooded gum (<i>E. rudis</i>), prickly moses (<i>Acacia pulchella</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), bracken fern (<i>Pteridium esculentum</i>), robin redbreast bush (<i>Melaleuca lateritica</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>).</p> <p>Dominant rushes and sedges: Bare twigrush (<i>Baumea juncea</i>), marsh club rush (<i>Bolboschoenus caldwellii</i>), bare twigrush (<i>Baumea juncea</i>) and pale rush (<i>Juncus pallidus</i>).</p> <p>Herbs, creepers & bulbs: Dodder (<i>Cassytha flava</i>), button weed (<i>Cotula</i> spp.) and angled lobelia (<i>Lobelia anceps</i>).</p>
Weeds	Pasture grasses, blackberry (<i>Rubus</i> sp.), phalaris (<i>Phalaris aquatica</i>), blowfly grass (<i>Briza maxima</i>), flat weed (<i>Hypochaeris</i> sp.), fleabane (<i>Conyza</i> spp.), stinkwort (<i>Dittrichia graveolens</i>), dock (<i>Rumex</i> spp.), black berry nightshade (<i>Solanum nigrum</i>) and birds' foot trefoil (<i>Lotus corniculatus</i>).
Bank stability and erosion	Some minor bank undercutting at two sites on the reach (CRS010 and CRS011); quite severe sedimentation mid-way down the reach (CRS011) and LWD at sites CRS006 and CRS007.
Special features, other comments	There is an artificial beach at Cardiff Town Pool (see photo PP78).

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
2a	MV/HT (1 site)	Site CRS012.	Weeds found at this site were Blackberry, Flat weed, Birdsfoot trefoil, Dock, Deadly nightshade, Phalaris and pasture grasses. There is no erosion of any significance but there is some LWD that could cause scouring.
2b	MV/MT (2 sites)	Sites CRS010 and CRS014.	Weeds found at these sites were Blackberry, Stink wort/weed, Birdsfoot trefoil, Deadly nightshade, Phalaris and pasture grasses.

			There is minor bank undercutting on both banks of site CRS010 and some LWD at this site and CRS014. Fencing is adequate at CRS010 but the left bank of CRS014 is completely unfenced. Since the adjacent lot is cleared and grazed, fencing should be installed at this site.
3a	MV/LT (1 site)	Site CRS008.	Two weeds were found – Blackberry and Blowfly grass. No erosion and fencing appeared adequate.
3c	LV/MT (3 sites)	Sites CRS009, CRS011 and CRS013.	Weeds found were Blackberry, Stink wort/weed, Flat weed, Birdsfoot trefoil, Dock, Deadly nightshade, Phalaris and pasture grasses. Minor bank undercutting, slumping but quite severe sedimentation was found at site CRS011. Fencing is adequate under current land uses.
3d	LV/LT (2 sites)	Sites CRS006 and CRS007.	Three weeds were found at these sites – Blackberry, Flat weed and Blowfly grass. No significant erosion apparent but there is LWD and even litter at both sites that could hinder/alter natural flow (see photo CRS006). Fencing at CRS006 appears adequate but there is no fencing on the left bank of CRS007; again, there should be to protect the foreshore from stock.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	Encourage the DEC to stabilise banks associated with CRS010 (lot D042758 and F4) through planting of local native species. Appendix 1 contains a list of local species suitable for planting.
Weeds	Blackberry has been sprayed at site CRS013 (see photo PP80), lot D042758 but this should be monitored to ensure there is no recovery. Landholders and DEC and others should be encouraged to target blackberry (present at all but one site in the reach), deadly nightshade and pasture grasses. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html
Fencing/loss of native vegetation	Landholders of grazed lots should be encouraged to complete fencing where necessary, especially lots D042469, COLLET 00150, 00151). Encourage landholders, local community groups and weed action groups in weed management (as above). Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Fish habitat can be improved by establishing and enhancing the riparian zone where cleared. Plant with local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access. As noted above, landholders should also be encouraged to install fences where stock are accessing the river. Install watering points to minimise bank damage and protect water quality.
Declining water quality	Encourage landholders to use large woody debris at sites where there is undercutting (i.e. CRS006, CRS007 and CRS013) and plant with emergent vegetation such as rushes and sedges will enhance habitat.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 12:



Pen-Scott B1 example, banks littered with old drums (CRS006)



PP78: Artificial beach at Town Pool



Pen-Scott C1 example, Graham Pool (CRS010)



PP79 sheep allowed access to river bed



Pen-Scott C1 example (CRS011)

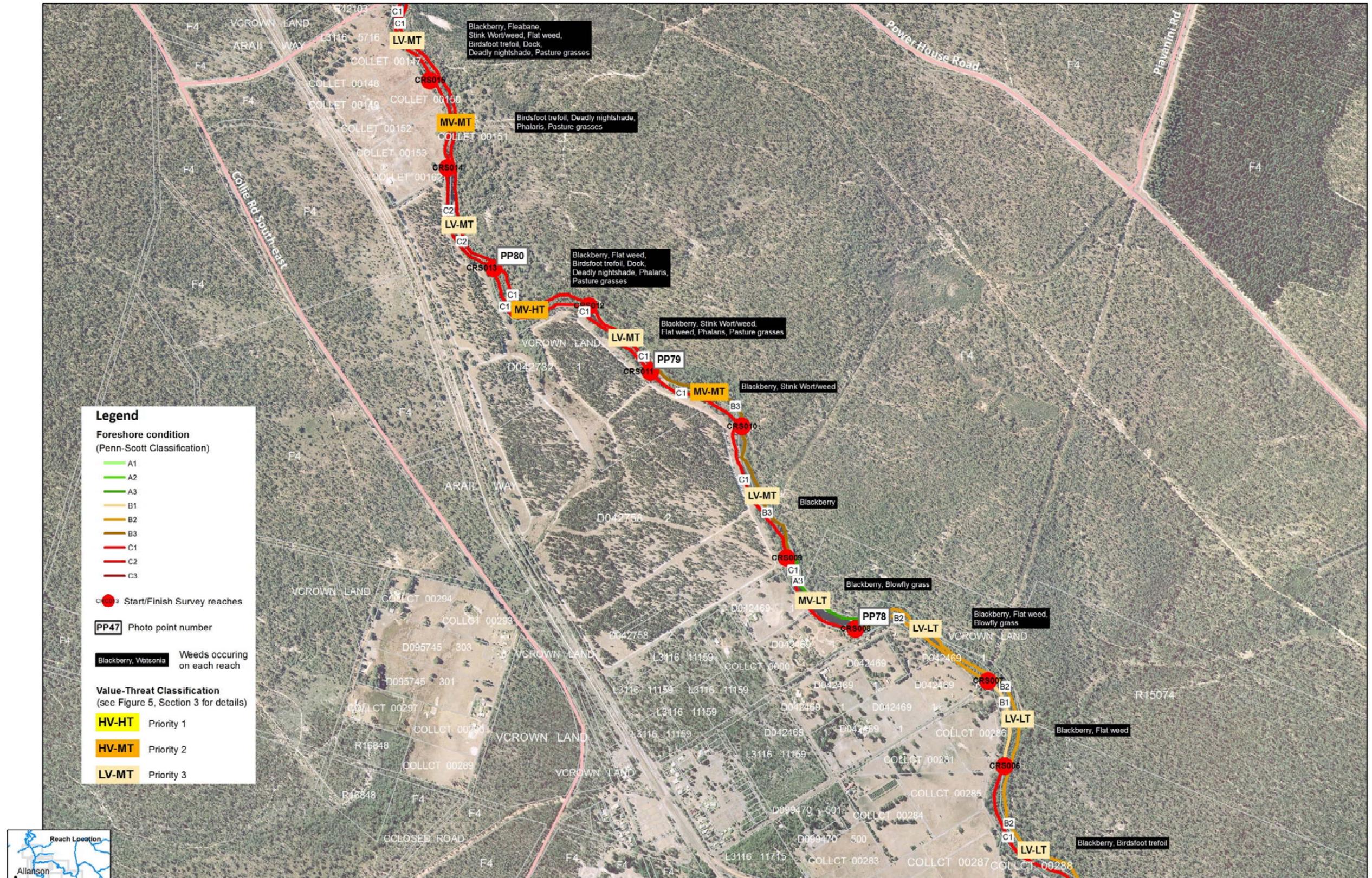


PP80: Sprayed blackberry

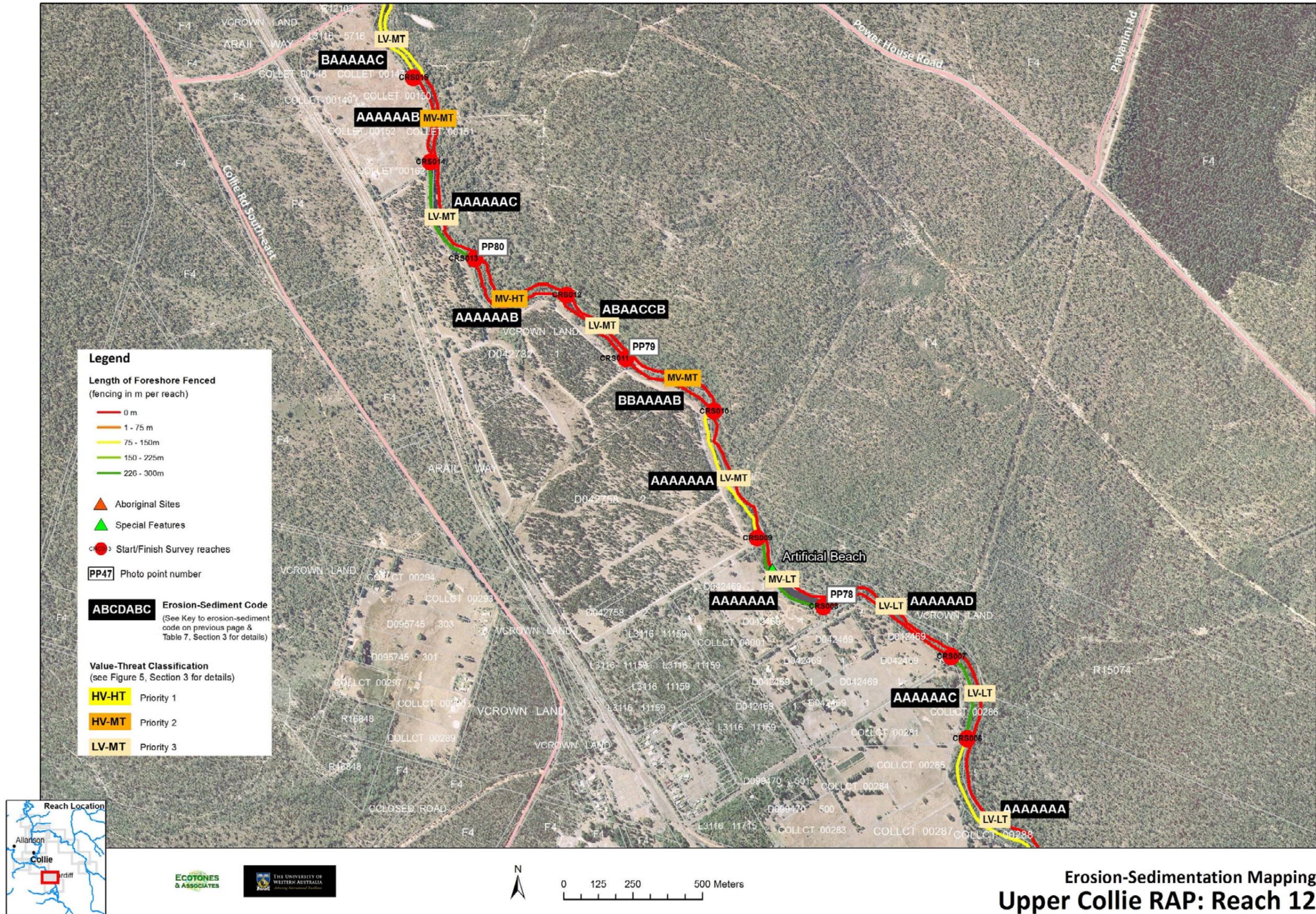
Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)



Foreshore Condition & Weed Mapping
Upper Collie RAP: Reach 12



REACH 13

This reach is the first of three that make up Collie R. South (CRS). The first survey site on Reach 13 (CRS001) is located about 500m north of Lake Kepwari (at the rail bridge) and extends approx. 2.8km downstream to site CRS005 (5 survey sites) and includes Jum's Pool and Long Pool.

Description

Feature	Comments
Landuse	Apart from the cleared grazing lot COLLET 00288, which has been cleared and is probably grazed, all other lots in the reach are forest reserves.
Land tenure	Forest reserves are managed by DEC.
Fencing	There is about 100 meters of fencing at lot COLLET 00288 but the remainder of both foreshores are unfenced.

Condition

Feature	Comments
Vegetation	Dominant trees & shrubs: Jarrah (<i>E. marginata</i>), flooded gum (<i>E. rudis</i>), modong (<i>Melaleuca preissiana</i>), astartea (<i>Astartea fascicularis</i>), swamp paperbark (<i>Melaleuca raphiophylla</i>), bracken fern (<i>Pteridium esculentum</i>), swish bush (<i>Viminaria juncea</i>) and grass trees (<i>Xanthorrhoea preissii</i>). Dominant rushes and sedges: Marsh club rush (<i>Bolboschoenus caldwellii</i>) and semaphore sedge (<i>Mesomelaena tetragona</i>),
Weeds	Blackberry (<i>Rubus</i> spp.), birds' foot trefoil (<i>Lotus corniculatus</i>) and flat weed (<i>Hypochaeris</i> spp.).
Bank stability and erosion	The river has had amelioration work carried out downstream of the rail bridge at site CRS001 (see photos PP76). The river has been artificially dug out after it filled with red mud from the mine site upstream. Some of this mud is still evident. Large woody debris at two sites on the reach is evident but not causing erosion.
Special features, other comments	There are two Aboriginal sites in this reach: Long Pool (AH 014) and the rail bridge/Jum's Pool (AH 13) (see photos below). The rail bridge marks the beginning of the foreshore condition survey for Collie R. South and this may also be regarded as a feature of common interest.

Management

Priority ranking (see Figure 5, Section 3 for explanation of methods) for management is as follows:

Priority ranking*	Value-threat classification	Site location/s (see map)	Main management concern/s found during survey
1c	HV/LT (1 site)	Site CRS001.	There has been some amelioration work carried out at this site (see above and photos), which has transformed the natural condition of the foreshores, but there is only minor active bank undercutting and slumping on the left bank.
3a	MV/LT (2 sites)	Sites CRS002 and CRS003.	The only weed found was Blackberry at CRS002. Some LWD is evident at CRS003 but otherwise no obvious erosion threats.
3d	LV/LT (2 sites)	Sites CRS004 and CRS005.	Three weed species found: Blackberry, Flat weed and Birdsfoot trefoil. Some LWD is present at CRS004 (see photo) but there was no other erosion at the time of survey. Fencing is incomplete on the left bank of CRS005 and if the adjacent lot is grazed then this should be completed.

* See Table 12 in Section 7 to identify dominant management approaches

Issue	Management Action/Advice
Erosion	DEC should be encouraged to align large woody debris to minimise erosion risk.
Weeds	DEC and others should be encouraged to target blackberry in this reach. Information regarding weed management may be obtained from: http://www.agric.wa.gov.au/PC_92738.html
Fencing/loss of native vegetation	The landholder responsible for the cleared lot COLLET 00288 should be encouraged to complete fencing if the lot is grazed. Install watering points to minimise bank damage and protect water quality. Encourage this landholder, local community groups and weed action groups in weed management (as above). Where weeds are removed, assist regeneration of native vegetation along foreshores through planting of local native species. Appendix 1 contains a list of local species suitable for planting. See Section 6 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority where weeds are removed.
Fish	Fish habitat can be improved by establishing and enhancing the riparian zone. After weed removal plant with local native species. Appendix 1 contains a list of local species suitable for planting. See Section 5 for detailed techniques and information. In particular, planting a variety of understorey species, including rushes and sedges, is a priority in areas degraded by weed invasion or past stock access. As noted above, the landholder should also be encouraged to install fences where stock are accessing the river.
Declining water quality	Encourage DEC to use large woody debris at the rail bridge site where there is minor undercutting and plant with emergent vegetation such as rushes and sedges will enhance habitat.

Please note ‘encourage’ and ‘support’ can mean to; provide financial support, education or technical advice, depending on the resources available.

Sample photos from Reach 13:



Pen-Scott C2 example, amelioration work underway (CRS001)



PP75: Rail bridge (CRS001)



Pen-Scott example, Jum's Pool, AH 013 (CRS001)



PP76: Pen-Scott A3 Long Pool, AH 014



PP77: Pen-Scott B1 example



Pen-Scott C1 example, fallen woody debris with erosion potential (CRS004)

Key to Erosion/Deposition Classes on Maps

Erosion sedimentation process	Bank undercutting		Bank slumping		Point bars	Pool aggradation	Large woody debris
	Left bank	Right bank	Left bank	Right bank			
Order of Class on map	1st	2nd	3rd	4th	5th	6th	7th
Example*	A	B	C	D	A	B	C

* (see Table 7, Section 3 for assessment criteria)

6. MANAGEMENT ADVICE – WHAT CAN BE DONE

Where to start

There are a number of management options available to landholders and responsible government agencies for addressing issues associated with protection of the rivers and their associated foreshores in the Upper Collie including stock control, revegetation, weed control and erosion control. These management approaches can be undertaken in isolation or as a combined, integrated approach. Strategically (at the catchment scale), the approach taken should consider the values-threats framework approach where the high values – high threats (HV/HT) sites take priority over medium value (MV) and low value (LV) sites. At the site scale, the approach taken will depend on the range of priorities, on the scale of the issues present, and the landholders' willingness and capacity to undertake the required work. There are community groups, such as the Leschenault Catchment Council, that may be able to assist with site assessment and make contribution to works.

Principles for active management

The main principles for riparian management are:

- conserve the best areas first;
- prioritise those reaches showing signs of recovery; and,
- then treat the more degraded parts of the system.

This advice applies to both individual properties and the system as a whole.

It is most cost effective to protect areas still retaining native vegetation. These areas are stable and the most likely to regenerate naturally. Assisting natural regeneration is a lot cheaper and easier than restoring degraded areas.

Work on the more degraded parts will be easier if the creek upstream is in good condition, erosion and weed infestations impact on the area downstream.

Both the Cape to Cape Landcare Companion (Cape to Cape Catchment Group 2004) and the Geographe Catchment Commission (GeoCatch 2004) contain excellent advice on planning a restoration and revegetation project. These manuals are available free, or a very little cost from GCC and GeoCatch. This advice and the lessons learnt from the implementation of other River Action Plans should be applied during the planning and prioritisation of individual on-ground activities. The Vasse River Action Plan also contains excellent advice on planning a restoration and revegetation project. Parts of this advice are included in Appendix 3 of this plan.

As a generic approach to taking action, DoW's State-wide Waterways Framework (Macgregor et al. 2009) suggests a twelve-stage process however it is notable that three of these stages (assess waterway condition (3), identify assets and threats (4), and set priorities (5)) correspond with the assessment that has been undertaken in this RAP. The remaining stages are as follows:

- 1) **Vision and goals:** Describe the broad 'vision' of what you, and other stakeholders want the waterway(s) to be like after implementing the management response. This would consider the geographic area anticipated e.g. the vision might be developed for one of the major rivers in the Upper Collie Catchment. This shared 'vision' will keep stakeholders on track.
- 2) **Gain support:** Waterway management projects are as much about people as they are about science and construction. From the beginning it is important to identify the stakeholders and groups who may support or oppose the goals of the project. There are a variety of techniques that may be employed to ensure stakeholder engagement is properly tailored to the project. The Victorian government's Department of Sustainability and Environment website is a useful

source of information on developing an engagement plan (visit: www.dse.vic.gov.au and search for 'engagement plan'). The effective *Engagement Planning Tool* can be downloaded from the website.

- 3) **Strategies:** What specific actions are required to protect and improve the waterway(s)? The dominant management responses described in the text associated with each of the 13 reaches (above) should guide actions. In addition to physical on-ground actions, some effort should involve capacity building and identifying and changing the behaviour of people who may use the waterway(s).
- 4) **Measurable objectives:** The specific actions should be turned into clear, measurable objectives that specify exactly what is to be achieved and where.
- 5) **Feasibility:** Are the objectives feasible? Resources inevitably play a central role in all restoration activity and these will be constrained by the capacity of the organisation, community and land managers to undertake the actions. Each of the objectives should be examined to determine whether or not they are feasible. Six questions related to feasibility may assist in this:
 - a) How much will each objective cost?
 - b) How technically feasible is each objective?
 - c) Will each objective effectively contribute to reduce the threat/s?
 - d) How long will it take for the objectives to reduce the threat/s?
 - e) Will the objectives be implemented and supported by relevant stakeholders?

Determining answers to each of these questions should make it possible to arrive at a final realistic list of activities.

- 6) **Detailed design:** In this stage a detailed design is developed to address the final list of activities. What specific things should be done to protect and/or enhance the higher value sites? These may range from doing nothing, to establishing planning controls, weed removal, revegetation, fencing to control stock, engineering works for erosion management etc.
- 7) **Evaluation:** How will the activities be evaluated? Every initiative should include evaluation to determine if it has met the intended objectives. The measurable objectives established in Stages 4 and 5 are the basis for the evaluation. Evaluation does not necessarily need to be detailed and expensive; however, wherever possible, the indicators should be SMART (specific, measurable, achievable, relevant and timely).
- 8) **Implementation:** The plan should be implemented by developing a time-line, allocating responsibilities, finalising funding, carrying out the works and organising the evaluation schedule.
- 9) **Maintenance:** The final stage is to maintain the work that is done, and to set a point in the future at which time the activities will be formally assessed using the information gathered during the evaluation stage. At a suitable time in the future a revised RAP should be prepared in order to re-prioritise activities.

The river restoration manual, *A guide to the nature, protection, rehabilitation and long-term management of waterways in Western Australia* (WRC 2002) and Water Notes provide further guidance on river management and restoration. These are available on the Department of Water's website via:

www.water.wa.gov.au/Waterways+health/Looking+after+our+waterways/Protecting/default.aspx and; www.water.wa.gov.au/Waterways+health/Looking+after+our+waterways/Restoring/default.aspx Advice is available on topics such as planning river restoration, river action plans, foreshore condition assessments, hydrology, stream channel analysis, ecology, fencing, stock crossings and watering points, revegetation, riffle and fishway construction, sediment management and bank stabilisation.

What follows now is a summary of actions that are implied by this RAP. Much of the information in these sub-sections has been taken from the River Action Plans for the Brunswick, Upper Preston and Lower Collie Rivers.

Stock control

The control of livestock access is the most important management tool in the protection and restoration of waterways and vegetation. Fencing is the best method to achieve this. APACE Green Skills and Pen (1997) provide good advice on the placement of fences alongside waterways.

‘Ideally fences should be placed above the river valley (Figure 11). Depending on the steepness of the embankment, the fence should be placed 5 m to 20 m back from the edge of the river valley (Figure 11A). Five metres is sufficient for a shallow valley a couple of metres deep but a broader zone, greater than ten metres, is required for valleys deeper than five metres. The purpose of fencing off the shoulders of the river is to enable trees on the upper part of the embankment and those above the river valley to anchor the adjacent land, and thereby prevent subsidence.

In the case of shallow river valleys, there is little chance that embankments will subside. Nevertheless, fence-lines should be located above the river valley (Figure 11B). This is because fences and firebreaks located within the river valley will be damaged and eroded by floodwaters. When they occur, firebreak washouts can be severe and contribute large quantities of sediment to the river system.

If the river valley is particularly broad and floodplains have been cleared for grazing, fencing them off may mean sacrificing good farmland. In this case it is necessary that only those areas that are prone to water erosion or stock damage, such as embankments and secondary river channels that flow strongly at times of flood, need to be fenced off (Figure 11C). Some of these fence-lines will be prone to flood damage, but this can be minimised if fences run, as much as possible, parallel to the direction of floodwaters.

In the flatter and broader valleys it may be acceptable to use fences to control the level of grazing rather than to exclude it altogether. A careful watch would need to be kept to ensure that the grazing is sustainable and is not so heavy as to prevent the regeneration of native trees, shrubs and sedges.’

Fencing may be used to exclude stock entirely from the river, or to allow restricted grazing. Once native species have regenerated or been re-established it may be appropriate to allow careful grazing for short periods to control weeds. Grazing may also be used to control weeds prior to planting. Heavy grazing that would degrade the riparian zone and ultimately eliminate native plant species should be avoided. Total exclusion of stock will be necessary where the bank is steep and sandy, or prone to collapse, or where the objective is to maintain high quality riparian habitat. It is important to note that there may be increased grassy weedy growth if previously grazed areas are fenced off. A long-term weed management and revegetation plan needs to be developed prior to fencing off riparian zones.

In areas where stock is not present, there is no need to fence. However on properties where stock are present, even for only part of the time, it is important to restrict stock access to the banks.

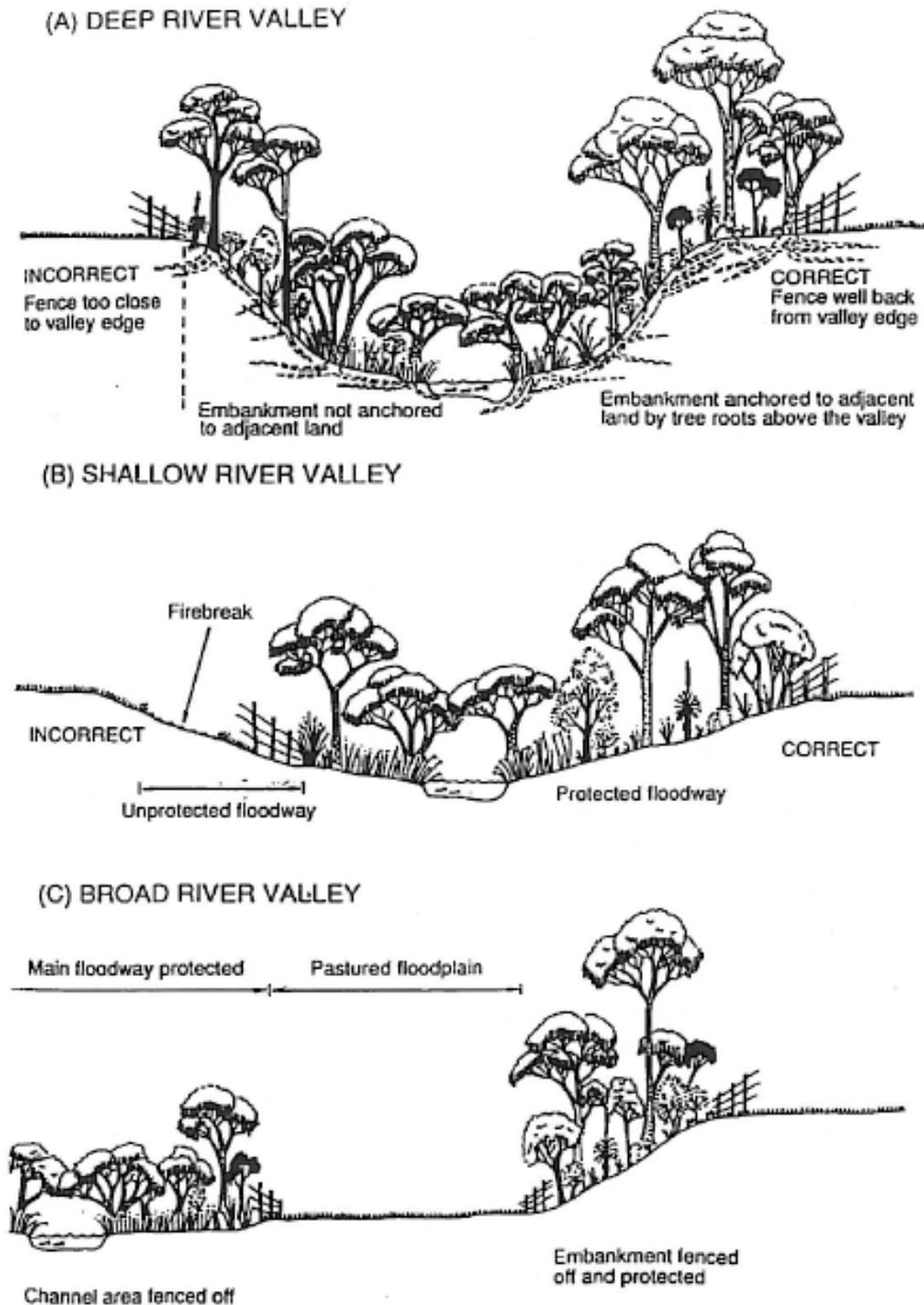


Figure 11: The correct placement of fences in relation to the river valley (A) the deep valley, (B) the shallow river valley and (C) the broad river valley with broad floodplain (after APACE Green Skills and Pen 1995)

Useful references on stock control

- Water and Rivers Commission. *Water Note 18, Livestock Management Fence Location and Grazing Control.*
- Water and Rivers Commission. *Water Note 6, Livestock Management: Construction of Livestock Crossings.*
- Water and Rivers Commission. *Water Note 7, Livestock Management: Watering Points and Pumps.*

- Water and Rivers Commission. *Water Note 19, Flood Proofing Fencing for Waterways*.

Water quality

Waterways in agricultural areas receive large quantities of nutrients, either dissolved in water, adhering to small soil particles eroded from the land or in dead plant and animal material, including manure washed from paddocks. Outlined below are a variety of ways to improve water quality (Pen 1999).

Vegetative buffers

Vegetated buffers alongside waterways can intercept and slow runoff and thereby trap suspended sediment, including organic material. Research has shown that vegetative buffers 10-50m wide can achieve phosphorus and nitrogen filtration rates in the order of 50-100% (Pen 1999). A vegetative buffer need not be of native vegetation and can be a simple grassy strip that is fenced off to control grazing. The nutrients assimilated by the vegetation can be utilised by crash grazing of preferably in hay production since the latter does not involve livestock returning nutrients to the grassy border as urine and manure.

Vegetation within the waterway itself forms a longitudinal buffer that, similarly, slows the flow rate, reduces erosion and traps soil, sediment and organic matter.

Farming practices

Kingdon (2000) recommend that to reduce soil erosion, the key is to keep reasonably high levels of vegetation on the soil for as long as possible, and especially during the times of high erosion risk. Achieving these conditions requires:

- Use of reduced tillage and direct drilling;
- Use of crop and pasture rotations that include well-managed perennial grasses and legumes;
- In row cropping; use of permanently raised beds and controlled traffic;
- Managing organic matter by retaining stubble and including pastures in a crop rotation;
- Ensuring vigorous plant growth through appropriate soil, crop and water management; and,

Cultivation along the contours, rather than at right angles to them, will slow the rate at which water flows across the land, reducing soil erosion by as much as 50% (Pen 1999).

Soil testing and fertiliser use

Fertiliser is generally applied according to traditional practice, usually some time before the winter/spring growing season. Today, we know that after a number of years of fertiliser application, many soils are rich in nutrients, but may be deficient in a few trace elements (Pen 1999). Soil should be tested to determine fertiliser requirements and avoid excess application of nutrients, a portion of which will find their way into waterways. Programs designed to assist landholders to better manage their fertiliser use through soil testing have recently been implemented by the Leschenault Catchment Council (LCC). This involved a paddock-scale- fertiliser plan to be produced, allowing landholders to better target soil deficiencies and improve yields. For more information, please contact LCC.

Mycorrhizal and soil bacteria testing is another related tool. Past farming practices have led to the gradual sterilisation of soils. Soil organisms interact with the root hairs of pasture and native plants and assist with nutrient uptake. A number of landholders in the South West have been trialling the use of organic and biodynamic solutions to improve soil health, with an ultimate goal of reducing fertiliser, herbicide and pesticide use whilst maintaining or improving yields. Contact the Department of Agriculture and Food, Western Australia (DAFWA) for more information.

Rural main drains and farm drains

The water quality on rural main drains and farm drains may be improved by the use of the above best management practices on farm. However, a number of practices can be used to stabilise the drains

themselves; for example, establishing and stabilising vegetation on drains to alleviate sedimentation problems and control stock access. For a more detailed description of managing rural drains you can contact the Water Corporation in regards to their paper on Native Plant Species to be Used in Stabilisation and Enhancement of Water Corporation Rural Main Drains in the South West Drainage Districts.

Useful references for protecting water quality through farming practices

- Kingdon, B. K. 2000. *Fertiliser Use Guidelines for the Swan Coastal Plain of WA*. Vasse-Wonnerup LCDC, Busselton, WA.

Erosion control

The foreshore assessment above has demonstrated that erosion is an issue requiring attention in many parts of Upper Collie Catchment, with some areas showing signs of severe incision, undercutting and bank slumping.

It should be noted that a detailed river geometry survey and a variety of calculations are required for the correct design of engineering works. It is also important to remember rivers are part of a dynamic system, that is, they are in a constant state of change. Care should therefore be taken when attempting to predict the outcome of alterations to channel form and capacity. Site-specific technical advice should be obtained prior to commencing any form of physical modification to the river channel. Engineers from the Department of Water can provide technical support.

In order to carry out erosion controls a number of important steps are required:

- Consultation with an engineer from the Department of Water may be needed to ensure that the erosion control techniques will be successful. An engineering survey may also be required.
- Permits are required before carrying out such works, such as a permit for ‘interfering with the bed and banks’ under the *Right in Water and Irrigation Act 1914* or under the *Aboriginal Heritage Act 1972*, the Department of Indigenous Affairs should be contacted to see if the site is registered; however, the location of registered sites have been identified on the maps in this document.¹ For a more extensive list of permits required, see Appendix 8.
- The works must be carried out in summer when the rivers are at their lowest and the banks are dry and easy to work on.

These steps can be time consuming. Thus, within a one-year project it is extremely difficult to carry out a successful erosion control program.

A number of approaches to erosion control as outlined in the Capel River Action Plan by Kirrily White and Sarah Comer (GeoCatch 1999) are described below.

Point bars

Once a riverbank becomes disturbed to the point where it is actively eroding, there is large potential for this to create sedimentation downstream through the formation of point bars. Water currents remove the material from the outside banks of meanders and deposit it on the inside banks where water moves more slowly, forming a point bar (Raine and Gardiner 1995). Over time these sand bars trap ore sediment and continue to accumulate, to a point where they may even start to support in channel vegetation growth. Some point bars are located and shaped in such a way that they actually divert the river flow onto the opposite bank further downstream, thus creating a new erosion point on the next outside bend. This cycle of erosion and deposition often continues downstream, and is a classic sign of a river in which the hydrological balance has been disturbed (Figure 12).

Removal of point bars may sometimes be needed in order to halt the progression of the erosion downstream. Generally, this should be undertaken in conjunction with other forms of restoration and

¹ Note: the entire length of the Harris and Collie rivers are regarded as Aboriginal cultural sites of special significance (site ID 16713).

care must be taken not to exacerbate the disturbance to the river channel. As discussed previously, a detailed river geometry survey of the problem areas is essential before this type of restoration procedure should be contemplated.

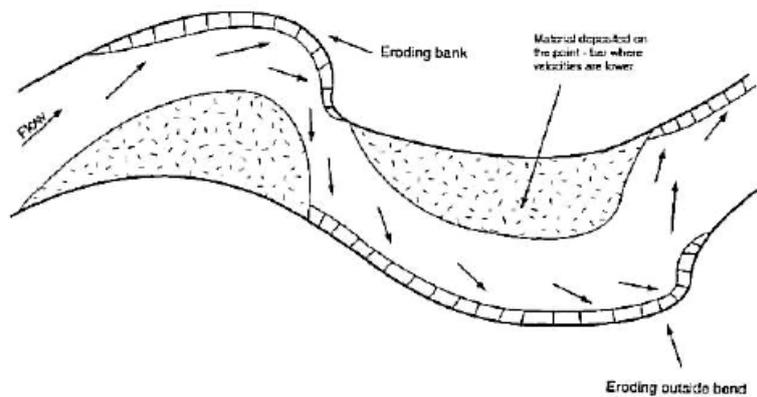


Figure 12: Outside bend bank erosion
Arrows mark the direction of flow showing that outside bends have the greatest erosion potential, so the meanders migrate downstream (Raine and Gardiner 1995)

Undercutting

Undercutting often occurs in conjunction with the formation of point bars. Material is scoured from the toe of the bank, resulting in loss of bank support; this often results in subsidence as illustrated in Figure 13, (Raine and Gardiner 1995). Previous experience has shown supporting and protecting the toe of the bank can prevent undercutting. Generally undercutting will occur where there is a meander. If this is the case, only the outside bends need to be supported as the flow velocity on the inside bend is much slower. Once an outside bend is stabilised, the corresponding inside bend will usually adjust its width to cater for the change in flow.

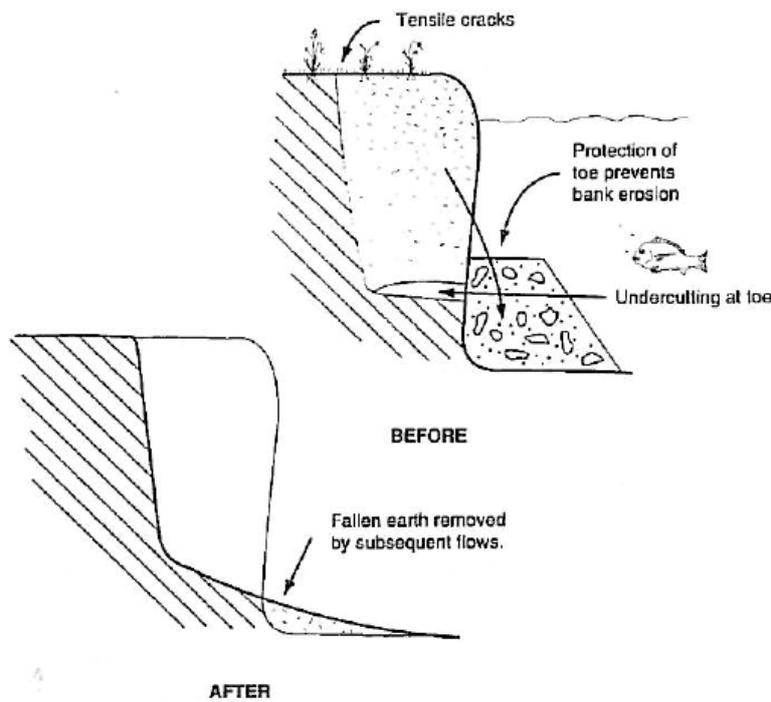


Figure 13: The use structural works to prevent undercutting (adapted from Raine and Gardiner 1995)

Bank slumping

Bank slumping can occur when poorly drained material within the bank becomes heavy with saturation and collapses into the river channel (Figure 14). This can occur with or without prior undercutting. It will often occur in response to the loss of native deep-rooted riparian vegetation which is critical to bank stability. The best way to manage this problem is to exclude stock with fencing set well back from the river channel, and revegetate the foreshore with suitable species. Raine and Gardiner (1995) provide the following advice on this process:

- Replant the toe with species that can withstand high velocities (e.g. native sedges). This replanting should be dense with spaces between plantings of less than 1 metre;
- Replant the middle to upper bank areas with fast growing, deep-rooted trees and large shrubs. These will hold the bank together, enhance drainage and remove excess moisture through transpiration;
- Vary the species that are planted to ensure differing root structures; and,
- Extend plantings from the toe to the floodplain. If a narrow band of trees is planted, this may serve only to add to the weight of the bank without providing the necessary network of root support.

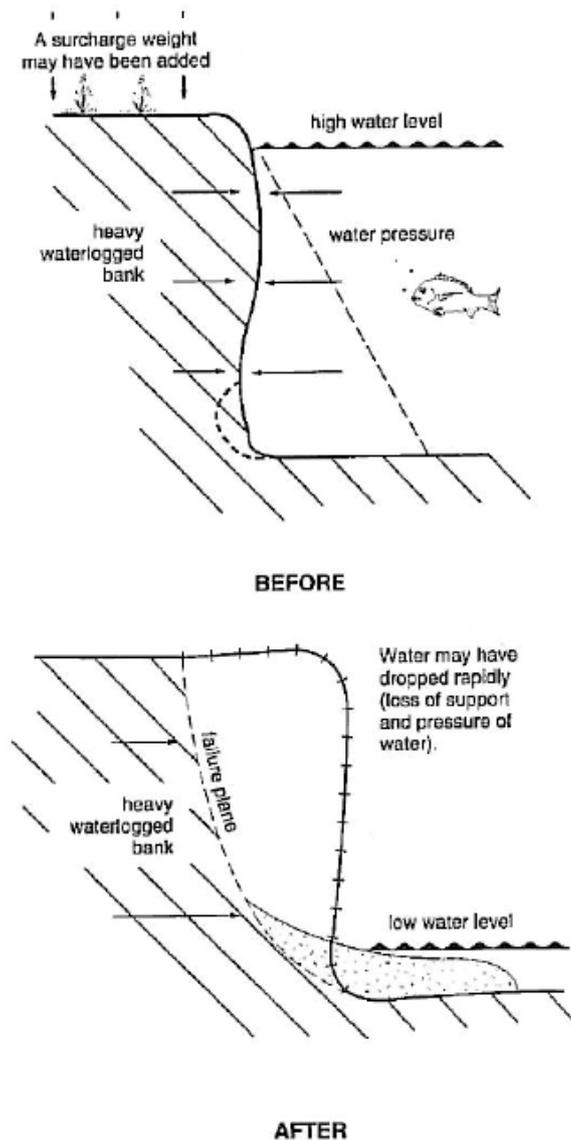


Figure 14: The process of bank slumping (adapted from Raine and Gardiner 1995)

Large woody debris

Snags, or large woody debris (LWD), are a natural component of the river system. They play an important role in river ecology by providing a range of flow conditions within the channel and habitat for aquatic life forms. Occasionally snags can divert the flow onto the bank and subsequently cause erosion in areas lacking support from native vegetation. While de-snagging rivers has been a common practice in the past, the current management emphasis is to leave as much woody debris as possible. Rather than removing large woody debris from the channel, it should be repositioned at an angle of 20° to 40° to the stream bank (Figure 15). This action will minimise the effect of the snag on flow levels and direction, whilst maintaining the habitat available for plants and animals that benefit from low flow conditions. Large woody debris can also be added to deflect flows from unstable areas.

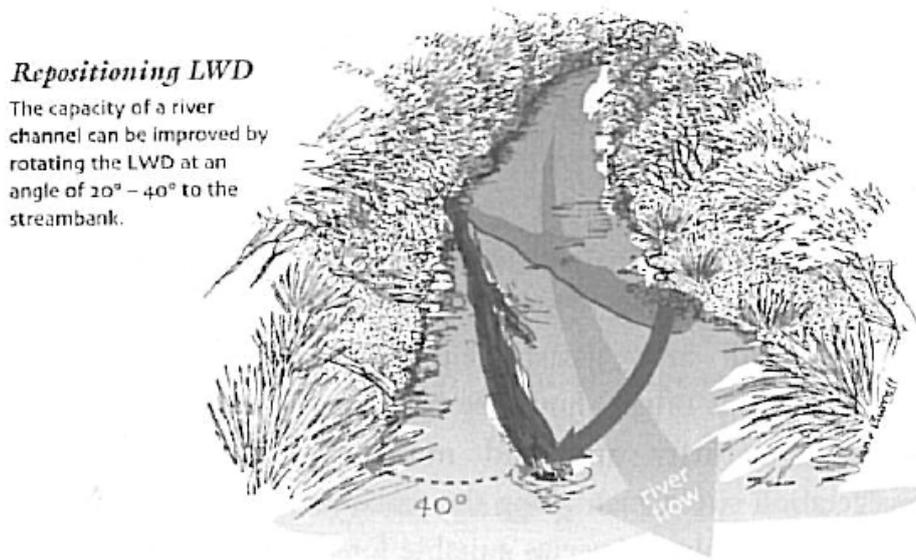


Figure 15: Repositioning large woody debris
(Gippel et al. 1998)

Useful references on erosion control

- Pen, L.J. 1999. *Managing Our Rivers*. Water and Rivers Commission, Perth.
- Water and Rivers Commission. 2001. *Stream Stabilisation*, River Restoration Report No. RR 10.
- Raine, A.W. and Gardiner, J.N. 1995. *Rivercare – Guidelines for Ecologically Sustainable Management of Rivers and Riparian Vegetation*. Land and Water Resources Research and Development Corporation, Canberra.

Regeneration and revegetation

In areas that still retain native trees and understorey, natural regeneration is the cheapest and easiest management option. Control of stock access and invasive weeds is essential to this strategy, and should be the first step taken. Natural regeneration can be assisted by making small piles of branches and burning to promote germination through smoke and heat. Smoke water can also be applied to encourage germination. Another technique to assist regeneration involves laying the seed bearing parts of native plants directly onto the ground, allowing seeds to fall from them. This is called brushing, and works best after weed control measures such as spraying to reduce competition once the seedlings start growing.

Sections of riparian vegetation that have been heavily grazed and cleared generally contain more weeds and have a diminished seed bank. Options for these areas include:

- *direct seeding;*
- *brushing with woody natives that contain seed;*
- *pre-seeded matting; and,*
- *planting of tube stock.*

The riparian zone should be planted in a wide band with a diverse suite of species including trees, shrubs, sedges, rushes and herbs and native grasses. This not only improves the habitat value of the foreshore, but also provides a matrix of different root structures that will improve bank stability and assist in erosion control. Where possible, seed should be collected from near by as this will ensure that the species used are suitable, local and part of the existing ecological web. Appendix 1 provides a list of species that were found in the area. Species for revegetation projects in the catchment should be selected from this list, choosing plants that are represented in nearby communities.

Good site preparation is crucial to successful revegetation. Elements that need to be considered are:

- *weed removal;*
- *soil amelioration; and,*
- *preparation of the soil surface for direct seeding or planting.*

Ongoing pest and weed control will need to be part of the project. Planting and sowing at the right time of year and at the appropriate depth will influence the success of the revegetation effort. Different revegetation techniques are outlined below.

Direct seeding

Direct seeding involves placing seeds directly in or into the soil on the site, either by hand or with machinery. For individual farm sized projects, a mix of local seeds can be prepared in clean (weed free) sand and sown into lightly cultivated or raked soil. For an increased cost but higher success rate, tree bags can be placed over these areas to protect seedlings from dehydration, wind and predation. These bags will also help to identify and protect plants during follow-up spot spraying for weeds over the coming seasons. Several areas in the catchment wood have good potential for the collection of local provenance² seed.

Direct seeding has a few distinct advantages over other revegetation methods:

- *It is less time consuming and requires less labour than planting tube stock;*
- *A mixture of trees, shrubs, sedges and groundcovers can be planted at the same time, resulting in a plant community with a more natural look, and better resilience due to increased diversity and synergy;*
- *Seeds will germinate over several years, giving a range of ages and growth forms, resulting in a more natural look;*
- *It is less expensive than using tube stock; and,*
- *The natural root development of seedlings grown from seed usually results in plants developing deeper taproots, requiring less follow-up care.*

However, direct seeding can be less reliable than planting, due to predation, specific germination requirements not being met, and poor conditions for direct seeding. Direct seeding may not be possible when high winds or strong water flow is present.

² The term 'provenance' is used to identify the geographic origin of seeds or parent plants. Often, genetically distinct local forms or varieties of a plant have evolved to suit a specific range of conditions, including soil, climate and water regimes. Direct seeding with local provenance seed ensures that the resulting plants will be suited to the localised conditions and maintain the ecological integrity of existing native plant communities (GeoCatch 1999).

Planting

Planting is an appropriate technique for embankment and in-stream revegetation, and where direct seeding difficult due to insufficient seed, excessive weed competition, or other factors. In these cases, nursery stock is ideally supplied from local provenance seed. A rule of thumb for planting densities is 3-4 rushes per 1m², 1 shrub per 1m² and 1 tree every 3m². When selecting plants and designing the revegetation of an area, it is also important to take into account: the budget for follow-up management; the availability of water over summer; the range of species available; existing vegetation cover such as tree canopy; soil types; and, the intended weed management approach.

Rushes and sedges should be planted in spring, when the water table is beginning to fall and the soil is still moist. Other seedlings should be planted when the surrounding soil is moist and follow-up rain is likely (usually May and July). Care should be taken to ensure that specimens are not root bound, and minimal damage to the roots occurs when removing from pots. Planting requires significant prior planning, as it is best to collect local seed and contract a nursery to raise them in time for planting in the following wet season.

Brushing

Brushing is an excellent technique for all zones apart from the channel bed. This technique can be used to spread seed and assist with erosion control simultaneously. Brush should be harvested from plants as seed maturity and laid immediately on the revegetation site. Brush along the embankment should be secured in place. Species suitable for this technique are those that retain seed on the plant, but shed it when the plant dries out. This includes many of the myrtaceous species (peppermints, tea trees, Melaleucas, and Eucalypts such as marri, jarrah and flooded gums). Brushing is easy to combine with other revegetation activities such as direct seeding, and provides shelter to plantings, increasing seedling survival rates.

Pre-seeded matting

Pre-seeded matting involves sowing seed onto appropriate fibre mulch, and laying the mat on-site in early winter after germination. This technique is excellent for steep embankments, since it provides erosion control and revegetation in a single step. It is generally only suitable for seeding with rushes and sedges, since matting usually requires rolling for transport to the site once seeds have germinated (like instant lawn). It can be difficult to source matting with seed of local provenance.

Division and transplanting of rushes and sedges

Many rushes and sedges propagate very well by vegetative division – plants can be easily split into individual plants (ramets) every two months or so, under good conditions. With planning the previous year, and a small initial outlay, a large number of these difficult to propagate (from seed) species can be raised by division. Some species of rushes and sedges such as *Juncus*, *Carex*, *Isolepis* and *Schoenoplectus* are suitable for growing from seed but others may be difficult to propagate.

Farmers often grub out or spray rushes and sedges in paddocks as they may limit options for crop cultivation. In some circumstances, paddocks adjacent to restoration sites may contain large numbers of these rushes and sedges that could be transplanted with success. This can be a cheap, but labour intensive form of revegetation. Care must also be taken to minimise erosion and not spread dieback.

Useful references on natural regeneration and revegetation

- Bradley, J. 1988. *Bringing Back the Bush: The Bradley Method of Bush Regeneration*. Lansdowne Press, Sydney.
- Buchanan, R.A. 1989. *Bush Regeneration: Recovering Australian Landscapes*. TAFE Open Training and Education Network, Strathfield, NSW.
- Scheltema, M. 1993. *Direct Seeding of Trees and Shrubs*. Greening Western Australia, Perth.
- Water and Rivers Commission. 1999. *Revegetation: Revegetating Riparian Zones in South-west Western Australia*. Water and Rivers Commission River Restoration Report No. RR4.
- Water and Rivers Commission. 1999. *Revegetation: Case Studies from South-west Western Australia*. Water and Rivers Commission River Restoration Report No. RR5.

- Water and Rivers Commission. 1999. *Using Rushes and Sedges in Revegetation of Wetland Areas in the South-west Western Australia*. Water and Rivers Commission River Restoration Report No. RR8.
- Water and Rivers Commission. 2000. *Water Note 20; Rushes and Sedges*.
- Geographe Catchment Council. 2004. *Geographe Catchment Companion*.
- Cape to Cape Catchments Group. 2004. *Cape to Cape Landcare Companion*.

Weed control

Weed invasion is a major threat along the Upper Collie Rivers, and in the catchment as a whole. Fencing the river and restricting stock access will result in the need for extra weed control. Weed control should be coordinated across the whole catchment for any action to be really effective. In foreshore areas, removal or control of weeds must take account of the erosive power of water. Clearing weeds in an unplanned manner could result in erosion in the river channel. Weed control principles to keep in mind include:

- *Weeds thrive in disturbed areas and on bare ground;*
- *Fire promotes weeds. Burning a remnant that is weed infested can make the weeds worse, unless there is follow-up weed control and revegetation. Native plants cannot compete with the rapid regrowth of weeds, which then become a greater fire hazard;*
- *Aggressive perennial weeds that spread readily along riparian corridors should be eradicated first, for example, bridal creeper, blackberry and cotton bush;*
- *If weed control is carried out, revegetate to prevent further weed invasion in the bare soil; and,*
- *Some native plants look and act like weeds. Do not begin weed control until you are sure a plant is a weed.*

Chemical control of weeds on waterways requires careful planning. Issues that must be considered prior to any type of chemical control include the effects of the herbicides on native flora and fauna, and on water quality. If you decide to use a herbicide, choose one that has a modified surfactant to reduce impact in waterways and wetlands, such as Roundup® Biactive. In surface or sheet erosion prone sites, spot rather than blanket spraying can help to reduce erosion from loss of weed cover whilst still providing opportunities for planting.

In some cases it may be appropriate to use restricted grazing to control weeds. Where banks are steep and sandy or prone to collapse, or where the objective is to maintain high quality riparian habitat, grazing should be avoided. However, where the riparian zone has a history of grazing and the exclusion of stock would lead to an explosion of weeds, maintenance of the zone by light grazing is an option. The landholder should keep a careful eye on the riparian zone to see that it has an adequate cover of a mixture of native and pasture plant species and that erosion is not occurring.

Troublesome major weeds should be identified at an early stage and eradicated immediately (Pen 1999).

Tackling invasive species in WA

The Invasive Species Program is responsible for the strategic and operational management of serious weeds and pest animals that pose a threat to agriculture production systems, related environmental resources, and market accessibility for agricultural produce in Western Australia.

- Animal pests: including vertebrate pests (mammals, birds, reptiles, amphibians) and some invertebrate animals; and,
- Plant pests: including plant species.

Activities include State and National policy development, risk assessment, research and development, provision of technical advice and information, implementation of regulation, emergency response,

property inspections, industry, local government and community liaison, education/awareness and the planning and coordination of significant species control/eradication programs. Further information may be obtained from: http://www.agric.wa.gov.au/PC_92738.html

Specific notes on certain weeds

A number of declared weeds (according to the *Agricultural and Related Resources Protection Act 1976*) were found in the study area. They are Apple of Sodom, Arum lily, Blackberry and Cotton bush. According to legislation, declared plants need to be controlled or contained depending on their status, and reported to the local Agricultural Protection Officer. More information on the requirements for control and treatment is available from the Department of Food and Agriculture, Western Australia (DAFWA).

Information on weeds and other priority weeds in the catchment has been compiled from other River Action Plans e.g. Brunswick River and from *Southern Weeds and their control* (Moore and Wheeler 2002), *Bushland Weeds: A Practical Guide to their Management* (Brown and Brooks 2002), and *Declared Plants Handbook: Recommendations for the Control of Declared Plants in Western Australia* (Department of Agriculture 2002). *Southern Weeds and their control* (Moore and Wheeler 2002) is a particularly useful guide to landholders and it provides information on weed identification and control. It is available from DAFWA offices. Also useful for weed identification is *Western Weeds* (Hussey et al. 1997).

The following is a guide of selected common weeds found in the study area – it is a summary guide only and specific information should be sourced from relevant authorities.

African Lovegrass (*Eragrotis curvula*)

This is a tufted grass to 1.2 m high. The greyish green inflorescence is loose and delicate, usually open and spreading with numerous small spikelets. The spikelets are 4-10 mm long, each with several florets which lack bristles. Grass-selective herbicides generally provide little or no control. Small infestations may be sprayed at any time of the year with a mixture of 100 mL glyphosate (450g/L) in 10 L water.

Blackberry (*Rubus* spp.)

A perennial plant with arching stems (canes) that was introduced from Europe as a fruit crop. Highly invasive, especially along creek lines. Mechanical control is difficult except for small infestations. Care must be taken to ensure all root material is removed. Herbicide control is most effective, with Triclopyr and Triclopyr plus Picloram having good results, but care must be taken near waterways with the latter. Some success has been had with mixtures of Metsulfuron and Glyphosate.

Birdsfoot Trefoil (*Lotus* species)

Includes Narrow-leaved Birdsfoot Trefoil, Hairy Birdsfoot Trefoil and Greater Birdsfoot Trefoil. Birdsfoot Trefoils are sprawling herbs with their leaves divided into 5, often hairy, leaflets. Three of the leaflets are towards the tip of the leaf and the remaining two at the base and often somewhat stem clasping. There are small stalked clusters of flowers – yellow to orange in colour and between 4-15 mm long. Herbicides provide the most effective control. Use picloram based products such as 100 mL Tordon 75-D plus 25 mL wetting agent in 10 L water for small infestations. Use 60 g/ha Logran or 200 g/ha Lontrel 750 for reasonably selective control in native vegetation. For hand spraying mix 25 mL wetting agent plus 1 g Logran or 4 g Lontrel 750 in 10 L water and apply in winter to early summer when actively growing. Do not burn infested areas.

Cotton bush (*Gomphocarpus fruticosus*)

This South African native forms a shrub up to 2m high and favours moist sites. A garden escape, cotton bush can be pulled from damp soils (up to late October/November). Alternatively, it can be cut at or just below ground level. The plant seldom re-grows following removal. Seed heads must be removed for this method to be effective. This weed contains cardiac glycosides and gloves should be worn and contact with sap avoided when undertaking control. Infestations should be sprayed between September and December with an appropriate herbicide.

Dock (*Rumex* species)

Common species include: Curled Dock (*Rumex crispus*) and Fiddle Dock (*Rumex pulcher*) Docks are erect herbs with leaves in a basal rosette and also up the stem. The small flowers are arranged in whorls up the flower spike, greenish in colour but turning reddish when in fruit. Each flower has small floral segments, 6 stamens and 3 styles. Isolated plants may be removed by cutting their roots at least 20 cm below ground level. Blanket wiping or manual application to individual plants using 1 L glyphosate (450 g/L) plus 20 g Chlorsulfuron (750g/kg) plus 2 L water in spring.

Edible fig (*Ficus carica*)

A large tree with distinctive lobed leaves and fleshy fruit. A garden escapee that tolerates damp conditions. Takes root easily from cutting and root fragments, with birds and animals also dispersing seeds. Hand pull seedlings, inject larger specimens with 50-100% Glyphosate in summer. Can be treated with the cut and paint method, however all branches, twigs and fruit must be removed and burnt.

Fat Hen (*Chenopodium album*)

An annual herb to 1 m high usually has striped stems with elliptic to diamond shaped leaves, 20-60 mm long and 5-30 mm wide with a pointed tip. It flowers in spring and autumn. Fat Hen often flourishes in areas that have recently been fenced off. Control involves hand pulling plants after elongation and before seeding in summer. Is relatively tolerant to normal rates of glyphosate. For small areas use 2 L/ha Spray.Seed plus 2kg/ha simazine (900g/kg) plus 1% spray oil in early summer for control of existing plants and residual control of seedlings for the season.

Fleabane (*Conyza* species)

Varieties include Tall (2 m high), Flaxleaf (1 m high) and Fleabane. Fleabanes are annual herbs with a basal rosette of entire or toothed leaves and an erect, often greyish, leafy flowering stem. The small flower heads are cream to white. Tiny fruits are topped by a ring of bristles. Hand pulling after stem elongation is effective on loose soils but on heavier soils a weed fork is required to prevent the plant breaking and regrowing from the base. Chemical control involves spraying with 1 L/ha glyphosate (450g/L) before flowering in late spring to summer each year.

Kikuyu (*Pennisetum clandestinum*), **Buffalo Grass** (*Stenotaphrum secundatum*), **Couch** (*Cynodon dactylon*) and **Water Couch** (*Paspalum distichum*).

These perennial introduced grasses all spread from runners or rhizomes and are very invasive. Manual control (except large scale scraping) is not effective. A spray-burn-spray regime using Glyphosate appears to work well in areas where water levels recede (allowing herbicide and fire use).

Victorian tea tree (*Leptospermum laevigatum*), **deciduous trees and other woody weeds.**

Woody weeds like Victorian tea tree and deciduous species like willows (*Sailx* spp.) and poplars (*Populus* spp.) can be controlled using stem injection or cut and paint with undiluted Glyphosate. To stem inject, holes should be drilled around the trunk and spaced no more than 5cm apart into the sapwood (just beyond the bark, but not into the heartwood) and herbicide injected immediately. The tree may take up to 3 months to die and can then be felled or left as habitat. To cut and paint, the tree should be felled with a chainsaw as close to the ground as possible and painted immediately with undiluted herbicide. All material must be removed and monitoring for suckers should occur for at least 2 years.

Watsonia (*Watsonia* sp.), **Gladioli** (*Gladiolus* sp.) and **African cornflag** (*Chasmanthe floribunda*).

These have been grouped together as growth form and control methods are similar. All are tufted bulbous species from South Africa with erect sword shaped leaves, and tall spike-like white, pink, yellow or orange flowering stems. Manual control (digging out) of African cornflag and Watsonia can be effective in small areas but is very labour intensive and requires many years of follow-up. Manual control of wavy Gladioli should not be attempted as numerous cormels will break off and cause a more severe than before. Spraying with Glyphosate or 2,2-DPA just prior to flowering gives best results. In sensitive areas, using a sponge glove or hockey stick wiper is best.

More information on weed control is available from DAFWA.

Useful references for weed identification and control

- Brown, K. and Brooks, K. 2002. *Bushland Weeds Practical Guide or their Management with Case Studies from the Swan Coastal Plain and Beyond*. Environmental Weeds Action Network, Greenwood, Western Australia.
- Department of Agriculture. 1999. *Wetlands not Weedlands*. Weed Note No. 1/99. Department of Agriculture, Perth, Western Australia.
- Department of Agriculture. 2002. *Declared Plants Handbook: Recommendations for the Control of Declared Plants in Western Australia*.
- Dixon, B. and Keighery, G. 1995. 'Suggested methods to control weeds'. In: *Managing Perth's Bushlands*, Scheltma, M. and Harris, J. (eds). Greening Western Australia, Perth, WA.
- Hussey, B. M. J., Keighery, G. J., Cousens, R. D., Dodd, J. and Lloyd, S. G. 1997. *Western Weeds: A Guide to the Weeds of Western Australia*. Plant Protection Society of Western Australia. Victoria Park, Western Australia.
- Hussey, B. M. J., and Wallace, K. J. 1993. *Managing your Bushland*. Department of Conservation and Land Management, Como, Western Australia.
- Moore, J. and Wheeler, J. 2002. *Southern Weeds and their Control*. Department of Agriculture, Bulletin No. 4558. Perth, Western Australia.
- Water and Rivers Commission. 1999. *Revegetation: Revegetating Riparian Zones in South-west Western Australia*.
- Water and Rivers Commission. *Restoration Report No. RR4*.
- Water and Rivers Commission. *Water Note 22, Herbicide Use in Wetlands*. Water and Rivers Commission Water Note 15, Weeds in Waterways.
- Water and Rivers Commission. *Water Note 25, Effects and Management of Deciduous Trees on Waterways*.

Fire hazard

The information below was taken from the Vasse River Action Plan (Geocatch 2000) by Margaret Scott but is equally applicable for the Upper Collie Rivers.

While a balance has yet to be struck between burning for fire protection and maintaining bush for habitat and species conservation, some general principles are well recognised.

Frequent burning of bush denies most plants the opportunity to reach maturity, seed and continue the species. Many plants need five to seven years or more to produce their first seeds. Consequently, the most resilient species (usually trees) survive, but even these are seldom replaced by young seedlings in a regime of annual burns.

Any reduction of the understorey, or disturbance the leaf litter mulch below trees and shrubs, allows weed invasion. Weeds out-compete most native species and annual burning promotes their seeding. With an understorey of flash fuels like wild oats, lovegrass or veldt grass, roadsides, reserves and drains catch fire easily, burning fiercely and spreading quickly.

For more information on fire management contact the Department of Environment and Conservation.

7. PRIORITISING MANAGEMENT ACTIONS IN THE UPPER COLLIE CATCHMENT

Principles learnt from previous river restorations

All RAPs are unique in that they are concerned with specific waterways. However, useful general observations from other RAPs (e.g. for the Brunswick, Upper Preston rivers and Lower Collie Catchment) offer useful lessons that should ensure the best possible results. First, the rationale for prioritising management activity, as described by the *Waterways Management Framework* (Macgregor et al. 2009) is notable since this was used to determine the prioritisation (e.g. HV/MT) displayed in the 13 reach maps³.

WA State-wide Waterways Management Framework priorities

The *WA State-wide Waterways Framework* offers landholders, the community, weed action groups and any others concerned with active management of waterways, a strategic approach to allocation of resources for management. There are a number of general management responses that people can consider and these can be summarised as follows:

1. To fully protect waterways values:
 - **Secure:** of such importance that action is needed to fully protect environmental, social and economic values.
 - **Maintain:** prevent negative alteration to existing waterway condition, practices and standards.
2. To improve waterway health:
 - **Restore:** reinstate specific values, conditions, standards or practices.
3. To manage degradation:
 - **Stabilise:** halt degradation processes.
 - **Contain:** limit degradation processes.
4. To manage function:
 - **Adapt:** accept that the waterway is highly degraded, identify the functions still operational and manage to those functions.
5. To identify drivers of change:
 - **Monitor:** conduct regular assessments of water quality and riparian condition to identify emerging threats if and when they arise.

The following description of waterways prioritisation categories has been taken from Macgregor et al.'s report (Table 8):

Table 8: Generalised management responses

Primary priority level	Sub-priority level	Dominant Management Response/s
1	1a (HV/HT)	Secure; Stabilise; Restore
1	1b (HV/MT)	Secure; Maintain; Restore
1	1c (HV/LT)	Monitor
2	2a (MV/HT)	Stabilise; Contain; Restore
2	2b (MV/MT)	Contain
3	3a (MV/LT)	Stabilise; Restore
3	3b (LV/HT)	Stabilise; Contain
3	3c (LV/MT)	Contain
3	3d (LV/LT)	Adapt

(Macgregor et al. 2009)

³ Detailed methodologies of how to score and prioritise waterways can be found in the *WA State-wide Waterways Framework* (Macgregor et al. 2009).

To determine the waterwise prioritisation categories for the sites surveyed in the Collie River RAP, data obtained for each site were scored and ranked according to values and threats criteria⁴.

Selection of criteria, indicators and measures for assessing values

The RAP sites along the reaches in this study were ranked according to ecological, social and economic value (Table 9). Ecological values were determined by three criteria (naturalness, diversity or richness and special features) using five indicators and 12 measures (Table 9). Social values were determined by four criteria (visual amenity, recreational and spiritual) using seven indicators and 10 measures (Table 10). Economic values were determined by one criterion (infrastructure) using two indicators and two measures (Table 10). Data obtained from the RAP survey was used for scoring measures. Where information was gathered separately for left and right banks of the river, these measures were scored separately.

Table 9: Ecological criteria, indicators & measures used in the Upper Collie

Criteria	Indicator	Measures used	Scoring
Naturalness	Level of riparian zone disturbance	Canopy cover of native overstorey riparian vegetation	3 = > 50 % cover 2 = 31 – 50 % cover 1 = 0 – 30 % cover
		Pen/Scott classification	3 = A 2 = B 1 = C
	Level of flow modification	Number of impoundments, weirs or other artificial barriers present	1 = presence of barriers
Diversity or richness	In-stream habitat heterogeneity	Presence and extent of small woody debris (< 20 cm diameter)	3 = > 50 % cover 2 = 25 – 50 % cover 1 = 0 – 5 % cover
		Presence and extent of large woody debris (20 – 40 cm diameter)	3 = > 50 % cover 2 = 25 – 50 % cover 1 = 0 – 5 % cover
		Number of logs > 40 cm diameter at 40° to the direction of water flow	3 = > 5 logs 2 = 3 – 4 logs 1 = 0 – 2 logs
		Presence and extent of submerged vegetation	3 = > 50 % cover 2 = 25 – 50 % cover 1 = 0 – 5 % cover
		Presence and extent of emergent vegetation	3 = > 50 % cover 2 = 25 – 50 % cover 1 = 0 – 5 % cover
	Floral diversity	Riparian vegetation understorey species richness	3 = high species richness 2 = moderate species richness 1 = low species richness
		Riparian vegetation middle-storey species richness	3 = high species richness 2 = moderate species richness 1 = low species richness
		Riparian vegetation over-storey species richness	3 = high species richness 2 = moderate species richness 1 = low species richness
	Special features	Significant areas	Presence of conservation, foreshore and road reserves as the dominant land use

⁴ Note: data demonstrating the values and threats score results and scoring methodology may be obtained by contacting the South West Catchments Council.

Table 10: Social and economic criteria, indicators and measures used in the Upper Collie

Criteria	Indicator	Measures used	Scoring
Visual amenity	Appealing waterscape	Presence of known scenic lookouts of waterway features	3 = presence 1 = absence
		Presence of known picnic areas	3 = presence 1 = absence
		Visual assessment of aesthetic value	3 = high aesthetic value 1 = no aesthetic value
Recreational	Boating	Presence of known canoeing/kayaking sites	3 = presence 1 = absence
	Recreational fishing	Presence of known fishing locations	3 = presence 1 = absence
	Swimming	Presence of known swimming sites	3 = presence 1 = absence
	Bush walking, cycling and horse riding	Presence of walking tracks or trails	3 = presence 1 = absence
		Presence of horse riding trails	3 = presence 1 = absence
Camping	Presence of caravan and camping sites close to the waterway	3 = presence 1 = absence	
Spiritual	Sites of cultural significance	Presence of registered and non-registered Aboriginal sites (e.g. sites containing archaeological artefacts, middens, fish traps, rock art etc.	3 = presence 1 = absence
Infrastructure	Waterway crossings	Presence of bridges (road, rail and foot), fords or other similar infrastructure	3 = > 2 crossings 2 = 1 crossing 1 = 0 crossings
	Water collection/storage	Presence/number of dams, weirs, diversions or extraction points	3 = > 2 dams, weirs etc. 2 = 1 dams, weirs etc. 1 = 0 dams, weirs etc.

Selection of criteria, indicators and measures for assessing threats

The Upper Collie RAP sites were also ranked according to threatening processes. Threatening processes were determined by four criteria (erosion and sedimentation, eutrophication, introduced plant and animal species and riparian zone degradation) using six indicators and 16 measures (Table 11).

Table 11: Criteria, indicators & measures used to assess threatening processes in the Upper Collie

Criteria	Indicator	Measures used	Scoring
Erosion and sedimentation	Presence and extent of erosion	Presence and extent of bank slumping	3 = 0.5 – 1 m 2 = 0.1 – 0.49 m 1 = 0 m
		Presence and extent of bank undercutting	3 = 0.5 – 1 m 2 = 0.1 – 0.49 m 1 = 0 m
	Presence and extent of sedimentation	Presence and extent of sediment bars	3 = > 25 % of active channel 2 = 5 – 25 % of active channel 1 = 0 – 4 % of active channel
		Visual assessment of surface water turbidity	3 = opaque turbidity 2 = slightly turbid 1 = clear
Eutrophication	Algal growth	Presence and extent of filamentous algae	3 = > 50 % cover 2 = 10 - 49 % cover 1 = ≤ 10 % cover
Introduced animal and plant species	Presence of riparian and aquatic weed	Presence and % cover of weeds	3 = > 74 % cover 2 = 21 – 74 % cover

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	species		1 = < 21 % cover
		Number of weed species	3 = > 7 species 2 = 4 – 7 species 1 = < 4 species
		Presence of Weeds of National Significance (WONS)	3 = presence
		Presence of Declared Plants (not including WONS)	3 = presence
Riparian zone degradation	Intactness of riparian vegetation	Width of riparian zone	3 = 0 – 30 m 2 = 31 – 60 m 1 = > 60 m
		Health of understorey vegetation	3 = many plants sick or dead 2 = some plants sick or dead 1 = no plants sick or dead
		Health of middle-storey vegetation	3 = many plants sick or dead 2 = some plants sick or dead 1 = no plants sick or dead
		Health of upper-storey vegetation	3 = many plants sick or dead 2 = some plants sick or dead 1 = no plants sick or dead
		Presence of recruitment of overstorey species	3 = no recruitment 1 = recruitment
	Livestock access	Evidence of stock trampling and pudging	3 = presence of trampling and pudging 1 = no evidence of trampling and pudging
		Presence and extent of fencing in riparian zones	3 = no fencing present 2 = 1 – 200 m of fencing 1 = > 200 m of fencing

Total scores for values and threats of all the sites surveyed in the Collie River Foreshore assessment were then plotted in values vs. threats matrix to prioritise management responses. The outcomes of this process are shown in Table 12.

Table 12: Site management priority rankings for sites surveyed in the foreshore assessment

Site	Reach	Primary priority level	Sub-priority level	Dominant management response/s
CRS018	11	1	1a HV/HT	Secure; stabilise; restore
CRE026	9	1	1b HV/MT	
CRE030	9	1	1b HV/MT	
CRE053	8	1	1b HV/MT	
CRE044	8	1	1b HV/MT	
CRS025	11	1	1b HV/MT	
CRC016	2	1	1b HV/MT	
CRC011	1	1	1b HV/MT	
CRC017	2	1	1b HV/MT	
CRC009	1	1	1c HV/LT	
CRE011	1	1	1c HV/LT	
CRS022	11	1	1c HV/LT	
CRS024	11	1	1c HV/LT	
CRC002	1	1	1c HV/LT	
CRC007	1	1	1c HV/LT	
CRS001	13	1	1c HV/LT	
CRC010	1	1	1c HV/LT	
CRS023	11	1	1c HV/LT	
CRC008	1	1	1c HV/LT	
CRC001	1	1	1c HV/LT	

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CRE018	9	2	2a MV/HT	Stabilise; contain; restore
CRS012	12	2	2a MV/HT	
CRE065	7	2	2a MV/HT	
CRE031	8	2	2a MV/HT	
CRE027	9	2	2a MV/HT	
CRC034	2	2	2b MV/MT	Contain
CRC035	2	2	2b MV/MT	
CRC032	2	2	2b MV/MT	
CRE056	8	2	2b MV/MT	
CRE016	9	2	2b MV/MT	
CRS016	11	2	2b MV/MT	
CRE012	10	2	2b MV/MT	
CRE001	10	2	2b MV/MT	
CRE066	7	2	2b MV/MT	
CRE004	10	2	2b MV/MT	
CRE009	10	2	2b MV/MT	
CRE051	8	2	2b MV/MT	
CRC030	2	2	2b MV/MT	
CRS010	12	2	2b MV/MT	
CRC029	2	2	2b MV/MT	
CRE090	6	2	2b MV/MT	
CRC028	2	2	2b MV/MT	
CRC020	2	2	2b MV/MT	
CRC022	2	2	2b MV/MT	
CRE047	8	2	2b MV/MT	
CRC018	2	2	2b MV/MT	
CRE045	8	2	2b MV/MT	
CRC021	2	2	2b MV/MT	
CRC019	2	2	2b MV/MT	
CRE069	7	2	2b MV/MT	
CRC042	3	2	2b MV/MT	
CRE028	9	2	2b MV/MT	
CRE068	7	2	2b MV/MT	
CRC073	4	2	2b MV/MT	
CRE055	8	2	2b MV/MT	
CRS027	11	2	2b MV/MT	
CRE043	8	2	2b MV/MT	
CRC026	2	2	2b MV/MT	
CRE054	8	2	2b MV/MT	
CRS028	11	2	2b MV/MT	
CRE083	6	2	2b MV/MT	
CRS031	11	2	2b MV/MT	
CRS014	12	2	2b MV/MT	
CRC044	3	2	2b MV/MT	
CRS026	11	2	2b MV/MT	
CRE029	9	3	3a MV/LT	Stabilise; restore
CRC012	1	3	3a MV/LT	
CRS030	11	3	3a MV/LT	
CRE052	8	3	3a MV/LT	
CRC006	1	3	3a MV/LT	
CRC014	2	3	3a MV/LT	
CRS020	11	3	3a MV/LT	

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CRS002	13	3	3a MV/LT		
HR001	5	3	3a MV/LT		
CRC005	1	3	3a MV/LT		
CRS008	13	3	3a MV/LT		
CRS003	13	3	3a MV/LT		
CRE025	9	3	3b LV/HT	Stabilise; contain	
CRE073	7	3	3b LV/HT		
CRE033	8	3	3b LV/HT		
CRE007	10	3	3b LV/HT		
CRE072	7	3	3b LV/HT		
HR015	4	3	3b LV/HT		
CRE017	9	3	3b LV/HT		
CRE081	6	3	3b LV/HT		
CRE019	9	3	3b LV/HT		
HR013	4	3	3b LV/HT		
CRE080	6	3	3b LV/HT		
HR010	5	3	3b LV/HT		
CRE021	9	3	3b LV/HT		
CRE064	7	3	3b LV/HT		
CRC062	3	3	3b LV/HT		
CRE074	7	3	3b LV/HT		
CRE092	6	3	3b LV/HT		
CRC039	3	3	3b LV/HT		
CRE034	8	3	3b LV/HT		
CRE014	10	3	3b LV/HT		
CRE076	7	3	3b LV/HT		
CRS011	12	3	3c LV/MT		Contain
CRC027	2	3	3c LV/MT		
CRC037	2	3	3c LV/MT		
CRC041	3	3	3c LV/MT		
CRE060	7	3	3c LV/MT		
CRC052	3	3	3c LV/MT		
CRE032	8	3	3c LV/MT		
CRC024	2	3	3c LV/MT		
CRC038	2	3	3c LV/MT		
HR014	4	3	3c LV/MT		
CRC033	2	3	3c LV/MT		
CRS029	11	3	3c LV/MT		
CRE035	8	3	3c LV/MT		
CRE022	9	3	3c LV/MT		
CRE077	7	3	3c LV/MT		
CRE008	10	3	3c LV/MT		
CRC050	3	3	3c LV/MT		
HR017	4	3	3c LV/MT		
CRE013	10	3	3c LV/MT		
CRC063	4	3	3c LV/MT		
CRC025	2	3	3c LV/MT		
CRC031	2	3	3c LV/MT		
HR012	5	3	3c LV/MT		
CRE079	6	3	3c LV/MT		
CRE084	6	3	3c LV/MT		
CRC067	4	3	3c LV/MT		

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CRC047	3	3	3c LV/MT
CRE078	7	3	3c LV/MT
CRE050	8	3	3c LV/MT
CRS013	12	3	3c LV/MT
CRE046	8	3	3c LV/MT
CRE091	6	3	3c LV/MT
CRC051	3	3	3c LV/MT
CRE071	7	3	3c LV/MT
CRC023	2	3	3c LV/MT
CRC070	4	3	3c LV/MT
CRC072	4	3	3c LV/MT
CRE082	6	3	3c LV/MT
CRC045	3	3	3c LV/MT
CRE003	10	3	3c LV/MT
CRC040	3	3	3c LV/MT
CRE041	8	3	3c LV/MT
CRC069	4	3	3c LV/MT
CRC036	2	3	3c LV/MT
CRE067	7	3	3c LV/MT
CRC057	3	3	3c LV/MT
CRE048	8	3	3c LV/MT
CRS015	11	3	3c LV/MT
CRE040	8	3	3c LV/MT
CRE093	6	3	3c LV/MT
CRE059	7	3	3c LV/MT
CRE061	7	3	3c LV/MT
CRE062	7	3	3c LV/MT
CRE042	8	3	3c LV/MT
CRE005	10	3	3c LV/MT
CRE039	8	3	3c LV/MT
CRC071	4	3	3c LV/MT
CRC060	3	3	3c LV/MT
CRE006	10	3	3c LV/MT
CRE089	6	3	3c LV/MT
CRC064	4	3	3c LV/MT
CRS019	11	3	3c LV/MT
CRE002	10	3	3c LV/MT
CRC056	3	3	3c LV/MT
CRC061	3	3	3c LV/MT
CRS009	13	3	3c LV/MT
CRE087	6	3	3c LV/MT
CRC066	4	3	3c LV/MT
CRE023	9	3	3c LV/MT
HR011	5	3	3c LV/MT
CRE036	8	3	3c LV/MT
CRS032	11	3	3c LV/MT
CRC004	1	3	3c LV/MT
CRE070	7	3	3c LV/MT
CRC068	4	3	3c LV/MT
CRE020	9	3	3c LV/MT
CRE057	8	3	3c LV/MT
CRC059	3	3	3c LV/MT

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CRE049	8	3	3c LV/MT	Adapt
CRE063	7	3	3c LV/MT	
CRS017	11	3	3c LV/MT	
CRE085	6	3	3c LV/MT	
CRS004	13	3	3d LV/LT	
CRE015	9	3	3d LV/LT	
HR002	5	3	3d LV/LT	
HR003	5	3	3d LV/LT	
CRE086	6	3	3d LV/LT	
CRE010	10	3	3d LV/LT	
CRS033	11	3	3d LV/LT	
CRC054	3	3	3d LV/LT	
HR008	5	3	3d LV/LT	
CRC058	3	3	3d LV/LT	
CRE058	7	3	3d LV/LT	
CRS007	13	3	3d LV/LT	
CRC053	3	3	3d LV/LT	
HR016	4	3	3d LV/LT	
CRC013	1	3	3d LV/LT	
CRE075	7	3	3d LV/LT	
CRC046	3	3	3d LV/LT	
CRS005	13	3	3d LV/LT	
CRC049	3	3	3d LV/LT	
HR006	5	3	3d LV/LT	
HR005	5	3	3d LV/LT	
HR004	5	3	3d LV/LT	
CRC003	1	3	3d LV/LT	
CRC015	2	3	3d LV/LT	
CRE024	9	3	3d LV/LT	
CRE088	6	3	3d LV/LT	
CRE038	8	3	3d LV/LT	
CRS021	11	3	3d LV/LT	
CRS006	13	3	3d LV/LT	
CRC043	3	3	3d LV/LT	
HR009	5	3	3d LV/LT	
CRC048	3	3	3d LV/LT	
CRC065	4	3	3d LV/LT	
HR007	5	3	3d LV/LT	
CRC055	3	3	3d LV/LT	
CRE037	8	3	3d LV/LT	

Table 13 summarises the sub-priority rankings for sites sampled in the foreshore assessment.

Table 13: Summary of sub-priority rankings for sites in the Upper Collie Catchment.

Sub-priority ranking	No of sites	Total % of rivers surveyed*
High value – high threat	1	0.5
High value – medium threat	8	3.7
High value – low threat	11	5.1
Medium value – high threat	5	2.3
Medium value – medium threat	40	18.4
Medium value – low threat	12	5.5
Low value – high threat	21	9.7
Low value – medium threat	82	37.8
Low value – low threat	37	17.0

* Total length of the rivers surveyed – approx. 80.9kms

Priority 1

Priority 1 sites are those sites considered high value. In this survey, a total of 20 out of 217 sites were found to be of high value (9% of all sites).

High value sites should be considered for management before waterways of medium or low value. This reflects the principle of always preserving or securing rare waterways, or waterways that are in good condition, first but it also acknowledges the pragmatic problems involved with NRM – especially cost-effectiveness. It should ensure managers obtain the ‘biggest bang for their buck’, i.e. management can decrease the majority of threats at the greatest rate per unit dollar (or time) invested. Consequently, management efforts within this priority are likely to be dominated by those that secure and/or stabilise waterways from threats. Where sites are not exposed to threats or threats are minimal, only monitoring is necessary.

Sub-priority 1a (HV/HT)

1 site (0.5% of all sites surveyed) was classed into this sub-category.

It is likely that sites in this class will require the greatest proportion of management (to protect and/or enhance high value assets) but the high threats exposure also implies the greatest effort and resources. In situations where degradation is high it is also important to consider potential off-site impacts; whether degradation is or may be passed on to other high-value sites currently unaffected – especially downstream. Where this is a possibility then management efforts should first stabilise degradation. In most situations securing and maintaining assets will have priority over restoration, mainly because the cost of protection is typically about one-tenth the cost of restoration. Only after degradation has been stabilised can restoration strategies be considered.

Sub-priority 1b (HV/MT)

A total of 8 sites (3.7% of all sites surveyed) were classed into this sub-category.

High-value assets in this sub-classification are exposed to threats that are slightly less significant than 1a. It is also likely that degrading processes are less of a threat to high-value stretches of waterways downstream. In that sense, there is not the sense of urgency apparent in 1a but management should still seek to secure assets where necessary.

Sub-priority 1c (HV/LT)

11 sites (5.1% of all sites surveyed) were classed into this sub-category.

Sites that fall into this sub-category are perhaps slightly unique from the other high-value sub-categories. Since these sites are regarded as being in good condition and under little exposure from threats there is little need to actively manage – such waterways will ‘manage themselves’ so long as conditions remain stable. Therefore, if resources are available, landholders and others could consider applying these to other high-value or even medium-value waterways to protect or improve their condition. However, this does not imply that waterways in this category can be ignored altogether; it would be prudent to consider establishing an appropriate longitudinal monitoring program.

Priority 2

Priority 2 sites are those considered medium value with either high or medium level threats. In this survey a total of 64 out of 217 sites were found to be of medium value (29.0% of all sites)

Sites in this class will have been damaged by human impact to a greater or lesser degree, but there is potential to protect assets and recover less damaged sites at reasonable cost. There are two sub-classes within this priority with those classed as medium-value, medium-threat being prioritised before medium-value, low-threat. Once again, recognising relative costs of protection compared with restoration, the most widespread benefit will be obtained by stabilising existing degradation before considering restoration. Any restoration efforts should improve the condition of easy fix sites first.

Sub-priority 2a (MV/HT)

A total of 5 sites (2.3% of all sites surveyed) were classed into this sub-category.

The worse examples of sites in this sub-category would be those that have been largely cleared of riparian and in-channel vegetation, with marginal water quality and some sediment deposition in the channel. Ideally, restoration is called for but as noted above, active degradation (erosion, weed spread and nutrient enrichment) should be stabilised or at least contained first. If restoration opportunities arise, pragmatism will dictate the order of attack. For example, it is easiest to expand a reach in relatively good condition, than to restore an isolated reach. Look for opportunities to enhance the higher values that are present. The following order of management should be considered:

- 1. Improve degraded assets in reaches with some high quality values.*
- 2. Work on a poor quality reach that links two value-rich reaches.*
- 3. Work on a poor quality reach connected by to a value-rich reach.*

Sub-priority 2b (MV/MT)

A total of 40 sites (18.4% of all sites surveyed) were classed into this sub-category.

Management options for this and lower value sites will inevitably be quite limited because higher value sites are likely to consume most of available resources. Given the relatively high cost of restoration, efforts should be directed more towards containment of degradation processes. However, if restoration opportunities arise then the order of priorities identified for sub-category 2a apply.

Priority 3

Priority 3 sites are considered relatively low value. In this survey a total of 152 out of 217 sites were found to be of low value (70% of all sites).

Given the nature of waterways management, and its heavy demand on resources, there will be very limited opportunity to manage Priority 3 sites to bring about dramatic improvements in their condition. However, it is important to acknowledge that sites in poor condition can be sources of threats to other more valuable sites or reaches downstream. In such cases, management efforts should seek to stabilise and contain degradation. For sites that pose little or no threat, resources may be more usefully directed to protecting or restoring higher-value sites – accepting that there is nothing that can effectively be done (adapt).

Sub-priority 3a (MV/LT)

A total of 12 sites (5.5% of all sites surveyed) were classed into this sub-category.

This sub-category occupies a slightly unique place in the waterways management framework – it is the only medium-value category with a Priority 3 rating. This in itself suggests that these waterways should be considered for management before 3b, 3c and 3d, which are all lower value. However, there is perhaps another important reason and it again relates to the basic logic of fixing the easy before the hard. Management should mainly be concerned with stabilising degradation with perhaps restoration where opportunities arise.

Sub-priority 3b (LV/HT)

21 sites (9.7% of all sites surveyed) were classed into this sub-category.

Typical sites in this sub-category are in very poor condition with little or no chance of recovery without significant restoration. Unfortunately restoration of such sites will be expensive and difficult. In terms of management response, if the site has potential to threaten sites downstream it is appropriate to take action to stabilise or contain. If this is unlikely, then protecting remaining ecosystem functions (adapt) would be appropriate.

Sub-priority 3c (LV/MT)

82 sites (37.8% of all sites surveyed) were classed into this sub-category.

As indicated above, management for this site must mostly be concerned with containment but since the site can be regarded as relatively low-value and there are minimal threats there is likely little to be gained by investing heavily in active restoration.

Sub-priority 3d (LV/LT)

37 sites (17% of all sites surveyed) were classed into this sub-category.

Management for this site is concerned with adaptation. While waterways in this sub-category are of low-value they will pose little if any threat to other higher value reaches. In terms of management there is probably less to do here than in any other sub-priority category. Adaptation is called for but remaining ecosystem functions could be managed to at least protect those.

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9. APPENDICES

APPENDIX 1.

Native flora found in the study area.

Trees and large shrubs (> 3 m tall)

Scientific name	Common name	Height m
<i>Acacia saligna</i>	Coojong	1.5 - 6
<i>Banksia littoralis</i>	Swamp Banksia	1.5 – 12
<i>Banksia seminuda</i>	River Banksia	1 - 25
<i>Casuarina obesa</i>	Swamp sheoak	1.5 - 10
<i>Corymbia calophylla</i>	Marri	Up to 40
<i>Eucalyptus marginata</i>	Jarra	Up to 40
<i>Eucalyptus megacarpa</i>	Bullich	2 – 25
<i>Eucalyptus patens</i>	Blackbutt	3 – 25
<i>Eucalyptus rudis</i>	Flooded gum	5 - 20
<i>Eucalyptus wandoo</i>	Wandoo	3 - 25
<i>Hakea falcata</i>	Sickle hakea	2 - 4
<i>Melaleuca preissiana</i>	Paperbark	2 - 9
<i>Melaleuca incana</i>	Grey honey myrtle	0.4 – 5
<i>Melaleuca raphiophylla</i>	Swamp paperbark	0.2 - 10
<i>Melaleuca viminea</i>	Mohan	0.6 - 5
<i>Nuytsia floribunda</i>	Christmas tree	Up to 10
<i>Oxylobium ebracteolatum</i>	Narrow leaved oxylobium	
<i>Taxandria linearifolia</i>		Up to 5
<i>Xanthorrhoea preissii</i>	Grass tree	Up to 5

Shrubs under 3m

Scientific name	Common name	Height m
<i>Acacia pulchella</i>	Prickly moses	0.3 - 3
<i>Astartea fascicularis</i>	Astartea	0.3 - 3
<i>Calytrix glutinosa</i>		0.2 - 1
<i>Hakea amplexicaulis</i>	Broad leaved hakea	1 - 3
<i>Hakea costata</i>		0.3 - 2
<i>Hakea trifurcata</i>	Two leaved hakea	1.5 - 3
<i>Hypocalymma angustifolium</i>		0 – 1.5

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<i>Macrozamia riedlei</i>	Zamia palm	0.5 – 3
<i>Melaleuca lateritia</i>	Robin redbreast bush	Up to 2.5
<i>Pericalymma ellipticum</i> var. <i>ellipticum</i>		Up to 3
<i>Pteridium esculentum</i>	Bracken fern	0.5 - 2
<i>Regelia cilata</i>		0.2 - 2
<i>Trymalium ledifolium</i>		0 – 1.5
<i>Viminaria juncea</i>	Swish bush	1 - 4

Herbs and vines

Scientific name	Common name	Height m
<i>Cassytha flava</i>	Dodder	N/A
<i>Cotula</i> spp.	Button weed	0.25
<i>Halosarcia</i> spp.	Samphire	Up to 0.5
<i>Lobelia anceps</i>	Angled lobelia	Up to 1.25

Sedges and rushes

Scientific name	Common name	Height
<i>Baumea articulata</i>	Jointed twig rush	1 – 2.6
<i>Baumea juncea</i>	Bare twig rush	0.2 – 1.2
<i>Bolboschoenus caldwellii</i>	Marsh club rush	0.3 – 1.2
<i>Carex</i> spp.	Sedges	
<i>Juncus pallidus</i>	Pale rush	0.5 - 2
<i>Juncus subsecundus</i>	Finger rush	0.3 - 1
<i>Lepidosperma effusum</i>	Spreading sword-sedge	Up to 2.5
<i>Lepidosperma longitudinale</i>	Pithy sword sedge	0.5 - 2
<i>Mesomelaena tetragona</i>	Semaphore sedge	0.3 – 0.8

Plant names and height have been taken from Florabase (2009). Available from:
<http://florabase.dec.wa.gov.au>

APPENDIX 2.

Common weeds found in the study area.

List includes weeds found during this RAP and in other studies in the catchment.

Scientific name	Common name	Declared plants (DP) and Weeds of National Significance (WONS)
<i>Acacia baileyana</i>	Cootamundra wattle	
<i>Acacia dealbata</i>	Silver wattle	
<i>Acacia podalyriifolia</i>	Queensland silver wattle	
<i>Agapanthus praecox</i>	Agapanthus	
<i>Amaryllis belladonna</i>	Easter lily	
<i>Ammophila arenaria</i>	Marram grass	
<i>Anagallis arvensis</i>	Pimpernel	
<i>Arctotheca calendula</i>	Capeweed	
<i>Arundo donax</i>	Giant reed	
<i>Asparagus asparagoides</i>	Bridal creeper	DP and WONS
<i>Avena barbata</i>	Bearded oat	
<i>Brassica tournefortii</i>	Wild turnip	
<i>Briza maxima</i>	Blowfly grass	
<i>Briza minor</i>	Shivery grass	
<i>Bromus</i> spp.	Brome grass	
<i>Cakile maritima</i>	Sea rocket	
<i>Carduus</i> spp.	Thistles	
<i>Cerastium glomeratum</i>	Sticky mouse-eared chickweed	
<i>Chaemaecytisus palmensis</i>	Tagasaste	
<i>Chenopodium murale</i>	Green fat hen	
<i>Conyza sumatrensis</i>	Tall fleabane	
<i>Cortaderia selloana</i>	Pampas grass	
<i>Crepis</i> spp.	Hawksbeard	
<i>Cynodon dactylon</i>	Couch grass	
<i>Cyperus</i> spp.	Dense flat-sedge	
<i>Disa bracteata</i>	South African orchid	
<i>Dittirchia graveolens</i>	Stinkwort	
<i>Ehrharta longiflora</i>	Annual veld grass	
<i>Ehrharta villosa</i>	Pyp grass	

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<i>Emex australis</i>	Doublegee	DP
<i>Eragrostis curvula</i>	African lovegrass	
<i>Erythrina sykesii</i>	Coral tree	
<i>Euphorbia paralias</i>	Sea spurge	
<i>Euphorbia peplus</i>	Petty spurge	
<i>Euphorbia terracina</i>	Geraldton carnation weed	
<i>Ficus carica</i>	Edible fig	
<i>Fumaria</i> sp.	Fumatory	
<i>Gomphocarpus fruticosus</i>	Cotton bush	DP
<i>Gladiolus undulatus</i>	Wavy gladiolus	
<i>Hedera helix</i>	Ivy	
<i>Helichrysum luteoalbum</i>	Jersey cudweed	
<i>Holcus lanatus</i>	Yorkshire fog	
<i>Hordeum</i> spp.	Barley grass	
<i>Hypochaeris</i> sp.	Flatweed	
<i>Isolepis prolifera</i>	Budding club-rush	
<i>Juncus bufonis</i>	Toad rush	
<i>Juncus articulatus</i>	Jointed rush	
<i>Juncus microcephalus</i>		
<i>Lagurus ovatus</i>	Hare's tail grass	
<i>Leptospermum laevigatum</i>	Victorian tea-tree	
<i>Lolium perenne</i>	Perennial ryegrass	
<i>Lotus corniculatus</i>	birds' foot trefoil	
<i>Marsilea mutica</i>	Nardoo	
<i>Mentha diemenica</i>	Garden mint	
<i>Mentha pulegium</i>	Pennyroyal	DP
<i>Modiola caroliniana</i>	Red-flowered mallow	
<i>Morus nigra</i>	Mulberry	
<i>Myriophyllum aquaticum</i>	Parrot's feather	
<i>Olea europaea</i>	Olive	
<i>Orbanche minor</i>	Lesser broomrape	
<i>Oxalis pes-caprae</i>	Purple wood sorrel	
<i>Oxalis purpurea</i>	Mauve oxalis	
<i>Paspalum dilatatum</i>	Paspalum	
<i>Paspalum vaginatum</i>	Saltwater couch	
<i>Passiflora edulis</i>	Passionfruit	
<i>Pelargonium capitatum</i>	Rose pelargonium	

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<i>Pennisetum clandestinum</i>	Kikuyu	
<i>Petrorhagia dubia</i>	Velvet pink	
<i>Phalaris aquatica</i>	Phalaris	
<i>Physalis angulata</i>	Wild gooseberry	
<i>Pinus radiata</i>	Radiata pine	
<i>Plantago lanceolata</i>	Ribwort plantain	
<i>Ranunculus muricatus</i>	Sharp buttercup	
<i>Raphanus raphanistrum</i>	Wild radish	
<i>Romulea rosea</i>	Guildford grass	
<i>Rorippa nasturtium-aquaticum</i>	Watercress	
<i>Rosa rubiginosa</i>	Sweet briar	
<i>Rubus</i> spp.	Blackberry	DP, WONS
<i>Rumex</i> spp.	Dock	
<i>Samolus valerandi</i>	Brookweed	
<i>Senecio elegans</i>	Purple groundsel	
<i>Silene gallica</i> var. <i>gallica</i>	French catchfly	
<i>Solanum linnaeanum</i>	Apple of Sodom	DP
<i>Solanum nigrum</i>	Black berry nightshade	
<i>Sparaxis bulbifera</i>	Freesia	
<i>Stellaria media</i>	Common chickweed	
<i>Stenotaphrum secundatum</i>	Buffalo grass	
<i>Tetragonia decumbens</i>	Sea spinach	
<i>Trifolium</i> spp.	Clover	
<i>Typha orientalis</i>	Bulrush	
<i>Vallisneria Americana</i>	Ribbon weed	
<i>Vinca major</i>	Blue periwinkle	
<i>Vitis vinifera</i>	Grapevine	
<i>Watsonia meriana</i>	Watsonia	
<i>Zantedeschia aethiopica</i>	Arum lily	DP

Common names and declared plant/WONS information taken from:

Hussey, B.M.J., Keighery, G.J., Dodd, J., Lloyd, S.G. and Cousens, R.D. (2007). Western weeds: A guide to the weeds of Western Australia (second edition). The weeds society of Western Australia, WA.

APPENDIX 3.

Planning advice

The following planning advice is taken from the Vasse River Action Plan and was prepared by Margaret Scott and Jenny Dewing (GeoCatch 2000).

Planning a project

Write down your objectives:

- What work will be done?
- Who will do the work?
- What will the work achieve?
- Who and what will benefit from the work?

A written list of objectives:

- Helps planners to stay within the goals;
- Encourages the recruitment of volunteers;
- Helps volunteers to understand their roles; and,
- Provides benchmarks of progress and success.

Site selection:

- Choose a workable sized site, small enough to complete the job;
- Select a site within easy travelling distance for volunteers; and,
- Favour a site which enables the volunteers, and if possible the general public, to view their achievements.

Organising a planning committee:

- Select a diverse group of people within the community;
- Draw on different groups of people within the community;
- Identify those people with supervising and planning skills; and,
- Enlist the local media to contribute their support.

Planning creek rehabilitation

Planning a revegetation project should commence in the year preceding the proposed planting or seeding and include researching the best revegetation approach.

Issues to be addressed include:

- The design of remedial work on the banks;
- The selection of suitable plant species;
- How to propagate (by green stock or direct seeding);
- Where to obtain seed;
- Who to get to propagate the seed;
- The position and design of fencing;
- Identifying likely weed problems, developing a weed action plan; and,
- Where to access funds if you intend applying for a grant.

It is essential to study the project site thoroughly. A thorough site survey will provide an inventory of assets such as:

- Existing indigenous vegetation;

- Plants that are naturally regenerating;
- Seed sources; and,
- Potential problems, for example, rabbit activity, weed infestations, eroding banks, areas of sedimentation.

The survey may result in the decision to manage the area to encourage natural regeneration rather than to restore the native vegetation by planting or direct seeding.

A survey may be used for monitoring the effectiveness of a particular management activity over time.

Bank erosion and/or sedimentation may require remedial action prior to revegetation. Advice should be sought from the Department of Water.

When to survey

Late autumn to early winter is a good time to survey when weed problems are apparent. Impacts of river activity can be easily seen – sections of eroding or slumping banks, and areas where sediment is being deposited. Later in winter, a survey of the river or stream in full flow is more likely to reveal the behaviour of the river rather than its impact.

What's growing on the creek or river

A list of existing native vegetation is useful for identifying suitable plant species for revegetation and potential populations of plants for obtaining seed. It is important to establish the position on the stream bank that each occupies and the type of soil in which it grows – sand, clay, loam, etc.

Native plants are easier to identify when flowering. While different species flower in different seasons throughout the year, the peak season is spring. Fringing species flower later to coincide with falling water levels. They flower and produce seed after winter flooding, to complete their cycle before the next winter rains. It may take several visits from winter onwards to identify all plants.

In summer, flowering suites of plants go mostly unnoticed as they flower when few people are walking and looking. Some of these include *Astartea fascicularis* (a tea tree), *Taxandria linearifolia* (swamp peppermint) and *Banksia littoralis* (swamp Banksia).

There is a slightly different community of plants growing along the banks of each local creek. These variations reflect the topographical features of the landscape and the soil types unique to that site.

It is not difficult to compile a list of plants specific to a site. The revegetation is then tailored to suit local insects, reptiles, frogs, birds and small mammals, and looks similar to existing remnant vegetation.

Identifying plants

Native rushes and sedges are difficult for untrained people to identify, and are often excluded from revegetation lists. The easiest way to identify them is to collect samples, including the base of the plant, and compare them with specimens in the regional or state herbarium. Generally perennial grasses, including spear, wallaby and kangaroo grasses, flower from late spring to summer. Rushes flower at the same time, while sedges flower from late spring through to autumn, depending on the species. These are important plants that help to hold the bank together, acting as 'foot soldiers' to the trees.

Where most understorey plants have been lost through clearing and grazing, selecting a vegetated site nearby with similar soil type and topography will assist in compiling a species list to use.

The Department of Environment and Conservation (formerly Department of Conservation and Land Management (DCLM)) publication *How to Create a Local Herbarium* is recommended for

landholders who wish to collect and preserve their own set of field specimens.

APPENDIX 4.

Permits required prior to commencing works in rivers

This information was provided by the Department of Water.

1. The riverbed and banks, which proposed works would affect are located in a corridor of Crown Land. In order to undertake any work on this land, permission must be sought from and provided in writing by the Department of Planning and Infrastructure (i.e. the landowner). Permission should be requested by sending a letter to the address given below, detailing the proposed works and the reasons for carrying out these works:

Department of Planning and Infrastructure

Land Asset Management Services
9th Floor, Bunbury Tower
61 Victoria Street
Bunbury WA 6230

2. Under the *Rights in Water and Irrigation Act 1914* a permit to ‘interfering with bed and banks’ must be obtained prior to undertaking work in a proclaimed waterway. This permit is applied for by completing and submitting a Form H, which can be obtained from:

Department of Water

South West Region
PO Box 261
Bunbury
WA 6231 Phone: 08 9726 4111

3. Under the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*, a permit for ‘clearing of native vegetation’ may be required for these works. It is only required if areas of native vegetation are to be cleared in addition to that affected by the proposed works (e.g. clearing required to gain access to the site or to stockpile materials). This permit is applied for by completing and submitting a Form C1, which can be obtained from:

Department of Environment and Conservation

North Boyanup Rd
Bunbury
WA 6230 Phone: 08 9725 4300

4. There are several other legal issues that may arise under the *Aboriginal Heritage Act 1972* and *Native Title Act 1993*:
 - Under the *Aboriginal Heritage Act 1972*, the Department of Indigenous Affairs should be contacted to:
 - a. Advise them of the proposed project;
 - b. Identify if your project is going to affect a registered Aboriginal site, and if so:
 - c. Request the names and contact details for the relevant Aboriginal people for consultation purposes.
 - Under the *Native Title Act 1993*, the Department of Land Administration should be contacted to determine if the project area is subject to a native title claim. If there is acclaim, the Department of Land Administration will be able to provide contact details of the claimants, as consultation with representatives from the Native Title Claimant groups will be required.

5. The Department of Water had developed a Pilot Study for anyone considering carrying out on-ground works at Aboriginal sites, available from:
<http://swcatchmentscouncil.com/uploads/File/ACEG-D-04-a-%20Mar%2008.pdf>
Under the *Aboriginal Heritage act 1972* approval must be obtained from the Minister for Indigenous Affairs for works on Aboriginal sites. These include activities such as river restoration (Bucktin 2002). Anyone carrying out river restoration activities on Aboriginal sites should also be aware of their obligation under the *Commonwealth Native Titles Act 1993* and the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*. Further information may be obtained from:

Department of Indigenous Affairs
Southern Office
129 Aberdeen Street
Albany, WA 6330 Phone: 08 9845 7300

APPENDIX 5.

Landcare project time line template

This information was provided by the Peel Harvey Catchment Council.

This is a suggested plan for landcare projects in the region. Each specific site may have different problems and challenges. Climatic variations each season may affect the timing of some actions.

August	<ul style="list-style-type: none"> • Plan your landcare project. • Apply for funding assistance
September to October	<ul style="list-style-type: none"> • Control weeds with Glyphosate spray. This early spray is important especially if couch or kikuyu are present. • Early fencing and spraying may discourage kangaroos from visiting the site and reduce damage when the seedlings are planted.
November to December	<ul style="list-style-type: none"> • Order seedlings from your preferred nursery. Early orders usually receive a discount so check the early order closing dates. • Control grasshoppers in the area by spraying or using bran baits. Check the high sandy areas for early hatchings and spray before the grasshoppers start to move.
January to February	<ul style="list-style-type: none"> • Plan your tree lines to follow the contours to prevent erosion. • Deep rip tree lines (minimum of 3 rows) to a depth of at least 50 – 70 mm. rows should be about 3 m apart to allow for vehicle access while spraying and planting. • Monitor previous year's impact for pests and weeds. • Poison rabbits and rip warrens.
March to April	<ul style="list-style-type: none"> • Disc or rotary hoe along rip lines to help break up the soil and weeds. This will ensure a better-formed mound especially on clay sites or if there are a lot of persistent weeds like couch or kikuyu. • Fence off the project area before mounding the site to restrict access, as cattle will destroy unprotected mounds. • After the first rains, mound along the rip lines in moist soils. The mounds are essential in low lying waterlogged areas and also provide a good growing environment for the seedlings in the higher areas. On deep sand sites it is better to furrow along the rip line to direct water to the roots that will improve survival rates.
May	<ul style="list-style-type: none"> • Good weed control is vital. Spray the weeds along the mounds/furrows. The use of Glyphosate and Simazine mix has been found to give better weed control (Glyphosate is a knockdown herbicide that kills on contact and Simazine is a residual chemical that will stop weeds germinating through winter and spring). • Allow at least 2 weeks before planting out seedlings.
June to July	<ul style="list-style-type: none"> • Plant seedlings 2 -3 m apart and a mix of trees and shrubs or you can make a more effective windbreak by planting one row of shrubs, then a row of tall shrubs and smaller trees and then a row of larger trees. • Monitor for pests – rabbits, kangaroos, ducks and black beetle to name a few.

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	<ul style="list-style-type: none">• Use tree guards if necessary.• Return your trays to the nurseries.
August to September	<ul style="list-style-type: none">• Monitor weed growth – spot spray may be necessary if initial weed control was not done properly.• Start planning for next year.

APPENDIX 6.

Best Management Practice (BMP) – 4.0 Water Management

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Definition

Management of important on-farm issues such as, erosion, nutrient inputs, vegetation, grazing and water sources, are all part of an integrated water quality management plan. This approach will have a greater cumulative effect than any one of these strategies used individually.

Description

The Western Australian dairy industry relies on a constant supply of fresh water for irrigation and stock watering. For this reason, production is usually located close to ground and surface water resources.

A major objective of this fact sheet is to maintain the high quality water resources that exist in most of Western Australia's dairy farming areas. These resources invariably have current or potential value for uses other than dairying.

Wetlands have nature conservation values. Dams on streams need to have 'environmental flows', that is, sufficient flowing water to maintain the natural biodiversity in the water and on the banks. Fresh groundwater aquifers may be required for potable water supplies in the future. Many estuaries are used for recreation and tourism activities and fisheries. The water quality of these resources must be maintained at levels suitable for all current and potential uses.

Pollution of water resources by agricultural nutrients and chemicals are major issues for the industry. Excessive levels of phosphorus and nitrogen can cause algal blooms in surface water during summer. Groundwater may be contaminated if management fails to prevent the downward leaching of fertilisers. In some parts of Europe and the USA, agricultural activities are regulated because groundwater aquifers have become so badly polluted by nitrates from fertilisers and by the chemical Atrazine that they are unfit for human consumption.

Whilst the impact on stream water quality and health is enormous, of equal importance is the impact of poor water quality on the health and happiness of both livestock and people in the community.

By following the water management practices discussed below, the expected environmental outcomes include:

- Water resource quality is maintained at levels acceptable for all of its beneficial existing and potential uses;
- Fertilisers and chemicals used for dairying do not pollute water resources; and,
- Stability and character of waterways are maintained and where possible enhanced.

Implementation

The first and most desirable strategy for erosion control is to prevent erosion and the subsequent transport of the sediment. Erosion management addressed sheet and rill erosion, wind erosion, stream bank erosion and erosion from construction and irrigation sites. Erosion and sediment control systems can and should be designed to protect against contaminating surface and groundwater.

Erosion management

Useful tools for erosion management:

- *Conservation*

Developing perennial cover will protect soil and water resources. Growing crops of grasses, legumes, or small grain will provide seasonal protection and soil improvement. Maintaining at least 30 percent soil surface cover by residue after planting will reduce soil erosion by water. Planting vegetation on high risk area will help reduce erosion. Growing windbreaks will reduce wind erosion.

- *Contour farming*

Farming sloping land on the contour will help stop erosion and reduce sediment and nutrient flow. This includes following established grades of terraces or diversions. Growing crops in an arrangement of strips or bands on the contour also reduces water erosion.

- *Water management structures*

Developing grassed waterways, whether natural or constructed for the stable conveyance of runoff. Planting a strip or area of vegetation for removing pollutants from runoff will reduce the amount of sediment reaching the waterways. Building grade stabilisation structures and basins to collect and store debris or sediment will reduce sediment loss. Building sediment traps and water detention basins will also reduce the effects of erosion.

Nutrient management

Nutrient management focuses on preventing nutrient loss. Efficient fertiliser use through nutrient management is important. Carefully planning nutrient applications is the key to controlling nutrient runoff.

Useful tools in nutrient management:

- *Testing*

Using soil surveys will help to identify nutrient loss sites. Soil testing for nutrients and plant leaf analysis helps identify the correct nutrient for each location and provides information of the right quantity to be applied.

- *Nutrient inputs*

Using proper timing, formulation, and application methods for nutrients will maximise utilisation and minimise loss. Split applications and banding of the nutrients, use of nitrification inhibitors and slow-release fertilisers will all help control nutrient loss. Use of gypsum instead of super phosphate as a sulphur source will help reduce the amount of phosphorous from either leaching into the soil or entering the waterways.

- *Buffer areas*

Use buffer areas around high-risk areas such as; land near surface water, areas at high risk of erosion or leaching soil and any irrigated land, to prevent nutrients entering the water table. Buffer zones should include vegetation to filter nutrients.

- *Engineered water structures*

Developing grassed waterways, whether natural or constructed will help runoff control. Building grade stabilisation structures and basins to collect and store debris or sediment will allow for nutrients to settle out. Building sediment traps and water detention basins will also reduce nutrient loss.

Vegetation management

Native vegetation intercepts rainfall and prevents rain splash erosion and also reduces gully, rill and sheet erosion by slowing runoff and binding soil together with root matter. It can take up nutrients and can be used in buffer strips for streams and surrounding nutrient intensive developments. Vegetation also acts to slow and filter sediment from runoff.

The following practices can be used:

- *Plantings*

Planting deep rooted perennials like lucerne and grasses to prevent erosion will reduce nutrient runoff. Plant local native vegetation in buffer zones surrounding intensive nutrient use to capture runoff and filter nutrient concentrations.

- *Remnant vegetation management*

Managing stands of remnant vegetation on paddocks, riparian areas and recreation and wildlife areas by biological means or by prescribed burning will ensure a vigorous stand and thereby reduce nutrient concentrations in runoff.

- *Fencing*

Fencing areas of good quality remnant vegetation and riparian zones will ensure these areas are protected from the pressures of grazing, stopping erosion and direct manure input.

Grazing management

Appropriated grazing management adjusts grazing intensity to reflect the available feed for livestock, and controls animal movements around paddocks. This ensures enough live vegetation and litter cover to protect the soil from erosion during winter and will protect riparian areas.

The focus of nutrient and sediment loss management is on the riparian zone. Erosion control from pastures and other grazing lands above wetland areas is vital. The key options to consider when planning a grazing management approach for a sensitive location, such as stream banks, wetlands, estuaries and riparian zones include:

- Limiting livestock access, best management practice is to exclude livestock. Grazing should only be considered in extreme situations;
- Providing stream crossings or hardened watering access for drinking;
- Providing alternative drinking water locations;
- Locating additional shade, if needed, away from sensitive areas;
- Reducing the physical disturbance and reduce direct input of animal waste and sediment caused by livestock.

Available information shows that:

1. aquatic habitat conditions are improved with proper livestock management;
2. pollution from livestock is decreased by reducing the amount of time spent in the stream through the provision of supplemental water; and,
3. sediment delivery is reduced through the proper use of vegetation, stream bank protection and planned grazing.

Water source management

Providing alternative water sources away from streams will help keep livestock from sensitive stream banks and riparian zones. The establishment of alternative water supplies for livestock is an essential component of sediment and nutrient loss management.

Providing water can be accomplished through the following practices.

- *Pipelines*

Piping water to watering points away from streams decreases sediment and nutrient pollution from livestock. This will prevent bank destruction with the resulting sedimentation, and will reduce animal waste directly entering the water.

- *Fencing*

Fencing acts as a barrier to livestock. Preventing livestock from being in the water or walking down the banks improves water quality. Fencing will protect wetland areas and riparian zones acting as sediment traps and filters along water channels and impoundment.

A controlled crossing or watering access point for livestock will control bank and streambed erosion.

- *Constructed wetlands*

Building dams, sediment basins, extended storage ponds or restoring existing wetlands will trap nutrients and sediments.

Land holders working together, helping each other to plan and implement strategies not only on a farm-by-farm basis but also in a whole catchment effort is the philosophical basis of the approach.

Advantages

- Guarantees suitable water supplies will be available in the future for irrigation and stock watering.
- The quality of water resources are maintained and enhanced to preserve all environmental, social, economic and recreational values.
- Healthy waterways located on private properties increases the land value.

Reference

Department of Agriculture (no date). Management strategies for nutrient and sediment loss in the Ellen Book catchment. Department of Agriculture, Western Australia.

APPENDIX 7.

Useful contacts and phone numbers

Leschenault Catchment Council

PO Box 21, Bunbury WA
Phone: (08) 9726 4111
Web: www.leschenaultcc.com

GeoCatch

72 Duchess Street, Busselton
PO Box 269, Busselton, WA 6280
Phone: (08) 9781 0111
Fax: (08) 9754 4335
Email: geocatch@environment.wa.gov.au
Web: www.geocatch.asn.au

Department of Agriculture and Food (Bunbury)

North Boyanup Road, Bunbury
Phone: (08) 9780 6100
Web: www.agric.wa.gov.au

South West Catchments Council

PO Box 5066 □ Bunbury DC WA 6230
Phone: (08) 9780 6193
Web: www.swcatchmentscouncil.com/

Department of Water (Bunbury)

35-39 McComb Road, Bunbury
Phone: (08) 9726 4111
Web: www.water.wa.gov.au

Department of Environment and Conservation (Bunbury)

North Boyanup Road, Bunbury
Phone: (08) 9725 4300
Web: www.naturebase.com.au

Ribbons of Blue (Leschenault)

c/o Department of Water
35-39 McComb Road, Bunbury
Phone: (08) 9726 4111

WA Museum

Perth Cultural Centre, James Street, Perth
Email: reception@museum.wa.gov.au
Web: www.museum.wa.gov.au

Department of Indigenous Affairs

Southern Office
129 Aberdeen Street
Albany, WA 6330
Phone: (08) 9845 7300
Web: www.dia.wa.gov.au/

