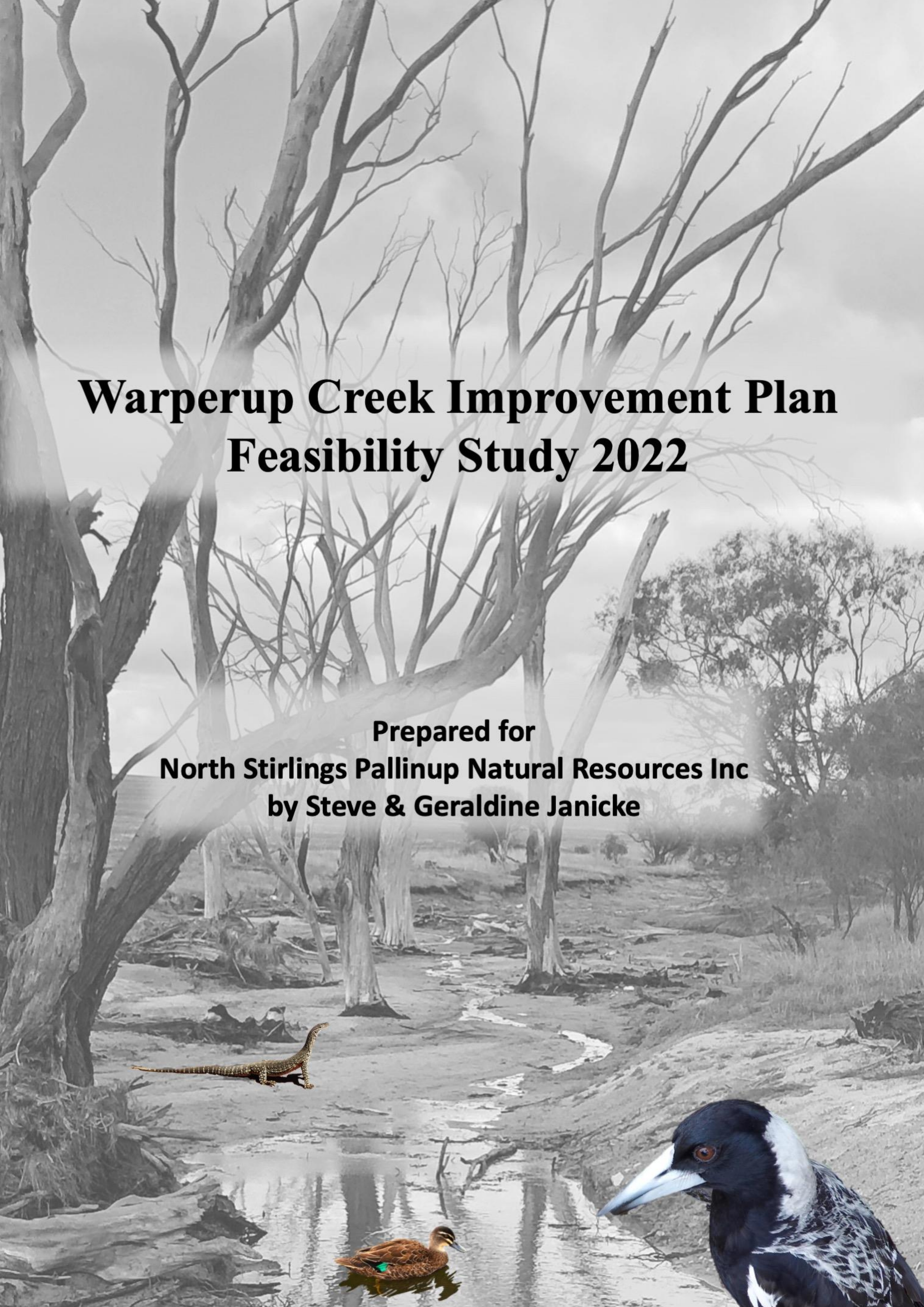

Warperup Creek Improvement Plan Feasibility Study 2022

Prepared for
North Stirlings Pallinup Natural Resources Inc
by Steve & Geraldine Janicke

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Prepared by Geraldine and Steve Janicke for North Stirlings Pallinup Natural Resources Inc
as part of the Waterways Restoration Project (CSGL19013).

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Cover graphic: S Janicke

All project information is provided in the form of a digital information package and includes final reports and associated files.

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CONTENTS

PREFACE

This feasibility study concerns the future condition of waterways within the Warperup Creek catchment (here referred to as 'the Warperup'). The aim of the study is to determine what would be involved in designing and implementing a long-term, waterway management plan for the entire catchment waterways network. The primary goal discussed in this study is 'improvement in waterway condition'. The definition of what improvement means is discussed, and it must of course include the values people attach to a resource. What we value we will work to protect, preserve and if necessary, improve. The authors consider that a strategic approach to waterway management which is prepared by the catchment community rather than for them, would therefore achieve more durable future outcomes for the ecological state of the waterways than taking a piecemeal approach. The study provides information to assist NSPNR and community members to determine a way forward.

A community owned management plan would involve seeking agreement between landholders with the assistance of natural resource management professionals to achieve satisfactory environmental outcomes along some 1064 kilometres of natural channels. Management of the waterways is to complement agricultural enterprises where possible and avoid imposing impractical constraints. This can only be achieved by developing an agreed approach to address a range of challenging practical issues with respect to managing water in a large catchment. The economics of actively managing riparian areas is perhaps the most common limiting factor for achieving beneficial outcomes, but a long-term community vision to do so is the most important ingredient.

A 'whole of landscape' management approach began to emerge across Australia in the 1980s and water catchments offered a logical division of regional areas into distinct physical units. Concerns about the future of the natural environment began to increase despite being lower on the list of economic priorities. Alan Pilgrim, Professor of Geography at Curtin University noted:

> *The term 'Landcare' did not appear until 1986 when it was introduced by Joan Kirner, then Minister for Conservation in the Victorian State Government. In the early 1980s, farmers and other land managers were organising themselves into groups to address the challenges of land degradation and the subsequent loss of agricultural and pastoral land.* [1]

Pilgrim noted that at the time, one of the directors of the WA Department of Agriculture, had described Landcare as 'little more than gardening'. This derogatory attitude reflected a purely exploitative view of the landscape. The natural values of the landscape were in one sense, considered obstacles to be conquered, tamed, or removed. Government was likewise focused on generating and controlling economic development with little comprehension of the forces of nature which, if not respected, will eventually undo what people desire to achieve.

The appreciation of natural features only as a source of raw materials made sources of fresh potable water a primary consideration. In agricultural circles rivers and creeks were often, and still are to some extent, considered merely as drains which otherwise have little connection to the profitability of farming enterprises unless flowing with clear, drinkable water. This was particularly true of saline waterways. However, a growing number of landholders began to place greater value on aspects of the natural environment which had at first seemed to be hindrances to successful farming. The idea of 'liveability' in the sense of enjoyment and preservation of aspects of the natural landscape, has certainly increased in importance.

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[1] 1 Alan Pilgrim. (2015) *Green Gems, Stories of the Alcoa Landcare Project 1989-2003*.

Land Conservation District Councils (LCDCs) were formed across the South Coast region and North Stirlings Pallinup Natural Resources Inc. is a subsequent development of these earlier initiatives. These groups sought a holistic approach to land management.

Landcare management approaches were, and are, largely considered the prerogative of individual landholders. As with many farming issues which require a broad community effort, such as fire and feral animal control, adequate environmental management also requires a coordinated approach, and this is especially true for waterways that intersect every part of a catchment. However, there is a diversity of opinions regarding what is adequate. This is a persistent topic of discussion and is often based on the assumption that the triple bottom line of economic, social, and environmental issues are disconnected aspects of land use. This perspective tends to slow down or even stall environmental initiatives.

The future condition of the waterways of the Warperup sub-catchment of the Pallinup River, and the future of agricultural enterprises will be determined in this multi-dimensional environment. Although agriculture is the primary focus of rural communities, many landholders appreciate that this does not exclude care and maintenance of the remaining natural values of the landscape. These values are well represented in waterways and many landholders in the Warperup have invested their energy and finances to maintain these values and where possible to enhance them.

INTRODUCTION

The question posed for this study was: can the Warperup catchment community go beyond what has already been achieved to further improve the ecological condition of the catchment waterways? A reasonable answer will require a clearer and realistic definition of what 'improvement' might mean.

A strategic waterways improvement plan at a catchment scale requires:

- various and challenging environmental degradation problems to be resolved,
- willing involvement of the larger part of the catchment community,
- a cultural shift in the values assigned to the creek systems,
- achieving a consensus on what effective stream management will mean in the long term,
- having a clear understanding of the form of the natural drainage network and the environmental processes that are taking place.

Three future waterway management approaches are possible:

- **APPROACH A;** What can be done has largely been done and the waterways can be left to fend for themselves perhaps with a bit of maintenance here and there.
- **APPROACH B;** Rehabilitation efforts continue in the same vein as for previous projects with the aim of filling in some of the gaps as opportunities arise.
- **APPROACH C;** Strategic ecological goals and new management methods are developed to improve the entire waterways network to achieve optimum condition.

To weigh up these approaches several supporting investigations were carried out and these are outlined in supplementary documents which should be read in conjunction with this report. The supplements are:

- Supplement 1 - Warperup Creek Landholder Survey 2022
- Supplement 2 - Warperup Creek Literature Review 2022
- Supplement 3 - Warperup Creek Water Condition Monitoring Framework
- Supplement 4 - Warperup Creek Water Condition Monitoring and Assessment Report 2022
- Supplement 5 – Warperup Creek Photo Audit

BACKGROUND

Numerous localised waterways rehabilitation projects have been undertaken in the Pallinup River catchment, including the Warperup sub-catchment. The main tactical approach has been to fence and revegetate the verges of creeks and to control if not exclude stock access and to enhance plant biodiversity. Various site works would hopefully connect, like jig-saw puzzle pieces, and gradually reverse the fragmentation of natural bush areas to achieve a more acceptable balance between agricultural enterprises and the retention of natural waterway values. An important question arising from the project work is: "has the effort been successful?" The definition for 'successful' has also remained unclear and is largely viewed in terms of kilometres of fringing streamline fenced and the number of hectares revegetated. These numbers are what distant funding bodies have tended to use to justify the funding of projects. To answer the question in ecological terms requires an understanding of the form and condition of the waterways, what they were, what they have become and importantly, what they might or will become.

Streamline revegetation projects tend to be undertaken on the cleared fringes of the riparian zone where there is easy access for machinery for weed control, ripping, mounding, and planting or scalping and direct seeding. The aim of the revegetation is to create a 'buffer' between the paddock and the floodway or to stabilise less productive soils in open flood prone areas. Regaining some level of agricultural productivity in denuded areas is also a common goal. Access into the uneven ground of the inner areas of the riparian zone is much more difficult and the effectiveness of fringing buffers to stabilise and enhance the entire floodway is unclear. For this reason, some have felt that planting a couple of lines of trees along the edges of streams is largely 'cosmetic'.

Ella Maesepp, a Katanning Landcare Officer[2] made a pertinent statement:

> *"The environment is a very, very interconnected thing. If you're planting a tree, you are helping (deal with) salinity, you're helping climate change, you're helping erosion, you're helping biodiversity - everything with that one tree".*

The message for waterways is that improvements will be incremental, a bit at a time over many decades. If biodiversity is considered an important feature of the landscape, then planting a native tree or shrub where one has been lost is a biodiversity improvement. On that basis it can be confidently argued that revegetation of stream verges has been valuable and effective in various ways. It has increased biodiversity and created a greater diversity of habitat for other plants and animals. These efforts are moving stream and river management in the right direction, but can more be achieved? The complexity of riparian systems means that rehabilitating floodway verges is important but achieving optimum improvements in waterway condition will involve the entire riparian zone and this is intimately connected to the wider landscape.

Project aims

The Warperup feasibility study commenced in 2020 and involved completing the four tasks listed below. This information would help determine what would be required for future environmental improvements to the waterways of the Warperup and to get a better idea of what may be achievable during the coming decades. The preliminary project tasks were:

- A questionnaire for landholders to share their perspectives of the value or otherwise of the catchment creeks in relation to their farming enterprise.

[2] Southerly magazine, Issue 37, December 2021: Interview with Ella Maesepp (Katanning Landcare)

- A desktop aerial image audit of the waterways in the catchment using a GIS (Graphic Information System) mapping technology.
- The establishment of ten reference reaches on the Warperup waterways to better define the character of the riparian system and to provide a starting point for long-term monitoring of waterway condition.
- A literature review to determine what information about the waterways was or was not available.

Justification

In 2017 a condition assessment of the Middle reaches of the Pallinup River was undertaken and fortuitously followed a major flood earlier in the year. The field assessment revealed that although the river corridor remained degraded there were signs it had reached a degree of stability and resilience to floods when compared with an earlier assessment in 2001. New erosion hot spots were noted and these suggested that specific river reaches were still vulnerable but would benefit from local rehabilitation work. The conclusion was that the investment in rehabilitation works up to that time had improved the riparian environment, however, sediment input from tributaries appeared significant and excessive and this compromised the physical structure of the river and the water quality.

Warperup Creek appeared to discharge a substantial amount of sediment during the 2017 flood, suggesting that mobilisation of existing sediment in the floodway, ongoing bank erosion or both, were still active processes. Figure 1 below shows large sediment slugs in the lower reaches of Warperup Creek. The differences over a five-year period give some idea of the active conditions in the floodway. The fragmented nature of the riparian vegetation, which is a common and obvious feature of the catchment waterways, can also be seen.

Figure 1: Google Earth imagery showing the movement of large sediment slugs along a lower reach of Warperup Creek in 2018 and 2013.

Greater stabilisation of the waterways to reduce erosion and limit further build-up of sediment in the floodway allows river pools to be reinstated and deepened during floods. This is an important goal for improving the environmental health of the system.

Defining the Waterways

The Warperup catchment occupies nearly 20% of the Pallinup River catchment area and therefore has a significant influence on the environmental condition of the river and eventually Beaufort Inlet at the ocean end of the river. To begin to understand what improvements may be feasible for the Warperup and hence the Pallinup River, it is useful to gain an understanding of the broadscale features of the drainage network and what these may mean at the farm scale. From a hydrological standpoint, Warperup Creek is not simply the main named channel connecting the towns of Borden and Ongerup but consists of the entire network of channels small, medium, and large which collect rainfall runoff and groundwater discharge from most parts of the catchment.

Sub-catchments

Warperup Creek has a catchment area of approximately 920Km^2 and can be divided into five sub-catchments (See Figure 1):

- Upper Warperup
- Ongerup including Ongerup Creek and several other tributaries with unknown names.
- Peerup including the Peerup Meenup and Kyarup Creek
- Peedillup
- Coromup including the Coromup, Long, Allen, Maileeup and Niliamongup Creeks

Coromup is the largest sub-catchment covering 32% of the total catchment area and includes the lower reaches of Warperup Creek. The other sub-catchments range from 14 to 18% of the total catchment area. For more details see Table 1.

The total length of streamlines is about 1064 kilometres and indicates the full extent of riparian areas involved across the catchment. That length of channel seems a daunting rehabilitation challenge. Fortunately, not every stream requires rehabilitation effort or a change in management practice. For example, a significant proportion of the smaller channels may already be sufficiently stabilised by pasture grasses or are cropped or have been revegetated and some stream reaches are in reasonable condition.

Table 1: Catchment and sub-catchment areas and streamline lengths.

Catchment	Area (Km^2)	% Warperup Catchment	Length of stream lines (Kms)	% Warperup Catchment
Upper Warperup sub-catchment	167	18%	89	8%
Ongerup sub-catchment	174	19%	226	21%
Peerup sub-catchment	125	14%	154	15%
Peedillup sub-catchment	160	17%	175	16%
Coromup, Long, Allen sub-catchment	295	32%	419	39%
Whole Warperup Catchment	920 Km^2	100%	1064 Kms	100%
Whole Pallinup Catchment	4800 Km^2			

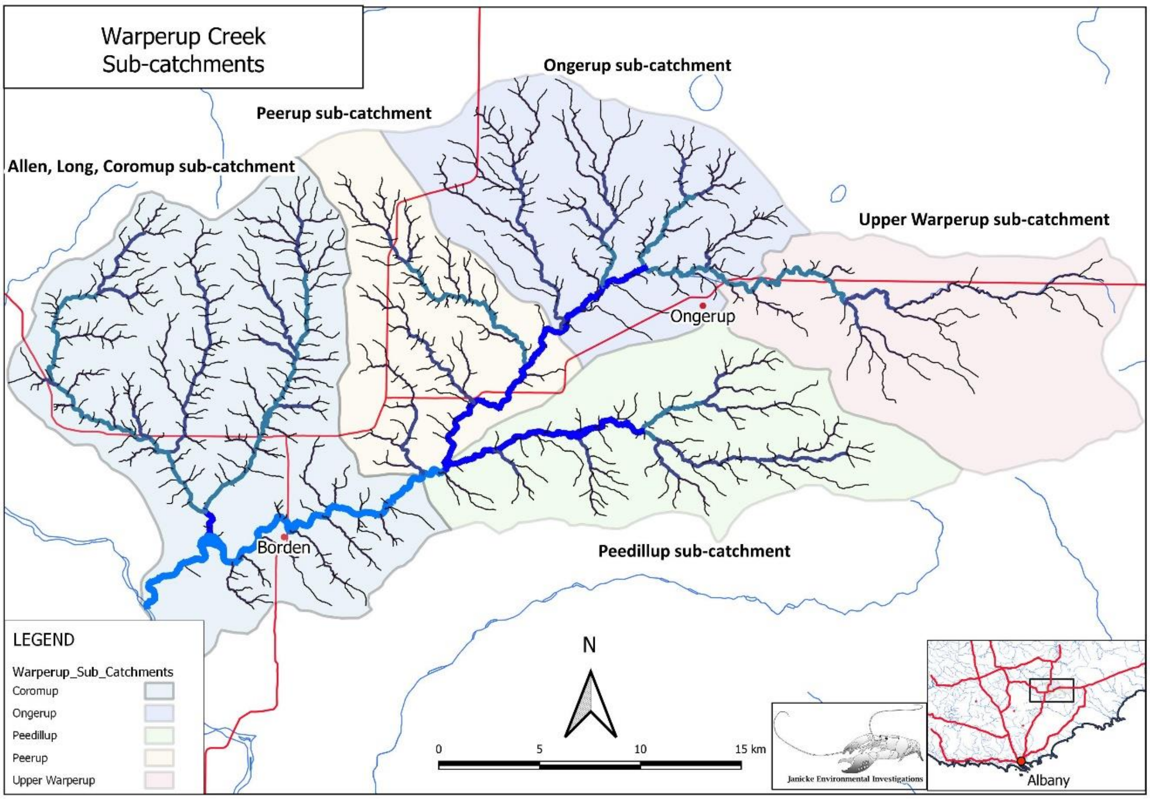


Figure 2: Warperup Creek sub-catchments and all the network of channels.

Stream bed slope

Graphical Information System (GIS) interpretation of aerial imagery yielded the data for Table 2 and Figure 3, which shows the lengthwise stream bed altitude profile of Warperup, Ongerup, Peedillup and Coromup Creeks. The erosive power of floods is in large part dependent on the slope of the channel as well as the size of the flood discharge and the profiles provide a crude picture of where the higher and lower power reaches are.

Warperup Creek descends from approximately 330 to 190 meters above sea level from east of Ongerup to its confluence with the Pallinup and is approximately 72 kilometres in length. The graph reveals that the bed slope of the main trunk is surprisingly uniform along its entire length, with relatively minor drops along the way. The average bed slope is low at slightly less than two metres per kilometre. This suggests that given relatively consistent storm rainfall across the entire catchment, the power of floods at any reach is largely dependent on the area of the catchment upstream.

Localised and intense storm cells in the catchment will have different impacts according to bed slope, the general ‘openness’ of the floodway, the rate at which rainfall runs off the landscape into the channels and the integrity of floodway soils. The power of floods will naturally increase in the downstream direction.

Table 2: Length, fall and slope of Warperup Creek and three main tributaries.

Waterway	Length (Kms)	Fall (metres)	Average slope (meters / Km)
Warperup main trunk	72	136	1.9
Ongerup Creek	15.4	86	5.6
Peedillup Creek	24.9	90	3.6
Coromup Creek	21.7	144	6.6

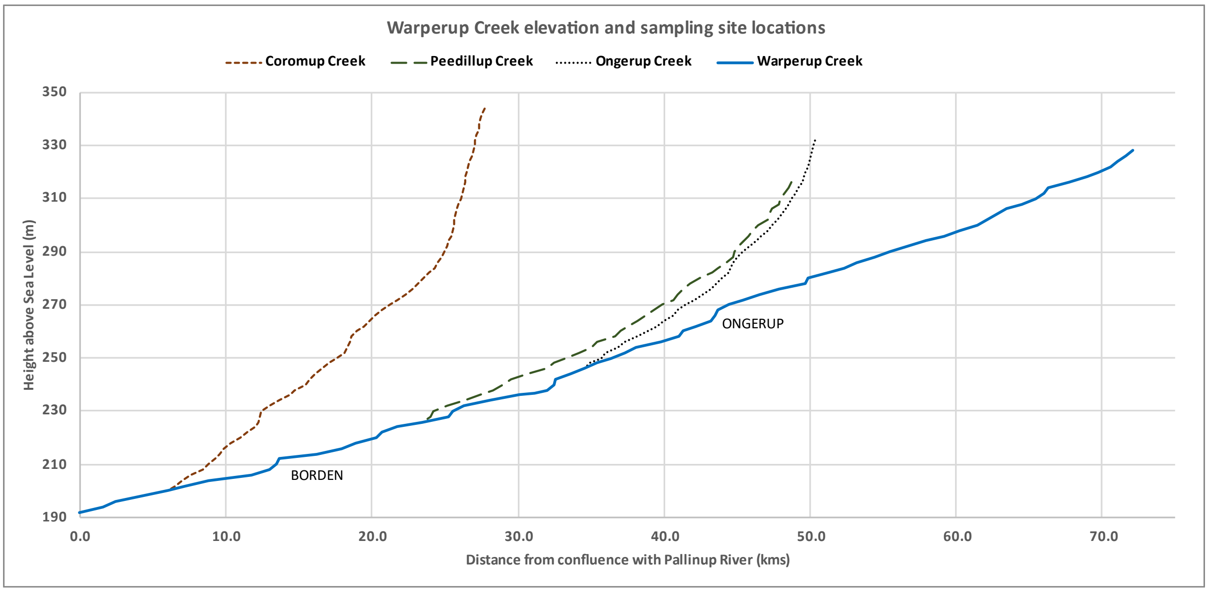


Figure 3: Lengthways bed slope of the Warperup Creek main trunk and selected tributaries. Note that the vertical axis has been greatly exaggerated (approximately 200 to 1) with respect to horizontal distance.

Coromup Creek descends from approximately 344 to 200 metres above sea level, over 21.7 kilometres, to its confluence with the main trunk of Warperup Creek. Its bed slope is the highest of the three tributaries examined with an average slope of 6.6 metres per kilometre although the upper reaches are steeper. This suggests that it is particularly dynamic during periods of high rainfall. The lower half of the catchment is likely to be more strongly impacted by sediment contributions from the tributary, however, the extent of contribution also depends on the soil type and the amount of bedrock in the channel.

Strahler Stream order

To understand the scale of the natural drainage network it is useful to introduce the idea of *stream order*. Several schemes have been developed by hydrologists to define the distribution of streams in catchments and the definition used in this study is known as Strahler stream order.

When rain falling on the ground is sufficient to start flowing across the surface it will gradually accumulate into rivulets which feed into permanent eroded pathways. These are the shallow swales and small established gullies commonly seen in paddocks and bushland and are called *first order* streams.

Where two first order streams meet, the downstream channel is called a *second order* stream. Where two second order streams meet, the downstream channel is called a *third order* stream, and so on. Figure 4 below illustrates this downstream progression.

An important part of the study has been to assess the number and extent of the various stream orders in the Warperup, since the management approach for specific reaches of the waterways can differ according to its stream order.

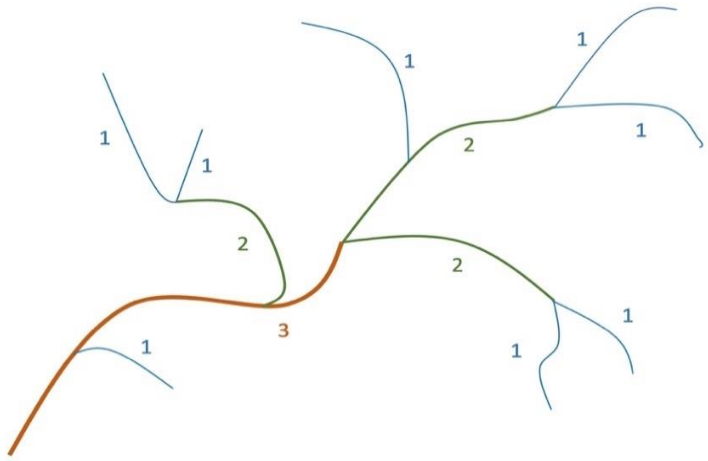


Figure 4: Stream order progression

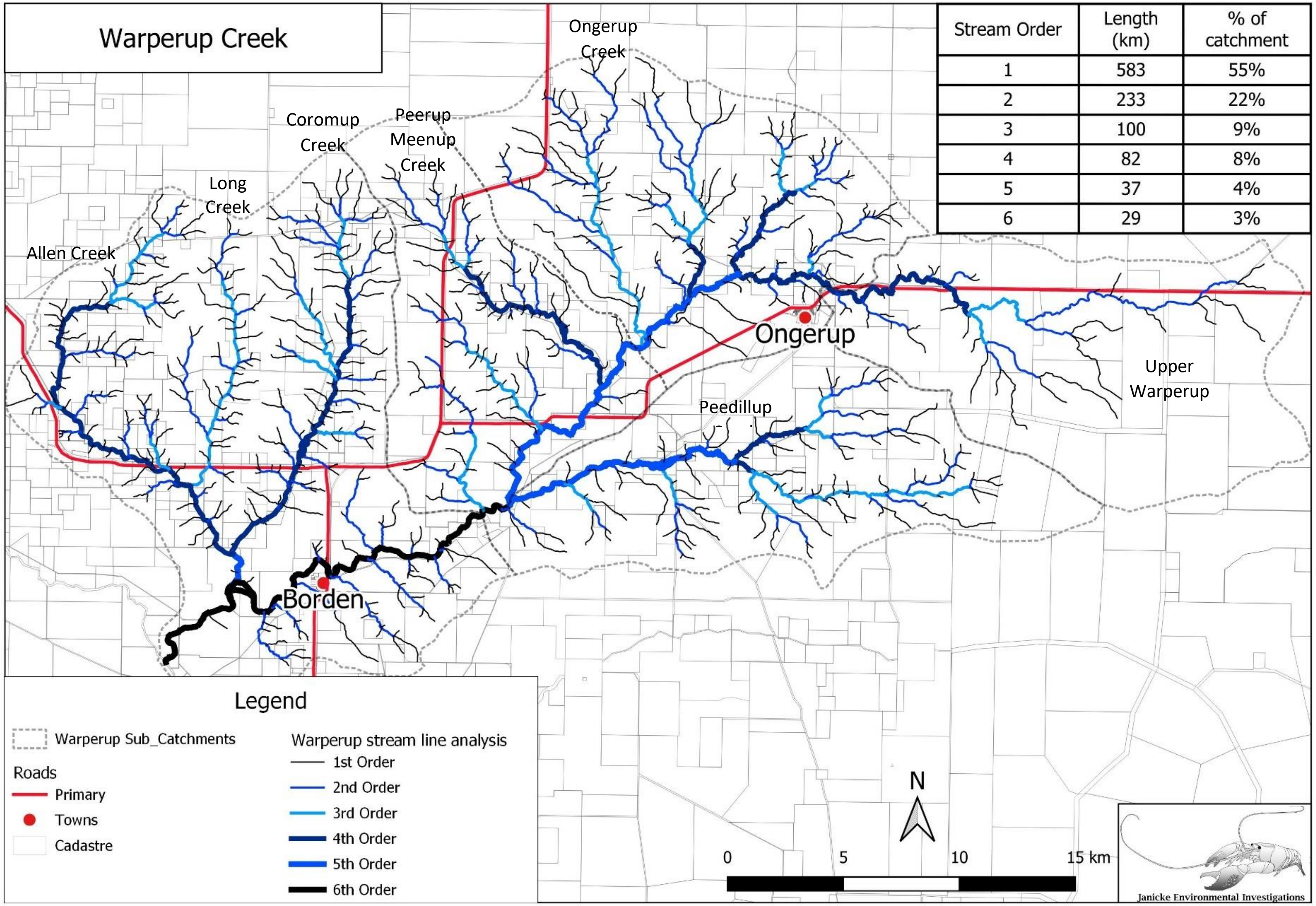
Riparian zones can be considered as distinct land management units, and stream order defines specific types of riparian zone generally associated with the size of the channel and/or its position in the landscape. In the past, rehabilitation works have largely been undertaken in relative isolation on a property-by-property basis. Information about each stream order enables current and proposed stream rehabilitation works to be put into a catchment-wide perspective.

Locating rehabilitation works with respect to stream order provides a way to gauge the environmental outcomes of enhancement projects at the catchment scale.

Figure 5, is a map of the location of the stream network of small (1^{st} and 2^{nd} order) channels feeding into medium (3^{rd} and 4^{th} order) channels, with these in turn feeding into the main channel of Warperup Creek (5^{th} and 6^{th} order channels).

The results of the aerial assessment show that approximately 77% of the catchment streams consist of short first and second order streams and Warperup Creek main channel is only 6% of the total waterway length. Although a single first or second order stream may not contribute much to the system by itself, taken all together these streams play a major role in the conditions of the Warperup.

It can be noted that the rate at which storm runoff is accumulated in the many first and second order streams and shunted downstream, will have a major influence on flood intensity at the lower end of the catchment.



Stream Order	Length (km)	% of catchment
1	583	55%
2	233	22%
3	100	9%
4	82	8%
5	37	4%
6	29	3%

Figure 5: Warperup Creek catchment including all the small and medium channels that feed into the main channel.

SECTION 1: WHAT MIGHT WATERWAY IMPROVEMENTS LOOK LIKE?

Is any improvement better than none?

Waterway Condition or Water Quality Improvement?

In this study the term *waterway condition* is used rather than simply focusing on *water quality*. *Waterway condition* can be thought of as taking in the spectrum of attributes that make up the riparian zone. Water quality is included and typically refers to salt content, acidity-alkalinity, nutrient concentrations, and other chemical and physical attributes. Water managers consider freshwater resources in terms of the quantities of usable water available and its chemical and physical composition. The key question has been, is the water usable? This poses a dilemma for the values attributed to South Coast catchments since the rivers and many wetlands are naturally saline to varying degrees. There are no major dams on South Coast rivers and therefore, this has provided little incentive to protect the catchment water quality. For this reason, water quality in this study is considered as one of four components which provide a broader ecological definition of waterway condition.

The four broad waterway condition components relevant to the state of Warperup streams are:

- Floodway and channel structure (stability and habitat)
- Aquatic biodiversity
- Riparian vegetation diversity
- Water quality

These components interact in a dynamic way and as each is constantly changing, the others are influenced in various ways. There are of course various other components which define riparian condition, and all the interactions can be considered *as internal pressures* acting within the riparian zone.

External pressures

There are a host of external pressures which can modify the four components of waterway condition and trigger changes. These include, storm events, soil tillage, drains, fertiliser runoff, stock, feral animals, weeds, roads, and so on. Therefore, improving waterway condition not only involves enhancing the internal qualities of the waterways but also managing the external pressures where the paddock meets the riparian zone. Therefore, revegetated verges of streams are often referred to as *buffers*.

The phrase 'degraded environment' refers to processes that lead to a simplification of the physical character of the waterway and a decrease or loss of the original biodiversity. The character of Warperup Creek prior to land clearing, commenced changing as soon as free-range stock were introduced during the nineteenth century. Early photographs suggest that much of the native ground cover vegetation and shrubs were soon lost.

River rehabilitation?

It is widely accepted that land clearing dramatically altered the hydrological functioning of the landscape and the waterways suffered collateral damage. Vegetation acts as a control on the infiltration of rainfall into the ground, surface water movement and storage of water in the landscape. The result has been greater bank erosion, an increase in salt and sand in the streams, fragmentation of native vegetation communities, an increase in weeds, feral pests and pathogens and the associated decrease in biodiversity.

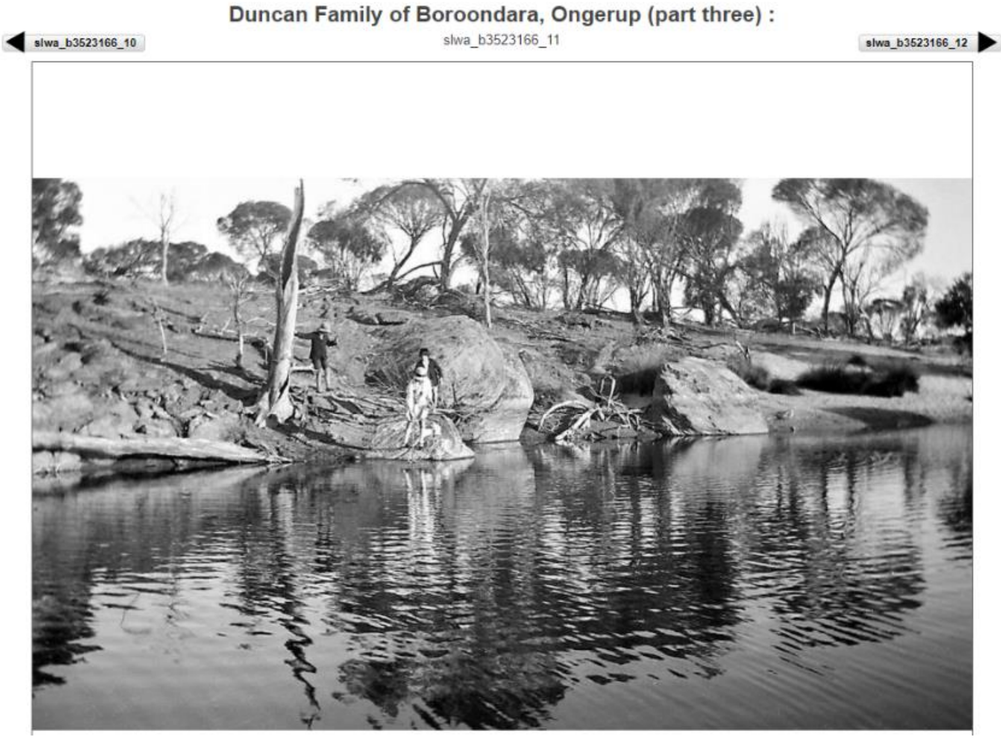


Figure 6: A photo taken in 1930s[3] at site PAL507 on Warperup Creek showing the bank denuded by stock access.

Several photographs of farming family activities, farm views and floods from the 1930s through to the 1950s were located during the literature review (i.e., Figure 6 above). These have provided some idea of the condition of the Warperup waterways in those times.

The presence of bare banks, washouts and sediment plumes imply that the condition of the floodway had already been significantly impacted by stock denuding the bed and banks and increased storm runoff. Current observations suggest there has been some recovery in areas, and this may reflect changing land management practices, particularly the transition to cropping and reduced grazing pressure. The waterways appear to have entered a new equilibrium phase.

The term *river restoration* is often used to describe waterway conservation efforts, but the new remodelled waterway systems cannot be returned to what they were in the past. For this reason, the term *rehabilitation* is more appropriate, and it implies the desirable goals are to first, to foster greater floodway stability and secondly to recreate an ecologically diverse riparian environment.

APPENDIX 1 is an informative insight into the character of Warperup Creek by Michael Wright and Ken Newby who farmed in the catchment in the 1990s to 2000s. The works they undertook represented innovative approaches to rehabilitation for the time and highlight common issues relevant to progressing rehabilitation at a catchment scale.

River structure

River studies in Australia indicate that major structural changes to a river or stream tended to occur in the three, or four decades, following land clearing. The removal of native vegetation across a catchment increases rainfall runoff intensity and frequency and storm events lead to deepening and widening of natural channels to accommodate the changed pattern of runoff.

[3] Accessed from State Library of Western Australia, https://purl.slwa.wa.gov.au/slwa_b3523166_11

This period is usually long enough for a catchment to experience one or more powerful floods which can drastically reshape the floodway within a short space of time. The results are enlarging channels, scouring of floodplains, creating new flow pathways, and mobilising sediment that fills in the river pools. The 'hard' ground and fragile duplex soils of the Warperup catchment aided storm runoff in the process.

Storm events in the early decades of the twentieth century and through to 1955 occurred in the post clearing era and were largely responsible for the massive changes seen in the Pallinup River and its tributaries. Subsequent large floods (1982, 2017 etc.) have maintained or extended the changes. The Warperup waterways have undergone similar structural changes, and these have established its current form and condition. Field observations suggest that degrading processes still appear to be active with intermittent larger floods aggravating structural weaknesses, especially in denuded sections of channel. Banks and adjacent flats experience erosion episodes and feed more sediment into the system.

New channels tend to form where previously only shallow, vegetated swales may have existed. Landholders endeavour to speed up the natural process by digging drains along the creek lines. However, the form of these excavated channels is dictated by the excavating machinery used and does not reflect how the channel would naturally develop. The result is increased bed and bank erosion and the soil, once excavated, can overwhelm downstream areas, filling pools with sediment and impacting the water condition and quality.

The key factors defining waterway structure and condition, apply worldwide in a general sense, but regional and local variations in climate, vegetation type and geological formations give each waterway an individual character. For this reason, the various condition factors, and opportunities for ecological improvement of riparian areas have been based on GIS aerial image interpretation and the monitoring of ten selected reaches. These have provided an environmental 'character reference' for the Warperup catchment.

Waterway terms

A creek or river can be broadly thought of as consisting of various zones and condition improvement will mean different things for each of these.

Figure 7 shows the various zones relevant to Warperup waterways. The more obvious features are common to streams in gently undulating landscapes along the South Coast. Factors such as bed-slope and sediment loads are key factors determining whether reaches are predominantly eroding or accumulating sediment.

Common stream improvement practice tends to focus on revegetating the floodway verge, but to date little attention has been given to the inner riparian areas and the 'active channel'.

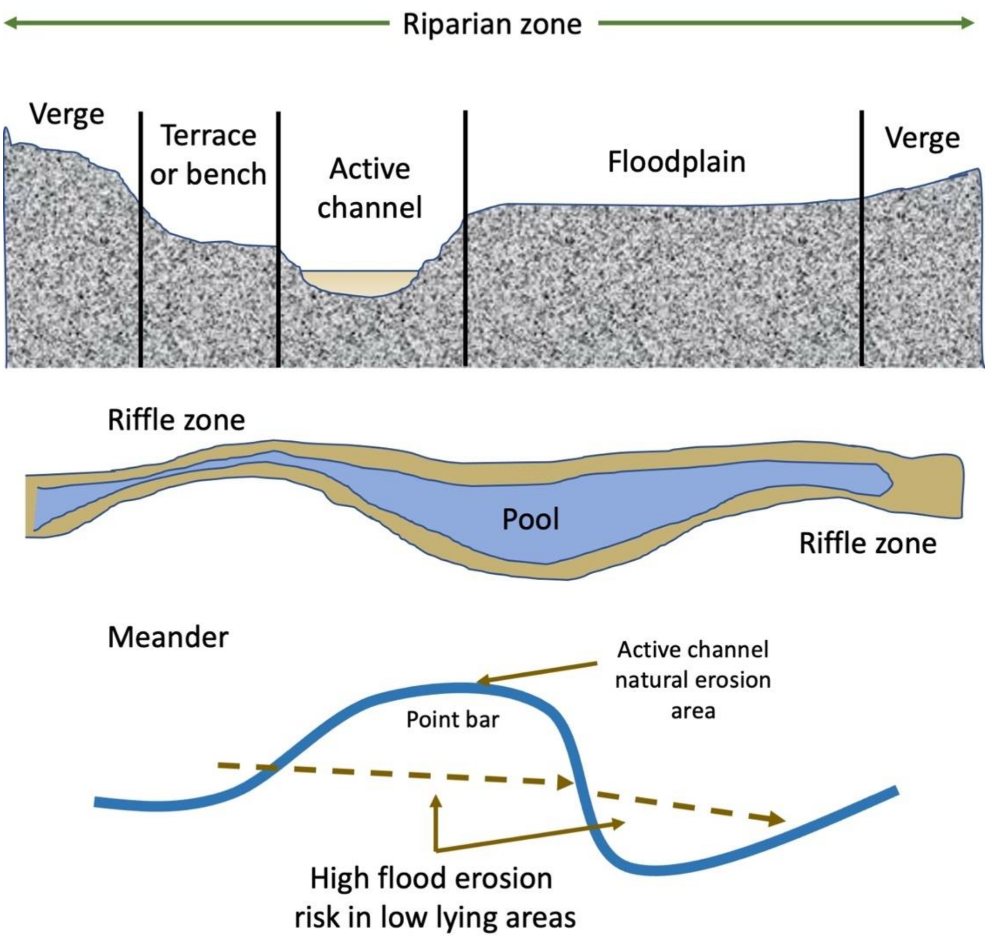


Figure 7: Typical features to be considered if improvements are to be made to the waterways.

The features are described as follows:

- The *riparian zone*: the interface between land and a river or stream.
- The *active channel*: The distinctive channel that carries stream flow for most of the time and includes pools, runs and riffle areas. Annual discharge in the active channel resists encroachment by vegetation. The active channel is sometimes called the *bank full channel,* and this typically carries the highest flows occurring on average once every 18 months.
- The *floodplain*: The area of the riparian zone intermittently inundated by floodwaters. (Also referred to as the *floodway terrace*.
- The *floodway verge*: The outer edge of the riparian zone which is rarely inundated.
- *Terrace* or *bench*: A flat area adjacent to the active channel, generally formed and maintained by moderate to large floods which can overtop the active channel banks.
- *Riffle zone:* The shallow areas at the top and bottom ends of pools, often rocky or with vegetation in the bed of the stream.
- *Run:* a section of channel that is not a pool but more canal-like and where water flows deeper and stronger.
- *Meander:* A bend in the active channel or floodway. The most active erosion takes place on the outside of the bend and conversely, sediment tends to be deposited on the inside of the bend forming what is called a *point bar*.

The river pools are an important feature of our waterways, and they are the chief aquatic habitat in low flow and no flow conditions common to South Coast River systems. The physical and biological condition of the pools provides a way to assess improvements in the aquatic environment.

The Warperup waterways are generally characterised by the following structures:

- Distinct active channels with low but steep sided banks.
- Narrow flood terraces flanking the active channel.
- Instream Paperbark patches acting as riffles defining the upper and lower ends of pools.
- Wider flood flats.
- Long, narrow pools in higher order streams
- Frequent granite bedrock outcrops and occasional short sections of rapids.
- Fringing Sheoaks, Yates, Paperbarks, Jam, Samphire and Sedges.
- Shifting sand slugs being frequently rearranged in river pools.
- Dead wood, instream and higher in the floodway.
- Little or no flow for parts of the year.
- Occasional powerful floods.

Figure 8: Typical features of the main channel of Warperup Creek are a relatively narrow floodway.

Other less desirable features include:

- Extensive weed cover.
- Exposed and unstable inner and outer banks of bends.
- Fragmented fringing vegetation.
- Filamentous algae and waters clouded by microscopic algal growth.
- Road crossings that act as sediment dams upstream and promote bed and bank scouring downstream.

Figure 9: Warperup Creek floodway showing extensive sand plumes, eroded banks, fragmented tree and shrub cover with grasses and Samphire dominating.

> *The creek floods about once every four years and a bank in a bend in the creek has eroded back about five to six metres in the last 12 years. Bank erosion is also occurring to a lesser degree at other sites along the creek – Michael Wright, former farmer.*

Vegetation assessment

The ecological structure of riparian ecosystems is extremely complex down to the microscopic level and a full assessment would require more detailed investigations. However, the condition of a waterway can be categorised by the presence or absence of various relatively obvious features, and these provide useful indicators of environmental values and can help define what condition improvement means in practice.

The Pen-Scott riparian condition rating has been found to be a simple but useful definition of the quality of South-West waterways, from pristine or A grade to degraded, weedy ditches or D grade. Figure 10 is a diagrammatic description of the Pen-Scott rating. A more detailed description is given in Appendix 3 of "*Supplement 4 - Warperup Creek Water Condition Monitoring Results 2020-2022*". It has been argued that the Pen-Scott rating is too general, and it is true from a rigorous scientific perspective, but it is useful for strategic planning because it is a 'whole of waterway' assessment and provides guidance for prioritising rehabilitation works. Progressive degradation of a waterway is represented by a change in condition from A to B, to C, to D grade. The goal of rehabilitation is to halt and, if possible, reverse this progression at least in part.

We encountered no reach in the Warperup catchment which might be reasonably labelled A Grade, although some localised reaches had qualities which reasonably rate in the B Grade category. C to D Grade appeared most common in many stream orders.

What Would Waterway Condition Improvement Look Like?

Waterway condition improvements can be thought of as consisting of two interdependent characteristics, improving the structural stability of the floodway, and increasing the natural biodiversity.

The ease or difficulty of management will depend on the size of the waterway reaches, whether relatively narrow and simple or wide and complex. For example, revegetation of the riparian verge may be quite adequate to improve the entire riparian width for narrow 1st and 2nd order streams with small channels but be less effective for broad floodways in higher order stream reaches.

> Several of the reference reaches which have B grade characteristics can provide benchmarks to help gauge the progress and quality of rehabilitation works in other more degraded streams.

The goal of moving from C, or D, to B Grade is feasible (see Figure 10) in terms of stream stability but improvements will have different structural and biodiversity characteristic from pre-clearing times. The 'new' riparian ecosystem will be one that has reached a level of sustainability with respect to the changed hydrological form of the catchment. However, the impacts of changing climatic conditions over future decades adds an unpredictable ingredient.

Figure 10 shows that as the diversity and density of riparian vegetation decreases the channel becomes more susceptible to erosion and if unchecked the result will be a shallow weed infested ditch (D grade). These are common in the Warperup catchment. The curved arrow in Figure 10 illustrates the process of degradation that has occurred during the 20th century and is still occurring in some stream reaches.

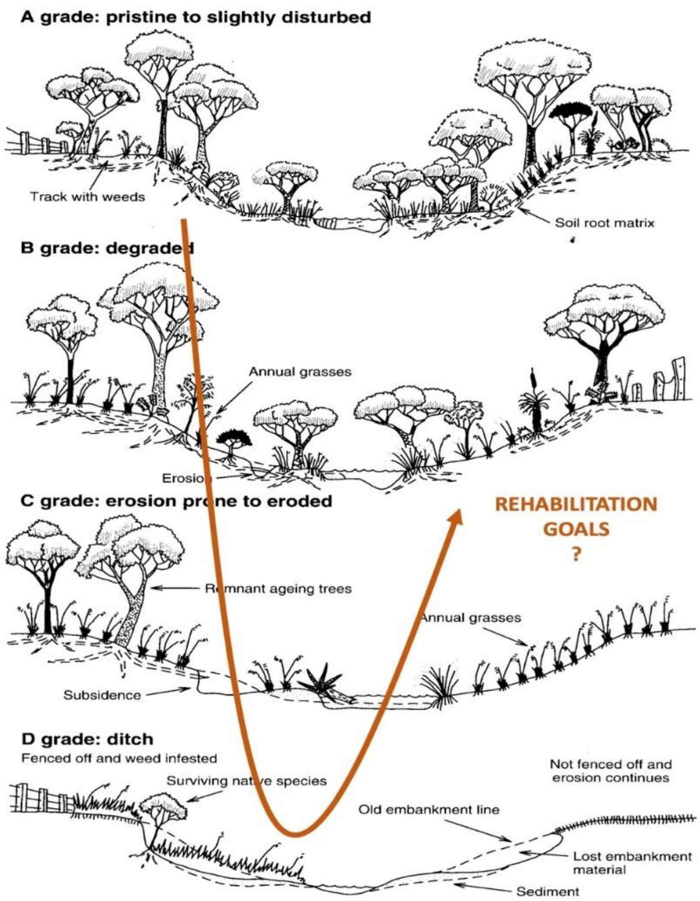


Figure 10: The Pen-Scott rating showing the stages of degradation of a pristine section of stream channel to a ditch. What is the rehabilitation goal?

The upward trending arrow pictures the rehabilitation goal, at least to B grade. As suggested, goals for condition improvement can in part be defined by considering the physical characteristics of B grade reaches in the catchment. While structural improvements to the active channel and flood terraces can be made, biodiversity improvements will need to be understood differently. Native plants will have to coexist with weeds and native fauna will have to coexist with feral pests.

The Pen-Scott rating suggests that improving waterway condition for degraded reaches, i.e., C and D grade, will involve revegetating riparian verges, which is the current project emphasis, but other improvements to consider are:

- Increasing tree density within the floodway.
- Increasing shrub and sedge species and density in riparian areas that are harder to access.
- Establishing species which can compete with weeds.
- Stabilising the slopes and terraces adjacent to the active channel.
- Using local sedges to stabilise the banks of the active channel.
- Decreasing sediment input from the catchment upstream.
- Managing in-stream dead wood.
- Developing revegetation methods which avoid disturbing floodway soils.
- Using common tree species, namely Paperbark and Sheoak to stabilise erosion scours.
- Considering options for dealing with large tracts of sediment in active channels and river pools.

Note that undertaking improvements may require some experimentation to develop techniques suitable for the Warperup catchment.

Principles for Managing South Coast Waterways

The scientific literature on riparian ecosystems involves many academic disciplines because of their complexity. There is a tendency to promote a theoretical or an ideological approach to waterway management. Scientific research does provide a better understanding of the hydrological and biological processes occurring in a catchment, but achieving desirable goals is a matter of practice not just theory. From a management perspective the critical questions are:

- What can be done,
- where can it be done,
- how can it be done,
- who pays and,
- how can value for cost and effort be assessed?

Waterway investigations on the South Coast over the past thirty years have improved understanding of the ecological processes which define the salty catchments of the South Coast. As knowledge of these has increased, there has also been a growing awareness that community 'liveability' and viability are not purely a matter of agricultural economics, but also involve the other two ingredients of the triple bottom line, the social and environmental dimensions. This has suggested guiding principles for developing natural resource management programs and projects. These principles indicate where planning and effort can be focused.

The principles suggested for waterways here are:

- The landscape environment of the South Coast of WA cannot be returned to its pre-agricultural form.
- Waterways require active management not indifference, neglect, or ad hoc interference.
- Outside of best agricultural production practices, active work by landholders to protect and enhance waterways on farms will take place in limited timeslots between essential farm enterprise activities.
- Improving waterway condition will involve incremental enhancements over long periods of time.
- Waterway management takes valuable time and effort and therefore requires funding input from external sources including government and industry (and this needs to be lobbied for by catchment communities).
- A section of waterway within a property is not an isolated landscape feature and what is done at one location may impact locations outside property boundaries.
    - Individual landholders can contribute to waterway condition improvement by considering the impacts that their land management practices have outside of their own property boundaries.
    - An appreciation of the natural laws of stream development will decrease the risk of adverse impacts downstream when implementing on-ground works in a floodway.
- Uncertain short-term contracts of employment for local natural resource management officers (NRMOs) is counterproductive to building community expertise and knowledge.
- Raising community awareness and understanding of hydrological processes will be an important part of a strategic waterway management approach.
- Developing and sustaining a community culture of best environmental management practices is important for achieving of long-term (generational) goals.
- Effective waterways protection and enhancement requires sound technical expertise and reliable data.
- The design of environmental monitoring programs and time frames should not be dictated by unpredictable funding events.

- Occasional auditing of waterway condition is essential for tracking changes into the future.
- Water monitoring programs should distinguish between:
  - Methods to describe current condition.
  - Methods to detect change and predict trends
  - Methods to determine the effectiveness of management initiatives.

  However, a well-designed monitoring program can achieve all three aims.

SECTION 2: THE CURRENT CONDITION OF WARPERUP CREEK

Aerial imagery provided an overview of the entire network of catchment waterways and a broad perspective of its vegetation status but did not provide detail of features at the reach and paddock scale. To gain a better understanding of specific on-ground conditions a set of representative reaches was chosen and assessed in greater detail. This helped clarify what management for improvement might require.

Aerial Imagery Interpretation

Riparian vegetation type, density and width was assessed for every section of the minor and major waterway reaches of the Warperup, from the watershed down to the confluence with the Pallinup River. Google Earth imagery was used to categorise the riparian vegetation. The categories used to describe vegetation type, density and width were general and limited by visual interpretation of the aerial imagery available. The imagery varied in age, with the most recent being 2018. Thus, the assessment was somewhat subjective but provides an initial measure of riparian extent and condition. The findings also provide a means of building a more accurate picture of waterway condition and identifying what level of intervention is sufficient to benefit the entire stream network.

Further information about the state of each stream reach and what level of intervention is appropriate can be added over time. This would enable measurable waterway condition improvement goals to be set at the catchment scale and help define what 'best management practice' will mean for the catchment during the coming decades. A further discussion of riparian vegetation status against stream order and for each sub-catchment within the wider Warperup Creek catchment is in Section 3: WHAT CAN BE DONE? - Vegetation Status Against Stream Order.

The following tables and pie charts summarise the assessment of riparian vegetation cover for the waterways in the Warperup catchment.

Riparian vegetation type

Remnant vegetation was noted as being absent or present and categorised as either "remnant" or "revegetated". The category "bare of trees and or shrubs" was mostly found in the upper parts of the catchment, i.e., first order streams that were in paddocks being cropped or grazed.

Revegetation works on the South Coast have been advancing strongly for about 30 years and the older works were hard to discern from aerial imagery. Some of the revegetation appeared to only consist of a single row of trees along a fence line. More recent works could be discerned by multiple rows visible in the aerial imagery.

As for remnant vegetation, there is no indication of width or density of vegetation in this category. It is encouraging to note that only 37% of the streams are bare of trees and shrubs and that at least 12% of the catchment streams have been revegetated in some way.

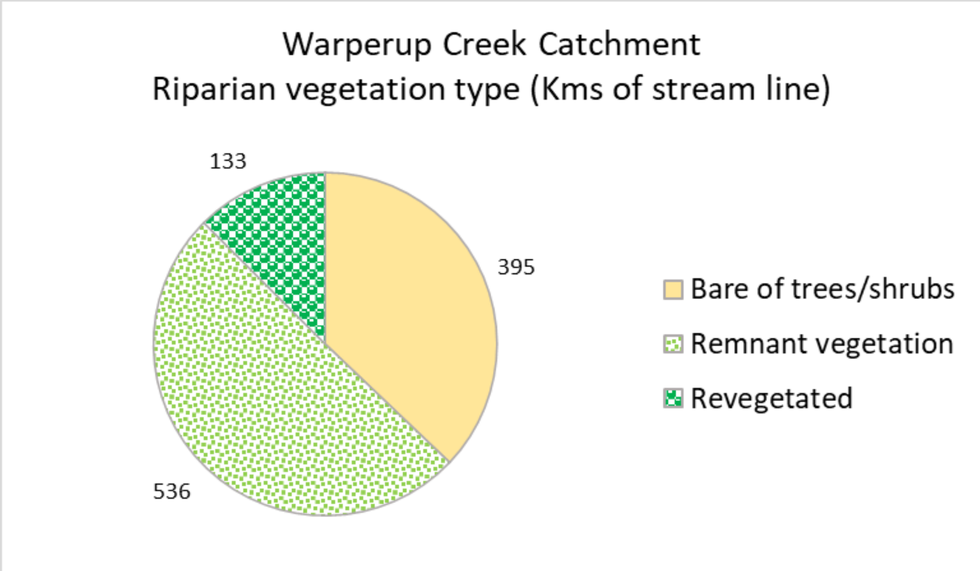


Figure 11: Length of streams within the Warperup Catchment that are bare, having remnant vegetation or revegetated.

Riparian vegetation density

The density of riparian vegetation was harder to discern from the aerial imagery and is somewhat subjective with broad categories. Some Google Earth imagery is darker making it difficult to determine density accurately. Again, there is opportunity to steadily improve the accuracy of this category with on ground visits. No distinction was made between the remnant vegetation and revegetated sections with respect to density.

There were 669 kilometres of stream lengths within the Warperup catchment with riparian vegetation and 366kms (34% of catchment) appeared to be moderately dense to dense in the aerial imagery. There were 302 kilometres with low density riparian vegetation (generally individual trees over grasses) which could be rehabilitated with greater diversity of vegetation.

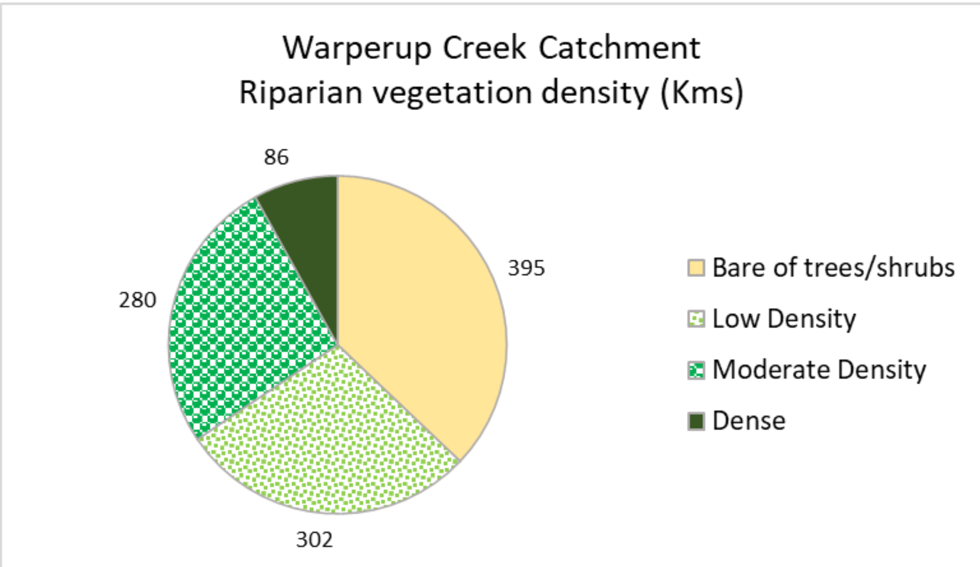


Figure 12: Density of riparian vegetation along streams in the Warperup Creek.

Riparian vegetation width

Vegetation along the streams was considered *narrow* when it was less than the width of a typical farm dam which is about 50 - 60 metres. Moderate to wide riparian vegetation is beneficial, especially when it consists of moderately dense vegetation however even narrow strips of riparian vegetation can be considered better than none. It is encouraging that 43% of streams in the catchment have moderate to wide riparian vegetation.

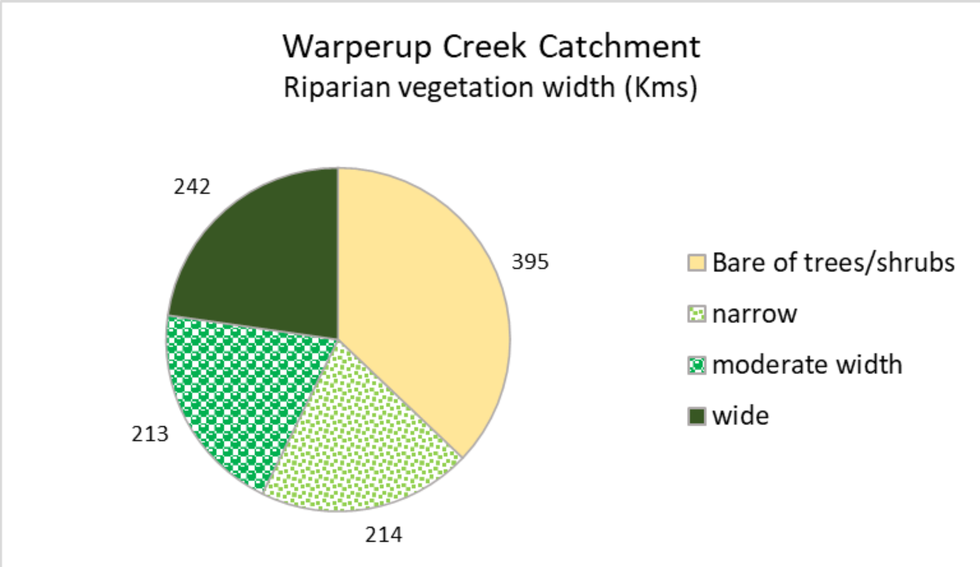


Figure 13: Width of riparian vegetation along streams in the Warperup Creek.

Representative Stream Reaches

Water quality is intimately tied to the physical characteristics of the landscape in which water flows and accumulates. As mentioned, in this study four basic characteristics of waterways were defined for the drainage network of Warperup Creek.

- Channel structure
- Water chemistry
- Aquatic biodiversity
- Riparian vegetation diversity

The reason for this division is that waterway condition has been a variable concept and can mean quite different things to different people. It may refer to water quality only, the condition of the main trunk, a favourite river pool, some sort of average condition or simply the ambience of the area. The Warperup waterways consist of 1064 kilometres of small, medium, and large channels and most of that length has little or no surface flow for parts of the year. From a management perspective, a useful assessment of waterway condition will therefore need to address the four waterway components across the catchment.

Given the extent of the waterways it is impractical to monitor all stream reaches and all waterway condition measures. For this reason, various reaches were selected to represent the entire drainage network. Since these reaches are influenced by what is happening upstream in the catchment they act as indicators of the nature and scale of environmental pressures, both internal and external, affecting the waterways.

Ten reference reaches

The ten chosen reference reaches are 220 to 600 metres long and capture many of the variations in channel form seen throughout the catchment. The reaches were established in October 2020 and provided snapshots of conditions. Although they can be used to represent the character of the entire system, there are some provisos. Figure 14 shows the location of the ten reference reaches, six of which are located along the main trunk of Warperup Creek and four on tributaries.

Photo points were established at 3 to 5 locations along each reach, and these provide information about channel form, erosion, sedimentation, vegetation condition etc. A water monitoring site was located at the downstream end of each reach. Site visits were made in October 2020, 2021, and 2022 when stream discharge was low to moderate. Site measurements included salinity, pH, temperature, and turbidity. Aquatic macroinvertebrate populations were sampled, and the dominant macroinvertebrate groups were identified in the field and estimates of relative abundance were made. Macroinvertebrate samples were placed in labelled vials and identified further in the laboratory. Water samples were collected and sent to a laboratory for analysis of Nitrogen and Phosphorus concentrations.

A range of other waterway condition and biodiversity components were not assessed, apart from noting casual observations. More detailed assessments of flora and fauna diversity, weeds, feral animals, and complex water quality parameters, may require specialists. This provides opportunity to attract researchers and in turn, wider interest in the Pallinup catchment.

Table 3: Reference reach details

Reach ID	Location	Reach length(m)	Number of Photo Points
PAL500	Warperup Creek, Maileerup Rd	490	5
PAL501	Warperup Creek, Borden Golf Club	390	3
PAL507	Warperup Creek, Meenup Confluence	320	4
PAL508	Warperup Creek, Ongerup confluence	460	5
PAL509	Warperup Creek, Jaekel confluence	390	5
PAL510	Warperup Creek, Jerramungup Rd	600	4
PAL520	Long Creek	320	4
PAL530	Coromup Creek	220	3
PAL540	Peedillup Creek	400	3
PAL550	Peerup-Meenup Creek	410	5

The site ID naming convention used by the Water and Rivers Commission in 1998-2000 coded sites by catchment and sub-catchment and was expanded for the Warperup study, as follows:

PAL Sites within the Pallinup River catchment

PAL100 to 199	Numbering available for sites within the Pallinup River main channel
PAL200 to 299	Numbering available for sites within the Salt Creek Catchment
PAL300 TO 399	Numbering available for sites within the Peenebup Creek Catchment
PAL400 to 499	Numbering available for sites within the Six Mile Creek Catchment
PAL500 to 599	Numbering available for sites within the Warperup Catchment
500 to 519	Numbering available for sites within the Warperup main channel
520 to 529	Numbering available for sites on Long/Maileeup Creek
530 to 539	Numbering available for sites on Coromup Creek
540 to 549	Numbering available for sites on Peedillup Creek
550 to 559	Numbering available for sites on Peerup-Meenup Creek.
560 to 599	Numbering available for sites on other tributaries of Warperup Creek.
PAL600 to 699	Numbering available for sites within the Jackitup Creek Catchment

Note that the range of ID numbers allows for future sites to be added without changing the convention.

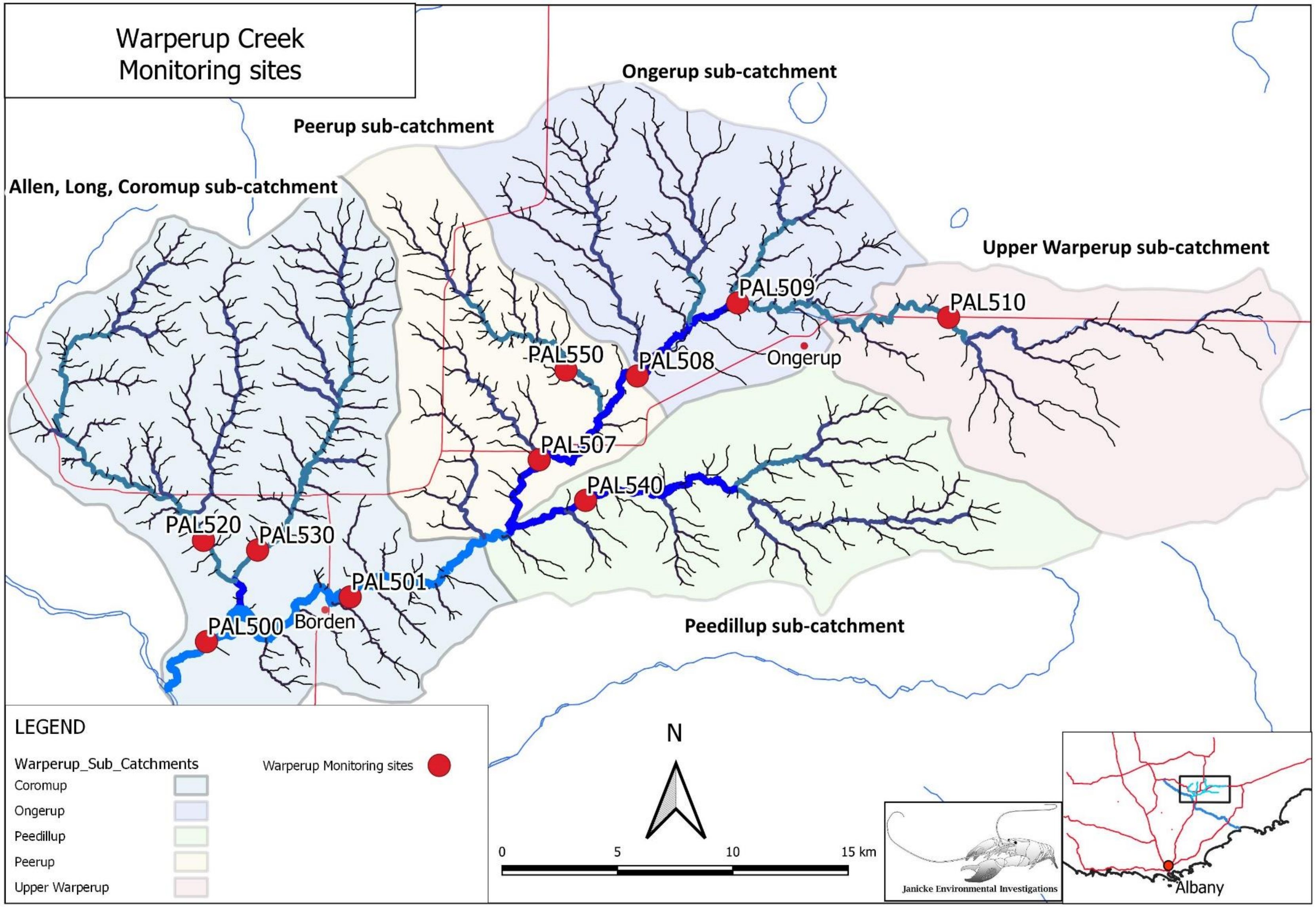


Figure 14 Map of the catchment showing the locations of the10 reference reaches

Janicke Environmental Investigations

Waterway Condition

Water condition monitoring is emphasised in this study for the simple reason that implementing any strategic plan will require information or ‘intelligence’ as the military refer to it. Waterway quality monitoring, done consistently over long periods of time, provides a means of assessing environmental trends as well as current conditions. For naturally variable data sets, such as salinity, long periods of time mean, 30 years or more.

Flows in streams not only reflect the quality of surface storm runoff from the catchment but also groundwater input (base flow). Distinguishing the relative inputs from both sources of discharge is difficult, but salinity provides clues. This information allows realistic and measurable goals to be set for maintaining and hopefully improving the quality of the resource. However, only a small percentage of the annual rainfall finds its way to the lower end of a catchment. In the case of the Pallinup River this may be as low as 2% although the runoff percentage can increase significantly during large storm events. For example, during the 1982 flood event which impacted Southwest rivers, including the Pallinup, it was estimated that the lower Blackwood River discharged approximately 20% of the rainfall from that event.

It may be assumed that the low and trickle base flows often seen in the upper streams and channels are of little consequence, but these maintain water levels in the pools and off-set the high evaporation rates, maintaining important aquatic habitat. They reflect groundwater discharge.

The monitoring approach initiated in this project involved three distinct levels of observation:

- *Direct measurements*, for example pH values and water temperature,
- *Categorical data*, for example estimates of tree health along the reach, and
- *Descriptive information*, for example bird species observed.

Water quality and riparian condition were assessed at each of the ten reference sites in mid-Spring for each of the years 2020, 2021 and 2022. The full results are presented in detail in “*Supplement 4 - Warperup Creek Water Condition Monitoring Results for 2020 to 2022”*. The results provided some insight as to what improvement goals might be feasible and importantly, achievable.

SUPPLEMENT 3 to this report titled *“Warperup Creek Water Condition Monitoring Framework*” discusses in more detail the requirements for developing a long-term monitoring and data management framework.

Historical Water Chemistry Data

During 1998 to early 2000 the then Water and Rivers Commission contracted a local resident, Shane Delury, to undertake water quality monitoring at various sites in the Pallinup River catchment. Three of those sites were on Warperup Creek. The data he collected provided a unique snapshot of water quality over eight seasons and this provided information about seasonal variations and differences in various parts of the catchment. This historical water quality data for Warperup Creek was sourced from DWER and contributed to this report.

In the mid-1990s, an AusRIVAS team collected water data throughout the southwest of Western Australia. This was part of a nationwide snapshot of waterways but only one site was visited in the Warperup catchment. In August 2007 the University of WA’s Centre of Excellence in Natural Resource Management (CENRM), which was based in Albany, undertook one visit to a site in the upper Warperup, to obtain aquatic data.

The 2020 reference reaches were chosen to include the three Water and Rivers Commission sites. This has allowed comparisons to be made with the 1998-2000 water quality results. The CENRM site which was in an extensive area of granite exposure was not chosen due to the nature of the reach.

The data has provided a better understanding of surface water conditions from the top of the catchment to the bottom end. Changes over time are a mixture of seasonal variations, annual variations, and differences between sites. These variations obscure longer-term trends. As a result, determining whether water quality is steadily trending in a certain direction requires monitoring for longer periods of time than the lifespan of most rehabilitation projects. The current data does however provide information about what water quality improvements might look like and whether rehabilitation goals can influence these or not, for example reducing water salinity and nutrient levels.

Rainfall

There had been three relatively dry years leading up to the 2020 sampling. In contrast, 2021 was much wetter and produced what was considered a one in ten-year flood. 2022, was slightly wetter than average. This variation in rainfall leading up to the monitoring event appears to be reflected in the water quality results.

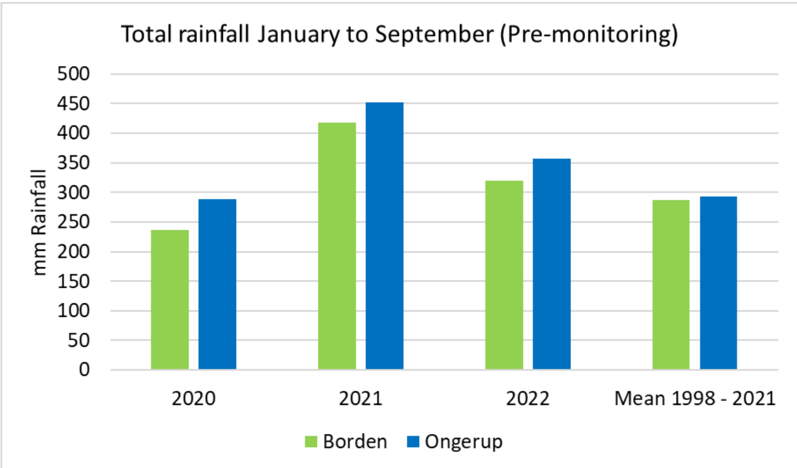


Figure 15: Rainfall in the 9 months leading up the 2020 – 2022 water monitoring events.

Salinity

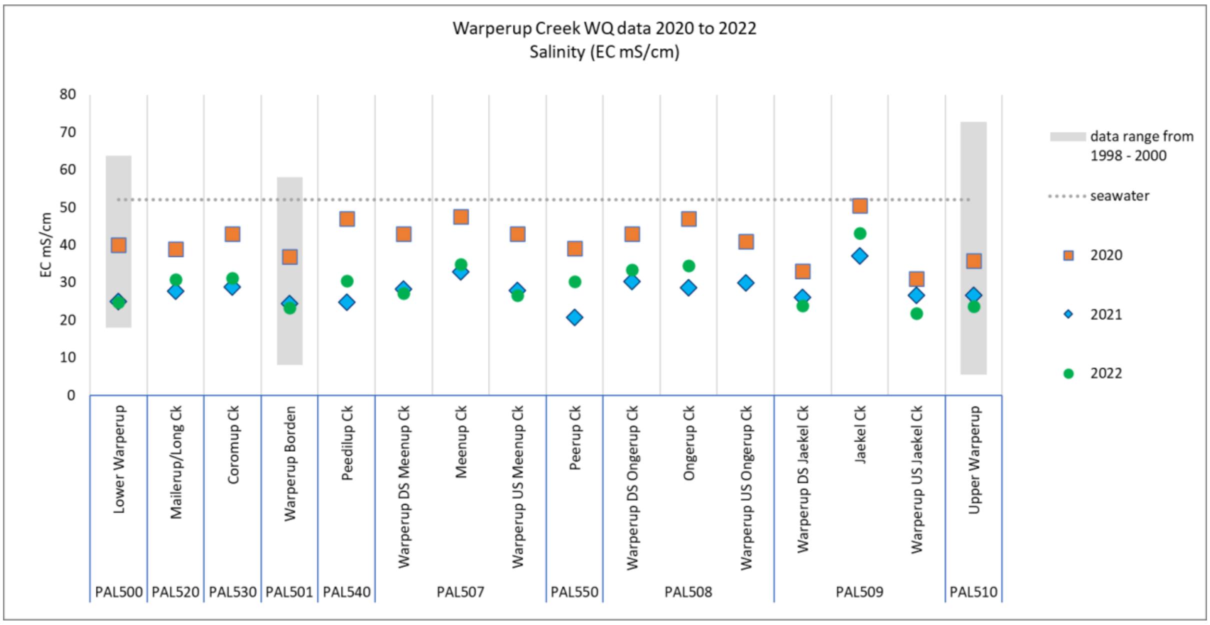


Figure 16: Salinity, as represented by electrical conductivity, of Warperup Creek and selected tributaries, October 2020, 2021 & 2022.

The graph in Figure 16 compares values along the main trunk of Warperup Creek and values at the major tributary sites for the three site visits in 2020 to 2022. The range of values obtained over 1998-200 for sites PAL500, PAL501 and PAL510 are shown as grey bars. The drier year in 2020 is reflected in the higher salinity values. The data collected in the late 1990s provided an opportunity to compare how water quality has varied at two sites after a moderate timespan. The two sites are PAL500 at the lower end of the catchment and PAL510 on the main trunk upstream of Ongerup.

Overall, conductivity appears remarkably similar both along the length of the main trunk and including the sub-catchments at the time of the 2020-2022 monitoring. This may say something about the nature of the groundwater system, although this would warrant further investigations.

The graphs in Figure 17 below give a pictorial comparison, but care should be taken to avoid reading more into the data than is advisable given the low number of data points.

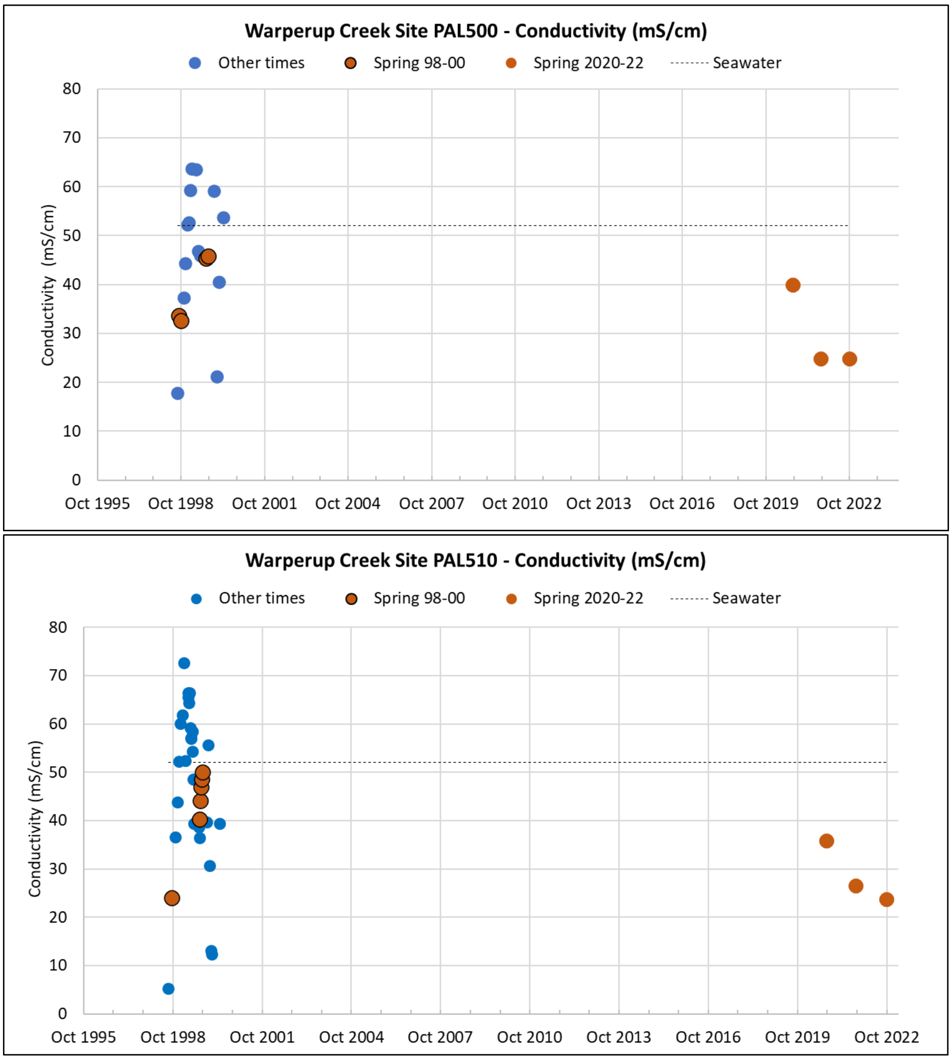


Figure 17: Salinity comparisons between 1998-2000 and 2020-2022 at sites PAL500 and PAL210.

The obvious features are first, the twenty-year period in which no consistent water monitoring took place and secondly the few measurements made in 2020 to 2022 compared with 1998 to 2000. The recent site visits were only done in mid-Spring and for this reason the recent and 1998 to 2000 Spring values are both coloured red. The 1998-2000 data does give an indication of the wide range of values which can occur at different times of the year and from year to year.

Nevertheless, it will be noticed that the three more recent measurements appear to be in the same 'ballpark' as their equivalents in 1998-2000. We might speculate that there is so far no indication that conditions have changed a great deal in the intervening twenty years. Ideally the 1998-2000 monitoring would be repeated at some stage and the results given to a statistician to determine if there has been a significant change in values at each of the two sites.

The conductivity results indicate that salinity levels can vary as much if not more over time (temporally) than between sites in the catchment (spatially). The implication is that the ten water monitoring sites paint a reasonable picture of water salinity in the waterway system. Any future monitoing may reasonably require a lesser number of sites to be visited in any one year.

Water acidity

When ground water comes up to the ground surface either naturally or via deep drains or case bores, and is exposed to the atmosphere, chemical processes can increase the acidity of the water. Acid water discharging into the waterways has an impact on the aquatic life for considerable distances downstream. The saline surface waters of South Coast River systems are typically basic, that is the pH is greater than 7 and values around pH 8 are common. Groundwater discharge can lead to pH values as low as pH 3 which is toxic to most aquatic species. For these reasons, pH offers a convenient and economical way to assess groundwater influences on the waterways and in some cases to monitor engineering interventions.

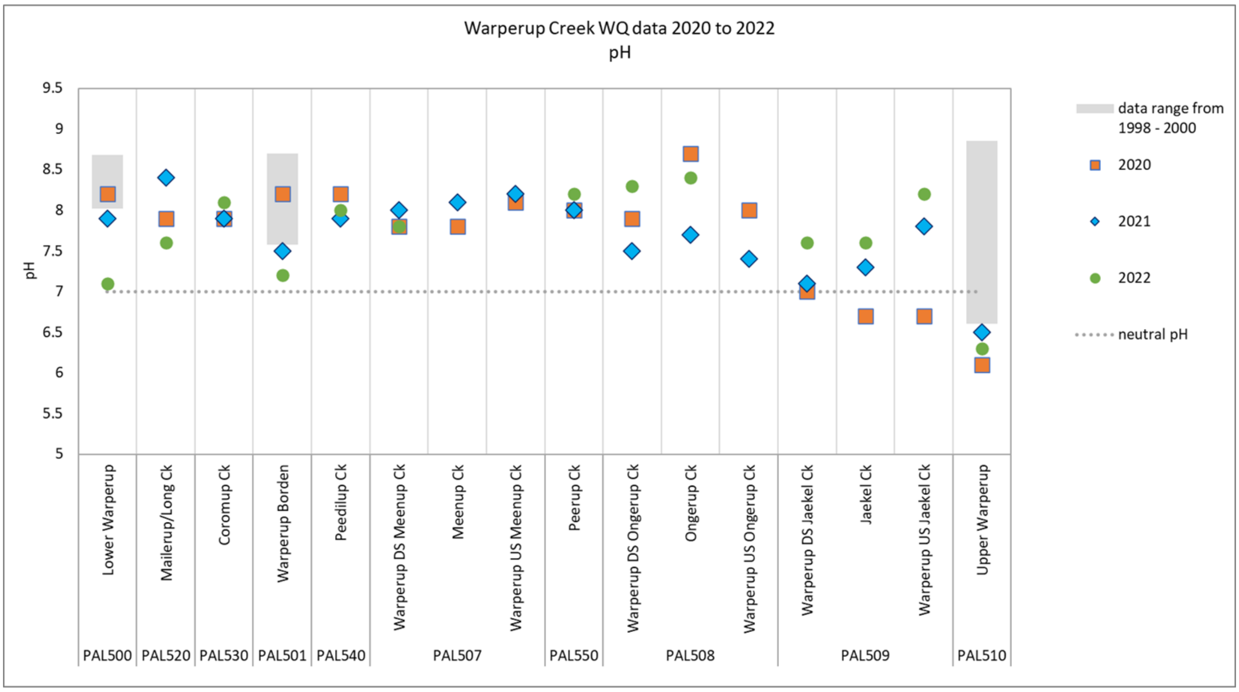


Figure 18: The pH of Warperup Creek and selected tributaries for 2020 to 2022. The data range from sampling three sites between 1998 and 2000 is shown as a grey bar.

The 2020-2022 pH values from the upper Warperup catchment were tending slightly to the acidic, indicating that there is potential for further acidification of the waters although the degree of risk is uncertain. The 1998-1999 values varied considerably across the seasons suggesting a dependency on seasonal and even weekly rainfall. The lack of data post 1999 again shows the deficiencies of conducting water quality monitoring in an inconsistent way over time. If consistent low level annual monitoring is not feasible, there is, as mentioned for salinity, a case for conducting another short term (2 to 3 year) seasonal monitoring program to collect data to compare with the 1998-1999 values at the PAL500 and PAL510 sites. If a trend is suspected routine monitoring can be undertaken.

Nutrients

Total Nitrogen (TN)

Total nitrogen consists of both dissolved mineral and organic forms of nitrogen. Nitrogen compounds are mostly quite soluble in water and for that reason are mobile in the landscape. Water samples were analysed for Total Nitrogen as an indicator of nutrient status at the reference reaches. Dissolved Inorganic Nitrogen (DIN) is mostly nitrates and nitrites (NOx-N), but also includes ammonia and dissolved molecular nitrogen gas (N_2). DIN infiltrates readily into groundwater and can be an important nitrogen source when surface flows decline.

The water analyses indicated during dry years TN was low and in wetter years TN was higher. No trend can be determined between the 2020 - 2022 data points and the 1998 - 2000 sampling values. The historical data showed that there was a strong seasonal relationship of increasing nitrogen values over summer and autumn. High nitrogen values promote algal growth in the waterway and a reduction in aquatic biodiversity. The volatility in TN values implies that nutrient monitoring requires a long-term commitment.

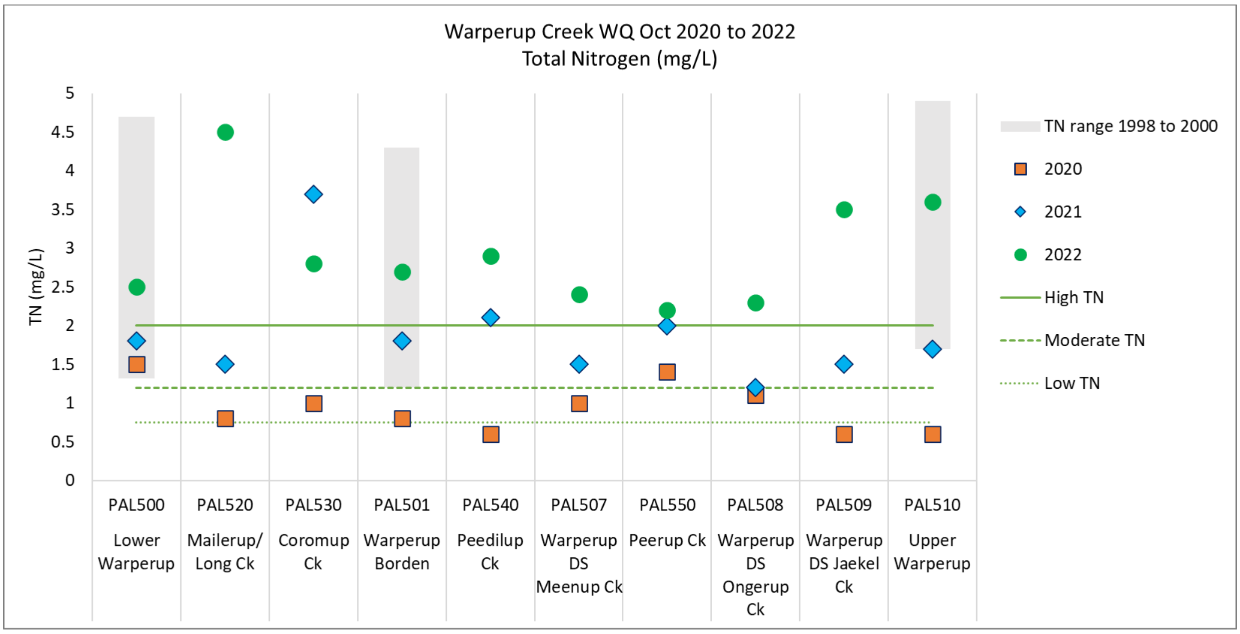


Figure 19: The Total Nitrogen (TN) of Warperup Creek and selected tributaries for October 2020 to 2022. The data range from sampling three sites between 1998 to 2000 is shown as grey bars.

Note: Values considered low, moderate, and high TN were taken from the Department of Water and Environmental Regulation FARWH Report No. 39[4].

Total Phosphorus (TP)

Total Phosphorus (TP) includes both dissolved and particulate forms of phosphorus. Although dissolved orthophosphate (soluble reactive phosphorus) is the form generally available for phytoplankton and algal uptake, phosphorus uptake and turnover rates are fast and total phosphorus is considered a better indicator of eutrophication risk.

The water analyses indicated that during dry years TP was low and in wetter years TP was higher. No trend can be determined between the 2020 - 2022 and the 1998 - 2000 sampling values.

[4] Storer, T, White, G, Galvin, L, O'Neill K, van Looij, E & Kitsios, A 2011, The Framework for the Assessment of River and Wetland Health (**FARWH**) for flowing rivers of south-west Western Australia: project summary and results, Final report, Water Science Technical Series, **Report No. 39**, Department of Water, Western Australia.

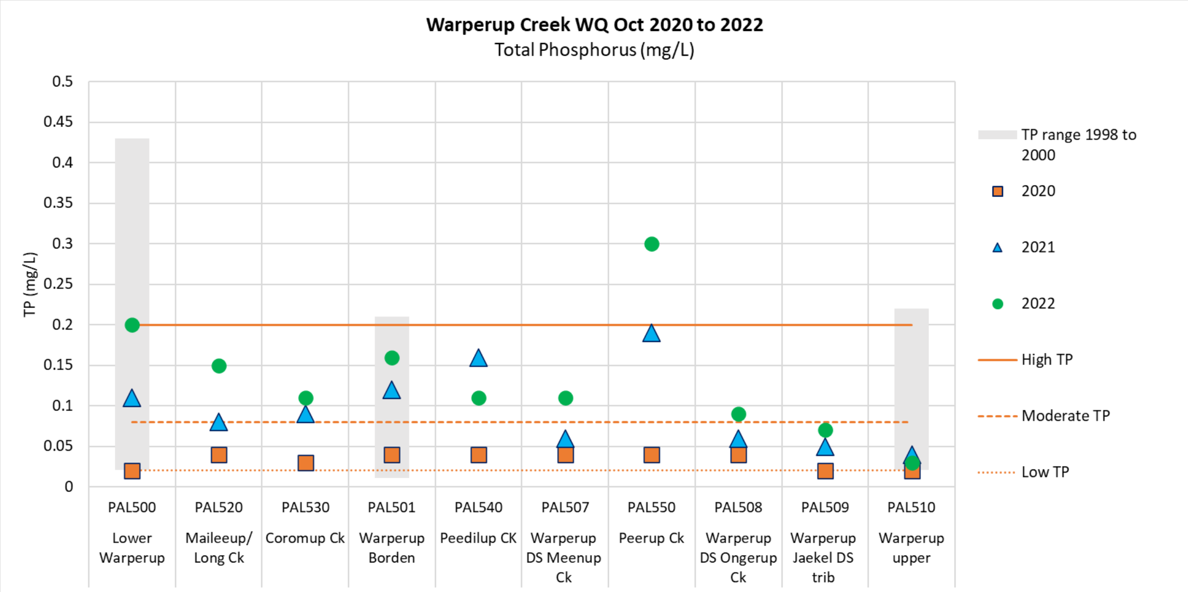


Figure 20: Total Phosphorus (mg/L) in water samples collected from Warperup Creek and tributaries, October 2020 to 2021.

Aquatic biodiversity

Macroinvertebrate composition

There were 40 different taxa observed over the three years of sampling in Warperup Creek and its tributaries. The diversity was dominated by insects, and specifically Dipterans, i.e., larvae from midge, mosquitos and various flies. However, in terms of abundance, Crustaceans dominated with 'scuds' (i.e., *Austrochiltonia subtenuis*), various species of seed shrimp (Ostracoda) and micro-crustaceans (Copepods).

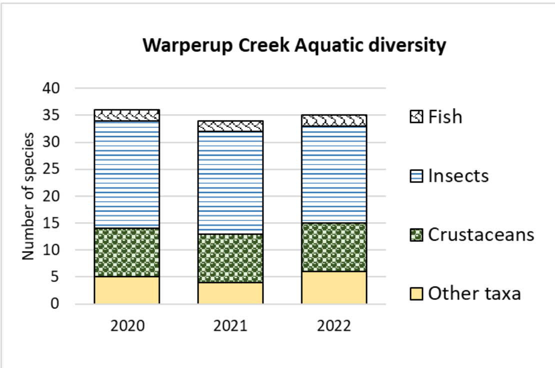


Figure 21: Aquatic diversity in Warperup Creek and its tributaries combined for each year.

There were no significant differences between the three years in aquatic diversity and only minor differences between sites within each year.

No comparable aquatic macro-invertebrate data was collected during the 1998-2000 monitoring period therefore the 2020-2000 data provides a baseline for future investigations.

Although Warperup Creek has been impacted by secondary salinisation, like most rivers on the south coast of WA, it probably has always been saline to varying degrees. A large diversity of endemic macroinvertebrates that are either halophiles (i.e., saltwater loving) or halotolerant (tolerant of salt water) have been found on the south coast and the Warperup sampling sites were dominated by these.

Table 4: Species diversity at ten reference sites in Warperup Creek for the three years.

Site	2020	2021	2022
PAL500 Lower Warperup	10	15	15
PAL520 Mailerup/Long Ck	13	11	11
PAL530 Coromup Ck	15	16	10
PAL501 Warperup Borden	17	13	10
PAL540 Peedillup Ck	15	14	18
PAL507 Warperup DS Meenup Ck	15	17	13
PAL550 Peerup Ck	13	14	16
PAL508 Warperup DS Ongerup Ck	18	14	11
PAL509 Warperup DS Jaekel Ck	21	21	18
PAL510 Upper Warperup	12	17	12

A study of south coast saline rivers[5] found that site species diversity ranged between 4 to 38 species with an average of 19 species per site. Table 4 shows the species diversity results from the recent sampling which is within the range for south coast rivers.

Macroinvertebrate species diversity was consistently highest at Site PAL509, downstream of Jaekel Creek. This is despite Jaekel Creek influencing the salinity at the site. It may reflect the rocky riffles and habitat diversity upstream in the main channel. The species diversity was consistently lowest on Mailerup/Long Creek, site PAL520. This site is a broad, shallow run with a sandy bottom and little habitat diversity.

The full results are presented in detail in "*Supplement 4 - Warperup Creek Water Condition Monitoring Results for 2020 to 2022"*.

Fish

The Blue-spot Goby, *Pseudogobius olorum* also known as the Swan River Goby was found at all sites except in Coromup Creek, site PAL530 and the uppermost pool, site PAL510. This is a bottom dwelling (benthic) species that can tolerate a wide range of salinities. With the first rains of winter, they can be found moving upstream to be ready to place their eggs (spawn) amongst submerged aquatic vegetation. They feed mostly on algae, fungi, bacteria, and small bottom dwelling microcrustaceans. They are also a food source for diving waterbirds.

The introduced Eastern gambusia - *Gambusia holbrooki* was found in large numbers at site PAL501 near the Borden Golf Club. Gambusia are a hardy fish that reproduce abundantly and thrive in the warm shallows of slightly saline waterways. The juvenile fish can be trapped on the feathers of ducks and travel to other waterbodies. They can seriously reduce native fish populations, but it is uncertain how this has compromised the abundance of native fish at this site and elsewhere.

Other native fish, e.g., the Common Jollytail - *Galaxias maculatus* and the Western Hardyhead - *Leptatherina wallacei* may also be present in the waterway however they are fast moving and would not be collected in a macroinvertebrate sweep net.

A small school of Common Jollytail were observed in the Warperup near the Hart Road crossing. They have a broad salinity tolerance, and it can be assumed that they are present in most of the Warperup Creek, although this would need to be researched.

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[5] Cook, Janicke, & Maughan, (2008). *Ecological values of waterways in the South Coast Region, Western Australia*. Report No CENRM079, Centre of Excellence in Natural Resource Management, University of Western Australia. Report prepared for the Department of Water.

Figure 22: The Blue-spot Goby, *Pseudogobius olorum (left),* the introduced Eastern gambusia - *Gambusia holbrooki* (right) and the Common Jollytail - *Galaxias maculatus*

Zoologist Andrew Chapman studied the native minnow (Galaxias maculatus) common in South Coast rivers and noted[6] that the species can tolerate water salinities to approximately one and a half times that of seawater (i.e., a conductivity of approximately 80 mS/cm). However, minnow do not tolerate water temperatures warmer than approximately 28^{o} C. He also observed water temperature differences between shaded and unshaded water can be 3 – 4 ^{o} Centigrade. This implies that increasing the area of shaded water in pools may improve the aquatic diversity.

Other fauna observations

A variety of ducks were observed using the waterway, often with ducklings which indicated the use of the river pools for breeding. Observations included:

- Dabbling ducks, including the Grey Teal and the Pacific Black Duck. Dabbling ducks upend for food in the shallow water and littoral zone, feeding on aquatic plants, insects, crustaceans as well as the salt-lake snail, *Coxiella* sp.
- Diving ducks including the Hardhead and Hoary-headed Grebe. These birds dive for bottom dwelling macroinvertebrates, plant material and small fish.
- Other birds including the White-Faced Heron had been observed occasionally. These are generalist feeders, feeding on frogs, insects, small fish and crustaceans found in shallows or in open grassy areas. A variety of song birds were heard at various sites.

Riparian vegetation diversity

Qualitative assessments of riparian condition were undertaken and recorded for each reference reach in 2020. Specific qualitative assessments were carried out at each water quality monitoring site in each year to provide context for interpreting the results of the aquatic macro-invertebrate sampling.

The simplest method of assessing riparian health is using the Pen-Scott rapid assessment of riparian condition. The Pen-Scott riparian condition grading uses a simple A - B - C - D scale, A being pristine and D being highly degraded. There are also three degrees within each grade, for example B1 – B2 – B3. The process of degradation is rated by considering the relative levels of native plants and weeds, their health, and the amount of soil disturbance.

[6] Andrew Chapman. Journeys in the Promised Land.
A memoir of childhood and zoology in Western Australia. 2022

In general, the riparian vegetation along the reference reaches of the tributaries were in better condition than along the main trunk of Warperup Creek. The lower end of Warperup Creek was in the poorest condition with annual grasses dominating the sandy riparian verge. The two reaches on Coromup Creek and Peedillup Creek appeared to be in the best condition compared with the other reference reaches, with trees and shrubs over a mainly grassy understory.

Table 5: Pen-Scott rating for left and right bank along the reference site reach.

Reference reach	Left bank	Right bank
PAL500 Lower Warperup	C3	D1
PAL501 Warperup Borden	C1	C1
PAL507 Warperup Meenup Creeks	C3	C3
PAL508 Warperup Ongerup Creeks	C1	C1
PAL509 Warperup Jaekel Creeks	C1	C1
PAL510 Upper Warperup	C1	B3
PAL520 Mailerup/Long Creek	B3	C1
PAL530 Coromup Creek	B2	B2
PAL540 Peedillup Creek	B2	B2
PAL550 Peerup Creek	C1	B2

Channel structure and stability

Sediment infilling of the waterway channels and river pools is a common problem of catchments in the southwest of WA.

Sediment at most Warperup reference sites has been very mobile with the 2021 high flow (one in ten-year flood) re-distributing large quantities of sand as seen in Figure 23 and Figure 24.

Figure 23: Zoomed in to the end of the pool at Site PAL508 on Warperup Creek, 2020 and 2021. Although the photo in 2021 was from a slightly different angle, the extent of sediment deposition can be seen.

Figure 24: Sediment infilling of the pool at Site PAL507 on Warperup Creek in October 2020 and October 2022.

Photo-point auditing

Stream erosion and its product, sediment, is very difficult to quantify and certainly beyond the capacity of catchment communities to consider undertaking. Therefore, a qualitative approach was adopted for each of the ten reference reaches and involved establishing Photo Points along the reference reaches. Four to five photo-points were set up along each reference reach in such a way that these can be revisited and photographed at any time in the future and the images compared. Photo comparisons enable simple questions to be answered. For example, do the banks appear stable or has erosion increased over time? Has the riparian vegetation changed and if so, how? Are sediment levels increasing or decreasing? Has rehabilitation worked, what are the impacts of major flood events etc?

It should be noted that although the approach may seem to be highly qualitative, photographs are quite objective. They show detail of what is or is not present and provide insight about characteristics which are not easily measurable, for example the rate of bank erosion, movement of sediment, tree and shrub regeneration, weed abundance etc.

The presence or absence of a physical feature impacts the quality of the riparian environment and is a valid assessment of waterway condition improvement or otherwise. Features of particular importance for improving water condition are areas of erosion and sedimentation. The photo audit provided ample evidence that sediment levels in the waterways are high and significantly compromise waterway condition by simplifying aquatic habitat and promoting bank erosion.

The advantage of photo point monitoring is that reaches, and photo-points can be added, without limit and this increases the representativeness of the data and hence provides increasing evidence to support any conclusions drawn. The photo point audit conducted in full in 2020 is reported in

Supplement 5 – Warperup Creek Photo Audit. The full set of images from 2020 and 2022 have been provided in the form of .jpeg files. The value of these images will be realised after ten plus years.

It can be expected that remote sensing technology will increase in accuracy and precision and decrease in cost to the point where purely ground-based assessments become more specialised. However, photo points and related images will provide the primary and indisputable historical description of what the physical appearance of the waterway environment used to be.

SECTION 3: WHAT IS ACHIEVABLE?

A review of several historic images of Warperup Creek provides some evidence that from the time of clearing until the 1950s, the riparian zone was increasingly denuded of all but occasional trees. This was largely due to stock having unrestricted access to the streams, combined with floods, periods of drought and perhaps wildfires. One historic image coincided with monitoring site PAL507 and could be compared with conditions in 2022 (Figure 25).

Figure 25: 1930s[7] image of Duncan family of Boroondara (State Library of WA) and the same location October 2022

[7] Accessed from State Library of Western Australia, https://purl.slwa.wa.gov.au/slwa_b3523166_11

Veldt grass now dominates the banks, but at least maintains a cover over the soil. How has the site improved and what further improvements if any, can be achieved at this site and others? Solving riparian degradation issues is a land management as well as a technical issue and for this reason a critical question to answer is, what approach is the catchment community prepared to pursue?

The Sustainability of NSPNR

North Stirlings Pallinup Natural Resources Inc. provides an essential role in taking a holistic view of the landscape. This includes the connections between environmental values and community sustainability and vitality. This role is summed up in the groups position statement:

> *Bringing together people, organisations, and information so that communities in the North Stirlings Pallinup region are able to drive the better management of natural resources resulting in social, economic and environmental sustainability; and inspiring current and future generations through coordination, education and example, showing the benefits accruing from sustainable management of the region's natural resources.*

The 2020 NSPNR Community survey determined that,

> *Support for current services and activities is good but there is stronger support for a range of potential future services and activities, particularly in relation to pest control, salinity and regenerative agriculture. Generally, there is strong indication for NSPNR to consolidate and reset its focus.*

Understanding Landcare history in the Pallinup

An understanding of how Landcare has evolved in the Pallinup catchment is important for determining the drivers of community values regarding the environment. The formation of catchment specific management groups along the South Coast was the "new vogue" in the 1990s and early 2000s. Government agencies were primary drivers of these strategic initiatives. The size and number of river systems and the NRM issues were daunting, but it was hoped that smaller catchment groups would be lasting key players with respect to environmental management. The Pallinup catchment was of particular interest to many stakeholders.

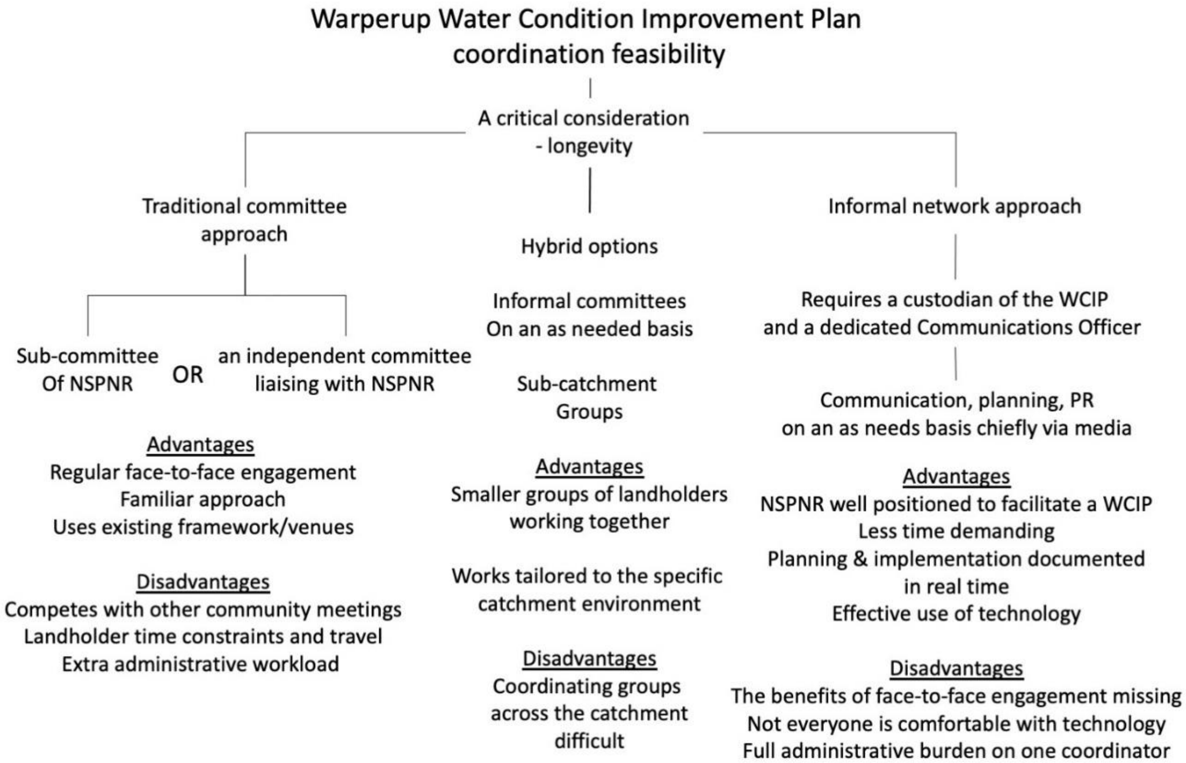
Landholders generally favoured a 'bottom up' rather than a government 'top down' approach to managing natural resources since they had the knowledge of their catchment areas, the practical issues, and a strong sense of independence. Funding support came from Federal or State programs such as the Natural Heritage Trust, while agencies provided technical support for specific investigations and recommendations.

Landcare groups, composed mostly of volunteers were able to secure enough funding to employ local, but generally part time project coordinators, who inevitably donated extra volunteer time and energy. This was a recipe for 'burn out' and a reason for Landcare Coordinators to move in and out of project positions taking what they had learnt with them. LCDCs reinvented themselves to remain a viable NRM presence in the various subregions. The consolidated NRM groups such as NSPNR have been effective in keeping environmental management issues in the public eye, but the capacity of catchment and sub-catchment communities to achieve beneficial environmental outcomes has remained challenging.

NSPNR have a good track record in the Pallinup River catchment and have managed to keep project funding trickling in to continue various activities to do with agricultural productivity and environmental management. However, issues for serious consideration are; duration of staff employment, retaining in-house technical skills, developing durable social marketing platforms for core business, facility development of better management practices, experimentation, and pursuing a diversity of funding sources. Development of existing core and potential business areas will be critical for NSPNR and although these are hinted at in the vision statement they do not appear to be clearly specified in an operational sense.

In the pursuit of relevance to the community there is a risk an NRM organisations may drift away from or demote their focus on enhancing natural landscape values since these may not be perceived as having little to do with economic pressures. The last part of a key finding from the 2020 community survey namely '*there is strong indication for NSPNR to consolidate and reset its focus',* requires clarification for this reason.

The chart below presents management options which may suit the development of a strategic plan for managing the waterways. Elements of these approaches are already in place for the Middle Pallinup through NSPNR, but what would work best for the Warperup is uncertain in the current economic climate.



NSPNR is ideally located to be the central repository of environmental information and to assess progress towards waterway condition goals. Ongoing development of staff skills such as knowledge of landscape processes, GIS technology, a waterway condition assessment framework, data archiving etc are essential to consolidate NSPNR as a rich community resource. The feasibility of achieving significant improvements in waterway condition will be very dependent on this. Nevertheless, waterways management will likely remain only one component of a wider Landcare management structure.

Pallinup Community Views and Concerns

In 2020, NSPNR commissioned a survey[8] of the Middle Pallinup community to help plan and guide the organisations future focus. The survey provided insight regarding community values and priorities for farming enterprises and the natural environment. The key findings were as follows:

[8] Your Region Your Input Community Survey report - Setting the course for natural resource management in North Stirlings-Pallinup. September 2020

- *The wider community value a range of environmental, social, and economic aspects of the sub-region and they are concerned about a range of environmental issues, particularly agricultural production and issues impacting the biodiversity of the region.*
- *Support for current services and activities is good but there is stronger support for a range of potential future services and activities, particularly in relation to pest control, salinity and regenerative agriculture. Generally, there is strong indication for NSPNR to consolidate and reset its focus.*
- *Approximately 28% of respondents were from the Borden-Ongerup area.*
- *Across the whole survey area respondents who indicated they worked in agriculture ranked productive agricultural environments highest followed by soil health, local businesses and the people and community.*

Issues ranked as extremely concerning were:

- *Quality and quantity of drinking and stock water.*
- *Wind and water erosion.*
- *Soil salinity.*
- *Maintaining ground cover.*

Other observations:

- *Respondents from other industries indicated the Stirling Range National Park as the highest natural value, followed by the people and community, local business and recreation in nature with soil health ranking much lower when compared to the full data set respondents.*
- *The greatest proportion of "not at all concerned" was for flooding followed by pesticide and fertiliser use.*
- *Tourism was ranked lowest as a concern.*

Opinion polls usually raise further questions about community perspectives and attitudes. For example, the low ranking for tourism is interesting since many would consider this is an important economic factor for community viability and growth. Does this suggest the respondents were less concerned with the economic viability of the towns other than perhaps as a depot in the farm supply chain and a local social outlet?

Does the low ranking of flooding as a concern reflect the scope of the survey or the low levels of infrastructure in flood prone areas or that the most flood prone infrastructure is the Shire or Main Roads responsibility only?

The dual concerns of agricultural production and biodiversity preservation have traditionally been viewed as opposing one another, however, improving waterway condition is about finding beneficial synergies between agricultural aspirations and natural processes.

A strategic plan for waterway improvement need not and should not be based solely on the few dominant issues, but as far as practical, incorporate all concerns.

Warperup Creek Landholder Survey

In 2022 Warperup landholders were contacted[9] by NSPNR to determine their perspectives on the value of local creeks in relation to their farming enterprises and to gauge their willingness to take part in discussions about improving the environmental condition of the waterways.

[9] Warperup Creek Improvement Plan Feasibility Study 2022 – Supplement 1: Warperup Creek Landholder Survey

Although less than half of possible landholders/managers in the Warperup catchment were able to be contacted, they represented approximately 58% of the catchment land area.

Landholder interest and long-term commitment to managing the structural stability and biodiversity values of their waterways will be the most significant factor determining the outcomes.

Figure 26 and Figure 27 indicate that the willing to participate in waterways management discussions represented more than half the catchment land area. This suggests many in the community feel there is merit in the idea of improving waterway condition.[10]

The 2022 Warperup survey did not include residents of the Borden and Ongerup township areas which accounted for 28% of the respondents in the 2020 Pallinup community survey. However, many of the concerns and priorities in the Pallinup community survey were affirmed in the 2022 responses.

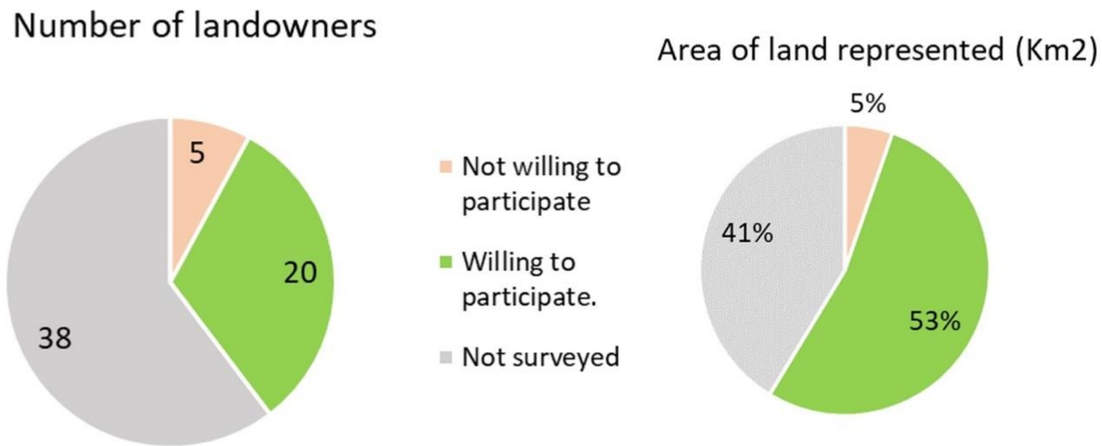


Figure 26: Numbers of landowners/managers willing to participate in waterways management discussions, and the area of land represented by them.

Reason for the difficulties in contacting all landholders with properties within the catchment are varied and include smaller holdings with absentee landowners, changing ownership of farms and paddock lots not reflected in databases, and people away or busy elsewhere at the time. It also suggests there are communication difficulties to be overcome. It should not be assumed that those who could not be contacted by NSPNR were all unwilling to respond to the questionnaire or are disinterested in the future management of the Warperup waterways.

Ambience appears to be a strong motivating factor. The contribution that waterways offer to a farming enterprise is often acknowledged but according to the survey responses, may be considered in a personal sense rather than as important for their ecological integrity or the economic value of the farm. Some consideration can be given to evaluating how the overall long-term condition of an agricultural property affects its future resale value. The condition of the waterways may be a powerful advertisement in this respect.

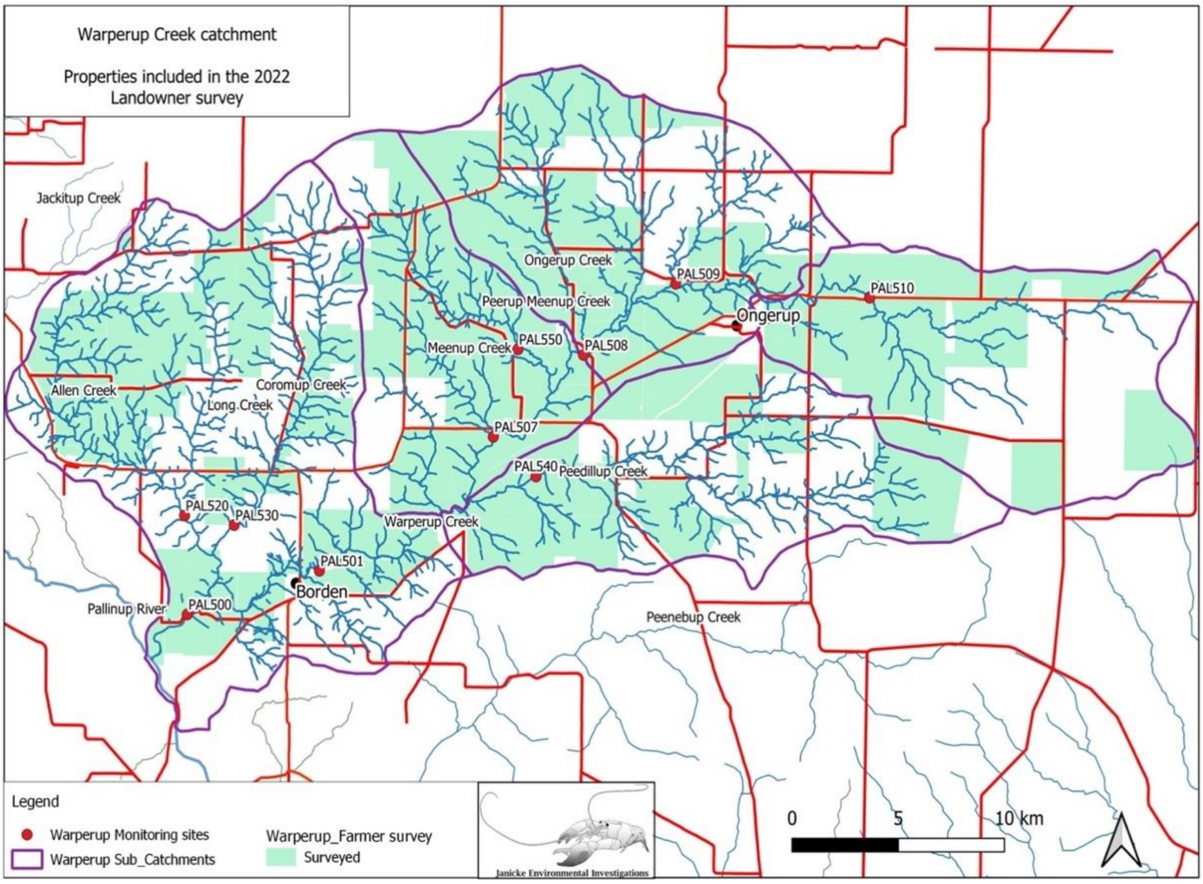


Figure 27: The distribution of respondent properties which shows there was a good representation of catchment management issues.

Engagement with landholders and managers will require updated ownership information and various methods of communication, e.g., phone call, SMS, email, social media, visit in person etc.

Some general observations from the 2022 phone interviews

- The responses reflected the importance of the dual considerations of agricultural viability and environmental protection in that order of priority.
- Not all landholders were clear about how the tributaries connect to Warperup Creek and the Pallinup River.
- Some comments imply that Warperup Creek is considered as simply the main trunk of the drainage system and therefore of little direct concern to properties higher in the catchment.
- There was a general positive attitude towards waterways with an appreciation of their contribution to the ambience of the farms despite problems of flooding, frost, and other operational issues.
- Over 60% of respondents had done fencing and revegetation work during the past 30 years with the dominant reasons being to protect the creek, bush, and wildlife.
- Other works included drainage and planting perennials to mitigate salinity. Most considered the works had been of benefit, but with some exceptions.
- The steeper gradient reaches providing opportunities for constructing dams and having less salt affected areas.
- It was commented that landholders who do not live on the properties may have no connection to the land, and therefore would not care about the condition of Warperup Creek.
- Overall, respondents felt the waterways were a benefit to their farming enterprise and commented on the various benefits, including drainage, stock shelter and movement.

- There were equally as many comments on the benefit of the waterways to personal health, through having pleasant or ‘sacred’ environments for the family to enjoy.
- A point was made regarding any proposed group discussion, that participants would not want to lead these discussions and present to others.

> One comment seemed to sum up the general outlook: “*Yes, I would be interested (in discussions about improving waterway condition). I think each farm has its own issues that need to be addressed in isolation but to come together for the greater good… yeh I’d be interested to see where this goes*.”

Promoting A Strategic Approach to Waterways Management

In the early days of Landcare activities, agencies began gathering environmental data to help delineate and hopefully find solutions to landscape problems, notably wind erosion and secondary salinity. When the “willing and able” in the community were engaged in NRM, the emphasis expanded to include ‘community awareness raising’. This involved educational and ‘capacity building’ events, however community engagement in these initiatives has been intermittent and unpredictable. This reflects what is perhaps the most significant factor affecting the feasibility of improving waterway condition at a whole of catchment scale and achieving durable strategic outcomes. It will require a significant cultural shift in rural community attitudes and practices regarding the natural environment in which people are embedded.

> What people value is what they will protect.

A critical question for navigating waterways management into the future is, how to facilitate a shift in cultural values? In other words, how to make a convincing case for pursuing a collaborative strategic approach. The community surveys have been a starting point for understanding current community values, but knowledge of what drives these values is the key to progressive and productive change. The engagement of a qualified sociologist to research these issues is one way in which this might be better understood. It is suggested that state funding bodies which are looking for substantial and demonstrative environmental outcomes, will place greater emphasis on robust strategic planning, including going beyond awareness raising of environmental issues to facilitating rural communities to adopt widely accepted and better management practices. Appendix 2 provides some insight into the way government is currently approaching soil and land conservation with the emphasis strongly on salinity issues. This has significant implications for Landcare and Rivercare in particular

Maintaining, and increasing interest in waterway management and commitment to ongoing action in rural communities is a difficulty commonly faced by local groups. It is suggested that an essential requirement is a resilient community communication approach, and this means pursuing investment in the ‘marketing’ side of Landcare. The tendency for environmental groups to be hustled into acting as extensions of government departments by funding accountability requirements easily sidelines the vital role of marketing as a core Landcare business. This should not be viewed as a ‘sideline’, to be handballed to project officers, nor should it be assumed that social marketing is obvious and simply addressed by advertising special events.

NSPNR is well placed to develop and facilitate ongoing marketing of the wide spectrum of environmental values and goals and in this case advancing waterways management, even if the impetus for specific projects would best come from the landholders themselves. Marketing of course, requires a clear understanding of the organisation’s products and services and this role would suit the services of a dedicated Communications Officer. The creation of a progressive Water Condition Improvement Plan (WCIP), in whatever form, will involve achieving a substantial shift in collective community values, expectations, and generational attitudes towards the agriculturally non-productive parts of the landscape. It can also assist in progressing community values.

We use the term 'progressive WCIP' as it will inevitably be a process spread over periods of decades and will always be ongoing. For this reason, ensuring the longevity of a waterways management approach is essential, but it is a unanimous endorsement of the rationale behind the plan, by a significant majority of landholders, which is critical.

The establishment of a strong communication approach by NSPNR, one which can adapt to the 'boom & bust' of community interest, changing demographics, agricultural emphasis, and unpredictable funding opportunities, is central to ensuring the feasibility of a successful WCIP being developed in and by the catchment community.

Building town and farm community engagement in waterways management

Greater engagement of townsfolk in NRM initiatives is an area for consideration.

The 2020 NSPNR Community survey drew responses from across the Gnowangerup district and included people working in industries associated with farming, non-farming businesses, interest groups and residents. The 2022 Warperup survey specifically canvassed landholders with streams on or passing through their properties.

Opinion polls usually raise further questions about community perspectives and attitudes. For example, the low ranking for tourism in the 2020 survey mentioned earlier, coupled with an appreciation of the Stirling Range as a local environmental asset, implies a disconnect in how different sectors of the community relate to the broader landscape. It also implies a degree of disconnection between farmers involved in agricultural enterprises and the viability of various businesses within the towns. Therefore, improving understanding and support between the various community sectors would be beneficial for the catchment community and can influence how the quality of the catchment landscape is valued. These values also flow on to visitors and can also impress external agencies.

To date, waterway rehabilitation projects across the SW have benefitted greatly from or even depended on the tireless efforts of NRM project coordinators for their implementation, and in many cases community volunteer input. The main trunk of Warperup Creek and almost all the tributaries flow through private properties. Landholders have generally been willing for agency people, consultants, and volunteers to be involved on their properties, provided the projects have been properly negotiated and are overseen by a local and credible NRM group. For these reasons, NSPNR project coordinators require time and opportunities to engage with individual landholders regarding progress with managing their sections of the waterways. The capacity to do this will be an essential component of a strategic plan. For the plan to be efficient and effective, funders will need to reconsider the role of NRM Project Coordinators in terms of the demands of funding application process, project administration and reporting requirements. These can occupy large portions of the working week at the expense of community engagement. Consideration can be given to how NSPNR can influence the way state funding bodies do NRM.

Public spaces such as nature reserves are few although some have a stream passing through them. Figure 28 below shows the distribution of reserves in the Warperup. Streams within reserves also require management given the external pressures impacting them. NSPNR may find it beneficial to determine the environmental status of the reserves, their current condition and to gauge whether they can provide educational opportunities which demonstrate pre-clearing environmental values. The reserves may also provide opportunities for community events oriented to members of the Ongerup and Borden town communities.

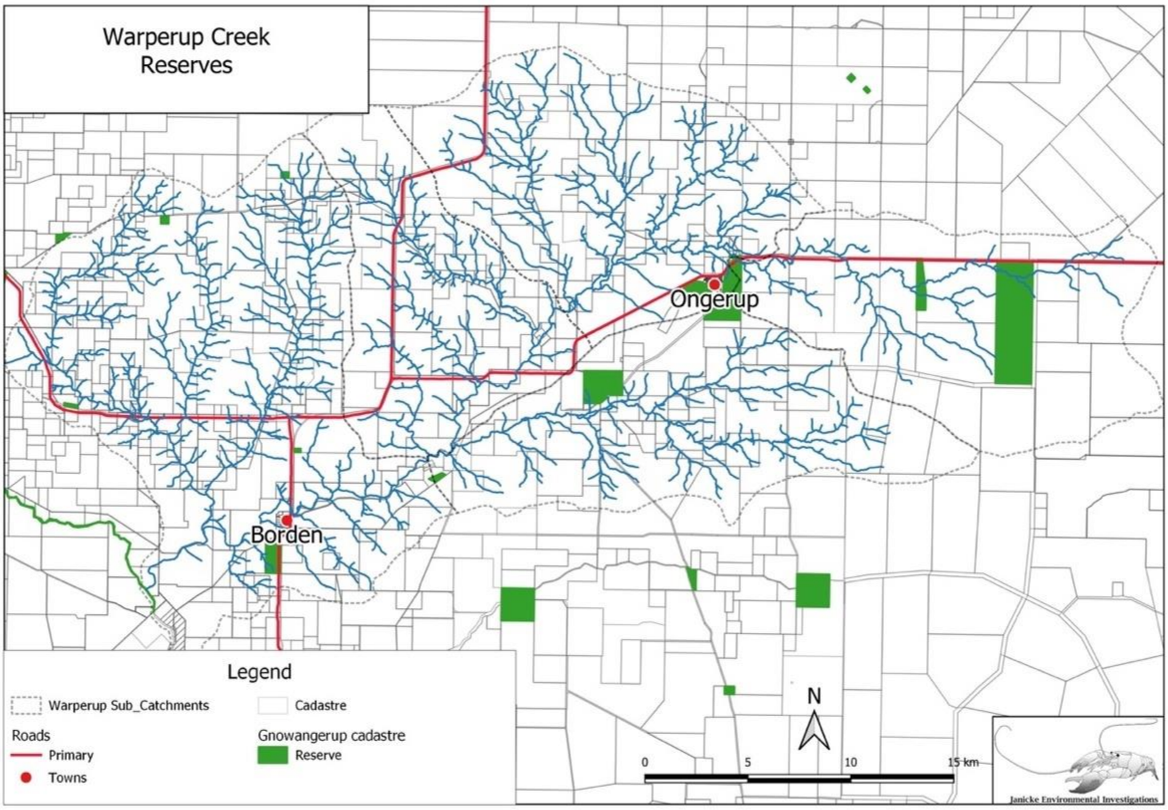


Figure 28: Nature reserves in the Warperup Creek catchment

Community engagement at the sub-catchment Level

The feasibility of engaging all the landholders within the Warperup Creek catchment is complicated by many factors:

- Logistical difficulty in engaging landholders in planning and strategic catchment management is increased when the perception is that the issues are not "on their turf".
- The factors impacting one sub-catchment may be quite different to those impacting another. For instance, salinity may be more of an issue in the Ongerup sub-catchment than in the Coromup sub-catchment.
- Most landholders are aware of who their neighbours are but are possibly less interested in entering into discussions with landholders who are perceived as being distant.

Discussion point: Engaging landholders in group catchment management discussions at the sub-catchment and neighbourhood level will involve more liaison by Natural Resource Management Officers, however, it has greater potential of achieving meaningful outcomes at the sub-catchment level.

Table 6 shows that the number of potential landholders in the sub-catchments ranges between 9 and 27. These figures are not current and possibly slightly inflated as ownership changes and some of the names include family members of a farm managed corporately.

Coromup sub-catchment is quite large in terms of number of possible landholders, area, and length of streams. There is potential to divide it further into the Long, Allen and Coromup Creek sub-catchments for the purposes of developing sub-catchment management plans which fits a strategic approach.

Table 6: Approximate number of landholders within each sub-catchment and their surveyed willingness to participate in catchment management discussions.

	Coromup	Peedillup	Peerup	Ongerup	Upper Warperup
Number of potential landholders *	27	9	13	17	13
Surveyed and willing to participate in discussions.	7	5	4	5	5
Surveyed and not willing to participate in discussions.	1	-	2	2	-

*Note: Landholder names came from an old Cadastre database and there will have been changes to property ownership and succession to family members in that time. These figures are to give an indication for planning purposes.

A Long-Term Monitoring and Data Management Framework

The ingredients suggest for a water condition monitoring framework for the Warperup are elaborated in *Supplement 3 – Warperup Creek water condition monitoring framework*. The justification for environmental monitoring as discussed in this report rests on the simple idea that systematic observation is an essential requirement for understanding how an ecosystem functions and understanding how it functions is essential for managing it well. Observations stand the test of time if they are made and recorded in a systematic way and are readily available for the local community. A systematic approach can also make room for more sophisticated investigations which can greatly increase understanding of natural processes, in this case, the Warperup waterways.

The aim of a well-designed waterway condition monitoring plan is to facilitate consistent and economical collection of data which will be relevant to planning future waterway rehabilitation projects rather than being defined by them.

Learning From Past Projects

Past on-ground rehabilitation works provide a wealth of information about what worked and what did not. This information is valuable for determining the success or otherwise of past on-ground works and for ensuring that revegetation methods can be refined. This will involve site visits and assessments and discussions with landholders. Fortunately, project sites can be revisited when convenient and in no particular time frame or order. It is suggested that a most important part of a strategic WCIP will the recording of information, storing it and ensuring access to it in the future. This is the end point a data management framework. This will require the routine use of the GIS database as a repository for waterway condition data. The database then provides a source of information for strategic planning, community reporting and supporting funding applications.

SECTION 4: WHAT CAN BE DONE?

The information presented in this study indicates that substantial improvements to the waterways can be made, but incrementally over time periods measured in decades rather than irregular project funding terms. Ongoing pressures on the waterways will mean that whatever waterway improvement works are undertaken will require some level of ongoing management as an accepted part of farm plans. Aside from logistical considerations of time and effort for undertaking rehabilitation of waterways, the issue of funding and economic value underpins much of the motivation to carry out works.

Management Approaches

The three waterways management options which were suggested at the beginning of this study were:

APPROACH A: *What can be done has largely been done and the waterways can be left to fend for themselves perhaps with a bit of vegetation maintenance here and there.*

The GIS assessment suggests otherwise and shows there is a lot of room for improvement. Although the main channel of the Warperup is the most obvious part of the network of waterways and is important, the many small tributaries are equally important for regulating the impacts of floods and determining waterway condition downstream. The assessment of the natural drainage network indicates there are many reaches for all six stream orders, requiring rehabilitation.

APPROACH B: *Rehabilitation efforts continue in the same vein as previous projects with the aim of filling in gaps as opportunities arise.*

APPROACH B would logically be included in a strategic approach to waterways condition improvement.

The stream orders identified in the GIS analysis provide a useful division of the waterways for determining what level of intervention may be sufficient and appropriate at each.

Although first order streams (totalling 583 Kms) represent the greater proportion of catchment streamlines by length (55%), not all will necessarily need proactive rehabilitation and a reasonable portion have already been enhanced. Some streamlines identified by aerial interpretation will be cropped or grazed and it may be quite sufficient to maintain grass or stubble cover to help reduce the risk of gully erosion. Biodiversity enhancements would not apply in these reaches.

Research on the east coast has demonstrated that grasses can be quite effective at stabilising smaller stream channels if it is able to grow to maturity, and particularly if it is not grazed (Rutherford et al) [11]. However, if a distinct gully has formed then stabilisation of the channel may be improved by creating a vegetated buffer strip of native plants along the channel verge.

Aerial image interpretation was not able to resolve which first order streams would benefit most by specific management actions and on-ground assessment would be required. The tables and pie charts represent best estimates of the state of the waterways at the catchment scale.

It is suggested that the standard practice of revegetating the fringes of channels is well suited to all orders of streams and will likely be sufficient for improving the structure and biodiversity of first order channels. Second order streams will generally have a distinct channel but depending on the width may

[11] Principles, for riparian land management Chapter 6 -The influence of riparian management on stream erosion. (2007) by Ian Rutherford.

also benefit from a simple vegetated buffer. Higher order streams will require additional work within the floodway, and this is a focus for pursuing Option C.

APPROACH C: *Further strategic ecological goals and new management methods are developed to improve the entire waterways network.*

The higher order streams (3 to 6) present more complex situations since revegetation on the riparian verges is further removed from the active channel, flood terraces and erosion-sedimentation prone areas. The management of these zones presents rehabilitation challenges since reliable methods have not been sufficiently developed for South Coast catchments.

The inner riparian areas of higher order (3 – 6) streams, those which occupy the lower areas of the catchment, include flood plains, terraces, meander bends, steep banks, active channels, pools, rocky outcrops and patches of remnant vegetation. These areas present logistical problems for access and rehabilitation. They do not lend themselves to the mechanised approaches used on open ground on the fringes of the riparian zone or adjacent flats and valley slopes. However, a rehabilitation aim can simply be to infill these areas, aiding natural regeneration and actively increasing vegetation density.

As mentioned, this is an area of waterways improvement which is not well developed and will require innovative approaches and experimentation. The current methods of assessing rehabilitation progress, are kilometres of fencing and area revegetated, which are the usual indicators of project outputs are not applicable in these areas. Effective rehabilitation will use concepts such as *infill planting*, *site stabilisation, bank armouring, habitat reconstruction, flood resilience, controlled grazing and so on.* The desired outcomes are not easily quantifiable, and for this reason, ongoing assessment of the ecological outcomes will be important since what is happening in the inner parts of the creeks can be 'out of sight and out of mind'.

In terms of weeds and feral animals it will be necessary to accept certain compromises. For example, stabilising stream beds and banks and flood terraces will mean accepting some level of presence of these species and in the long term, a lesser level of native biodiversity. Many introduced plants are now well-established, and eradication is no longer feasible nor a good use of resources. The emphasis will shift to encouraging local species that can adequately compete with them.

Dealing with Bank and Bed Erosion

Stream bank erosion is a natural process and erosion sites are expected features of waterways, but erosion becomes a problem when a channel can no longer accommodates storm runoff from the catchment (See Figure 29). This occurred when catchment rainfall runoff increased due to land clearing and can happen if the climate gets wetter.

Figure 29: Left: A second order tributary to the Peerup-Meenup Creek. Right: Allen Creek, a fourth order stream. Both would benefit with localised revegetation to minimise channel erosion.

Floods create and maintain river pools, but this process has been interrupted in the Warperup due to too much sediment in the system. Flood energy is expended in shifting sediment, widening channels (Figure 29), cutting new channels across bends, and excavating soil from terraces and floodplains. Vegetation acts to moderate flood velocities and for that reason is the engineering material of choice to make the inner areas of the floodway more resilient.

Granite outcrops are seen throughout the Warperup catchment and basement rock appears to be mostly near the surface. This suggests channel widening as a source of sediment is of greater importance. Observations suggest that channel widening does appear to be significant but is not uniform in the Warperup waterways. The channel banks appear to be the predominant erosional areas and this accords with research findings in cleared catchments elsewhere in Australia. Indications are that the Warperup has most likely passed its period of primary enlargement following catchment clearing and there are signs that the major floods which occurred during the twentieth century have resulted in enlarged channels and these are now capable of handling larger flows. If this is so, and there are indications that it is, then many erosion hotspots may be largely a product of local bank weaknesses, and this can be improved by planting resilient species such as the Sheoaks (Figure 30).

Figure 30: At this site near Borden, Sheoak have naturally seeded onto clay-based erosion scours, aided by a thin layer of sediment.

Figure 31: Warperup main channel downstream of Hart Road with Salt-water paperbarks (*Melaleuca cuticularis*) colonising the active channel. Other locations may just need a bit of help.

Salt-water paperbarks *(Melaleuca cuticularis)* is a coloniser of active channels. However, in-stream patches of Salt-water paperbarks tend to deflect high flows into adjacent banks potentially creating new erosion hotspots.

Extensive sediment deposition in the active channels as a result of bank erosion is the dominant degrading factor of the aquatic environment of Warperup Creek and its tributaries, and this has likely impacted aquatic biodiversity. The waterways can benefit from local rehabilitation works to reduce 'topping up' the existing excessive sediment that has been dumped in the streams. Floods will continue to exploit weaknesses in the banks and improving waterway condition would therefore involve increasing the stability of stream banks using tree and shrub species which can readily recolonise these areas.

Rutherford (et al)[12] has concluded that:

- *At catchment scale, the cumulative effect of riparian revegetation is to increase flood stage (depth) and duration in headwater streams (where flooding is usually not a problem anyway), but decrease flood stage in larger streams, further downstream, where flooding may in the past have been a problem (local-scale versus network-scale effects).*
- Although all streams erode*, streambank erosion is a dominant source of sediment in many river systems.*
- *A consistent conclusion of the research is that about 80% of the sediment in a catchment is generated from just 20% of the area of that catchment, be it from gullies, stream banks or steep lands. These sediment sources are called 'hotspots' of sediment production.*

One promising option is the use of sedges (such as Sea Rush, *Juncus kraussii*) along active channels. Figure 32 shows a view of Gnowangerup Creek below the bridge on the eastern edge of town. The bare riparian verge was revegetated some years ago. Sedges have colonized the bed unaided and are common upstream of the town centre. Sedges have the useful property of laying flat during floods and therefore do not significantly impede the flow. Their dense root system holds them in place as well as armouring the soil. The sedge bank shown mid-channel is deflecting flow into the banks on either side and it is these areas which would also benefit from their stabilising influence. Transplanting may be a simple and effective technique for increasing the stability of the banks.

Figure 32 : Gnowangerup Creek revegetation site with Sea Rush (*Juncus kraussii*) colonising the bed.

[12] Ian Rutherfurd, Brett Anderson, and Anthony Ladson. Principles, of Riparian Lands management. Chapter 5: Managing the effects of riparian vegetation on flooding and Chapter 6 -The influence of riparian management on stream erosion. (2007)

The historical photograph near Ongerup taken in the 1930s (Figure 6) shows a clump of native sedges and implies these were present prior to clearing. Why these have vanished is uncertain but stock grazing and displacement by Veldt Grass and other weeds are implicated.

Dense swaths of Samphire can also be effective at stabilising wide stream beds. Figure 33 below is an example on Coromup Creek. However, it has been observed that Samphire can be more easily dislodged or killed by powerful floods. On the plus side, it can rapidly recolonise floodway flats.

Figure 33: Dense Samphire colonisation along a reach of Coromup Creek (stream order 4).

Dealing with Sediment

The most obvious feature of the streams in the Warperup catchment is the massive amount of sand and silt in the system. These form into long sediment slugs that are moved slowly downstream. Large amounts can be deposited where the floodway slope lessens such as in the 5th and 6th order waterways. Pools are filled (such as shown in Figure 23 and Figure 24) and the shallow water reduces variations in aquatic habitat and increases water temperature, which impacts the aquatic life. Features such as deep holes, logs, fringing vegetation, and variable water temperatures are lost. Figure 34 shows examples of sediment moving downstream in a 1st order, 3rd order and 6th order waterway in Warperup catchment.

One of the most significant examples of infilling of river pools can be observed adjacent to the Borden Golf Club. Figure 34 shows historic images from around the 1930s which were brought to the community event “Stories of the Pallinup” in Borden on 25th of July 2017. The pool was reportedly up to 24 feet deep and long enough to allow for the activities of the Borden Sea Scouts. The pool no longer exists.

> *“That is the Warperup and the Sea Scouts and according to Uncle Graeme again, who I spoke to today, it was 24 feet deep. He said you couldn’t touch the bottom and couldn’t dive down. They used to do swimming races there and sailing. (Where on the Warperup?) At the Golf Club. There are still some sleepers there where there is, like a landing stage.”*
>
> *Richard Milne: (Transcripts of Stories of the Pallinup River) As related at a community event “Stories of the Pallinup” in Borden on 25th of July 2017.)*

A significant improvement to the aquatic characteristics of higher order waterways would be the deepening of pools. Large floods can accomplish this naturally over time provided sediment input from upstream is reduced to naturally manageable levels.

Figure 34: Sediment deposition in a number of waterways in the Warperup catchment. Top left: A 1st order tributary to Peerup Meenup Creek. Top right: A 3rd order section of Ongerup Creek. Lower image: A 6th order section of the Lower Warperup Creek.

The option of employing mechanical removal of sediment has been suggested. Mechanical removal has been undertaken along the Avon River and a report to Wheatbelt NRM in 2011 by the Department of Water and Environmental Regulation, discusses the ecological impacts of the removal.[13] Unfortunately, the conclusions were indecisive due to lack of adequate data prior to removal. The mechanical removal of sediment poses problems apart from cost.

Excavators can promote further erosion by destroying existing vegetation in the floodway and disturbing the soil surface. Once sediment is removed it will have to be relocated higher in the landscape out of the path of subsequent floods.

There may be merit in revegetating some sediment plumes to increase their resistance to floods and slow the movement of sand. The 2017 storm event demonstrated the power of the flood to overwhelm even well anchored trees and shrubs, and as a result revegetating sand slugs carries a higher risk of failure.

[13] Assessment of the ecological impacts of sediment removal at Gwambygine Pool, Katrine Pool and Reserve Pool. Unpublished report to Wheatbelt NRM. Department of Water. September 2011.

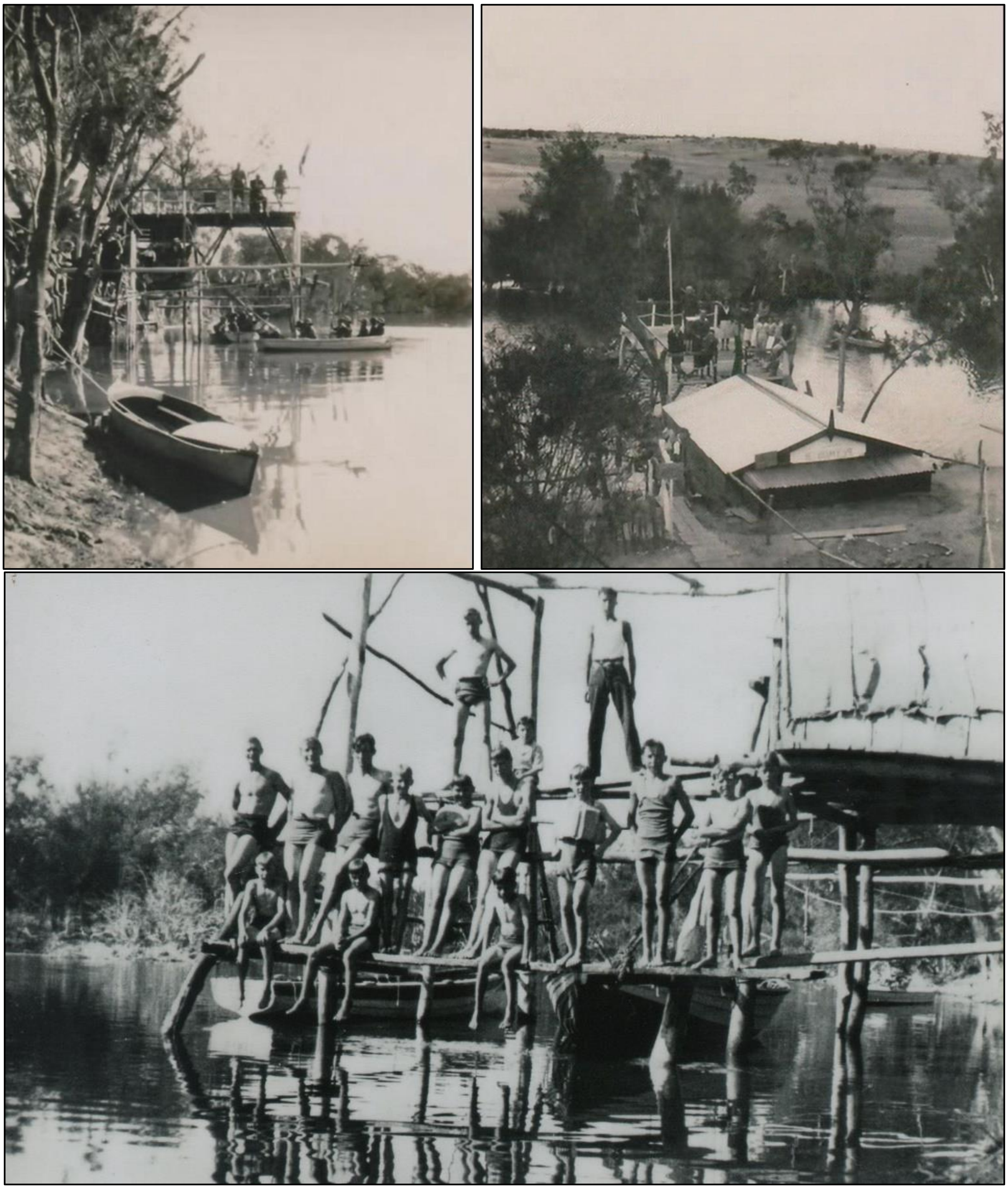


Figure 35: "That is the Warperup and the Sea Scouts and according to Uncle Graeme again, who I spoke to today, it was 24 feet deep. He said you couldn't touch the bottom and couldn't dive down. They used to do swimming races there and sailing. (Where on the Warperup?) At the Golf Club. There are still some sleepers there where there is, like a landing stage." Richard Milne: (*Transcripts of Stories of the Pallinup River*) As related at a community event "Stories of the Pallinup" in Borden on 25th of July 2017.)

Improving Riparian Biodiversity

Figure 36: Examples of reaches lacking riparian habitat diversity. Top Left: First order tributary to the Peerup-Meenup Creek. Top Right: 2nd order tributary to Lower Warperup Creek. Lower left: Ongerup Creek, 2nd order. Lower right: Lower Warperup Creek, 6th order waterway.

Increasing habitat diversity through biodiversity plantings within wide floodways provide feasible opportunities for a variety of other flora and associated fauna to re-establish. Insects, reptiles, native fish, birds etc. are sensitive to the availability of habitat as well as to food sources. Increasing habitat diversity facilitates the introduction of critical links in the food chain.

Opportunities for improving the ecological character of the Warperup waterways, besides verge revegetation can include establishing plants such as Sea rush (*Juncus kraussii*), that overhang the stream banks and even relocating logs to bare areas where they are not easily moved by floods. Jam (*Acacia acuminata*) is also a vigorous re-coloniser of flood terraces and verge slopes, provided stock are excluded.

A criticism of riparian revegetation is that it provides habitat for feral animals, namely foxes, feral cats etc., or encourages kangaroos. However, improving physical habitat does not directly increase breeding but increasing food sources does. The domesticated farmland has a more significant influence on populations compared with increasing the quality of places where animals can lay low during the day or night. There may be value in researching the reality of these assertions and projects could suit university honours or PHD students.

Improving Water Quality

Salinity - What would improvement look like?

Annual rainfall has a strong influence on surface water salinity values with the 2020 spring conductivity values substantially higher than in the subsequent 2 wetter years. This level of sensitivity means that using salinity to demonstrate improvements in water quality requires data to be gathered over a long period of time. In addition, seasonal monitoring would be required, and this would mean a minimum of 3 sampling events per year.

The requirements for reducing salinity levels remain unclear but are probably untenable from a land use perspective. The ecological value of pursuing such a goal for a naturally saline system is also questionable.

Given the variability of salinity levels between seasons and years, its use as an indicator of waterway condition improvement is negligible, but it does contribute to better understanding of the hydrological functioning of the catchment. Salinity levels are therefore useful and are relatively simple to monitor.

Acidity - What would improvement look like?

The 2020-2022 pH values from the upper Warperup catchment were tending to the acidic indicating there is potential for further acidification of the waters although the degree of risk is uncertain. Of concern is the acidification for the upper pool at site PAL510. This pool has not been impacted by high levels of sediment infill and otherwise seems to be in reasonable condition. There are many salt scalds on the upstream channels and pH offers a convenient and economical way to assess this groundwater influence on the pool and to monitor interventions.

pH values varied considerably across the seasons suggesting a dependency on seasonal and even weekly rainfall. No reliable conclusion can be made regarding a trend in pH over the twenty-two-years from 2000 - 2022. If consistent low level annual monitoring is not feasible, there is a case for another short term (2 to 3 year) seasonal monitoring program to collect data to compare with the 1998-2000 values at the PAL500 & PAL510 sites. The saline surface waters of South Coast River systems are typically basic, and rather than an improvement, maintaining a pH greater than 6 to 7 may be an adequate goal.

Nutrients - What would improvement look like?

Nutrient pollution can compromise aquatic ecosystems directly and indirectly. The most common problem is the growth of cyanobacteria (a component of benthic algal mats) and phytoplankton blooms which can dominate and change the dynamics of an aquatic ecosystem.

TN:TP ratios for the 1998-2000 and 2020-2022 water samples were generally high implying that Phosphorus concentrations are an important limiting factor with respect to eutrophication risk. Thus, controlling Phosphorus inputs would be important for managing eutrophication risk in the waterways.

Nutrient input to the waterway is via two pathways, surface run-off and ground water flow. Phosphorus comes in several forms, as phosphates, organic phosphorus and attached to sediment. Changes in on-farm nutrient management such as soil testing and fertiliser management have been shown to reduce phosphorus inputs into waterways. Riparian vegetation, including perennial grasses, can trap sediment and nutrients coming down the slopes.

The goal would be to reduce nutrient levels in the waterway to below moderate levels as defined in the Department of Water and Environmental Regulation FARWH Report No. 39[14].

Table 7: Nutrient levels as defined by Department of Water and Environmental Regulation FARWH Report No. 39.

	High	Moderate	Low
TN	2 mg/L	1.2 mg/L	0.75 mg/L
TP	0.2 mg/L	0.08 mg/L	0.02 mg/L

Improving Aquatic Biodiversity

Since saline rivers are a natural feature of the South Coast of WA, the aquatic fauna including those which live in Warperup Creek are adapted to varying levels of salinity. The greatest threat to aquatic biodiversity for the Warperup is the movement of excessive amounts of sediment into and within the waterway. These impacts include:

- Reduced depth of pools making them susceptible to higher temperatures over summer.
- Conditions favouring exotic species such as Gambusia.
- Reduced habitat diversity in the pool with aquatic vegetation being smothered.
- 'Sand blasting' of the aquatic fauna during high flows.
- Proliferation of algae and bacterial mats.

The addition of channel verge vegetation potentially helps to shade the waterway, keeping water temperature within the boundaries of liveability for a range of aquatic fauna. Leaf litter and woody debris falling into the waterway provides food sources and habitat for aquatic micro and macro-organisms.

A positive observation at the reference sites was that ducks were frequently seen during the 2020 – 2022 site visits. This implies the river pools still have sufficient aquatic fauna to attract them. Other birds were also observed, and this implies that improvements to habitat and food sources will help maintain populations.

Areas to focus on for rehabilitation are those sections of waterway which are:

- in sandy or otherwise easily eroded soil types.
- bare of trees and shrubs
- have low density vegetation i.e., occasional trees over grasses
- are second order streams or higher

It was observed that deep sands are common along the lower reaches of the Warperup. Revegetation works to reduce sediment entering the waterways could initially focus on areas with sandy or easily eroded soil types. Information regarding the location and extent of these areas was not available to the authors and will have to be determined at a farm and sub-catchment scale through discussion with landholders.

[14] Storer, T, White, G, Galvin, L, O'Neill K, van Looij, E & Kitsios, A 2011, *The Framework for the Assessment of River and Wetland Health (**FARWH**) for flowing rivers of south-west Western Australia: project summary and results, Final report*, Water Science Technical Series, **Report No. 39**, Department of Water, Western Australia.

Aquatic diversity - What would improvement look like?

A study of south coast rivers[15] found that site species diversity in the saline rivers ranged between 4 to 38 species. The highest species diversity at site PAL509 was 21 and implies there is potential for increasing the species diversity in the Warperup.

Salinity has a major influence for aquatic diversity and species composition[16] . Warperup Creek and its tributaries will remain saline to varying degrees with salt tolerant macroinvertebrates continuing to dominate. Other factors that influence aquatic diversity and composition are habitat diversity and acidity.

The infilling of the river pools with sediment and the rearranging of sediment during high flows reduces habitat diversity and thus species diversity. Actions that reduce bank erosion and sedimentation in the waterway will help to enhance species diversity.

Pool depth is an important habitat factor, providing zones of different temperatures which in turn will favour a greater diversity of aquatic macro-invertebrates and native fish. The introduced pest fish Gambusia enjoys warm, shallow saline waters and is a threat to native fish populations. Reducing its preferred habitat can qualify as an improvement to the aquatic biodiversity.

Carbon Farming and Waterways Health

NSPNR in conjunction with the Gillamii Centre have been successful in attracting funding for a joint project called Restoring an Ancient Landscape - Through Community & Carbon (2021 – 2023). The project aims to restore 550 hectares of large-scale, high-value, biodiverse vegetation on private properties that have been strategically selected to improve areas which are critical to ecosystem function.

Carbon Farming is being actively promoted across Australia to improve the rate at which carbon dioxide is removed from the atmosphere and stored in plant material. This process has been linked to the wider economy in the negative sense that increasing levels of CO_2 in the atmosphere will change the climate and associated powerful, weather events will adversely impact agricultural production.

Landscape management purely for environmental benefits can be viewed as a liability on the farm balance sheet, but carbon farming offers a stronger link between desirable features of the natural environment and economic necessities. A robust synergy between environmental care and farm profitability is an attractive goal and one which has eluded natural resource managers in the past.

The early adopters of carbon farming will likely consider it in a plantation or cropping sense. From the perspective of waterways rehabilitation and because vegetation is the engineering material of choice, consideration can be given to determining whether rehabilitation of riparian zones offers opportunities for increasing carbon farming income. However, a model for costing fragmented on-ground works would need to be developed. Areas which may provide benefits both ways are wide uncropped flats (as in Figure 37) and largely denuded flood prone areas adjacent to streams.

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[15] Cook, Janicke, & Maughan, (2008). *Ecological values of waterways in the South Coast Region, Western Australia*. Report No CENRM079, Centre of Excellence in Natural Resource Management, University of Western Australia. Report prepared for the Department of Water.

[16] Pinder, Halse, McRae and Shiel (2004) *Aquatic invertebrate assemblages of wetlands and rivers in the wheatbelt region of Western Australia* Records of the Western Australian Museum Supplement No. 67: 7–37 (2004).

Figure 37: A broad uncultivated area adjacent to a creek that is a potential carbon farming site.

The benefit for waterways is that Increased tree cover can act to lessen flood power, reducing floodway erosion and encouraging the re-formation of deep river pools. Of course, these areas often set aside for stock management purposes.

Carbon farming also has the potential to mitigate fertiliser run-off and sub-surface flow, thus reducing nutrient inputs into the waterways. This study did not consider the requirements or viability of carbon farming in degraded riparian areas but suggests the subject should be given due consideration.

Large Woody Flood Debris

Figure 38: Snag piles along the lower Warperup Creek

Large floods in the Pallinup catchment have mobilised dead wood and this is eventually lodged against trees creating snag piles (Figure 38). This is most evident in the lower catchment areas. Although these are common in the waterways most are minor and are a natural feature. However, since some snag piles keep accumulating, they may be a liability by increasing flood pressure against living trees and increasing the risk that they are pushed over. This can in turn, deflect flows into otherwise stable banks creating local erosion hot spots (Figure 39).

Dead wood is a common feature of bushland and from an ecological perspective, standing or fallen, it forms an important ecological function by diversifying habitat for the numerous, small but important creatures which also contribute to the biodiversity of the waterways. Decomposing wood slowly adds nutrients to the soils encouraging a wide range of micro-organisms. It can be appreciated that the critical factor for sustaining a biodiverse system is continuity in the food chain. A preoccupation with reinstating trees only, misses the critical role of a multitude of less obvious parts of the ecosystem and the connections between them.

The removal of logs from streams is generally discouraged since it does not reduce the risk of erosion but rather amplifies it by increasing water velocities. Logs create turbulence and effectively reduce the average velocity of low to high flows. The lower the water velocity the less its power to erode bed and banks. The trade-off is that reduced velocity can increase flow depth and hence the area flooded. This may or may not be an issue at the reach scale.

Figure 39: Debris piles, including newly fallen trees blocking the active channel on the Middle Pallinup following the 2017 flood.

The easier, and cheaper solution is to reorient a log to redirect flow back to the middle of the channel, rather than removing it. There is a case for relocating or reorienting excessive accumulations of wood which threatens to damage trees or deflect flows into banks causing unnecessary erosion (Figure 40).

Excess wood could be relocated to help protect already eroded areas or dragged to the riparian verge where it can enhance habitat opportunities without being exposed to floods strong enough to remobilise the material.

Figure 40: The snag pile shown above in 2001 (Right) and increased in size (Left) after the 2017 flood. This has pushed the low flow channel further to the left side of the floodway.

Vegetation Status Against Stream Order

Table 8 shows the lengths of waterway that are bare of trees and shrubs or have varying density of riparian vegetation for each of the stream orders. The minor first order swales are situated mostly in paddocks that are either cropped or grazed and not all will necessarily need proactive rehabilitation. It may be quite sufficient to maintain grass or stubble cover to help reduce the risk of gully erosion. Biodiversity conservation measures would not apply in these reaches.

All swales, gullies and creek lines that are bare, potentially contribute sediment and nutrients into the waterway network. The length of streams of order 2 and greater which are bare of trees and shrubs add up to approximately 83 kilometres (coloured orange in Table 8). Where occasional trees or low density vegetation have been left along the minor swales and gullies (first and second order streams) it implies their existence is an accepted part of the farming landscape. These sections are of strategic value for revegetation works and add up to approximately 192 kilometres (coloured yellow in Table 8).

All the higher order waterways with low density vegetation provide opportunities for revegetation works and these add up to a further 110 kilometres (coloured grey in the Table). The lengths of stream requiring rehabilitation add up to large areas and may seem unachievable, at least in the short to medium term. However, when these lengths are divided between the main sub-catchments of Warperup Creek, the scale of works appears achievable.

Table 8: Vegetation density by stream order for the Warperup catchment

Stream Order	Bare of trees/shrubs	Low Density	Moderate Density	Dense	Total kms
1	312	124	106	42	583
2	59	69	73	33	233
3	12	42	43	3	100
4	6	29	42	3	81
5	5	18	10	5	37
6	1	21	7		29
Total kms	395	302	280	86	1064
Focus sections (kms)	83	192 110			

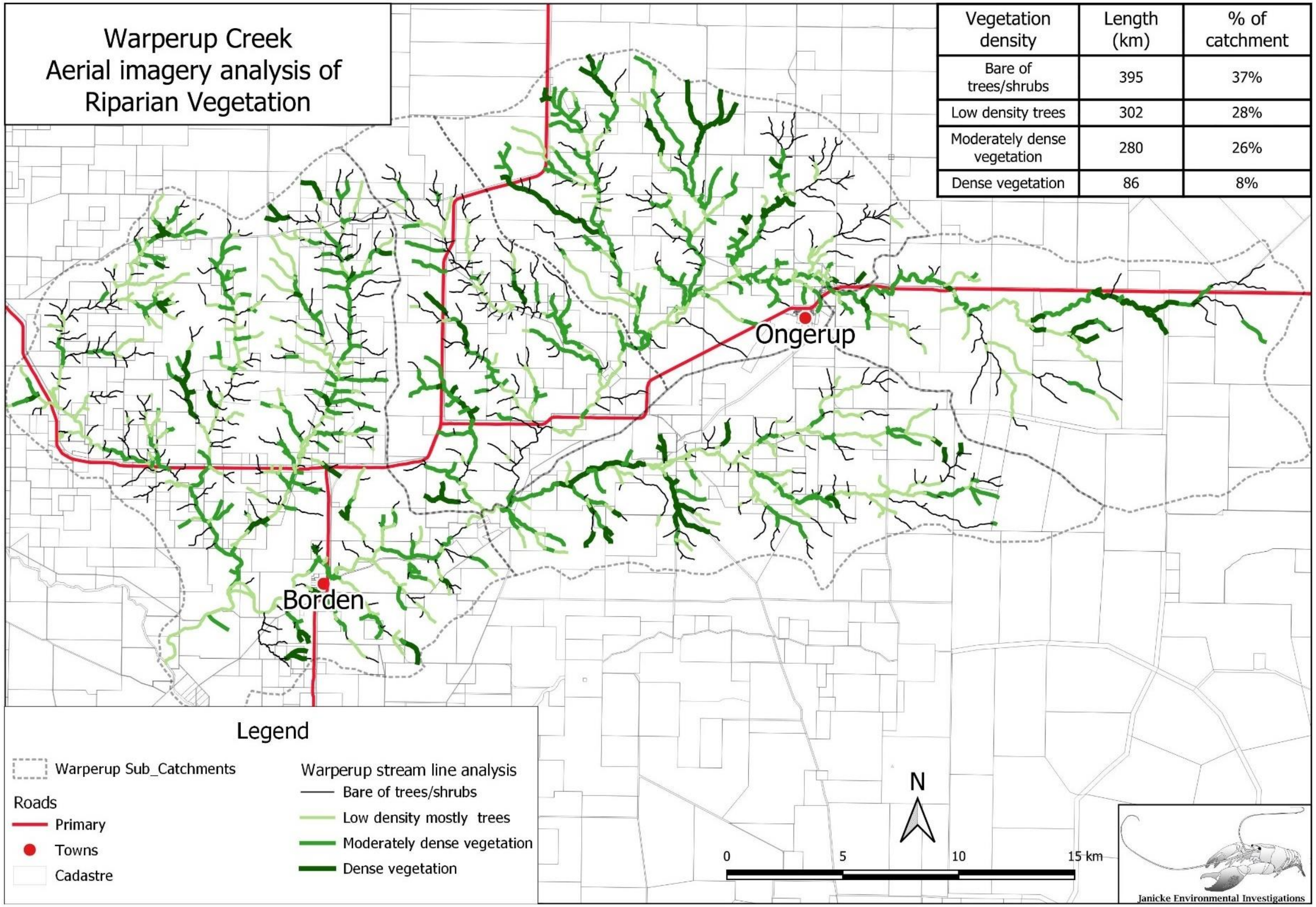
Vegetation Status for Each Sub-Catchment

The vegetation status against stream order for each sub-catchment is given in Table 9. These figures can help refine stream sections that are strategic with respect to revegetation works.

Table 9: Lengths of streams that are bare or with low density vegetation within each sub-catchment

	Coromup		Peedillup		Peerup		Ongerup		Upper Warperup	
Stream Order	Bare	Low density	Bare	Low density	Bare	Low density	Bare	Low density	Bare	Low density
1	124	53	51	27	55	6	57	27	25	11
2	26	27	8	11	9					
3 and 4	5	35		15	6	17	14	21	5	14
5 and 6	1	20		9	5	6		4		

Note that the 5th and 6th order stream lengths in the Coromup sub-catchment consist of the main channel of Warperup Creek and a section of Maileeup Creek (which is the coming together of Allen, Long and Coromup Creeks). These sections have considerable movement of sand during moderate to high flows as seen at monitoring site PAL500 adjacent to Maileeup Road.



Vegetation density	Length (km)	% of catchment
Bare of trees/shrubs	395	37%
Low density trees	302	28%
Moderately dense vegetation	280	26%
Dense vegetation	86	8%

Figure 41: Map of Warperup Creek catchment with density of riparian vegetation colour coded.

Research Opportunities

Extensive research into agricultural productivity at a whole of landscape scale, including water resources, has helped moved the issues of general environmental health from the sidelines into mainstream economic planning. Environmental issues have also widened community concerns at a regional, state, and national level. Research brings critical issues of concern to the attention of the public, agencies, enterprise professionals, academics, and politicians. This attention is a potential benefit to rural areas rather than a threat to the sense of independence which farmers value.

Research has the capacity to reveal unique aspects of the environment which have been overlooked or poorly understood. Researchers are attracted to cooperative communities who have a good understanding of their environment and who are custodians of reliable environmental data. This can in turn lead to innovative projects which can benefit the local community. The Yongergnow Centre at Ongerup which showcases the conservation of Mallee fowl in the area, is a case in point.

While farm productivity is a pivotal consideration for viable agricultural communities, it is not the only factor affecting the health and liveability of people living in rural areas. Concerns about physical and mental health in country areas has highlighted this fact. Research has shown that there is an association between dryland salinity and depression, indicating that environmental degradation may be aggravating ill-health in these populations[17]. Other potential human health impacts of dryland salinity are wind-borne dust and respiratory health; and altered ecology of mosquito-borne disease Ross River virus[18]. Waterways are implicated in these issues and the role which these, whether in proper ecological function condition or degraded, is an area of research that could be relevant to the adoption of a strategic waterway condition improvement plan.

The literature review indicated that environmental data for the Warperup is sparse, but the catchments setting on the South Coast is in a part of Western Australia that is attracting strong state, national and even international interest. The changes to the landscape which have compromised the condition of the waterways are relatively recent and for this reason there is an opportunity for South Coast catchment communities to be at the forefront of water management research at all levels. It is suggested that this opportunity should not be wasted in the Pallinup River catchment.

The Warperup catchment is well suited to attract research into waterways function, rehabilitation and management and human health in rural areas of the SW. The moderate size of the catchment makes this an achievable goal. Collaborative research projects often attract further funding.

17 Speldewinde, P., Cook, A., Davies, P. and Weinstein, P. (2009) *A relationship between environmental degradation and mental health in rural Western Australia.* Health & Place 15, 880-887

18 Jardine, A., Speldewinde, P., Carver, S. and Weinstein, P. (2007) *Dryland Salinity and Ecosystem Distress Syndrome: Human health Implications* EcoHealth 4, 10-17

CONCLUSIONS

All three potential ways forward, itemised as approaches A, B & C in the introduction, are shown to be feasible options, but a strategic Waterway Condition Improvement Plan does not mean that all stream orders or individual reaches require the same blanket approach.

Approach A is the ‘do nothing more’ option and has the advantage of being the cheapest and least demanding, but if applied to all streams it presents the highest risk of leading to ongoing degradation. However, it is suggested that even apart from normal agricultural practices there are waterways sections where this approach is likely to be the most realistic.

Approach B recognises that many stream reaches will benefit from continuing to extend vegetated buffers along the floodway verges and to connect these wherever possible. The aerial image interpretation discussed in Section 1 implies that there is still a large percentage of catchment streams that would benefit from this ongoing work. The experiences of landholders over the past thirty years or more demonstrates that it is feasible to continue this approach into the future and the only strategic component would involve pursuing unanimous agreement amongst landholders to buffer the streams passing through their properties where and when they can.

Approach C would require building on approaches A and B to develop new ways of improving the ecological state of the higher order (2 and above) streams. In these riparian areas incremental ‘tweaking’ of waterway features would be required, to enhance floodway stability and biodiversity a bit at a time, over periods of decades. The current intermittent funding model is not effective for achieving improvements at this level of rehabilitation. This puts a strong case for developing a compelling, strategic vision within the community, one which can be presented to agencies and funding bodies.

Consideration would need to be given to the idea of developing cooperative arrangements within sub-catchment landholder groups to achieve consistency and longevity of a WCIP. NSPNR is well placed to facilitate engagement between sub-catchment groups.

In practical terms, improvements in riparian condition for Warperup waterways can be broadly defined and achieved by,

- Increasing erosion resistance in the riparian zone using suitable infill vegetation,
- Increasing physical terrestrial and aquatic habitat diversity
- Increasing native understorey plant species diversity.

Each of these improvements is co-dependent with the other two.

All degraded streams can benefit from verge revegetation and for low order (1st and 2nd) streams this may represent a sufficient improvement.

Verge revegetation may not be sufficient for higher order streams due to their greater width and more complex floodway characteristics including floodway terraces, uneven slopes, rocky outcrops, and the structure of the active channel. This is an important area for rehabilitation but is not well addressed by current revegetation methods. In these zones, establishing suitable perennial ground cover species will be important. For example, the use of Sea Rush to armour the ‘toe’ area of steep banks.

Tree trunk and shrub density in the floodway plays an important role in controlling water velocities during floods and hence erosive power. The capacity of the riparian vegetation and soil structure to withstand and moderate this need not necessarily mean dense plantings are required. For example, an increase in tree density by as little as 10% may provide a sufficient increase in resilience for erosion prone soils. This would need to be tested.

These works are site specific, and the geometrical positioning of vegetation is an important consideration. For example, increasing the shading of exposed pools. This is an area that would benefit from research input.

In partially vegetated areas, infill planting with understory and ground cover species will be an improvement, increasing habitat options and providing ecological links in the food chain. Experimentation will be required since flood resistance and salt tolerance will be important characteristics for any species used.

Granite basement rock outcrops occur at all 10 reference reaches and were commonly observed in streams elsewhere in the catchment. This suggests stream beds are geologically controlled and resistant to downcutting. Erosion control can focus on the channel banks and adjacent terraces and slopes. It can be noted that increasing vegetation density in the floodway tends to keep the active channel narrow and this will encourage flood flows to clear sand plumes and deepen pools working from the upper to the lower reaches of the catchment.

Pool depth is an important habitat factor, providing zones of different temperatures which in turn will favour a greater diversity of aquatic macro-invertebrates and native fish. The introduced pest fish Gambusia enjoys warm, shallow saline waters and is a threat to native fish populations. Reducing its preferred habitat can qualify as an improvement to the aquatic biodiversity.

Sedges provide significant bank armouring without impeding flood flows because of their ability to lay flat as water passes over them. However, the re-establishment of this type of vegetation requires experimentation and successful establishment will be site dependent. Other perennial grasses, and dense Samphire can serve a similar purpose in some situations, for example on broad bare flats.

Stock control, if not total exclusion, remains a critical requirement for maintaining riparian zones in good condition.

Sheoak and paperbark have been observed to regenerate vigorously on bare bank areas, especially when aided by a relatively thin layer of sandy topsoil. Paperbark will colonise a wider range of environments including sediment plumes in the middle of channels. However, because they are resistant to flood pressure this can have the adverse effect of directing flows into adjacent banks and aggravating erosion. Jam (*Acacia acuminata*) is also a vigorous re-coloniser of flood terraces and verge slopes, provided stock are excluded.

The progress of improvements in water condition for the entire catchment can be measured by determining the proportion of channels rehabilitated over time. A GIS platform facilitates this but requires trained users.

Observations of what is working naturally in various locations provides useful guidance for rehabilitation proposals. Revisiting rehabilitation project sites at 5-year or so intervals or immediately following floods will help improve rehabilitation strategies and tactics. A strategic approach should factor such site visits into a monitoring plan and provide opportunities for NRM staff to undertake such assessments in a systematic way.

Systematic Photo-Point monitoring provides a rapid condition and progress assessment method for project sites and a review of can suggest opportunities for further improvements.

Once the initial stabilising revegetation is successfully established it provides habitat opportunities for other less robust species to be added.

Relocation of large dead wood piles produced by floods can provide a resource for erosion control at specific sites. The Department of Water and Environmental Regulation (DWER) can provide guidance on methods for stabilising eroding banks.

Restricting sheep access and encampment on bare ground in floodway areas encourages grasses and Samphire to re-establish and this may be a sufficient initial improvement.

Increasing shading over pools along denuded banks is an ecological improvement.

Mechanical removal of excess sand in the active channels has been considered however the risk of soil disturbance increasing erosion risk makes this a limited option. Access into riparian areas is often difficult and if sediment is excavated it would need to be relocated out of the floodway to prevent floods putting it back.

Stabilisation of in-stream sand plumes may slow the movement of sediment downstream but requires experimentation as the plumes are loose material that is easily moved by moderate flood flows. Observations suggest Samphire will colonise sediment plumes and dense patches can resist high flows. Samphire favours the toe area of stream banks but is not particularly resilient during large floods.

Stream crossings tend to act as sediment dams where the cross-sectional area is significantly reduced. On the downstream side pipes concentrate flow and this can cause considerable bank erosion for tens of meters and up to 100 metres downstream. DWER recommend constructed crossings should avoid reducing the cross-sectional area by more than 10%.

APPENDIX 1: EXCERPTS FROM SOUTH COAST RIVERCARE CASE STUDIES

(Interactive CD ©WRC 2001, created May 2001 WRC: Steve Janicke, Photos: Angela Sanders, HTML: Kaye Stott and Geoff Prince)

Both Michael Wright and Ken Newbey were farmers in the Warperup Catchment. Their stories and those of many others on the South Coast of Western Australia were captured by the Waters and Rivers Commission (Steve Janicke, Angela Sanders and Kaylene Parker)

Warperup Creek Restoration and Protection

Michael Wright, Ongerup

"If every farmer could do a bit each year it is certainly going to help wind erosion, the environment, salt, production and add value to the farm too"

Michael Wright has managed the 3200 Hectare farm on the Warperup Creek, for the past 12 years. It was the original farm in the area and a cottage that was built in 1890 still stands there[19]. The farm is situated 9.5 kilometres southwest of Ongerup on the Ongerup-Gnowangerup Road. Eight kilometres of the Warperup Creek runs through the property before emptying eventually into the Pallinup River to the southwest. The head of the Warperup Creek is some 14 kilometres to the northeast and is fed by numerous tributaries, including the Ongerup and Meenup Creeks. The creek has many exposed granite outcrops along its length and the original vegetation included Yate, Melaleuca and Sheoak woodland. In 1997 Michael began rehabilitation of the creek using fencing and replanting.

The Problem

Michael was told that in 1955 a flood washed the creek clear of vegetation, and that prior to that people used to swim in the pools along the creek. The stock had access to the creek until 1977 and they had grazed the vegetation until the creek line was bare. Erosion of the banks of the Warperup Creek occurs mainly on the bends

The creek floods about once every four years and Michael has noticed that the bank in a bend in the creek has eroded back about five to six metres in the last 12 years. Bank erosion is also occurring to a lesser degree at other sites along the creek. Some natural regeneration has taken place in the creek line since fencing.

The Solution

To attempt to stabilise the creek and prevent further bank erosion a program of fencing and replanting along the creek line began in 1997. In September 1997 the creek was fenced on both sides leaving a corridor ranging from 50 to 100 metres wide. The corridor was direct seeded, and also seedlings were planted in three rows where possible, depending on space for the tractor and Chatfield Planter. No herbicide was used prior to seeding but the creek was baited for rabbits.

Frost killed about 30% of the seedlings in 1997 and rabbits ate many more. Some natural regeneration has taken place since fencing.

Michael is experimenting with a program of seeding native tree species and Jam (*Acacia acuminata*) in a floodplain area between two branches of the Warperup Creek. In the first year he planted Jam then in the following year he plants Sandalwood in between the rows of Jam. It is still too early to say if this is going to be successful but early signs are encouraging.

After being fenced for 18 years natural regeneration can be seen clearly in the creek bed A section of the creek south of the Ongerup-Gnowangerup Road was fenced 18 years ago and natural regeneration can be seen clearly in the creek bed. Species that have regenerated include Samphire, Melaleuca,

[19] Wyoming Farm

Acacia, Jacksonia and native rushes and sedges. To further enhance the riparian corridor Michael planted trees along the fence line. This section now appears to be stable and in time he hopes that the rest of the creek will respond in the same way.

Outcomes and Observations

As well as stabilising the creek Michael has found that fencing has made it easier to manage the sheep. In time he believes that there will be an improvement in the aesthetics of the farm and a better environment overall.

Michael has learned from this project, and he believes that at least three rows are needed to make an effective windbreak. He also found that gates are needed in the fence for fire access in emergencies. Rabbits have been a major problem and Michael would always carry out rabbit control before any future seeding or planting. He decided not to plant in some areas because of rabbits. He has found that direct seeding has been the most successful, even though no pre-seeding weed control was carried out, and believes that direct seeding is able to compete adequately with the weeds.

Cleveland Creek Protection and Restoration

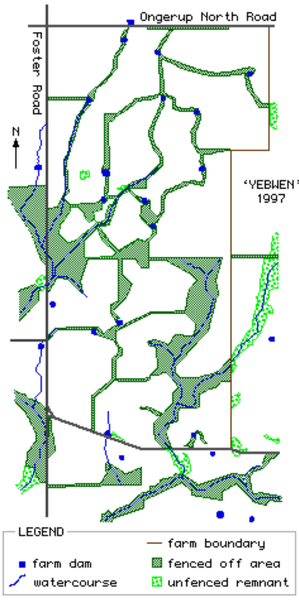
Stephen Newbey, Foster Road, Ongerup

Steve Newbey

"Getting the pools back is so important, they are the life of these rivers"

Background

The northwest Ongerup area was opened up for agriculture in 1911 and the Newbey family bought the 1080-hectare property "Yebwen" in 1938. Clearing and land development took place from then up until 1962. Steve started working on the farm in 1978 and took over its management in 1988.



Cleveland Creek is the local name of the small network of tributaries which runs through Steve's property. Jaekel Creek runs down the eastern side of the farm into the Ongerup Creek then the Warperup Creek, which eventually joins the Pallinup River to the southwest. The top portion of the creek catchment is in a neighbour's farm to the north. The riparian zone originally comprised an open woodland of salmon gum and yate, samphire floodplain, swamp mallet, mallee and paperbark species in the lowest part of the creek. Jaekel Creek catchment is between 90% to 95% cleared of native vegetation and there are no large remnants.

Since 1988 Steve has created 29 kilometres of revegetated corridors across the property and has incorporated most of his dams into the network. Thousands of trees have been planted and the network is linked to adjoining corridors and road reserves and now forms part of a major wildlife corridor between an important mallee fowl breeding area on Foster Road to the north and Warperup Creek to the south. Steve has also played a big part in getting the entire Warperup Creek fenced from Ongerup to the Pallinup River. The property is now registered under the Land for Wildlife scheme with the Department of Conservation and Land Management.

The Problem

When he first took over management of the farm Steve saw the major management issues as:

- waterlogging
- increasing salinity
- erosion of the creek lines
- lack of shelter belts for stock
- lack of wildlife habitat
- lack of dams
- erosion

He has completed a whole-farm plan to address these issues and its implementation is ongoing.

The restoration of Jaekel Creek was part of the plan as it had been grazed ever since the surrounding land was cleared in the late 1940s and was quite bare of vegetation prior to fencing in 1994. The problem was exacerbated by the sheep congregating on the bare areas, which were then susceptible to wind erosion.

The water was fresh when Steve fenced the creek off and because of that he planted *Eucalyptus megacornuta* in the riparian zone. Steve has noticed that the salt has moved upstream over the past ten years and has killed some of the trees. The creek is now severely silted up from runoff from the mainly cleared catchment.

The Solution

To help to address the issues of erosion and lack of shelter belts, Jaekel Creek was fenced during 1994 and planted with local native species in 1996. About six kilometres of fencing was installed along with thousands of trees. Prior to planting the area was shallow ripped to prevent any underlying clay clods being brought to the surface. The revegetation was carried out using a Chatfield Tree Planter, which scalps the area removing weeds and stored seeds. Four rows of seedlings were planted at a spacing of five metres and a row space of six metres. At the same time the area was direct seeded using a seed box on the back of the planter. The following year the area between each row was direct seeded, giving eight rows in total. Steve collects local seed for direct seeding as much as possible, with as many different shrub and understorey species as he can collect. He has achieved a survival rate of about 70% with his planted seedlings.

Steve uses only shrubs and other understorey species in the revegetation as he has found that trees tend to grow too quickly, and they shade out the understorey as well as competing for water and nutrients. He has also found that the overstorey regenerates naturally given time. A small number of trees are hand-planted where shade is required in a shorter time and Steve carries this out on an ongoing basis as time permits.

Some healthy original vegetation remained in the corridor and some natural regeneration took place soon after fencing. Steve has noticed that the pigface has all regenerated despite being trampled by sheep for over 40 years. A trial of wavy-leaf saltbush was put in on a bare salt scald during 1969-70. He has noticed that it has taken over 20 years to spread a few metres outside the trial plot. In hindsight Steve would like to have put the fence further out in some places as some of the saline areas now extend beyond the existing fence.

A small tributary of Jaekel Creek has been fenced to a width of about 20 metres but Steve believes that this is not wide enough. "The reason I did it was simply to stabilise the gully". He planted trees and direct seeded in the corridor and has noticed that Acacia saligna is now the dominant shrub. He sees this as a really good example of what happens if too much A. saligna is included in the seed mix.

Steve applied for fencing funding through the Remnant Vegetation Protection Scheme but this was unsuccessful and so he has paid for all the work on Jaekel Creek himself. A total of 60 hectares of the creek is now fenced off. In the future Steve would like to try and control weeds around the small granite outcrops in the riparian zone. He would also like to convert areas of bare salt within the Jaekel Creek system to wetlands by diverting some surface water into them as well as retaining the water in the creek. He says that they would then become effective evaporation ponds and valuable wetlands for fauna.

Rabbits have been a problem, eating seedlings and digging up roots in the creek corridor, so permanent bait stations have been established about every 100 metres along its length. This seems to have been successful and many more species have been able to regenerate in the absence of rabbits. Rabbit guards have also been placed around some of the larger seedlings. Steve included Melaleuca thyoides and *M. hamulosa* in his rehabilitation but has found that the rabbits like living under the dense bushes. He has now started planting a type of M. thyoides that grows on clay and instead of growing bushy right down to the ground it grows up higher. He says, "I would rather grow them because they don't have the potential to be rabbit harbourage like the ones on my farm".

Where Jaekel Creek leaves the property, the Gnowangerup Shire built the road up and installed a box culvert. Two years later it was washed away in a flood and in the interim a lot of sand built up behind it on Steve's property. The creek is now in the process of re-establishing the old creek bed and as a consequence sand is being washed downstream giving the appearance of an erosion problem. Steve has elected to do nothing at this stage and allow the creek to form its own path.

To address the lack of dams Steve decided not only to build more dams, but also to plan them so that siltation sedimentation was minimised (therefore reducing management costs) and wildlife habitat was created. Steve is a Community Landcare Technician, so he has been able to survey all his own dams. Since 1989 ten dams have been added to the property and these have been sited to reduce evaporation. "I try to get shelter belts to be near dams to keep the wind off the surface of the dam. Ideally you would have bush all around a dam, but you've got to have access for stock somewhere, so you have to put up with wind from one direction". The shelterbelts also filter the water for the dams. ".... I quite happily fence them off because you get a summer thunderstorm, and you don't get your dam full of sheep manure and soil".

Some of the dams have stock access only on one side and they can only reach the water by climbing over the back wall, thus reducing the funnelling effect of tracks at the front of the dam. This will reduce siltation and Steve estimates that he will only need to clean out these dams every 50 years instead of every 10-20 years for an unfenced dam.

In an innovative project Steve has constructed shelters for waterbirds in the overflow areas of some of his dams. These structures have been built using old jam fence posts and they are in a variety of shapes such as a wigwam, fort, BBQ and a wall. They act as islands and the nesting ducks are able to shelter their young from birds of prey, cats and foxes. He has further increased the value of these dams for nature conservation by encouraging the recolonisation of sedges and rushes with the aim of recreating wetland sites. Suitable trees and shrubs have also been planted to enhance the habitat.

The Outcomes and Observations

Steve wants to leave behind a healthier farm for future generations and felt that revegetation of the creek lines would contribute towards this goal. His planning and implementation have resulted in stable creek lines and more diverse wildlife habitat. For example, he has noticed that fat-tailed dunnarts are using the mounds between rows for shelter. "They particularly like where the tree planter scalps and tips the soil over and they get in the grassed area in the middle. It is like a Swiss roll and they live in there. They also seem to live in the samphire areas as well". He also saw, for the first time, a blue tongue skink in one of the corridors during the summer.

At present Steve believes that the benefits of all the restoration works to his farming enterprise have been mainly as shelter for sheep. He has also noticed that crops and pasture grow better adjacent to shelter belts, particularly on the east side of a patch of bush. "I have put shelter belts around all my paddocks here for that very reason, because the wind comes from every direction, and the creek ones fit into that a fair bit".

"You've got to take responsibility for the quality and amount of water that leaves your property. There is no excuse for exporting water that is silty or full of nutrients. Anywhere where water concentrates on this farm is fenced off. If it runs out of a contour bank down a grassed waterway it is fenced off. Anywhere where a dam overflows it is fenced off. The other thing with that too is it actually helps the water quality in the dam because you're filtering out all the rubbish here before it actually gets into the dam. So, the water quality in the dam is improved for the sheep too. It is not all 'green' thinking. That is what it started off with, to filter the water for the sheep and then I thought if I'm going to have this pool of water lying there that the sheep can't use any more what can I do with it?"

"The shelterbelt of trees goes around the north side of the dam so that will protect that water from the hot northerly and north-westerly winds. On the farming side of things, the shelterbelt, apart from reducing dam evaporation, is also on the south side of the paddock to provide shelter for the livestock when we get cold southerlies. I really think that if people think about it, they can make conservation fit in very well with their farming".

Steve has been delighted to see black ducks, wood ducks and grey teal successfully raising young on his dams and using the shelters. "A lot of birds come in to drink here so they're not just for the ducks. The other thing I've noticed is in the summer when it's hot and birds come in to the dam for a drink, they'll quite often hang around in the shade around them. The plovers in particular seem to like it. Even if a hawk came along there is somewhere where they can dart into and not be seen". With the dams Steve has successfully reduced his own costs and at the same time has created wildlife habitat. He is constantly experimenting with ideas and learning as he goes about implementing his farm plan. "In the early days of planting I used to plant a couple of rows of trees. I have been filling these areas in using the tree planter recently".

The revegetation work in Jaekel has been successful and in time he hopes it will provide a buffer for the waterway. Showing his optimism for the future Steve says, "I think that in 10 years if we can continue along the way we're going, when water leaves my house here as soon as it goes down to the creek at the bottom it will go all the way from there to the sea in fenced off wetland corridors". He likens the network of dryland and wetland corridors to a cardiovascular system. ".... corridors are now like your veins and arteries and the blue ones are the water ones and the red ones are the land ones. So, you've got a cardiovascular system. I think that the river ones and the watercourse ones are important, like your veins are important. But they're not much good without the arteries, so you've got to try and get your arteries, which are your road verges and the other ones that you can get here and there on dry land". Where possible Steve has also tried to link with remnant vegetation on neighbouring farms. He says, "even if it’s not fenced off, I assume in time it will get fenced off".

The Jaekel Creek corridor is quite wide in some places and Steve says, "I really think there's the ability to make [wildlife] corridors out of some of these salt creeks as long as you can tap in on these little bits and pieces that are along them. Rather than having something that is half a kilometre wide the whole distance, if you have something that might narrow down to 20-30 metres and then widens out to a couple of hundred metres, to me you still create a corridor. Just when you first start fencing those off it looks like a lot of land to fence off, but I think in 30 years that fence will come out further and in a hundred years' time it will be half way up to the shearing shed; but you go in stages".

Carrying on the family interest in birds Steve is monitoring them across his farm to get some idea of the success or otherwise of his restoration work for nature conservation. He has documented birds returning to the farm, some of which haven't been recorded since his teenage years.

APPENDIX 2: STATE SALINITY PERSPECTIVES

Given that salinisation issues across the SW agricultural area have resurfaced, the following government stance on salinity may be relevant to a strategic waterway condition improvement plan for the Warperup and other sub-catchments of the Pallinup River.

Salinity – State perspectives

In 2018 the Office of the Auditor General, Western Australia submitted a report to Parliament titled: *Management of Salinity – Report 8*: May 2018. The Audit referred to the SW agricultural district. The conclusions were as follows:

- Predictions are that, without some level of intervention, the area of land affected by salinity could more than double over the next 50 to 100 years. Intervention on such a scale is a huge task and needs to be balanced against the possible cost, which could also be large.
- Government must decide how much intervention is both feasible and economically sound but is currently in no position to make an informed decision. Since 2008, there has been a lack of strategic direction and agencies have reduced monitoring the extent and impact of salinity.
- Managing dryland salinity is a shared responsibility, with shared benefits, and experience to date indicates that effectiveness relies on coordinated local action. It also relies on all landholders taking appropriate action to protect their land. But, in the absence of strategic direction, agencies have focused on protecting individual assets.
- The last satellite imagery analysis that mapped salinity was in 2000. At that time, the Department of Primary Industry and Regional Development (DPIRD) calculated that severely salt affected land was increasing by 14,000 hectares per year.
- The Department does not know if this rate of increase has continued or decreased or accelerated.
- DPIRD monitors water tables throughout the South West because there is a link between water table height and salinity. This does provide an indication of areas at risk. DPIRD reported water table data in 2013, however, there are gaps in the data and DPIRD has advised that its monitoring effort has reduced since 2010.
- There is currently (2018) little coordinated management across government agencies, landholders, and stakeholders. As a result, efforts to manage dryland salinity are unlikely to achieve any landscape wide improvement.
- Salinity is spread unevenly across the landscape, resulting in varying impacts. Addressing it is a shared responsibility and experience to date indicates that effectiveness relies on coordinated local action. It also relies on all landholders taking appropriate action to protect their land, even those who are not affected and stand to gain relatively little.
- There are currently no goals and targets for reducing water tables or planting deep rooted species and decisions to protect land are left to individual landholders. Relying purely on private benefit can result in landholders either acting alone, or not at all.

This raises questions regarding the Warperup catchment:

What is the soil salinity status and is secondary salinisation increasing, decreasing or stable?
What actions have worked, what have not and what is currently being done?
Do NSPNR or landholders assess salinity to fill the knowledge gap?

Department of Water and Environmental Regulation response to Report 8.

- The Department of Water and Environmental Regulation (DWER) accepts the key findings contained in the report and notes that the benefits of the previous investment into salinity management are often intangible.
- While the setting of targets to reduce water tables and re-plant deep-rooted trees may appear attractive, the Department was of the view that the scale of intervention required for even small reductions in salinity levels places unreasonable and unobtainable expectations on land managers. It may also impose significant costs without realisation of benefits commensurate with the scale of investment required.
- The Department believes that the current targeted approach to salinity mitigation whereby activity is focussed in areas where there is a high chance of success is a much more efficient use of limited resources and provides a far greater return on investment than spreading the effort across large geographical areas.

The State does not have all the information it needs to effectively manage salinity

- There is a lack of complete and current knowledge about the extent, impact, and cost of dryland salinity. In large part, this is because agencies have reduced monitoring and evaluation, and the Soil and Land Conservation Council, the key independent advisor to Government, has not met since 2003. This impacts on the State's ability to manage salinity effectively and efficiently and increases the risk that poor decisions will be made.
- In December 2017, it announced the formation of a Ministerial Advisory Committee to guide the re-establishment of the Soil and Land Conservation Council. The Council is a statutory body with members appointed by the Governor. It functions to provide advice to the Minister for Regional Development; Agriculture and Food, and to coordinate, supervise, and promote land conservation activities.

New laws to modernise Soil and Land Conservation Council

A State Government media statement on Thursday, 11 November 2021 comments on the Soil and Land Conservation Council:

The McGowan Government has introduced legislation to modernise and improve the effectiveness of the Western Australian Soil and Land Conservation Council. The amendments to the Soil and Land Conservation Act 1945 will pave the way for a skills-based Council, with members appointed by the Agriculture and Food Minister based on their expertise and experience to help drive soil conservation and ecological sustainability.

The Council will be comprised of members with involvement in soil science and conservation, agricultural production, environmental conservation, land management, local government and planning and pastoral land management, rather than representation from stakeholder groups.

The changes are in response to recommendations by the Soil Ministerial Advisory Committee, which undertook extensive consultation across industry, government and academia. The McGowan Government in 2019 resurrected the statutory Soil and Land Conservation Council, which had been defunct for 16 years.