Warperup Creek Improvement Plant Feasibility Study 2022

SUPPLEMENT 3 - Waterway condition assessment framework

Prepared for North Stirlings Pallinup Natural Resources Inc

By Steve and Geraldine Janicke

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Janicke Environmental Investigations

GOVERNMENT OF WESTERN AUSTRALIA

natural resource management program

NORTH STIRLINGS PALLINUP NATURAL RESOURCES

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

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Cover Photo: Stevi Filipowski sampling on the Warperup Creek, site PAL530. ©*Janicke*

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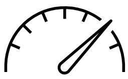
PREAMBLE

Towards a long-term waterway monitoring and data management framework

This supplement outlines the essential components of a waterway monitoring framework suitable for stimulating and guiding proactive management of the waterways which form the Warperup catchment. The framework goes beyond water quality assessment to consider the structural and ecological qualities of riparian areas in the catchment. Water quality monitoring is included. This has generally been viewed as the realm of specialist activity requiring a high level of technical expertise and scientific capability. However, advances in technology and ready access to information has increased the capacity of catchment communities to adopt in-house environmental monitoring programs that are quite adequate for serving environmental management needs. The monitoring approaches can be developed further by input from environmental professionals but are primarily intended for local strategic planning and directing project actions.

Information is gathered to help answer questions such as, what is the ecological condition of the waterways, can they be protected, is intervention required, can they be improved and if so, how? These considerations are implicitly about the values people place on their environment and waterway condition assessment is more than a simple description of the current situation. In this case the primary reason for doing monitoring is to gain a better understanding of the nature of the waterways and to make management decisions that enhance rather than degrade their ecological qualities. In this sense monitoring plays a similar role to the dashboard gauges in a vehicle that provides checks in real time to assist the driver to get to their destination.



When short-term project funding criteria dictate what water quality monitoring is done, the result is often an erratic collection of data which is inadequate to guide a strategic approach to waterways management. Although people have been enjoying waterways and writing poems and songs about them for centuries, understanding of the hydrological and ecological processes taking place has not been widespread.

During the 1980s, river ecologist Dr Luke Pen and Margaret Scott, developed a process for assessing the 'condition' of reaches along South-West waterways using a simple grading. This was prompted by growing concerns that our rivers and creeks and wetlands were neglected and deteriorating into weed infested ditches that served no other purpose getting water away from more valuable assets.

The Pen-Scott Foreshore Condition Assessment was designed for interested community members to be able to quickly audit the general quality of their stretches of waterway by simple, but consistent observation.

The result was an A, B, C or D rating, A being pristine through to D grade, being highly degraded. The Pen-Scott condition assessment primarily helped determine the general extent of degradation along a river and to prioritise where to focus rehabilitation effort. However, there are distinct limitations to using the rating to track any improvements over time. The framework discussed here, builds on the Pen-Scott rapid assessment approach to include specific structural waterway feature and water quality. A brief description of the Pen-Scott condition assessment grading is given in Appendix 1.

NSPNR are well placed to be custodians of a waterway monitoring framework for the Warperup, and landholders are well placed to help facilitate the role. The monitoring framework can also be extended to other waterways within NSPNR operational area.

Basic water quality monitoring involves many years of data collection to be able to track changes over time. Hydrographers typically quote 5 to 10 years of water data collection to establish an adequate baseline for future comparisons. Assessing other ecological parameters can be more or less demanding and may be difficult to measure. Failure to establish a consistent monitoring framework has resulted in many catchment communities remaining largely ignorant of changes to their waterways and whether rehabilitation project outcomes have justified the investment, particularly at the catchment scale.

Routine environmental data gathering is not an idealistic goal but should become core business for communities who desire to live in a healthy environment. Three good reasons for doing this are:

- Environmental data forms the foundation for knowing what you are dealing with.
- Trends can be detected and progress towards agreed goals can be tracked.
- Environmental data cannot be collected retrospectively.

The logistical reality is that the current resourcing of environmental monitoring programs does not cater for routine long-term waterway condition data collection. This situation may continue.

Therefore, to gain value from any monitoring effort when resources are available, what is done should complement earlier data sets. This is achieved by conforming monitoring to a monitoring plan which has a degree of flexibility with respect to the timing of activities.

The purpose of the framework is to:

a. adequately describe the features of the waterways and
b. describe them in such a way that changes can be tracked over time.

Historical data collection

The literature review (Supplement 2) revealed that descriptions of conditions in the Pallinup River catchment, from the 1800s into the 1900s are anecdotal. Nevertheless, this has helped to gain some appreciation of the likely characteristics of the catchment prior to and during extensive agricultural activity.

For example, the following comments concerned the area around Gnowangerup.

Merle Bignell makes the following comment[1].

> *"They (the Stone brothers) chose a site of fresh soakage around the junction of the Warperup and Pallinup River. They were never to regret their choice. The water persisted even in the heart of a drought".*

> *"The landholder has to constantly curtail the area of cultivation adjacent to the watercourse on account of salt and requests revaluation on the basis that 100 acres has gone salt out of a total of 677 acres." (Inspectors report, Jan 1935).* [2]

Government agencies began collecting landscape data for agricultural development purposes following land clearing, but the collection of data specifically for natural environmental features is a more recent concept. For example, the Department of Water and Environmental Regulation's (DWER) river gauging site at Bull Crossing near Chillinup on the lower Pallinup River has been operating since the 1970s. Its primary purpose is to gauge how much surface water flows out of the Pallinup River

[1] Merle Bignell (1977) The fruit of the country - A history of the Shire of Gnowangerup Western Australia.

[2] *Pallinup Pioneers - The Whites of Whitworth*

catchment. The data reveals certain hydrological characteristics of the catchment as a whole but provides little insight into the ecological character of the river system.

Waterway monitoring in the Warperup catchment has been frugal but has provided some estimates of water quality at various sites and times and this 'reconnaissance' data has helped to define what sort of monitoring might be appropriate for a long-term program.

Characteristics of a waterway monitoring framework.

A useful waterway monitoring framework will have the following characteristics and these act as a checklist for project activities:

- ☐ A consistent approach to monitoring has been established.
- ☐ Data can be routinely added to the data pool over periods measured in decades.
- ☐ Information about the data is documented.
- ☐ All data remains relevant as better monitoring methods are developed.
- ☐ The data remains relevant despite periods when monitoring is non-existent.
- ☐ New types of data can be added.
- ☐ Data and associated information are stored in a durable and readily accessible archive.
- ☐ Preservation and custodianship of the data is assured.

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

The type of data collected should be within the technical capabilities of local NRM officers, interested community members and contractors. This would require project managers to have knowledge of the monitoring framework and methods used and how new projects and initiatives can contribute to historical data and vice versa. Waterway condition data should be sufficient to inform land managers about conditions in the waterways and the outcomes of management initiatives.

An important component of this part of the feasibility study was to determine what basic parameters are useful for long-term waterway condition monitoring. Two waterways assessment approaches were employed, and it was concluded that these provide a suitable foundational framework.

The two approaches are:

1. Using a GIS database to enable information to be attached to individual sections of the catchment drainage network. This provides a way to audit the progress and outcomes of on-ground works in real time.
2. Establishing Reference Reaches to provide specific water quality and ecological information for key locations. These provide indicators of changes and trends in waterway condition.

GIS WATERWAY CONDITION DATABASE

GIS basics

A geographic information system (GIS) is a system that creates, manages, analyses, and maps all types of data. GIS began in the 1960s with early computers and was commercialised in the 1980s. As personal computers became popular, open-source GIS software was developed and first released in 2009. Now it is a freely available software compatible with most operating systems. The use of GIS software is fast becoming an essential computing skill set like word processing and spreadsheets.

GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making[3].

Online agency and business tools

Agency websites offering sophisticated landscape mapping tools are becoming more common and accessible to the public. Such platforms are being constantly developed and will likely be replaced by new applications. Some may disappear altogether. The agencies may allow users to store their data online however, it is important that the original environmental data has been archived by NSPNR in durable, standard industry formats.

Some examples of specific GIS applications that are becoming available online include: LandMonitor, GeoVIEW.WA, NRInfo (https://dpird.maps.arcgis.com/apps/webappviewer) and Interactive map of Noongar Land Estate.

Warperup streamline analysis

The foundation of a GIS waterway condition database is a streamline vector file[4]. This can be hand drawn by tracing over an existing map, however this is a slow process. It is also available as DWER drainage network layer "Hydrography Linear". This file contains georeferenced lines that have various attributes[5], such as length, name and hydrographic type. For the Warperup Feasibility Study, this file was clipped to the Warperup Creek Catchment and used as a base layer for the **Warperup streamline analysis**. All non-streamline features such as dams and contour drains were removed leaving only 'Watercourse' and 'Natural Pool' hydrographic types. Some watercourse lines were split at property boundaries and others were merged as appropriate.

Attributes (columns in the table) from the original layer that were kept were HYD_TYPE, and HYDNAM and new attributes (column) were added. The attributes can be seen in spreadsheet form in Figure 1 below. The attribute table works in a similar way as a spreadsheet. Each row is a feature, a (usually short) length of georeferenced waterway. Each feature is given a unique identification number (fid). The georeference details for each feature are in a linked file hidden from general view but are what links the features with their attributes to the map. A full description of the GIS file "Warperup streamline analysis" can be found in APPENDIX 2 at the end of this document.

A	B	C	D	E	F	G	H	I	J	K	M	O	P
fid	HYD_TYPE	HYDNAME	Subcatchment	Hyd_ order	cover_type	Veg-densit	Cov_width	Features	COMMENT_	Length_m	Property_N	PiParcel	Lot_ Num
2119	Watercourse - non-perennial	WARPERUP CREEK	Upper Warperup	4	Remnant	moderate	wide			86.25	Reserve 17481	Kent L 00540 P227232	540
2120	Watercourse - non-perennial	WARPERUP CREEK	Upper Warperup	4	Remnant	moderate	wide			72.81	Reserve 17481	Kent L 00540 P227232	540
2121	Watercourse - indefinite	Warperup Upper Trib 02	Upper Warperup	1	Remnant	low	narrow			546.16		Kent L 00290 P227323	290
2122	Watercourse - indefinite	Peedillup Creek Trib 05	Peedillup	2	bare	bare		In-stream dam	Occasional trees	637.09	Blytheswood	KENT L 00292 P227323	292
2123	Watercourse - indefinite	Peedillup Creek Trib 05	Peedillup	1	bare	bare		In-stream dam		917.87	Blytheswood	KENT L 00292 P227323	292
2124	Watercourse - indefinite	Peedillup Creek Trib 05	Peedillup	1	bare	bare		In-stream dam		625.49	Blytheswood	KENT L 00292 P227323	292
2125	Watercourse - indefinite	Peedillup Creek Trib 05	Peedillup	2	bare	bare		In-stream dam	Occasional trees	402.79	Blytheswood	KENT L 00292 P227323	292
2126	Watercourse - indefinite	Peedillup Creek Trib 05	Peedillup	2	Remnant	low	narrow			676.76	Blytheswood	KENT L 00292 P227323	292
2127	Watercourse - minor, non-perennial	Upper Warperup minor	Upper Warperup	1	bare	bare				426.98		Kent L 00290 P227323	290
2128	Watercourse - minor, non-perennial	Upper Warperup minor	Upper Warperup	2	Reveg	moderate	moderate			377.86		Kent L 00290 P227323	290
2129	Watercourse - minor, non-perennial	Upper Warperup minor	Upper Warperup	1	Remnant	moderate	wide	Braided channel	Treed along fenceli	414.32		Kent L 00290 P227323	290
2130	Watercourse - indefinite	Warperup Upper Trib 03	Ongerup	1	bare	bare				611.77		Kent L 00286 P227322	286
2131	Watercourse - minor, non-perennial	Warperup Upper Trib 03	Ongerup	2	bare	bare		Salt scald		1182.85	Linthorpe	Kent L 00282 P227322	282
2132	Watercourse - minor, non-perennial	Warperup Upper Trib 04	Ongerup	1	bare	bare		Salt scald		273.39	Linthorpe	Kent L 00281 P227322	281
2133	Watercourse - minor, non-perennial	Warperup Upper Trib 04	Ongerup	1	bare	bare		Salt scald		472.01	Casengary	Kent L 00308 P227324	308

Figure 1: A section of the table in the GIS file "Warperup streamline analysis"

[3] Esri website overview, "What is GIS?"

[4] **GIS Vector** files represent features as points, lines and polygons that are georeferenced.

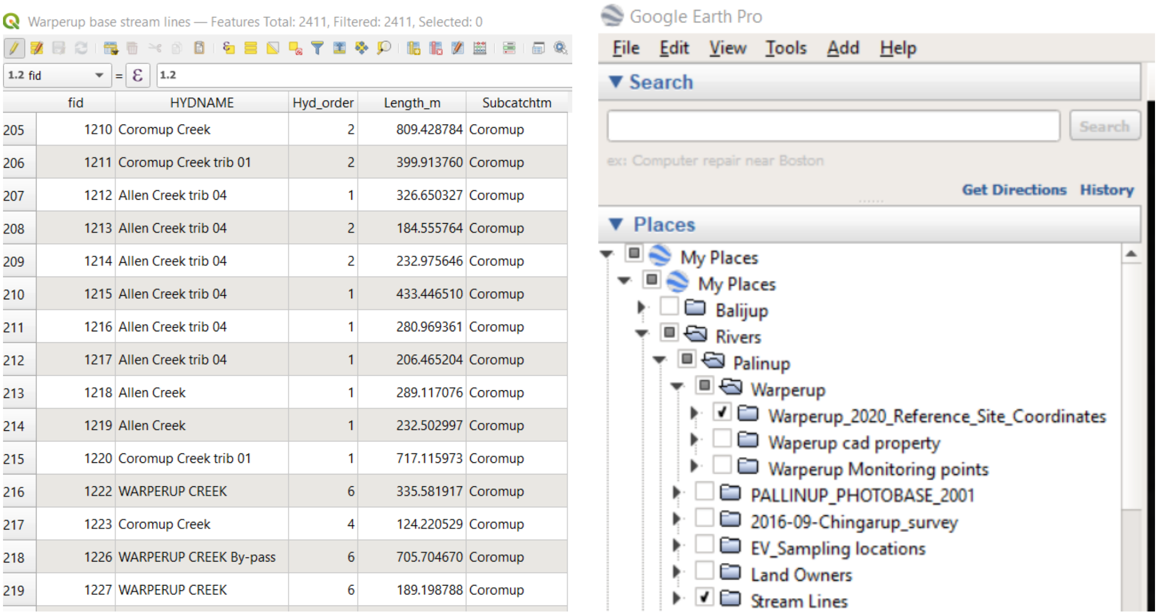
[5] **GIS attribute** is information about a feature, usually stored as columns in a table (columns) and linked to a feature (rows) by a unique identifier.

The GIS database table can be exported as Comma Separated Values (.csv) and imported into a spreadsheet for further analysis. For example, the lengths of waterway sections revegetated can be summed against each stream order and within each sub-catchment. These tables can assist with understanding what has occurred in the catchment and help with strategic planning.

Adding to the GIS database

The basic stream sections for Warperup Creek (*Warperup base stream lines.shp* Figure 2) can have attributes added as extra columns in the GIS table, i.e., revegetation works, fencing, trial plots, and other features. Alternately, areas of revegetation or lengths of revegetation can be added as separate vector files.

The reality for most project officers is that they are time poor and have limited understanding of how to use a GIS application. We would encourage project officers to familiarise themselves with the basics of GIS. Staff training is therefore an important component of the monitoring framework. As a very minimum, data such as revegetation works, and fencing should be added as polygons and lines to Google Earth. Figure 2, right image shows the authors folder structure for a range of data that has either been added to Google Earth or, created on Google Earth. Each folder can be exported from Google earth as a kmz or kml file and imported into a GIS application making it a very useful feature.


Warperup base stream lines — Features Total: 2411, Filtered: 2411, Selected: 0

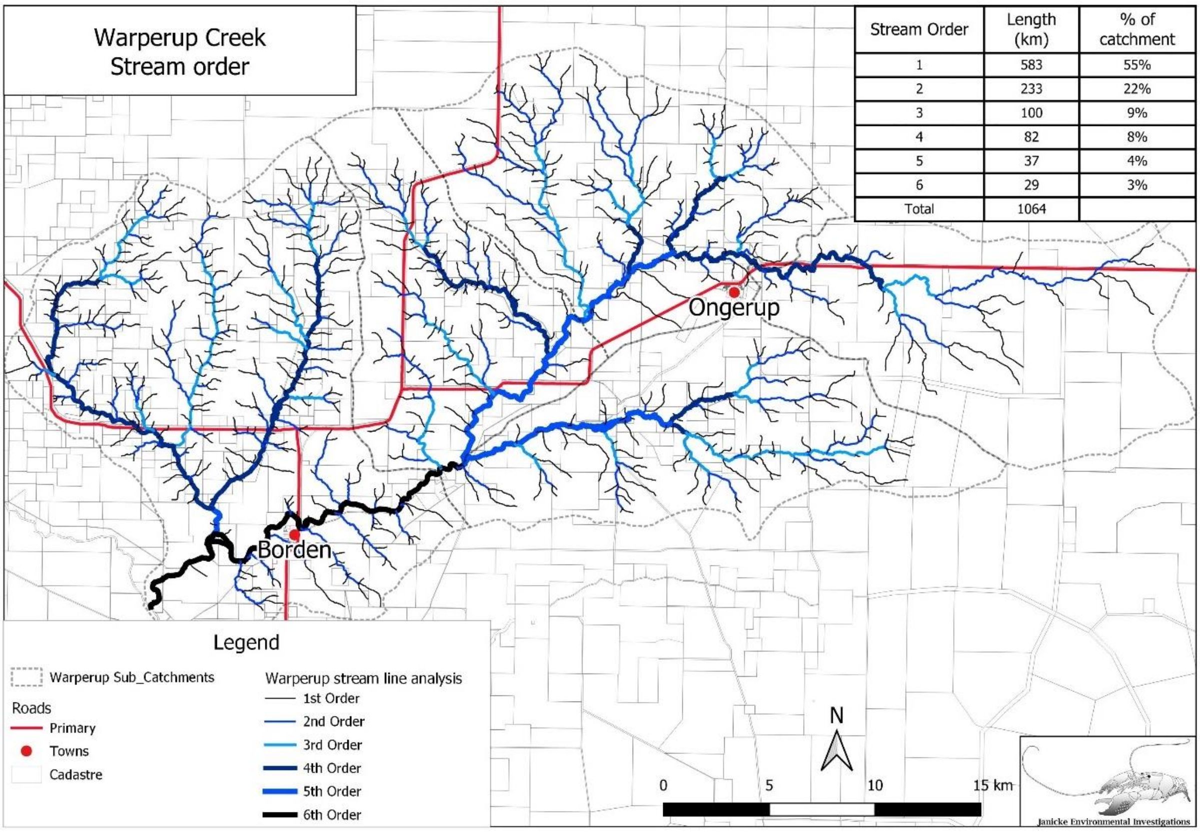
	fid	HYDNAME	Hyd_order	Length_m	Subcatchtm
205	1210	Coromup Creek	2	809.428784	Coromup
206	1211	Coromup Creek trib 01	2	399.913760	Coromup
207	1212	Allen Creek trib 04	1	326.650327	Coromup
208	1213	Allen Creek trib 04	2	184.555764	Coromup
209	1214	Allen Creek trib 04	2	232.975646	Coromup
210	1215	Allen Creek trib 04	1	433.446510	Coromup
211	1216	Allen Creek trib 04	1	280.969361	Coromup
212	1217	Allen Creek trib 04	1	206.465204	Coromup
213	1218	Allen Creek	1	289.117076	Coromup
214	1219	Allen Creek	1	232.502997	Coromup
215	1220	Coromup Creek trib 01	1	717.115973	Coromup
216	1222	WARPERUP CREEK	6	335.581917	Coromup
217	1223	Coromup Creek	4	124.220529	Coromup
218	1226	WARPERUP CREEK By-pass	6	705.704670	Coromup
219	1227	WARPERUP CREEK	6	189.198788	Coromup

Figure 2: Left, The GIS table for the layer; *Warperup base stream lines.shp*. Right, the authors Google Earth folder structure.

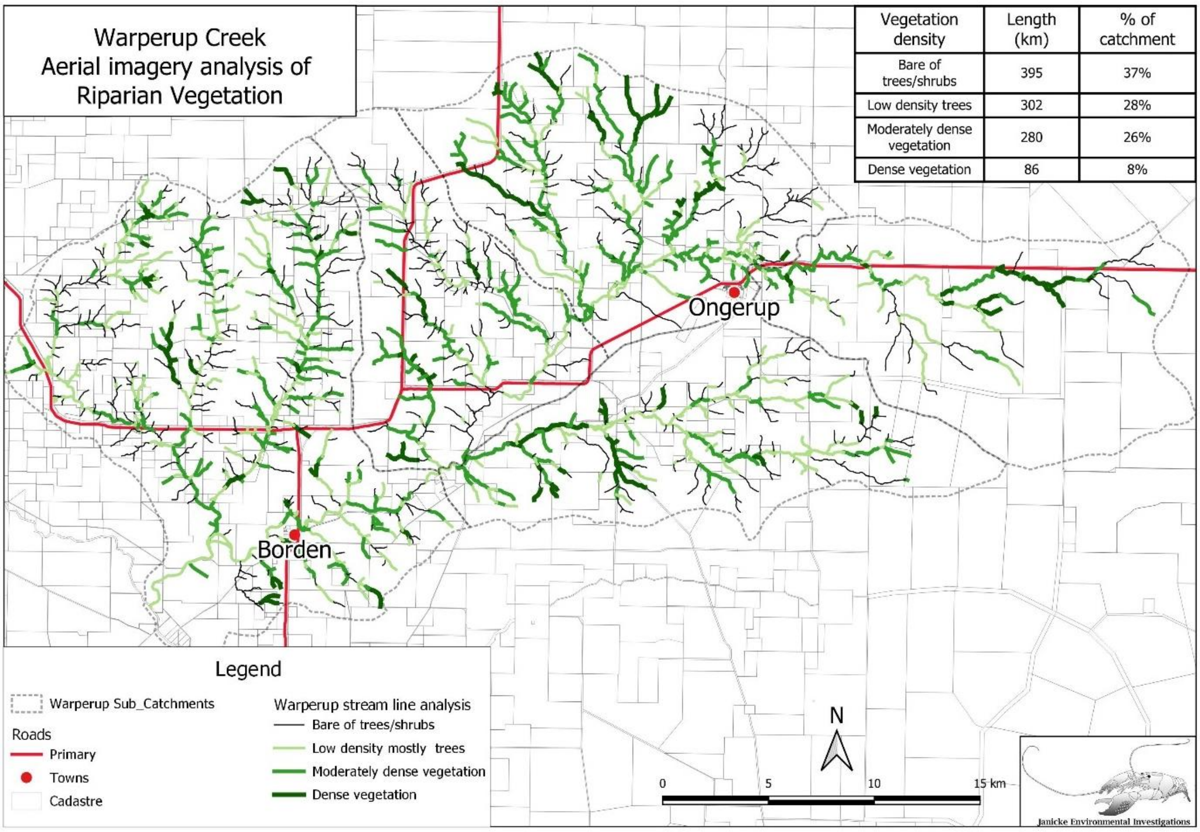
Mapping

Attributes were assigned to each small section of waterway as seen in the column headings and these can be mapped. Other vector files (known as shape files) can be layered on the map. Figure 3 are two examples of maps showing;

1. Upper map: the stream order of waterways in Warperup catchment. Each section of waterway was assigned a stream order value (Hyd_order in the table). When mapped, each section of stream was shown as a different thickness and colour line according to the stream order value.
2. Lower map: the density of riparian vegetation adjacent to each stream section in Warperup Creek. Each category was assigned a different colour when mapped.
3. Other layers including cadastre (property lots), towns, roads and sub-catchment boundaries are included.



Stream Order	Length (km)	% of catchment
1	583	55%
2	233	22%
3	100	9%
4	82	8%
5	37	4%
6	29	3%
Total	1064	



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 3: Two maps with the attributes, *stream order* (upper) and *Riparian vegetation density* (lower) mapped for Warperup Creek.

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REFERENCE REACH CHARACTERISTICS

What to monitor and why?

There is some justification for gathering water data opportunistically with no immediate application for it and without posing a question which needs answering. The only reason for doing this is simply that the information might become useful at some future date, and you cannot go back in time to get it. However, for water condition monitoring to support a strategic plan a structured approach is necessary. This was the reason for selecting specific reference reaches across the catchment which could reasonably represent common characteristics of the entire waterways network. These reaches would provide a consistent source of data over time. Realistically, such an approach would also have to work in an unpredictable funding environment.

The following basic waterway condition measures were used at the ten reference reaches chosen for the study. Possible reasons and uses for gathering the data are also offered:

Table 1: Suggested basic water condition monitoring in the Warperup Creek catchment

Parameter	Use for waterways protection and enhancement	Suggested minimum requirements for monitoring
Salinity	Detecting hydrological trends across the catchment. Usefulness of water as a resource. Providing a window into understanding groundwater sources, movement and processes and how they connect to the waterways. Detecting the ecological conditions influencing aquatic biodiversity.	Three strategic sites corresponding to the upper, middle and lower main trunk. Sites at the lower ends of significant tributaries and suspected salt discharge ‘hotspots’. At least 3 measurements per annum at each site to pick up seasonal variations. A reliable conductivity meter is required as well as some training in its use, care and calibration. Alternatively, water samples can be sent to an accredited laboratory.
pH	Detecting hydrological trends in both ground and surface water discharge. Impacts of drainage works. Qualifying the ecological conditions influencing aquatic biodiversity.	Selected sites as for salinity with at least 3 measurements per annum at each site. A reliable pH meter is required as well as some training in its use, care and calibration. pH is best done in-situ.
Nutrient concentrations	Assessing the benefits of increasing riparian vegetation cover upstream. Understanding nutrient inputs from farmed areas and the outcomes of rehabilitation projects. Qualifying the ecological conditions influencing aquatic biodiversity.	Water samples are processed by an accredited laboratory which will also specify how samples are to be collected and processed. Minimum nutrient parameters are Total Nitrogen and Total Phosphorus. Useful parameters are Nitrates and Nitrites (NOx) and Soluble Phosphorus (SRP or FRP).

Aquatic macro-invertebrates	A key waterway biodiversity characteristic. Assessing aquatic biodiversity status and response to catchment and local environmental influences and pressures.	No fixed interval monitoring required. An early October sampling is sufficient for general assessment. PAL509 – representing the site of greatest aquatic biodiversity in 2020-2022. PAL501 – Representing the Warperup Creek main trunk PAL500 – representing influences from the larger tributaries Coromup, Long/Maileerup. PAL510- Representing the uppermost part of the catchment Taxonomic expertise is required for identification of species.
Photo Points	Erosion, sediment and flood resilience assessment. Tree and shrub health. Natural vegetation regeneration. Determining rehabilitation outcomes. Habitat structure. Weed colonisation.	No fixed interval required for repeat image capture but assessing changes following major flood events can provide useful information regarding the processes and pressures acting on the waterways.
Bird life	Assessing the outcomes of habitat improvements Assessing riparian connectivity along and between waterways.	A systematic approach is essential and would need to take seasonal activity into account. Birdlife Western Australia can provide guidance with monitoring methods.
Ground fauna	Assessing the effectiveness of riparian habitat improvements. Aiding feral animal control.	Can vary from low key observations recorded by interested community members to professional assessments.

Although 10 reference reaches were defined, not all ten sites need to be re-assessed at the same time and the number of sites visited can be adjusted to match project budgets. There is also the option of cycling the sites visited and adding in addition locations if there is a specific issue to investigate.

Other categorical assessments can be made by interested community members and project officers and include the Pen-Scott Foreshore condition assessment, dominant plant species and their health, floodway characteristics etc. APPENDIX 3 is an example of a Waterway Description Proforma that can be used in part or in full to aid consistent recording of data.

Overview

Two levels of waterway condition improvement have been evaluated. Level one concerns the percentage of the 1064 kilometres of streamline that have received some degree of protection or rehabilitation. Level two concerns the ecological function and quality of improvements along specific waterway reaches. This division between the catchment scale and the paddock scale enables improvements to be demonstrated in two ways, first by considering the amount of on-groundwork which has been accomplished overall and secondly by considering the type and quality of ground works undertaken in specific areas. First level improvements can be assessed from project records, consultation with landholders and aerial image interpretation. Second level improvements at rehabilitation sites can be quantified by assessing planted species condition, survival rates and other relevant ecological measures.

Two levels of waterway condition assessment

Whole of catchment drainage network specifications
Individual stream reach specifications

Aerial imagery provides the means to view the entire catchment stream network and to rate the environmental condition of the waterways at a strategic scale, but it does not provide sufficient detail about the ecological processes taking place at the reach scale. This may improve as remote sensing technology improves. The reference reaches do provide this detail and for this reason are an important component of a long-term monitoring framework for the waterways. Although they do not identify every ecological feature of the diverse areas of the catchment, they do represent the key environmental characteristics which make the Warperup what it is. The reference reaches can therefore help define what improvements in the overall condition of the waterways will mean in practice.

Improvements or otherwise can also be evaluated qualitatively, for example by the presence or absence of various features (e.g., bird diversity) before intervention and their presence or absence after. This level of assessment will require various degrees of expertise and keeping reliable site records. Long term environmental improvements or otherwise, can be determined by revisiting and reassessing the condition of sites against historical datasets. The value of doing this should not be underestimated since knowing what worked, what did not work and why, is essential for increasing the chances of achieving successful project outcomes.

Possible uses of reference reaches

Having established reference reaches and obtained preliminary data regarding their form and condition, how can they be used to help guide waterway management into the future? Suggestions are:

- Observing the progress of riparian and hydrological processes.
- Demonstrating best management practices.
- Establishing experimental sites to trial innovative rehabilitation methods.
- Benchmarks for assessing rehabilitation works elsewhere in the catchment.
- Keeping tabs on catchment water quality.
- Educational activities.
- Attracting research grants and researchers.
- Providing ground truthing sites for developing remote sensing technology.
- Providing reality checks.

- The methods developed to assess and monitor the reference reaches also provides a model for assessing long-term environmental outcomes at rehabilitation sites.

Are ten reference reaches enough?

Although the ten reaches were initially chosen to represent the entire catchment, they do not capture every situation. Drive-by observations of other parts of the catchment suggested that the ten sites do provide a realistic overview of typical conditions and management issues in the waterways, but there is no reason why more reference reaches cannot be established. Information gathered at these would increase the reliability of any conclusions drawn from ongoing monitoring.

Comment: The ten site assessments undertaken in 2020 to 2022 occupied three days each year and some components could be undertaken by two persons at a Citizen Science' level. Sample and data processing added to the time and expertise required, depending on the level of analysis required.

When should reference sites be revisited?

There is no set interval, however much can be learnt by revisiting sites at five to ten year intervals or immediately following major flood events. Although large floods events are the source of sudden and perhaps spectacular changes to the waterways, the impacts of long periods of low rainfall and droughts are also important and assessments after or during extended dry periods may provide important management information. Significant changes in adjacent land use may also prompt visits.

Key characteristics of the reference reaches

The following table provides a short summary of the key features found at each of the ten reference reaches. These represent a wide variety of rehabilitation challenges and provide insight for what might be accomplished.

Table 2: Key characteristics of the reference reaches

Reference reach	Key features
PAL500 Lower catchment Main channel	Broad grass dominated flood terraces, former extended river pool, significant numbers of tree deaths, high in stream sediment load, sandy terrace soils, dense grass cover. Highly degraded.
PAL501 Lower catchment Main channel	Steep sided meander bend, broad & narrow flood terraces, narrow, incised low flow channel, trees in reasonable condition but patchy cover, dense grasses dominating exposed flood terraces. Degraded central channel.
PAL507 Middle catchment Main channel	Broad shallow floodway, highly exposed verge on south side, high sediment load, bank erosion scours, tributary with high sediment input, exposed floodway, mature planted trees above floodway, active Paperbark regeneration in channel, river pool.
PAL508 Middle catchment Main channel	Similar to PAL507. Large bank scour on bend, broad flood terrace with 20 year plus revegetation sites on flood terraces both sides, extensive rock outcrops at downstream end, river pool at lower end, scattered tree cover, Opuntia cactus present, Hart Rd crossing at upstream end acts as a sediment dam. Confluence with Ongerup Creek
PAL509 Upper catchment Main channel	Stable, rocky, incised floodway, extensive rock outcrops upstream. Narrow flood terraces. Degraded tributary confluence.
PAL510 Upper catchment Main channel	Long, broad and deep pool with a narrow band of vegetation between the pool and farmland on one side.

Reference reach	Key features
PAL520 Lower catchment Mailerup Creek	Below Long and Allen Creek confluence. Broad, shallow floodway and active channel, extensive shallow sand deposits, bare salt seeps along banks, scattered trees of various ages
PAL530 Lower Coromup Creek	Steep sided floodway, rocky cascades and channel, sediment filled pool.
PAL540 Middle catchment Peedillup Creek	Broad floodway with generous remnant bush verge, distinct but sediment dominated pool. Intact, but vegetation degrading.
PAL550 Peerup-Meenup Creek	Broad, shallow floodway, narrow active channel, well vegetated on the north side with wide flats and dense tussock grass cover and scattered trees. Dense samphire dominated at the upper end of the reach. Open and degraded on south side adjacent to farmland. Bare salt scalded areas at the lower end of the reach with a narrow, scoured low flow channel. Moderate condition overall.

DATA MANAGEMENT

Data management is the process of collecting, storing, organizing, and accessing data created or collected by an organization. The aim is to make sure that the data is accurate and available to future NRM practitioners, in this case NSPNR staff. Too often, environmental data is collected and stored in an ad-hoc manner on assorted devices. When the custodian leaves, the data is often lost. An appraisal of the types of data collected and used by NSPNR would help to decide on a storage and retrieval system. If such a system already exists it should be reviewed periodically. Although establishing a data management system may seem time consuming, it is vital for the longevity of the organisation. There is potential to obtain funding for this task. Other NRM groups have already gone through the process and may be willing to share their experiences.

Past project information

Descriptions of past on-ground rehabilitation works provides a wealth of information about what worked and what did not. This information is valuable for determining the longer-term success or otherwise of on-ground works. In turn, this can contribute to improving rehabilitation approaches and methods as well as adjusting aims and expectations. An important part of site visit will be to gather and record useful information that can be imported into the GIS database.

CONCLUSION

The Warperup waterways can be understood in two ways, their physical form and their biodiverse inhabitants. This is an ecological perspective. The framework components discussed above provides a foundation for assessment of these two aspects for project planning purposes. Riparian ecosystems are complex and dynamic and certainly lend themselves to rigorous scientific research with sophisticated monitoring approaches to gain a full and accurate understanding of the systems of interest. At the same time, land managers would benefit from straightforward measures of environmental condition which can aid management in real time and provide feedback about the results of their management efforts. The foundational elements of the monitoring framework discussed above can accommodate the wide spectrum of aims from community engagement in river-care to achieving greater scientific understanding of landscape processes.

APPENDIX 1: PEN – SCOTT FORESHORE CONDITION GRADING SYSTEM

The concept of general riparian condition for South-West waterways was developed by Dr Luke Pen and Margaret Scott and their definition has been widely used to illustrate the average quality of riparian vegetation along our rivers and creeks. The stream condition rating is based on the form and stability of natural channels and the balance between native plants and grassy weeds.

Stream reaches are graded on a simple A - B - C - D scale, A being pristine (A) 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 degree of soil disturbance. B Grade corresponds to a situation where native plant species and exotic weeds are both common and bed and bank erosion arising from external pressures is starting to compromise the integrity and resilience of the riparian ecosystem. Once degraded to B, C and D categories, streams will not be returned to A1 grade given the change of stream flow pattern due to land clearing, the proliferation of weeds, feral animals, and other irreversible disturbance factors. Nevertheless, improvements to stream condition would ideally halt and reverse various degrading processes and the floodway would move from D grade to C grade and possibly to B grade.

A Grade

Foreshore has healthy native bush (i.e., similar to that found in nature reserves, state forests and national parks).

A1. Pristine

The river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.

A2. Near Pristine

Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact.

A3. Slightly Degraded

Native vegetation dominates, but there are some areas of human disturbance where soil may be exposed, and weeds are relatively dense (i.e., along tracks). Native vegetation would quickly recolonise if human disturbance declined.

B Grade

The foreshore vegetation had been invaded by weeds, mainly grasses and looks similar to typical roadside vegetation.

B1. Degraded – weed infested

Weeds have become a significant component of the understorey vegetation. Native species are still dominant, but a few have been replaced by weeds.

B2. Degraded – heavily weed infested

Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined.

B3. Degraded – weed dominant

Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared.

C Grade

The foreshore supports only trees over weeds or pasture. Bank erosion and subsidence may occur in localised areas.

C1. Erosion prone

Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (i.e., annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support.

C2. Soil exposed

Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through humans use and activity. Low level soil erosion has begun.

C3. Eroded

Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.

D Grade

The stream is little more than an eroding ditch or a weed infested drain.

D1. Ditch – eroding

There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas but are doomed to be undermined eventually.

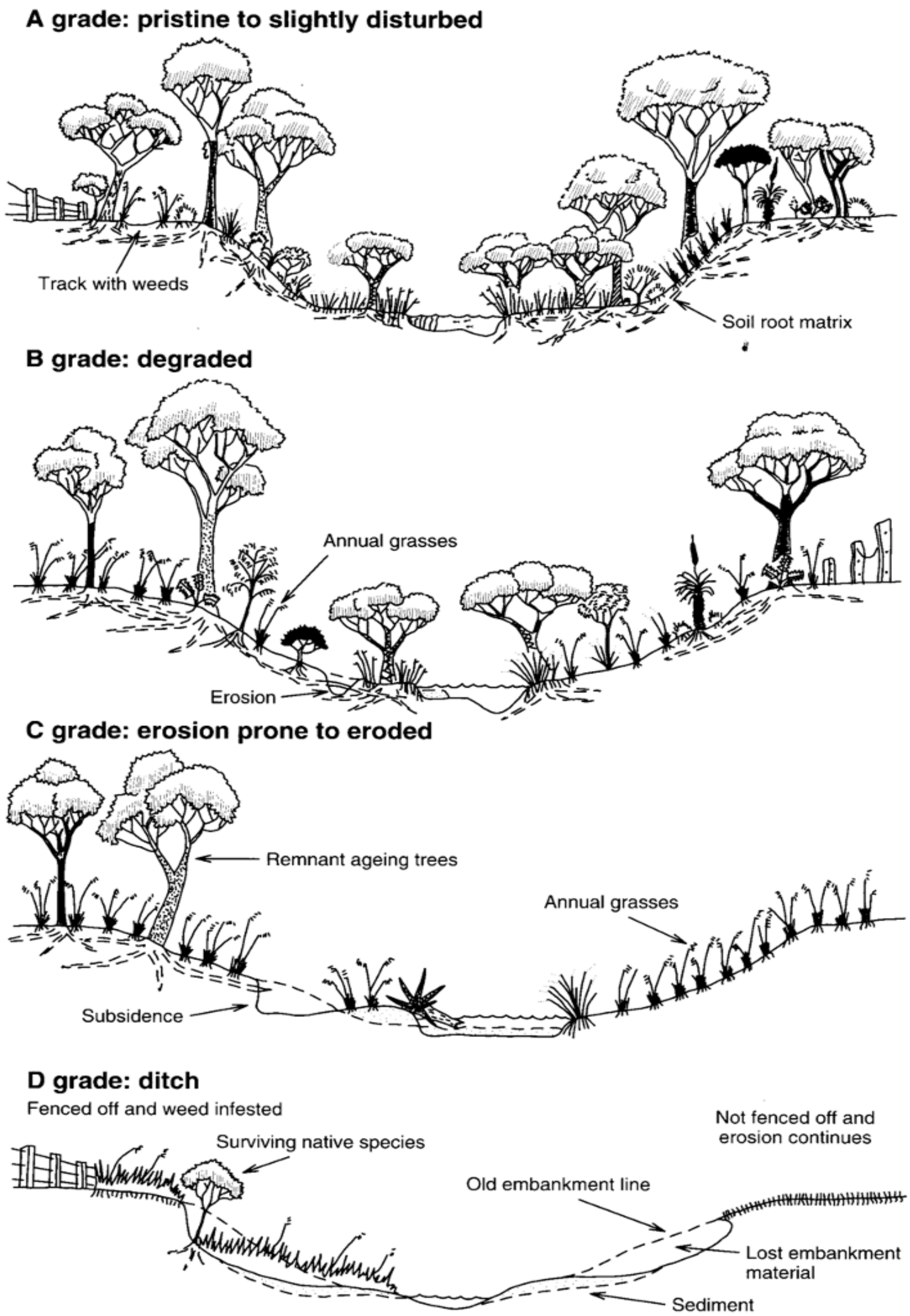
D2. Ditch – freely eroding

No significant fringing vegetation remains, and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel.

D3. Drain – weed dominant

The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established, and the river has become a simple drain.

The Pen-Scott assessment is very broad by definition, and its main use is for prioritising stream reaches for rehabilitation, especially in an environment where funding is limited. The classifications are subject to the discretion of the observer and ratings will often differ from person to person. For this reason, using the rating to track improvements is questionable. The main limitation is that it only describes riparian condition in general terms.



: Pictorial representation of the Pen-Scott four basic foreshore condition grades

APPENDIX 2: GIS AND AERIAL IMAGE INTERPRETATION

The foundation of the GIS waterway condition database is a streamline analysis. Riparian vegetation and stream order were assessed for every discernible section of the minor and major reaches of watercourses from the catchment boundary down to its confluence with the Pallinup River. The assessment clarified the size and a rating of the basic state of each section of the waterways sufficient to set overarching improvement goals.

The DOW 2004 drainage network layer “HydrographyLinear” was clipped to the Warperup Creek Catchment and used as a base layer for the Warperup streamline analysis. All non-streamline points and lines were removed leaving only ‘Watercourse’ and ‘Natural Pool’ hydrographic types. Some watercourse lines were split at property boundaries and others were merged as appropriate.

Attributes from the original layer that were kept were HYD_TYPE, and HYDNAM and new attributes were added. The attributes are described in the table below.

The *Strahler* stream order for each section was assessed and the length of each section was calculated. Shallow swales and small established gullies commonly seen in paddocks and bushland 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. This downstream progression is illustrated below.

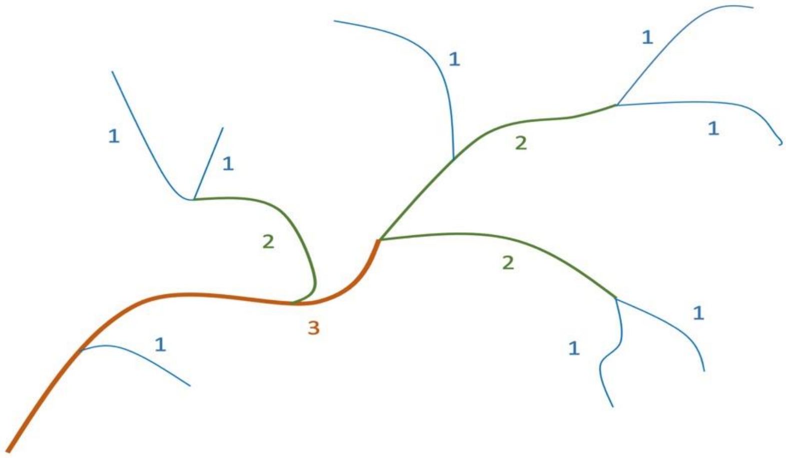


Figure X: Stream order defined

Riparian vegetation cover was assessed for each reach by examining Google Earth imagery. This imagery varied in age, with the most recent being 2018. The categories used to describe vegetation type, density and width are general and limited by image resolution and visual interpretation of the available aerial imagery.

Property information (Property_N, Party_Name, PiParcel, Lot_Number) for sections of watercourse was obtained from the 2002 cadastre layer “Gnowangerup_Parcel_region” and the 2017 cadastre layer “0073_cad_cur_poly_GDA94z50”. Some of the ownership details were updated based on the 2022 Farmer survey conducted by NSPNR. However, it should not be assumed that this information is current since farms and individual lots are regularly bought and sold. These attributes will need updating to reflect changes of ownership. The GIS attributes are described as follows:

GIS attributes

Field	Type	Length	Precision	Comment
fid	Real	20	0	Unique identifier for each record
HYD_TYPE	String	50	0	A categorisation of the type of water course: Natural Pool - non-perennial Natural Pool - perennial Watercourse - claypan Watercourse - indefinite Watercourse - major, non-perennial Watercourse - major, perennial Watercourse - minor, non-perennial Watercourse - non-perennial Watercourse - perennial Watercourse -bypass channel.
HYDNAME	String	80	0	Creek names where known or an allocated numbering for tributaries e.g. “Coromup Creek trib 01”.
Subcatchtm	String	50	0	The catchment is divided into five sub catchments: Coromup, Ongerup, Peedillup, Peerup, Upper Warperup.
Hyd_order	Integer64	10	0	Stream order “1 through to 6”.
Length_m	Real	10	6	The length in meters of each section.
Features	String	50	0	Comments regarding the watercourse, in stream dams, salt scalds, sandy channel, samphire flats, rock constrained etc.
cover_type	String	50	0	Riparian vegetation cover type: “bare” appears bare of trees and/or shrubs “Reveg” appears to be revegetated, rows of trees. “Remnant” appears to be natural vegetation.
Veg-densit	String	50	0	Density of riparian vegetation: “bare” bare of trees and/or shrubs “low” low density, usually trees with spaces between “moderate” moderate density, usually trees, some overlapping “dense” trees and shrubs dominating.
Cov_width	String	50	0	The width of riparian vegetation: “Narrow”, less than the width of a dam “Moderate”, up to twice the width of a dam “Wide”, wider than twice the width of a dam.
COMMENT_	String	80	0	Various comments regarding the vegetation.
Property_N	String	100	0	Farm name, as recorded in various Cadastre layers.
Party_Name	String	100	0	Farm owner or manager, as recorded in various Cadastre layers
PiParcel	String	20	0	A parcel of land with unique identifier including lot number
Lot_Number	Integer64	10	0	Lot number of the parcel of land

Vegetation Assessment categories

Vegetation type categories	Vegetation density categories		Vegetation width categories	
Bare	Bare	Bare of trees and shrubs		
Remnant vegetation	Low	Low density vegetation	Narrow	Narrow band vegetation
Revegetated (as it appears on Google Earth)	Moderate	Moderate density vegetation	Moderate	Moderate width vegetation
	Dense	High density vegetation	Wide	Wide area of vegetation

Riparian vegetation cover type:

"bare" appears bare of trees and/or shrubs

"Reveg" appears to be revegetated, rows of trees or vegetation in lines.

"Remnant" appears to be natural vegetation.

Remnant riparian vegetation was assessed as it appeared on Google Earth. One difficulty was interpretating whether the vegetation was in planted lines, indicating some rehabilitation work, or that the shadows of trees made it appear they were in lines. In some cases, there was overlap with patches of the riparian vegetation revegetated, or trees planted in lines along the fence line. There is opportunity to steadily improve the accuracy of this category when doing on ground visits.

Density of riparian vegetation:

"bare" bare of trees and/or shrubs
"low" low density, usually trees with spaces between
"moderate" moderate density, usually trees, some overlapping and some shrubs or smaller trees
"dense" trees and shrubs dominating.

The assessment of riparian density is subjective and for this reason the categories are broad and focused on trees and shrubs of sufficient size to be discernible. 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.

Width of riparian vegetation

When riparian vegetation was present, the following three categories were noted.

Narrow approximately as wide as a typical farm dam or less.
Moderate wider than a dam but less than two dam widths.
Wide wider than two dam widths.

Remnant riparian vegetation varies in width, even over short sections and a subjective average width was estimated.

Examples of vegetation type, density and width categories

Bare of trees and shrubs

The majority of the stream section is bare of trees and shrubs. Width was not recorded.

Remnant vegetation, low density

Remnant vegetation, low density, narrow width.

Remnant vegetation, low density, moderate width, and low density, wide.

Remnant vegetation, moderate density

Remnant vegetation moderate density, narrow and moderate density, moderate width

Remnant vegetation moderate density, moderate width and moderate density, wide. Note some revegetation apparent, and Samphire increasing density of cover.

Remnant vegetation, high density

Remnant vegetation, high density, narrow and high density, wide. Note the flood bypass with lines of Sheoak trees.

Remnant vegetation, high density, wide and high density, wide with a patch of revegetation.

Revegetated

Revegetated, low density, narrow and moderate density and moderate width.

Revegetated, moderate density, moderate width and dense, narrow

Revegetated, dense, narrow and dense, wide with patches of remnant vegetation.

The approach outlined above can be refined and complemented by improved remote sensing technology and ground-truthing, without compromising the existing assessments.

Results of the aerial image interpretation (2022)

Riparian vegetation density	Stream length (kms and % of sub-catchment)									
	Coromup		**Peedillup**		**Peerup**		**Ongerup**		**Upper Warperup**	
Bare of trees/shrubs	159	38%	59	34%	75	49%	71	32%	30	34%
Low density	134	32%	62	35%	30	19%	52	23%	25	28%
Moderate density	103	24%	37	21%	41	27%	78	34%	22	25%
Dense	23	5%	18	10%	8	5%	25	11%	12	14%
Total	419	100%	175	100%	154	100%	226	100%	89	100%

Riparian vegetation density for the sub-catchments of Warperup Creek. (Kilometers of stream length and percentage of sub-catchment)

Riparian vegetation type	Kilometers of stream length and percentage of sub-catchment									
	Coromup		**Peedillup**		**Peerup**		**Ongerup**		**Upper Warperup**	
Bare of trees/shrubs	159	38%	59	34%	75	49%	71	32%	30	34%
Remnant vegetation	211	50%	112	64%	56	36%	110	49%	47	52%
Revegetated	48	12%	4	2%	23	15%	45	20%	12	14%
Total	419	100%	175	100%	154	100%	226	100%	89	100%

Vegetation type for the sub-catchments of Warperup Creek. (Kilometers of stream length and percentage of sub-catchment)

Riparian vegetation width	Stream length (kms and % of sub-catchment)									
	Coromup		**Peedillup**		**Peerup**		**Ongerup**		**Upper Warperup**	
Bare of trees/shrubs	159	38%	59	34%	75	49%	71	32%	30	34%
Narrow	107	26%	34	20%	20	13%	42	19%	11	12%
Moderate	83	20%	37	21%	45	29%	36	16%	10	12%
Wide	69	16%	44	25%	14	9%	77	34%	38	42%
Total	419	100%	175	100%	154	100%	226	100%	89	100%

The figures tabled above suggest a simple way to quantify improvements in waterway condition at the catchment scale and set measurable goals. For example, the figures for Coromup Creek indicate that 159 km of the streamlines are bare of trees and shrubs while only 48 Km appear to have been revegetated to some extent. If 50% of the bare channels have potential to be improved by revegetating them (that is 80 Km) then lifting the percentage of revegetated streamlines in the catchment from 12% to 30% represents a significant improvement in waterway condition.

APPENDIX 3 – WATERWAY DESCRIPTION PROFORMA – PHYSICAL FEATURES

Recorders Name:	Proforma completion check by:
Waterway Name:	Site Code
Property address:	Date: Time
Landholder Name:	Contacted: Y N

GPS WAYPOINT COORDINATES

Datum: WGS 84/ GDA94, Zone: 50J

Photo point or Features	**Side L/R**	**Photo #**	**Easting**	**Northing**	**Compass direction**	**Way Pt No.**

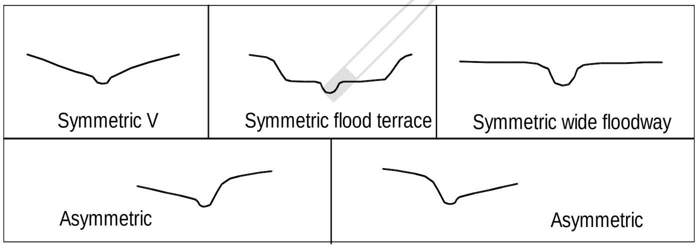
Note: **LEFT** and **RIGHT** banks are defined looking **DOWNSTREAM**

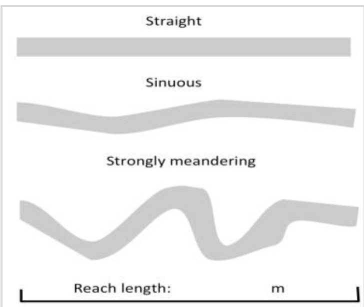
STREAM ARCHITECTURE FOR 200 – 500 M STREAM REACH

Reach General Form	**Tick as appropriate**
Pool	
Sediment in-filled pool	
Broad Incised Channel	
Narrow Incised Channel	
Meandering Channel (dominant)	
Rocky Bed	
Pool/channel dimensions (metres)	Width, length, depth

Fencing Category	**Proportion of reach**	
	Left	**Right**
1. Unfenced		
2. Fenced, inadequate to exclude stock		
3. Unfenced, but protected		
4. Fenced to exclude stock		
Fence Condition Poor 0, Reasonable 1 Good 2		

General cross-sectional shape of floodway





Floodway plan form

Floodplain features observed:
e.g. secondary channels, adjacent wetlands, seepage areas, flood scours, tributary entry, channel modifications etc. Note: include photo #s and GPS coordinates in table above
Disturbance factors e.g. Stock access, rubbish, ford, culvert crossing etc.

SITE PROFORMA – WATER QUALITY & SITE FEATURES Site Code________

WATER QUALITY	Sampling site	IF Tributary	Upstream of confluence
GPS Northing			
GPS Easting			
GPS Way Pt No.			
Salinity / EC (give unit)			
Temperature °C			
pH			
Turbidity tube NTU			
Stream flow category			
WQ samples collected			

Turbidity categories: clear, tannins, cloudy, opaque, muddy, phytoplankton
Stream flow categories: Nil, Trickle, Low, Bank-full, High, Large flood.

Bank condition *(tick appropriate boxes)*	**L**	**R**	**Bed Stability**	
Stable			Stable bed	
Limited erosion			Scoured bed	
Moderate erosion Intermittent			Active deepening	
Extensive erosion			Intermittent sediment deposition	
Extreme widening			Significant sediment deposition	
Sediment deposition				
Bank soils	**L**	**R**	**Bed Soils**	
Sandy			Sandy	
Loamy			Loamy	
Silty			Silty	
Clay			Clay	
Rocky			Rocky	
Bank shading	**L**	**R**	**Stream shading**	
0 <5% <20% <50% >50%			0 <5% <20% <50% >50%	
Bank leaf litter cover	**L**	**R**	**Dominant land use**	
0 None, 1 sparse, 2 moderate cover, 3 dense			left bank	right bank
Pen/Scott category	**L**	**R**		
A1,2,3 – B1,2,3 – C1,2,3 – D1,2,3				

Note: **LEFT** and **RIGHT** banks are defined looking **DOWNSTREAM**

Animals – Along reach and on opposite bank	**Level of Activity**		
Native wildlife/birds (seen / heard / signs of)	**Low**	**Medium**	**High**
Feral Animals (seen / heard / signs of)	**Low**	**Medium**	**High**

SITE PROFORMA – WATER QUALITY & SITE FEATURES   Site Code________

Recorders Name:	Proforma completion check by:
Waterway Name	Site Code
Property address:	Date: Time
Landholder Name:	Contacted: Y N

GPS WAYPOINT COORDINATES

Datum: WGS 84/ GDA94, Zone: 50J

Photo point or Features	**Easting**	**Northing**	**Compass direction**	**Way Pt No.**

VEGETATION CLASSIFICATION – At sampling site

Pen/Scott category (A1 – D3)	**Left Bank**	**Right Bank**

RIPARIAN VEGETATION DESCRIPTION – At sampling site

Diversity - None, Low (1-3 spp), Moderate (4-15spp), High (>15 spp)
Cover - None, Sparse (<10%), Moderate (10-50%), Dense (>50%)
Health - Healthy, Some sick, Many sick/dying, Majority dead

	Tree layer	**Shrub layer**	**Herb Layer**
Native Species diversity (None, Low (1-3 spp), Moderate (4-15spp), High (>15 spp))			
Native vegetation cover (None, Sparse (<10%), Moderate (10-50%), Dense (>50%))			
General height of trees			
Health of native vegetation (Healthy, Some sick, Many sick/dying, Majority dead)			
Weed cover (None, Sparse (<10%), Moderate (10-50%), Dense (>50%))			
Native Recruitment abundance (None, Sparse (<10%), Moderate (10-50%), Dense (>50%))			
Recruitment health (Healthy, Some sick, Many sick/dying, Majority dead)			
Recruitment type natural, planted, seeded			

COMMENTS and Species of note.

Animals – Along reach and on opposite bank - **Level of Activity**

Include Birds/ducks and feral animals.

SITE PROFORMA – WATER QUALITY & SITE FEATURES Site Code________

SITE CHARACTERISTICS Tick or estimate cover

Cover: 0 - none, 1 - sparse(<10%), 2 - moderate(10-50%), 3 - dense(>50%) Note: total cover can be greater than100%

Instream habitats	Instream plants	Riparian plants
Submerged vegetation	*Triglochin* spp. (Ribbon weed)	Eucalyptus spp.
Emergent vegetation	*Potamogeton* spp. (Pond weeds)	Paper barks (*Melaleuca spp.)*
Filamentous algae	*Charales* spp.	She-oaks (*Casuarina spp.)*
Overhanging vegetation	*Ruppia* spp.	Acacia (non-weed spp.)
Leaf litter	*Lepilaena* spp.	Samphire
Small wood (<20cm)	Filamentous Algae	Gahnia sedge
Large wood (20 – 40 cm)	Benthic mat	Other Clumped sedges
Logs (> 40 cm)		Rhizomatous sedges

Macroinvertebrate sampling – using a 250micron mesh D frame net. Sample all observable habitats covering at least 15 metres or for 5 minutes. Stir up the sediments lightly to collect benthic invertebrates BUT try to avoid getting too much sediment in the net.

AQUATIC MACROINVERTEBRATE OBSERVATIONS

Abundance scoring (approx. only, it is not necessary to count animals in the tray)	
Fish	**Abundance**
Fish (type)	
INSECTS	
Mayfly larvae (Ephemeroptera)	
Stonefly larvae (Plecoptera)	
Caddisfly larvae (Trichoptera)	
Dragonfly larvae (Anisoptera)	
Damsel fly larvae (Zygoptera)	
Diving Beetle larvae (Dytiscidae)	
Diving Beetles (Dytiscidae)	
Scavenger Beetle larvae (Hydrophilidae)	
Scavenger Beetles (Hydrophilidae)	
Whirligig beetle (Gyrinidae)	
Water strider (Microvelia sp.)	
Water-boatmen (Corixidae)	
Backswimmers (Notonectidae)	
Biting Midge larvae (Ceratopogonidae)	
Non-biting Midge larvae (Chironomidae)	
Mosquito larvae (Culicidae)	
Soldier fly larvae (Stratiomyidae)	
Brine fly (Ephydridae)	
Cranefly larvae (Tipuliidae)	
Blackfly larvae (Simuliidae)	

Habitat sampled Pool – edge – middle, Sandy channel, Rocky channel, Other –	**Size of Pool or channel sampled (m)**
Arachnids	**Abundance**
Spiders	
Water mites	
CRUSTACEANS	
Freshwater crayfish (Cherax sp)	
Glass Shrimp (Palaemonetes sp.)	
Brine and Fairy Shrimps	
Copepods	
Isopods – Pill bugs	
Amphipods - Scuds	
Water fleas (Cladocera)	
Seed shrimp (Ostracoda)	
Large green Ostracods	
Large white Ostracods	
Small green Ostracods	
Other small Ostracods	
SNAILS and MUSSELS	
Pea shells, Mussels, Bivalvia	
Snails, Coxiella	
Snails, Other	
OTHER GROUPS	
Springtails (Collembola)	
Flatworms	
Aquatic worms	

Janicke Environmental Investigations