EcoProTem

CLLMM Restoration monitoring methods assessment

Coorong, Lower Lakes and Murray Mouth Program

21st of May 2012

Summary

The purpose of this document is to assess the use of revegetation monitoring methods around the Coorong and Lower Lakes, list the monitoring which is currently being done and identify the most suitable standardized monitoring framework for moderate term monitoring of the CLLMM project. Although the locations of the monitoring sites are not known, this report does provide recommendations for the generalized locational requirements, timing of monitoring and the analysis to be done.

As monitoring methods are selected from current standard methods, this report simply refers to them. It does not contain any baseline assessments, field verification or testing of recommended methodologies. It is expected that this will be done during the initial pilot monitoring event.

This monitoring is not meant to be a comprehensive ecological survey but a rapid site assessment to enable management action. Parameters have been selected on their ability to guide management of these sites and highlight each sites progress toward an end target.

For the purposes of this report, the monitoring program has been divided into two parts – Short term (first year) and moderate term (1-5 years).

The short-term monitoring aims to demonstrate annual compliance against planting seasons and enable continual improvement. The moderate length component will track the progress of each site toward a target ecosystem and the resilience of the sites to threats. Combined, these two monitoring programs will track compliance towards the overall vegetation program objectives

The short term monitoring is currently underway and appears to be adequate. The only recommendation is that the annual survival monitoring could benefit from an autumn survey, to help identify the cause of plant death.

To identify suitable monitoring frameworks, seven existing standard systems were assessed. Out of these frameworks, the most suitable was deemed to be the EFA method, developed in 1986 by CSIRO. The well known Landscape Function Analysis is the first step of the expanded Ecosystem Function Analysis, which also includes assessments of vegetation and habitat structure and complexity.

The EFA methodology has been applied to a range of ecosystems, from tropical rainforest and riparian zones, to semi arid coastal and wetland habitats. The framework includes a wide range of parameters, measured by mainly standard methodologies. EFA methods and the analysis have been found to be valid in most terrestrial ecosystems, as long as there is some slope and therefore potential for erosion on the site.

In 2008, PIRSA adapted the EFA methodology as the standard practice for South Australian mine sites. The method was trailed at Cooke Plains, which is near to the CLLMM project site.

The recommended moderate term monitoring is based on the most modern form of Ecosystem Function Analysis. It is to include observations of landscape context, photopoint monitoring, EFA vegetation and soils assessments, soil analysis and recording of environmental conditions.

Initially, it is expected that community involvement will be low, however we strongly encourage the use of local specialists, who can mentor community groups to slowly take over the monitoring program, as the sites become more established.

It is recommended that monitoring be undertaken at the same time each year, which is likely to be autumn. Although most items will need monitoring every year, there are some parameters which will only need infrequent assessment.

1. Introduction

Faith Cook (EcoProTem) was contacted by Katherine Goss (Monitoring and Vegetation Officer, Coorong and Lower Lakes Restoration, CLLMM Program) to provide a quote for undertaking a grey literature assessment of revegetation monitoring methods around the Coorong and Lower Lakes. The purpose of the review is to recommend the most suitable one(s) to address CLLMM Program needs.

The overarching goals of the project are to stabilise the ecological decline of the CLLMM region and to deliver a healthy and resilient wetland and community, which is able to adapt to changing water levels. This objective is to support aquatic-terrestrial connectivity, self sustaining populations and habitat complexity.

The work conducted comprised of;

- Reviewing departmental grey papers (provided by the client)
- Reviewing additional grey papers already in the project team's possession
- Listing the monitoring which is currently being done,
- Reviewing the suitability of State or National standardized monitoring frameworks in light of the project objectives and habitat types
- Recommending the most suitable monitoring framework and monitoring methodologies from those reviewed
- Preparing a report listing the monitoring to done, locations, timing and analysis

The scope of work did not include collection and review of extensive, externally sourced documentation on monitoring these particular habitats and situations, as this level of analysis would not fit into the required project timelines.

As monitoring methods will be selected from current standard methods, the project report will contain references to these methods, rather than reproducing them in the document. Project outcomes will not include field sheets or spreadsheets for undertaking analysis, although methods with this material available will be preferentially selected for recommendation.

The project does not include any baseline assessments, field verification or testing of recommended methodologies.

2. Consultants

EcoProTem was created to provide interim environmental managers on a contractual basis. We provide part-time or temporary senior environmental management personnel to mining companies, local government, community groups and industrial enterprises.

Services to these organisations range include providing environmental managers on a permanent part-time basis, provision of an experienced manager to deliver a project for a community group and short-term replacements while staff members are on leave.

3. Monitoring need

Large-scale tubestock plantings are being undertaken around the Coorong and Lower Lakes. These plantings are being done to increase the resilience of these habitats, from climate change, low water and high water events. It is also envisaged that these plantings will reduce lakeside erosion and help improve water quality in the lakes by replacing high loss ecosystems with more retentive ones.

As things stand, or stood prior to revegetation, many of the areas being revegetated are dominated by Kikuyu, with scattered remnant plants. The remanant plants were generally in poor condition with little or no recruitment occurring. The Kikuyu swards provide good protection from wind or rain-driven erosion, however they provide very little protection from overland flow or slumping driven erosion events.

The monitoring needs to identify if the resilience of the ecosystems has increased, it needs to identify any future challenges to the success of the project and be cost effective.

Typical measures to identify the resilience of an ecosystem include local species diversity, habitat condition, presence and cover of weed species, nutrient loads, pathogen loads, grazing pressure, soil structure and fertility.

This monitoring is not meant to be a comprehensive ecological survey but a rapid site assessment to enable management action. Parameters have been selected on their ability to guide management of these sites and highlight each sites progress toward an end target. They were selected to balance the needs for accuracy and time efficiency. Each parameter to be assessed is one that is difficult to measure by remote means.

For the purposes of this report, the monitoring program has been divided into two parts – Short term (first year) and moderate term (1-5 years). Although long-term monitoring has not been included within this report, it is expected that the moderate-term monitoring will be scalable to long-term monitoring requirements, if they arise.

3.1 Current short-term monitoring

The short term monitoring is currently underway. It is focused on revegetation compliance, quality and output reporting. Broad scale, coarse detail (no species specific assessments) includes;

- What percentage of plants from previous season survived planting & first summer?
- Were there significant differences in survival between landform zones?
  Audits and quality assurance of pest and weed control work, site preparation, planting, nurseries etc.
- Feedback loops for follow up pest work and plant infill.

- Assessments of potential improvements and how recommendations have been acted on.

All of these components are currently underway or planned and working to a suitable level. However the annual survival monitoring could benefit from an autumn survey, to help identify the cause of plant death.

Dr Clare Moyle (Rural Solutions) prepared an excellent short to moderate term monitoring plan for the lake bed plantings, which had a lot in common with the moderate term monitoring recommended within this report. Early flooding of the plantings has ment that only limited data was collected using this monitoring program, however the data that exists should be reasonably comparable to data collected under this program.

The main difference between the program proposed in this report and that of Clare Moyle's is the level of spatially and statistically analyzable data for each parameter, which is higher within the recommended program, due to the framework utilized.

3.2 Scope of future intermediate term monitoring

Scoping the moderate or intermediate term monitoring is the purpose of this report. The objective of the moderate term monitoring is to track trends towards a 'restored' state, in particular demonstrating self sustaining populations and habitat complexity.

It is expected that many of the restored habitats may not reach a fully restored state over the five year monitoring period; however the ability to identify if they are likely to ever reach this point is critical. There is also a chance that some components of the monitoring will continue beyond the current five year time frame.

A separate project is mapping and defining vegetation communities. These could be used as the target reference conditions to track trends towards.

Ten demonstration sites are currently being selected, which are geographically spread across the region and cover a range of delivery partner sites. They are also visible from road or have public access. Sites are divided into zones. There are ten standard zones based on landforms and associated plant communities. Most sites have 2-4 zones represented.

Aspects to be addressed by the moderate term monitoring include;

- Changes in habitat structure and cover over time
- Presence of reproductive materials or self-regeneration
- Plant health
- The long term survivorship
- The suitability of plant selection for each landform and environmental pressures

Community involvement is encouraged in all parts of the CLLMM program. For monitoring, opportunities for volunteer assistance or involvement should be incorporated wherever possible.

3.3 Conjunctant programs

A number of other sub-projects are occurring within the CLLMM project. These all have data outputs and monitoring programs. Outputs of these subprojects include;

- Spatial data on changes in connectivity
- Use of remediated habitats by indicator taxa versus control habitats over time
- Audited details of the species planted and their initial survival
- Remote sensed data on habitat cover etc.

This monitoring program will need to take these other monitoring programs into account and utilize existing data wherever practicable.

4. Frameworks

4.1 Why use an existing framework?

Although not essential, the use of an existing framework and methodologies means that those who are asked to undertake this monitoring are all following the same textbook. It also means that data from this project can be compared against similar projects.

By using an existing methodology, there is a greater set of datum to compare the project against and fewer scientific resources are needed to prove the selection.

When preparing a compliance and delivery monitoring program – In other words, one that is needed for auditing success, rather than research – It is definitely easier to borrow from existing systems, rather than designing from scratch.

4.2 What type of framework do we need?

Ecosystem assessment frameworks are generally created for one of four reasons and sometimes a combination of both. These reasons are;

- Compliance against a funding contract
- Valuing a habitat for the purposes of seeking funding
- Tracking progress (or threats to progress) of a restored ecosystems toward a target
- General resource assessment

The short-term monitoring aims to demonstrate annual compliance against planting seasons and enable continual improvement. The moderate length component will track the progress of each site toward a target ecosystem and the resilience of the sites to threats. Combined, these two monitoring programs will track compliance towards the overall vegetation program objectives

When comparing monitoring frameworks, you also need to identify if you are after qualitative or quantitative outputs, or a mixture of the two.

Looking at the last decade of ecosystem analysis around the Coorong, Lower Lakes and Murray Mouth, the trend has been for more and more systematic monitoring and assessment methods, involving scientifically defendable matrixes. It is assumed that this systematic, quantitative approach is also the desired outcome of this monitoring program.

4.3 Framework comparison and selection

The monitoring framework is the structure of the program, which sets out the general principles of the monitoring, purpose, level of accuracy and how the data will be processed. Frameworks considered for this program included;

- Habitat hectares (HH)
- Bucks for Bush (B4B)
- Ecosystem Function Analysis (EFA) , which includes Landscape Function Analysis (LFA)
- Bush Condition Monitoring (BCM)
- Rapid Appraisal of Riparian Condition (RARC)
- Ecological Integrity Framework (EIF)
- South Australian Biodiversity Assessment Tool (SABAT)

When comparing frameworks, a number of aspects were considered. These were;

- Purpose for which the program was designed
- Use of the framework on similar target ecosystems
- Use of the framework on similar initial ecosystems
- Frequency of use in Australia
- Frequency of use within the Region
- Inclusion of appropriate parameters
- Commonly accepted methodologies
- Project appropriate indicators and indexes

- Cost of implementation
- Usability of data for management decisions
- Complexity of training, software or skills required

A summary of this comparison is provided in the table on the following pages. Although the parameters being measured differed significantly between each framework, the methods by which they made their measures were startlingly similar, showing that great minds really do think alike. After the included parameters, the main differences were in the purpose for the framework and the way the data is analysed.

Which framework is most suitable?

Out of these seven considered frameworks, the most suitable was deemed to be the EFA method, which was originally developed in 1986 by twelve well known CSIRO ecologists, for a property at Lake Mere in New South Wales. Landscape Function Analysis is the first step of the expanded Ecosystem Function Analysis, which also includes assessments of vegetation and habitat structure and complexity.

Lake Mere is a saline lake, surrounded by semi-arid (250mm-500mm) woodland, within the Murray Darling Basin. As such, it shares several geophysical aspects in common with the CLLMM project site, although there are just as many aspects which are not in alignment.

Since 1986, the EFA methodology has been applied to a range of ecosystems, from tropical rainforest and riparian zones, to semi arid coastal and wetland habitats. The framework includes a wide range of parameters, measured by mainly standard methodologies. Analysis is by a freely available spreadsheet and basic statistical calculation.

Both the EFA methods and the analysis method are valid in most terrestrial ecosystems, as long as there is some slope and therefore potential for erosion on the site.

According to a validation review of the framework and indexes by the CSIRO (2003);

The EFA indicators were shown to have a very high degree of verification with the measured properties in the surface soil. Where verification was not fully met, the reasons behind this have been explained in the context of the specific locations.

The EFA procedure was the same for all the minesites, which was an original design factor: generic procedure. As the sites varied from sandy deserts with 200 mm rain fall to tropical rain forests with about 4000 mm rainfall the method has shown very broad potential application.

It may well be possible to refine the procedure for use at specific locations to give results with higher precision, or greater sensitivity, but this is not necessary for monitoring, especially if the ecosystem trajectory process is followed.

The quality of many of the relationships were sufficient to use to model soil stability, infiltration and nutrient cycling if hill slope and above scale studies were required. EFA could provide an extensive data set of adequate quality at a fraction of the cost of direct measurements.

In 2008, PIRSA adapted the EFA methodology as the standard practice for South Australian mine sites. The method was trailed at Cooke Plains and detailed within a information leaflet, which is accessible from their website (see link below). The leaflet contains a diagram, showing the relationship between EFA and LFA, which has been reproduced below.

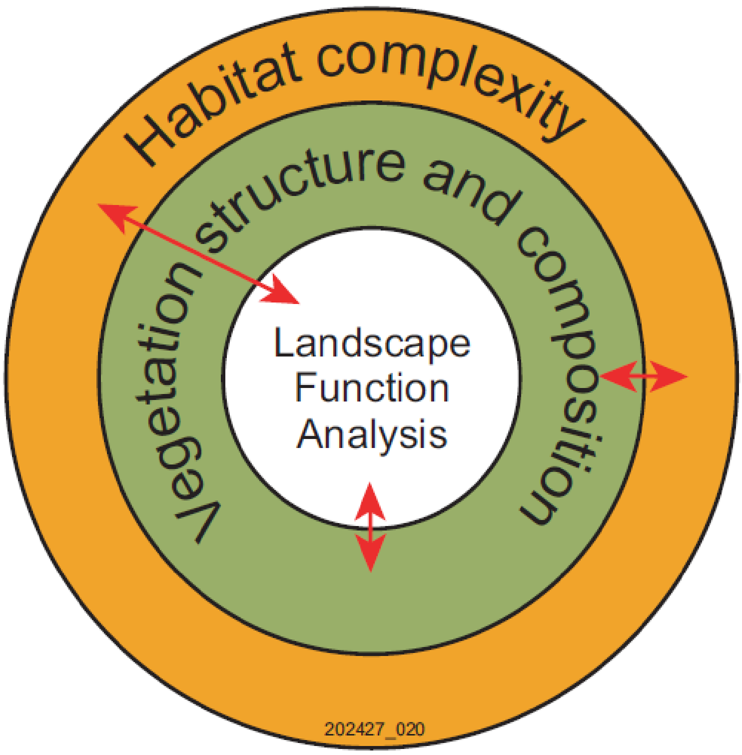

Figure 1: The EFA model (Tongway & Hindley, 2004) as shown in the PIRSA EFA leaflet.

http://www.pir.sa.gov.au/__data/assets/pdf_file/0008/11024/mj35_ecosystem.pdf

	Purpose	Target habitat	Initial habitat	Used in Aust.	Used in Region	Parameters	Methods	Indicators and indexes	Cost	Useability	Complexity
HH	Providing a value for Habitat Tender program and identifying ways in which the landholder could improve the site.	Yes	No	In VIC	No	Vegetation area and perimeter Weeds Native vegetation diversity Litter % cover Native vegetation recruitment Habitat structure Habitat maturity Vegetation life forms	Mainly expert observation, with some measurement to get the assessor's eye in.	Not appropriate for this habitat type. New benchmarks would need to be developed for these ecosystems.	$$$ Needs palm-pilot and software. Take up to a day per site.	The Habitat Hectares framework is highly dependant on the use of appropriate, well studied, highly specific benchmarks. Without appropriate benchmarks, this system does not work.	Specialised software and up to two weeks of training required. Without this training, this framework would be highly subject to assessor variance.
B4B	Providing a value for Bucks for Bush habitat auctions.	Yes	No	In NSW and SE SA	No	Bucks for Bush is the NSW equivalent to Habitat Hectares. The program was developed for an auction system in NSW. Although one of the EcoProTem team has been involved in using this program, we could not source a manual, so specific details have not been included here.		Not appropriate for this habitat type. New indicators would need to be developed.	We assume that this would be similar to Habitat Hectares.		Specialised software and training required.

	Purpose	Target habitat	Initial habitat	Used in Aust.	Used in Region	Parameters	Methods	Indicators and indexes	Cost	Useability	Complexity
EFA /LFA	Assessing the success of mine site revegetation or remediation of other impacts (grazing, clearance etc).	Yes	Yes, although we recommend that moderate term monitoring not commence until revegetation has been completed, to avoid statistical complexity.	All states	Yes – At several mines and revegetation sites within the region.	Erosion Litter accumulation Vegetation diversity Vegetation cover Stability Infiltration Recruitment Soil respiration Ecosystem trajectory Vegetation function	A wide array of standard landscape ecological methods. Includes linear transects, wandering transects, plotless quadrats, photo points, soil tests etc.	The framework stipulates the development of project specific indexes, using a given methodology.	$$	Highly useable. Tracks the site against a set of reference values and provides an indication of management challenges. The ecosystem trajectory, stability index and functional Vegetation Index are particularly relevant to this project.	Moderately complex. Analysis is done with a free spreadsheet. Requires two days of training. The analysis requires a landscape process mindset, as it uses terms such as triggers, transfers, reserves, pulses, ploughback, feedback, outflows and off-takes.
BCM	Impact identification on remnant scrub. Required for funding through some NRM Boards.	Yes	No	Yes –SA only.	Main monitoring framework.	Vegetation diversity Vegetation cover Grazing pressure Tree health Habitat value Weed and pest cover and diversity Habitat structure Plant life forms Regeneration Pathogen and disease presence	Quadrats Photopoints Expert observation Plotless point quadrat for trees. There are a number of graphical representations of various covers and	Indexes have been developed for the whole region, although only limited ones applicable to the lakeside. In the absence of reference sites for this	$$$. Can take up to 2 days per site.	The data set collected is very comprehensive. Some of the data has limited use from a management perspective, however it does indicate the health of	Requires 1-3 days of training. Even after training, new surveyors often continue to report a degree of uncertainty. Each experienced surveyor seems to have developed their own short cuts, which could damage the integrity of the

	Purpose	Target habitat	Initial habitat	Used in Aust.	Used in Region	Parameters	Methods	Indicators and indexes	Cost	Useability	Complexity
						Litter % cover Tree hollow score. Canopy cover Disturbance history. Full species list Red alert weeds Comprehensive landscape context assessment	impacts, which would be useful for surveyors using any of the described frameworks.	monitoring program, parts of these indexes could be used to provide an interim context for this monitoring program.		the system and its progress toward a set target. The detail in this framework makes this system highly subject to seasonal variation.	regional dataset.
RARC	Assessing riparian health	No – Wrong landfor m	No	All States	Yes – on occasion.	Native cover Weed cover Vegetation structure Debris Species present Erosion	Standard vegetation assessment methods, but focusing on visual transects and assessments.	Not applicable to this landform.	$	Moderately useable.	Very simple. No specific training or specialised software required
EIF	Prioritising managemen t actions in parks	Yes	No	No	No	Vegetation diversity Level of risk Impact assessment	Standard vegetation and impact methods	Not applicable	$$	Moderately useable	Requires someone both trained in the method and with significant environmental management experiance.
SABIT	Valuing remnant scrub	Yes	No	Yes – SA only	Used in the Upper South East	Vegetation diversity	Wandering transect. Expert observation.	Scores are based on the complexity of the habitat and the presence of	$$$ Needs palm-pilot and software. Take up to	Moderately useable	Specialised software and extensive training required.

	Purpose	Target habitat	Initial habitat	Used in Aust.	Used in Region	Parameters	Methods	Indicators and indexes	Cost	Useability	Complexity
								rare species, which will not be applicable in this situation.	a day per site.		

4.4 Selecting parameters and methodologies

When comparing possible monitoring programs, the proposed program needed to include a wide range of quickly implemented methodologies, which provided data that would fit the project requirements, while being able to be used across a wider resource assessment setting.

To determine the resilience of the planted areas, a number of parameters needed to be measured;

- Species diversity
- The ability of the site to conserve and retain a bank of resources (organics, nutrients or moisture) within its soil profile
- The ability of the site to provide for the biomass that has been planted on it
- The ability of the habitat to recruit the next generation
- The ability of the vegetation to withstand weed and grazing pressures
- The ability of the vegetation to withstand changing water and climate variables
- Presence of and response to disease

It is expected that other CLLMM programs will measure the area, connectivity and faunal use of the sites.

As the density of the plants will vary significantly, the best estimate of species diversity will be a plotless method, such as a point quarter or wandering transect. The point quarter method is likely to be the better option, as it provides a more accurate measure of density and therefore biomass.

The Landscape Function Analysis (LFA) landscape organisation transect methodology is a slightly modified version of a very common group of methods loosely termed transect-based patch sized frequency analysis (Bender & Fahrig 2005, Xiaobing & van der Maarel 2009, King & Franz in-press). It is found to be a very robust tool to measure the short-term resource retentiveness of an ecosystem, across a range of habitat types. Longer term retentiveness can be measured by a range of soil tests, which are discussed within the recommendations.

The combination of biomass, surface soil condition and soil samples will also provide you with an idea of the carbon being sequestered by the planted habitats.

4.5 Developing indicator species, indexes and targets

To a degree, Bush Condition Monitoring targets can be used as interim target ecosystems, however project-specific reference sites will be required in the long run, no matter which monitoring method is used. Without these targets, we will know where we have been, but we will not know where we are going.

No single monitoring framework is going to have indicator species or indexes appropriate for this specific project, as this project is unique in its landscape setting, purpose and implementation.

Most projects are unique is some way, so we recommend that the acceptable values for each indicator and index be reassessed and calibrated for the specific environment and desired outcomes.

For some frameworks, the development of indicators and indexes comes through experience. For other frameworks (such as EFA), the development of these indexes comes from regular observation and the use of reference sites.

Without seeing the proposed monitoring sites or planted species lists, it is impossible to determine what these indexes and indicators would be.

It is expected that those undertaking the initial round of monitoring will develop their own index thresholds through examining the generated data and comparing it to reference sites, which will then be able to be monitored through statistical analysis of the data. Once an appropriate mass of data has been collected, the level of monitoring can be carefully decreased, to maximise the return on investment.

5. General recommendations

5.1 Reporting

All monitoring reports should contain the maximum amount of detail and raw data within the report or on a supplied electronic media. This detail should include parameters which are not statistically analysable in their current form, as further data collection or new methods of analysis could make these significant in the medium to long term. Copies of photos and field sheets should be provided if at all practicable.

5.2 Short term monitoring

The current short term monitoring appears well planned. The only shortfall is the inability to identify the cause of plant death and the species being affected earlier in the process, so that they can be corrected prior to summer.

An additional site assessment a month or two after planting, but before summer, will allow early intervention and a better idea of the species being affected.

5.3 Intermediate monitoring

The recommended intermediate monitoring is based on the most modern form of Landscape (Ecosystem) Function Analysis.

Although the initial time requirements for this methodology appear high, this will change over time. The requirements for the first monitoring event are higher than following events, as a statistical baseline needs to be produced, which will need rationalising down, once the amount of variance has been established.

Once the EFA indicators have stabilised and the revegetation seems to have reached its final ecosystem structure, use of EFA monitoring methodology will be less critical. At this stage, reverting to Bushland Condition Monitoring by community groups may be the ideal way to monitor long term resilience.

6. Detailed recommendations for intermediate monitoring

6.1 Landscape context

Notes on the site and surrounding influences should be made during every site visit. When done by an experienced person, these observational records can contain more information on site management improvements than any amount of formal monitoring. There is a form within the EFA handbook which provides a reasonable framework for these observations

6.2 Photo point monitoring

A photo point should be established at each location, to show the visual changes in vegetation condition and growth. Depending on the topography, these may also show changes in the surrounding environment.

There are a number of methods for photo point monitoring. In the end, the method used does not matter for the purposes of this project, as long as it is repeatable.

Care must be taken in establishing the photo point, so that the marker will stay in place, not pose a hazard to those visiting or driving on the site, that it will provided the required level of information and that it will not be 'out-grown' too quickly.

Often, a suitable location for a photo point is positioned on top of a fence post, beyond the outer edge of the revegetation site. This location will need marking and the location recording. To record the location, we recommend using both a GPS and distance measurements from surrounding features.

Catalogued as per DENR Guidelines is important for the longevity and usability of these photos.

Measurements should be taken from the photos of vegetation condition and growth. Observations regarding the efficiency of the vegetation cover to prevent erosion should also be noted.

6.3 Ecosystem Function Analysis

The Ecosystem Function Analysis (EFA) framework provides for a range of soil and vegetation monitoring methods, mainly based around a down slope transect.

The best known methodology within this framework is Landscape Function Analysis (LFA), which uses a transect (generally 20-100m long, depending on habitat) based assessment of the soil surface and vegetation distribution to identify the stability, nutrient cycling and infiltration scores of the revegetated habitat.

For the LFA portion of the monitoring program, it should be done in compliance with Tongway and Hindley (2004) Landscape Function Analysis: Procedures for monitoring and assessing landscapes. This document can be accessed from http://live.greeningaustralia.org.au/nativevegetation/pages/pdf/Authors%20T/7a_Tongway.pdf

The same manual contains basic methodology and field data sheets for the vegetation dynamics portion of EFA.

It is recommended that the Point Centred Quarter (PCQ) methodology is used. This methodology is the most repeatable, statistically. The same transect can be used as for the LFA assessment. It is standard to have a 5m spacing for PCQ points, however some areas of the revegetation sites may not have enough plants to allow for correct application of the method using this spacing. Incorrect application occurs where less than 20 plants can be found without having overlapping measurement areas. In these cases, a spacing of up to 10m should be used.

The location and number of the permanent transects at each site should be determined by the nature of water runoff, vegetation structure and patchiness, soil types, infra-structure effects, and areas of erosion. In general , more transects are established during the baseline assessments than will be required in the longer term. From the baseline data, the surveyors should be able to determine the number of transects need for future monitoring.

Use of permanent markers should be carefully considered, so that they do not pose a hazard to people walking or driving spray equipment through the sites, if required.

The manual goes on to describe the Habitat Complexity section of EFA. In young habitats the Habitat Complexity analysis is unlikely to provide useful data. It is also expected that this data will be captured by conjunctant programs within the CLLMM. Opportunistic fauna usage should be recorded whenever possible.

GIS layers, showing survey results should be produced by the surveyors on an annual basis, to enable targeted site management to occur.

6.4 Physical and chemical processes

6.4.1 Environmental conditions

The Coorong and Lower Lakes areas have an abundance of weather stations. Some of these provide more regular data than others, however it is expected that the monitoring personnel will access BOM rainfall data for the site closest to each monitoring site and assess its usability.

At some of the sites, it is possible that the monitoring will need to take into account the level of water with the adjacent lake, wind direction, wind speed and groundwater level.

6.4.2 Erosion

There are a range of optional extras that can be done in areas where erosion is a concern. These include erosion pins for sheet erosion, distance from pin measures for bank erosion, rill surveys and LIDAR.

It is also possible to use LIDAR (Light Detection and Ranging) technology to map the surface of the sites, which provides an accurate three dimensional assessment of erosion, however this can be a costly process, so should be considered on its merit.

6.4.3 Soil moisture

It is important to monitor soil moisture at several locations within the trial locations, as this provides information on the availability of moisture for the survival of vegetation. It will provide some reflection on the appropriateness of each location to the species planted and an indication of why certain plants are dying.

Soil moisture should be analysed during every monitoring event, in the soils at the end of each transect. This sample should be taken at 10-30cm of depth, which is the depth of most plant feeder roots. Taking a number of discrete samples and combining them at each sample site is likely to provide a more representative result.

6.4.4 Soil chemistry and carbon sequestration

Assessments of basic soil chemistry will provide an idea of the increasing resilience of the habitats or the aspects which may have caused failure. In conjunction with other assessments, they will also provide an indication of carbon sequestration for the site.

During the first monitoring event, soil samples (as described in 6.4.3) should be examined for pH, electrical conductivity and total organic matter. There are a number of total organic matter analysis methods, however the most common is the loss on ignition method (LOI 500). This detailed soil analysis should also be done at the end of the CLLMM project, to allow project staff to report on changes in soil composition.

Although not strictly necessary for this process, there are a number of other soil chemical properties that may be measured, which could provide an indication of why sites are not successful, if this is the case. These include nutrient assessments, soil fertility and levels of exchangeable cations.

Additional soil analysis can be expensive and will not be necessary if all sites are successful; however it is too late to test them once failure occurs. The decision on whether to test these parameters will be a budgetary and risk decision, to be made by the project team.

6.5 Community involvement

The reliance of this methodology on closely guided observations and measurement means that it is possible for community members to eventually do most of the leg work for this monitoring program, although the analysis may always need to be done by a landscape ecologist.

Toward this goal, it is recommended that the community be initially involved through replicating the photo-point surveys as required.

In the longer term, it might be possible for the contractor to train up local community members, particularly those studying for a Conservation and Land Management Certificate in the methodology, so that they can take over the longer term assessment of project success.

6.6 Timing

It is recommended that monitoring be undertaken at the same time each year. Given that immediately after the autumnal break is the time when revegetated ecosystems are showing both the greatest stress and greatest potential, we recommend that monitoring occur at these times (nominally May-June).

Another time, such as spring, could be chosen for this monitoring, as the important aspect is consistency of timing, not the actual time of year.

Monitoring and analysis that is not to be done during every monitoring event (such as the soil chemistry) should be done during the first and last event, at a minimum. If budgets allow, monitoring these aspects every three years would be ideal.

6.7 Analysis and outputs

All intermediate monitoring reports should contain all data collected on that run, a comparison to previous monitoring events, recommendations for reducing or increasing monitoring at specific sites and recommendations for management actions.

The CSIRO spreadsheets are relatively straight forward. Completed spreadsheets for each site should be provided to the CLLMM team after each monitoring event.

It is also expected that the reports contain the most modern forms of David Tongway's EFA analysis, which include Ecosystem Trajectory graphs, as show in the figure below.

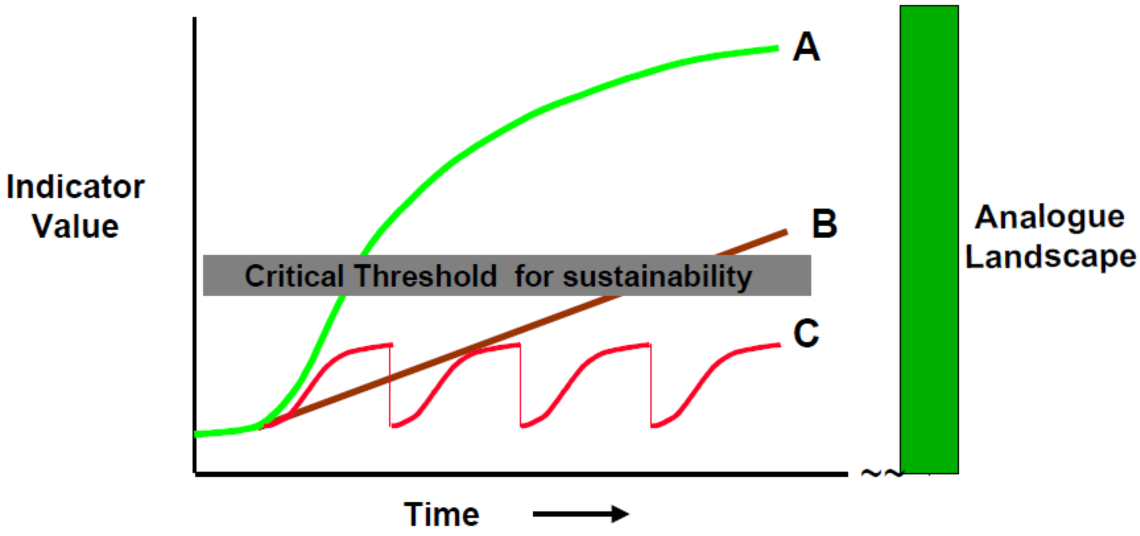

Figure 2: Image from Tongway & Hindley (2003) showing three contrasting ecosystem function trajectories. Trajectory A shows a satisfactory response over time, passing rapidly through a critical functional threshold and continuing to improve. It is likely to be self-sustaining. Curve B represents a system that develops slowly and is therefore subject to stochastic events and possible failure for a longer period. Curve C represents a system that frequently succumbs to external threats and fails to develop into a self-sustainable system.