Technical Guidance

Flora and Vegetation Surveys for Environmental Impact Assessment

Environmental Protection Authority

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Contents

1.0 Introduction

The purpose of this technical guidance is to ensure adequate flora and vegetation data of an appropriate standard are obtained and used in environmental impact assessment (EIA). The technical information provided within this guidance is applicable to flora and vegetation only and should be applied in conjunction with the Environmental Protection Authority's (EPA) Environmental Factor Guideline for Flora and Vegetation.

This guidance should be applied when planning and undertaking flora and vegetation surveys for environmental impact assessment of significant proposals under Part IV of the *Environmental Protection Act 1986* (EP Act).

This guidance provides advice on:

- survey preparation and desktop study;
- determining the type of survey required;
- sampling techniques and survey design; and
- data analysis and reporting.

This guidance is intended for use in all areas of the State however, in an area as large and diverse as Western Australia, site-specific circumstances may require deviation from the techniques in this document. Justification for use of an alternative method and how best practice has been applied must be presented in the limitations section of the survey report. If possible, consultation with the appropriate agency on the adequacy of the approach should occur.

For the purposes of this document, the term "botanist" is used as a broad label for individuals who plan and implement flora and vegetation surveys.

2.0 Preparation for survey

Flora and vegetation surveys should be coordinated and led by botanists with experience in systematic sampling and analysis methods. It is essential that survey is led by a botanist with knowledge and experience in the ecology of the flora and vegetation of the biogeographic region (bioregion) to be surveyed. The botanist leading the survey should have at least five years' experience in botanical survey in the bioregion in which the survey is to be conducted. Where the bioregion has been poorly surveyed, the experienced botanist should have more than five years' experience planning and leading surveys in that bioregion.

The experienced botanist should ideally lead the survey from beginning to end. Team members who are less experienced in surveys should be trained and supervised at all times by an experienced botanist. The experienced botanist should ensure that plant identifications undertaken by less experienced team members are checked for accuracy.

Appropriate licences should be obtained to collect flora and permission must be obtained from landholders or managers to access or undertake surveys on their lands.

3.0 Desktop study

The purpose of a desktop study is to gather contextual information on the area to be surveyed from existing surveys, literature, database searches and spatial information. A desktop study is not a survey. A desktop study should be undertaken before making a decision on an appropriate survey type and the information should be used to provide background information for the field survey and subsequent reporting.

Prior to using data from previous surveys, a judgement on the reliability of data should be made taking into account a number of factors, including suitability of methods, data analysis, timing of survey or status changes since reporting. The judgement/s should be provided in the limitations section of the survey report.

At the completion of the desktop study, there should be sufficient information to identify the potential range of flora and vegetation that may be affected by a proposal and their distribution in relation to the survey area.

The following sub-sections outline the information that should be collected as part of a desktop study.

3.1 Flora

An evaluation of previous flora and vegetation surveys should be undertaken to develop an understanding of dominant flora species, typical Families and potential diversity. *NatureMap* (Parks and Wildlife 2007-) or *FloraBase* (Western Australian Herbarium 1998-) should be used to create a list of known and expected flora species for the survey area. The Atlas of Living Australia (ALA 2015) may also be a useful reference, particularly for surveys close to the state boundary.

A search of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Threatened Flora list and the WA Department of Parks and Wildlife's threatened and priority flora databases are essential for all surveys. A wide search area encompassing the survey area should be selected for database queries for threatened or priority flora.

Any information, such as identifying characteristics, flowering period and habitat, likely to be useful during field survey to identify the characteristics and habitat of significant flora or vegetation should be recorded. Restricted geological features (e.g. outcropping), soil types and hydrology should be targeted where there has been limited survey in the bioregion.

The desktop study may also identify other flora from the area that, while not listed, are also significant.

3.2 Vegetation

Investigation of known and likely characteristics of vegetation within the study area should be undertaken. The investigation should focus on identifying structural characteristics, composition and soil/landform associations, as well as regional and local mapping relevant to the study area. Regional vegetation mapping coverage may be statewide (Beard 1968-1981, Beard 1972-1980 and Beard *et al.* 2005) or region-specific (Heddle *et al.* 1980). More than one regional dataset may be relevant to the study area.

Quadrat-based regional datasets may be available for some regions and, in some cases, are supported by data analysis and an evaluation of vegetation significance, e.g. Gibson *et al.* 1994; Gibson *et al.* 2004; Lyons *et al.* 2004; on *NatureMap* (Parks and Wildlife 2007). Quadrat-based regional datasets should be used as a foundation for data collection and analysis.

A search of EPBC Act List of Threatened Ecological Communities and Parks and Wildlife's threatened and priority ecological communities' databases is essential for all surveys. A wide search area encompassing the survey area should be selected for database queries.

The following sources should be used to gather information about threatened ecological communities (TECs) and priority ecological communities (PECs):

- EPBC Act list of TECs;
- Parks and Wildlife's threatened and priority ecological community list (Parks and Wildlife, 2015a & 2015b);
- reports that contain the original descriptions of particular communities;
- nomination or listing descriptions of the TEC or PEC, if available from Parks and Wildlife or the Commonwealth;
- recovery plans and other reports containing information on the preferred habitats and distributions of TECs that can be checked against the study area; and
- survey reports or references in the region or locality (refer to Appendix A for a list of selected flora and vegetation reports).

Desktop study may also identify vegetation units that are not currently listed as TECs or PECs but may have significance for other reasons. Any information likely to be useful during field survey to identify the characteristics and habitat of significant communities should be recorded.

3.3 Restricted landforms and soil types

Areas that may contain unusual or restricted geological features (e.g. outcropping), distinctive soil types or hydrological features should targeted for survey as these areas may support significant flora and vegetation.

During the desktop study, satellite imagery or aerial photography may assist in identifying these areas.

4.0 Survey

This guidance outlines three types of survey. The proponent should ensure that a decision on the appropriate survey type is based on the scale and nature of potential impacts set against the contextual flora and vegetation information acquired in the desktop study.

Flora and vegetation surveys should provide adequate information for the assessment of impacts in a local and regional context. The proponent should ensure a survey undertaken for EIA is consistent with the standards outlined in this document, as well as any environmental scoping document (ESD) instructions. An appropriate survey type should provide adequate information to determine impacts, conditions, offsets and an analysis of the cumulative impacts.

4.1 Reconnaissance survey

A reconnaissance survey is undertaken to provide context and gather broad information about a survey area. Generally, a reconnaissance survey is required where flora and vegetation values are well defined, the area is not likely to support significant flora or vegetation and the scale and nature of potential impacts are not likely to be significant. In many cases, the reconnaissance survey may indicate that more detailed information will be required to determine potential impacts to the flora and vegetation, initiating a detailed survey.

A reconnaissance survey may be adequate to describe the environmental values where there are no direct impacts to flora and vegetation, for referral of schemes and scheme amendments for consideration for assessment under s48A of the EP Act.

A reconnaissance survey is undertaken to verify the information obtained from the desktop study, characterise the flora and delineate the vegetation units present. In some instances a reconnaissance survey is necessary to determine the type of survey required.

A reconnaissance survey generally involves a site visit by an experienced botanist to undertake low intensity sampling of the flora and vegetation, to describe the general vegetation characteristics and condition at an appropriate scale.

The reconnaissance survey should clarify whether the area may support any significant flora or vegetation. If significant flora or vegetation is located or considered likely to be present during a reconnaissance survey, a targeted or detailed survey may be required.

4.2 Targeted survey

A targeted survey is used to gather comprehensive information on significant flora and/or vegetation. A targeted survey aims to determine the size and extent of all significant flora populations or vegetation in the survey area and to place any impacts into context.

A targeted survey requires one or more site visit/s by an experienced botanist to locate and record details of significant flora individuals and populations, and/or extent of vegetation. Surveys should be undertaken when the targeted flora and/or vegetation are most detectable and identifiable in the field (usually when in flower).

All potentially suitable habitats should be systematically searched for significant flora or vegetation. Sufficient resources should be allocated for field time to undertake the targeted survey. Where the habitat extends outside a predefined survey area, the full extent of the population or community should be surveyed. The presence and distribution of significant flora and vegetation cannot be described on the basis of their occurrence within quadrats. Additionally, a follow-up targeted survey may be required where significant flora or ecological communities are found during opportunistic sampling.

The results of a targeted survey may indicate that a proposal is likely to have an impact on significant flora or vegetation. If this is the case, targeted surveys beyond the survey area will be required to further quantify and provide context for local or regional impacts on significant flora or vegetation.

4.3 Detailed survey

A detailed survey will be required if the desktop study finds that the area supports a high diversity of flora or vegetation, restricted landforms or vegetation units, significant flora or vegetation, if the related proposal is in a region that has been subject to minimal survey effort, or the scale and nature of the potential impacts are likely to be significant. The purpose of a detailed survey is to provide adequate local and regional context relative to the values of the flora and vegetation within the survey area. A targeted survey may also be required.

A detailed survey is necessary for significant proposals to adequately address the EPA's objective for Flora and Vegetation, as a preliminary or key environmental factor of assessment.

A detailed survey requires comprehensive survey design. Survey design should pay particular consideration to optimal survey timing for the botanical province (Section 6.4), disturbance events that may affect survey results (such as fire) and supplementary survey requirements. Adequate survey may necessitate multiple sampling events in the same season or in different seasons to describe the representative flora and vegetation of the survey area.

Survey effort should include multiple quadrats located at representative points throughout each preliminary vegetation type. To clarify vegetation unit boundaries, additional quadrats can be deployed and quadrats rescored during supplementary surveys. Traverses or transects may also be used to provide supplementary information.

If the desktop study indicates that there is adequate local and regional context, the detailed survey can be carried out within the proposal area. Where this information is not available, it is necessary to survey beyond the proposal area to provide suitable local and/or regional context.

5.0 Sampling techniques

The sampling techniques used during field survey will vary according to the type of survey required. The definitions and purpose of sampling techniques used in EIA are outlined below.

Relevés and traverses, in addition to opportunistic sampling, are common techniques for reconnaissance surveys. A combination of systematic and informal sampling techniques such as quadrats, transects, traverses and opportunistic sampling can be used for targeted and detailed surveys.

5.1 Traverse

A traverse is an informal, unmarked route along which data are collected. Traverses are a useful method of gathering information for general characterisation of flora and vegetation and may also aid in identifying the boundaries of vegetation units or selecting sites for detailed sampling.

Traverses can be used for targeted searches for significant flora or vegetation and can also be used to collect opportunistic or supplementary data. Generally, the effective search width for traverses will be determined by the distance over which a targeted species can reasonably be observed, considering the general vegetation structure/density within the search area and conspicuousness of the species being targeted.

An effective width of 10 m is acceptable for many flora in the South West, equating to a 5 m search area either side of the walked transect. Some orchids and smaller herbs are likely to require more intensive searches. Wider transect search widths may be considered acceptable for other Botanical Provinces, depending on the likelihood of the presence of significant flora.

As a minimum, the following data should be recorded along a traverse: a descriptive location; GPS coordinates and datum; targeted species or community data/vegetation unit boundary/potential quadrat location (dependant on purpose of traverse); landform; aspect; soils; vegetation condition; period since the last fire; description of disturbances; and any apparent correlation between vegetation and landform features.

5.2 Transect

A transect is a defined straight line along which data are recorded. Data can be collected from quadrats, or by using point or line intercept methods (Clarke 2009a). Transects are useful for measuring vegetative cover, determining composition and species dominance within a vegetation unit or measuring vegetation changes across vegetation unit boundaries.

The number and length of transects will depend on the purpose of the survey, the diversity of topography and vegetation units, and the dimensions of the survey area. Additional information on establishing and using transects to collect data is available from Parks and Wildlife's website and Clarke (2009a).

Information collected along a transect should include location, GPS coordinates and datum, quadrat data/vegetation unit boundaries/intercept data (dependant on the purpose of the transect), landform and soils, assessment of vegetation condition, description of disturbances and any apparent correlation between vegetation and landform features.

5.3 Relevé

A relevé is an unmarked area within which data are collected. Relevés are a low intensity survey technique for gathering information for reconnaissance surveys. Relevés can be used to collect supplementary data in detailed surveys but should not be considered a primary sampling technique.

Information collected within a relevé should include location, GPS coordinates and datum, list of species, vegetation structure, landform and soils, vegetation condition, period since the last fire, and description of disturbances.

5.4 Quadrat

A quadrat is an area with a marked boundary within which data are collected. Square quadrats are recommended to provide for comparability between survey datasets. Where a square quadrat does not fit within the vegetation unit boundary, the shape can be amended provided the total area remains the same. Quadrats are used to record floristic presence and characterise vegetation units. As quadrats have a defined boundary, they provide repeatable and verifiable location and abundance information. Quadrats are an essential part of any detailed survey and may also be necessary for a targeted survey.

Quadrats should be positioned to avoid the boundary or transition zone between vegetation units and to minimise the influence of edge effects. Quadrats should also be located to avoid local disturbances and major environmental gradients, such as changes in soil type or aspect. Where possible, quadrats should be located in intact mature vegetation (Hnatiuk *et al.* 2009; Thackway *et al.* 2008) and in areas of best condition. All quadrats should be measured out and either all corner locations recorded with a high accuracy GPS or one corner permanently marked. Additional information and methods for establishing quadrats is available in Clarke (2009b).

Information collected in each quadrat should include:

- site code;
- location, with GPS coordinates (estimate of their accuracy) and datum;
- size and shape of quadrat;
- photograph/s from north-west corner;
- landform and soil description;
- dominant growth form, height, cover and species for the three traditional strata (upper, mid and ground) compatible with NVIS Level V (Executive Steering Committee for Australian Vegetation Information ESCAVI 2003);
- any other location information that might be useful in vegetation classification including slope, aspect, litter, fire history, vegetation/landform/soil correlations;
- assessment of vegetation condition and description of disturbances;
- a comprehensive species list, including weeds; and
- quadrat marking method.

Table 1 provides indicative quadrat sizes for the biogeographic regions of Western Australia, based on commonly used quadrat sizes for regional surveys in those regions.

Table 1: Guide to indicative quadrat sizes for bioregions within Western Australia

Bioregion	Quadrat Size
Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Warren	10m x 10m
Avon Wheatbelt, Esperance Plains	10m x 10m understorey 20m x 20m overstorey
Coolgardie*, Gascoyne, Hampton, Mallee*, Murchison, Yalgoo*	20m x 20m
Carnarvon	30m x 30m
Central Ranges, Central Kimberley, Dampierland, Gibson Desert, Great Sandy Desert, Great Victoria Desert, Little Sandy Desert, Northern Kimberley, Nullarbor, Ord Victoria Plain, Pilbara, Tanami, Victoria Bonaparte	50m x 50m

* Where there is extensive tree canopy in the Yalgoo, Mallee and Coolgardie bioregions, the recommended quadrat sizes follow those for the Avon Wheatbelt.

5.5 Opportunistic sampling

Opportunistic sampling is any informal survey technique used to supplement sampling data. Flora found through opportunistic sampling that have not been recorded through other sampling methods should be recorded and collected. This is particularly important in areas where sampling by quadrat is difficult, where there is the likelihood of new or significant flora being present but not recorded in the quadrats or where there is a paucity of information.

5.6 Vegetation condition rating

The condition of vegetation can provide complementary information for assessing the significance of potential impacts. Categorising vegetation condition can vary based on the assessor, the time of year the assessment is made, following the germination of annuals (native and weeds) and time since disturbance (e.g. fire, flood or clearing). The ranking can also be influenced by the knowledge of what a particular vegetation unit looked like historically and knowledge of how a vegetation unit generally appears when in good condition. It relies on reliable field identification of plant species so that the ratio of native and introduced species can be compared (Brown *et al.* 2011).

Vegetation condition should be mapped across a site. If applying vegetation condition to vegetation mapping units, a range can be given with the most commonly encountered condition recorded first. A table should be provided with the area (hectares) and associated condition rating.

Table 2 adapts the vegetation condition scales outlined in Keighery (1994) for the South West and Interzone Botanical Province and Trudgen (1988) for assessment within the Eremaean and Northern Botanical Province. Table 2 uses the vegetation condition names and descriptions of Keighery (1994) as well as the corresponding descriptions from Trudgen (1988). The vegetation condition ratings described below relate to vegetation structure, the level of disturbance at each structural layer and the ability of the vegetation unit to regenerate.

Table 2: Vegetation Condition Scale (adapted from Keighery 1994 and Trudgen 1988)

Vegetation Condition	South West and Interzone Botanical Provinces	Eremaean and Northern Botanical Provinces
Pristine	Pristine or nearly so, no obvious signs of disturbance or damage caused by human activities since European settlement.	
Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species. Damage to trees caused by fire, the presence of non-aggressive weeds and occasional vehicle tracks.	Pristine or nearly so, no obvious signs of damage caused by human activities since European settlement.
Very Good	Vegetation structure altered, obvious signs of disturbance. Disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.	Some relatively slight signs of damage caused by human activities since European settlement. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds, or occasional vehicle tracks.
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.	More obvious signs of damage caused by human activity since European settlement, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or slightly aggressive weeds.
Poor		Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of human activities since European settlement, such as grazing, partial clearing, frequent fires or aggressive weeds.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. Disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds at high density, partial clearing, dieback and grazing.	Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species present including very aggressive species.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees and shrubs.	Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

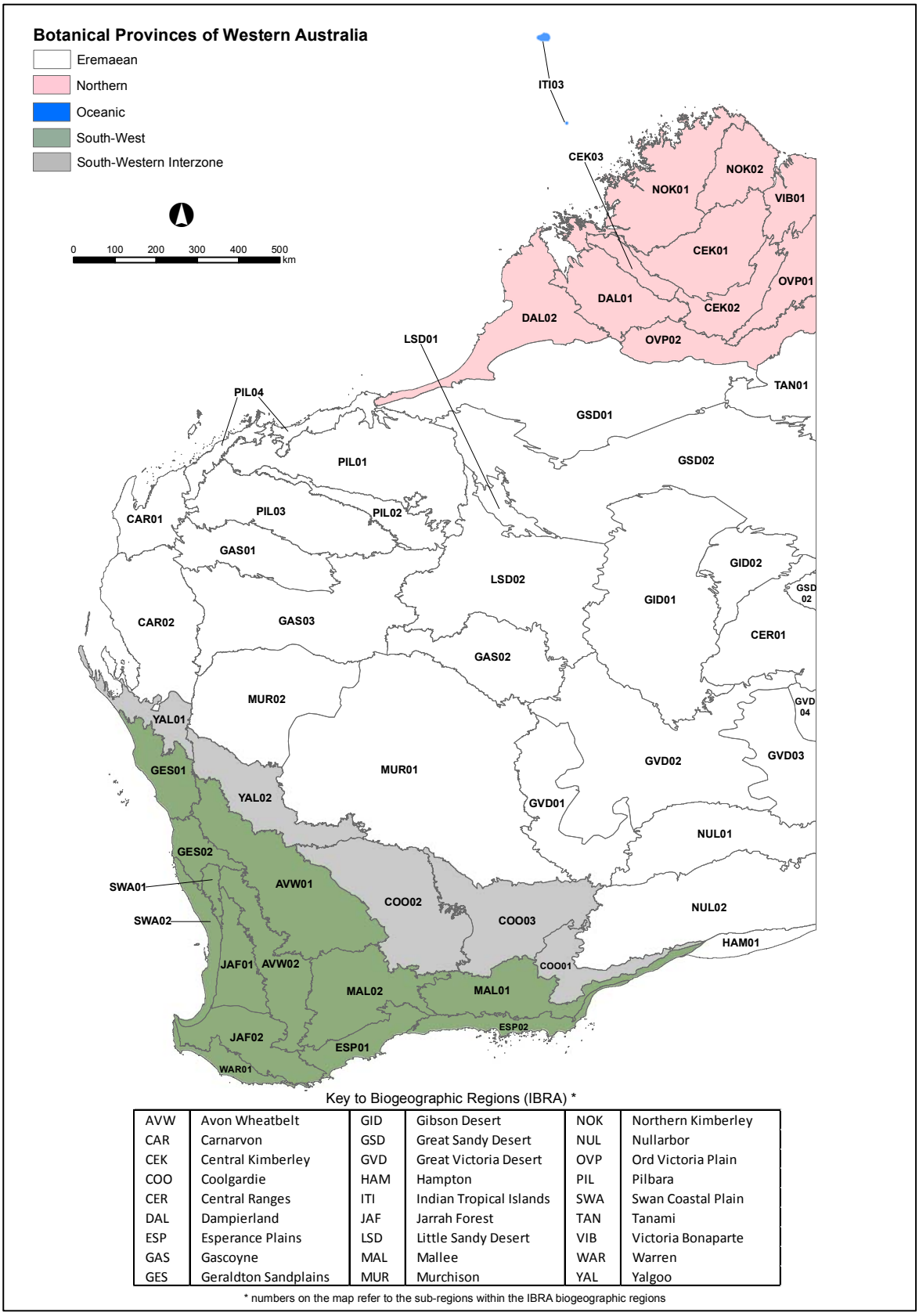
6.0 Survey design

Known or likely environmental values, nature of the environment, flora and vegetation being targeted and level of existing information are used to determine the type of survey and subsequent survey design. Survey design will also be influenced by a range of factors relating to the bioregion being surveyed.

The factors may vary between, and within, bioregions (Figure 1) including variability of climate, floral diversity and endemism, patterning in vegetation units, seasonal variation in detectability, distribution of restricted landforms or soil types and extent of historical disturbance.

Survey design should consider and, where possible, mirror the method applied in relevant regional studies to ensure results are comparable, including equal or greater intensity of sampling (e.g. one or multiple sampling events).

Most importantly, the survey design should be adequately explained and justified in the methods section of the survey report.



Key to Biogeographic Regions (IBRA) *

AVW	Avon Wheatbelt	GID	Gibson Desert	NOK	Northern Kimberley
CAR	Carnarvon	GSD	Great Sandy Desert	NUL	Nullarbor
CEK	Central Kimberley	GVD	Great Victoria Desert	OVP	Ord Victoria Plain
COO	Coolgardie	HAM	Hampton	PIL	Pilbara
CER	Central Ranges	ITI	Indian Tropical Islands	SWA	Swan Coastal Plain
DAL	Dampierland	JAF	Jarrah Forest	TAN	Tanami
ESP	Esperance Plains	LSD	Little Sandy Desert	VIB	Victoria Bonaparte
GAS	Gascoyne	MAL	Mallee	WAR	Warren
GES	Geraldton Sandplains	MUR	Murchison	YAL	Yalgoo

* numbers on the map refer to the sub-regions within the IBRA biogeographic regions

Figure 1: Botanical Provinces of Western Australia (Beard 1980) with biogeographic regions (Commonwealth of Australia 2012)

6.1 Survey area

The area surveyed should be sufficient to provide adequate information to assess direct and indirect impacts. For example, a proposal including a borefield requires survey in areas where there is a risk that groundwater drawdown may affect flora and vegetation as well as those areas cleared for infrastructure.

Botanists must ensure that an adequate area has been surveyed to enable assessment of all impacts to flora and vegetation. The size of the survey area will vary depending on the availability of existing survey information and scale of potential impacts. It may be necessary to survey beyond the proposal area to provide a local and regional context, particularly in an area or region that has been subject to minimal survey effort.

6.2 Survey effort

The survey effort should be adequate to characterise the flora and vegetation within the survey area. While survey effort can be estimated based on information gathered in the desktop study, the final decision on the appropriate sampling techniques, capture scale for vegetation mapping and amount of time required to sample the survey area should be determined based on the variability of landforms, flora and vegetation units encountered in the field.

Survey effort for a reconnaissance survey will be lower than that required for a targeted or detailed survey. In most cases, sampling techniques such as traverses or opportunistic sampling will provide sufficient survey effort for a reconnaissance survey.

Quadrat sampling is necessary for a detailed survey. The number of quadrats required will be dependent on the diversity of vegetation units present, heterogeneity within these vegetation units, the size of the vegetation units mapped and the size of the survey area. A minimum of three quadrats should be sampled in each vegetation unit. Quadrats within a widespread vegetation unit should be located to sample throughout its geographic range therefore the number of quadrats required within a vegetation unit is proportional to the area (hectares) of the unit.

Botanists must demonstrate that adequate sampling effort has been undertaken to enable an assessment of the proposal's impacts on flora and vegetation. The survey effort should also consider the number of quadrats required for adequate replication in data analysis. Species accumulation curves will generally indicate if an area has been adequately sampled.

When undertaking a detailed survey, a botanist should not rely on quadrats to obtain a comprehensive inventory of an area. Opportunistic collections, systematic transects and targeted inspections of potential habitat are also required to verify that the survey area has been well characterised and important values identified.

It may also be appropriate to increase the survey effort in areas that appear to have unusual habitat or potential to provide habitat for significant flora or vegetation, such as permanent or ephemeral wetlands, salt lakes, rocky outcrops, claypans, unusual geologies and cliffs. In such areas, it may be appropriate to install additional quadrats, survey along a transect and/or expend more time on opportunistic sampling (Figure 2).

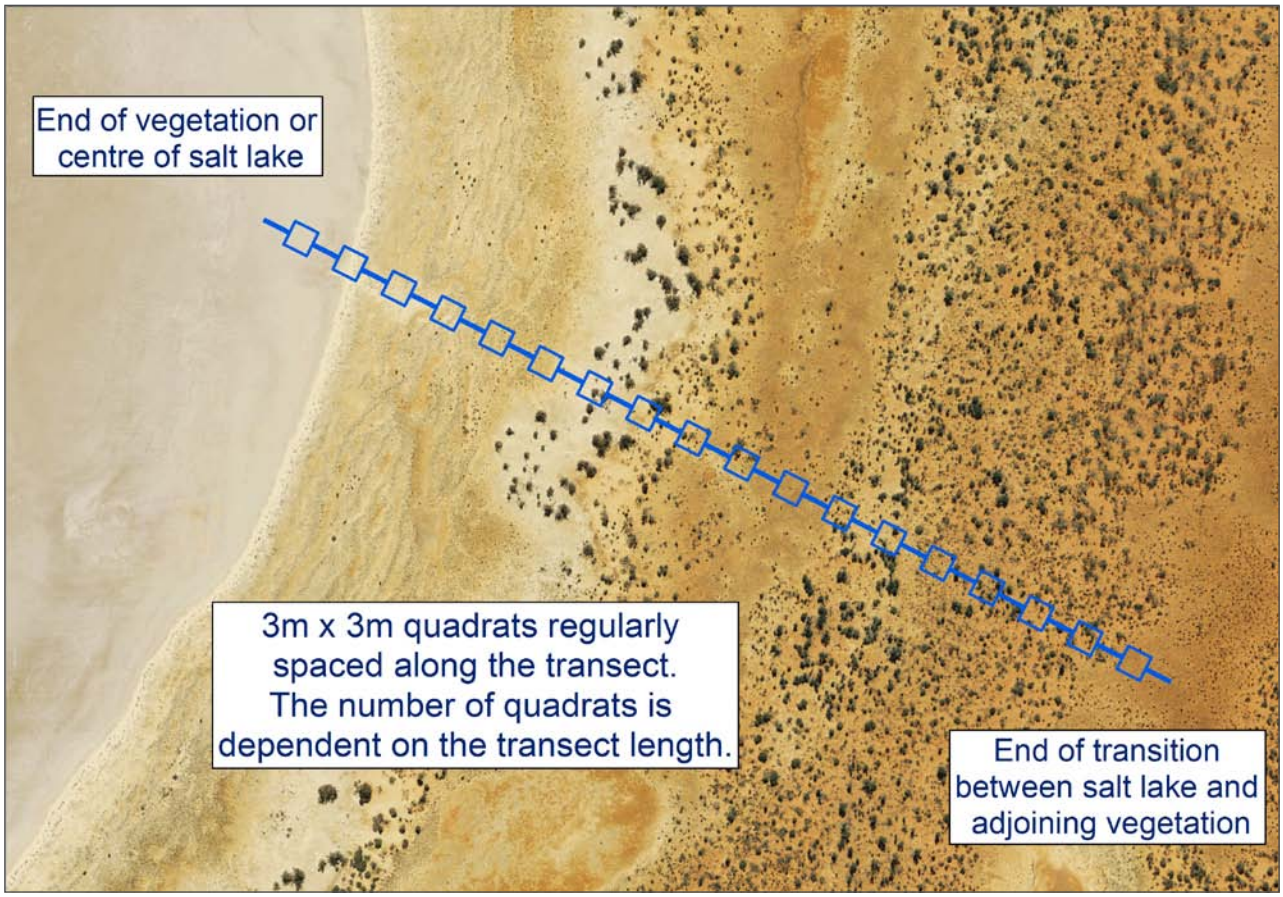


Figure 2: Example of increased survey intensity for salt lakes

6.3 Site selection

Site selection is a key aspect of survey design and field sampling as it determines the extent to which flora and vegetation can be defined. The aim of site selection is to characterise the flora and vegetation units within the survey area by collecting data at appropriate locations for the purpose of the survey.

For a reconnaissance survey, site selection should validate and elaborate on the desktop study information and map the vegetation units at a broad scale.

Site selection for a targeted survey should be guided by the habitat preference of the flora or vegetation being targeted.

In a detailed survey, sampling sites should be placed at representative locations throughout the survey area considering landform, geology, elevation, slope, aspect, surface or groundwater expression, and soil type, as well as structure, composition and condition of vegetation.

Sampling sites should be positioned to avoid the boundary or transition zone between vegetation units and to minimise the influence of edge effects.

Aerial photography is useful during survey design to determine the general location of sampling sites based on visual vegetation unit definition. Interpretation of vegetation boundaries and selection of sampling sites should be conducted with the use of aerial photography at 1:10,000 – 1:40,000 scale. The number and location of sites may require adjustment if variations in floristic patterning become evident during the survey, or if access or safety issues are encountered.

6.4 Survey timing

Surveys should be conducted during the season that is most suitable for detection and identification of the range of flora likely to occur in the survey area. This is particularly important where ephemeral or cryptic flora may be the target of survey.

Table 3 provides survey timing based on the Botanical Province (Figure 1) in which the survey area is located. Optimal survey timing may vary from year to year according to the occurrence of major 'break of season' rainfall events in the Eremaean and Northern Botanical Provinces. The amount and timing of winter rainfall may impact on appropriate survey timing in the South-West and Interzone Botanical Province. Flexibility in survey timing may be required to ensure the best chance of detection and collection of adequate survey data.

A survey undertaken in the optimal time is defined as the primary survey. More than one primary survey may be required if the area to be surveyed is affected by flooding, drought or fire. Supplementary survey is undertaken during secondary peaks in rainfall or the flowering period for additional suites of species and is commonly used to supplement the data collected in the primary survey.

Table 3: Recommended survey timing for vegetation surveys for each Botanical Province

Botanical Province	Primary survey (approximate timing)	Supplementary survey (approximate timing)
South-West and Interzone	Spring (September – November)	After Autumn rains
Eremaean	6-8 weeks post wet season (March – June)	Dry season survey (After Winter rainfall if available)
Northern	Wet season (January – March)	Post wet season

In periods of below average rainfall, supplementary sampling in succeeding years (with suitable rainfall) may be necessary to compensate for low diversity recorded during a survey (especially ephemeral species). This will be highly desirable in cases where drought is prolonged or in the absence of a range of species that might normally be expected in the environment.

6.5 Flora population census

The size and extent of significant flora populations can be determined using various techniques. Detailed counts and an understanding of area of occupancy of significant flora are generally required; however estimates (using appropriate techniques) may be sufficient for large or widespread populations. Detailed counts will be required where significant impacts are indicated (Section 4.2). More information about appropriate methods is available in the Parks and Wildlife's *Threatened and Priority Flora Report Form - Field Manual* (Department of Parks and Wildlife 2010).

Survey design for population census should consider relevant techniques including individual counts along a traverse, transect or in a quadrat to estimate density where the boundary of a population is known. Establishing the boundaries of a population of a significant flora and determine the mean densities of plants (with range) within those areas of occupancy may be more useful and relevant to impact assessment than locating every individual plant.

Less conspicuous flora such as annuals or geophytes and cryptic or disturbance sensitive species (whether threatened, priority or otherwise significant) will require more intensive survey effort.

6.6 Linear corridor survey

Detailed surveys of linear infrastructure should incorporate vegetation unit characterisation of an area from 500 m to 1,000 m on both sides of the infrastructure corridor (where this is not already part of the survey area) to provide context for EIA. Vegetation unit extrapolation can be undertaken using survey data and aerial photography.

It should be possible, in most cases, to identify suitable habitat for significant flora and vegetation during the survey and conduct more detailed targeted searches as appropriate.

7.0 Flora

It is essential that survey reports use consistent and recognised nomenclature. Nomenclature should follow the contemporary Western Australian Plant Census. Where there is uncertainty with identifications or a potential new species is identified, every effort should be made to resolve preliminary taxonomic uncertainty by consulting with the Western Australian Herbarium.

7.1 Collection and identification of specimens

The collection of flora is a critical aspect of survey to ensure specimens can be independently verified at a later date and in providing a permanent record of a species distribution. Multiple specimens should be collected where flora appears to be unusual or may be outside its known range.

Details of appropriate methods for collecting and drying specimens suitable for submission to the Western Australian Herbarium are available on the Western Australian Herbarium website. Specimens should be collected and presented in a manner consistent with the information. Information on submitting specimens to the Herbarium is also available on the Western Australian Herbarium website.

Identification of specimens should be undertaken using taxonomic keys (published in books, journals and CDs), comparison with herbarium specimens and consultation with taxonomic experts. Specimen identification skills vary widely among individuals and between projects, depending on factors such as experience with the flora, quality of specimens collected in the field and timelines for projects. The quality of specimen identifications is a critical aspect of quality control in EIA. If specimens are incorrectly identified, the entire basis of an EIA process is flawed, and decisions arising from the process compromised. Seeking expert advice on specimen identification, where required, provides greater confidence in the outcomes.

7.2 Vouchering

The Western Australian Herbarium may request collection and vouchering of species in certain bioregions that may be under-collected or otherwise of value to the collection. The following should be vouchered in all surveys:

- specimens of new populations of threatened and priority flora;
- specimens of key species in new occurrences of TECs and PECs;
- specimens that appear to represent new species or that have atypical characteristics; and,
- specimens of bioregional range extensions, including introduced (weed) species.

7.3 New species

An issue in flora and vegetation survey is the uncertainty of the significance of new species and how this may impact on assessment. The Western Australian Herbarium should be consulted on all specimens considered to have potential to be new species or anomalous flora specimens.

If a new flora species is confirmed or suspected, targeted surveys should be undertaken to quantify numbers of individuals and populations. The preferred habitat of the new species within the survey area should be described.

There is no expectation that new species taxonomy will be finalised during the EIA process.

8.0 Vegetation

Vegetation classification is the process of identifying and characterising discrete vegetation units using empirical data. The aim of vegetation classification in EIA is to identify and describe the vegetation units present within a survey area, identify the local or regional significance of the identified units and to provide sufficient information to enable analysis of the significance of impacts.

Two primary methods are used to classify vegetation units in Western Australia: one is based on dominant species and vegetation structure and the other is based on analysis of floristic composition data.

A consistent approach to vegetation classification and description across surveys in similar regions is critical for the assessment of cumulative impacts at the local and regional scale. Differences in classification and analysis methods, consideration of scale, interpretation of floristic and structural vegetation information and terminology can lead to incompatibility. The approach outlined below provides a repeatable and consistent approach for Western Australia that is also consistent with national standards.

8.1 Structural vegetation classification

Structural vegetation classification uses vegetation structure and dominant species to describe differences between vegetation units. Structural vegetation classification provides information on height of strata, foliar cover and dominant species.

Structurally based classification is acceptable for reconnaissance surveys. Low level preliminary classification of structural vegetation units may be described from a desktop study and confirmed or amended during fieldwork. Final classification should be confirmed from low intensity field sampling, such as traverses and relevés.

8.2 Floristic composition vegetation classification

Floristic composition vegetation classification can be used to describe vegetation units based on analysis of species recorded in sampling sites. Surveys in areas with high species turn-over within short distances, such as kwongan heaths, banded iron formation ranges of the Yilgarn Craton and the Swan Coastal Plain bioregion, have demonstrated that floristic patterning is key to describing variation in the sub-canopy.

Floristic composition vegetation classification is the preferred classification system for a detailed survey as the method is repeatable and is considered more suitable for identification of significant vegetation as it focuses on the suite of species present within a quadrat.

Botanists should use appropriate analysis techniques and software and provide a rationale for their data treatments and interpretations. In some instances it may be necessary to seek the advice or services of an experienced practitioner for appropriate techniques, analysis and the interpretation of results. If expertise is sought, this should occur prior to data collection to ensure all data required for optimal analysis techniques are available.

When comparing quadrat data with data from another survey, it is recommended that only species presence/absence data be used, as variation in cover estimates may significantly affect the analysis. Ensuring that all taxon names are representative of the same nomenclature is critical for analyses involving multiple data sources (data reconciliation). When interpreting the results of analysis from multiple data sources, consideration should also be given to the influence of differences in survey effort, timing of survey, seasonal conditions and disturbance history.

Use of different elements of the data may be considered in complementary statistical analysis, such as annuals, singletons, cover and/or opportunistic collections. Ephemeral species should be included in data analyses for classification in areas where they may clarify vegetation patterning (such as the Swan Coastal Plain) and excluded where they can obscure vegetation patterning (such as the Goldfields) or where ephemeral species can occupy a range of vegetation types. Ephemeral species should be excluded when using data collected over multiple survey seasons or long periods, which may affect ephemeral expression/identification. Singletons may clarify patterns in different circumstances, particularly where they may dominate a given vegetation unit or have other significance. Indicator species analysis may also be useful.

Multivariate comparative (cluster) analysis should be performed on a species-by-site matrix to measure the similarity between sites based on the presence or absence of species. A clearly legible dendrogram (Figure 3) should be produced to illustrate the similarities between the vegetation units that have been identified.

Decisions made during data interpretation require the judgement of a botanist who is experienced in the bioregion. The basis for similarities and differences between vegetation units should be described. Any correlation that exists between vegetation unit and landform, soil types, subcropping and outcropping geology, hydrology, period since fire, grazing and rainfall history should be considered in describing differences between vegetation units. The impact of vegetation condition on the outcomes of analysis should also be identified.

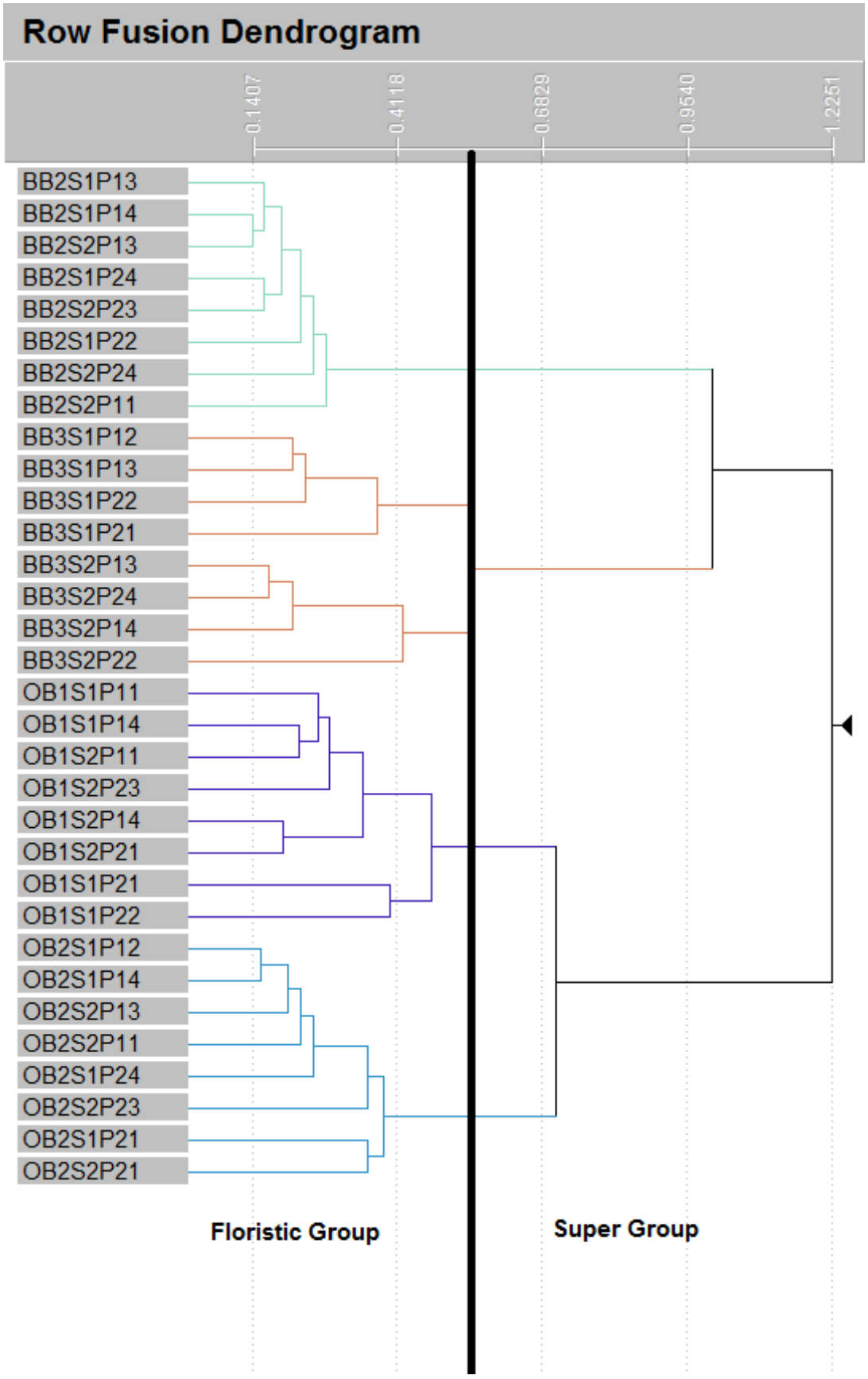


Figure 3: Example dendrogram (PATN, Belbin 2003) showing floristic and super group

The grouping of floristically similar vegetation units at a broad scale (super group) should be used when presenting regional floristic composition classification information (Figure 3). Vegetation units that are statistically distinct at a fine scale (floristic group) are suitable to classify vegetation at a local scale.

The level at which floristic and super groups are defined should be made based on data analysis and experience. Interpretation of the dendrogram should be informed by extensive and detailed field observations and supported by the relationship of the vegetation units to landform, geology, soils and hydrological conditions.

8.3 Vegetation description

The National Vegetation Information System (NVIS) (ESCAVI 2003) is the nationally adopted classification system and should be used for vegetation description for EIA in Western Australia. The use of a nationally accepted standard for documenting vegetation information provides consistency and comparability between data across a wide range of surveys, which will contribute to an improved understanding of the vegetation at a range of levels (local, regional, state, national) over time. This is particularly important for EIA where cumulative impacts across bioregions need to be considered. Current practice vegetation description in Western Australia and comparable NVIS classification hierarchy is presented in Table 4.

Local scale vegetation units should be described at NVIS Level V - Association. The term "Vegetation Type" should be used for local scale vegetation units as "Vegetation Association" is commonly used at the regional scale in Western Australia. In areas where no existing regional data is available, vegetation units should be described at NVIS Level III – Broad Floristic Formation for regional scale and cumulative impact assessment. Where vegetation units of known significance will be impacted, they should be described and mapped at the scale used in the report in which the vegetation unit was originally described.

The description of each vegetation unit should be representative of the entire area and not just the location of a quadrat. The accepted level of variability within and between vegetation units should be assessed and described. Where vegetation units contain more than one structural grouping, the range of structural variation should be presented in the description. The presence of mosaic units or smaller units within broader scale vegetation units should also be clearly identified.

Table 4: The NVIS Information Hierarchy and comparable WA current practice

Western Australia Current Practice			National Standard		
Hierarchy of terms	**Brief description in WA**	**Indicative scale**	**NVIS Level**	**Description**	**NVIS structural/floristic components required**
Vegetation formation	Structure and growth form – Forest, Woodland.	1:5 000 000	I	Class	Dominant growth form for the ecologically or structurally dominant stratum.
Vegetation sub-formation	Structural and dominant vegetation layer - Eucalypt Forest, Banksia Woodland.	1:2 500 000	II	Structural Formation	Dominant growth form, cover and height for the ecologically or structurally dominant stratum.
Vegetation association	Structural form and dominant species - Medium woodland; York gum (Eucalyptus loxophleba) & Wandoo	1:1 000 000 to 1:250 000	III	Broad Floristic Formation	Dominant growth form, cover, height and dominant land cover genus for the uppermost or dominant stratum.
Vegetation complex	Structural and floristic description linked to geomorphology – Quindalup Complex.	1:250 000 to 1:100 000	IV	Sub-Formation	Dominant growth form, cover, height and dominant genus and Family for the three traditional strata. (i.e. Upper, Mid and Ground).
Vegetation type	Floristic definition by strata with structural detail. Often represented with a code and floristic description.	1:100 000 to 1:10 000	V	Association	Dominant growth form, height, cover and up to 3 species for the three traditional strata. (i.e. Upper, Mid and Ground).
Plant community	Basic unit of vegetation classification, site specific and highly localised with detailed floristics for each stratum.	1:10 000	VI	Sub-Association	Dominant growth form, height, cover and up to 5 species for all layers/ strata.
Floristic Community Type	Floristic composition definition; e.g. Northern banksia woodlands over herb rich shrublands on the Swan Coastal Plain.	No absolute scale			

8.4 Defining Threatened and Priority Ecological Communities

The Department of Parks and Wildlife should be consulted regarding information for determining TECs or PECs and where advice is needed as to whether vegetation units are representative of listed TECs or PECs. Analysis of whether vegetation units described in the survey area represent TECs or PECs is a significant part of the vegetation classification process for EIA. Information gathered during the database and literature search stage of the desktop study should provide an early indication as to whether any known TECs or PECs occur within the survey area.

TECs and PECs may be described and listed at a number of scales. For example, communities can be described at a regional scale which incorporates many vegetation units (e.g. Vegetation Complexes of the Finnerty Ranges), regional scale describing a large area of potential occupancy (e.g. Horseflat land system of the Roebourne Plains PEC) to local scale descriptions (e.g. Sedgelands in Holocene dune swales of the southern Swan Coastal Plain).

As with priority flora, the PEC listing may reflect the level of local and regional survey information available, and the definitions, descriptions and scales of the communities described may be amended over time as better information becomes available. Where TECs or PECs are defined at a local scale, the objective of the vegetation classification will be to determine whether and where these occur within the survey area. Where the TEC or PEC is defined at a regional scale (association, alliance, complex, system or broader), vegetation sub-units of the listed ecological community should be identified so that the overall impact on the biodiversity values of the TEC or PEC can be evaluated.

Where vegetation units fall within the definition or mapped extent of a described TEC or PEC, qualitative or spatial comparison should be completed using the description and/or documented location of the TEC or PEC. Identification of TECs or PECs should be undertaken using formal descriptions of these ecological communities.

Where TECs or PECs have been described from quadrat-derived data, similarity should be determined by comparing data from the survey quadrats with data from the survey in which the TEC or PEC was identified. These data are often available in the literature or directly from Parks and Wildlife. The datasets from Gibson *et al.* (1994) and Bush Forever (2000) are available for download from NatureMap and notes on survey and analysis methods to determine floristic community types on the southern Swan Coastal Plain are also available from Parks and Wildlife.

9.0 Mapping

The results of a survey should be mapped to present information such as survey effort, distribution of vegetation units, significant vegetation and populations of significant flora in the survey area and provide complementary information to determine the significance of impact.

All maps should be legible, with an explanatory title and current information. Aerial photography should be the base layer for most maps with the subject of the map overlaid with transparent colours and labelled features. Colours of features and/or shapes of point symbols should be readily distinguishable from one another. The colours or textures used to indicate recurring features (e.g. impact footprint) should be consistent for all maps within the survey report. See Figure 4 for an example map showing minimum features. The scale of maps will vary depending on the size of the survey area, spatial heterogeneity of vegetation and amount of information that needs to be displayed.

The suite of maps presented in survey reports should include the following information (where relevant):

- an inset or separate map showing the location and extent of the survey area in a meaningful regional context (e.g. major roads, rail, Local Government Area boundaries);
- land system, soil or geological mapping for the survey area;
- mapping of the regional vegetation units, or other relevant dataset illustrating the regional context;
- the extent of previous surveys and known disturbance history;
- sampling effort depicted using GPS tracking data and/or location of sampling sites;
- distribution of vegetation units within the survey area with location of all sampling sites;
- local and regional distributions of all significant flora. If populations may be impacted, fine scale maps will be required to provide sufficient detail;
- local and regional distributions of all significant vegetation. If occurrences may be impacted, fine scale maps will be required to provide sufficient detail; and
- vegetation condition mapping (if applicable, see Section 5.6).

Significant species which may be subject to lower levels of impact may be mapped with less accuracy than those subject to high levels of impact.

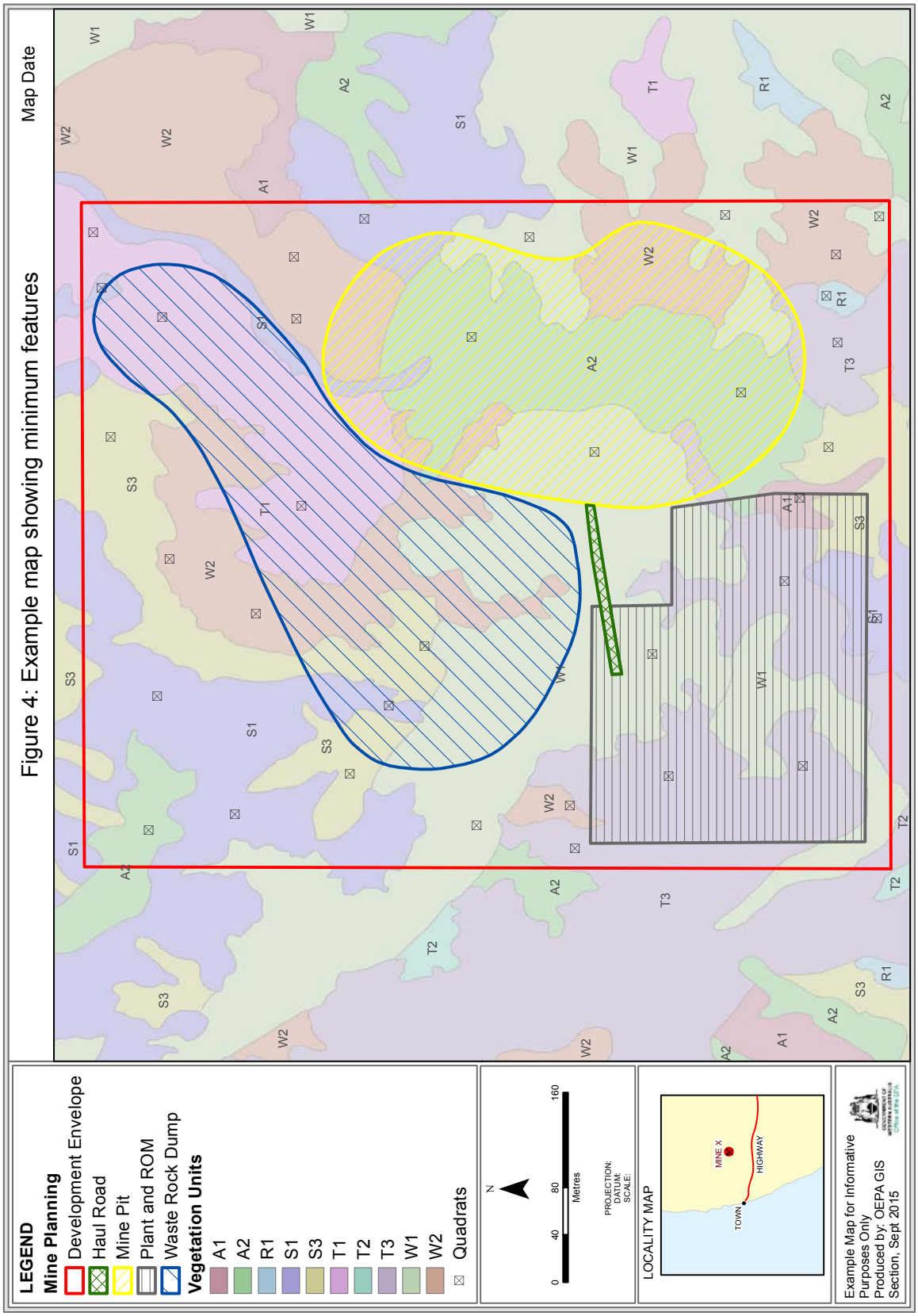


Figure 4: Example map showing minimum features

10.0 Reporting

The structure, content and detail of the survey report should be based on the objective/s of survey.

The survey report should be an accurate reflection of the information gained through survey, rational interpretation of the survey results and demonstrate that contemporary survey methods and guidance have been used.

The survey report should be prepared by the botanist involved in planning and conducting the survey where possible or should be based on interpretation by a professional in this field. Any significant changes to the report by those not involved in the survey should be justified.

The executive summary should be a succinct overview of the purpose of the survey, methods employed, key results and conclusions.

10.1 Introduction

The introduction should contain a clear statement of the objectives of the survey, the proposal and the area (hectares) of survey. Regional information such as location, climate, biogeography and disturbance history should be presented in this section.

Background information gathered during the desktop study should be presented in this section, including summaries of the results of previous studies in the area and database searches.

10.2 Methods

All reports should contain a section outlining the scope of the survey, the methods used and limitations of the survey. Justification of the type of survey conducted and the survey design, including any deviation from this guidance, should be provided.

Any survey-specific issues/limitations should be addressed in the limitations section. The following limitations should be addressed as standard, whether they were a limitation of survey or not:

- availability of contextual information at a regional and local scale;
- competency/experience of the team carrying out the survey, including experience in the bioregion surveyed;
- proportion of flora recorded and/or collected, any identification issues;
- was the appropriate area fully surveyed (effort and extent);
- access restrictions within the survey area;
- survey timing, rainfall, season of survey; and
- disturbance that may have affected the results of survey such as fire, flood or clearing.

The survey design, type of survey and choice of vegetation classification system used (structural or floristic) should be stated and justified. The rationale of data preparation for analysis should be detailed, including data reconciliation or data omitted to reduce 'noise' or outliers. A detailed description of the data analysis should be presented, including level of floristic and super group separation.

For detailed surveys, species accumulation curves should be presented as part of survey reporting. This analysis is particularly important where species composition was inconsistent with regional data or a different quadrat size from the recommended size was used.

10.3 Results

Survey results should be presented in text and tabular format summarising relevant flora and vegetation values within the survey area. Data may also be presented in graph or mapped form. Data collected during survey should be clearly differentiated from data gathered from published or unpublished sources and sources of information used should be clearly referenced in the report.

Information on flora recorded within the survey area should be presented in a flora sub-section, including numbers of taxa, genera and family representation, conservation status, any significant weed species and significant flora. Quantitative information on the size and location of significant species or populations of significant species recorded within and outside the survey area must be provided.

Information on vegetation should be presented in a vegetation sub-section. Where classification and mapping is primarily based on structural features, a two-way table organised by vegetation unit is required to illustrate the floristic variation in the units. A dendrogram should be presented where vegetation classification is based on floristic composition, with supporting text explaining the outcome of the vegetation classification. Illustrations (including dendrogram) should clarify and support interpretations made in the report. The clustering of the units within the dendrogram should illustrate the vegetation units described in the text. Any discrepancy between the dendrogram and described vegetation units should be explained in the text.

Quantitative information on the extent and location of vegetation types must be provided as well as a discussion of elements relevant to its distribution, such as landform, soils or aspect, associated flora species, groundwater or surface water dependence. There should also be a similar discussion of the regional vegetation units present within the survey area and relationship/s to described vegetation types.

An analysis indicating whether communities present in a survey area represent known TECs or PECs should be provided. Quantitative information on the size and location of significant vegetation recorded within and outside the survey area must be provided.

10.4 Discussion

A discussion should be provided on the values and significance of flora and vegetation identified within the survey area at a local and regional context. The discussion should be a synthesis of the values based on an objective interpretation of the results.

Where significant values were identified, through the desktop study, as potentially occurring in the survey area are not found, the report should discuss possible reasons for the divergence.

10.5 Conclusions

The survey report should conclude with a summary of the findings of the survey and any recommendations. All conclusions should be substantiated by the data and/or reference to the literature. The influence of survey limitations on the results should also be noted.

It is particularly important to highlight flora and vegetation issues to be mitigated in planning a proposal within the survey area, to provide advice to assist the management of potential issues (such as weeds) or where survey work is required to further define flora or vegetation values.

10.6 Appendices

Appendices should include:

- a complete list of all the species recorded during the survey grouped by family;
- a summary of database search results (if not already included in the report);
- a clear description of each sampling site with flora recorded, allocated vegetation unit, location details (GPS waypoints with datum), site photographs and any other relevant information ;
- a matrix of all species recorded during the survey by either vegetation type (reconnaissance, targeted and detailed survey) and vegetation type by quadrat (detailed survey); and
- any other information relevant to the survey.

Raw data should be provided electronically in tabular format (preferably MS Excel or Access) to allow for assimilation into future government reference datasets. To avoid publication of detail on conservation significant locations, appendices with database searches and TPRFs should be identified as being for agency reference only.

11.0 Glossary

Bioregion: see Interim Biogeographic Regionalisation of Australia (IBRA).

Context: An understanding of the survey area in relation to the local area or region. **Local context** should be considered at a scale that allows comparison of survey data and any detailed surveys found at desktop study. **Regional context** is considered at a broad scale, defined by existing regional studies.

Diversity: The variety and variability of living organisms and the environment in which they occur.

Ecological community: Naturally occurring biological assemblage that occurs in a particular type of habitat. The scale at which ecological communities are defined will often depend on the level of detail in the information source. Therefore no particular scale is specified (English & Blyth 1999).

Ecosystem: A dynamic complex of plant, animal, fungal, and microorganism communities and the associated non-living environment interacting as an ecological unit (Commonwealth of Australia 1996). (That is, all living and non-living parts of a system and their interaction. Non-living factors include climate, atmosphere, and the geosphere.)

Endemic: Being restricted to a specific region or location.

Interim Biogeographic Regionalisation of Australia (IBRA): Categorisation of the Australian continent into regions of like geology, landform, vegetation, fauna and climate (Commonwealth of Australia 2012).

National Vegetation Inventory System (NVIS): An Australia-wide consistent framework for describing and compiling data and vegetation information.

Population: All members of the same species in a given area of occupancy. Plants separated by >500 m (or a significant landscape feature) comprise a separate population

Priority ecological community: Possible threatened ecological communities that do not meet the stringent survey criteria for the assessment of threatened ecological communities, listed by Parks and Wildlife.

Priority flora: Plant taxa listed by Parks and Wildlife that are either under consideration as threatened flora but are in need of additional survey to adequately determine their status, or are adequately known but require monitoring to ensure that their security does not decline.

Proposal area: The area impacted by clearing for proposal and any adjacent indirect disturbance or impacts that may result from operation, including changes to hydrology or introduction of weeds.

Range extension: The presence of a species or vegetation unit outside its previously known range.

Refugia: Habitat that through long-term isolation or as a remnant of a previously more widely distributed habitat, may act as an important refuge for flora and vegetation that require specific biotic or abiotic conditions.

Significant flora and vegetation: Flora and vegetation may be considered significant for a range of reasons, including, but not limited to the following:

Flora

- being identified as threatened or priority species
- locally endemic or association with a restricted habitat type (e.g. surface water or groundwater dependent ecosystems)
- new species or anomalous features that indicate a potential new species

- representative of the range of a species (particularly, at the extremes of range recently discovered range extensions, or isolated outliers of the main range)
- unusual species, including restricted subspecies, varieties or naturally occurring hybrids
- relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

Vegetation

- being identified as threatened or priority ecological communities
- restricted distribution
- degree of historical impact from threatening processes
- a role as a refuge
- providing an important function required to maintain ecological integrity of a significant ecosystem.

Species/area curve: Number of species versus area (Lewis 1977); usually depicted as a graph.

Taxa (singular **Taxon):** A taxonomic grouping. Depending on context, this may be a species or one of their subdivisions (subspecies, varieties etc.), a genus or higher group.

Threatened Ecological Community (TEC): A naturally occurring assemblage of plants and animals listed by Parks and Wildlife, and endorsed by the Minister for Environment, as being threatened with extinction by human activity, or in danger of being destroyed or significantly modified by development and other pressures.

Threatened flora (Declared Rare Flora – Extant, DRF): Western Australian flora species that have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such under the *Wildlife Conservation Act 1950* – at time of writing the listing is *Wildlife Conservation (Rare Flora) Notice 2014* (Government of Western Australia 2014). Properly known as threatened flora in accord with modern international practice, they are termed Declared Rare Flora under the WC Act.

Undescribed (new flora): Species which have not yet been formally described and published in a recognised journal.

Vegetation: The various combinations that all populations of all vascular plant species form within a given area, and the nature and extent of each combination (Lewis 1977; Onions 1978). The term 'vegetation' has been applied at a range of scales in general use (as have 'community' and 'habitat').

Vegetation association: A vegetation unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy defined by Beard (1980).

Vegetation complex: Broad-scale vegetation units mostly defined in relation to geomorphology, soils and climatic conditions defined by Heddle et al. (1980).

Vegetation community: A term sometimes used colloquially to refer to plant communities or vegetation units. For the purposes of this document, vegetation unit is preferred for use in flora and vegetation survey reports.

Vegetation mosaic: The pattern of different vegetation units; two or more vegetation units occurring in a pattern too detailed to map separately at the scale being applied.

Vegetation unit: A generic term applied to a distinct type of vegetation regardless of scale. For the purposes of this document, this terminology is preferred for use in flora and vegetation survey reports.

Weed: Plants that establish and persist in a natural ecosystem where they did not previously exist. Weeds may, or may not, have detectable environmental or economic impacts

12.0 References

Atlas of Living Australia website at http://www.ala.org.au. Accessed 4 November 2015.

Beard, J.S. (1972-1980). *Vegetation survey of Western Australia*, *1:250,000 vegetation series*. Vegmap, Perth.

Beard, J.S. (1968-1981). *Vegetation survey of Western Australia*, *1:1,000,000 vegetation series*. Sheets 1-7. University of Western Australia Press, Nedlands.

Beard, J.S. (1980). A new phytogeographic map of Western Australia. *Western Australian Herbarium Research Notes* 3: 37-58

Beard, J.S., Beeston, G.R., Harvey, J.M., Hopkins, A.J.M. and Shepherd, D.P. (2005). *The vegetation of Western Australia: 1:3,000,000 map with explanatory memoir* 2nd edition). Conservation Science in Western Australia – Special Publication. Department of Conservation and Land Management, Perth.

Belbin, L. (2003). *PATN, A revised User's Guide*. Unpublished report prepared by Blatant Fabrications, Tasmania.

Brown, K., Bettink, K., Paczkowska, G., Cullity, J. and French, S. (2011). *Techniques for mapping weed distribution and cover in bushland and wetlands.* Standard Operating Procedure No. 22.1. Department of Environment and Conservation, Western Australia.

Clarke, V. (2009a). *Establishing vegetation transects*. *Standard Operating Procedure No. 6.2.* Department of Environment and Conservation, Western Australia.

Clarke, V. (2009b). *Establishing vegetation quadrats*. *Standard Operating Procedure No. 6.1*. Department of Environment and Conservation, Western Australia.

Commonwealth of Australia (1999). *Environment Protection and Biodiversity Conservation Act*.

Commonwealth of Australia (2010). *Australia's Biodiversity Conservation Strategy 2010-2030*. Department of the Environment, Canberra. https://www.environment.gov.au/biodiversity/conservation/strategy

Commonwealth of Australia (2012). *Interim Biogeographic Regionalisation for Australia (IBRA) 7*. Department of the Environment, Canberra. http://www.environment.gov.au/land/nrs/science/ibra

Department of Agriculture and Food and Department of Environment and Conservation (2012–). P*re-European Vegetation*. Spatial dataset.

Department of Parks and Wildlife (2007–). *NatureMap: Mapping Western Australia's Biodiversity*. Department of Parks and Wildlife. http://naturemap.dpaw.wa.gov.au/

Department of Parks and Wildlife (2010). T*hreatened and Priority Flora Report Form – Field Manual*. Department of Parks and Wildlife. http://www.dpaw.wa.gov.au/

Department of Parks and Wildlife (2015a). *Priority ecological communities for Western Australia Version 22, 6 June 2015.* Department of Parks and Wildlife, WA.

Department of Parks and Wildlife (2015b). *List of threatened ecological communities endorsed by the Minister for the Environment, 25 June 2015.* Department of Parks and Wildlife, WA.

Executive Steering Committee for Australian Vegetation Information ESCAVI (2003). *Australian Vegetation Attribute Manual: National Vegetation Information System, Version 6.0.* Department of Environment and Heritage, Canberra. http://www.environment.gov.au/node/18927

Gibson, N., Keighery, G.J., Lyons, M.N. and Webb, A. (2004). Terrestrial flora and vegetation of the Western Australian wheatbelt. *Records of the Western Australian Museum* Supplement 67: 139-189.

Gibson, N., Keighery, B.J., Keighery G.J., Burbidge, A.H. and Lyons, M. (1994). *A Floristic Survey of the southern Swan Coastal Plain.* Unpublished Report for the Australian Heritage Commission prepared by Department of CALM and Conservation Council of WA (Inc.).

Government of Western Australia (1950). *Wildlife Conservation Act.*

Government of Western Australia (1984). *Conservation and Land Management Act.*

Government of Western Australia (1986). *Environmental Protection Act.*

Government of Western Australia (2000). B*ush Forever, Volume 2 Directory of Bush Forever Sites.* Published by the Department of Environmental Protection, Perth.

Government of Western Australia (2002). *Conservation and Land Management Regulations*.

Government of Western Australia (2014). Wildlife Conservation (Rare Flora) Notice 2014. *Government Gazette*, WA, 02 December 2014.

Heddle, E.M., Havel, J.J. and Loneragan, O.W. (1980). Vegetation Complexes of the Darling System, Western Australia. In: *Atlas of natural resources darling system, Western Australia.* Department of Conservation and Environment, Perth, WA.

Hnatiuk, Thackway and Walker (2009). Vegetation. In McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (eds.) *Australian Soil and Land Survey Field Handbook* (3rd edition). The National Committee on Soil and Terrain, CSIRO Publishing, Australia.

Keighery, B.J. (1994). *Bushland Plant Survey: a Guide to Plant Community Survey for the Community.* Wildflower Society of WA (Inc.), Nedlands, Western Australia.

Lewis, W. H. (1977). E*cology Field Glossary: a Naturalist's Vocabulary.* Greenwood Press, Westport, Connecticut, 152pp.

Lyons, M.N., Gibson, N., Keighery, G.J., and Webb, A. (2004). Wetland flora and vegetation of the Western Australian wheatbelt. *Records of the Western Australian Museum* Supplement 67: 39-89.

Onions, C.T. (1978). *The Shorter Oxford Dictionary, on Historical Principles.* Third Edition. Claredon Press, Oxford.

Sandiford, E.M. and Barrett, S. (2010). *Albany Regional Vegetation Survey; Extent, Type and Status.* A project funded by the Western Australian Planning Commission (EnviroPlanning "Integrating NRM into Land Use Planning" and State NRM Program), South Coast Natural Resource Management Inc. and City of Albany for the Department of Environment and Conservation. Unpublished report prepared by the Department of Environment and Conservation, Western Australia.

Shepherd, D.P., Beeston, G.R. and Hopkins, A.J.M. (2002). *Native Vegetation in Western Australia: Extent, types and status.* Department of Agriculture, Western Australia.

Thackway, R., Neldner, V.J. and Bolton, M.P. (2008). Vegetation. In McKenzie, N.J., Grundy, M.J., Webster, R. and Ringrose Voase, A.J. (eds) *Guidelines for surveying soil and land resources* (2nd edition). CSIRO Publishing, Melbourne.

Trudgen, M.E. (1988). *A Report on the Flora and Vegetation of the Port Kennedy Area.* Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

WAPC (2010). *Geraldton Regional Flora and Vegetation Survey.* Western Australian Planning Commission, Perth.

Western Australian Herbarium (1998–). *FloraBase — the Western Australian Flora*. Department of Parks and Wildlife. http://florabase.dpaw.wa.gov.au/http://florabase.dpaw.wa.gov.au/

Appendix A:
Selected flora and vegetation survey reports for contextual reference

General

Beard, J.S. (1990). *Plant Life of Western Australia.* Kangaroo Press, Kenthurst, New South Wales.

Commonwealth of Australia (2012). *IBRA 7.* Department of Sustainability, Environment, Water, Population and Communities, Canberra, June 2012.

Department of Agriculture and Food and Department of Environment and Conservation Conservation (2012–). *Pre-European Vegetation*. Spatial dataset.

Department of Parks and Wildlife (2007–). *NatureMap: Mapping Western Australia's Biodiversity.* Department of Parks and Wildlife. URL: http://naturemap.dpaw.wa.gov.au

May, J.E. and McKenzie, N.L. (2003). *A biodiversity audit of Western Australia's 53 biogeographical subregions in 2002.* Department of Conservation and Land Management, Kensington WA.

Series of reports – Vegetation survey of Western Australia 1:250,000 vegetation series. Several examples are provided here, but other papers in the series cover other areas.

Beard, J.S. (1980). The vegetation of the Corrigin area, Western Australia: map and explanatory memoir, 1:250,000 series. Vegmap, Perth.

Beard, J.S. (1972). The vegetation of the Southern Cross area, Western Australia: map and explanatory memoir, 1:250,000 series. Vegmap, Perth.

Series of reports – Vegetation survey of Western Australia 1:1,000,000 vegetation series. Several examples are provided here, but other papers in the series cover other areas.

Beard, J.S. (1981). Swan: vegetation survey of Western Australia 1:1,000,000 vegetation series Sheet 7. University of Western Australia Press, Nedlands.

Beard, J.S. (1968). Great Sandy Desert: vegetation survey of Western Australia 1:1,000,000 vegetation series Sheet 2. University of Western Australia Press, Nedlands.

South-West Province and South-Western Interzone

Regional

Department of Planning and Ecoscape (Australia) Pty Ltd (2010). *Geraldton regional flora and vegetation survey.* Western Australian Planning Commission, Perth WA.

Freeman, K., Keighery, B.J, Keighery, G.J, Longman, V.M, Black, A. and Molloy, S. (2009). *The flora and vegetation of the Dawesville to Binningup region (Swan Coastal Plain): a report for the Environmental Protection Authority as part of the Swan Bioplan Project.* Department of Environment & Conservation, Perth WA.

Gibson, N., Meissner, R., Markey, A.S. and Thompson, W.A. (2012) Patterns of plant diversity in ironstone ranges in arid south western Australia. *Journal of Arid Environments* 77: 25-31.

Gibson, N., Keighery, G.J., Lyons, M.N. and Webb, A. (2004). Terrestrial flora and vegetation of the Western Australian wheatbelt. *Records of the Western Australian Museum.* Supplement 67: 139–189.

Gibson, N., Keighery, G.J. and Keighery, B.J. (2000). Threatened plant communities of Western Australia 1. The ironstone communities of the Swan and Scott Coastal Plains. *Journal of the Royal Society of Western Australia* 83: 1-11.

Gibson, N., Keighery, B.J., Keighery, G.J., Burbidge, A.H. and Lyons, M. (1994). *A Floristic Survey of the southern Swan Coastal Plain.* Unpublished Report for the Australian Heritage Commission prepared by Department of Conservation and Land Management and Conservation Council of WA (Inc.).

Government of WA (2000a). *Bush Forever: keeping the bush in the city - final report.* Volume 1, policies, principles and processes. Western Australian Planning Commission, Perth.

Government of WA (2000b). *Bush Forever: keeping the bush in the city.* Volume 2, directory of Bush forever sites. Department of Environmental Protection, Perth.

Griffin, E.A. (1992). Floristic survey of remnant vegetation in the Bindoon to Moora area, Western Australia. *Resource management technical report 142.* Department of Agriculture, South Perth WA.

Griffin, E.A. and Keighery, B.J. (1989). *Moore River to Jurien Sandplain survey.* Western Australian Wildflower Society, Nedlands WA.

Hearn R., Stoneman, G.L., Keighery, G.J., Burrows, N., Yates, C. and Hopper, S. (2003). *Management of Significant Flora values in South-west Forests and Associated Ecosystems.* A report for the Conservation Commission's Forest Management Plan Steering Committee.

Heddle, E.M., Loneragan, O.W. and Havel, J.J. (1980). Vegetation complexes of the Darling System, Western Australia. In Department of Conservation and Environment (ed.) *Atlas of Natural Resources, Darling System, Western Australia.* Department of Conservation and Environment, Perth WA.

Keating, C. and Trudgen, M.E. (1986). *A Flora and Vegetation Survey of the Coastal Strip From Forrest Beach-Cape Naturaliste-Woodlands.* A report for the Department of Conservation and Environment, Western Australia.

Keighery, B.J., Keighery, G.J., Webb, A., and Longman, V.M. (2008). *A floristic survey of the Whicher Scarp.* Department of Environment and Conservation, Perth WA.

Keighery, B.J., Dell, J., Keighery, G.J., Madden, S., Longman, V.M., Green, B., Webb, A., McKenzie, B., Hyder, B., Ryan, R., Clarke, K.A., Harris, E., Whisson, G., Olejnik, C. and Richardson, A. (2006). *The vegetation, flora, fauna and natural areas of the Peel Harvey eastern estuary area catchment (Swan Coastal Plain): a report for the Department of Environment and Conservation as a contribution to the Peel Harvey Eastern Estuary Area Catchment Environmental Assessment Project and the Swan Bioplan Project.* Department of Environment and Conservation, Perth WA.

Keighery, B.J. and Longman, V.M. (eds.) (2002). *Tuart* (Eucalyptus gomphocephala) *and tuart communities.* Wildflower Society of WA - Perth Branch, Nedlands, WA.

Keighery, B.J and Trudgen, M. (1992). *Remnant vegetation on the alluvial soils of the eastern side of the Swan Coastal Plain.* Department of Conservation and Land Management, Perth WA.

Keighery, G.J. (1990). *Coastal Limestone Endemic*s. Unpublished report for the Department of Conservation and Land Management, Perth, Western Australia.

Keighery, G.J. (1999). *Conservation Status of Vascular Flora of the Southern Swan Coastal Plain.* Unpublished report for Australian Nature Conservation Agency National Reserves System Cooperative Program Project: N710 and Department of Conservation and Land Management, Perth, Western Australia.

Keighery, G.J. (2004). State Salinity Strategy biological survey of the Western Australian wheatbelt: background. *Records of the Western Australian Museum.* Supplement 67: 1-6.

Lyons, M.N., Gibson, N., Keighery, G.J., Lyons, S.D. (2004). Wetland flora and vegetation of the Western Australian wheatbelt. *Records of the Western Australian Museum*. Supplement 67: 39–89.

Markey, A. (1997). *Floristic Survey of the northern Darling Scarp.* Unpublished report to the WA Department of CALM, the WA Department of Environmental Protection and the WA Conservation Council for the Australian Heritage Commission.

Mattiske, E.M. and Havel, J.J. (1998). *Regional Forest Agreement vegetation complexes.* Department of Conservation and Land Management, Como WA.

Muir, B.G. (1977). Biological Survey of the Western Australian Wheatbelt. Pt. 2. Vegetation and habitat of the Bendering Reserve. *Records of the Western Australian Museum* Supplement 3.

Sandiford, E.M. and Barrett, S. (2010). *Albany Regional Vegetation Survey: extent, type and status.* Department of Environment and Conservation, Albany WA.

Smith, F.G. (1973). *Vegetation Survey of Western Australia, 1:250,000 series – Busselton & Augusta.* Western Australian Department of Agriculture, Perth, Western Australia.

Smith, F.G. (1974). *Vegetation Survey of Western Australia, 1:250,000 series – Collie.* Western Australian Department of Agriculture, Perth, Western Australia.

Trudgen, M. (1991). *A flora and vegetation survey of the coast of the City of Mandurah.* Department of Planning and Urban Development, Perth WA.

Webb, A., Keighery, B.J., Keighery, G.J., Longman, V.M. and Black, A. (2009). *The flora and vegetation of the Busselton Plain (Swan Coastal Plain): a report for the Department of Environment and Conservation as part of the Swan Bioplan Project.* Department of Environment and Conservation, Perth WA.

Local

Cranfield, R.J. and Parker, C.M. (1995). Flora survey of the Moresby Range, August 1983. *Western Australian Naturalist* 20: 1-12.

Keighery, B.J., Keighery, G.J. and Gibson, N. (1997). *Floristics of Reserves and Bushland Areas of the Perth Region (System 6). Parts XI - XV.* Wildflower Society of Western Australia (Inc.), Nedlands, Western Australia.

Keighery, B.J., Keighery, G.J. and Gibson, N. (1996). F*loristics of reserves and bushland areas of the Busselton region (System 1). Parts I-IV.* Wildflower Society of WA, Nedlands WA.

Keighery, G.J. and Keighery, B.J. (1991). *Floristics of Reserves and Bushland Areas of the Perth Region (System 6). Parts II—IV.* Wildflower Society of Western Australia (Inc.), Nedlands, Western Australia.

Keighery, G.J., Keighery, B.J. and Gibson, N. (2008). Flora and Vegetation of Dardanup Forest Block. *Western Australian Naturalist* 26: 27-66.

Kitchener, D.J., Chapman, A. and Dell, J. (1975). A biological survey of Cape Le Grand National Park. *Records of the Western Australian Museum* Supplement 1: 1-38.

Lyons, M.N., Keighery, G.J., Gibson, N. and Wardell-Johnson, G. (2000). The vascular flora of the Warren bioregion, south-west of Western Australia: composition, reservation status and endemism. *CALMScience* 3: 181-250.

Trudgen, M.E. (1988). *A Report on the Flora and Vegetation of the Port Kennedy Area.* Unpublished report prepared for Bowman Bishaw and Associates, West Perth.

Series of reports – Biological survey of the Western Australian Wheatbelt, Western Australia. Several examples are provided here, but other papers in the series cover similar areas.

Kitchener, D.J., Chapman, A., Dell, J., Johnstone, R.E, Muir, B.G. and Smith, L.A. (1976). Biological survey of the Western Australian Wheatbelt. Preface to the series and Part 1: Tarin Rock and North Tarin Rock Reserves. R*ecords of the Western Australian Museum* Supplement 2: 1-87.

Dell, J., Chapman, A., Kitchener, D.J., McGauran, D.J. and Muir, B.G. (1981). Biological survey of the Western Australian Wheatbelt. Part 14: East Yuna and Bindoo Hill Nature Reserves. *Records of the Western Australian Museum* Supplement 13: 7-105.

Eremaean Province

Pilbara Biological Survey Database – available at http://science.dpaw.wa.gov.au/projects/pilbaradb/ . This database can be used to search for reports related to the Pilbara area. Current in 2006, contains some 800 reports.

Regional

Department of Environment and Conservation, and Department of Industry and Resources (2007). *Strategic review of the conservation and resource values of the banded iron formation of the Yilgarn Craton.* Government of Western Australia, Perth.

Gibson N., Meissner R., Markey A.S. and Thompson, W.A. (2012). Patterns of plant diversity in ironstone ranges in arid south western Australia. *Journal of Arid Environments* 77: 25-31.

Keighery, G.J., Halse, S.A., McKenzie, N.L. and Harvey, M.S. (eds.) (2004). A biodiversity survey of the Western Australian agricultural zone. *Records of the Western Australian Museum* Supplement No. 67: 1-384.

Muir, B.G. (1977). Biological Survey of the Western Australian Wheatbelt. Pt. 2. Vegetation and habitat of the Bendering Reserve. *Records of the Western Australian Museum* Supplement 3.

Trudgen, M.E. and Keighery, G.J. (1995). *Flora of the Shark Bay World Heritage Area and environs.* Department of Conservation and Land Management, Woodvale WA.

Van Leeuwen, S. (ed.) (2002). *Biological survey of the south-western Little Sandy Desert: National Reserve System Project N709: final report, June 2002.* Department of Conservation and Land Management, Perth WA.

Van Vreeswyk, A.M.E., Payne, A.L., Leighton, K.A. and Hennig, P. (2004). An inventory and condition survey of the Pilbara region, Western Australia. *Department of Agriculture Technical Bulletin 92*, December 2004.

Series of reports – Biological survey of the eastern goldfields of Western Australia. Several examples are provided here, but other papers in the series cover similar areas.

Newbey, K.R., Dell, J., How, R.A, and Hnatiuk, R.J. (1984). A biological survey of the eastern goldfields of Western Australia. Part 1, introduction and methods; Part 2, Widgiemooltha-Zanthus study area. *Records of the Western Australian Museum* Supplement 18: 21-158.

Burbidge, A.A., Hall, N.J., G.J. Keighery and McKenzie, N.L. (eds.) (1995). A biological survey of the eastern goldfields of Western Australia. Part 12, Barlee-Menzies study area. *Records of the Western Australian Museum* Supplement 49: 169-312.

Local

Richards, J.D. and Wilson, B. (eds.) (2008). A biological survey of Faure Island, Shark Bay World Heritage property, Western Australia. *Records of the Western Australian Museum* Supplement 75: 1-75.

Series of reports – Flora and vegetation of the eastern goldfields ranges. Several examples are provided here, but other papers in the series cover similar areas.

Gibson, N., Lyons, M.N. and Lepschi, B.J. (1997). Flora and vegetation of the eastern goldfields ranges. Part 1: Helena and Aurora Range. *CALMScience* 2: 231-246.

Gibson, N. (2004). Flora and vegetation of the eastern goldfields ranges. Part 7: Middle and South Ironcap, Digger Rock and Hatter Hill. J*ournal of the Royal Society of Western Australia* 87: 49-62.

Series of reports – Flora and vegetation of banded iron formations of the Yilgarn Craton. Several examples are provided here, but other papers in the series cover similar areas.

Markey, A.S. and Dillon, S.J. (2008). Flora and vegetation of banded iron formations of the Yilgarn Craton: the central Tallering Land System. *Conservation Science Western Australia* 7: 121-151.

Meissner, R. and Caruso, Y. (2008). Flora and vegetation of banded iron formations of the Yilgarn Craton: Koolanooka and Perenjori hills. *Conservation Science Western Australia* 7: 73-88.

Northern Province

Regional

McKenzie, N.L., Johnston, R.B. and Kendrick, P.G. (eds.) (1991). *Kimberley Rainforests.* Surrey Beatty & Sons, Sydney.

Western Australian Museum (1981). B*iological survey of Mitchell Plateau and Admiralty Gulf, Kimberley, Western Australia.* pp 1-274. Western Australian Museum, Perth.

Local

Kabay, E.D. and Burbidge, A.A. (eds.) (1977). A Biological survey of the Drysdale River National Park, North Kimberley, Western Australia, in August, 1975. *Wildlife Research Bulletin Western Australia* 6: 1-133. Department of Fisheries and Wildlife, Western Australia, Perth.

Miles, J.M. and Burbidge, A.A. (eds.) (1975). A Biological survey of the Prince Regent River Reserve, north-west Kimberley, Western Australia, in August, 1974. *Wildlife Research Bulletin Western Australia* 3: 1-113. Department of Fisheries and Wildlife, Western Australia, Perth.

Environmental Protection Authority 2016, *Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment*, EPA, Western Australia.

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