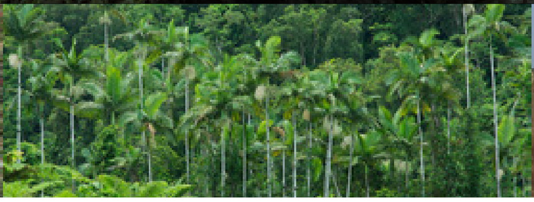
Methodology for surveying and mapping regional ecosystems and vegetation communities in Queensland

Version 7.0



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Prepared by:
V.J. Neldner, B.A. Wilson, H.A. Dillewaard, T.S. Ryan, D.W. Butler, W.J.F. McDonald, D. Richter, E.P. Addicott and C.N. Appelman
Queensland Herbarium, Science and Technology Division
Department of Environment, Science and Innovation
PO Box 5078
Brisbane QLD 4001

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Main cover image:

Botanist Eda Addicott conducting ground cover assessments in *Eucalyptus reducta* woodland on metamorphics hills (RE 7.11.33b), near Irvinebank, Wet Tropics bioregion QBEIS site 18352 (M.R. Newton, Queensland Herbarium, Queensland Government)

Inset images:

Left: Botanist Joy Brushe conducting a vegetation survey on coastal headlands within the Central Queensland Coast Bioregion. Middle: Palm forest in the Wet Tropics Bioregion. Right: Grassland on clay plains in the Gulf Plains Bioregion showing termite mounds.

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1. Introduction

1.1 Purpose of this document

Vegetation and regional ecosystem survey and mapping is a labour-intensive activity. The process requires a high level of informed scientific judgment, ecological knowledge and skill in mapping and defining plant communities, which often lack sharply defined boundaries in terms of space or species composition. A large number of people are currently involved in vegetation and regional ecosystem survey and mapping in Queensland. The aim of this document is to provide a practical guide for vegetation ecologists to ensure that compatible methodologies are used by Queensland Herbarium officers and other people producing regional ecosystem (RE) and vegetation maps.

The manual provides:

- specific procedures for regional ecosystem and vegetation survey and mapping staff from the Queensland Herbarium, and
- general guidelines for other individuals or organisations carrying out similar mapping.

The manual generally follows more traditional approaches to survey and mapping based on floristic survey and aerial photo-pattern interpretation, but incorporates some of the recent developments in use of satellite imagery and computer-aided technologies.

The manual describes the Queensland Herbarium methodology and methods for:

- the classification of vegetation and regional ecosystems (section 2)
- mapping vegetation and regional ecosystems (section 3), and
- collection of site data (section 4 and Appendix 2).

Separate methodology documents have been written for the wetlands mapping and classification (EPA 2005) and groundwater-dependent ecosystems mapping (DSITI, 2015) conducted by the Queensland Herbarium.

1.2 Version history

Neldner (1993) documented the background of vegetation survey and mapping at the Queensland Herbarium which formed the basis of the development of survey and mapping methods for Queensland through a number of versions.

Version 1.0 (Thompson et al. 1996) and **Version 2.0** (Neldner et al. 1999) detailed the methods used by the Queensland Herbarium to survey and map vegetation in Queensland.

Version 3.0 (Neldner et al. 2004) provided major updates to the previous documents, including methods used to map and classify regional ecosystems for vegetation management legislation, Queensland's *Vegetation Management Act 1999* (VMA).

Version 3.1 (Neldner et al. 2005) incorporated more detailed methods for map modification assessments (Queensland Herbarium, 2002) which were referred to, but not included in Neldner et al. (2004).

Version 3.2 (Neldner et al. 2012) reorganised content to more clearly separate the classification methodologies (section 2) from the mapping methods (section 3) and incorporate other updates throughout the document which were developed after feedback from users and updates to the *Vegetation Management Act 1999* including introduction of Property Maps of Assessable Vegetation (PMAVs) and the cessation of Map Assessment Requests (MARs) by the Queensland Herbarium.

The history and development of the regional ecosystem biodiversity inventory, planning framework and information system is documented in Neldner et al. (2017a).

Version 4.0 (Neldner et al. 2017b) updates references and links to data and mapping sources. It also clarifies the mapping process for remnant vegetation and refines rules around recognising new regional ecosystems and vegetation communities. The CORVEG proforma has been slightly modified and improved, and a completed CORVEG proforma added as Appendix 7.

Version 5.0 (Neldner et al. 2019) updates references and links to data and mapping sources. Regrowth vegetation is discussed in section 2.3.5 and the definition and mapping of high-value regrowth is described in Appendix 8. The rules for describing REs in the long description have been added in section 3.11.3. A rainforest data collection method is described in Appendix 9.

Version 5.1 (Neldner et al. 2019) updates the definition and mapping of high-value regrowth in Appendix 8 and updates details of the line intercept method of assessing crown cover in section 2.4.1. Use of the term 'median' has been replaced with 'mean' throughout the document.

Version 6.0 (Neldner et al.2022) makes updates to reflect the decommissioning of CORVEG and the release of the Queensland Biodiversity and Ecology Information System (QBEIS) into production. It includes updated field proformas to reflect these changes. Figure 3 has been updated to include the High Value Regrowth category.

Version 7.0 (this document) adds explanation of the new VM REDD, and definitions of grassland and woody grassland ecosystems and their classification under the vegetation Management framework in section 2.2.2. The rainforest data collection method described in Appendix 9 has been revised to include a detailed rainforest site collection method. Figure 3 has been updated to include additional High Value Regrowth pathways.

1.3 Background

Vegetation communities or ecosystems have been widely used as surrogates for biodiversity (Austin and Margules 1986) and conservation planning (Sattler 1999). For example, forest communities recognisable and mappable at 1:100 000 scale were considered to be the appropriate units for planning a comprehensive nationwide forest reserve system (JANIS 1997). In the Australian Regional Forest Agreements, vegetation survey and mapping were fundamental components for the development of a Comprehensive, Adequate and Representative (CAR) reserve system. A basic requirement for an objective informed resource assessment of any study area is the consistent and comprehensive mapping of spatial ecosystem units undertaken at an appropriate scale.

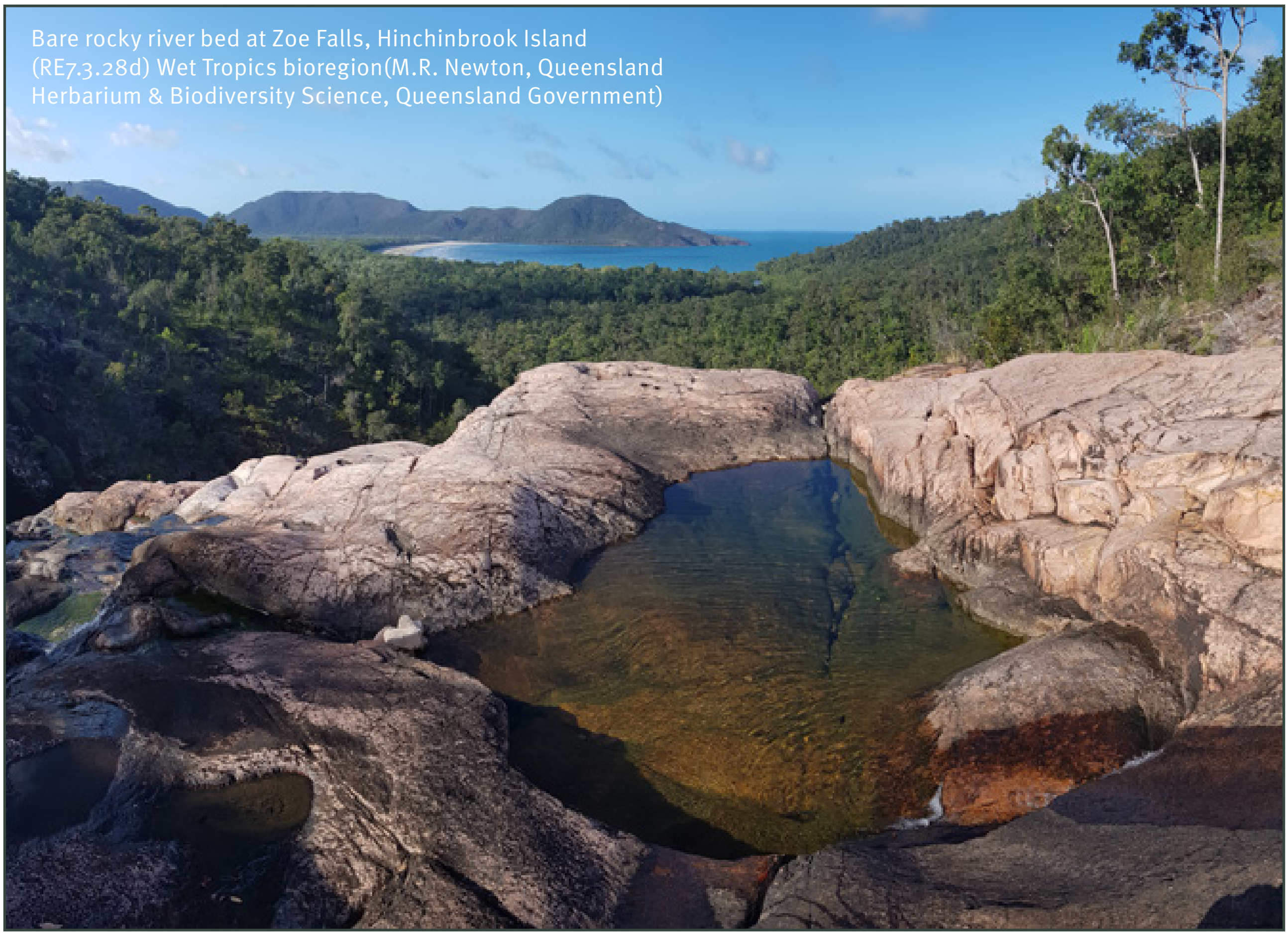
A variety of methods are used to classify and map vegetation throughout Australia and several attempts have been made to develop a nationally consistent system for recording vegetation attributes (for example, Anderson and Gillison 1982; Walker and Hopkins 1990; National Forest Inventory 2003; NLWRA 2001). Sun et al. (1997) outlined the methods used by the major survey and mapping organisations in Australia. The attributes being recorded and the methods used to classify and map vegetation cover a wide range. The floristic and/or structural attributes of the vegetation, at times in combination with environmental attributes, are often used to classify vegetation in Australia. Because different classification schemes assign varying degrees of importance to each type of attribute (structural, floristic, environmental), it is often difficult to equate units from different classification systems (Table 1).

Mapping and site data collections that contain compatible data are easier to store in a database and to analyse than data collected by a variety of methods. The more applications for which data can reliably be used, the greater the value of those data. Collection of data using methods compatible with those described here will facilitate comparison of such data with the large database of vegetation site data stored in the Queensland Biodiversity and Ecology Information System (QBEIS), formerly CORVEG. The Herbarium therefore encourages ecologists in all government departments and independent organisations to use these methods, or an extension of them, in their vegetation survey and mapping projects.

Queensland's vegetation is diverse, ranging from relatively simple communities in terms of both structure and floristics, such as *Astrebla* dominated grasslands, through to structurally and floristically complex rainforests. A standard approach for data collection that can be applied across the full range of vegetation types is needed. Extra measurements may be required for further detailed study of specialist vegetation types, such as additional life form attributes or indicators for rainforests (Webb 1978).

While the method described in this document allows for individual creativity and innovation, it stresses the importance of compatible, consistent and repeatable data collection and mapping methods, and the importance of collecting quantitative data. The Queensland Herbarium is the lead agency for vegetation survey and mapping in Queensland. The Regional Ecosystem Survey and Mapping program has made a significant contribution to Herbarium specimen collections and botanical knowledge (Neldner 2014). This method for vegetation surveying and mapping has developed from examining the extensive literature on the subject, conducting more than 40 years of mapping and vegetation survey activity (Neldner 1993; Thompson et al. 1996; Neldner et al. 2012; Neldner et al. 2017a) and from learning from the difficulties encountered in analysing data and edge-matching adjoining mapping coverages in the past.

While the method explained here can be applied to any scale of mapping, it is specifically targeted at the regional scale (1:50 000 – 1:100 000) mapping that is currently being conducted throughout Queensland. Thus this publication documents the current best practice method used in the survey and mapping of vegetation and regional ecosystems in Queensland.



Bare rocky river bed at Zoe Falls, Hinchinbrook Island (RE7.3.28d) Wet Tropics bioregion(M.R. Newton, Queensland Herbarium & Biodiversity Science, Queensland Government)

Table 1: Summary of key components of vegetation classification and mapping systems used by major Australian forest management agencies

	Floristics				GF[5]	Structure (no classes)			Height class (m)	Levels	Mapping scale	Basic classification unit	
	Dominance		CS[3]	SR[4]		Height	Crown	Density				As named by users	Standardised for comparison[5]
	OS[1]	US[2]					PFC[6]	CC[7]					
For wood production purposes													
NSW SF	+				+					3	1:25 000	Forest type	Association
Qld DPI Forestry	+				+	+(6)	+(6)	+(6)	›40	3	1:2500	Forest type	Association
Vic DNRE forest types	+				+	+(4)	+(4)		›40	2	1:63 360	Forest type	Association
Vic DNRE forest mapping	+				+	+(6)		+(6)	›51	2	1:25 000	Forest type	Association
SA DPI Forestry	+				+	+(3)	+(4)		›30	2	1:2 000 000	Forest type	Association
Tas. Forestry					+	+(7)		+(5)	›76	3	1:25 000	Forest type	Formation
WA CALM	+				+	+(5)		+(6)		2	1:25 000	Forest type	Association
For conservation and environmental purposes													
NSW NPWS													
Coastal veg. Mapping	+				+	+(9)		+(6)	›35	3	1:25 000	Plant association	Association
Multi-attribute mapping	+				+	+	+	+(6)		1		Plant association	Association
Rainforest	+				+	+(3)				3		Suballiance	Suballiance
Wheat belt region				+	+	+(9)		+(6)	›30	2	1:250 000	Map unit	Association
NSW RBG	+	+			+	+(3)	+(4)		›30	2	1:100 000	Plant community	Association
NSW DLWC		+						+(5)					Formation
Qld Herbarium	+	+			+	+(3)	+(3)		›30	2	1:250 000	Vegetation group	Association
Qld Herbarium	+	+		+	+	+(9)		+(6)	›35	1	1:100 000	Regional ecosystem	Alliance
Vic. DNRE Floristic comm.	+	+	+	+						2	1:250 000	Subcommunity	Association
Eco. veg. classes	±			±	+					1	1:100 000	Eco. veg. classes	Formation
Vic. LCC	+				+	+(4)	+(3)		›40	2	1:1 000 000	Vegetation unit	Association
SA DENR	+	+		+	+	+(3)	+(4)		›30	2	1:1 000 000	Plant community	Association
SA DHUD			+	+	+					2		Plant community	Association
WA Dept. Ag.	+	+			+					2	1:250 000	Site type	Alliance
Tas. NPWS				+	+	+						Plant community	Association
NT PWCNT	+	+			+	+(3)	+(4)		10–30	2	1:1 000 000	Plant community	Association
ACT ACTFS	+					+(3)	+(4)		›30	2	1:25 000	Plant association	Association

1 = overstorey; 2 = understorey; 3 = character species, 4 = species relation; 5 = growth form, 6= projective foliage cover, 7 = crown cover, 8 = with Beadle & Costin (1952)—in descending order—formation, alliance, suballiance, association. Source: Sun et al. 1997

SF = State Forests; DPI = Department of Primary Industries; DNRE = Natural Resources and Environment;
CALM = Conservation and Land Management; NPWS = National Parks and Wildlife Service; RBG = Royal Botanic Gardens;
DLWC = Land Water and Conservation; DEH = Environment and Heritage; LCC = Land Conservation Commission;
DENR = Environment and Natural Resources; DHUD = Department of Housing and Urban Development; Ag = Agriculture;
PWC = Parks and Wildlife Commission; FS = Forest Service

2. Classification

The Queensland Herbarium has historically classified vegetation using the association unit defined by Beadle and Costin 1952. More recently, this vegetation classification has been incorporated into the regional ecosystem classification, which is based on vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil (Sattler and Williams 1999).

2.1 The distinction between mapping and classification of site data

The processes used in mapping and classification in Australia are summarised in Figure 1. In many ecological studies the final output is a classification of vegetation or ecosystems with descriptions of the assemblages. Classifications may be based on some kind of numerical analysis of data from vegetation sites (e.g. plots), with varying degrees of expert field knowledge incorporated into the final groupings. The objective classification of vegetation pioneered by the Australian worker Goodall (1953a, 1953b, 1954, 1961) has had a profound effect on the development of vegetation classification throughout the world. Since Goodall's time, numerical methodologies developed by Australians have been at the forefront of techniques used worldwide (Lance and Williams 1967; Williams 1976; Belbin et al. 1984; Minchin 1987; Faith et al. 1987; Belbin 1988).

The numerical techniques vary greatly according to the analysis package (PATN, TWINSPAN and R being the most frequently used in Australia) and the algorithms and distance measures applied. Classifications may be hierarchical agglomerative (Keith and Saunders 1990); polythetic divisive (e.g. Russell-Smith 1991 and Specht et al. 1995 used TWINSPAN), or monothetic divisive, (e.g. Duncan and Brown 1985 used DIVINF). In addition ordination methods (Havel 1975a, 1975b; Strelein 1988) can assist in the interpretation of classifications by providing insight into the relationships between sites, as well as checking the distinctiveness of site or species groups (Faith 1991). Most of these studies are represented by the right-hand pathway in Figure 1, and the distribution of the classified vegetation communities derived from site data is often not spatially represented in a map. However, Specht et al. 1995 use a 30 minute by 30 minute grid to show the distribution of TWINSPAN-derived groups on a map.

The type of data used in these analyses varies greatly, with most analyses using presence/absence floristic data for the perennial or woody species only. Analyses can also be based on structural vegetation data, which results in different outcomes. For example, a classification of rainforests based solely on species composition (Webb et al. 1967) differed markedly from a classification based on structural attributes (Webb et al. 1970). Quantitative species data (such as species stem density or basal area) are less frequently used in analyses, usually because of lack of sufficient data. Neldner and Howitt (1991) found that analyses based on basal area and stem density allowed a more informative examination of the dominance of species within each site group than analyses based on binary (presence/absence) floristic data. Addicott et al. (2018a) found removing rare species and weighting species by height to be useful techniques for identifying plant communities from plot-based classifications which are conceptually consistent with those in landscape scale mapping. Environmental data are generally used to aid in the interpretation of the groups rather than being directly used in classification.

The results of numerical classification of site data can be incorporated into the description and delineation of vegetation communities. Most vegetation mappers in Australia have proceeded in a largely intuitive fashion (Kirkpatrick and Dickinson 1986), using intuitive data analysis techniques (see Figure 1). However, numerical techniques are increasingly being used in Australian vegetation mapping to assist in defining map units (Wilson et al. 1990; Elsol 1991; Addicott et al. 2018a). The numerical classifications developed by Addicott et al. (2018a) have led to a revision of the vegetation units in Cape York Peninsula and the Gulf Plains bioregions, and are guiding revision in other bioregions.

Mapping the outcomes of numerical classifications requires the derived floristic assemblages to be linked to the appropriate spatially delineated photo-patterns. This linkage is made on the basis of expert field knowledge, and by equating the occurrence of sites from a species assemblage with the spatial occurrence of photo-patterns. Many of the vegetation assemblages defined by numerical techniques are difficult to map because of limitations of scale and are often amalgamated (Kirkpatrick and Dickinson 1986).

Coutts and Dale (1989) and Neldner and Howitt (1991) compared the vegetation classification derived by computer analyses with the vegetation communities defined for a 1:5000 and 1:25 000 scale vegetation map respectively. While they found broad agreement in the groupings, correspondence at finer detail was limited because environmental variables were not incorporated into the numerical analysis. Both the intuitive and numerical classifications have inherent subjectivity and limitations. It is suggested therefore that both classifications be performed, as together they provide more useful information than either in isolation (Mueller-Dombois and Ellenberg 1974; Kirkpatrick and Dickinson 1986; Austin and McKenzie 1988). A numerical classification can assist in defining the limits of vegetation units, while a vegetation map can test a classification by forcing the interpreter to accommodate all of the variations observed in the field (Mueller-Dombois and Ellenberg 1974; Neldner and Howitt 1991, Addicott et al. 2018b).

Vegetation coverages or maps are produced by the spatial extension of vegetation classification by using photo-patterns recognised on remotely sensed imagery, usually aerial photographs. As shown in Figure 1, the delineation of vegetation boundaries uses a number of factors, including the landform pattern and elements, substrate data (geology, soils), the reflectance from the aerial photography or satellite imagery, and importantly, the site data and field knowledge of the interpreter.

Ecological knowledge of the distribution of species in the landscape is most effectively gained by field experience. In some studies (such as Forestry Tasmania's forest typing), the aerial photo-interpretation is done by laboratory-based staff, whereas in most other vegetation surveys the field ecologist does the photo-interpretation or at least has a major role in the process. Knowledge of the distribution of species in the landscape is imperative when mapping the distribution of vegetation communities, particularly closely related units such as open forests dominated by eucalypt species where the reflectance of the different species does not vary much. In these situations, substrate and position in landscape are important attributes determining the species composition and are used to delineate communities.

Most satellite data do not allow stereoscopic viewing (with the exception of SPOT). Therefore the use of satellite data for mapping vegetation communities at larger scales over extensive areas is limited, due to the importance of topography in interpretation.

The pixel size of the most frequently used imagery is relatively coarse (LANDSAT TM 30 m pixels) when compared to aerial photographs, which again limits the discrimination of vegetation pattern possible. LANDSAT TM data have been used successfully for small-scale mapping (Wilson et al. 1990) and structural typing of vegetation (Ritman 1995).

2.2 Vegetation classification

2.2.1 Association

The basic unit in the vegetation community classification within the regional ecosystem classification is the plant association or sub-association. An association is defined as a vegetation community of which the predominant layer has a qualitatively uniform floristic composition, and exhibits a uniform structure as a whole (based on Beadle and Costin 1952, as modified in Beadle 1981). The predominant layer (also referred to as the ecological dominant layer or stratum or the predominant canopy) is defined as the layer that contributes most to the above-ground biomass (Neldner 1984, 1991, 1993; Neldner and Clarkson 1995). Different associations are recognised by differences in life form, leaf size and dominant floristics, giving due consideration to structure. Therefore this vegetation classification is based on life form and structure using height and cover, and on the dominant species in the predominant layer and associated species in the other layers (Neldner 1993).

While the association focuses on the predominant layer, sub-associations can be discriminated on the basis of different elements in the subdominant layers, such as shrub and ground layers. Sub-associations are described by structural data on the height, crown cover and stem density of each structural layer, and a list of the most frequent species in each layer. An alliance is defined as a group of floristically related associations of similar structure (Beadle and Costin 1952).

2.2.2 Structural formation

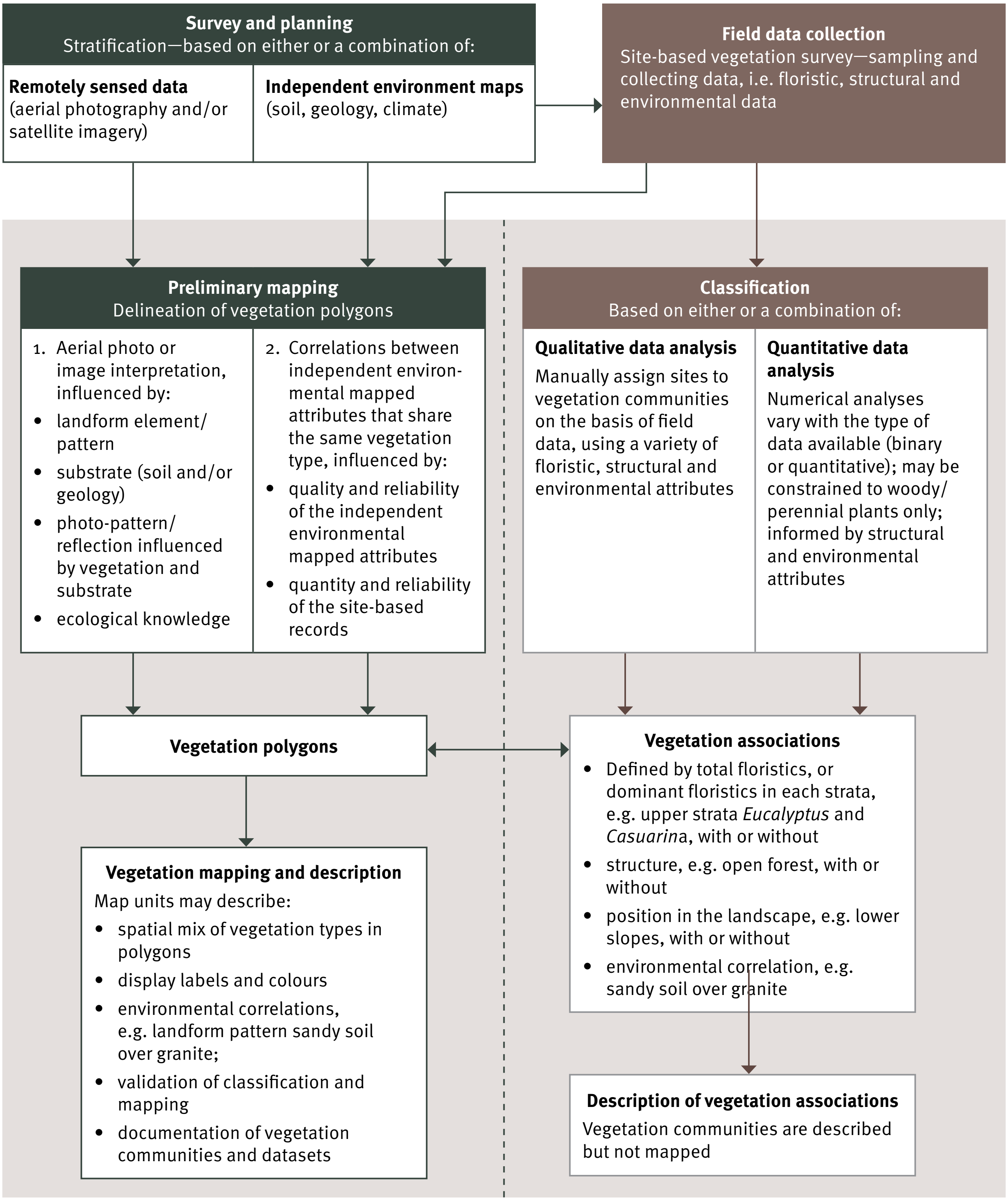


Figure 1 Summary of vegetation survey and mapping processes used in Australia

Vegetation is usually organised into layers, or strata. Height, cover and life form of the predominant layer are used in the standard vegetation structural classification schemes in Australia, that is, the Specht classification system (Specht 1970, 1981) and the Walker and Hopkins system (Walker and Hopkins 1990), which is adopted in the latest Australian Soil and Land Survey Field Handbook (Hnatiuk et al. 2009).

For non-rainforest vegetation the Queensland Herbarium uses the structural classes from Neldner (1984) which are based on the Specht (1970) system, and aligned to Hnatiuk et al. (2009). However, while Specht (1970) classifies vegetation on the basis of the tallest stratum, the Queensland Herbarium uses the ecologically dominant layer (EDL). The Queensland Herbarium also has an additional life form; Forb (Table 27) compared to Specht (1970). Rainforest vegetation is classified and described using Webb's classification (Webb 1978, Tracey 1982). Thus the structural classification used in Queensland (Table 28) is referred to as 'modified Specht (1970)' classification system, and includes the Vegetation Management Act structure category for use under Queensland's vegetation management framework.

2.2.2.1 Non-rainforest vegetation

In the modified Specht (1970) system, the Queensland Herbarium describes the vegetation by the ecologically dominant layer (EDL) which is the one that is assessed as contributing the most above-ground biomass. The tallest stratum is regarded as the emergent layer if it does not form the most above-ground biomass, regardless of its canopy cover. For example, emergent *Eucalyptus populnea* trees above a low woodland of *Acacia aneura*. The Herbarium measures the height and cover of each layer independently; that is, it assigns separate height and cover values for the emergent (where present) and canopy layers. Section A2.3.6 of this document gives further details on dividing vegetation into layers. Non-rainforest vegetation communities are labelled and described using the structural formation classification in Table 28.

2.2.2.2 Rainforest vegetation

The rainforest classification follows that devised by Webb (1978) and is listed in Table 29. Walker and Hopkins (1990) and Hnatiuk et al. (2009) use most of the elements of this classification, which has its origins in Webb (1959a) and is further developed in subsequent publications by that author. The Webb (1978) system classifies rainforest by:

- complexity (of life forms)
- size of leaves of dominant plants
- complexity of dominant species
- leaf-fall characteristics [not used by Walker and Hopkins (1990) and Hnatiuk et al. (2009)] and
- indicator growth forms.

2.2.3 Grasslands

Grasslands are ecosystems in which the predominant stratum is composed of grasses. Under Queensland's vegetation management framework grasslands are further divided into grassland and woody grassland regional ecosystems and are determined as follows:

Grassland – vegetation dominated by grasses that at a landform pattern scale consistently has no or minimal woody emergent trees or shrubs, being ‹1% emergent crown cover. Grassland regional ecosystems are identified / listed in the Vegetation Management Regional Ecosystem Description Database. (DoR, 2023)

woody grassland - vegetation dominated by grasses that at a landform pattern scale consistently has some woody emergent trees or shrubs, being›1% emergent crown cover. Woody grassland regional ecosystems are identified / listed in the Vegetation Management Regional Ecosystem Description Database. (DoR, 2023)

2.2.4 Broad vegetation groups

Broad vegetation groups (BVGs) are a higher-level grouping of vegetation units or ecosystems. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid to arid climatic zones (Neldner et al. 2021). In order to provide an overview and/or map vegetation across the state or a bioregion and allow comparison with other states, the vegetation units and regional ecosystems are amalgamated into the higher-level classification of BVGs.

The Queensland Herbarium amalgamates ecosystems on an ecological basis to form BVGs (Neldner et al. 2021). Some BVGs encompass vegetation types that are generally dominated by a single species, such as *Melaleuca viridiflora*, or a suite of species, such as *Acacia* spp. on residuals. Other groups are typified by a distinct structural formation (such as tussock and closed tussock grasslands) or by a combination of a structural formation and habitat (such as dry woodlands, primarily on coastal sandplains and dunes). Specialised habitats such as coral islands and intertidal areas form other groups. The digital map layers allow the user to easily produce maps based on the structural formation, the map unit or the BVG (Neldner and Clarkson 1995). There are three levels of broad vegetation groups which reflect the approximate scale at which they are designed to be used: 1:5 000 000 (national), 1:2 000 000 (state) and 1:1 000 000 (regional).

Similar high-level broad groupings are used at the national level, in the native vegetation assessment carried out by the National Land and Water Resources Audit (NLWRA 2001), where vegetation communities were summarised into major vegetation groups (MVGs). MVG classifications contain different mixes of plant species within the canopy, shrub or ground layers, but are structurally similar and often dominated by the same genus. The BVGs that make up the MVGs are described in Appendix 4 of Neldner et al. (2021).

The relative numbers of classification units (association, maps units, broad vegetation groups) in each of the vegetation classification levels are shown in Table 2.

Table 2 shows that a number of associations may make up a map unit. This is because in many cases the different plant associations recognised as making up a map unit cannot be reliably separated on the basis of photo-pattern and field knowledge (at the scale of mapping). The association level relates to the floristic vegetation community level as used in Victorian floristic studies and the land unit level of land resource surveys (Sun et al. 1997).

Table 2: Number of classification units from various Queensland studies

Study area	Associations	Map units	Structural formations	Broad vegetation groups	Reference
South Western Queensland	67	31	14	8	Boyland 1984
South Central Queensland	167	73	26	14	Neldner 1984
Central Western Queensland	113	51	17	11	Neldner 1991
Cape York Peninsula	309	201	21	30	Neldner and Clarkson 1995

2.3 Regional ecosystem classification

During the 1990s the regional ecosystems (RE) classification framework was developed and widely adopted in Queensland to assist in planning, regulation and management for biodiversity, both on and off conservation reserve estate. Regional ecosystems were defined by Sattler and Williams (1999) and in the *Vegetation Management Act 1999* (VMA 1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. This system informs legislation and policy at local, state and national levels, underpinning decisions that have wide-ranging implications for biodiversity and people's livelihoods. It therefore needs to be robust from a scientific and legal perspective. Addicott et al. (2021) discusses the RE system in a global context and outlines the updated approach that incorporates quantitative class definition procedures. Readers should refer to Sattler and Williams (1999) and Neldner et al. (2017a) or to REDD (Queensland Herbarium 2021 or subsequent versions), for background information about regional ecosystems and the bioregional planning framework used in Queensland.

Compilation of the information about regional ecosystems presented in Sattler and Williams (1999) was derived from a broad range of information sources including land system, vegetation and geology mapping and reports. However, the framework is dynamic and is regularly reviewed as new information becomes available. The Queensland Herbarium has developed a program for explicitly mapping regional ecosystems across Queensland. This has resulted, and will continue to result, in updates to the descriptions and status of regional ecosystems. Updated regional ecosystem descriptions in the format of Sattler and Williams (1999) are maintained in REDD (Queensland Herbarium 2021 or subsequent versions).

2.3.1 Regional ecosystem hierarchy

The regional ecosystems classification is based on a hierarchy, which is reflected in the three-part code given to each regional ecosystem. The land is classified by bioregion, then land zone, and then vegetation. A fourth part of the code may be added for vegetation communities or proposed new regional ecosystems.

Bioregion

The first part of the regional ecosystem classification and associated number refers to the biogeographic region, or bioregion, in which the regional ecosystem is found. Currently thirteen bioregions (numbered from 1 to 13) have been defined for Queensland (Sattler 1999); however, parts of five regions are small extensions of nationally recognised bioregions (Thackway and Cresswell 1995) in adjacent states and the Northern Territory. Bioregions provide the primary level of classification of land for biodiversity values on a statewide and nationwide basis and have been mapped at scales smaller than 1:1 000 000.

Outliers

Outliers are regional ecosystems that are spatially within one bioregion but have the regional ecosystem code from an adjacent bioregion. They occur when a regional ecosystem that is found mainly within one bioregion 'extends' slightly into adjacent parts of an adjoining bioregion.

An area may be assigned as an outlier regional ecosystem if:

- it does not match the description (in terms of dominant species and land zone) of a regional ecosystem from the bioregion it occurs in, but does match the description from an adjacent bioregion, and
- it occupies an area in the bioregion of less than 1000 ha., or if more than 1000 ha., does not occur more than 30 km from the bioregion boundary.

If a regional ecosystem meets the description, area and/or distance requirements, it may be regarded as an outlier and coded with the regional ecosystem from the adjacent bioregion. The regional ecosystem status is calculated across the whole regional ecosystem including any occurrence of that regional ecosystem as outliers in adjacent bioregions.

Land zone

The second part of the regional ecosystem classification, and associated number, refers to the land zone on which the regional ecosystem occurs. Land zones represent major differences in geology and in the associated landforms, soils, and physical processes that gave rise to distinctive landforms or continue to shape them (Sattler and Williams, 1999). Land zones are generally derived by amalgamating a range of geological, land system and/or soil mapping units at 1:100 000 to 1:250 000 scale. The twelve different land zones in Queensland are defined in Wilson and Taylor (2012) and listed on the Queensland Government website. Landform is defined as patterns and elements from Speight (2009) and are listed in Tables 25 and 26. Soils terminology follows Isbell (2002).

Ecosystem

The third part of the regional ecosystem classification denotes different ecosystems which may be differentiated by vegetation types. The basic classificatory unit of the vegetation classification is the plant association. A regional ecosystem may consist of one or several plant sub-associations or associations.

2.3.2 Vegetation communities and proposed new regional ecosystems

The fourth part of the regional ecosystem classification, which may not always be present, denotes different vegetation communities or proposed new regional ecosystems. A vegetation community is an association or sub-association within a regional ecosystem that has similar floristics and occurs within the same land zone. These vegetation communities are generally mappable at scales larger than 1:100 000. A number of vegetation communities may make up a single regional ecosystem, and are usually distinguished by differences in dominant species composition, frequently in the shrub or ground layers. Many vegetation communities are restricted to a single or a few subregions, although some may occur throughout the bioregion.

With further survey and mapping work, and after review by a bioregional panel, new regional ecosystems will be described in REDD and mapped. For all other purposes, including the EP Act, the regional ecosystems recognised as current in REDD apply (Queensland Herbarium 2023).

Similarly, the Vegetation Management Regional Ecosystem (VMRE) map, which shows regional ecosystems for VMA purposes, is not necessarily equivalent to the latest Regional Ecosystem map. The VMRE map is periodically updated to reflect revised RE mapping, but the two products are for different purposes. The VMRE map is a regulatory instrument whereas the RE map is a science-based product mapping remnant regional ecosystems across Queensland.

For VMA purposes the Regulated Vegetation Management (RVM) map and VMRE map should be used, for all other uses the latest RE map is generally most suitable.

Different vegetation communities are denoted by the postscript a, b, c, etc. as listed in Table 3. New regional ecosystems or vegetation communities may be defined following the criteria outlined in Appendix 5. Proposed new regional ecosystems that do not fit well to those described in REDD are denoted by the postscript x 1, x2 etc., as listed in Table 3.

Table 3 **Labelling convention for vegetation communities and proposed new regional ecosystems**

Label	Explanation
9.3.1	Fits the **regional ecosystem** description in the REDD.
9.3.1a, 9.3.1b	The letters a, b, c, etc. are recognised **vegetation communities** and associated landforms, soils or geological substrate that make up different components of the regional ecosystem 9.3.1. At a larger scale they could be mapped as separate units. They may have a distinct suite of species or species that are geographically restricted. These units are attributed with the same VMA class or biodiversity status as 9.3.1.
9.3.1 x 1, 9.3.1 x 2, etc.	This unit does not match 9.3.1 and is probably a new **regional ecosystem**. Even though the dominant species are different, functionally it may have more in common with 9.3.1 than with other regional ecosystems. These units are attributed with the same VMA class or biodiversity status as 9.3.1.
9.3.1 x 1a, 9.3.1 x 1b, etc.	This situation allows the two **vegetation communities** that make up the proposed new RE 9.3.1 x 1 to be mapped separately. These units are attributed with the same VMA class or biodiversity status as 9.3.1.

Vegetation communities and/or proposed new regional ecosystems are listed under the description field for a regional ecosystem in REDD (Queensland Herbarium 2019). Within a regional ecosystem the vegetation communities and proposed new regional ecosystems have the same VMA class or biodiversity status. Regional ecosystems that appear in REDD but not in the VM regulations (i.e. new regional ecosystems) have been assigned a VM equivalent RE to enable users to identify the appropriate VM class (similar to the way proposed new REs are treated, e.g. 9.3.1 x 1 in Table 3).In Figure 2 the unique number refers to a regional ecosystem, 11.4.3, which is found in the Brigalow Belt bioregion (region 11) on Cainozoic clay plains (land zone 4) and which is usually vegetated with *Acacia harpophylla* (brigalow) and *Casuarina cristata* (belah) (open forest (the third vegetation community described within bioregion 11 and land zone 4).

The description of this regional ecosystem also includes a range of associated species such as *Eucalyptus woollsiana*, *E. populnea*, *E. cambageana* and *E. thozetiana*. In low-lying areas *Melaleuca bracteata* may be locally dominant. *Acacia harpophylla* and *Casuarina cristata* occur together in other situations in the Brigalow Belt, for example on alluvial plains and on fine-grained sedimentary rocks. These latter occurrences would equate to different regional ecosystems because they are on different land zones, specifically 11.3.1 and 11.9.5, however they occur in the same BVG25a.

This example demonstrates the importance of:

- accurately determining the land zone from geology or other available mapping such as soils and land system maps when using the regional ecosystem descriptions to verify mapping in the field, or when mapping in greater detail at a larger scale
- reading the description of a regional ecosystem in the latest version of the REDD and associated technical descriptions (if available). A list of references is provided in the supplementary description field in REDD, which may contain useful information to assist with interpretation, such as different vegetation communities, species variation that may occur from place to place, a particular characteristic of the landform and/or geology and other species that may be diagnostic, and
- consultation with the Queensland Herbarium bioregional co-ordinator

Statistics can be produced for any individual RE code (Accad et al 2023) and may be used in the analysis of conservation status.

Eucalyptus leucophloia low open woodland with *Triodia brizoides* and *Triodia molesta* ground layer on ferricrete southwest of Dajarra (RE 1.7.1a) (D. Kelman, Queensland Herbarium & Biodiversity Science, Queensland Government)

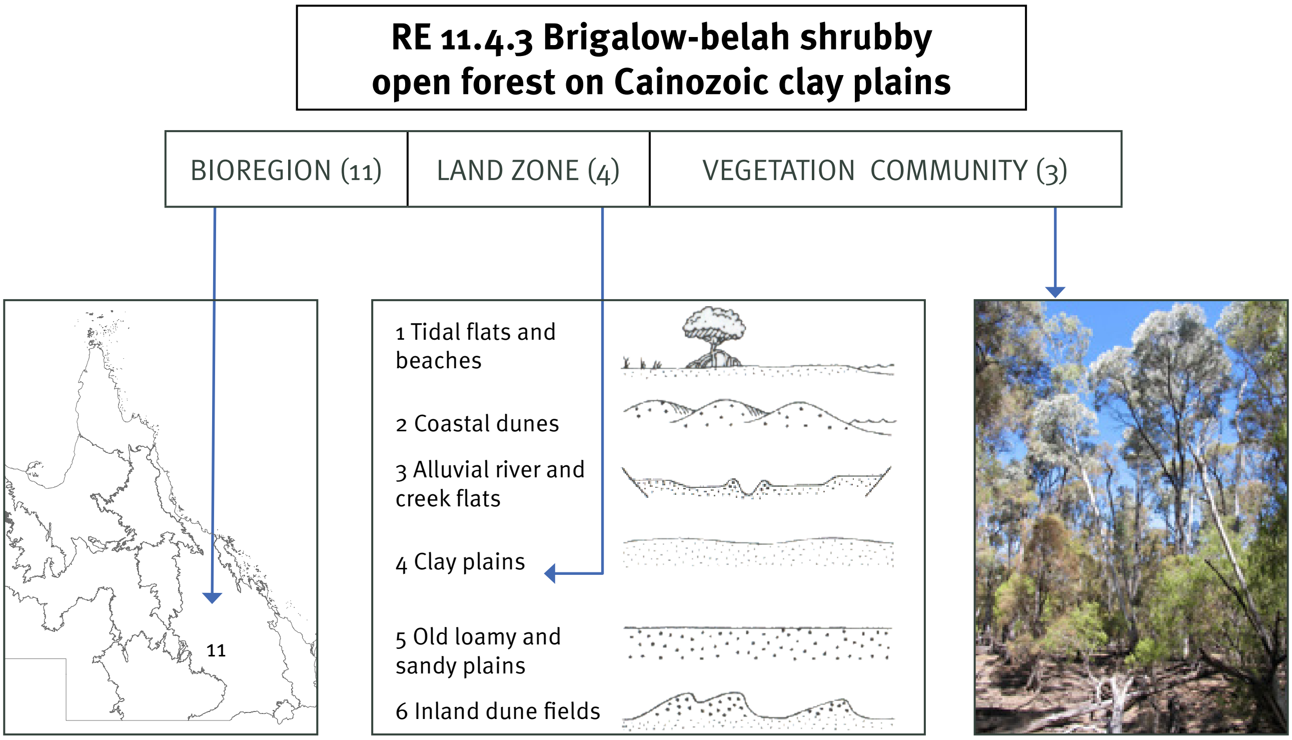


Figure 2 Example of regional ecosystem classification

Allocation to existing regional ecosystem classification

All pre-clearing and remnant vegetation is assigned to a regional ecosystem from the current REDD (Queensland Herbarium 2023). Where vegetation does not match the REDD database exactly, it is assigned to the regional ecosystem within the same land zone that most closely describes the attributes of the vegetation.

2.3.3 Pre-clearing regional ecosystem

Pre-clearing vegetation or regional ecosystem is defined as the vegetation or regional ecosystem present before clearing. This generally equates to terms such as 'pre-1750' or 'pre-European' used elsewhere (e.g. AUSLIG 1990). Pre-1750 vegetation is a widely used standard for recording vegetation prior to major impacts from non-indigenous people, such as extensive clearing, altered fire regimes, the introduction of grazing animals, etc. It has also been referred to as pre-European vegetation.

Since 1996 the Queensland Herbarium has used the term pre-clearing as a more accurate and defendable standard to map. Ecosystem boundaries are dynamic, and some may have moved since 1750. Mapping of regional ecosystems is based on extrapolation across an area based on a limited sample of known points and the consistent patterns detectable on imagery covering the whole region. Since no consistent imagery exists for Queensland before the early 1960s and no reliable comprehensive sample points exist for the period before 1970, it is difficult to map 'pre-1750' or 'pre-European' extent throughout much of the state with any certainty.

Although the definitions of pre-1750 and pre-European vegetation differ from that of pre-clearing, the resultant maps are generally equivalent. This is primarily because there is no imagery and very little robust and accurately located site data (apart from localised explorer and early settler records) on which to base a pre-1750 extent map. Thus where pre-1750 maps are derived from interpretation of imagery, it is generally derived from the same primary data, that is, historical aerial photographs, using similar methods as those used to derived pre-clearing maps.

2.3.4 Remnant vegetation

The assessment of remnant vegetation uses different criteria for woody and non-woody dominated vegetation.

2.3.4.1 Woody dominated vegetation

Woody vegetation is vegetation for which the predominant stratum is composed mainly of woody vegetation such as trees or shrubs. The Herbarium assesses and maps woody dominated vegetation as remnant if it meets the definition used in the *Vegetation Management Act 1999*, which is:

- 'vegetation, part of which forms the predominant canopy of the vegetation—
- (a) covering more than 50% of the undisturbed predominant canopy; and
- (b) averaging more than 70% of the vegetation's undisturbed height; and
- (c) composed of species characteristic of the vegetation's undisturbed predominant canopy.'

Remnant vegetation is mapped as Category B on the regulated vegetation map produced by the Department of Resources.

The undisturbed predominant canopy, for vegetation, is defined in the VMA as the predominant canopy the vegetation normally has, while the undisturbed height, for vegetation, means the height to which the vegetation normally grows. Sites that have not been cleared are considered to support normal vegetation and are therefore classified as remnant. Where there is evidence of clearing and it is not obvious that the site meets the above criteria the site is assessed against normal vegetation or a reference site (section 3.3).

The attributes of canopy height, canopy cover and characteristic canopy species were chosen to enable relatively consistent, rapid and reliable mapping across the 173 million hectare area of Queensland using remotely sensed data. The definition is better able to differentiate levels of development of the vegetation than alternative criteria such as a time cut-off or where vegetation has been subject to a range of clearing and/or thinning regimes dating back to at least the early 1900s. This latter situation occurs across large parts of Queensland. In vegetation with woody or shrubby canopies, the definition does not consider the composition or condition of the ground layer—that is, the layer usually dominated by grasses and herbs.

Characteristic species are any native species that generally occur within the canopy (or vegetation association, regional ecosystem or stratum when used in those contexts). This includes any species found at a reference site or in a technical description (e.g. Addicott and Newton 2012) for the vegetation community, regional ecosystem or stratum that is being assessed. If a technical description is not available then the detailed description of the regional ecosystem in REDD (Queensland Herbarium 2021 or subsequent versions) should be used. Characteristic species may range from the full diversity expected through to as few as one species.

The definition of remnant vegetation is straightforward in many cases and includes vegetation that is commonly referred to as 'intact', 'natural', 'virgin', 'never cleared' or 'pre-clearing'. However, it also includes vegetation that may have been lightly thinned, or cleared, or heavily thinned but substantially regrown, or 'parkland' cleared to remove the shrubs and saplings (Wilson et al. 2002). Vegetation that has undergone considerable changes in structure and composition may still be classified as remnant. Examples of changes in vegetation structure and composition in relation to remnant vegetation classification are given in Appendix 3.

In some cases where vegetation that has been disturbed and regrown it may be difficult to differentiate strata. In these cases the vegetation is defined as remnant if the cover of all vegetation that is taller than 70% of the minimum height of the undisturbed predominant canopy is greater than 50% of the cover of the undisturbed predominant canopy.

2.3.4.2 Non-woody dominated vegetation

Non-woody vegetation is vegetation in which the predominant stratum is composed of grasses and / or other non-woody vegetation. Defining remnant status in non-woody dominated vegetation, such as grasslands, on the characteristics of the height and cover of the canopy—that is, the grasses and forbs—is not practical. The dominant layer in these vegetation types is highly variable according to seasonal conditions, and can be rapidly modified through the use of grazing, fire or mechanical mowing. In addition, variations in the composition and condition of the non-woody vegetation may not be readily and consistently recognised from Landsat TM imagery.

Therefore the Herbarium assesses and maps non-woody dominated vegetation as remnant if it meets the definition of areas of non-woody dominated vegetation that can be mapped as remnant under the *Vegetation Management Act 1999*—an area of vegetation that:

- has not been cultivated for 15 years
- contains native species normally found in the regional ecosystem
- is not dominated by non-native perennial species.

Therefore the assessment of remnant status of non-woody vegetation may require a two-step process: mapping extent according to time since cultivation, and then making a site assessment based on the composition of the vegetation. The time since cultivation is based on ecological research, which has shown that the native species composition generally requires 15 years to return in ploughed grasslands (Butler 2005). The native and exotic species assessment is based on the principal that areas that do not meet these criteria are unlikely to return to 'good native condition' within 15 years even with sympathetic management.

2.3.5 Regrowth vegetation

Different vegetation types have different potential recruitment responses post clearing. The same vegetation type potentially could produce a different response depending on the type of clearing operation, e.g. bulldozing, chaining, blade ploughing, chemical poisoning, was the debris burnt or not, and the seasonal conditions immediately before, during and after the clearing. Vegetative regeneration from lignotubers, e.g. tropical savanna eucalypts or buried roots, e.g. brigalow, can lead to very high density of stems in the regeneration. Similarly, a mass recruitment from seed may occur after clearing or be stimulated by a fire, e.g. some Acacias or flooding event, e.g. *Eucalyptus tereticornis*. Over time the tree densities will usual self-thin to a density that is more at equilibrium with the site conditions. Hence in some areas regrowth vegetation may have stem densities higher than the benchmarks expected for that regional ecosystem.

The *Vegetation Management Act 1999* in Queensland recognizes High Value Regrowth (HVR) which is currently defined as native vegetation regrowth greater than 15 years old. HVR is mapped as Category C on the regulated vegetation map produced by the Department of Resources. See Appendix 8 for more information on HVR.

Death of trees usually occurs in water stressed conditions particularly if accompanied by high temperatures. Periodic droughts can cause the death of mature and regrowth trees in remnant and regrowth areas. Fensham and Holman (1999) found 30.9% of the trees in the eucalypt-dominated woodlands in north Queensland died in the drought that peaked in 1996. The multi-year drought that lasted to 2003 in the Desert Uplands bioregion resulted in the death of 18.6% of the trees in the eucalypt woodlands investigated (Fensham et al. 2015). In the Mulga Lands the mid-2000s drought resulted in the death of 27.6% of trees over large areas dominated by *Acacia aneura* woodlands (Fensham et al. 2012).

The revegetation trajectory of regrowth after clearing may be affected by post-clearing management while most vegetation will recruit and move towards the preclearing native vegetation, treatment or seasonal events may deviate the trajectory. In addition, weedy species may also recruit particularly in disturbed soils to produce regrowth that is a mixture of native and non-native species, i.e. a novel ecosystem. For some vegetation such as rainforest the earliest regrowth species may be the fast growing early succession species with mature climax species only becoming dominant over time.

Regrowth vegetation will generally be actively growing and sequestering carbon. In most cases it will be sequestering carbon at a higher rate than remnant vegetation. It therefore has a high value for this ecosystem service it provides, in addition to the stabilising of riparian channels and waterways and the protection of soil surfaces from erosion. Regrowth vegetation supports a wide variety of biodiversity with older regrowth generally exhibiting more of the habitat values and biodiversity of remnant vegetation. The landscape context of the regrowth is also important as it can act as corridors between remnant vegetation patches or act as a buffer zone to existing remnant patches. In these cases the presence and maintenance of the regrowth also enhances the biodiversity values of the adjoining remnant patches.

2.3.6 Vegetation condition

It is recognised that within vegetation mapped as remnant the condition of the vegetation can vary substantially. BioCondition (Eyre et al. 2015) is a site-based method for assessing the condition of the vegetation at the site relative to a reference state. Eyre et al. (2017) is a manual for collecting all the data needed for independent reference sites. Most of these data can be derived from QBEIS secondary sites. However, there are a number of attributes additional to those currently collected for a secondary QBEIS site to be collected from reference sites for the purpose of deriving benchmarks for attributes used in BioCondition; namely the number and size of large trees; and the amount of coarse woody debris. BioCondition benchmarks for a number of regional ecosystems are available at http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/.

There are a number of technical difficulties in attempting to map vegetation condition. Buck et al. (2009) have attempted to map vegetation condition in the Mulga Lands using satellite imagery, ALOS (radar) and LIDAR (laser) imagery. The Queensland Herbarium and Remote Sensing Centre have used machine learning models to map the vegetation condition across Queensland (Department of Environment and Science, 2021). Further field work and model enhancements are being conducted to improve on this product.

2.4 Scale

2.4.1 Specifying scale

Scale has traditionally been determined and specified by the cartographic standards that dictate what can be practically depicted on a map at a specified scale. Thus at a scale of 1:100 000, the traditional minimum recommended area for polygons is about 5 mm width on the map which equates to a ground area of 20 ha or 3 mm width on the map for an elongated polygon which equates to 30 m on the ground (Table 5). However, more recent mapping has adopted smaller size limits based on a minimum of 2 x 2 mm (Table 4). These standards set a minimum size of about 0.25 ha and 25 m for linear features at 1:25 000 scale; 1.0 ha and 50 m at 1:50 000 scale; and 4 ha and 100 m at 1:100 000 scale.

Table 4 Recommended data resolution for various map scales

Feature	Size on map	Map scale				
		1:10 000	1:25 000	1:50 000	1:100 000	1:250 000
Surface area of the smallest mapped feature	2 x 2 mm	0.1 ha	0.25 ha	1.0 ha	4 ha	25 ha
Minimum width for linear features	1 mm	10 m	25 m	50 m	100 m	250 m
Precision of line-work1	±0.5 mm	10 m	25 m	50 m	100 m	250 m
Imagery pixel size		≤0.1 m	≤1 m	≤5 m	≤10 m	≤25 m

Adapted from BRS (2002), based on equivalent size on the ground.

[1] Assumes line can be drawn within 0.5 mm of feature on image.

Agathis microstachya in complex notophyll vine forest (RE 7.8.2a) Lake Barrine, Wet Tropics bioregion (V.J. Neldner, Queensland Herbarium & Biodiversity Science, Queensland Government)

Table 5 Class of land resource surveys to scale and recommended uses

Land resource survey class	Typical scales	Area (ha) = 1 cm² of map	Minimum area shown*		Recommended uses
			Uniform occurrence (ha)	Elongated occurrence (ha)	
Very high-intensity	1:5000 1:10 000	0.25 1.0	0.05 0.20	0.07 0.27	Horticultural research and production areas, agricultural research areas, pasture research areas, forestry research areas, irrigation implementation, urban development, waste disposal, highway planning, mine site rehabilitation, engineering uses, property planning.
High-intensity	1:20 000 1:25 000	4.0 6.25	0.8 1.2	1.1 1.7	Agricultural production areas, pasture research areas, forestry production areas, irrigation implementation, urban development, waste disposal, highway planning, mine site rehabilitation, engineering uses, management of small catchments, shire planning (agricultural areas), conservation management.
Medium-intensity	1:50 000	25.0	5.0	6.7	Agricultural production areas, pasture production areas, forestry areas, irrigation feasibility, management of small catchments and conservation reserves, shire planning (agricultural areas).
Low-intensity	1:100 000	100	20	27	Agricultural feasibility studies and production areas, pasture production areas, forestry production areas, irrigation feasibility studies, management of large catchments, shire planning (pastoral areas), conservation management.
Reconnaissance	1:250 000 1:500 000	625 2 500	120 500	170 675	Agricultural development potential, pasture production areas, national or regional resource inventory, conservation management.
Synthesis	1:2 000 000	40 000	8 000	11 000	National resource inventory, teaching, global planning.

* Assumes that uniform occurrence is circular, with a diameter of 5 mm in the map, and elongated occurrence is rectangular with sides of 3 and 9 mm in the map. Source: Adapted from Reid (1988)

2.4.2 Definition of scale for classification

The definition of regional ecosystems and remnant vegetation for survey and mapping must also include a specified scale. Ideally the optimum scale will be determined by the complexity of the vegetation, the associated environment and the ecological relationships being defined. For example small open grassy areas in western Queensland might be defined as a component of the open woodland ecosystem they occur with, while grassy areas of the same size within a coastal heath might be defined as a separate ecosystem. While much of the terminology used to describe scale comes from mapping, such as minimum polygon size, the scale specified in a regional ecosystem or remnant vegetation definition is applied irrespective of whether the entities are being mapped.

Two main aspects of scale are discussed below:

1. the minimum size of an area of remnant vegetation
2. the minimum size of a regional ecosystem.

2.4.2.1 Remnant vegetation cover

In general, Queensland Herbarium remnant vegetation cover is defined at a scale of 1:100 000 scale, which delineates a minimum area for remnant vegetation of 5 ha and 75 m width limit for linear features.

For other urban or industrial areas, offshore islands, and coastal areas (see below), it is appropriate to define remnant vegetation at a scale larger than 1:100 000. These areas generally have better information (such as detailed local government mapping) and more vegetation landscape diversity, and development is usually at a finer scale. Remnant vegetation in these areas may be delineated down to the size of 1 ha and/or 35 m in width. Existing regional ecosystem mapping may not be at the scale specified for the subregion or bioregion.

Coastal areas include:

- Brigalow Belt subregions 1 (Townsville Plains), 2 (Bogie River Hills) and 14 (Marlborough Plains)
- Cape York Peninsula subregion 2 (Starke Coastal Lowlands)
- Einasleigh Uplands subregion 3 (Hodgkinson Basin)
- Central Queensland Coast bioregion
- Southeast Queensland bioregion.

The Wet Tropics bioregion remnant vegetation cover mapping is at 1:50 000 scale, but delineates a minimum area for remnant vegetation of 0.5 ha and 20 m width limit for linear features. This is because of the complexity of vegetation in the Wet Tropics bioregion and the availability of consistent, detailed mapping conducted by Stanton and Stanton (2005) for the Wet Tropics Management Authority.

The above size limits refer to remnant vegetation cover. Therefore a smaller individual polygon of a regional ecosystem can be delineated if it is contiguous with a larger area of remnant vegetation. This may occur when an area has been cleared leaving thin strips or small areas of a particular regional ecosystem.

These size definitions apply irrespective of the mapping scale. Large scale mapping (e.g. 1:10 000, 1:25 000) may be required for property level assessments (e.g. Property Map of Assessable Vegetation (PMAVs)) and application of the regional ecosystem framework. While this mapping is required to improve the accuracy of line-work for boundary location, to conform to the scale definitions used here, the minimum polygon sizes defined above should still apply. For example a small, 0.25 ha area in Southeast Queensland which has an open canopy that does not meet the remnant definition, may still be defined as remnant vegetation as it is assessed for remnant status as part of a larger 1.0 ha area of vegetation.

2.4.2.2 Regional ecosystems

Regional ecosystems and vegetation associations are generally mapped and defined at 1:100 000 scale. While the level of classification used in mapping is commensurate with the mapping scale, polygons in the regional ecosystem mapping may be attributed with multiple regional ecosystems that cannot be individually delineated at the specified mapping scale. The regional ecosystem classification is also incorporated into property, local government, national park or other larger scale mapping which provides further potential for subdivision of regional ecosystems. For example an area defined as one regional ecosystem at 1:100 000 scale could be divided into two distinct regional ecosystems as 1:50 000 scale. Therefore limits to the scale of classification of the regional ecosystems are defined to promote consistency in the scale of the regional ecosystem classification and mapping irrespective of what scale they are mapped at.

Limits to the scale of classification are defined using minimum patch-size limits. These limits vary from region to region to reflect differences in spatial complexity of the landscape and associated regional ecosystems. In general, minimum size limits of 5 ha (and 75 m for linear features) for inland areas and 2 ha (35 m for linear features) for coastal areas, are defined beyond which regional ecosystems (or land zones) cannot be further subdivided no matter what scale of mapping is carried out. These size limits become important where there are patches of a repeatable, albeit often not clearly mappable, pattern that is closely associated with a particular regional ecosystem, but could also be matched to a different regional ecosystem.

For example, under the description for 12.5.3 in Queensland Herbarium (2009) there is a comment that patches that equate to this regional ecosystem on Cainozoic to Proterozoic sediments that are >2 ha in size are defined as 12.9–10.4, while patches of these sediments smaller than this are defined as 12.5.3. Analogous comments, with a minimum size of 5 ha, occur in relation to grassland and open woodland on basalt (11.8.5 versus 11.8.11) and alluvium (11.3.21 versus 11.3.3) in the Brigalow Belt bioregion.

The above scale limits apply to the pre-clearing extent of regional ecosystems. Areas of remnant regional ecosystems can remain, and be recognised, after clearing has left fragments smaller than the above limits. These remnants may also have a different species composition to the overall composition of the regional ecosystem emphasising the need to identify regional ecosystems from a pre-clearing context.

Corymbia stockeri and *Eucalyptus cullenii* woodland (RE 3.10.6x4) on a sandstone headland, Stanley Island in the Flinders Island group, Cape York Peninsula bioregion (M.R. Newton, Queensland Herbarium & Biodiversity Science, Queensland Government)

3. Mapping

3.1 Overview

The methodology and methods for vegetation and regional ecosystem survey and mapping has been developed over 40 years of Queensland Herbarium mapping activity (Neldner 1993; Neldner et al. 2017a). For the majority of Queensland the regional ecosystem maps are produced at 1:100 000 scale, which is the scale recommended for conservation management and regional resource inventory (Reid 1988; JANIS 1997).

The two major mapping products of the Queensland Herbarium are maps (and digital coverages) of current remnant and pre-clearing regional ecosystems and vegetation. The pre-clearing mapping is derived primarily from 1960s aerial photographs in conjunction with a range of other imagery and other information. The remnant mapping is derived primarily from Sentinel-2 and Landsat TM imagery in conjunction with larger scale SPOT imagery and high resolution aerial photography. The remnant mapping shows the extent of vegetation at the time of the imagery and is updated about every two years (current remnant mapping exists for 1997, 1999, 2000, 2001, 2003, 2005, 2006, 2007, 2009, 2011, 2013, 2015, 2017, 2019 and 2021). The maps are ground-truthed, which involves the collection of quantitative site data for the classification and description of regional ecosystems and vegetation types.

Where regional ecosystem maps are questioned a detailed re-assessment may be performed. This involves examination of historical and recent aerial photographs, historical and recent satellite imagery, any existing field data and, if required, field assessment. Where an assessment justifies a change in the mapping, these changes are incorporated into the pre-clearing and remnant coverages. This means that when a new version of mapping is released, all pre-clearing and remnant maps and associated statistics are re-issued (Accad et al. 2001; Accad et al. 2003; Accad et al. 2006; Accad et al. 2008; Accad et al. 2012, Accad and Neldner 2015, Accad et al. 2017, Accad et al. 2019 , Accad et al. 2021, Accad et al. 2023).

Appendix 1 provides a summary of the preferred survey and mapping process. The methods used to assess and map pre-clearing, remnant vegetation cover and remnant regional ecosystem/vegetation mapping are outlined below. Variations to these methods do occur depending on availability and appropriateness of information. For example, in parts of the state where appropriate information exists (e.g. Wet Tropics bioregion or some local government areas in southeast Queensland), detailed vegetation mapping is used as the basis for forming remnant regional ecosystem maps.

3.2 Pre-clearing vegetation

Mapping of pre-clearing vegetation is based on the interpretation of landscape primarily as depicted on aerial photographs, with a range of other information including satellite imagery and other land resources survey and mapping, and ground-truthed on a limited but representative sample of known points. The Queensland Herbarium uses the 1960s 1:80 000 black-and-white photographs as the standard imagery for mapping pre-clearing vegetation. These older aerial photographs provide a high-quality, complete coverage of the state, and show larger areas of uncleared vegetation than more recent imagery. The pre-clearing mapping coverages depict the distribution of the natural vegetation shown on the 1960's aerial photographs.

Where vegetation has already been cleared on these aerial photographs, the pre-clearing vegetation may be reconstructed by the botanist using landform, soils, geology, field data and ecological knowledge. Field data from adjacent or nearby remnant vegetation and isolated trees, and patches of remnant vegetation and regrowth within cleared areas are collected and also used to attribute the vegetation types occurring in cleared areas. In addition, historical survey records of vegetation types and older aerial photographs (if they exist) are used extensively in this reconstruction (see Fensham and Fairfax (1997) for discussion). Experience has shown that wherever investigations by Herbarium officers have assessed surveyors' records from the early 1920s and earlier, the vegetation boundaries shown in these records have been the same as, or very similar to, the vegetation boundaries that exist on the 1960's and current aerial photography.

In some instances it may be possible to reconstruct the pre-clearing structure and floristics of locations where adequate aerial photographs, site data or observations exist (Fensham and Fairfax 1997). However, this is intensive work that can be applied only to limited areas and is beyond the scope of the state-wide mapping program. Ecological modelling of species or community distributions (where available) is an additional input that may be used to reconstruct the pre-clearing vegetation.

Draft digital maps are produced from the interpreted aerial photographs by digitising or scanning the polygons drawn by the botanists on the aerial photograph overlays. Generally, standardised mapping techniques using IMAGINE and ARCINFO software followed by some enhancement using on-screen digitising over the satellite imagery are used to capture the linework onto a Geographic Information System (GIS). The Universal Transverse Mercator (UTM) projection with the current Australian standard of the Geocentric Datum of Australia 1994 (GDA94) datum is used for all standard map products. The draft hard-copy maps or digital coverages on laptops are checked by botanists and technicians during field work (section 4).

3.2.1 Interpretation of aerial photographs

Pairs of aerial photographs (with stereo overlap) are examined under a stereoscope allowing the land surface and vegetation to be viewed in three dimensions. This is a standard technique for the mapping of many natural resources, such as vegetation, soils, geology and land systems (Gunn et al. 1988). The method is rapid, accurate and relatively inexpensive and has been tested throughout the world (Colwell 1960; Beckett 1968). In addition, Landsat TM satellite imagery and other natural resource information, such as existing topographic, vegetation, soils, geology and land systems maps and site data for the area, are examined to assist in interpretation of the patterns depicted on the aerial photographs. The botanist uses all of this information to delineate unique mapping areas (UMAs), also referred to as polygons, either directly on the aerial photographs using a chinagraph pencil or on a clear plastic overlay attached to the aerial photographs. The polygons show areas of similar photo-pattern, such as texture and tone, colour, height of vegetation, landform and land surface characteristics. The principal factors causing differences in photo-pattern are changes in landform and vegetation (Gunn et al. 1988).

The three dimensional view of the landscape is particularly important when interpreting landform.

- 'Landforms generally reflect the nature of underlying rocks and materials and the history of weathering, erosion and deposition. Landforms are identified by stereoscopic examination of photographs by means of their relief, structural form, drainage networks, the presence or absence of strike and relationships to adjacent landforms. Together with geological information, landforms indicate the nature and mode of formation of soil parent materials and hence the kind of soils present' (Gunn et al. 1988, p. 95).

The interpretation of landform and the geological mapping for the polygon determine the appropriate land zone (the second part of the regional ecosystem number) for the polygon.

- 'The distribution of undisturbed native plant communities generally reflects the complex environmental conditions (climatic, physiographic, edaphic, biotic) of a survey area and is an important factor controlling differences between photographic patterns. On plains of low relief it is often the most important factor. Changes in tone and texture of patterns are caused mainly by variations in the light-reflecting properties of species, the density of tree canopies, proportion of ground cover exposed, and shadow effects.' (Gunn et al. 1988, p. 95).

3.2.2 Assessment of land zone

The following general procedure is used to classify an area to the correct land zone.

The most up-to-date information about the land zone classification for a bioregion is consulted. The expanded and updated land zone definitions are available on the Queensland government website and described in Wilson and Taylor (2012). These definitions replace the descriptions of land zones in section 1 and Table 4 in Sattler and Williams (1999).

The latest geology maps and/or digital data available for the area in question are then obtained and examined. In some areas this may only be at 1:250 000 scale, but in many coastal areas and some inland areas 1:100 000 or larger scale is available.

Additional land resource mapping and data such as soils maps, land system maps, regolith maps and publications, may be available for some areas and may also be consulted to assist in determination of land zone. In addition, land resource mapping may subdivide larger geological units based on special soil types. In other cases there may be additional data e.g. detailed consultants reports, or detailed soil and geology points, geochemistry and borehole information and these are examined if readily available to assist in determining the land zone.

Topographic maps, aerial photographs and satellite images are also examined to provide the landform and geomorphological context for the site.

A land zone determination is generally possible from these data sources; however a field inspection may be necessary. During the course of a field inspection, features such as the landform pattern, the presence of rock outcrop or surface ooliths, e.g. ironstone nodules, and any nearby cuttings or gullies are observed to assist in confirming a land zone determination. A soil auger hole may also be dug to assess soil type, depth and layers present in the soil profile.

Consultation with the Queensland Herbarium bioregional coordinator may also be required.

3.2.3 Allocation to existing regional ecosystem classification

The following general procedure is used to classify an area to the correct regional ecosystem.

All available information including the latest version of the remnant vegetation and pre-clearing cover for the area, satellite images, QBEIS and quaternary sites, geology, land system and soils mapping and contours are assembled for an area.

Any additional hard copy land resource information for the area of interest may be consulted for information on the geology, landforms, soils and vegetation of the area. The procedure for determining land zones for the area is documented above (section 3.2.2).

All available site data including pre-existing data on the Queensland Herbarium databases may be consulted.

The latest version of the REDD (Queensland Herbarium 2023) is consulted for the current description of the regional ecosystems mapped.

Interpretation of aerial photographs using a stereoscope may be used in conjunction with the above land resource information and the data collected or available to the person making the assessment.

A regional ecosystem determination is generally possible from these data sources; however a field inspection may be necessary plus consultation with the relevant Queensland Herbarium bioregional co-ordinator.

3.3 Remnant vegetation cover

Figure 3 shows the sequence of steps used to assess and map remnant vegetation cover. The steps require the assessment of imagery followed by more detailed assessment if there is clearing indicated. The assessment has different criteria for woody and non-woody dominated vegetation as detailed in section 2.3.4.

Landsat TM satellite imagery, supplied and rectified by the State Land and Tree Study (SLATS) (Department of Environment, Science and Innovation), is used as the primary base for the compilation of remnant vegetation cover maps. This imagery has been complemented with rectified SPOT imagery for Queensland for 2005–2012. The satellite images are stored in digital format and can be viewed on the computer screen.

The boundaries of the clearing are drawn directly on the satellite image on the computer screen using GIS software. Generally, the interpretation of satellite imagery is carried out in conjunction with examination of recent and historical aerial photography and ground truthing of the draft maps in the field. In some coastal areas that have been mapped in more detail larger-scale ortho-rectified aerial photography is used as the primary imagery. In addition, the SLATS woody cover (and woody cover change) is used to aid interpretation of imagery.

Vegetation is assessed as remnant unless there is evidence, from satellite imagery, SLATS woody cover and/or available aerial photographs and/or orthorectified imagery, that there has been anthropogenic (caused by humans) clearing. Where there has been tree death caused by natural causes, e.g. drought death, fire, cyclone, storm or hail damage or insect or fungal attack, the vegetation is still regarded as remnant. Where there is evidence of anthropogenic clearing, the vegetation may still be classified as remnant if it is assessed as meeting the 50% cover, 70% height and characteristic species criteria. By studying satellite imagery and aerial photographs and comparing the pattern on the imagery with the extant vegetation in the field, Queensland Herbarium botanists, technicians and computer support officers (GIS) gain expertise in the recognition of remnant vegetation for different types of vegetation and regional ecosystems from the imagery and aerial photographs. This includes knowledge of the time it takes for a vegetation type to grow back to remnant status after clearing. For example, no eucalypt woodland or open forest vegetation types cleared in the last 20 years have met the remnant definition following on ground assessment. These vegetation types usually take 30 years to regain remnant status (Queensland Herbarium, unpublished data, March 2004).

Field assessment of the remnant status of vegetation may be required where there is evidence of extensive mechanical or chemical disturbance on available imagery and where there is doubt that the vegetation meets the remnant criteria. Remnant vegetation is assessed in the field by measuring the canopy criteria at a site and comparing it to a reference site to determine if it meets the cover, height and characteristic species thresholds. This remnant or non-remnant assessment can then be extrapolated to other areas using satellite image, aerial photographs and/or field observations (Wilson 2000).

Areas of non-woody dominated regional ecosystems are mapped as remnant where there is no evidence of cultivation in the past 15 years (generally detectable on Landsat imagery). Subsequent field assessment, by a botanist, of the composition and cover of native and exotic perennial species may be required to verify the remnant status of a grassland or herbland. In many cases assessment of these criteria is difficult during drought or dry times of the year and a definitive assessment may have to be delayed until after rain.

Recently cleared areas on the Landsat TM satellite imagery produce very low or zero values for woody cover and are classed as non-woody by SLATS. They are conspicuous on the Landsat TM satellite imagery as even-textured, often pink or pinkish coloured areas. Areas of bare soil or cropping are also very conspicuous, and plantations can be distinguished by the even appearance on the image, and the usually straight line boundaries of the patches. The colours on a Landsat TM satellite image can be adjusted as an aid to interpretation using different combinations of the different wavelength sensors to enhance woody vegetation, or geological features.

Satellite imagery

Remnant vegetation is mapped using the Sentinel-2 and Landsat Thermal Mapper TM satellite imagery supplied by Geoscience Australian, as well as other orthorectified digital imagery. Digital data collected by the numerous detectors and sensors attached to a satellite are transmitted back to Earth to ground stations and processed to create images not too dissimilar from an aerial photograph. In addition to Landsat and Sentinel-2, and high resolution Earth-i imagery has been acquired and used in the woody cover and regional ecosystem mapping. Satellite imagery for all of Queensland is purchased and processed by the Statewide Landcover and Trees Study (SLATS), Department of Environment, Science and Innovation, at least every two years.

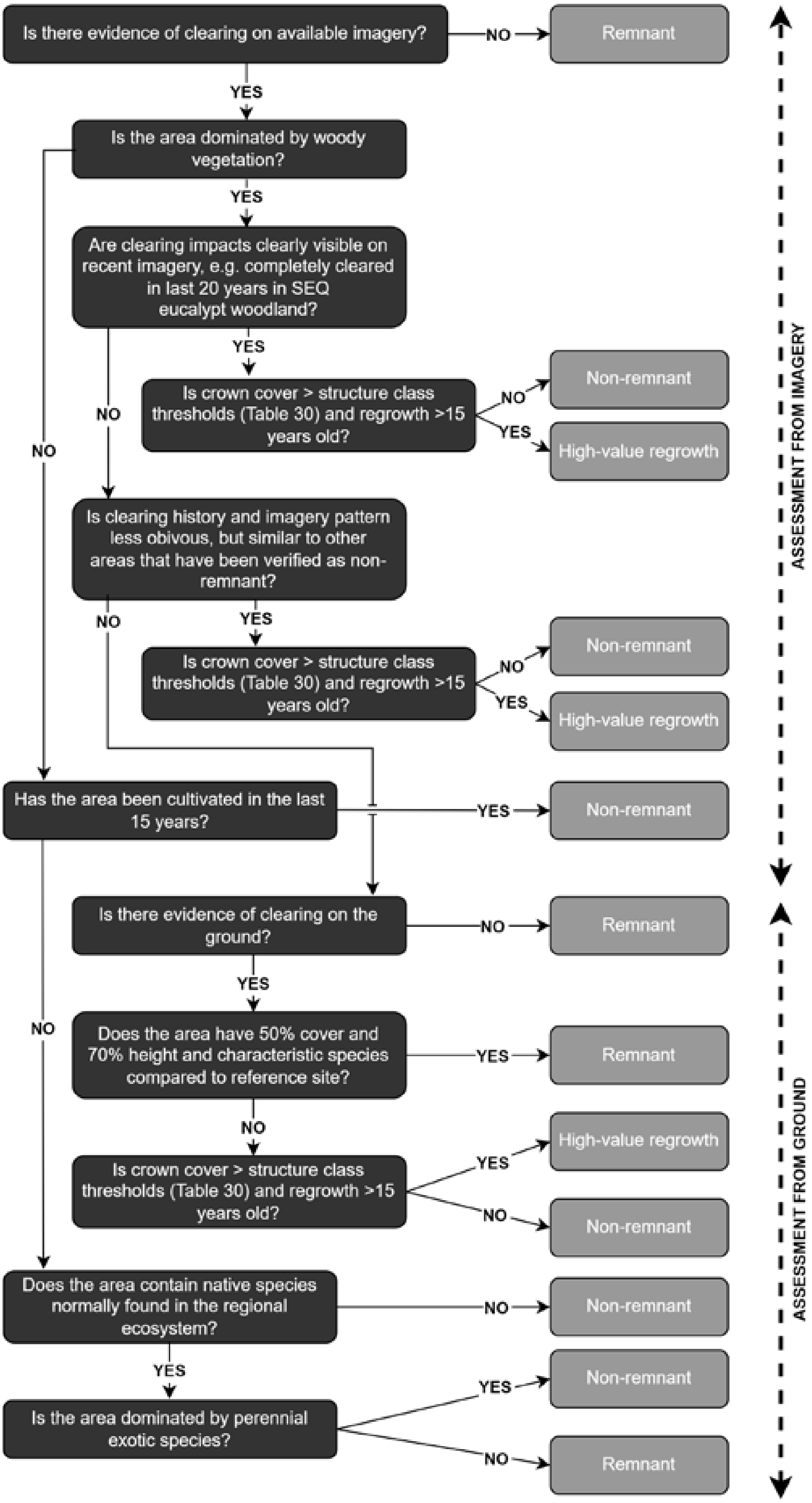


Figure 3 **Flowchart showing assessment sequence for mapping vegetation cover**
* Areas mapped as remnant until ground assessment is carried out

SLATS provides accurate information about woody vegetation cover and woody vegetation cover change (DNRM 1997, 1999, 2000, DNR 2003, DNRM 2004, 2006, DNRW 2007, 2008, 2009, QDSITIA 2014a,b, QDSITI 2016, DES 2018). The Landsat TM satellite imagery collects data at a resolution of 30 m, enabling most areas of vegetation change (one hectare or greater) to be detected. The SLATS method is regarded as best practice in remote sensing and has been used in Queensland- and Australia-wide assessments of land clearing rates (Barson et al. 2000). The information provided by SLATS is widely accepted by most stakeholders, as illustrated by the following quote: 'The SLATS team of 14 scientists and technologists have combined various world class information technologies into an integrated system that has now proved itself in delivering timely mapping and statistical information.' *Queensland Farmers' Federation Weekly Bulletin*, 12 July 2002.

As the Landsat TM satellite imagery used by SLATS is captured in the dry season (July–September) in Queensland, the green leaves of the woody vegetation are readily distinguished from the dry grasses and herbs in the ground layer. Sensors in the Landsat TM satellite record the amount of green in each individual pixel, and these data are used to provide the values for woody cover.

Reference sites

Reference sites are required to determine remnant/non-remnant status in cases where there is evidence of clearing of the predominant canopy and it is not obvious that the 50% of cover and 70% of height and characteristic species definition (section 2.3.4) is met. Reference sites are selected by choosing areas that represent the vegetation that would normally be present at the site. Sites are generally chosen where there is no evidence of clearing of the predominant canopy evident on the aerial photograph archive or in the field.

The normal canopy height (and cover and species) may vary within regional ecosystems according to environmental conditions. Therefore reference sites should occur as close as possible to the area to be assessed and have similar environmental conditions, such as the same vegetation community and climate (same subregion), landscape conditions (soil, slope, position in the landscape, geology etc.) and natural disturbance (cyclone impacts or fire history). For this reason, field measurements of the height, canopy cover and species composition of the area of interest are compared, where possible, to measurements from a local reference area, i.e. a nearby area of comparable vegetation that is known to be remnant, such as a road reserve.

Where it is not possible to find an appropriate local reference site, the mean height and canopy cover values may be obtained from published Queensland Herbarium Regional Ecosystem technical descriptions, QBEIS sites, published benchmark descriptions or other published descriptions for the relevant regional ecosystem. In general the closer the QBEIS site or published description is to the physical situation of the area of interest, the more valuable it is as an indicator of its normal predominant canopy.

The definition of reference sites above is similar to that used to define benchmarks for assessment of vegetation condition in Australian (e.g. Parkes et al. 2004; Gibbons et al. 2005; Eyre et al. 2015, 2017).

3.4 Remnant regional ecosystem

Remnant regional ecosystem maps are produced by intersecting the remnant vegetation cover (section 3.3) with the pre-clearing coverage (section 3.2). This process is carried out using GIS software and can be likened to using a biscuit cutter to cut out shapes (remnant or non-remnant areas) from dough (the broader pre-clearing coverage). Areas of non-remnant vegetation are removed from the pre-clearing coverage while the remnant areas are attributed with the polygons and regional ecosystem codes of the pre-clearing coverage.

The latest rectified satellite imagery and the relevant aerial photographs are re-examined for areas mapped as heterogeneous polygons (polygons with more than one regional ecosystem occurring in them) to adjust for any preferential clearing (Fensham et al. 1998). The proportions of the area of the polygon that each regional ecosystem occupies are adjusted if there is evidence of preferential clearing; that is, uneven clearing such that the agriculturally productive vegetation (such as brigalow) is cleared, while the less productive vegetation (such as ironbark woodland) is not cleared (Fensham et al. 1998).

Regional ecosystem coverages (digital maps) are then produced by Herbarium computer support (GIS) officers following standardised mapping techniques using ARCGIS software. The GIS unit runs a series of automated checking programs and refers any inconsistencies or errors, such as missing attributes, differences between pre-clearing vegetation and remnant vegetation to the botanists for checking. Once checking has been completed and the resulting amendments have been finalised, the digital coverages are available for release and distribution.

3.5 Incorporation of mapping from third parties

In some areas other mapping, such as regional ecosystem or vegetation mapping from local governments in Southeast Queensland, has been used by the Herbarium and incorporated into the regional ecosystem mapping layers. In some cases this mapping has required minor editing and updating before incorporation while in other cases this mapping requires more substantial translation and editing before incorporation.

3.6 Monitoring remnant regional ecosystem and vegetation extent

The remnant mapping reflects the extent of remnant vegetation at the time of the capture of the satellite imagery. The initial remnant regional ecosystem map is based on the 1997 Landsat imagery. Updated imagery (1999, 2000, 2001, etc.) is used to map change in remnant extent. This is intersected with the previous remnant coverage with re-interpretation of polygon proportions to allow for differential clearing to produce an updated remnant regional ecosystem and vegetation community cover.

The change mapping generally uses the woody cover change supplied by SLATS (Kuhnell et al. 1998) as a starting point, but further checking occurs to ensure that the changes indicate vegetation changing from remnant to non-remnant and that they are due to clearing and not drought death, fire or other natural disturbance. Areas of non-woody vegetation (e.g. grasslands) that have been cultivated in the two years between map updates do not appear on the SLATS change cover but are removed from the current remnant extent mapping by the Herbarium. Accad et al. (2012) discuss the differences between woody and remnant vegetation cover.

The extent of remnant vegetation across Queensland is monitored by a comparison of the pre-clearing and remnant coverages for various years (Accad et al. 2001; 2003; 2006; 2008; 2012, Accad and Neldner 2015, Accad et al. 2017, Accad et al. 2019 Accad et al. 2021, Accad et al. 2023). The extent of individual regional ecosystems is also monitored in these analyses and supplied by bioregion, subregion, catchment, local government area and other areas of relevance to natural resource management.

3.7 Map versions

The Queensland Herbarium mapping is updated and released as different versions. Generally updates and versions correspond with two yearly updates in remnant extent mapping, e.g. 1997 (version 2.0), 1999 (version 3.0), 2001 (version 4.0), 2003 (version 5.0), 2006 (version 6.0b), 2009 (version 7.0), 2011 (version 8.0), 2013 (version 9.0), 2015 (version 10.0), 2017 (version 11.0), 2019 (version 12.0 and 12.1), 2022 (version 12.2) and 2023 (version 13.0).

In addition each version includes mapping of previously unmapped areas and/or revisions of previously mapped areas. Therefore each version includes a release of all pre-clearing and remnant extent coverages. For example, version 5.0 included pre-clearing and 1997, 1999, 2001, 2003 and 2005 remnant extents. Version 7.0 included pre-clearing and 1997, 1999, 2001, 2003, 2005, 2006, 2007 and 2009 remnant extents. Therefore monitoring of regional ecosystem extent over time requires comparison of remnant extent coverages and associated statistics from within each version (e.g. Accad et al. 2001, 2003, 2006, 2008, 2012, 2017, Accad and Neldner 2015, Accad et al. 2017, Accad et al. 2019, Accad et al. 2021, Accad et al. 2023). Comparisons between versions would confound changes in extent with changes in base mapping.

3.8 Regional ecosystem data sources

Pre-clearing and remnant regional ecosystem mapping data and the BVG derived layers are available for most of Queensland in shapefile format through the Queensland Government data website https://data.qld.gov.au/. Use the search term 'regional ecosystem'.

Broad vegetation group (BVG) maps in Portable Document Format (PDF) are available online https://apps.des.qld.gov.au/map-request/re-broad-veg-group.

Alternatively regional ecosystem and BVG mapping can be viewed on the Queensland Globe: https://qldglobe.information.qld.gov.au.

Regional ecosystems maps and reports for user-defined areas are made freely available through environmental reports online https://apps.des.qld.gov.au/map-request/re-broad-veg-group.

3.9 Mapping scale and minimum size depicted

The Herbarium regional ecosystem mapping scales, including minimum polygon size delineated, use the remnant vegetation cover definitions in section 2.4.2.1.

3.9.1 3.9.1 Heterogeneous polygons

A heterogeneous polygon is simply a polygon (each discrete area delineated on a map) that has more than one vegetation or regional ecosystem code. Many parts of Queensland have a high spatial diversity of vegetation communities. Therefore, at 1:100 000 scale, it is not always possible to spatially delineate each vegetation community into homogenous (pure) polygons.

Aerial photography can often detect a number of vegetation patterns that occupy areas smaller or narrower that are below the minimum limits for the scale of mapping. Where two or more ecosystems are present and consistently detectable on aerial photography but unable to be mapped separately, they are included in a single heterogeneous polygon and the proportion of each component regional ecosystem is quantified (Bean et al. 1998). This approach allows the flagging of regional ecosystem diversity which is beyond the scale of 1:100 000 scale mapping, but also allows robust area estimates of the component regional ecosystems to be calculated.

A maximum of five vegetation units may be attributed in a heterogeneous polygon, and for a vegetation map unit to be included in a heterogeneous polygon it must occupy at least 5% of the polygon. This means that at 1:100 000 scale, where the minimum mappable area of a polygon is 5 ha, areas of vegetation types smaller than this could be included in the map coverage. Hence the use of heterogeneous polygons provides a mechanism to include areas of vegetation that would normally be too small to be shown at the scale of mapping. These small areas, such as narrow riparian vegetation or scattered wetland or rainforest patches in tropical savannas, often support significant biodiversity or require special management considerations.

Examples of heterogeneous polygon types are described in Appendix 4.

3.9.2 Assigning polygon proportions

The actual percentage of the area of the polygon occupied by each regional ecosystem or vegetation type is recorded for pre-clearing and remnant vegetation coverages. The vegetation units are ordered from largest to smallest proportion (Figure 4).

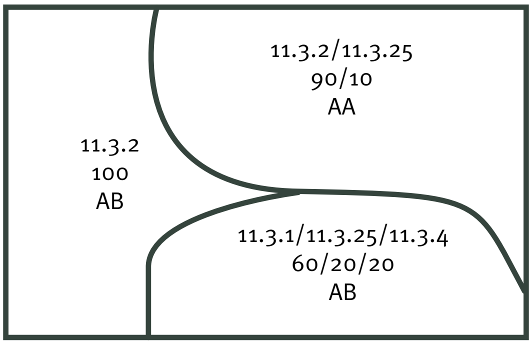


Figure 4 Example of polygon labels

The labels for the polygon in the top right corner consist of regional ecosystem codes (11.3.2/11.3.25), an estimate of the percentage of the polygon occupied by each regional ecosystem (90/10) and the spatial accuracy of the polygon boundaries (A: see section 3.10.1.2 for an explanation) and attributes (B: see section 3.10.1.2 for an explanation) .

Estimation of the proportions of the vegetation types within polygons is initially derived during interpretation of the photo-patterns present. The field data can be displayed over the polygon coverages and assist in finalising the proportions. This procedure is particularly useful for estimating proportions in polygons over cleared land (presence of roadside remnant trees) and where differences in vegetation types are not readily apparent in photo-patterns.

3.10 Accuracy

3.10.1 Accuracy assessment methods

Mapping accuracy is assured and assessed by:

- quantitative assessment using independently collected data, and
- validation and qualitative assessment and reliability codes for each polygon.

3.10.1.1 Quantitative assessment

A quantitative accuracy assessment is undertaken to assess how close an estimate the final product is to its true value (ERIN 1999). The most rigorous assessment of the accuracy of survey and mapping requires the collection of an independent data or reference set which is known to be the 'truth', which can then be statistically compared to the mapping results. Accuracy assessments are required to ensure that the map meets specified standards and to give users a general indication of the attribute accuracy (Sivertsen and Smith 2000).

In practice, such an independent assessment is difficult to do unless it can be derived from other readily available remotely sensed imagery, such as where water bodies have been mapped from satellite imagery and checked for accuracy against large-scale colour aerial photographs (Bruinsma and Danaher 1999; Kingsford et al. 2001). As much of the regional ecosystem can be assessed only from independent field sampling, this assessment is often carried out only after the mapping for a region is completed.

The vegetation and regional ecosystem survey and mapping aims to achieve a greater than 80% accuracy across Queensland. Accuracy will vary from area to area and across regional ecosystems. Accuracy assessments (Queensland Herbarium, unpublished data) indicates that for ecosystems with less than 40% remaining, the mapping over-estimates the extent remaining as a per cent of pre-clearing by 10%. This factor is incorporated into the calculation of status under the VMA. While the mapping gives a good regional perspective on distribution and status of ecosystems, property level inspections and property maps of assessable vegetation (PMAVs) are used to progressively improve the accuracy of the vegetation maps and associated information (e.g. vegetation site data). This information will be combined with monitoring of ongoing clearing to periodically update regional ecosystem statistics, distribution maps and the vegetation management class of regional ecosystems.

3.10.1.2 Validation and qualitative reliability codes

Validation is undertaken before the preparation of final products (ERIN 1999). It is generally part of the method and may take the form of decision or assessment rules. Various assessments of the adequacy of sampling and GIS analyses can also provide an indication of the scientific rigour of the field data underpinning the map product (Neldner et al. 1995).

Validation steps for the survey and mapping program may include:

- steps/rules in the method that check for internal inconsistencies in the database and maps
- a record of a site or sites in the QBEIS or the quaternary site database that provides validation of individual polygons or regions
- recording of the source of all derived products and polygons
- checking of final products by an independent mapper/bioregional coordinator to ensure that the method has been followed
- distribution of preliminary maps to regional staff and/or a technical panel for review
- random checking of line work against imagery to assess the proportion that meets specified accuracy standards
- review and checking of completed bioregion by expert bioregional technical review panel.

The Queensland Herbarium also provides a qualitative reliability code which captures the confidence of the interpretation by the mapper of the vegetation on a particular parcel of land. As well as being a guide for further supplementary studies, it also provides an indication of the reliability and hence the range of purposes for which the data about a particular parcel can be used.

Separate reliability codes are assigned for the accuracy of the line work (boundaries) and attributes of each polygon. The codes are assigned to individual polygons, taking into consideration the data sources used in decision making and gathered during field work, and the confidence in the interpretation. A polygon with a mosaic of vegetation units will have only one reliability code for line work and attributes. Some codes may always apply to the same pattern: for example, an 'A' reliability rating for all highly distinctive and predictable patterns, regardless of the data available.

Maps showing the reliability classes give an indication of the confidence in mapping and where further field work is required. Neldner et al. (1995) and Neldner and Clarkson (1995) have published examples of these applications.

Spatial accuracy of boundaries

The spatial or positional) accuracy of the polygon boundary line is indicated by the field 'L'. Confidence ratings are as follows:

A = high confidence in accuracy of polygon boundary

B = moderate confidence in accuracy of polygon boundary

C = low confidence in accuracy of polygon boundary

Examples:

- Discrete structural/floristic boundaries, such as grassland/woodland, closed forest/woodland or permanent wetlands/terrestrial vegetation, would have a high accuracy (class A).
- Diffuse boundaries, such as the continuum of change in eucalypt dominance across a gentle environmental gradient, would have low accuracy (class C). This could mean that the actual boundary is less accurate than specified, or more frequently, that the boundary is actually a continuum of gradual change across a zone of up to one kilometre.
- Field data would be used in the assessment of these ratings: for example, ground traverses will increase confidence in the boundary of a polygon. Polygons will adjoin different vegetation types on different sides (the accuracy of the boundary may vary), but only one summary rating will be given for the entire polygon perimeter.
- The cartographic standard used to digitise the mapped boundaries are that 95% of the boundaries are within 50 m of where they should be on the image for 1:100 000 scale areas and within 25 m of imagery at 1:50 000 scale. As the imagery has an accuracy of 25 m the final spatial accuracy of the mapping is 75 m for 1:100 000 scale areas and 50 m for 1:50 000 scale areas. The spatial errors are smaller in coastal areas or individual properties where the mapping has been updated using ortho-rectified photography.

Attribute accuracy

The attribute accuracy of the polygon regional ecosystem attributes is indicated by the field 'V'. This includes the regional ecosystem and vegetation classificatory units and the proportions. Confidence ratings are as follows:

A = high confidence in accuracy of polygon attributes

B = moderate confidence in accuracy of polygon attributes

C = low confidence in accuracy of polygon attributes

Examples:

- Highly distinctive photo-patterns, such as closed forests, will allow for a high confidence in the polygon attributes (class A). There is usually a high confidence in polygons where the photo-patterns may not be as distinct, but the environmental position makes the vegetation type highly predictable, such as *Rhizophora* spp. closed forests, eucalypts on serpentinite, etc.
- Indistinct photo-patterns, particularly in environments which do not force floristic or structural change/sifting, would have a low confidence in the attributes (class C). There are a number of possibilities for this polygon; because of the variation in the vegetation a very broad unit has to be defined. The presence of site data and traverses in polygons is generally associated with a high confidence in accuracy of the attributes.

3.11 Description of regional ecosystem and vegetation units

The description of the pre-clearing and remnant vegetation is based on the QBEIS site data collected at the time of sampling. For the eastern part of Queensland, the majority of these data have been collected since 1989, while reasonably comprehensive site data from the late 1970s exist for some parts of western Queensland. Sites are generally selected to represent the best current condition of the vegetation and to avoid extensive disturbance, e.g. previously cleared, severely eroded or weed-infested areas are avoided. The QBEIS sites have a defined area which is generally standardised to 500m^2, which has been shown to be adequate to capture the species biodiversity at a site (Neldner and Butler 2008). However, sites and, hence, the vegetation description and classification will still incorporate structural and floristic variation associated with variation within 'normal' management regimes (e.g. grazing, fire, presence of feral plant and animal species) as well as the variation associated with abiotic factors (e.g. soil, landscape position) within a given vegetation or regional ecosystem type.

Descriptions of the dominant and/or characteristic species and structural attributes of regional ecosystems and vegetation communities are provided in REDD (Queensland Herbarium 2023). Regional ecosystems/vegetation communities are represented by a **numerical code**, which is given a label in the **short description**, and given more detail in the **long description**, fully described in the **technical description** and summarised for the attributes defining condition in **benchmarks**. More comprehensive technical descriptions of regional ecosystems and vegetation communities can be produced from the QBEIS data, and may be published as separate publications (e.g. Neldner 1984, 1991) or as journal papers (e.g. Kemp et al. 2007) or as technical descriptions on the Queensland government website http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/ (e.g. Addicott and Newton 2012). Benchmarks for condition assessment of regional ecosystems are available at http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/.

3.11.1 Map legends and labels

Mapping units and labels are developed progressively through the mapping process using the following guidelines:

- assess whether the unit encountered matches currently described units for the bioregion or from adjoining map areas
- if the unit is similar but differs enough that the mapper considers it to be different, then keep it separate, at least initially, but document differences (these may be combined later in the light of further field data)
- assign sites into photo-patterns and sort them into groups
- conduct numerical classification to guide and inform intuitive groupings. For the most powerful analysis, use only woody species and some measure of abundance, preferably crown cover (Addicott et al 2018a) or basal area (Neldner and Howitt 1991). Addicott et al. (2018a) developed a standardised method of ranking abundance on the basis of crown cover and height of the layer
- progressively build new legend units if these are not yet in the legend or in other legends
- refine mapping as more data become available.

The regional ecosystem and vegetation code (veg) classification units are subject to an overall review after completion of the mapping of a bioregion through technical review committees (see criteria for new regional ecosystem/vegetation unit in Appendix 5). On the completion of each map sheet, an individual map sheet legend is created which includes a sheet-specific code and label for each category as well as veg and regional ecosystems (see example in Table 7).

3.11.2 Label/short description format

Each regional ecosystem or vegetation label (or short description in Queensland Herbarium 2021) follows the general format of species, structural formation and habitat.

A limited, but not exhaustive, number of characteristic species are listed in order of dominance, with punctuation that indicates their relative abundance and/or frequency (Table 7). The species in the predominant layer (for example, canopy T1 layer) that are consistently present are listed, in order of decreasing biomass and separated by a comma (,). These species are then followed by diagnostic species which generally have a high biomass but which are not consistently present are denoted by the symbol (±) which literally means with or without. Where no dominant species are consistently present the species are separated by 'and/or'. Dominant or characteristic species of other layers, such as shrub or ground layers may be included, following the same hierarchy as for the tree layers where they are diagnostic. Technical descriptions provide a more comprehensive list of the characteristic species.

Species are followed by the structural formation, with only the frequent formations (from Table 28) included. Where more than one structural formation is listed the most frequent or 'typical' one is first.

The associated habitat (landform and frequent geological substrate) is also usually included, particularly where it is diagnostic.

Where common names are included, they should be consistently used or excluded for the whole bioregion and should be in brackets after the species names. They must not be included in the regulations under the VMA.

Plant names follow those listed in the *Census of the Queensland Flora* (Brown, 2021 or subsequent versions of that list). Non-native species are denoted by an asterisk (*) and are generally included under the comments field.

Complex example of legend unit:

A, B, C ± D ± E ± F open forest to woodland. G, H ± I ± J shrub layer is frequently present. Occurs predominantly on alluvial plains

Explanation:

- Species A is the dominant species in the predominant canopy layer, and B and C are always present but have a lower biomass than A. D may be present in places and can have a relatively high biomass. E is also present in places and has a lower biomass than D. F is also sometimes present, with a lower biomass than E.
- The shrub layer is generally but not always present, and is dominated by G and H, with G having a greater biomass. I and J are sometimes present in the shrub layer.

A, and/or B, open forest to woodland. Occurs predominantly on alluvial plains.

Explanation:

- Species A and B are the dominant species in the predominant canopy layer but only one may be present.

Melaleuca fluviatilis with *Eucalyptus camldulensis* fringing woodland (RE 9.3.13) Emu Creek near Petford, Einasleigh Uplands bioregion (M.R. Newton, Queensland Herbarium & Biodiversity Sciences, Queensland Government)

3.11.3 Regional ecosystem long description format

The standard format for the long description follows the order—species, structural formation and habitat. It is formatted the same as the short description but with more detail. Each structural formation inherently has a height and cover range so actual height/cover ranges are unnecessary. Mean height and cover and ranges for these in each layer are documented in the technical descriptions.

There are three exceptions to the standard format:

1. Rainforests, e.g. 'Notophyll vine forest', where structural type is the key criterion.
2. Mixed ecosystems. These are REs/vegetation communities where no one or more species combined make 50% or more of the crown cover of the EDL (Hnatiuk et al. 2009). The standard format is 'Mixed woodland, including combinations of the species *Eucalyptus tetrodonta*, *Corymbia pocillum*, *Erythrophleum chlorostachys*, *C. polycarpa* and *C. clarksoniana*.' This means that at a particular site any or all of the species mentioned may be present, but it does not require or mean they will all be present. The first sentence of a mixed community should stop at six most frequent species. A second sentence if required should start with 'Occasional canopy species include…'.
3. A community is primarily defined by the landscape, e.g. rock pavements, lakes, billabongs, swamps, e.g. 'Seasonal swamps (wooded). *Eucalyptus microtheca* and/or *Acacia cambagei* low woodland to woodland, commonly with *Excoecaria parvifolia*. The ground layer is tussock grasses or sedges. Occurs in closed depressions in Quaternary residual sandsheets overlying Tertiary clay deposits. Cracking clay soils.'

The frequency of species occurring in a RE/vegetation community should be consistently applied. The standardised terms are:

- 'usually'—frequency 70–100%,
- 'commonly' 40–69%,
- 'occasionally' 10–39% and
- 'rarely' <'10%.

These terms are to be used in the long description rather than +/-. The term 'including' can be used, where a species is often found in the community but not consistently in the site data, e.g. 'A shrub layer may occur, including *Petalostigma pubescens* and *Melaleuca* spp.' Whereas if a species is consistently dominant and defining of a layer in the detailed site data, it should be described, e.g. 'The ground layer is dominated by *Triodia pungens*.'

Table 6 Example of map sheet legend

Vegetation type code	RE code	Vegetation label	Landscape label
Subcoastal hills			
21	3.12.7	*Corymbia clarksoniana*, *Eucalyptus brassiana* open forest	On granite ranges
22a	3.12.9	*Corymbia tessellaris* +/- *Welchiodendron longivalve* +/- *Eucalyptus cullenii* open forest	On footslopes of granite hills
Coastal floodplain			
34	3.3.8	*Corymbia tessellaris*, *C. clarksoniana* woodland to open forest on coastal alluvial plains	Coastal floodplain with flat to slightly undulating terrain

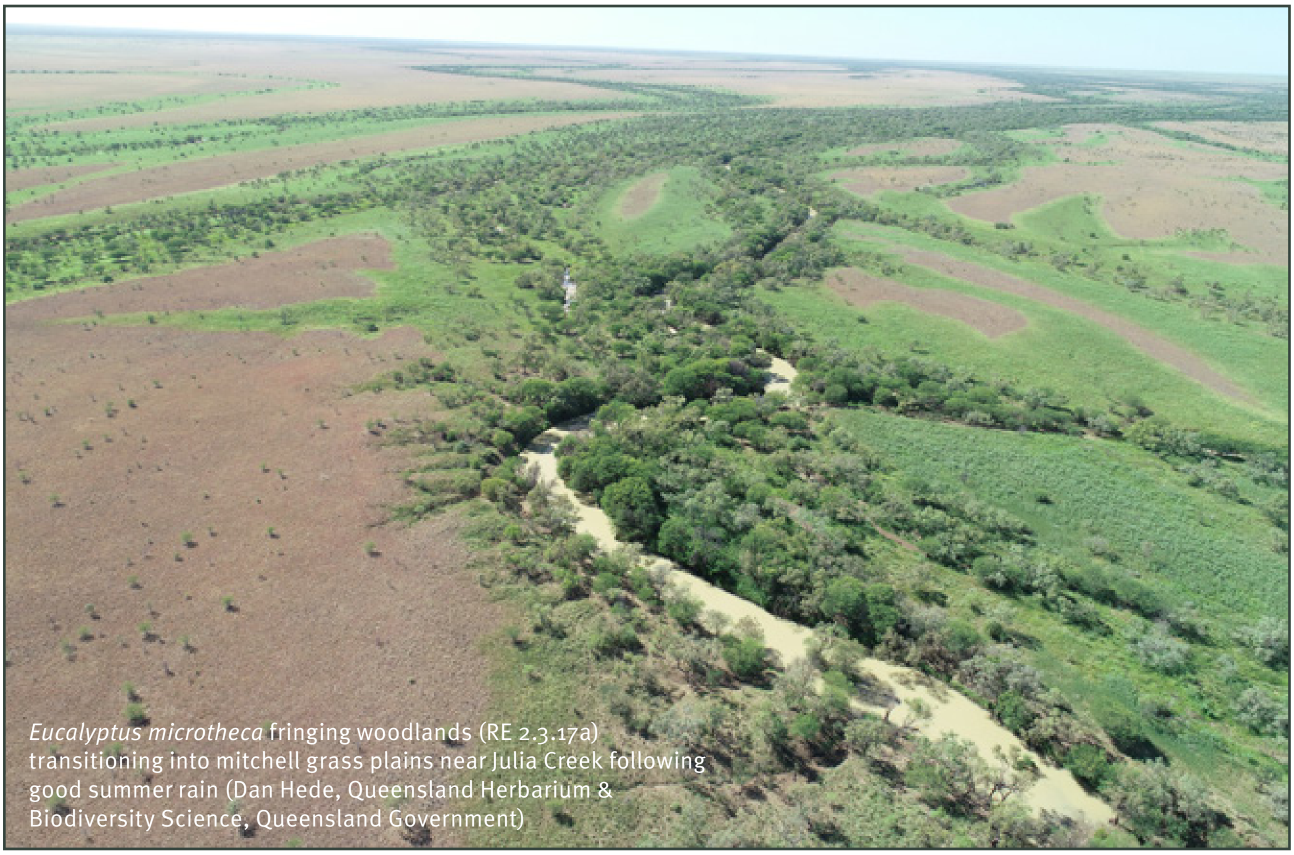
Table 7 Standard symbols in map unit vegetation label or regional ecosystem description

Connective	Example	Meaning
,	A, B	A and B are always present
±	A ± B	A is always present; B is sometimes present and sometimes absent
or	A or B	A is present or B is present; A is never present with B
and/or	A and/or B	A is present or B is present or A and B are present

3.11.4 Regional Ecosystems Descriptions Database (REDD) vs Vegetation Management Regional Ecosystems Descriptions Database (VMREDD)

The Regional Ecosystems Descriptions Database (REDD) (Queensland Herbarium 2023) contains the attributes used to describe and classify regional ecosystems. 34 attributes are either expertly or numerically populated for each RE including: floristics and structure, Biodiversity status and notes, distribution and condition, soils and geology, special values and protected areas and fire management guidelines. For wetland REs an additional 17 attributes mostly relating to terrain and hydrology are assigned and populated.

The Vegetation Management Regional Ecosystems Descriptions Database (VM REDD) (DoR, 2023) contains a subset of the attributes contained within REDD (Queensland Herbarium 2023) and replaces the Vegetation Management Regulation 2012. The VM REDD is a statutory instrument under section 22 of the Vegetation Management Act 1999 and provides the vegetation management classes (endangered, of concern, least concern) and other regional ecosystem information for use under the vegetation management framework. It's important that VM REDD is used for identifying regional ecosystem information under the vegetation management framework and its related regulations, policies and codes.



Eucalyptus microtheca fringing woodlands (RE 2.3.17a) transitioning into mitchell grass plains near Julia Creek following good summer rain (Dan Hede, Queensland Herbarium & Biodiversity Science, Queensland Government)

4. Field survey and collection of site data

Different types of sites are used in survey and mapping to validate and ground truth the mapping and to give detailed descriptions of the regional ecosystems. Survey sites are a small area of limited size and shape around an accurately located point. The information collected at the site is representative of a larger area, generally a particular and explicitly specified, regional ecosystem, vegetation community or photo-pattern.

Draft maps produced from photographic interpretation are modified, updated and finalised on the basis of site and other information collected in the field. Site data are used to derive comprehensive reference descriptions of the vegetation association or regional ecosystems. These technical descriptions include the mean and range of variation for structural and floristic attributes occurring in the particular unit. Finalised technical descriptions are available on the Queensland Government (e.g. Addicott and Newton 2012). The resulting site database provides a comprehensive record of areas ground-truthed during the mapping process and a basis for future updating of mapping or other relevant work such as species modelling.

4.1 Types of sites used in survey and mapping

Four types of sites are recognised, primary, secondary, tertiary and quaternary, in order of decreasing level of detail of the data collected. In addition, informal notes made and species collected are used to ground-truth maps. Site data collected during other studies using different methods may also be incorporated into QBEIS and used for ground-truthing and description purposes. The data collected and main purposes of each category of sites are briefly discussed. More detailed methods and a proforma are provided in Appendix 2.

4.1.1 Primary

Primary sites are permanently marked plots where the individual tree and shrub species are marked and tagged or permanently located (location of each individual gridded) so that the growth of individual plants can be monitored over time. These sites are may be larger in extent than standard QBEIS sites. Examples include the Transect Recording and Processing System (TRAPS) sites of the former Queensland Department of Primary Industries, the Detailed Yield Plots (DYP) of the former Department of Natural Resources, Mines and Energy, and Herbarium monitoring sites (Neldner et al. 2005, Ngugi et al. 2014, Accad et al. 2016, Neldner and Butler 2021). Initial sampling of these sites may take a number of hours, with a large number of measurements, such as location within plot, height, cover and diameter breast height, made on individual plants.

Primary sites will generally include the collection of all secondary site attributes with additional data depending on the aims of the specific project.

4.1.1 Secondary

Secondary sites are used for classification and detailed descriptions of regional ecosystems and vegetation communities.

Data collected include all location, environmental and overall structural information as well as a list of all species present and basal area (of woody stems using the Bitterlich stick method), percentage cover and stem density measures of abundance.

Secondary sites generally take between 40 and 60 minutes to complete, depending on the familiarity of the recorders with the flora, the complexity of the vegetation, the site terrain and the condition of the vegetation—in particular the ground layer. If large plant collections are required to verify plant identifications, this can substantially add to the time required at each site.

4.1.2 Tertiary

Tertiary sites may be collected instead of secondary sites where seasonal conditions such as drought make a full assessment of species impractical or where third parties (who may not have the skills to compile a complete floristic inventory of non-woody vegetation) collect the data.

Data collected include all location, environmental and overall structural information (mean height and cover of each layer) as well as a comprehensive list of woody species, individual woody species cover by layer and basal area measure of abundance (of woody stems using the Bitterlich stick method). Generally only the dominant or conspicuous species in the ground layer are recorded.

Tertiary sites normally take from 15 to 30 minutes to collect, although in some deciduous communities the identification of some species may be problematic if they are leafless. As woody species are present regardless of season, the woody species information from tertiary sites can be used for quantitative analysis and descriptions of vegetation.

4.1.3 Quaternary

Quaternary site data are used primarily as a record of field traverses and to verify regional ecosystem/vegetation mapping. These sites are generally collected throughout the field survey and entered on spread sheets or databases. Quaternary sites may be collected at regular intervals along a traverse, and/or made where REs/vegetation communities change.

Quaternary sites are recorded via a proforma, on topographic maps, aerial photographs, satellite images, notebooks, data app and/or tape recorder. Tape recorders are useful on rough roads where it is difficult to write notes, and have been used to record observations during low-level helicopter flights (Neldner and Clarkson 1995).

These sites normally take less than one minute and are often collected without stopping the vehicle. The reliability and comprehensiveness of the information collected is therefore reduced. While attributes collected vary according to region and individual preference, there are some mandatory fields and the sites are collated into a standardised quaternary site database as shown in Table 8.

4.1.4 Other

Other sites are also included on QBEIS where these have been collected for other uses. The minimum amount of information is:

- coordinates in a known projection
- date
- collector
- project name
- species
- level of detail (comprehensive, incomplete woody only).

In addition, the basal area, cover and stem density for each species present (that is, not by strata) and any other information compatible with QBEIS may also be included.

Table 8 Summary of quaternary site attributes

Attribute	Comments
Mandatory fields	
Date	Date on which data were collected
Collector	Name of person or persons making observations
x-coordinate	x-coordinate (GDA94, GDA2020)
y-coordinate	y-coordinate (GDA94, GDA 2020)
IDNT	Site identifier, generally from GPS or whatever is meaningful to the collector (e.g. Project site number)
File name	The name of the file supplied, preferably meaningful to the supplier, e.g. Rock250.xls (or dbf)
Species present	Full names of species present, separated by commas The data can be collected in codes but must be converted before supply. It is preferred that notes are recorded in a separate field (see below) although species names can be extracted as a separate list (if full names are used and they are correctly spelt). Species that are absent or from nearby areas (e.g. on hills in distance) should be recorded in notes field).
Non-mandatory fields; kept as separate fields on database	
Remnant vegetation cover	Codes e.g. r = remnant, rg = regrowth
RE map unit	Regional ecosystem code of map unit code
Notes	These will include other information relevant to mapping such as notes, comments on absent species or any other fields (geology, landform, land zone, draft map unit, trip identifier). This information is concatenated from fields separated by '//' and preceded by '‹field name› –'
Other fields, concatenated into a second notes field. Examples include:	
Structural code	e.g. OF, OW.
EDL Height	Estimate of the mean height of the dominant layer in metres
EDL cover	Estimate of the cover of the dominant layer in %
Land zone	3, 5, etc. or notes on geology and landform
Context	Description of extent
Vm_job_no	Map modification identifier

4.2 Opportunistic collections and records

Plant specimen collections

Specimens (preferably fertile) of plants to be incorporated into the Herbarium include:

- all threatened or near-threatened species
- new records of any species for the 1:100 000 (or 1:250 000 for western areas) sheet.

Data collected at these sites need to be adequate for vouchering specimens to be incorporated into the Herbarium.

Informal observations

In addition to the detailed survey plots, numerous ground-truthing data are collected while traversing roads and tracks. These data are used to confirm the remnant vegetation and regional ecosystem mapping and to check hypotheses about the relationship between classificatory units (vegetation associations, regional ecosystems, photo-patterns) and landscape features.

The actual time taken to complete each site type will vary according to the number of species and complexity of the structure at a site, accessibility, ecologist, terrain, weather conditions, etc.

4.3 Site size

The Queensland Herbarium has adopted a 10 x 50 m^2 plot as the standard for secondary and tertiary sites. This plot size is widely accepted internationally and is often used in surveys in Australia (Austin 1978; Benson 1981). It is time-efficient as it requires only a single 50 m tape to be placed along the centre line. Individual woody plants within 5 m of either side of the tape are generally apparent and easily measured. Rectangular plots are usually more efficient than square or circular shapes (Greig-Smith 1964) because of the general tendency of clumping in vegetation. Bormann (1953) also recommends that rectangular plots be used in phytosociological sampling and that the long axis be located across any observed contour. For Herbarium surveys, the plots are generally located near the centre of a photo-pattern and along any observed contour, so as to typify the pattern. The actual plot size should be modified so that the plot remains within the vegetation community/RE, for example riparian vegetation such as *Eucalyptus camaldulensis* woodland fringing a drainage channel, a narrower plot of 5 x 100 m^2 is more appropriate. It is important that the total plot size is always recorded. For Queensland vegetation apart from rainforests, a comprehensively surveyed 500 m^2 plot captures the majority of the vascular plant diversity at a site (Neldner 1993; Neldner and Butler 2008).

A BioCondition reference site, one that is a relatively undisturbed and structurally intact example of that ecosystem, generally requires a larger plot size. A full description of the method for collecting this data and the reference site datasheets are provided by (Eyre et al. 2017).

4.4 Site location

In general survey data should cover the full range of environmental space and be sampled proportionally (Margules and Stein, 1989) or biased to less common types (Austin and Heyligers, 1989), with replicates covering the geographic range of the biota studied (Nicholls, 1989). For surveys conducted by the Queensland Herbarium, sites are selected to ensure that all vegetation and regional ecosystems are adequately sampled across their geographic range. Allocation of sites should be generally proportional to the area of each vegetation type, except for rare vegetation types, which are often oversampled relative to area (Neldner et al. 1995). The sites and traverses are distributed in such a way as to sample as much as possible the environmental variability across the landscape, given the time and accessibility constraints. While sites are located to describe 'representative' or 'best on offer' examples of each vegetation/photo-pattern type, care is taken to sample the full range of variation within a vegetation association or regional ecosystem in remnant condition. However ecotone areas are generally to be avoided as the purpose of representative sites is to document the 'typical' or 'central' expression of the vegetation community/RE.

Although approximate site locations are generally predetermined from the office, it is sometimes necessary to relocate sites in the field because of accessibility problems or disturbance. Sites are relocated when the stand area is less than one hectare in area or there is excessive disturbance associated with edges of roads, tracks, quarries, fence lines or other cleared areas or they occur in atypical vegetation in ecotonal areas or at the boundaries of polygons. This is especially desirable to minimise possible bias in the basal area sweep. Additional sites may be established where variation not accounted for in the preliminary stratification is observed in the field.

The preferred method for site selection is essentially a relaxed grid survey (Reid 1988) with stratification similar to that discussed in Vegetation Survey and Mapping of Upper North East New South Wales (NPWS 1995), and field sites located subjectively. This approach evolved from the method documented by Neldner (1993).

The following steps are used to develop a preliminary stratification for mapping at 1:100 000

- preparation of a geology overlay at 1:100 000 scale from the best available geology mapping
- preliminary stratification on an overlay using the geology map and patterns on the LANDSAT image and black-and-white 1:83 000 aerial photographs. The main aim at this stage of the method is to identify land zones. Land zone recognition is essential for defining regional ecosystems (REs). The preliminary strata include cleared land and major photo-patterns which correspond to the geology
- flagging of the major vegetation and regional ecosystems with the aid of the photo-patterns delineated in conjunction with forestry, geology, topographic and rainfall maps, and existing data from reports, maps or other sources
- selection of potential sites that appear relatively undisturbed, and typical of a photopattern/satellite signature that avoid mapping boundaries and ecotones. Selected sites may be stored as waypoints in a GPS or laptop to facilitate their location in the field. Once located in the field a further assessment of their condition is made before commencing site sampling.

4.5 Site density

The total number of sites (secondary, tertiary and quaternary) required to adequately sample an area depends on the variability in the vegetation and the condition of the ground layer as well as mapping scale, the amount of remnant vegetation present and the number of existing sites in adjoining regions.

The minimum recommended ground observation density for soil surveys is a useful framework for planning and appraising vegetation surveys. Under these soil guidelines the minimum density for sampling a standard (e.g. 1:50 000, 1:100 000 etc.) map sheet at the specified scale is about 625 sites However, sampling densities do not need to be as high for vegetation surveys. This is because vast amounts of mapping data can be rapidly gathered as informal observation and quaternary sites while traversing (on foot, by vehicle or aircraft), as opposed to soil surveys, which require subsurface sampling (Neldner 1993). For example, Neldner et al. (1995) used a minimum sampling index of half those listed in FAO (1979).

Offsetting the need for fewer sites for vegetation compared to soils is the fact that the minimum size of areas delineated by the Herbarium (Table 4) is smaller than the minimum size on which the soil sampling densities are based (Table 5). Therefore, the minimum density of sites listed in Table 9 is adopted by the Queensland Herbarium as the minimum standard that the Herbarium aims to collect to ground truth each map sheet.

Table 9 Recommended minimum ground observation density for land surveys at various scales

Scale of map	ha cm² of map	cm² of map km² on ground	Observation* density per 100ha (km²)
1:5 000	0.25	400	100
1:10 000	1.00	100	25
1:20 000	4	25	6.25
1:25 000	6.25	16	4
1:50 000	25	4	1.0
1:100 000	100	1	0.25
1:150 000	225	0.44	0.11
1:250 000	625	0.16	0.04
1:500 000	2500	0.04	0.01
1:1 000 000	10 000	0.01	0.003

Observation density km² figures from Gunn (1988, Table 6.2) and based on 0.25 observations cm² of published map.

Site type

The total number of sites will be a mixture of detailed (secondary/ tertiary) sites for unit description and less detailed (quaternary) sites for ground truthing mapping. Generally of the 625 sites required for a full 1:100 000 sheet, 50–100 will be secondary sites and the remainder quaternary sites, as well as additional unrecorded observations made between sites. In practice the number and mix of types could be greater or lower, depending on the complexity of the vegetation, the amount of remnant vegetation present and the amount of existing data in similar vegetation in adjoining areas. A minimum of three secondary sites per vegetation community/ regional ecosystem type is desirable. An informal indication of adequate sampling of a vegetation community/ regional ecosystem can be determined when additional sites do not add substantial numbers of additional species or structural variation from that already sampled.

Deciduous vine thicket (RE 9.11.9) on a large quartz outcrop amongst rolling metamorphic hills with *Eucalyptus crebra* woodland (RE 9.11.16), west of Forsayth, Einasleigh Uplands bioregion (M.R. Newton, Queensland Herbarium & Biodiversity Science, Queensland Government)

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Appendix 1. Preferred survey and mapping process

The preferred survey and mapping method recommended by the Queensland Herbarium includes the following tasks:

- Project scoping and planning
- Gathering existing data
- Reconnaissance phase
- Mapping
- Field work
- Finalising mapping
- Final checking
- Generating map unit descriptions
- Final report production

A1.1 Project scoping and planning

The initial stage is critical in the planning of a successful regional ecosystems or vegetation survey and mapping project. Important decisions have to be made regarding:

- definition of the study area—boundaries of the survey area, for example 1:100 000 map sheet
- the scale of mapping—1:100 000 for regional studies, 1:25 000 for coastal areas
- the nature of the vegetation to be mapped—condition states to be defined, e.g. remnant/non-remnant
- budgets
- personnel
- equipment needs
- timelines
- milestones
- outputs
- work plan.

The work plan will include a search of a wide range of existing data types including:

- existing mapping
- consulting with regional officers;
- finding out whether there are any existing mapping projects, such as soil, geology;
- types of data:
  - geological mapping
  - regolith mapping
  - vegetation mapping
  - regional ecosystem mapping
  - land system mapping
  - soils mapping
- site data from any of these projects
- quality control
- age of data, such as currency of plant nomenclature
- consideration of who did the work, rectification, accuracy of satellite image and positional accuracy.

A1.2 Gathering existing data

Existing data may include maps and other relevant information about vegetation and other landscape attributes, including reports, sites and spatial coverages of relevant land resource themes, such as vegetation, regional ecosystems, geology, soils, regolith, aerial photographs and satellite imagery.

A1.3 Reconnaissance phase

Usually a short reconnaissance field trip is undertaken to gain an understanding of landscape relationships and flora.

The field reconnaissance survey is designed to cover the full range of vegetation and habitats present across the map sheet via the most expedient route. Work on this trip generally includes:

- collecting specimens to familiarise botanists with flora
- consulting experts in particular taxonomic groups
- making notes on field characters
- making a field herbarium
- developing hypotheses on landscape–vegetation relationships
- drawing preliminary profile diagram;
- consulting aerial photographs and Landsat images in the field
- collecting some quaternary sites.

A1.4 Mapping

After the reconnaissance phase, a draft pre-clearing map should be produced.

This is done primarily through interpretation of aerial photographs, while referring to geology, land system, vegetation and soils data and Landsat imagery. In general, consideration should be given to issues including:

- aerial photographic interpretation alongside any existing mapping—that is, edgematch at the start of the mapping sheet
- reference to existing quaternary or other data sites
- starting with distinctive boundaries first—that is, riparian systems, closed forest
- separating as much detail as possible at the specified mapping scale. Remember, it is easier to combine units later than to split them
- making notes on each photo-pattern, ‘type pattern’ on a particular photo, landform position, geology, texture and unique number.

The draft map may only be attributed with photo-patterns, although where an area is already well known it may be possible to attribute directly with draft regional ecosystem and vegetation codes.

In areas that have been extensively cleared, a draft remnant vegetation cover map should also be produced at this stage to allow subsequent ground truthing. This mapping is based on screen digitising of Landsat imagery with reference to current and historical aerial photography. Issues to be considered include:

- the need to define categories (intact, disturbed, partially cleared, regrowth etc.)
- specification of minimum polygon size
- GIS-derived coverage, such as SLATS.

This phase results in the production of a preliminary pre-clearing map and a remnant vegetation cover map, which is then ground truthed.

A1.5 Field work

Field work is carried out to ground truth preliminary maps and to gather site and observational data to define and describe mapping units.

Field work is planned to cover the environmental variation across the study area by encompassing the geographical range of the map sheet as well as the range of vegetation photo-patterns, geology and landforms delineated in the preliminary maps produced above.

Ground truthing of preliminary maps includes collecting site data and proposing and testing hypotheses for plant distributions, for example, making profile diagrams and photographing vegetation communities, species and landscapes. Sample sites are often pre-selected in the office on the basis of their representativeness of a photo-pattern, and put into the GPS as waypoints to be located in the field. Alternative sites are sometimes required because of poor access or condition, and additional sites are often sampled. Permission to enter private land should be gained by letter, email or phone call before entry. Public land managers should also be contacted prior the field trip.

A1.6 Data entry and analysis

Plant specimens are determined using the Herbarium flora keys and reference specimens. The finalized data is entered into QBEIS and thoroughly checked. The data for an area can then be extracted and a numerical classification applied. The results of the classification assists in assigning QBEIS sites to regional ecosystems and vegetation communities.

A1.7 Finalising mapping

Maps are modified and updated on the basis of information collected in the field. Once checking has been completed and the resulting amendments have been finalised, the digital coverages are finalised by the botanist and then made available to clients.

Finalisation of mapping includes the production of:

- a final legend;
- final map coverage attributes including regional ecosystems, vegetation and reliability codes and proportions; and
- final metadata.

At this stage, a remnant regional ecosystem vegetation community coverage will also be produced. This is derived by intersecting the pre-clearing and remnant vegetation cover and then reinterpreting proportions to allow for differential clearing of mosaics (Fensham et al. 1998).

Finalisation of the legend includes standardisation with other map sheets and bioregional regional ecosystem and veg codes to match descriptions, codes, legends and polygons at map edges.

A1.8 Final checking

Final checking includes checking of map and site data. Automated GIS checks and plots are run to check with other mapping in the bioregion for missing legend units, discrepancies between pre-clearing and remnant vegetation and edgematching.

This will include the manual viewing of each individual unit with on-screen GIS and/or hard-copy maps and peer review by the bioregional coordinator or regional staff/stakeholders.

Attributes of regional ecosystem and vegetation maps, current and pre-clearing, that require verification and standardisation include legends, edgematching of polygons and labels, vegetation type, definitions and reliability codes for each map unit.

All of the products have quality control which includes standardisation through field training programs, spot checking of satellite image interpretation, and spot checking of polygon labels in the field.

A1.9 Generating map unit descriptions

Regional ecosystem and vegetation descriptions are generated for each map tile and incorporated into updates of regional ecosystem descriptions for the bioregion. Potential new regional ecosystems are discussed with the relevant bioregional coordinator and reviewed by the bioregional technical committee. Descriptions of regional ecosystems or vegetation communities are derived from the representative site data relating to that regional ecosystem.

A1.10 Report production

Final reports are generally done for a whole bioregion once mapping has been completed and reviewed. Report compilation includes:

- checking and updating the database to facilitate automated floristic components of descriptions
- GIS analyses—areas, individual maps, intersects with geology etc.
- checking floristics and adding structural description and ecological notes
- using field transect diagrams in conjunction with maps to product final transect diagrams
- data analysis
- writing
- editing
- peer review/refereeing
- approval.

Appendix 2. QBEIS site data collection method

QBEIS is the vegetation community site database that is used to store and report on regional ecosystems. This appendix lists the attributes of secondary and tertiary QBEIS site types, and instructions on filling in forms. It includes QBEIS lookup tables and the proforma which is provided at the end of this Appendix. This supersedes the previous QBEIS manual (McDonald and Dillewaard 1993).

A2.1 Recommended requirements

Equipment includes Global Positioning System (GPS), camera, metal site tag, wire for attaching tag, 50 m tape, 5 m builders tape, compass, clinometer and/or hypsometer, Bitterlich stick or gauge, DBH tape or calipers, specimen collecting bag, tags, three x 1 m lengths of PVC pipe with two elbows for quadrat, clipboard, proforma, pencils and eraser.

Site layout

A central tape should be laid out for 50 m with the boundaries of the plot being easily estimated or paced out 5 m either side of the tape. Marking the boundaries of the site using flagging tape is good practice. The long axis of the site is located at right angles to the environmental gradient (parallel to the contour). A longer length may be used to estimate canopy cover of the tree layer where density is low or variable. It is imperative that site remains within the vegetation community to be sampled. The compass bearing from the origin of the plot must be recorded.

A2.2 Environmental data

General information

Project

The text field identifying the project will generally be in the form ‘three letter bioregion code_ Map sheet’, for example ‘BBS_Dalby’, although any meaningful unique identifier, such as CYP_Trip1, is valid.

This may be a project reference for external sites, e.g. Fensham (1999).

Bioregion

The bioregion that the site is allocated to. Note in the case of outliers this may not match the state wide bioregion map.

Site visit name

The site number is alphanumeric, assigned by project. Where sites are re-visited (monitored) the first visit is assigned Site visit name_1, the second Site visit name_2, the third Site Visit name_3, etc

Site visit Id

The Site visit Id is a unique identifier assigned by QBEIS on data entry.

Date

The date shows day, month, year.

Recorders

The names of recorders are entered.

Sample level

The sample level is calculated by the QBEIS database based on the attributes recorded as either secondary, or tertiary, or quaternary/other:

- D Secondary site—full floristics, structural and abundance information
- R Tertiary site—primarily focused on the woody layers
- Q Quaternary site (observational level—ground truthing of mapping).

Detail of species list (or sample floristics)

Level of completeness of species information recorded as:

- A complete list of all species present within the site (default for Secondary)
- B list of all woody species present within the site (trees, shrubs, climbers) (default for Tertiary)
- C woody species plus perennial herbs (trees, shrubs, climbers plus perennial herbs)
- D dominant characteristic species only/incomplete record of species presented. This is not filled out for secondary or tertiary sites but is used when site data from other projects are incorporated into QBEIS (default for Quaternary)
- E other (project-specific, such as weed survey).

[3]Abundance measures recorded

One or more of the three abundance measures by species by strata may be recorded depending on the sampling level.

Table 10 QBEIS sites minimum abundance measures

Secondary site	Basal area by species by strata	Cover by species by strata	Stem count by woody species by strata	Ground layer cover by species
Tertiary site	Basal area by species by strata	Cover by species by strata		Ground layer cover by species

Tertiary: basal area and cover by species by strata.
Secondary: basal area, cover and stem count by species by strata.

[3]Transect length and width

The dimensions of plot are specified.

Location information

Position

Show how position was derived from the following values:

- A GPS
- B topographic map
- C other.

The position is recorded at the start (origin) of the plot, generally as an easting and northern with a GDA2020 datum (although other values and datums can be converted before entering). It is recommended to record the end and centre point location.

Datum

Default is GDA2020. Datum can be entered in either GDA94 or GDA2020, QBEIS will transform GDA94 to GDA2020 automatically and store both datums. Information in other datum's is converted before entering into QBEIS.

Coordinate

Zone, easting and northing or latitude and longitude in GDA94 and GDA2020 coordinate system can be entered into QBEIS. Decimal degrees are also stored in QBEIS. There is space on the QBEIS proforma for degrees, minutes and seconds, although these will have to be converted to decimal degrees or easting and northing before data entry.

Precision

In (±) metres. This is the radius within which the true location lies. The value from the GPS reading should be entered. If not, it is assumed that a GPS position will equate to a precision of (±) 10 metres. If topographic maps are used then a precision corresponding to the scale and detail should be entered.

Note for many (Garmin) GPS units used by the Queensland Herbarium, the accuracy value is the radius that the true location is within 50% of the time. These values should be multiplied by 2.5 to give the radius that the true location is within 99% of the time.

Tag spp.

In wooded communities, a metal tag (e.g. Queensland Herbarium monitoring site tag) can be attached via a loose loop of wire to a tree or large shrub at or near the origin of the plot (e.g. tag attached to *Eucalyptus microcorys* tree at 5.6 metres along the tape and 1.2 m to the left). Note the species that has been tagged on the proforma, as the tags will assist in re-locating these sites accurately in future comparative studies. For grasslands a metal tag can be buried at the plot end points so that it can be located with a metal detector in the future.

Figure 5 Queensland Herbarium monitoring site tag

Bearing

It is important that the compass bearing of the plot from the origin be recorded.

Locality

Brief description of the location using distance from point features such as mountain peak, town, homestead, national park etc., for example, 46 km south west of Calliope in Kroombit Tops SF 316.

Site context

Community description

A description of the community represented by the site in terms of the predominant species and structure and if appropriate, associated environment (such as landform geology): for example, *Eucalyptus crebra* with occasional *Corymbia erythrophloia* open woodland and grassy ground layer on low hills derived from basalt.

Structural formation

The relevant structural formation class from Table 28 that applies to the Ecologically Dominant Layer (EDL). Usually assigned based on the line intercept cover and strata height measurements.

General notes

Miscellaneous comments regarding the site

The community area and width are estimates of the extent of the vegetation community in the immediate area that the site represents (derived from observation travelling to and from the site and/or imagery at the time of sampling).

Community width

For linear communities the width of the community around the site is estimated in the categories from Table 11. This is recorded in the field named 'community extent' on QBEIS.

Table 11 QBEIS community extent codes

Code	Extent
A	<35 m wide
B	35–75 m
C	75–150 m
D	150–300 m
E	>300 m
F	Not linear

Community area

For all communities from the codes in Table 12.

Table 12 QBEIS community area codes

Code	Area
A	Does not extend beyond the site
B	<1 ha
C	1–5 ha
D	5–20 ha
E	20–50 ha
F	>50 ha

Mapped or not

Recorded as 'yes' or 'no' or left blank.

This field indicates whether the site corresponds to the attributes on the regional ecosystem mapping (Yes). Very small communities beyond the scale of mapping may not be attributed (No). This attribute may often be assigned after mapping is complete and is maintained by the bioregional coordinator.

Regional ecosystem

The regional ecosystem that the site is classified as.

Representative site
(this is generally completed back in the office)

- Y Yes, the site has been checked, it is representative of the allocated remnant regional ecosystem.
- N No, the site has been checked but it is not representative of the allocated regional ecosystem (generally this will be because of excessive disturbance, or it is regrowth (non-remnant)).

Landform

Relief class

Ther reief classes defined by Speight (2009). Refer to Table 28.

Pattern

A three-letter code taken from Speight (2009), such as floodplain, hill etc., and listed in Table 25 at the end of this appendix. Landform pattern can be derived from erosional pattern with the aid of tables 6 and 7 in Walker and Hopkins (1990). Landform (and erosional) patterns are in the order of 600 metres wide (Speight 2009).

Erosional pattern

Two-letter code taken from Speight (2009, table 5) and listed in Table 24.

Erosional pattern is a combination of local relief (hill, plain) and slope class (flat, undulating, steep). The slope class may not be the same as the slope recorded for the site (for example, a site situated on a hill crest landform element of a steep mountain landform pattern).

Landform element

The three-letter code taken from Speight (2009), such as cliff, crest, bank etc. and listed in Table 26 at the end of this appendix. Landform elements are in the order of 40 metres wide (Speight 2009).

Slope

The slope and aspect are taken at the centre of the site using a compass and clinometer.

Type

Morphological type is broadly classified into types from Speight (2009) from the codes in Table 13.

Table 13 QBEIS landform morphological type codes

Code	Slope type
C	Crest
R	Ridge
H	Hillock
S	Simple slope
U	Upper slope
M	Mid slope
L	Lower slope
F	Flat
V	Open depression
D	Closed depression

Source: Speight (2009)

Slope (º)

Degrees, measured by clinometer to the nearest degree. While percentage is more precise, measurement to the nearest degree can unequivocally be converted to relief classes in Speight (2009, Table 2) using Table 24 at the end of this appendix.

If the slope is recorded as a percentage, this is converted to degrees before entry.

Aspect (º)

Degrees, measured by compass. North can be 0º or 360º. No aspect (that is when slope is zero) is left blank.

Altitude

This is given in metres and derived from best available information (from a topographic map or GPS).

Site sketch/notes

Sketch comments showing structure and/or location of site in relation to surrounding vegetation, landforms, etc. This information is not entered onto the database.

Soils

Source

Recorded as one of the following values; map, cutting, soil core or surface observation.

Reliability

The default value is L (low) but can be one of the following:

- H high—by a pedologist (or specialist)
- M medium—experienced non-pedologist or obvious

Broad soil types

Broad soil types derived from the QBEIS soil type and geological codes the categories in the tables aim to provide options for non-experts to recognise a broad category of soil and geology, while an expert soil scientist or geologist will be able to classify the soil or geology to a more precise level. QBEIS allows the entry of the soil or geological code provided on soil/ geological coverages and these should be added to the database. The nomenclature of the Australian Soil Classification (Isbell et al. 2016) has been applied to the soil codes used in Table 20. This classification should be used for all newly collected soils site data.

[1]Additional information

Default values is 'no'. Can be filled in with 'yes' if a detailed soil site is done at same location (which is described in the notes field)

Top soil colour

Broad surface soil colour classes from Table 19.

Top soil texture

Broad soil surface texture from Table 19.

Isbell code/ map unit

Isbell (2002) soil code. This will generally only be entered when the site is established in conjunction with a soil site (and reliability is marked 'High').

Some older sites have been coded with the Principle Profile Form, or PPF (from Northcote 1979).

Depth

The depth of soil in metres before rock is encountered. Generally measured from a soil core or nearby cutting.

[4]Additional information

Ad hoc notes/description of soils or other relevant features.

Soil pH and Munsell colour code were fields on previous versions of QBEIS. These are no longer collected but may be entered in the notes section.

Geology

Source

Recorded as map, cutting, core or outcrop (or any surface) observation

Reliability

The default value is L (low):

- H high—by a pedologist (or specialist)
- M medium—experienced non-pedologist
- L low—person with no experience in geology

Map unit

The geological map unit taken from the relevant geology map (such as Qa etc.). This code may differ from what is on the geology map if the latter is obviously wrong; for example, if the geology map shows sandstone when is obviously alluvium, then Qa is entered. In this case the source is listed as outcrop (surface observation).

Lithology

The type of bedrock prevalent.

[4]Notes

Ad hoc notes: for example, ‘rock outcrop or other features such as land zone’; or ‘no evidence of rock outcrop dead flat looks like Cainozoic clays plain; land zone 4’.

Disturbance

The disturbance data are designed to record whether the site may be unrepresentative because they have been subject to abnormal disturbance. Therefore, generally sites will only be located in a disturbed area where no undisturbed sites could be located. Disturbance abundance estimates are made for the proportion of the disturbance occurring within the 10 m – 50 m quadrat into the classes listed in Table 14. The observation type, most frequently visual should be recorded for each disturbance assessed. Fields are left blank where disturbances are absent.

Table 14 QBEIS proportion, age of disturbance and height of disturbance codes

Proportion of site affected by disturbance category (%)		Time since event (years)		Height impacted (m)	
0	0	1	<1 year	0	≤1
1	<1	2	1 to 3 years	1	>1 to ≤3
2	1–5	3	>3 to 5 years	2	>3 to ≤6
3	>5	4	>5 to 10 years	3	>6 to ≤12
		5	>10 years	4	>12

Grazing

Grazing by domestic stock, feral animals and native animals evident in damage to the ground layer plants and/or presence of animal faeces or tracks is recorded as:

- Severity – N = None; MI = Minor; MO = Moderate; S = Severe
- Time since event (scale 1–5).

Erosion

An estimate of the area as a proportion (Table 14) and type and severity of accelerated erosion (Table 16: as compared to natural erosion as discussed by McDonald, Isbell and Speight, 2009) is recorded.

Table 15 QBEIS erosion type and severity codes

Code	Type and severity	
N	sheet	N = None; MI = Minor; MO = Moderate; S = Severe
S	rill	N = None; MI = Minor; MO = Moderate; S = Severe
R	gully	N = None; MI = Minor; MO = Moderate; S = Severe
T	tunnel	N = None; MI = Minor; MO = Moderate; S = Severe
B	stream bank	N = None; MI = Minor; MO = Moderate; S = Severe
M	mass movement	N = None; MI = Minor; MO = Moderate; S = Severe
W	wind	N = None; MI = Minor; MO = Moderate; S = Severe
C	scald	N = None; MI = Minor; MO = Moderate; S = Severe
Y	wave	N = None; MI = Minor; MO = Moderate; S = Severe

In addition for gully erosion the average depth of the gullies are recorded using the scale
0 = <0.3m; 1 = ≥0.3–1.5 m; 2 = ≥1.5–3.0 m; 3 >3 m

Weeds

The percentage cover of exotic species at the site is recorded. In the case of secondary sites this figure is derived by adding the cover of weed species from the comprehensive species list (the cover values are added ignoring any overlap between strata). This then guides the severity rating scale from N = none to S = severe.

Fire

Record the proportion of the site burnt, age (from above) and tallest vegetation impacted by fire Table 16. If the type of fire is known, it is recorded as wildfire (FW) or prescribed burn (FP).If the type of fire is unknown it is recorded as FU.

Table 16 QBEIS fire height codes

Code	Height (m)
1	<1
2	1–6
3	6–12
4	>12

Storm damage

This is identifiable by the presence of broken branches in the crowns. Estimate the proportion of crown cover damaged on the site and the age of the damage using Table 14.

Logging

Record the severity and age and the number of stumps at the site.

Flooding

Record the severity and age.

Roadworks

Record old snig tracks and other tracks; record proportion and age of the site affected using Table 14.

Feral animal digging

These are recorded as the proportion of the site impacted.

Treatment

Includes ringbarking, poisoning, thinning. Record the severity and age and the number of stems impacted at the site.

Clearing

Record if the site has been previously cleared/thinned and regrown. Recorded as severity and age.

Salinity

Record the proportion of the site affected by severe anthropogenic-caused salinity.

[2]Other

Notes on other disturbances may also be recorded in the general notes field for the site.

A2.3 Species data

All species and basal area, percentage cover and stem density measures of abundance are recorded for secondary sites. All woody species ± dominant non-woody species and cover and basal area measure of abundance for woody species are recorded for tertiary sites. The species are recorded by walking from one end of the tape recording all species seen, and collecting and tagging any unknown species for identification later. Search 5 m either side of the tape to cover the entire 50 m x 10 m plot.

Site size (sample)

Area

In square metres. The normal dimensions for secondary and tertiary sites are 50 x 10m^2 = 500 m^2. This is the area were species lists and cover measures are estimated for.

Basal area (BA) factor

The basal area factor is the numeric value used to convert the basal area count to m^2/ha.

A Bitterlich stick (or basal area gauge) that is 0.5 m long has a basal area (BA) factor of 1 if the wedge width is 1 cm, a BA factor of 0.50 for 0.71 cm width, and a BA factor of 0.25 for 0.5 cm width.

Stem density area

In square metres. Default value is 500 m^2, although this may be varied for strata depending on the density of stems. For example, for widely spaced trees it is generally 500 m^2, but may be smaller for lower strata where there is a higher stem density of shrubs.

Structural summary

The height, cover and dominant species are recorded for each layer or stratum.

Mean canopy height

The mean canopy height in metres is recorded for each stratum. Canopy heights may be estimated for low (‹ 10m vegetation) or where height estimates have been calibrated with measurements of vegetation with similar heights at other sites on the same field trip. Otherwise the heights of the crown of at least three trees, that are estimated to represent the mean canopy height, are measured using a hypsometer or clinometer and tape measure. This includes measuring to the point directly below the highest point of the tree canopy where top of the tree is not directly above the base of the trunk. When using a clinometer, adjustments are also made for the height of the recorder and any slope in the land surface.

[1]Height range

The range in individual heights for each stratum is recorded. There may be a continuous variation in height within a stratum.

Total cover

The percentage crown cover for each stratum. The preferred method is to record the crown cover of the predominant layer as it intercepts the tape and convert to percentage cover, as described below under measurement of cover for species. The QBEIS database allows a minimum and maximum cover to be entered for importation of other data sets that have recorded cover as a range.

[2]Key species

Up to five predominant species per stratum. However, species recorded in this section of the proforma should be recorded again in the species section on the latter pages for ease of data entry. The species are only recorded in this part of the proforma to facilitate manual sorting of plot sheets.

The strata are defined as per methods below.

Measurements in recently cleared vegetation

In compliance cases, where tree clearing has already occurred, a canopy cover cannot be determined in the field. However, it can be measured on an aerial photograph of suitable quality using the method of Fensham *et al.* (2002). Alternatively the canopy cover of an area of the same vegetation type in the vicinity of the area of interest, shown by aerial photography to have had the same clearing history, can be measured. Canopy heights can be estimated by measuring fallen trees with appropriate compensation for the loss of upper limbs and leaves.

Measurements of diameter at breast height over bark (DBHOB) of fallen trees in recently cleared areas of interest and standing canopy trees in nearby reference remnant sites can assist comparison of canopy structure. There is a direct relationship between basal area measured by DBHOB and canopy cover (e.g. Kuhnell *et al.* 1998). Therefore if the height and diameter breast height over bark of fallen trees is similar to that of standing trees in remnant areas and the vegetation had not been previously substantially altered, then it can be concluded that the vegetation was remnant when it was cleared.

Rainforest

This additional information is only collected for rainforest sites and is only present in the QBEIS rainforest proforma.

Complexity (C)

The content of this field is restricted to one of the following letters or can be left blank:

- S simple
- X simple-complex
- C complex

Leaf size (L)

Leaf size of the sun leaves of the tallest stratum (excluding emergent) trees. It is usually easy to decide which two adjacent leaf classes are most common from a visual inspection (Webb, 1978, page 356). Where this is difficult the method described by Walker and Hopkins (1990, page 81) may be used in which the leaf size of ten adjacent canopy trees is assessed. Leaf size classes are listed in Table 17.

The content of this field is restricted to one of the following numbers or can be left blank:

1. macrophyll
2. macrophyll-mesophyll
3. mesophyll
4. mesophyll-notophyll
5. notophyll
6. notophyll-microphyll
7. microphyll
8. microphyll-nanophyll
9. nanophyll

Leaf-fall characteristics

The field indicates the degree of deciduousness associated with rainforest vegetation:

- A evergreen
- C semi-evergreen
- D deciduous
- E semi-deciduous

The proportion of deciduous, semi-deciduous semi-evergreen and strictly evergreen species in the canopy that is highest is used to allocate leaf-fall classes which are defined in Webb (1978) as follows. ‘Deciduous’ means species or certain individuals of a species that obligatorily lose their leaves completely each year. ‘Semi-deciduous’ indicates that most leafless species are truly deciduous but that some are facultative, i.e. leaf fall is controlled by the severity of the dry season. ‘Semi-evergreen’ means that few or none of the species are truly deciduous and that most of those that shed their leaves do so incompletely depending on the severity of the dry season. ‘Evergreen’ means species that do not loose leaves in a seasonal pattern.

Indicator growth forms (GF)

Many of the simple forests and some of the complex and simple-complex forests develop strata that are visually dominated by particular growth forms. Four growth forms have particular environmental significance (Webb 1968) and the fifth can indicate prior catastrophic disturbance. Refer to Illustrations in Webb *et al.* (1976):

1. moss
2. fern
3. fan palm
4. feather palm
5. vine
6. no dominant indicator growth form

Table 17 QBEIS leaf size categories for rainforest trees

Leaf size category	Leaf area (mm^2)	Approx. length of lanceolate leaf (mm)	Approx. length of cordate or peltate leaf (mm)
Macrophyll	>18,225	>250	>160
Mesophyll	4500–18,255	125–250	80–160
Notophyll	2025–4500	75–125	60–80
Microphyll	225–2025	25–75	20–60
Nanophyll	25–225	<25	<20

Source: Walker and Hopkins (1990, table 20). Walker and Hopkins present a figure that has actual size templates for use in the field.

Emergent tree/shrub layers

Species by abundance data

The botanical name and abundance measure (basal area, cover and stem count) are recoded by strata.

Botanical name

Of species recorded at the site (all species or woody species only ± dominant non-woody species for tertiary site). These are entered into the database by their full name.

Dead trees

Dead trees within the site are recorded with a species name ‘dead trees’ and measures as per live trees, in the general notes field. If the species of dead trees are known they can be recorded in the BioCondition attributes form.

Abundance measures

For each species (including dead trees), the three abundance measures are recorded by strata using the methods listed in section A2.3.5.

Basal area

For each species by strata using the Bitterlich stick method described below. Basal area is recorded at breast height (1.3 m). The actual count is recorded in data base which is converted to m^2/ha using the basal area factor when used.

Cover

Cover is recorded as the percentage crown cover (using the methods outlined below) except for the ground layer which is recorded as projective foliage cover (pfc). Species are recorded as present ‘p’ if they occur in a 500 m^2 site but do not record a quantitative value from the line intercept. For secondary sites the cover of species by strata is recorded for all species, while usually only cover of dominants is recorded in a tertiary site. Dead plants are recorded as a 'pseudo-species' in the species by strata by abundance data (see A2.6) for site characterisation purposes but only live plants are used in calculation of site and strata cover.

Stem count

Collected for secondary sites only, using the method described below.

The actual count is recorded in the database and later, is converted to stems/ha using the stem density plot area.

Other species attributes

Tag

For species which have been identified from collected specimen a project-specific collection number or Herbarium AQ number for vouchered collections (if available) may be entered.

Identification type

Record whether a specimen was collected for identification as:

- 'C' if a specimen has been collected at the site, and identified later but not vouchered
- 'V' if a specimen has been vouchered, i.e. lodged in a herbarium, or
- 'F' if specimen identified in the field.

Miscellanous (MISC)

'+' for additional species found in the community but outside of the quadrat (such species may be included in basal area sweep that occur outside the site).

Notes

For species which have been identified from collected specimen a project-specific collection number or Herbarium AQ number for vouchered collections (if available) may be entered.

Other comments on species may also be entered in this text field (e.g. species identification to be verified).

A2.4 Methods for estimating abundance

A2.4.1 Cover

The Queensland Herbarium collects data on 'crown cover' as defined by Walker and Hopkins (1990) using the methods outlined below. In previous versions of CORVEG (before 1997), crown cover classes were used instead of actual values.

Vegetation communities are labelled and described using the structural formation classification in Table 28. This table includes a generalised conversion between crown cover and the foliage cover classes as defined by Walker and Hopkins (1990) equivalent to the projective foliage cover' classes used by Specht (1970). Information on crown type (Walker and Hopkins 1990) may also be collected to enable more accurate conversation of crown cover to foliage cover to verify the relationship in Table 28.

Several methods may be used to estimate crown cover of species or strata. Method 1 is the preferred method for estimating tree cover, while method 6 is the preferred method for measuring ground layer cover.

1. Crown or line-intercept method (Greig-Smith 1964). A 50 m tape is laid down and the vertical projection onto the tape of the start and finish of each crown by species is recorded. A clinometer or vertical sighting tube may be used to ensure that the crown intercepts are vertically projected. The total length of crown is divided by the total length of the tape to give an estimate of percentage crown cover. In areas with low or more variable crown cover and the mean ground cover across each 50 m length is variable, more transects over a wider area may be required.

   The total cover of all species within a strata typically equals the total cover of that strata unless there are overlapping crowns of different species, when it is then possible for the total of all species crown covers to exceed the total cover for the strata. The area of overlap of different species within a strata is only counted once when calculating the total cover of the strata.

2. Visual estimation. Such estimates may show large variation between observers where there is no calibration against standards (Sykes *et al.* 1983). Therefore this method should only be used when interspersed with more quantitative methods in similar vegetation to check and calibrate results.
3. Using a vertical densitometer (Stumpf 1993). This is an instrument that allows the presence or absence of a crown (or foliage for projective foliage cover) to be recorded at a single point vertically above the operator. Systematically sampling at an adequate number of points (such as 1000) gives an accurate measure of percentage cover (projective foliage cover) over an area.
4. Summing estimates of the area of the individual crowns. This involves vertically projecting imaginary boundaries of individual crowns onto the ground and estimating their area. The crown areas are then summed and expressed as a percentage of the quadrat. This method may be suitable for very sparse vegetation where there are few canopy crowns.
5. While not directly recording crown cover, leaf area index measures have been derived using hemispherical photos acquired near dawn and dusk (Cunningham et al. 2018). Ground based laser scanners also have the potential to provide detailed vegetation structure data.
6. Sub-sampling using a number of small quadrats. At 0–1 m, construct a 1 m x 1 m ground layer quadrat using the three PVC pipes and the tape edge as one side. Estimate the percentages of each of the species present, with single occurrences being recorded as '0.01'. Continue the species recording, walking slowly and sampling a ground layer quadrat at 10 m intervals, giving a total of five 1 mx 1 m quadrats for the site. If practical, alternate sides of the tape for location of ground layer quadrats.

The line intercept method (1) is the preferred method for tree and shrub cover estimates as it has been found to be repeatable between operators and provides an acceptable level of accuracy.

Use the line intercept proforma for recording the distance along the tape where the crown starts and then the distance where it finishes for each layer. If the crown is continuous with the same species, then the initial start and the final crown edge for that species should be recorded. Where there are overlapping crowns of different species, the start and finish of each species is recorded. Recorders may choose to evaluate layers individually involving a number of passes along the transect, or in simpler structured communities record the tree and shrub layers in one pass.

Visual estimates of ground cover have been shown to be highly correlated with ground cover estimates derived by various more objectively repeatable methods including digital image analysis and point quadrant methods (Murphy and Lodge, 2002).

A2.4.2 Basal area

Basal area is estimated by plotless sampling using the Bitterlich method described by Grosenbaugh (1952) and Loetsch *et al.* (1973).

Basal area is recorded by species and stratum using a single sweep of a Bitterlich stick or basal area prism or dendrometer with basal area factor of 1 (BAF1) from the centre of the plot. Each tree counted contributes 1 m^2/ha of basal area. A smaller basal area factor of 0.75 is used in more lightly wooded areas, such as open woodlands and semi-arid and arid areas. Species located outside the 50 x 10 m plot are included in the basal area count, as this is a plotless recording measure, but given a '+' because they occur outside the plot. Counts for all stems at 1.3m height greater than the gap or exactly the same as the gap in the Bitterlich stick at breast height are recorded by layers (E, T1, T2 etc.) and species.

The basal area data provide an independent additional measure of the relative contribution that woody species or layer make to the overall site biomass. The proportion of the basal area occupied by species in a layer or the basal area of the entire layer provides additional quantitative data for determining the predominant species or layer.

Basal area data provide a rapid measure of tree species abundance (importance) in each layer, and help paint a description of the vegetation community. They are to be applied in tertiary sites as well, and provide an abundance measure that can be analysed (numerical classification) for all secondary and tertiary sites. Basal area and height can be used to provide biomass calculations for carbon accounting.

Scope

All woody plants, that is, trees and shrubs at 1.3 m height, are included within the 360° sweep. This is a plotless technique, and even species only found outside the plot should be noted and counted in the basal area estimate. Often only trees will be captured in this way, but at some sites large-trunked plants from the shrub layer may be included, such as *Macrozamia* species, *Cyathea* species etc.

Procedure

First assign strata—that is, Canopy T1, Subcanopy T2 if present, Shrub S1 and Lower Shrub S2.

Second, select basal area factor to be used, so that between 8 and 15 counts are included in the sweep. This generally a 1 cm gap for closed forests, open forests and woodlands, and a smaller gap for more open communities. Note the basal area factor used on the QBEIS sheet.

From centre point of plot, record all stems that at breast height (1.3 m) appear larger than the gap in the Bitterlich stick or gauge, being careful to record the species and the strata in which they occur. Hence a divided tree may have two trunks counted for basal area, but only be counted as one individual in the stem density count.

In linear communities—for example, narrow riparian communities such as *Melaleuca bracteata* fringing open forests—plots are adjusted to remain within the riparian community (100 m x 5 m), so that Bitterlich sweeps do not include species from outside the riparian community. In these cases, an adjustment may be necessary to provide a reflection of the true basal area of the community: for example, in narrow communities a half sweep from the edge of the community is taken and values are doubled.

Additional species should be noted as coming from outside the plot.

A2.4.3 Stem count

Purpose

The primary purpose of doing a stem count by strata and by species is to provide another measure of species abundance (importance) in each layer, and to help paint a description of the vegetation community. Stem count measures may also have the potential to be used in biomass calculations provided they are done consistently.

Scope

All woody plants, that is, trees, shrubs and subshrubs, with no height or diameter breast height restrictions or cut-offs.

Procedure

First assign strata, that is, Canopy T1, Subcanopy T2 if present, Shrub S1 and Lower Shrub S2. Then commence count.

Stem count for tree layers: Count the number of individual trees in 50 m x 10 m plot by species and strata. A tree that branches into two or more stems above 30 cm above the ground is counted as one individual. Dead trees are counted separately and assigned to species labelled ‘dead’. For mallees, such as *Eucalyptus bakeri* and *E. normantonensis*, which have multiple stems at ground level, count the number of stems but note the number of individual plants: for example, 60 stems (8 plants). The figure of 60 will be entered into QBEIS.

Stem count for shrub layers: Count the number of individual plants in a 50 m x 2 m plot (if dense shrubs) or 50 m x 10 m plot (where relatively sparse). It is important to record the actual area counted for each layer. Shrubs by definition are multi-stemmed from near the ground, but count the number of individual plants. Individual plants may be problematic at times, but generally individuals (closely clumped stems) can be recognised. Single stemmed woody forbs, such as *Indigofera* spp. and *Gomphocarpus physocarpus*, may also be included in these layers. Juvenile trees are included in the shrub layer once they meet the height requirements for that stratum.

Seedlings of trees and shrubs included in the ground layer are not included in stem counts.

A pragmatic approach is required to measure stem density, particularly for shrubs. A lack of accuracy at one site can be compensated for by a larger number of sites through the vegetation community. Shrub density often fluctuates greatly between sites according to management regime/condition, so a large number of reasonably accurate 'ballpark' figures is justifiable.

The exception to this general rule is where monitoring of change at a site is occurring and it may be justifiable to count individual stems, as this is less subjective where recorded by multiple recorders over time.

A2.4.4 Height measurement

The height of woody vegetation is measured from the ground to the tallest live part, i.e. uppermost leaves. The height of grasses is measured from the ground to the tallest foliage. Frequently tall grasses such as *Sarga* spp. or *Heteropogon triticeus* have inflorescences that may extend to two metres in height, but generally the tallest foliage only reaches 80 to 100 cms.

Canopy height taller than 5 m is generally measured using a clinometer or hypsometer.

To expedite data collection at tertiary sites, tree height is estimated visually. Bonner (1974) reported the satisfactory use of visual estimation for forest inventory, although regular checks of height estimates using either the clinometer or hypsometer are essential.

A2.5 Stratifying vegetation layers at a site

2.5.1 Purpose

The primary purpose of stratifying vegetation is to form a consistent basis for the classification of the vegetation at a site on the basis of structure. Vegetation usually consists of a mixture of growth forms (such as trees, shrubs, grasses etc.) of varying height (strata, layers or continua) and spacing (crown cover or crown separation). These three features (growth form, height and spacing) account for most of the appearance of the vegetation and are used to classify its structure (Walker and Hopkins 1990, pp. 63–64).

Many vegetation communities in Queensland are arranged into different layers defined by height. These are frequently made up of different life forms, species or cohorts of species tied to episodic stochastic events, such as a run of exceptional wet years, storm disturbance, a hot fire etc. In relatively undisturbed areas, this episodic recruitment results in most Queensland vegetation communities having easily recognised distinct horizontal layers. For example, most of the savanna woodlands typically have a canopy tree layer (T1), a sparse subcanopy of scattered shorter trees (T2), a generally sparse shrub layer (S1) and a ground layer of mixed life forms (G). However, in communities of high natural complexity, such as rainforests, or areas with regular disturbances caused by human disturbance, such as selectively logged forests, the determination of the vertical structure is more difficult, as the vertical arrangement of biomass may appear continuous. This section seeks to provide some rules to assist users in arriving at a consistent vertical stratification of vegetation communities.

A2.5.2 Number of layers

All vascular plants on a site are included. The Queensland Herbarium has adopted a method in which there is a maximum of seven layers or strata at any one site. Height intervals for each stratum are regarded as the heights (height of the top leaves) of the tallest and shortest individuals in that stratum.

For tree-dominated vegetation, there here may be one emergent layer, E, dominated by trees. There may be up to three tree layers (in addition to an emergent layer):

T1 usually referred to as canopy

T2 also referred to as subcanopy

T3 often referred to as low tree layer, not always present particularly in low woodlands.

There may be two layers that are dominated by shrubs:

S1 tallest shrub layer. This may also include some low trees. If only one shrub layer is present, then it is S1

S2 lower shrub layer. This may be referred to as a sub-shrub layer, often not recognised apart from shrub dominated vegetation such as heathlands.

The shrub and tree layers may have other life forms present, including twining vines and epiphytes, but are dominated by shrubs or trees. Lianas and epiphytes are frequently present in the tree layer of rainforests. The shrub layer may also include predominantly non-woody life forms that reach the height of the shrub layer, such as *Xanthorrhoea* spp., cycads, tree ferns, *Gahnia sieberiana*, *Gymnostachys anceps* etc.

There is one ground layer (G) although it may be absent. This layer may contain graminoids, forbs, sprawling vines and other plants that are short in stature and overlap in height with the grasses. Seedlings of trees and shrubs will generally be included in this layer, if not already allocated to a separate shrub layer. The ground layer most frequently extends from 0 cm to 100 cm.

However, if shrubs are recorded with a height of 0.7 m and grasses reach a height of 0.3 m, then they should be separate shrub (S1 if only one layer, S2 if a taller layer is present) and ground (G) layers. In rare cases the ground layer will be taller than the lowest shrub layer; for example in the Northwest Highlands, the grasses of the ground layer may be up to 90 cm in height, with an S2 layer of *Acacia* spp. to 30 cm in height.

A2.5.3 Rules for determining layers

A maximum of seven layers may occur at any site.

There is generally a decrease in height from E, T1, T2, T3, S1, S2 to G*. For the tree dominated layers, E is always taller than T1, T1›T2, T2›T3. Similarly, S1 is always greater than S2.

The ranges for layers should not overlap; that is, the top of the T2 layer should not overlap with the height range of the T1 layer*.

Different layers are often defined by the presence of different species or life forms, such as a T2 layer of *Casuarina* in eucalypt (T1) woodlands, or *Acacia chisholmii* forms a S1 layer (1.5–2.5m tall) with a distinct S2 layer of *A. hilliana* at 0.5 m tall, or a different cohort of a species (as indicated by structural characteristics in addition to height, such as stem diameter and crown growth form).

For all tree layers except E and T3, the maximum height range of each layer should be no more than 50% of the mean height. For example, for a T1 layer of 20 m, the height ranges should be no more than 10 m. An exception may occur in the emergents in some complex closed forests, or in very tall open forests where this rule would lead to more than three tree layers. Where tree layers are indistinct, the allocation of trees to each layer is determined by including the tallest tree in the T1 layer and then maximising the range of each strata using the above rules.

The T3 layer can have a wider range than for rule 5, and will include all trees greater than 2 m tall up to the maximum height of the T3 layer.

There is no minimum requirement for cover or abundance to determine a layer; that is, even a single tree or widely scattered trees could form a layer.

For life forms such as grasses and sedges which may have flowering stalks that extend vertically well above the leaf biomass, such as *Heteropogon triticeus*, the height of the layer is determined by measuring to the top of the main leaf biomass: for example, height of leaf layer 80–100 cm with flowering racemes to 200 cm.

Vines will be recorded in the tallest layer they are present; for example, a *Parsonsia* species that grows up into the T1 layer will be recorded as present in the T1 layer and can be given a density, cover and even basal area for that layer. It will not be recorded as present in the S1 and G layer if already recorded in the T1 layer

Epiphytes and mistletoes should be recorded as present in the layer in which they occur: for example, *Cymbidium canaliculatum* in the T1 layer.

* There rarely maybe exceptions to this with the ground and shrub layers, e.g. the grasses of the ground layer may be 90 cm tall, with an S2 layer of *Acacia* spp. to 30 cm tall.

A2.5.4 Determining the ecologically predominant layer

Once the vegetation community has been classified into layers using the process outlined above, the determination of the predominant layer is made. The predominant layer contains the greatest amount of above-ground vegetation biomass (Neldner 1984). In the majority of cases in wooded communities it is the tallest layer that forms the most above-ground biomass, except in the case of emergent trees. Exceptions include rainforest canopies with emergent species, grasslands with scattered trees and shrubs etc.

In most cases, the term predominant layer equates with ‘ecological dominant layer’, ‘ecologically dominant stratum’ (NLWRA 2001), ‘dominant stratum’ (Beadle and Costin (1952) and, for woody vegetation, the predominant canopy (VMA, 1999). The predominant layer ‘because of its physiognomy and relative continuity, dominates the rest of the community in the sense that it conditions the habitats of the other strata’ (Beadle and Costin 1952).

Generally a visual estimation is sufficient to identify the predominant layer, but in some communities the height, density and cover of each layer may need to be used to calculate approximate biomass volumes. As there is generally a relationship between biomass and the commonly used abundance measure of basal area (Kuhnell et al. 1998; Burrows et al. 2000), dominance of woody vegetation can be readily assessed by estimates of the latter.

A2.5.5 Range of variation within a vegetation community

The structural characteristics of a vegetation community can vary across its range depending on the environmental conditions on site and the management history. Therefore the height range limits may not apply to a description of the vegetation community which encompasses the full range of sites where the vegetation has been recorded.

A2.5.6 Emergent layer

Emergent layers occur where the tallest defined stratum is not the predominant layer. The definition used here is different to that used by Walker and Hopkins (1990) who define an emergent layer as the tallest stratum which comprises less than 5% of the total tree canopy cover. In practice, most emergent layers as defined by the Herbarium have a canopy cover that is less than 5% of the total crown cover, and therefore equate to the same layer defined by Walker and Hopkins (1990). An emergent layer (E) of very sparse trees can often occur in vegetation dominated by shrubs or the ground layer, ie. The EDL is S1 or G. Very occasionally there may be effectively two or three emergent layers consisting of very sparse trees or shrubs of different species and different characteristic heights occur, e.g. 12.2.15g Swamps dominated by Empodisma minus, Gahnia sieberiana, other sedges and forbs and shrubs such as Leptospermum liversidgei where Eucalyptus robusta 9 m tall forms the E layer, Melaleuca quinquenervia 6 m tall is a second E layer but designated T1, and Leptospermum liversidgei forms a very sparse third E layer (designated T2) 3.5 m tall.

Table 18 Summary of rules for determining layers/strata in vegetation

Stratum	Growth form	Height range	Notes
E: emergent	Tree	≤½ mean ht of E	
T1: canopy	Tree	≤½ mean ht of T1	
T2: sub-canopy	Tree	≤½ mean ht of T2	
T3: low tree layer	Tree	Trees <T2 layer	
S1: tallest shrub layer	Shrub (low trees)	≤ 8 m	
S2: lower shrub layer	Shrub	Distinct layer below S1	Infrequently recognised
G: ground layer	Graminoids/forbs/ sprawling vines, seedlings	0 m ≤ G ≤ 2 m; usually <1 m	Height measured to top of main leaf biomass; flowering racemes may be taller

- a maximum of 7 strata is allowable
- the height ranges for strata should not overlap
- there is no minimum requirement for cover or abundance to determine a layer, a single tree or widely scattered trees could form a layer (albeit emergent)
- tree: woody plant more than 2 m tall with a single stem at the base (or within 200 mm of the ground)
- shrub: woody plant less than 8 metres tall and multi-stemmed at the base (or within 200 mm from ground level) or, if single-stemmed, less than 2 m tall.

Ground layer profroma

The PFC of each plant species is estimated with a number of quadrats. Five is the standard in a QBEIS site but 10 or 15 quadrats can be used

Logs

Branches and logs >10 cm diameter

Coarse litter

Estimate of the percentage of the site that is covered by detached plant material on the soil surface, i.e. litter. (≥2 cm diameter and <10 cm diameter).

Fine litter

Estimate of the percentage of the site that is covered by detached plant material on the soil surface, i.e. litter. (<2 cm diameter).

Bare ground

Estimate of the percentage of the site that is bare ground.

Rock

Estimate of the percentage of the site that is exposed rock (individual fragments >6 cm wide).

Cryptogam

Estimate of the percentage of the soil surface covered by cryptogams.

Cryptogams are cryptogamic soils crusts comprising lichens, bryophytes and an assortment of microscopic organisms. Rocks covered with lichen etc. are recorded as rock cover.

Water

Estimate of the percentage of the site that is covered with surface water.

Manure

Estimate of the percentage of the site that is covered with animal dung.

Note: The percentage of bare ground, coarse and fine litter cover, logs, cryptogams, exposed rock, cryptogams, water, manure and plant ground cover should total 100%. That is, the covers are estimated by looking vertically and, for example, not recording rock covered by litter in the rock cover and excluding roots, trunks, buttresses and other parts of plants from non-ground strata from ground cover estimates.

Litter depth

Estimate of the depth of surface litter (cms).

A2.6 BioCondition attributes

Measurements of coarse woody debris and large tree diameter at breast height (DBH) are collected at a site to enable it to be used for a benchmark or reference site for BioCondition. The completion of a BioCondition reference site would only be required if the site is a relatively undisturbed and structurally intact example of that ecosystem. A full description of the method for collecting this data and the reference site datasheets are provided by (Eyre et al. 2015) and summarised below. QBEIS BioCondition attributes proforma is used to record this information (A2.6.1).

A2.6.1 Coarse woody debris

Coarse woody debris (CWD) refers to logs or dead timber on the ground that are >10 cm diameter and >0.5 m in length and more than 80% of the length in contact with the ground. Assessment is conducted by measuring the length of all CWD to the boundary of the plot, generally a 50 x 20 m plot. The length of a large log is only recorded to the edge of the plot area. Any woody material smaller than this is included as litter cover (see Eyre et al. 2015, page 21).

A2.6.2 Large trees

The species and DBH of all trees larger than 30 cm (for *Eucalyptus*, *Corymbia*, *Lophostemon* and *Angophora* species) and 20cm (for non-eucalypts) are generally recorded within a 100 m by 50 metre plot area for a BioCondition assessment. However, the plot size and stem threshold measured varies between communities (see Eyre et al. 2015, page 16). The stem threshold and plot size must be recorded at each site. For monitoring sites, individual trees can be tagged and their height recorded and this can be recorded on the Biocondition assessment profroma.

A2.7 Landscape descriptor codes

For the QBEIS soil type and geological codes, the categories in the tables aim to provide options for non-experts to recognise a broad category of soil and geology, while an expert soil scientist or geologist will be able to classify the soil or geology to a more precise level. QBEIS allows the entry of the soil or geological code provided on soil/geological coverages and these should be added to the database. The nomenclature of the Australian Soil Classification (Isbell et al. 2016) has been applied to the soil codes used in Table 21. This classification should be used for all newly collected soils site data.

Table 19 QBEIS broad soil colour and texture codes

Code	Colour	Code	Colour	Code	Texture	Code	Texture
A	whitish	G	red	A	clay	G	stony
B	greyish	H	black	B	clay loam	H	silty clay
C	mottled	I	dark	C	silty loam	I	sandy clay
D	yellow	J	grey	D	loam	J	silty clay loam
E	orange	K	pale	E	sandy loam	K	sandy clay loam
F	brown			F	sand	L	loam sand

Table 20 QBEIS soil type codes—alphabetical listing

Code	Soil type	Code	Soil type
G	Alluvial soils	V	Organic soils
Q	Black earth	V	Organosols
Q	Black soil	V	Peat
I	Brown calcareous soils	V	Podsol or Podosols
Z	Brown earth	W	Podsolic soils
I	Brown hardpan soils	W	Prairie soils
Z	Brown soils (non-calcic)	Q	Red Brown earths
Q	Brown soils of heavy texture	Z	Red calcareous soils
B	Calcareous sands	I	Red earths
I	Calcareous soils, brown	Z	Red hardpan soils
I	Calcareous soils, red	I	Red loams
B	Calcarosols	I/Y	Redzinas
Z	Chocolate soils	Q	Rocky soil (growing in rock)
Z	Chernozems	A/ G	Rudosols
C	Chromosols	E	Saline (marine) soils
H	Clay loam	T	Sands
J	Clay loam with clay subsoil	A	Sands with clay subsoil
K	Clay unspecified	C	Sandy clay
D	Clayey sand	N	Sandy clay loam
Z	Dermosols	H	Sandy clay loam with clay subsoil
I	Desert loams	J	Sandy clay loam, light
M	Duplex	D	Sandy clay, fine
J	Duplex soil with clay loam surface	N	Sandy loam
F	Duplex soil with loamy surface	D	Sandy soil
C	Duplex soil with sandy surface	D	Siliceous sands
B	Earthy sands	B	Silt
Y	Euchrozems	G	Silt loam
Y	Ferrosols	D	Silt loam with clay subsoil
K	Clay unspecified	C	Sandy clay
D	Clayey sand	N	Sandy clay loam

Table 21 QBEIS soil type codes

Codes	Short name	Soil type
A	RUDOSOLS/ TENOSOLS	RUDOSOLS/ TENOSOLS Sands: siliceous sands, earthy sands
B	CALCAROSOLS Calcareous sands	CALCAROSOLS Calcareous sands
C	SODOSOLS/ CHROMOSOLS/ KUROSOLS	SODOSOLS/ CHROMOSOLS/ KUROSOLS Sands with clay subsoil (texture contrast soil with sandy surface)
D	Loamy sand	Loamy sand, sandy loam, silty loam, loam, sandy soil, clayey sand, light sandy clay loam
E	HYDROSOLS Marine	HYDROSOLS Marine soils, saline (marine) soils
F	Loamy duplex sand	Loamy sand with clay subsoil (texture contrast soil with loamy surface)
G	RUDOSOLS Alluvial silt	RUDOSOLS Silt, alluvial soils
H	Clay loam	Sandy clay loam, silty clay or clay loam
I	CALCAROSOLS Desert loam	CALCAROSOLS Grey, brown and red calcareous soils, desert loams, red and brown hardpans
J	Hardpan with clay subsoil	Hardpan with clay subsoil (texture contrast with clay loam surface)
K	Clay	Clay unspecified
M	Duplex	Duplex, texture-contrast
N	Sandy clay	Sandy clay, fine sandy clay, silty clay, light clay
P	Gradational	Gradational soil (texture not specified)
Q	VERTOSOLS Heavy clay	VERTOSOLS Heavy clay, black soil, black earth, heavy soil, grey and brown soils of heavy texture
S	SODOSOLS Solodic	SODOSOLS Solodic soils, solonetz and solodic soils, soloths
T	RUDOSOLS Lithosol	RUDOSOLS Lithosols, skeletal soils, growing in rock, rocky soil
U	Uniform	Uniform soil (texture not specified)
V	ORGANOSOLS Organic soils	ORGANOSOLS Peat, organic soils, humic gleys
W	PODOSOLS	PODOSOLS Podsolic soils, podsol
X	Laterite	Lateritic soil formation, lateritic podzolic soils
Y	FERROSOLS Krasnozem	FERROSOLS Krasnozems and associated soils, euchrozems, xanthozems
Z	KANDOSOLS/ DERM OSOLS	KANDOSOLS/ DERMOSOLS Red earths

Table 22 CORVEG geology codes *The CORVEG geology codes have been superseded by Table 23 and are no longer used in QBEIS*

Table 23 QBEIS substrata lithology codes—alphabetical listing

Code	Geology	Code	Geology
AD	Adamellite	JA	Jasper
AG	Agglomerate	LI	Limestone
AC	Alcrete (bauxite)	MB	Marble
AM	Amphibolite	ML	Marl
AN	Andesite	ME	Metamorphic rock (unidentified)
AH	Anhydrite	MD	Microdiorite
AP	Aplite	MG	Microgranite
AR	Arkose	MS	Microsyenite
AF	Ash (fine)	MI	Migmatite
AS	Ash (sandy)	MU	Mudstone
BA	Basalt	MY	Myolite
BB	Bombs (volcanic)	PG	Pegmatite
BR	Breccia	PE	Peridotite
KA	Calcarenite	PL	Phonolite
KM	Calcareous mudstone	PH	Phyllite
KS	Calcareous sand	PC	Porcellanite
KL	Calcilutite	PO	Porphyry
KR	Calcirudite	PY	Pyroxenite
KC	Calcrete	QZ	Quartz
CH	Chert	QP	Quartz porphyry
C	Clay	QS	Quartz sandstone
CO	Coal	QU	Quartzite
CG	Conglomerate	RB	Red-brown hardpan
CU	Consolidated rock (unidentified)	RH	Rhyolite
SD	Detrital sedimentary rock (unidentified)	S	Sand
DI	Diorite	SA	Sandstone
DR	Dolerite	ST	Schist
DM	Dolomite	SK	Scoria
FC	Ferricrete	SR	Serpentinite
GA	Gabbro	SH	Shale
GS	Gneiss	LC	Silcrete
GN	Granite	Z	Silt
GD	Granodiorite	ZS	Siltstone
GR	Granulite	SL	Slate
GV	Gravel	SY	Syenite
GW	Graywacke	TR	Trachyte
GE	Greenstone	TU	Tuff
GY	Gypsum	UC	Unconsolidated material (unidentified)
HA	Halite	VB	Volcanic breccia
HO	Hornfels	VG	Volcanic glass
IG	Igneous rock (unidentified)		

Table 24 QBEIS types of erosional landform patterns by slope and relief class codes

Slope class							
Class	LE Level	VG Very gently inclined	GE Gently inclined	MO Moderately inclined	ST Steep	VS Very steep	PR Precipitous
Percentage	<1	1–3	3–10	10–32	32–56	56–100	100
Degrees (rounded to nearest whole number)	0–0°35'	>0°35'–1°45'	>1°45'–5°45'	>5°45'–18°	>18°–30°	>30–45	>45
Relief class	**Erosional landform pattern**						
M Very high >300 m (about 500 m)	—	—	—	RM Rolling mountains	SM Steep mountains	VM Very steep mountains	PM Precipitous
H High 90–300 m (about 150 m)	—	—	UH Undulating hills	RH Rolling hills	SH Steep hills	VH Very steep hills	PH Precipitous hills
L Low 30–90 m (about 50 m)	—	—	UL Undulating low hills	RL Rolling low hills	SL Steep low hills	VL Very steep low hills	B Badlands
R Very low 9–30 m (about 15 m)	—	GR Gently undulating rises	UR Undulating rises	RR Rolling rises	SR Steep rises	B Badlands	B Badlands
P Extremely low (<9 m)	LP Level plain	GP Gently undulating plain	UP Undulating plain	RP Rolling plain	B Badlands	B Badlands	B Badlands

Source: Speight (2009), table 2

Table 25 QBEIS landform pattern description codes (from Speight 2009)

Code	Landform pattern	Description
ALF	Alluvial fan	Level (less than 1% slope) to very gently inclined complex landform pattern of extremely low relief. The rapidly migrating alluvial stream channels are shallow to moderately deep, locally numerous, but elsewhere widely spaced. The channels form a central trifugal to divergent, integrated, reticulated to distributary pattern. The landform pattern includes areas that are bar plains, being aggraded or eroded by frequently active channelled stream flow, and other areas comprising terraces or stagnant alluvial plains with slopes that are greater than usual, formed by channelled stream flow but now relict. Incision in the up-slope area may give rise to an erosional stream bed between scarps. Typical elements: stream bed, bar, plain. Common element: scarp. Compare with sheet flood fan, pediment.
ALP	Alluvial plain	Level landform pattern with extremely low relief. The shallow to deep alluvial stream channels are sparse to widely spaced, forming a unidirectional integrated network. There may be frequently active erosion and aggradation by channelled and overbank stream flow, or the landforms may be relict from these processes. Typical elements: stream channel (stream bed and bank), plain (dominant). Common elements: bar, scroll, levee, back plain, swamp. Occasional elements: oxbow, flood-out, lake. Included types of landform pattern: flood plain, bar plain, meander plain, covered plain, anastomotic plain, delta, stagnant alluvial plain, terrace, terraced land.
ANA	Anastomotic plain	Flood plain with slowly migrating deep alluvial channels, usually moderately spaced, forming divergent to unidirectional integrated reticulated network. There is frequently active aggradation by over-bank and channelled stream flow. Typical elements: stream channel (stream bed and bank), levee, back plain (dominant). Common element: swamp. Compare with other types under alluvial plain, flood plain.

Code	Landform pattern	Description
BAD	Badlands	Landform pattern of low and extremely low relief (less than 90 m) and steep to precipitous slopes, typically with numerous fixed erosional stream channels which form a non-directional integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep and channelled stream flow. Typical elements: ridge (dominant), stream bed or gully. Occasional elements: summit surface, hillcrest, hill slope, talus. Compare with mountains, hills, low hills, rises, plain.
BAR	Bar plain	Flood plain with numerous rapidly migrating shallow alluvial channels forming a unidirectional integrated reticulated network. There is frequently active aggradation and erosion by channelled stream flow. Typical elements: stream bed, bar (dominant). Compare with other types under alluvial plain, flood plain.
BEA	Beach ridge plain	Level to gently undulating landform pattern of extremely low relief on which channels are absent or very rare; it consists of relict parallel beach ridges. Typical elements: beach ridge (co-dominant) and swale (co-dominant). Common elements: beach, fore dune, tidal creek. Compare with chenier plain.
CAL	Caldera	Rare landform pattern typically of very high relief and steep to precipitous slope. It is without stream channels or has fixed erosional channels forming a centripetal integrated tributary pattern. The landform has subsided or was excavated as a result of volcanism. Typical elements: scarp, hill slope, lake. Occasional elements: cone, hillcrest, stream channel.
CHE	Chenier plain	Level to gently undulating landform pattern of extremely low relief on which stream channels are very rare. The pattern consists of relict, parallel liner ridges built up by waves, separated by, and built over flats (mud flats) aggraded by tides of over-bank stream flow. Typical elements: beach ridge (co-dominant), flat (co-dominant). Common elements: tidal flat, swamp, beach, fore dune, tidal creek. Compare with beach ridge plain.
COR	Coral reef	Continuously active or relict landform pattern built up to sea level of the present day or a former time by corals and other organisms. It is mainly level, with moderately inclined to precipitous slopes below the sea level. Stream channels are generally absent, but there may occasionally fixed deep erosional tidal stream channels forming a disintegrated non-tributary pattern. Typical elements: reef flat, lagoon, cliff (submarine). Common elements: beach, beach ridge.
COV	Covered plain	Flood plain with slowly migrating deep alluvial channels, usually widely spaced and forming a unidirectional integrated non-tributary network. There is frequently active aggradation by over-bank stream flow. Typical elements: stream channel (stream bed and bank), levee, back plain dominant. Common element: swamp. Compare with other types under alluvial plain, flood plain.
DEL	Delta	Flood plain projecting into a sea or lake, with slowly migrating deep alluvial channels, usually moderately spaced, typically forming a divergent integrated distributary network. This landform is aggraded by frequently active over-bank and channelled stream flow that is modified by tides. Typical elements: stream channel (stream bed and bank), levee, back plain (co-dominant), swamp (co-dominant), lagoon (co-dominant). Common elements: beach ridge, swale, beach, estuary, tidal creek. Compare with other types under alluvial plain, flood plain, chenier plain.
DUN	Dune field	Level to rolling landform pattern of very low or extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind. Typical elements: dune or dune crest, dune slope, swale, blow-out. Included types of landform pattern: longitudinal dune field, parabolic dune field.
ESC	Escarpment	Steep to precipitous landform pattern forming a linearly extensive, straight or sinuous inclined surface, which separates terrains at different altitudes, that above the escarpment commonly being a plateau. Relief within the landform pattern may be high (hilly) or low (planar). The upper margin is often marked by an included cliff or scarp. Typical elements: hillcrest, hill slope, cliff-foot slope. Common elements: cliff, scarp, scarp-foot slope, talus, foot slope, alcove. Occasional element: stream bed.
FLO	Flood plain	Alluvial plain characterised by frequently active erosion and aggradation by channelled or over-bank stream flow. Unless otherwise specified, ‘frequently active’ is to mean that flow has average recurrence interval of 50 years or less. Typical elements: stream channel (stream bed and bank), plain (dominant). Common elements: bar, scroll, levee, back plain, swamp. Occasional elements: oxbow, flood-out, scroll. Included types of landform pattern: bar plain, meander plain, covered plain, anastomotic plain. Related direct landform patterns: stagnant alluvial plain, terrace, terraced land (partly relict).

Code	Landform pattern	Description
HIL	Hills	Landform pattern of high relief (90–300 m) with gently inclined to precipitous slopes. Fixed, shallow erosional stream channels, closely to very widely spaced, form a non-directional or convergent integrated tributary network. There is continuously active erosion by wash and creep, in some cases, rarely active erosion by landslides. Typical elements: hillcrest, hill slope (dominant), drainage depression, stream bed. Common elements: foot slopes, alcove, valley flat, gully. Occasional elements: tor, summit surface, scarp, landslide, talus, bench, terrace, doline. Compare with mountains, low hills, rises, plain.
KAR	Karst	Landform pattern of unspecified relief and slope (for specification use the terms in Table 25, for example 'karst rolling hills') typically with fixed deep erosional stream channels forming a non-directional disintegrated tributary pattern and many closed depressions without stream channels. It is eroded by continuously active solution and rarely active collapse, the products being through underground channels. Typical elements: hillcrest, hill slope (dominant), doline, Common elements: summit surface, valley flat, plain, alcove, drainage depression, stream channel, scarp, foot slope, landslide. Occasional element: talus.
LAC	Lacustrine plain	Level landform pattern with extremely low relief formerly occupied by a lake but now partly or completely dry. It is relict after aggradation by waves, and by deposition of material from suspension and solution in standing water. The pattern is usually bounded by wave-formed features such as cliffs, rock platforms, beaches, berms and lunettes. These may be included or excluded. Typical element: plain. Common elements: beach, cliff. Occasional elements: rock platform, berm. Compare with playa plain.
LAV	Lava plain	Level to undulating landform pattern of very low to extremely low relief with widely space fixed erosional stream channels that form a non-directional integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (lava flow) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow. Typical elements: plain, hill slope, stream bed. Occasional element: tumulus.
LON	Longitudinal dune field	Dune field characterised by long narrow sand dunes and wide flat swales. The dunes are oriented parallel with the direction of the prevailing wind, and in cross-section one slope is typically steeper than the other. Typical elements: dune or dune crest, dune slope, swale, blow-out. Compare with parabolic dune field.
LOW	Low hills	Landform pattern of low relief (30–90 m) and gentle to very steep slopes, typically with fixed erosional stream channels, closely to very widely spaced, which form a non-directional or convergent integrated tributary pattern. There is continuously active sheet flow, creep and channelled stream flow. Typical elements: hill crest, hill slope (dominant), drainage depression, stream bed. Common elements: foot slope, alcove, valley flat, gully. Occasional elements: tor, summit surface, landslide, doline. Compare with mountains, hills, rises, plain.
MAD	Made land	Landform typically of very low or extremely low relief and with slopes in the classes level and very steep. Sparse, fixed deep artificial stream channels form a non-directional interrupted tributary pattern. The landform pattern is eroded and aggraded, and locally built up or excavated, by rarely active human agency. Typical elements: fill-top (dominant), cut-over surface, cut face, embankment, berm, trench. Common elements: mound, pit, dam.
MAR	Marine plain	Plain eroded or aggraded by waves, tides, or submarine currents, and aggraded by deposition of material from suspension and solution in sea water, elevated above sea level by earth movements or eustasy, and little modified by sub-aerial agents such as stream flow or wind. Typical element: plain. Occasional elements: dune, stream channel.
MEA	Meander plain	Flood plain with widely spaced, rapidly migrating, moderately deep alluvial stream channels, which form a unidirectional integrated non-tributary network. There is frequently active aggradation and erosion by channelled stream flow with subordinate aggradation by over-bank stream flow. Typical elements: stream channel (stream bed, bank and bar), scroll, scroll plain (dominant). Common element: oxbow. Compare with other types under alluvial plain and flood plain.
MET	Meteor crater	Rare landform pattern comprising a circular closed depression (see crater landform element) with raised margin; it is typically of low to high relief and has a large range of slope values, without stream channels, or with a peripheral integrated pattern of centrifugal tributary streams. The pattern is excavated, heaved up and built up by a meteor impact and now relict. Typical elements: crater (scarp, talus, foot slope, and plain), hillcrest, hill slope.

Code	Landform pattern	Description
MOU	Mountains	Landform pattern of very high relief (greater than 300 m) with moderate to precipitous slopes and fixed erosional stream channels that are closely to very widely spread and form a non-directional or diverging integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep, and channelled stream flow. Typical elements: hillcrest, hill slope (dominant), stream bed. Common elements: talus, landslide, alcove, valley flat, scarp. Occasional elements: cirque, foot slope. Compare with hills, low hills, rises, plain.
PAR	Parabolic dune field	Dune field characterised by sand dunes with a long scoop-shaped form, convex in the downwind direction so that its trailing arms point upwind; the ground plan when perfectly developed approximates the form of a parabola. Typical elements: dune or dune crest, dune slope, swale, blow-out. Compare with longitudinal dune field.
PED	Pediment	Gently inclined to level (less than 1%) landform pattern of extremely low relief, typically with numerous rapidly migrating, very shallow incipient stream channels, which form a centrifugal to diverging integrated reticulated pattern. It is underlain by bedrock, eroded, and locally aggraded, by frequently active channelled stream flow or sheet flow, with subordinate wind erosion. Pediments characteristically occur down-slope from adjacent hills with markedly steeper slopes. Typical elements: pediment, plain and stream bed. Compare with sheet flood fan and alluvial plain.
PEP	Pediplain	Level to very gently inclined landform pattern with extremely low relief and no stream channels, eroded by barely active sheet flow and wind. Largely relict from more effective erosion by stream flow incipient stream channels as on a pediment. Typical element: plain.
PNP	Peneplain	Level to gently undulating landform pattern with extremely low relief and sparse slowly migrating alluvial stream channels, which form a non-directional, integrated tributary pattern. It is eroded by barely active sheet flow, creep, and channelled and over-bank stream flow. Typical elements: plain (dominant), stream channel.
PLA	Plain	Level to undulating or rarely, rolling landform pattern of extremely low relief (less than 9 m). Compare with mountains, hills, low hills, rises.
PLT	Plateau	Level to rolling landform pattern of plains, rises or low hills standing above a cliff, scarp or escarpment that extends around a large part of its perimeter. A bounding scarp or cliff landform element may be included or excluded; a bounding escarpment would be an adjacent landform pattern. Typical elements: plain, summit surface, cliff. Common elements: hillcrest, hill slope, drainage depression, rock flat, scarp. Occasional element: stream channel.
PLY	Playa plain	Level landform pattern with extremely low relief, typically without stream channels, aggraded by rarely active sheet flow and modified by wind, waves and soil phenomena. Typical elements: playa, lunette, plain. Compare with lacustrine plain.
RIS	Rises	Landform pattern of very low relief (9–30 m), and very gentle to steep slopes. The fixed erosional stream channels are closely to very widely spaced and form a non-directional to convergent, integrated or interrupted tributary pattern. The pattern is eroded by continuously active to barely active creep and sheet flow. Typical elements: hillcrest, hill slope (dominant), foot slope, drainage depression. Common element: valley flat. Occasional elements: gully, fan, tor. Compare with mountains, hills, low hills, plain.
SAN	Sand plain	Level to gently undulating landform pattern of extremely low relief and without channels; formed possibly by sheet flow or stream flow, but now relict and modified by wind action. Typical element: plain. Occasional elements: dune, playa, lunette.
SHF	Sheet flood fan	Level (less than 1% plain slope) to very gently inclined landform pattern of extremely low relief with numerous rapidly migrating very shallow incipient stream channels forming a divergent to unidirectional, integrated or interrupted reticulated pattern. This pattern is aggraded by frequently active sheet flow and channelled stream flow, with subordinate wind erosion. Typical elements: plain, stream bed. Compare with alluvial fan and pediment.
STA	Stagnant alluvial plain	Alluvial plain on which erosion and aggradation by channelled and over-bank stream flow is barely active or inactive because of reduced water supply, without apparent incision or channel enlargement that would lower the level of stream action. Typical elements: stream channel (stream bed and bank), plain (dominant). Common elements: bar, scroll, levee, back plain, swamp. Occasional elements: oxbow, flood-out, lake. Compare with flood plain, terrace.

Code	Landform pattern	Description
TER	Terrace (alluvial)	Former flood plain on which erosion and aggradation by channelled and over-bank stream flow is barely active or inactive because deepening or enlargement of the stream channel has lowered the level of flooding. A pattern that has a former flood plain and a significant active flood plain, or that has former flood plains at more than one level, becomes terraced land. Typical elements: terrace plain (dominant), scarp, channel beach. Occasional elements: stream channel, scroll, levee.
TEL	Terraced land (alluvial)	Landform pattern including one or more terraces; often a flood plain. Relief is low or very low (9–90 m). Terrace plains or terrace flats occur at stated heights above the top of the stream bank. Typical elements: terrace plains, terrace flats, scarp, scroll plain, stream channel. Occasional elements: stream channel, scroll, levee.
TID	Tidal flat	Level landform with extremely low relief and slow migrating deep alluvial stream channels, which form non-directional integrated tributary patterns: it is aggraded by frequently active tides. Typical elements: plain (dominant), internal flat, supratidal flat, stream channel. Occasional elements: lagoon, dune, dune beach, ridge, beach.
VOL	Volcano	Typically very high and very steep landform pattern without stream channels, forming a centrifugal interrupted tributary pattern. The landform is built up by volcanism, and modified by erosional agents. Typical elements: cone, crater. Common elements: scarp, hillcrest, hill slope, stream bed, lake, maar. Occasional element: tumulus.

Source: Speight (2009)

Table 26 QBEIS landform element codes (from Speight 2009)

Code	Landform element	Brief description
ALC	Alcove	Moderately inclined to very steep, short open depression with concave cross-section, eroded by collapse, landslides, creep or surface wash.
BKP	Back plain	Large flat resulting from aggradation by over-bank stream flow at some distance from the stream channel and in some cases biological (peat) accumulation; often characterised by a high watertable and the presence of swamps or lakes; part of a covered plain landform pattern.
BAN	Bank (stream bank)	Very short, very wide slope moderately inclined to precipitous, forming the marginal upper parts of a stream channel and resulting from erosion or aggradation by channelled stream flow.
BAR	Bar (stream bar)	Elongated, gently to moderately inclined low ridge built up by channelled stream flow; part of a streambed.
DUB	Barchan dune	Crescent-shaped dune with tips extending leeward (downwind), making this side concave and the windward (upwind) side conves. Barchan dunes tend to be arranged in chains extending in the dominant wind direction.
BEA	Beach	Short, low, very wide slope, gently or moderately inclined, built up or eroded by waves, forming the shore of a lake or sea.
BRI	Beach ridge	Very long, nearly straight low ridge built up by waves and usually modified by wind. A beach ridge is often a relict feature remote from the beach.
BEN	Bench	Short, gently or very gently inclined minimal mid slope element eroded or aggraded by any agent.
BER	Berm	Short, gently inclined to level minimal mid slope in an embankment or cut face, eroded or aggraded by human activity. Flat built up by waves above a beach.
BOU	Blow-out	Usually small, open or closed depression excavated by the wind.
BRK	Breakaway	Steep maximal mid-slope or upper slope, generally comprising both a very short scarp (free face) that is often bare rockland, and a stony scape-foot slope (debris slope); often standing above a pediment.
	Channel	See stream channel.
CBE	Channel bench	Flat at the margin of a stream channel aggraded and in part eroded by over-bank and channelled stream flow; an incipient flood plain. Channel benches have been referred to as ‘low-terraces. Terrace should be restricted to landform patterns above the influence of active stream flow.

Code	Landform element	Brief description
CIR	Cirque	Precipitous to gently inclined, typically closed depression of concave contour and profile excavated by ice. The closed part of the depression may be shallow, the larger part being an open depression like an alcove.
CLI	Cliff	Very wide cliffed (greater than 72°) maximal slope usually eroded by gravitational fall as a result of erosion of the base by various agencies, sometimes built up marine organisms (cf. scarp) .
CFS	Cliff foot slope	Slope situated below a cliff, with its contours generally parallel to the line of the cliff, eroded by sheet wash or water-aided mass movement and aggraded locally by collapsed material from above.
DOC	Collapse doline	Steep-sided, circular or elliptical closed depression, commonly funnel-shaped. characterised by subsurface drianage and formed by collapse of underlying caves within bedrock.
CON	Cone volcanic	Hillock with a circular symmetry built up by volcanism. The crest may form a ring around a crater.
CRA	Crater	Steep to precipitous closed depression excavated by explosions due to volcanism, human action, or impact of an extra-terrestrial object.
CUT	Cut face	Slope eroded by human activity.
COS	Cut over surface	Flat eroded by human activity.
DAM	Dam	Ridge built up by human activity so as to close a depression.
DBA	Deflation basin	Basin excavated by wind erosion which removes loose material, commonly above a resistant or wet layer.
DDE	Drainage depression	Level to gently inclined, long, narrow, shallow open depression, with smooth concave cross-section rising to moderately inclined side slopes, eroded or aggraded by sheet wash.
DUN	Dune	Moderately inclined to very steep ridge or hillock built up by the wind. This element may comprise dune crest and dune slope.
DUC	Dune crest	Crest built up or eroded by the wind (see also dune).
DUS	Dune slope	Slope built up or eroded by the wind (see also dune).
EMB	Embankment	Ridge or slope built by human activity.
EST	Estuary	Stream channel close to its junction with a sea or lake, where the action of channelled stream flow is modified by tides and waves. The width typically increases downstream.
FAN	Fan	Large gently inclined to level element with radical slope lines inclined away from a point, resulting from aggradation, or occasionally from erosion, by channelled, often braided, stream flow, or possibly by sheet flow.
FIL	Fill-top	Flat aggraded by human activity.
FLD	Flood-out	Flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over-stream flow, or by channelled stream flow associated with channels developed within the over-bank flow; part of a covered plain landform pattern.
FOO	Foot slope	Moderately to very gently inclined waning lower slope resulting from aggradation or erosion by sheet flow, earth flow or creep (cf. pediment).
FOR	Fore dune	Very long, nearly straight, moderately inclined to very steep ridge built up by the wind from material from an adjacent beach.
GUL	Gully	Open depression with short, precipitous walls and moderately inclined to very gently inclined floor or small stream channel, eroded by channelled stream flow and consequent collapse and water-aided mass movement.
HCR	Hillcrest	Very gently inclined to steep crest, smoothly convex, eroded mainly by creep and sheet wash. A typical element of mountains, hills, low hills and rises.
HSL	Hill slope	Gently inclined to precipitous slope, commonly simple and maximal, eroded by sheet wash, creep or water-aided mass movement. A typical element of mountain, hills, low hills and rises.
DUH	Hummocky (weakly oriented dune)	Very gently to moderately inclined rises or hillocks built up or eroded by wind and lacking distinct oriented or regular pattern.
ITF	Intertidal flat	See tidal flat.
LAG	Lagoon	Closed depression filled with water that is typically salt or brackish, bounded at least in part by forms aggraded or built up by waves or reef-building organisms.
LAK	Lake	Large water-filled closed depression.

Code	Landform element	Brief description
LDS	Landslide	Moderately inclined to very steep slope, eroded in the upper part and aggraded in the lower part by water-aided mass movement, characterised by irregular hummocks.
LEV	Levee	Very long, very low, nearly level sinuous ridge immediately adjacent to a stream channel, built up by over-bank flow. Levees are built, usually in pairs bounding the two sides of a stream channel, at the level reached by frequent floods. This element is part of a covered plain landform pattern. For artificial levee, use embankment; see also prior stream.
DUF	Linear or longtitudinal (seif) dune	Large, sharp-crested, elongated, longtitudinal (linear) dune or chain of sand dunes, oriented parallel rather than transverse (perpendicular) to the prevailing wind. (Not to be confused with the trailing arms of parabolic dunes.)
LUN	Lunette	Elongated, gently curved, low ridge built up by wind on the margin of a playa, typically with a moderate, wave-modified slope towards the playa and a gentle outer slope.
MAA	Maar	Level-floored , commonly water-filled closed depression with a nearly circular steep rim, excavated by volcanism.
MOU	Mound	Hillock built up by human activity.
OXB	Oxbow	Long, curved commonly water-filled closed depression eroded by channelled stream flow but closed as a result of aggradation by channelled or over-bank stream flow during the formation of meander plain landform pattern. The floor of an oxbow may be more or less aggraded by over-bank stream flow, wind, and biological (peat) accumulation.
	Pan	See playa.
DUP	Parabolic dune	Sand dune with a long, scoop-shaped form, convex in the downwind direction so that its horns point upwind, whose ground plan approximates the form of a parabola. The dunes left behind can be referred to as trailing arms. Where many such dunes have traversed an area, these can give the appearance of linear dunes.
PED	Pediment	Large gently inclined to level (less than 1%) waning lower slope, with slope lines inclined in single direction, or somewhat convergent or divergent, eroded, sometimes slightly aggraded by sheet flow (cf. foot slope). It is underlain by bedrock.
PIT	Pit	Closed depression excavated by human activity.
PLA	Plain	Large very gently inclined or level element, of unspecified geomorphological agent or mode of activity.
PLY	Playa	Large, shallow level-floored closed depression, intermittently water-filled, but mainly dry due to evaporation, bounded as a rule by flats aggraded by sheet flow and channelled stream flow
PST	Prior stream	Long, generally sinuous low ridge built up from materials originally deposited by stream flow along the line of a former stream channel. The landform element may include a depression marking the old streambed, and relict levees.
REF	Reef flat	Flat built up to sea level by marine organisms.
RER	Residual rise	Hillock of very low to extremely low relief (<30 m) and very gentle to steep slopes. This term is used to refer to an isolated rise surrounded by other landforms.
REC	Risecrest	Crest of hillock of very low to extremely low relief (<30 m) (see Residual rise).
RES	Riseslope	Slope of hillock of very low to extremely low relieve (>30 m) (see Residual rise).
RFL	Rock flat	Flat of bare consolidated rock, usually eroded by sheet wash.
RPL	Rock platform	Flat of consolidated rock, eroded by waves.
SCD	Scald	Flat, bare of vegetation, from which soil has been eroded or excavated by surface wash or wind.
SCA	Scarp	Very wide steep to precipitous maximal slope eroded by gravity, water-aided mass movement or sheet flow (cf. cliff).
SFS	Scarp-foot slope	Waning or minimal slope situated below a scarp, with its contours generally parallel to the line of the scarp.
SCR	Scroll	Long, curved very low ridge built up by channelled stream flow and left relict by channel migration. Part of a meander plain landform pattern.
SRP	Scroll plain	Large flat resulting from aggradation by channelled stream flow as a stream migrates from side to side, the dominant element of a meander plain landform pattern. This landform element may include occurrences of scroll, swale, and oxbow.
DOI	Solution doline	Steep-sided, circular or elliptical closed depression, commonly funnel-shaped, characterised by subsurface.

Code	Landform element	Brief description
STB	Stream bed	Linear, generally sinuous open depression forming the bottom of a stream channel eroded and locally excavated, aggraded or built by channelled stream flow. Parts that are built up include bars.
STC	Stream channel	Linear, generally sinuous open depression in parts eroded, excavated built up by channelled stream flow. This element comprises streambed and banks.
SUS	Summit	Very wide level to gently inclined crest with abrupt margins, commonly eroded by water-aided mass movement or sheet wash.
STF	Supratidal	See tidal flat.
SWL	Swale	Linear, level-floored open depression excavated by wind, or left relict between ridges built up by wind or waves, or built up to a lesser height than them Long, curved open or closed depression left relict between scrolls, built up by channelled stream flow
SWP	Swamp	Almost level closed or almost closed depression with a seasonal or permanent watertable at or above the surface, commonly aggraded by over-bank stream flow, and sometimes biological (peat) accumulation.
TAL	Talus	Moderately inclined or steep waning lower slope, consisting of rock fragments aggraded by gravity.
TEF	Terrace flat	Small flat aggraded or eroded by channelled or over-bank stream flow, standing above a scarp and no longer frequently inundated; a former valley flat, or part of a former flood plain.
TEP	Terrace plain	Large or very large flat aggraded by channelled or over-bank stream flow, standing above a scarp and no longer frequently inundated; part of a former flood plain.
TDC	Tidal creek	Intermittently water-filled open depression in parts eroded, excavated, built up and aggraded by channelled tide-water flow; type of stream channel (q.v.) characterised by a rapid increase in width downstream.
TDF	Tidal flat	Large flat subject to inundation by water that is usually salt or brackish aggraded by tides. An intertidal flat (ITF) is frequently inundated; a supratidal flat (STF) is seldom inundated.
TOR	Tor	Steep to precipitous hillock, typically convex, with a surface mainly of bare rock, either coherent or comprising sub-angular to rounded large boulders (exhumed core-stones, also themselves called tors) separated by open fissures; eroded by sheet wash or water-aided mass movement.
TRE	Trench	Open depression excavated by human activity.
TUM	Tumulus	Hillock heaved up by volcanism (or elsewhere, built up by human activity at a burial site).
VLF	Valley flat	Small, gently inclined to level flat, aggraded or sometimes eroded by channelled or over-bank stream flow, typically enclosed by hill slopes; a miniature alluvial plain landform pattern.

Table 27 QBEIS plant growth forms

Code	Label	Description
A	Cycad*	Members of the families *Cycadaceae* and *Zamiaceae*.
B	Bryophyte*	Mosses and Liverworts. Mosses are small plants usually with a slender leaf-bearing stem with no true vascular tissue. Liverworts are often moss-like in appearance or consisting of a flat, ribbon-like green thallus.
C	Chenopod shrub*	Single or multi-stemmed, semi-succulent shrub of the family *Chenopodiaceae* exhibiting drought and salt tolerance.
D	Tree fern*	Spirally arranged crowns on erect trunks several metres high (U.N.E 1989), characterised by large and usually branched leaves (fronds), arborescent and terrestrial; spores in sporangia on the leaves.
E	Fern	Ferns and fern allies. Characterised by large and usually branched leaves (fronds), herbaceous to arborescent and predominantly terrestrial; spores in sporangia on the leaves. Does not include aquatic or epiphytic ferns. Also excludes tree ferns.
F	Forb	Non graminoid herbaceous or slightly woody, annual or sometimes perennial plant, including ground orchids. Usually a dicotyledon. Includes tall annual to triennial forbs which are structurally similar to a shrub but may be single stemmed, for example, *Aeschynomene indica, Sida rhombifolia*.

Code	Label	Description
G	Tussock grass	Forms discrete but open tussocks usually with distinct individual shoots, or if not, then forming a hummock. These are the common agricultural grasses.
H	Hummock grass	Coarse xeromorphic grass with a mound-like form often dead in the middle; genera are Triodia and Plectrachne.
I	Fungi*	Usually multicellular eukaryotic organisms that are heterotrophs (cannot make their own food). Spore-producing organisms feeding on organic matter, including moulds, yeast, mushrooms, and toadstools.
J	Seagrass*	Flowering angiosperms forming sparse to dense mats of material at the subtidal and down to 30m below MSL. Occasionally exposed.
K	Epiphyte*	Epiphytes (including orchids), mistletoes and parasites. Plant with roots attached to the aerial portions of other plants. Often could also be another growth form, such as fern or forb.
L	Vine	Climbing, twining, winding or sprawling plants usually with a woody stem.
M	Mallee (tree/shrub)*	Woody perennial plant usually of the genus Eucalyptus. Multi-stemmed with fewer than 5 trunks of which at least 3 exceed 100mm at breast height (1.3m). Usually 8m or more.
N	Lichen*	Composite plant consisting of a fungus living symbiotically with algae: without true roots, stems or leaves.
O	Alga and Cyanobacteria*	Alga and Cyanobacteria. Lower order plants.
P	Palm*	Palms and other arborescent monocotyledons. Members of the Arecaceae or the genus Pandanus. (Pandanus is often multi-stemmed).
Q	Aquatic*	Plant growing in an inland waterway or wetland with the majority of its biomass under water for most of the year. Fresh, saline or brackish water.
R	Rush	Herbaceous, usually perennial erect monocot that is neither a grass nor a sedge. Include the monocotyledon families Juncaceae, Typhaceae, Liliaceae, Iridaceae, Xyridaceae and the genus Lomandra. I.e. "graminoid" or grass-like genera.
S	Shrub	Woody plants multi-stemmed at the base (or within 200mm from ground level) or if single stemmed, less than 2m.
SF	Sprawling forb	A herbaceous plant which sprawls on the ground, without any adaptations for climbing e.g. most Ipomoeas, Indigofera linnaei and Boerhavia spp.
T	Tree	Woody plants, more than 2m tall with a single stem or branches well above the base.
U	Samphire shrub	Genera (of Tribe Salicornioideae, viz: Halosarcia, Pachycornia, Sarcocornia, Sclerostegia, Tecticornia and Tegicornia) with articulate branches, fleshy stems and reduced flowers within the Chenopodiaceae family, succulent chenopods (Wilson 1980). Also the genus Sueda.
V	Sedge	Herbaceous, usually perennial erect plant generally with a tufted habit and of the families Cyperaceae (true sedges) or Restionaceae (node sedges).
W	Other grass	Member of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
X	Grass tree*	Australian grass trees. Members of Xanthorroeaceae.
Z	Heath shrub	Shrub usually less than 2m, with sclerophyllous leaves having high fibre:protein ratios and with an area of nanophyll or smaller (less than 225 sq. m.). Often a member of one the following families: Epacridaceae, Myrtaceae, Fabaceae and Proteaceae. Commonly occur on nutrient-poor substrates.

* These life forms are rarely dominant and therefore do not have corresponding structural formations in table 30. Areas dominated by these lifeforms are allocated a structural formation as per existing Table 29 cover categories, e.g. an area dominated by rushes with a cover 30–70% would be termed a rushland.

Source: after Walker and Hopkins (1990), ESCAVI (2003) and Hnatiuk et al. (2009).

Table 28 Structural formation classes

Proj. foliage cover	**>70%**	**>30–70%**	**10–30%**	**<10%**
Crown class	**Dense/closed**	**Mid-dense**	**Sparse**	**Very sparse**
Crown cover %[1]	**>80%**	**>50–80%**	**20–50%**	**<20%**
VMA structure category	**Dense**	**Mid-dense**	**Sparse**	**Very sparse**
GROWTH FORM[2]	**Structural formation classes (qualified by height)**			
Trees >30 m	tall closed forest TCF	tall open forest TOF	tall woodland TW	tall open woodland TOW
Trees 10–30 m	closed forest CF	open forest OF	woodland W	open woodland OW
Trees 2–10 m	low closed forest LCF	low open forest LOF	low woodland LW	low open woodland LOW
Shrubs 2– 8 m	closed scrub CSC	open scrub OSC	tall shrubland TS	tall open shrubland TOS
Shrubs 1–2 m	closed heath CHT	open heath OHT	shrubland S	open shrubland OS
Shrubs <1 m	dwarf closed heath DCHT	dwarf open heath DOHT	dwarf shrubland DS	dwarf open shrubland DOS
Succulent shrub	closed succulent scrub CSSC	succulent scrub SSC	succulent shrubland SS	open succulent shrubland OSS
Hummock grasses	closed hummock grassland CHG	hummock grassland HG	open hummock grassland OHG	sparse hummock grassland SHG
Tussock grasses	closed tussock grassland CTG	tussock grassland TG	open tussock grassland OTG	sparse tussock grassland STG
Herbs[3]	closed herbland CH	herbland H	open herbland OH	sparse herbland SH
Forbs	closed forbland CFB	forbland FB	open forbland OFB	sparse forbland SFB
Rush	closed rushland CR	rushland R	open rushland OR	sparse rushland SR
Vines	closed vineland CVI	vineland VI	open vineland OVI	sparse vineland SVI
Ferns	closed fernland CFN	fernland FN	open fernland OFN	sparse fernland SFN
Sedges	closed sedgeland CV	sedgeland V	open sedgeland OV	sparse sedgeland SV

1 In this table the crown cover classes listed are used to allocate the modified Specht (1970) structural formation labels (after Hnatiuk et al. 2009, Table 17, p81) and the relationship in Scarth et al. (2008) These approximate the Specht (1970) projective foliage cover (pfc) classes and derivation by converting crown cover to pfc using crown density types.

2 Growth form of the predominant layer (the ecologically dominant layer). See table 28 for definition of growth forms.

3 Herbland refers to associations in which species composition and abundance is dependent on seasonal conditions and at any one time grasses or forbs may predominate.

Source: after Specht (1970), Neldner (1984), Walker and Hopkins (1998) and Hnatiuk et al. 2009.

Open forest of *Eucalyptus carnea* with *Corymbia citriodora* subsp. *variegata*, *E. crebra*, *E. major* (RE 12.9–10.17c) Karawatha Forest (V.J. Neldner, Queensland Herbarium & Biodiversity Sciences, Queensland Government)

Table 29 Field key to structural types of Australian rainforest vegetation (Webb, 1978)

1. Mesophylls and notophylls most common	
2. Robust lianes, vascular epiphytes, plant buttresses, macrophylls and compound mesophylls prominent; trunk spaces generally obscured by aroids and palms; stem diameters irregular, many av. 60–120 cm; canopy level av. 21–42 m.	
3. Deciduous emergent and top canopy trees rare.	
4. Palm trees not prominent in canopy	Complex mesophyll vine forest (CMVF)
4. Feather palm trees prominent in canopy	Mesophyll feather-palm vine forest (MFPVF)
3. Deciduous and semi-deciduous emergent and top canopy.	
4. Mostly mesophylls	Semi-deciduous mesophyll vine forest (SDMVF)
4. Mostly notophylls	Semi-deciduous notophyll vine forest (SDNVF)
2. Robust lianes and vascular epiphytes not conspicuous in upper tree layers which are simplified; spur rather than plank buttresses prominent; trunk spaces open, stem diameters (except for evergreen emergents) generally regular, av. 60 cm; canopy level av. 24–36 m. Simplification of structural features does not, however approach that of simple notophyll evergreen types. Sclerophylls (e.g. *Acacia*) may be scattered in canopy.	
3. Deciduous emergent and top canopy trees rare or absent. Mostly mesophylls.	
4. Palm trees not prominent in canopy	Mesophyll vine forest (MVF)
4. Fan palm trees prominent in canopy	Mesophyll fan-palm vine forest (MFAPVF)
1. Notophylls and microphylls most common	
2. Robust and slender woody lianes, vascular epiphytes, plank buttresses, and compound entire leaves prominent; trunk spaces generally obscured by the Aroid *Pothos*; stem diameters irregular, many av. 60–120 cm.	
3. Canopy level uneven, av. 21–45 m, emergents mostly evergreen and umbrageous.	Complex notophyll vine forest (CNVF)
3. Canopy level uneven, av. 15–36 m, occasional deciduous species with common emergent *Araucaria* or *Agathis*, reaching av. 36–51 m	Araucarian notophyll vine forest (ANVF)
2. Robust lianes and vascular epiphytes inconspicuous in tree tops; slender woody and wiry lianes prominent in understorey; plank buttresses inconspicuous; simple toothed leaves prominent; trunk spaces open; stem diameters (except for emergents) generally regular av. 60 cm; tree crowns evergreen and generally sparse and narrow; strong tendency to single species dominance (e.g. *Ceratopetalum*) in upper tree layers; canopy level even, av. 21–33 m often with sclerophyllous emergents and co-dominants.	Simple notophyll evergreen vine forest (SNEVF)
2. Robust lianes, vascular epiphytes and plank buttresses present, but not so prominent as in complex types; tree crowns mostly evergreen, but with a few semi-evergreen or deciduous species, i.e. structural features are intermediate between simple and complex types	Notophyll vine forest (NVF)
2. Robust and slender lianes generally present, wiry lianes (climbing ferns) generally conspicuous in understorey; vascular epiphytes and plank buttresses inconspicuous; feather palms generally conspicuous; tree crowns evergreen; canopy level av. 20–25 m	Evergreen notophyll vine forest (ENVF) ± feather palms
2. Robust, slender and wiry lianes generally inconspicuous; fleshy vascular epiphytes may be prominent on trunks; plank buttresses inconspicuous; simple entire leaves prominent; deciduous species generally absent but many tree crowns become sparse during the dry season, i.e. semi-evergreen; typically mixed with sclerophyllous emergents and co-dominants.	
3. Canopy level av. 10–20 m	Simple semi-evergreen notophyll vine forest (SSENVF)
3. Canopy level av. 3–9 m, generally even, and canopy trees often branched low down (shrub-like)	Simple semi-evergreen notophyll vine thicket (SSENVT)

1. Microphylls most common	
2. Mossy and vascular epiphytes inconspicuous in top tree layers; robust lianes generally prominent; plank buttresses absent; prickly and thorny species frequent in usually dense shrub understorey; ground layer sparse; compound leaves and entire leaf margins common.	
3. Canopy level uneven, av. 9–15 m with mixed evergreen and semi-evergreen emergent and upper tree layer species; Araucarian and deciduous emergents rare or absent	Low microphyll vine forest (LMVF)
3. Canopy level uneven, av. 9–15 m with some deciduous and semi-evergreen species; frequent Araucarian (*Araucaria cunninghamii*) emergents to av. 21–36 m.	Araucarian microphyll vine forest (AMVF)
3. Canopy level uneven and discontinuous, av. 4–9 m with mixed evergreen, semi-evergreen and deciduous emergents to av. 9–18 m, swollen stems ('Bottle Trees' common)	Semi-evergreen vine thicket (SEVT)
3. Canopy level uneven and discontinuous, av. 4–9 m; practically all emergents are deciduous, and many understorey species are deciduous or semi-evergreen; swollen stems ('Bottle Trees' and other species may be common)	Deciduous vine thicket (DVT)
2. Mossy and vascular epiphytes usually present in top tree layers; robust lianes inconspicuous; slender and wiry lianes generally prominent; plank buttresses absent; prickly and thorny species absent; simple leaves with toothed margins common; strong tendency to single species dominance (*Nothofagus, Eucryphia*) in tree layer; tree ferns and ground ferns prominent; sclerophyll emergents generally present in marginal situations.	Microphyll fern forest (MFF)
3. Canopy level tall, even except for sclerophylls, av. 20–45 m	
3. Canopy level stunted, generally even and mixed with sclerophylls, av. 6–9 m	Microphyll fern thicket (MFT
1. Nanophylls most common	
2. Mossy epiphytes conspicuous; robust lianes and true prickles and thorns absent or rare; plank buttresses absent; simple leaves with toothed margins common; strong tendency to single species dominance (*Nothofagus*) in tree layer; tree ferns and ground prominent; floor often peaty and covered by mosses; sclerophyll emergents generally present.	
3. Canopy level tall, except for sclerophylls, av. 18–40 m	Nanophyll fern forest (NFF) and mossy forest (NMF)
3. Canopy level stunted, uneven, often with sclerophylls, av. 6–9 m	Nanophyll fern thicket (NFT) and mossy thicket (NMT)

Astrebla spp. tussock grassland, RE 4.9.1c near Julia Creek, (D. Hede, Queensland Herbarium & Biodiversity Science, Queensland Government)

A2.8 Blank QBEIS proforma

Site visit ID:

QBEIS: Vegetation survey recording form

Project:

Bioregion:

Site visit name:

Date: / / 20

Intended sample level:

2° (D)

3° (R)

4° (Q)

Sample floristics: (circle)

A Complete list (min required for 2° with BA and stem count)
B Woody species
C Woody species and perennial herbs
D Dominant characteristic species
E Other

Position derivation (circle):

A GPS Datum:
B Topographic map
C Other

Precision (m) ± :

Start:
Middle:
End:

Recorders:

	ZONE	EASTING	NORTHING	LATITUDE (-dd.ddddd)	LONGITUDE (ddd.ddddd)
S					
M					
E					

Transcect L x W (m):

Bearing:

Tag spp.:

Locality:

Commuity description:

Structural formation (Table 28):

General notes:

Community width (circle): **A** <35 m wide **B** 35–75 m **C** >75–150 m **D** >150–300 m **E** >300 m **F** not linear

Map unit:

Community area (circle): **A** site only (point) **B** <1 ha **C** 1–5 ha **D** >5–20 ha **E** >20–50 ha **F** >50 ha

Mapped? **YES** **NO**

Photos:

RE:

Representative site? **YES** **NO**

LANDFORM				SLOPE			ALTITUDE
Relief class	Pattern	Eros pattern	Element	Type	Slope (°)	Aspect (°)	

Site sketch/notes:

SOILS								GEOLOGY			
Source	Reliability	Type	Top soil colour	Top soil texture	Isbell code/MU	Depth	Add. info	Source	Reliability	Mapunit	Lithology
I Map **E** Cutting **B** Core **S** Surface observation	High Medium Low							**I** Map **E** Cutting **B** Core **O** Outcrop	High Medium Low		
Notes:								Notes:			

Site visit name:

DISTURBANCE

Disturbance	Obs. type All = ☐	Type	Gully depth	Proportion	Severity	Age	Height	Cover (%)	Count
Grazing	V R I M				N MI MO S	1 2 3 4 5			
Erosion	V R I M	N S R G T B M W C V	0 1 2 3		N MI MO S	1 2 3 4 5			
Weeds	V R I M				N MI MO S				
Fire	V R I M	FU FW FP		0 1 2 3	N MI MO S	1 2 3 4 5	0 1 2 3 4		
Storm	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Logging	V R I M				N MI MO S	1 2 3 4 5			
Flood	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Roadworks	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Feral digging	V R I M			0 1 2 3					
Treatment	V R I M				N MI MO S	1 2 3 4 5			
Clearing	V R I M				N MI MO S	1 2 3 4 5			
Salinity	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Other	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Notes									

Observation type: **V**= visual; **R**= records; **I**= informant; **M**= imagery/mapped
Type (erosion): **N**=none; **S**=sheet; **R**=rill; **G**=gully; **T**=tunnel **B**=stream bank; **M**=mass movement; **W**=wind; **C**= scald; **V**= wave
Type (fire): **FU**= Fire undefined; **FW**= Wildfire; **FP**= Prescribed burn
Gully depth: **0**= (none); 1= (>0.3m to <1.5m); 2= (≥1.5m to ≤3m); 3= (>3m)
Proportion (%): 0= (0); 1= (≤ 5); 2= (>5 to ≤20); 3= (>20)
Severity: N= none; MI= minor; MO= moderate; S= severe
Time since event (years): 1= (≤1); 2= (>1 to ≤3); 3= (>3 to ≤5); 4= (>5 to ≤10); 5= (>10)
Height (m): 0= (≤ 1); 1= (>1 to ≤3); 2= (>3 to ≤6); 3= (>6 to ≤12); 4= (>12)

STRUCTURAL SUMMARY

Stratum	Mean canopy height (m)	Range in strata height (m)	Total crown cover (%)	Key species
Emergent				
Tree 1				
Tree 2				
Tree 3				
Shrub 1				
Shrub 2				
Ground			**Total PFC cover (%)**	

Emergent/tree/shrub layers (not ground) form

BA Factor (circle):
2 (1.4cm)
1 (1 cm)
0.5 (0.71 cm)
0.25 (0.5 cm)
0.1

Cover method (circle):
L = Photographic
V = Visual estimate
I = Line intercept

MISC = Off site

ID
C = Collected
V = Voucher
F = Field

E:
T1:
T2:
T3:
S1:
S2:

Stem count plot size (m^2)**:**

Site visit name:

BASAL AREA COUNT					SPECIES	Tag	ID	MISC	CROWN COVER (%)						STEM COUNT					
E	T1	T2	T3	S1					E	T1	T2	T3	S1	S2	E	T1	T2	T3	S1	S2

Emergent/tree/shrub layers (not ground) form continued

BA Factor (circle):
2 (1.4cm)
1 (1 cm)
0.5 (0.71 cm)
0.25 (0.5 cm)
0.1

Cover method (circle):
L = Photographic
V = Visual estimate
I = Line intercept

MISC = Off site
ID
C = Collected
V = Voucher
F = Field

Stem count plot size (m²):
E:
T1:
T2:
T3:
S1:
S2:

Site visit name:

BASAL AREA COUNT					SPECIES	Tag	ID	MISC	CROWN COVER (%)						STEM COUNT					
E	T1	T2	T3	S1					E	T1	T2	T3	S1	S2	E	T1	T2	T3	S1	S2

Ground layer only (projective foliage cover (PFC) (%))

Site visit name:

GROUND SPECIES	Tag	ID	MISC	G1	G2	G3	G4	G5	Av.G
LOGS (≥ 10cm)									
COARSE LITTER (≥ 2cm & < 10cm)									
FINE LITTER (< 2cm)									
BARE GROUND									
ROCK									
CRYPTOGAM									
WATER									
MANURE									
TOTAL VEGETATIVE COVER (PFC)									
TOTAL									
LITTER DEPTH (cm)									

Ground layer only continued

Site Visit name:

GROUND SPECIES	Tag	ID	Misc	G1	G2	G3	G4	G5	Av.G

Line intercept form

Crown cover: %

Transect length: m

Site visit name:

SPECIES	STRATA	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End

Line intercept form continued

Site visit name:

SPECIES	STRATA	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End

BioCondition attributes

Site visit name:

COARSE WOODY DEBRIS	
Coarse woody debris (record length in metres of all debris > 10 cm wide, ≥ 0.5 m long, and > 80% in contact with the ground) **Plot size: x m^2**	
	TOTAL (m):

Tree measures plot size (tick): ☐ 100 x 50 m^2 ☐ 100 x 20 m^2 ☐ 100 x 10 m^2 ☐ 50 x 10 m^2 ☐ m^2

Eucalypts measured greater than : ☐ cm **Non-Eucalypts measured greater than :** ☐ cm

TAG NO.	TREE SPECIES	STRATA	DIAMETER BREAST HEIGHT (DBH) measured at 1.3 m height in cm	HEIGHT (m)	NOTES

BioCondition attributes continued

Site visit name:

TAG NO.	TREE SPECIES	STRATA	DIAMETER BREAST HEIGHT (DBH) measured at 1.3 m height in cm	HEIGHT (m)	NOTES

Appendix 3. Changing vegetation: principles and examples

This Appendix outlines some principles used to classify and map vegetation where changes have occurred between the pre-clearing and remnant coverages.

Vegetation that is heavily disturbed, by either natural or unnatural processes, may regrow following a variety of successional pathways depending on conditions during the recovery phase. Similarly, uncleared vegetation can also undergo changes in structure and composition associated with changes in climate and/or other environmental factors. Many of these changes can occur rapidly and are more appropriately dealt with by an assessment of 'condition', which is outside the scope of the current Queensland Herbarium survey and mapping program. For example, a change in *Eucalyptus populnea* woodland where the ground layer changes from one dominated by grasses to one dominated by shrubs over the last 50 years would not be reflected in the regional ecosystem mapping or classification.

Some changed vegetation is readily mappable from Landsat imagery and represents a natural community type or a stable anthropogenic community, such as a plantation. If mappable, these communities are delineated using standard techniques.

The definition of remnant vegetation (see section 2.3.4) means that changes associated with normal disturbance cannot make vegetation non-remnant. Thus, the process causing the vegetation change must be considered. If the change is not caused by anthropogenic clearing—such as drought death caused by long-term climatic extremes—then the altered vegetation is still considered remnant. If this change is readily reversible, it will be considered as change in condition within the one regional ecosystem (example 7). If the change is considered difficult to reverse, the altered vegetation may be recognised as a separate regional ecosystem (examples 1 and 3).

Some changes, such as altered fire regimes, are associated with changes in structure or composition of natural vegetation that are mappable and difficult to reverse. Where the resulting vegetation matches a different regional ecosystem, the remnant mapping will reflect this change (example 3). The Queensland Herbarium terms such cases 'encroachment'.

If the vegetation change is caused by clearing but the structure has remained intact, or recovered to, meet the 50–70% height and cover and characteristic species rules (see section 2.3.4) the vegetation is considered remnant. This includes areas where species, even if dominant, are completely removed and the canopy is composed of species that are usually sub-dominant, but still characteristic, of the undisturbed canopy (see example 11).

If the vegetation change is caused by clearing or other extensive human disturbances (Wilson 2000) that are not associated with change in the underlying abiotic factors and the resulting vegetation does not meet the remnant criteria used by the Queensland Herbarium, the resultant vegetation is considered non-remnant (most clearing and example 5).

If the changes are caused by extensive human disturbances that are associated with a change in underlying abiotic factors, such as hydrology, and the current vegetation matches a current regional ecosystem description, the vegetation is considered remnant (example 9).

1. *Sarga* spp. grasslands have been encroached on by *Melaleuca viridiflora* low open woodlands in some areas on Lakefield National Park (Neldner et al. 1997). The *Sarga* grasslands and *M. viridiflora* low open woodland both match existing regional ecosystem descriptions. Thus the pre-clearing vegetation is mapped from the 1960's photos as grassland (RE code 3.3.59), while the remnant vegetation is mapped as *M. viridiflora* low open woodland (3.3.50) from current imagery and ground truthing.
2. Natural grasslands have been oversown and are now dominated by the exotic buffel grass (*Cenchrus ciliaris*). They are generally no longer remnant as the native species are completely dominated by buffel grass, and are unlikely to recover in the short term (Fensham 1999; Butler and Fairfax 2003). While identification of grassland composition from imagery is unreliable, ploughing is readily detectable on aerial photographs and satellite imagery. Generally, if a grassland has been ploughed within the past 15

years, then there is a complete species change, so it is mapped as non-remnant. Field inspections at these sites may further assess the grassland condition based criteria listed in section 2.3.4.

3. Coastal eucalypt open forests are being colonised by rainforest species on Cape York Peninsula, Central Queensland Coast and the Wet Tropics bioregion (Stanton et al. 2014). Providing the vegetation still contains numerous emergents of the original sclerophyll dominants, these rainforest-invaded examples are treated as the same regional ecosystem as those with an open grassy or sclerophyll shrub layer. The description of the regional ecosystem encompasses both states. The resulting Vegetation Management Class does not reflect any 'loss' due to rainforest invasion, however this is reflected in the Biodiversity Status where the threatening process of rainforest invasion is used to change the status to a more threatened state. The vegetation unit in the pre-clearing mapping can usually be compared with the current mapping to determine the degree of rainforest invasion (e.g. in Wet Tropics, Vegetation Unit 56 is (RE7.3.42b) *E. grandis* with a sclerophyll shrub layer and 56v is (RE7.3.42a) *E. grandis* with a well-developed vine forest subcanopy).
4. Rainforests cleared near Kuranda and Eungella. The vegetation is advanced regrowth (at least 20 years old). *Acacia celsa* dominates the upper stratum, however other rainforest species form a well-advanced secondary tree layer (at or just below the Acacia canopy height) and can be easily observed on aerial photographs through frequent gaps in the Acacia canopy. While Acacias are considered to be an early succession or pioneer species in rainforest, even primary rainforest exists as an overlapping mosaic of regenerating units depending on past disturbance history at a site (Hopkins, 1981). Therefore given that *Acacia celsa* typically occurs in areas of natural disturbance, i.e. *A. celsa* is a characteristic canopy species, the Kuranda/Eungella rainforest communities are considered to be a seral stage of the rainforest type and to be remnant vegetation under the *Vegetation Management Act 1999* provided they meet the height and cover criteria when compared to a normal canopy. These areas qualify as high-value regrowth provided they have not been cleared in the last 15 years.
5. However, pure stands of *Acacia celsa* which are generally regrowth from clearing or logging and which have not reached the height and cover requirements are not considered remnant. In these areas, for example near Lake Eacham on the Atherton Tableland, *Acacia celsa* forms a very distinct canopy and a uniform 'cauliflower' pattern on aerial photos. A lower layer of other rainforest species is non-existent or poorly developed.
6. Pre-clearing vegetation has been cleared and replaced by non-remnant vegetation that can be predictably interpreted on the Landsat imagery. For example hoop pine plantations are mapped on the remnant coverage. Near Brisbane airport there is a planted *Casuarina glauca* open forest that resembles a native community (12.1.1) but does not have the typical structure and diversity. This area has been mapped as a *Casuarina glauca* plantation on the remnant coverage.
7. Semi-arid *Astrebla* grasslands invaded by the exotic species *Vachellia nilotica* in places become an *V. nilotica* open woodland/woodland. When sparsely distributed *V. nilotica* does not have a major impact on the composition of the ground layer. It also cannot be reliably and consistently detected on the available satellite imagery time series. These areas are currently mapped as remnant *Astrebla* grasslands, as they would revert rapidly to *Astrebla* grasslands if the *V. nilotica* were removed. However in higher rainfall situations, greater densities and cover of *V. nilotica* or other woody weed species may occur and alter the ground layer species composition such that these areas are no longer considered remnant.
8. Extensive drought death in ironbark (*Eucalyptus* spp.) woodlands, such as 11.11.15, can be detected from Landsat imagery and may be mistaken for mechanical or chemical clearing. DNRM (1999) have estimated drought death as covering 69 000 ha, while Fensham and Holman (1999) reported that 29% of trees in an area of 55 000 km² were dead or nearly dead. This is a natural process and therefore considered to be a

normal canopy for this vegetation type at these sites. Similarly, dieback of mangroves around the Gulf of Carpentaria is considered to be the result of extreme weather conditions (Duke et al. 2017) and therefore considered natural.

9. Fire is considered a natural disturbance factor over much of the vegetation in Queensland. Unless there are very frequent (several over 3-5 years) hot fires, the impacts of fire in these communities is not considered to equate to clearing but to normal variation in abiotic factors. However, in some vegetation types, such as those dominated by fire sensitive species and with little grass cover (e.g. rainforest, brigalow) the occurrence of fire is considered anthropogenic and its impacts are defined as clearing. For areas of these regional ecosystems to be mapped as non-remnant because of clearing by fire there must be clear evidence that there has been a fire and that it has cleared the vegetation, with no evidence of sustainable regeneration. The sources of evidence used by the Queensland Herbarium to verify this are: the removal of the canopy (caused by fire) that is visible on Landsat TM imagery and/or available aerial photographs and/or observations of dead stags and burnt stumps in a field inspection. For many historical fires (> 40 years ago) evidence that the fire removed the canopy is not available and therefore the vegetation is classed as remnant.
10. Increase in cover of gidgee (*Acacia cambagei*) has taken place on *Astrebla* open grassland (4.9.1) or wooded downs (4.9.7) (Fensham and Fairfax, 2004). In many cases, the increase in *A. cambagei* is not enough to change the regional ecosystem to a different type on the remnant compared to the pre-clearing coverage. The *A. cambagei* trees are low and scattered, so the current remnant regional ecosystem is still classed as a grassland (albeit with denser tree cover) or wooded downs on the remnant regional ecosystem map.
11. The installation of dykes or levees in coastal areas is associated with changes in hydrology. In some cases, these structures have blocked the inflow of saltwater on land zone 1 plains and have altered the vegetation from a saltwater inundation system, such as remnant 11.1.1, to a freshwater system remnant, such as 11.3.27. In other areas impoundments may have altered the hydrology such that the current regional ecosystem now matches a (wetland) regional ecosystem that is different from that mapped on the pre-clearing extent. In this case, where it is a wetland regional ecosystem on the pre-clearing map and the wetland area is now enhanced, it will be mapped as remnant wetlands. Large artificial deep water impoundments (such as Lake Wivenhoe) and farm dams are mapped as ‘water’ on the remnant coverages, as they do not match any natural regional ecosystem.
12. In areas in western Queensland mass recruitment of *Acacia cambagei* seedlings in the wet years in the early 1970s has led to a thick 2–4 m shrubland of *A. cambagei*, which has killed the sparsely spread taller *A. cambagei* trees (7–12 m tall). In this natural event, the structure of the community has changed although the species composition is similar. Despite the low height of the *A. cambagei* shrubs, this community is still considered remnant vegetation.
13. Where thinning or logging has removed *Araucaria cunninghamii* emergents from rainforest communities, the area is still considered remnant where the predominant canopy remains intact. Similarly areas where logging has completely removed some canopy species but left others, even if these were originally sub-dominant, is remnant if the 70/50% height and cover criteria are met.

Appendix 4. Examples of heterogeneous polygons

A heterogeneous polygon is a polygon (area delineated on a map) that has more than one vegetation or regional ecosystem code occurring in it. Section 3.9.1 provides background information on heterogeneous polygons. Listed below are examples of different situations where heterogeneous polygons are created.

A4.1 Discrete photo-patterns

A4.1.1 Riparian/alluvial systems

Alluvial systems, which are legitimately mapped as one land system in land system studies, often consist of a number of different land units that support distinct vegetation types. For example, in Cape York Peninsula (CYP), the stream channels and river banks support flood-tolerant species such as *Melaleuca fluviatilis* ± *M. leucadendra* fringing open forests (map unit 48, RE 3.3.10), while the high banks and levees may support evergreen notophyll vine forest (map unit 18, RE 3.3.5), and the alluvial back plains support *Eucalyptus leptophleba*, *Corymbia tessellaris* ± *C. clarksoniana* woodlands (map unit 80, RE 3.3.24). Each of these distinct vegetation types has a distinct structure and floristic composition, is highly predictable in terms of where it will occur in the landscape and is readily detectable from aerial photographs. It is important to map these vegetation types as distinct units. Most frequently these units occur in narrow bands that follow the streamlines. These narrow bands are generally below the minimum specifications (<3 mm wide on the map), but occasionally they may expand out into areas wide enough to be mapped as homogeneous areas. However, because of their linear nature and the 1:100 000 scale of mapping, these map units will generally be mapped as heterogeneous polygons, with their areal proportions attributed to individual polygons.

It is important to remember that the character of watercourses changes as they move from source to estuary. It is therefore legitimate and desirable that the vegetation of a streamline be broken into discrete sections to represent the separate stages of the stream. For example, the large levees and alluvial floodplains generally occur only in the lower reaches of streams, while closer to the source a different mixed vegetation unit may occur in the incised gullies. Where the width of the alluvial influence falls below the minimum specification, then the riparian units are no longer delineated, but included in the attributes of the surrounding polygon. The marked boundary should follow the edge of the alluvial influence—that is, the boundary between land zone 3 and the surrounding land zone. Occasionally small portions of the surrounding vegetation are captured in the alluvial polygon, but must amount to less than 30% of the total polygon area.

A4.1.2 Tidal flats

Other examples where there are discrete photo-patterns include mixtures of small areas of saltpans (CYP map unit 194, RE 3.1.6) in mangroves, or narrow predictable bands of *Rhizophora stylosa* ± *Bruguiera gymnorhiza* closed forest (CYP map unit 34, RE 3.1.1) surrounded by *Ceriops tagal* ± *Avicennia marina* var. *eucalyptifolia* low closed forest (CYP map unit 131, RE 3.1.3). In both cases the photo-patterns are readily discernible from 1:80 000 scale black-and-white aerial photographs, and the units could be mapped as discrete homogeneous map units at 1:25 000 scale, but the only way such diversity can be represented at 1:100 000 scale in some situations is through heterogeneous polygons. It must again be stated that where the areas of any of these vegetation types are large enough (that is, greater than 20 ha at 1:100 000 scale) they should be mapped in homogeneous polygons. As the photo-patterns for these units are distinct and predictable, it is relatively easy to assign proportions to each on an individual polygon basis.

A4.2 No discrete photo-patterns

This situation is more difficult to explain and more open to interpretation. While the interpretation of aerial photographs, with additional information from satellite imagery, is the primary source of mapping, the ecological understanding and field experience of the botanist are also inputs to the final vegetation map coverage. As part of the ground-truthing process, the botanist will check and sample what vegetation type represents each photo-pattern delineated through the aerial photograph interpretation.

Through this process, it may be realised that two or more distinct plant associations may occur in the same photo-pattern which occupies a similar landform, geology, etc. For example, *Eucalyptus populnea* and *E. melanophloia* may dominate pure woodlands that have essentially an identical photo-pattern (for the aerial photographs used) and occur in similar landform situations. With this particular example, a continuum of woodland communities ranging from canopies dominated purely by *E. populnea* (for example, on the Darling Downs) to canopies dominated purely by *E. melanophloia* (for example, north of Mitchell), and a range of canopies consisting of both species in various levels of dominance can occur (*E. p*opulnea ± E. melanophloia woodland or E. melanophloia ± *E. populnea* woodland). Clumping can also occur where some areas up to 5 ha (the minimum polygon size for the 1:100 000 mapping scale) are dominated solely or predominantly by *E. populnea* and other clumps by *E. melanophloia* (this situation should be represented by *E. populnea* or *E. melanophloia* woodland).

On the basis of field knowledge, the botanist can confidently predict that one of these situations occurs for the particular photo-pattern. The botanist uses the large numbers of quaternary sites to make judgments about areas actually visited, and then makes predictions about other areas of the photo-pattern not visited. Where there is a large amount of variation, a low reliability should be assigned to areas not ground-truthed, and, if attributed as a heterogeneous polygon, the proportions should be assigned as similar proportions to those polygons that have been ground traversed. The *E. populnea* or *E. melanophloia* woodland unit should only be used to describe the situation of distinct clumping of largely homogeneous canopies of either *E. populnea* or *E. melanophloia*.

A similar example occurs in the *Acacia* dominated woodlands of central Queensland. In most areas either *Acacia harpophylla* or *Acacia cambagei* or *A. argyrodendron* dominate separate communities that are readily mappable. However, in various areas mixes of species may dominate the canopy; for example, in the south-west portion of the Mt Coolon sheet, all three species can occur together in the canopy, and no distinct clumping of individual species occurs. In this situation, which can be reasonably geographically defined on the basis of field work, it is justified to construct a mixed canopy unit of *Acacia harpophylla* and/or *Acacia cambagei* and/or *A. argyrodendron* woodland. This type of mixed unit is only justifiable where it cannot be separated into component plant associations at larger-scale mapping, and its distribution can be defined on the basis of field work.

A4.3 Most vegetation cleared on aerial photographs

In many areas of coastal and subcoastal Queensland, significant clearing of vegetation had already occurred before the 1960s (the most frequently used aerial photography for this work program). While still older photographs may show more remnant vegetation, in many areas a large amount of vegetation reconstruction is required to produce the pre-clearing coverage. Historical survey records and other natural resource theme mapping can assist in the reconstruction. Although there can be a reasonable reliability in the types of vegetation that would have been present, it is difficult or often impossible to spatially delineate where each plant association would have occurred. In these situations, it is desirable to use heterogeneous polygons to indicate what vegetation types would have been present and their proportions, without spatially delineating them, even though this spatial mapping is done in other parts of the map sheet where clearing had not occurred at the time the aerial photographs were taken.

Appendix 5. Guidelines for defining new regional ecosystem or vegetation community

A5.1 New regional ecosystem

For a new regional ecosystem to be recognised, all requirements must be met, and at least one of the criteria conditions satisfied. These are in addition to the bioregion and land zone that are part of the regional ecosystem classification (section 2.3). It is expected in the majority of cases at least two criteria will be satisfied; that is, a change in landscape position will be reflected in a change in floristics or structure.

Definition: a vegetation community or communities# in a bioregion that is consistently associated with a particular combination of geology, landform and soil.

Component vegetation communities may only be mappable at a scale larger than 1:100 000.

Caveats: The regional ecosystem framework is based on the 1:100 000 scale of mapping (Sattler and Williams 1999). When assigning land zones it is expected that geological or landsystem mapping at a comparable scale will be used.

A5.1.1 Requirements

All requirements must be met.

- **Area:** Total pre-clearing area >100 ha, or if <100 ha then at least three distinct patches
- **Information:** Adequate information to assess the species, structure and landscape criteria is required. This will generally be in the form of a technical description derived from secondary or tertiary site data.
- **Mappability:** The regional ecosystem must be consistently mapped at regional scale.
- **Equivalence check:** Checked for equivalence in Regional Ecosystem Description Database (REDD). Search regional ecosystem descriptions | Environment, land and water | Queensland Government.
- **Consultation:** Other botanists/experts for bioregion consulted. Final endorsement required from bioregional technical committee via the bioregional coordinator, who is the senior author listed against each bioregion in REDD (Queensland Herbarium 2021).
- **Non-outlier:** Regional ecosystem matches the description from an adjacent bioregion (that is, dominant species and land zone are equivalent), and has area in the bioregion of at least 1000 ha or if less than 1000 ha then occurs at least 50 km from existing bioregion boundary and occurs in more than two patches. If does not meet these area and/or distance requirements it is regarded as an outlier and coded with the regional ecosystem from the adjacent bioregion

A5.1.2 Criteria

At least one of the criteria conditions must be met.

- **Floristic:** Dominant canopy species different from established regional ecosystems within the same bioregion and land zone
  or
- Combination of dominant and subdominant canopy species (species making up bulk of the biomass) different from established regional ecosystems. If the only floristic difference is in the subdominant canopy species, then at least one other criterion (structure or landscape) must also be satisfied;
  or
- If canopy matches established regional ecosystem, then a distinct, consistently present (>50% sites) shrub layer with at least 10% projective foliage cover, for example, *Corymbia citriodora* subsp. *variegata* +/– *E. crebra* open forest with *Melaleuca irbyana* shrub layer (12.9–10.27, as compared to *Corymbia citriodora* subsp. *variegata* +/- *Eucalyptus crebra* open forest (RE 12.9–10.2). If the only floristic difference is in the shrub layer, then at least one other criterion (structure or landscape) must also be satisfied;
  or
- If canopy matches established regional ecosystem, then a distinct, consistently present (>50% sites) ground layer that is dominated by different species/growth form from established regional ecosystem, for example, *Acacia georginae* low open woodland with *Astrebla* spp. dominated ground layer (RE 4.9.14) or *Acacia georginae* tall open shrubland with *Triodia* spp.

dominated ground layer (RE 4.5.7). If the only floristic difference is in the ground layer then at least one other criterion (structure or landscape) must also be satisfied.
or

- **Landscape:** Dominant species and vegetation description may fit established regional ecosystem, but occur on different landform and/or geological substrate from established regional ecosystem.
or
- **Structural:** Floristic description matches established association or sub-association, but the structural formation consistently occurs outside the structural range for the established association or sub-association, such as different Specht (1970) structural formation. Generally ecosystems are not differentiated on structure unless the landscape criteria or the ecosystem occupies a distinct geographical range.

A5.2 New vegetation community

All requirements must be met, and at least one of the criteria conditions satisfied. It is expected in the majority of cases that a number of criteria will be satisfied: that is, a change in land zone or landscape position will be reflected in a change in floristics or structure.

A5.2.1 Requirements

All requirements must be met.

- **Area:** Total pre-clearing area >100 ha, or if <100 ha then at least three distinct patches. The mapped area may be less than these thresholds where the vegetation community is not consistently mappable and ground truthing has confirmed that the area requirements are met.
- **Information:** Adequate information to assess the species, structure and landscape criteria is required. This will generally be in the form of secondary or tertiary site data but may also be in the form of detailed vegetation and habitat descriptions.
- **Equivalence check:** Checked for equivalence with existing vegetation communities.
- **Consultation:** Other botanists/experts for bioregion consulted

A5.2.2 Criteria

At least one of the criteria conditions satisfied.

- **Floristic:** Dominant canopy species different (if monospecific) from established vegetation communities.
or
- Combination of dominant and subdominant canopy species (species making up bulk of the biomass) different from an established vegetation community. If the only floristic difference is in the subdominant canopy species, then at least one other criterion (structure or landscape position) must also be satisfied.
- If canopy matches an established vegetation community, then a distinct, consistently present (>50% sites) shrub layer with at least 10% projective foliage cover, for example, *Eucalyptus populnea* woodland with *Eremophila mitchellii* shrub layer (vegetation unit 48, Neldner 1984), *Eucalyptus populnea* grassy woodland (vegetation unit 42, Neldner 1984).
or
- If canopy matches an established vegetation community, then a distinct, consistently present (>50% sites) ground layer that is dominated by different species/growth form from established vegetation community, for example, *Acacia georginae* low open woodland with *Astrebla* spp. dominated ground layer (vegetation unit 10a, Neldner 1991) or *Acacia georginae* tall open shrubland with *Triodia* spp. dominated ground layer (vegetation unit 28a, Neldner 1991).
or
- **Structural:** Floristic description matches established association or sub-association, but the structural formation consistently occurs outside the structural range for the established association or sub-association, such as different Specht (1970) structural formation with at least 2 m difference in height and at least 5% projective foliage cover from established Specht formations. Generally units are not separated on structure unless there is a consistent environmental correlate (geology, soils, landform) or sub-dominant species.

Appendix 6. Glossary

alliance a group of floristically related associations of similar structure

alien any species denoted by an * (considered naturalised in Queensland) in Brown, 2021; also any native species known to be naturalised outside its known natural distribution, e.g. *Corymbia torelliana* and *Schefflera actinophylla* in the Moreton Region.

anthropogenic caused by humans.

anthropogenic clearing killing of plants/ vegetation by deliberate human action such as mechanical or chemical clearing.

associated species any species is present in a stratum but does not contribute more than 10% of the total biomass of the stratum in which it occurs.

association a vegetation community where the predominant stratum has 'a qualitatively uniform floristic composition and which exhibits a uniform structure as a whole'. This is based on the definition of Beadle and Costin (1952) but the predominant (one with most biomass, Neldner 1984) rather than the dominant (tallest) stratum is used.

bare ground the amount of ground surface not covered by litter, coarse woody debris, cryptogams, water, manure or rock.

basal area a measure of the total cross-section area of stems at breast height (1.3 metres above the ground).

benchmarks the mean value of the range in the natural variability within a particular regional ecosystem that is relatively unmodified by humans since European settlement, based on Best-on-Offer (BOO) or reference sites.

Best-on-Offer (BOO) or reference sites sites in a regional ecosystem that is mature and relatively unmodified by human management since European settlement.

bioregion (biogeographical region) an area of land that comprises broad landscape patterns that reflect major structural geologies and climate, as well as major floristic and faunal assemblages (from Sattler and Williams 1999).

brief description the description of the regional ecosystem or vegetation type provided in the map legend. This description is listed under the *Vegetation Management Act 1999* regulation

broad vegetation groups (BVGs) a higher-level grouping of vegetation units (or regional ecosystems) (see Neldner et al. 2021).

canopy is the stratum (or layer) formed collectively by the crowns of adjacent trees or shrubs. It may be continuous or discontinuous. **The canopy** refers to the predominant stratum. This definition is more specific that that used by Beadle and Costin (1952) who include the cover for the community as a whole (i.e. across all tree layers) as well as one of its component layers.

canopy cover is the cover, measured as crown cover or projective foliage cover, of the canopy.

characteristic species any species that typically occurs within the vegetation association, regional ecosystem or stratum. This includes any species found at a reference site or an area of undisturbed vegetation, or listed in the detailed description of the regional ecosystem in (Queensland Herbarium 2019 or subsequent versions) or listed in a technical description for the vegetation community, regional ecosystem or stratum that is being assessed.

clearing means vegetation has been removed, cut down, ring-barked, pushed over, poisoned, or destroyed by burning flooding or draining, but does not include destroying vegetation by stock or lopping a standing tree.

coarse woody debris (CWD) logs or dead timber on the ground that is >10 cm diameter and >50cm long, and >80% in contact with the ground (Eyre et al. 2015).

codominant species where two or more species contribute more or less equally to form the dominant above-ground biomass of a particular stratum.

CORVEG Queensland Herbarium database for site data, now upgraded and replaced by Queensland Biodiversity and Ecology Information System (QBEIS).

crown cover (%) *sensu* Walker and Hopkins (1991) is the percentage of the ground surface covered by the vertical projection of the periphery of plant crowns. Crowns are treated as opaque meaning that small gaps within the crown are ignored. Crown cover (%) of a stratum is measured for the stratum as a whole i.e. ignoring crown overlaps within a stratum.

cryptogams cryptogammic soil crusts comprising lichens, bryophytes and an assortment of microscopic organisms.

dense the structure category where the crown cover is greater than 80% (Hnatiuk et al. 2009, Table 17).

dominant species (= predominant species) a species that contributes most to the overall above-ground biomass of a particular stratum.

dominant layer or species is the layer or species making the greatest contribution to the overall biomass of the site and the vegetation community. Equivalent to the predominant layer or species.

ecologically dominant layer is the layer making the greatest contribution to the overall biomass of the site and the vegetation community (NLWRA 2001).

encroachment is where a regional ecosystem on a pre-clearing map has changed to a different regional ecosystem.

emergent layer/stratum the tallest layer/stratum is regarded as the emergent layer if it does not form the most above-ground biomass, regardless of its canopy cover, e.g. *Eucalyptus populnea* trees above a low woodland of mulga.

foliage cover (*sensu* Walker and Hopkins 1992 after Carnahan 1977) is the percentage of the ground occupied by the vertical projection of foliage and branches. This is the same as projected plant cover and is between 0 and 10% higher than pfc (Armston et al. 2009, figure 5).

frequently occurring species a species that has a constancy value of greater than 50%.

grass any plant of the family Gramineae or Poaceae, characterised by jointed stems, sheathing leaves, flower spikelets, and fruit consisting of a seed-like grain or caryopsis (true grasses).

grassland vegetation dominated by grasses that at a landform pattern scale consistently has no or minimal woody emergent trees or shrubs, being <1% emergent crown cover. Grassland regional ecosystems are identified / listed in the Vegetation Management Regional Ecosystem Description Database. (DoR, 2023)

gravel particle size from 2 to 60 mm (McDonald and Isbell 1990).

heterogeneous polygon is a polygon (area delineated on a map) that has more than one vegetation or regional ecosystem code. The Queensland Herbarium has an upper limit of five codes by polygon.

high-value regrowth vegetation means vegetation located—(a) on freehold land, indigenous land, or land subject of a lease issued under the *Land Act 1994* for agriculture or grazing purposes or an occupation licence under that Act; and (b) in an area that has not been cleared (other than for relevant clearing activities) for at least 15 years, if the area is—(i) an endangered regional ecosystem; or (ii) an of concern regional ecosystem; or (iii) a least concern regional ecosystem.

land zone land zones represent major differences in geology and in the associated landforms, soils, and physical processes that give rise to distinctive landforms or continue to shape them. The twelve different land zones in Queensland are defined in Wilson and Taylor (2012) and listed on the Queensland Government website.

layer in a vegetation community produced by the occurrence at approximately the same level (height) of an aggregation of plants of the same habit (Beadle and Costin 1952).

litter (also organic litter) includes both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter (Eyre et al. 2015).

map a systematic representation of all or part of the earth on a flat surface.

map unit a map unit contains a relatively uniform photo-pattern of vegetation delineated to maximise homogeneity within boundaries and maximise differences between boundaries. The term is synonymous with unique mapping area (UMA) and polygon.

method(s) is a mode of procedure, especially an orderly or systematic mode: *a method of instruction*.

methodology is the science of method, especially dealing with the logical principles underlying the organisation of the various special sciences, and the conduct of scientific inquiry.

mid-dense the structure category where the crown cover ranges from 50–80% (Hnatiuk et al. 2009, Table 17).

minimal area used here in the sense of sampling for species diversity. Hopkins (1956) and Mueller-Dombois and Ellenberg (1974) provided further details on the method for determination of minimal area and layout of nested quadrats. Minimal area for sampling structural attributes (Story and Paine 1984) needs to be determined.

mixed ecosystems REs/vegetation communities where no one or more species combined make 50% or more of the crown cover of the EDL (Hnatiuk et al. 2009).

native a plant taxa that have evolved in Queensland unaided by human intervention, or have migrated to and persist in Queensland unaided by human intervention. This does not include taxa that are naturalised to Queensland or a particular bioregion. Brown, 2021, lists plant taxa that are accepted as native to Queensland.

naturalised plant taxa that have originated outside Queensland or a bioregion that have been introduced to Queensland or a bioregion by or with the help of human intervention, and persist there unaided by human intervention. Brown, 2021, lists plant taxa that are naturalised in Queensland or particular pastoral districts.

non-remnant vegetation all vegetation that is not mapped as remnant vegetation. May include regrowth, heavily thinned or logged and significantly disturbed vegetation that fails to meet the structural and/ or floristic characteristics of remnant vegetation. It also includes urban and cropping land. Non-remnant vegetation may retain significant biodiversity values.

non-woody vegetation the vegetation in which the predominant stratum is composed of grasses and /or other non-woody vegetation.

organic litter (also litter) includes both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter (Eyre et al. 2015).

outlier a regional ecosystem that does not match the description of a regional ecosystem in the bioregion in which is occurs, but matches the definition of an RE in an adjacent bioregion, and has a pre-clearing distribution in the bioregion of less than about 1000 ha and the closest edge of the polygon occurs within about 50 km of the bioregion boundary.

polygon in mapping terminology, a polygon is an area enclosed by lines on a map.

polygon proportions the proportion of each polygon occupied by the attributed vegetation types or regional ecosystems.

pre-clearing extent of vegetation (or regional ecosystems) the vegetation present before clearing.

pre-1750 or pre-European vegetation (or regional ecosystems) these terms generally equate with pre-clearing vegetation as defined above. Vegetation boundaries are dynamic, and many are likely to have moved in the last 220 years. Pre-1750 vegetation is a widely used standard for recording vegetation prior to major impacts from non-indigenous people, e.g. altered fire regimes, introduction of grazing animals, etc. It has also been referred to as pre-European vegetation.

predominant species a species that contributes most to the overall above-ground biomass of a particular stratum.

predominant stratum (or layer) the stratum (or layer) that contains the greatest amount of above-ground vegetation biomass. This is also referred to as the ecologically dominant layer or stratum or the predominant canopy in woody ecosystems.

primary site synonymous with reference sites or detailed field sites. The main function of primary sites is for research purposes including monitoring changes such as those caused by fire, grazing and the effect of weeds. These sites may be chosen as type localities for vegetation types.

projective foliage cover (pfc) (*sensu* Specht 1974, Walker and Hopkins 1992) is the percentage of the ground occupied by the vertical projection of foliage. This is the same as foliage protected cover (fpc) measured by SLATS (Armston et al. 2009).

province see subregion.

QBEIS Queensland Biodiversity and Ecology Information System—Queensland Herbarium database for site data.

QSIS Queensland Spatial Information System http://dds.information.qld.gov.au/dds/

quaternary site notes collected while traversing and relates to the vegetation type by structure, predominant species and geology with GPS location.

rainforest follows the definition by Webb (1978) for rainforest in Australia. Rainforests typically occur as scattered patches of varying sizes and interspersed with *sclerophyllous* elements. The opacity, texture and colour of its closed canopy readily sets it apart from most other vegetation. Rainforest trees are closely spaced with the crowns arranged in one or more continuous storeys or strata, the uppermost of which forms the closed canopy, which may be even, uneven or very broken and in places descends to ground level. Rainforest is distinguished from other closed canopy forests by the prominence of characteristic life forms such as epiphytes, lianes, root and stem structures and by the absence of annual herbs on the forest floor.

REDD is the Regional Ecosystem Description Database which contains the latest descriptions of regional ecosystems. These are available via (Queensland Herbarium 2023) or subsequent versions.

reference or Best-On-Offer (BOO) site site in a regional ecosystem that is mature, and relatively unmodified by human management since European settlement.

reference state the ecological state of a regional ecosystem that is mature, and relatively unmodified by human management since European settlement.

regional ecosystem means a vegetation community or communities in a bioregion that is consistently associated with a particular combination of geology, landform and soil. Regional ecosystems of Queensland were originally described in Sattler and Williams (1999). The Regional Ecosystem Description Database (Queensland Herbarium 2023) is maintained by Queensland Herbarium and contains the current descriptions of regional ecosystems.

regrowth vegetation is non-remnant vegetation that has a significant woody component but fails to meet the structural and/or floristic characteristics of remnant vegetation. Includes vegetation that has regrown after clearing or been heavily thinned or logged and may retain significant biodiversity values.

relative reliability the level of confidence placed on the proportions of the vegetation types listed for each polygon. Relative reliability depends on predictability, distribution and density of traverses, and distribution and density of sites.

remnant map a map showing remnant vegetation (*Vegetation Management Act 1999*).

remnant vegetation is vegetation, part of which forms the predominant canopy of the vegetation—

(a) covering more than 50% of the undisturbed predominant canopy

(b) averaging more than 70% of the vegetation’s undisturbed height

(c) composed of species characteristic of the vegetation’s undisturbed predominant canopy.

remnant vegetation cover the digital coverage (or hard-copy map) that shows the distribution of vegetation that is regarded as remnant vegetation. A map showing remnant vegetation cover is the same as a ‘remnant map’ defined under the *Vegetation Management Act 1999*.

rock rocky materials >6cm diameter, equates to boulders, stones and cobbles in Speight and Isbell (2009).

secondary site a level of detail in QBEIS site sampling method. Includes environmental information and all species with measures of basal area, cover and stem density.

site an area of vegetation with relatively uniform structure, floristics and geology where botanical data are collected such as primary, secondary, tertiary or quaternary sites. For trees, the site includes the area covered by a basal area sweep (Bitterlich stick or prism).

SLATS is the State Land and Tree Study, a remote sensing project of the Remote Sensing Centre, Department of Environment, Science and Innovation.

sparse the structure category where the crown cover ranges from 20–50% (Hnatiuk et al. 2009, Table 17).

stratum see layer.

structural formation the structural class combined with the dominant life form of a vegetation community, e.g. open forest.

structure the spatial arrangement of plants within a vegetation community (Beadle and Costin 1952).

subcanopy refers to the layer immediately below the ecological dominant layer.

subdominant species a species is considered to be subdominant when it contributes less biomass than the dominant species, but occurs as more than an isolated individual. As a general rule, the species must individually contribute more than an associated species i.e. more than 10% of the total biomass of the stratum in which it occurs.

subregion (province) a subdivision of a bioregion. Subregions delineate the major geomorphic patterns within bioregions (Morgan 2001) and may be defined by a suite of land systems, geological units and associated landforms, or environmental domains. Subregions are referred to as provinces in Sattler and Williams (1999).

technical description of the vegetation community or regional ecosystem is provided in the text of the technical description report. The descriptions consist of a list of the predominant species and commonly occurring species within the structural layers, the overall structure and a description of the landscape. Finalised technical descriptions are available on the Queensland government (e.g. Addicott and Newton 2012).

tertiary site a level of detail in QBEIS site sampling method. Includes environmental information and all woody species with measures of basal area and cover by layer.

traverse the route travelled by vehicle or on foot in the field. For determination of relative reliability it represents a record of where the surveyor has been and is an index to the amount of informal observations.

understorey any stratum below (i.e. lower height than) the predominant stratum. Used in the rainforest classification of Webb (1978).

undisturbed vegetation layer (canopy) means the layer (canopy) the vegetation normally has.

vegetation code (veg) a vegetation code that is applied consistently across bioregion or map sheet. It frequently represents an amalgamation of vegetation sub-associations or vegetation units that have been mapped at larger scales in various parts of the study area but have similar structural and floristic attributes. Used to form a consistent legend across a bioregion where component map sheets have been mapped by a number of botanists.

unique mapping area (UMA) a unique mapping area contains a relatively uniform photo-pattern delineated to maximise homogeneity within boundaries and maximise differences between boundaries. The term is synonymous with the term ‘polygon’. Unique mapping areas may consist of single vegetation units or mosaics of units.

vegetation the entirety of the plant cover at a point on the earth’s surface at a particular time. It is the spatial and temporal expression of the flora of an area, as expressed in plant assemblages (communities) which consist of individual species with varied lifeforms (Raunkiaer 1934). The present vegetation is a reflection not only of the site potential as determined by climatic, physiographic, edaphic and biotic factors (Webb et al. 1970; Gunn et al. 1988), but also the history of land use and disturbance. Irregular catastrophic events, e.g. intense fires, prolonged droughts and clearing, whether natural or human-induced, can be important factors determining the floristic composition and structure of present day vegetation (Mueller-Dombois and Ellenberg 1974; Neldner 1984).

vegetation community (equivalent to land type in Sattler and Williams 1999) is an area of vegetation which is relatively uniform with respect to structure and floristics The basic unit in the vegetation community classification within the regional ecosystem classification is the plant association or sub-association . A number of vegetation communities may make up a single regional ecosystem, and are usually distinguished by differences in dominant species composition, frequently in the shrub or ground layers and denoted by a letter following the regional ecosystem code (e.g. a, b, c).

Vegetation Management Act 1999 an Act to regulate the clearing of vegetation.

vegetation map a map whose primary purpose is to show the geographical distribution of the various vegetation types of a given area.

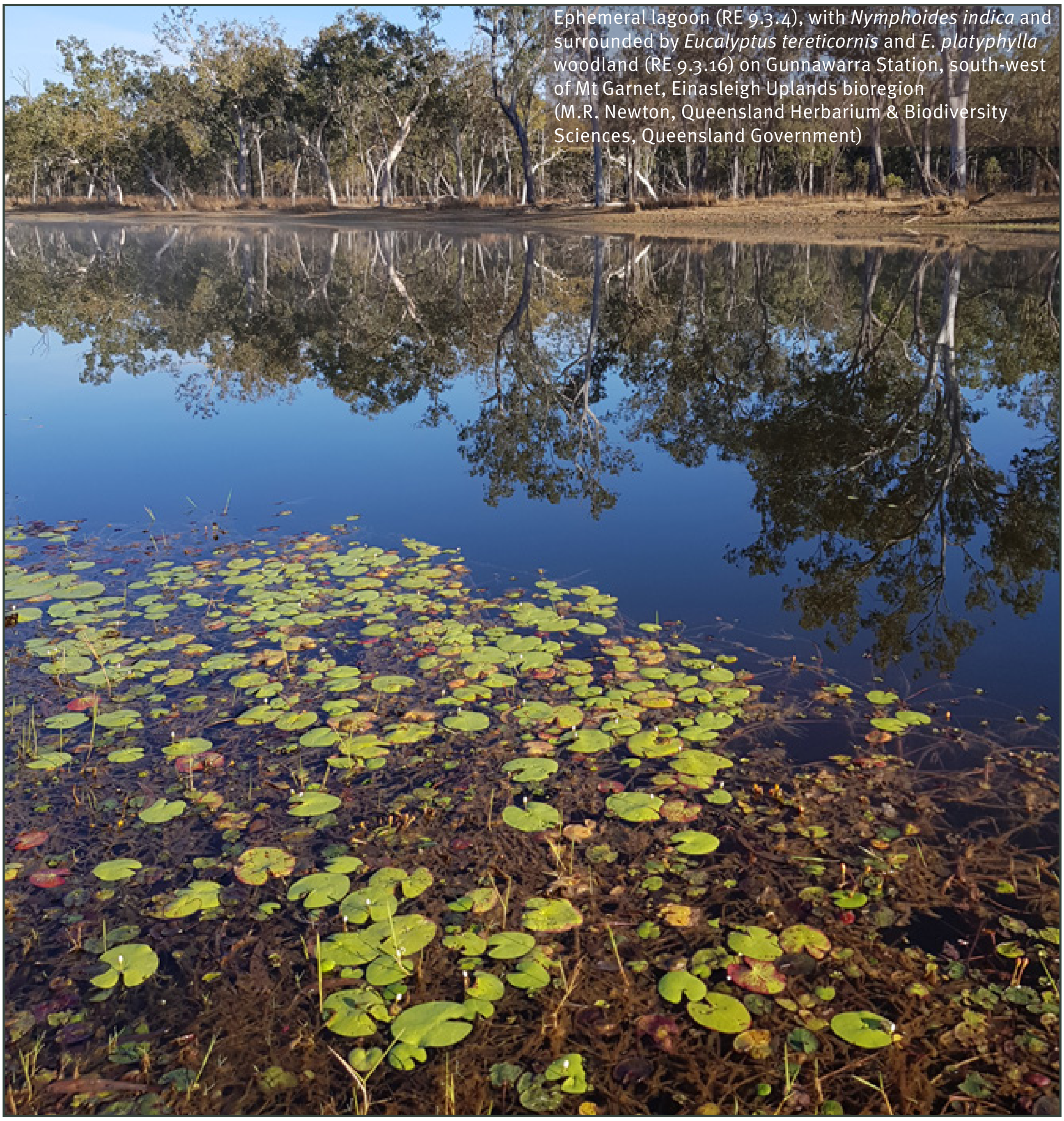
vegetation map unit a vegetation community that has been mapped consistently in the study area at the scale of mapping applied.

vegetation type a plant community, described by grouping field sites that have relatively closely overlapping composition of predominant species in the predominant stratum with similar structure and geology. The definition of a vegetation type parallels that of the association (see above).

very sparse the structure category where the crown cover is less than 20% (Hnatiuk et al. 2009, Table 17).

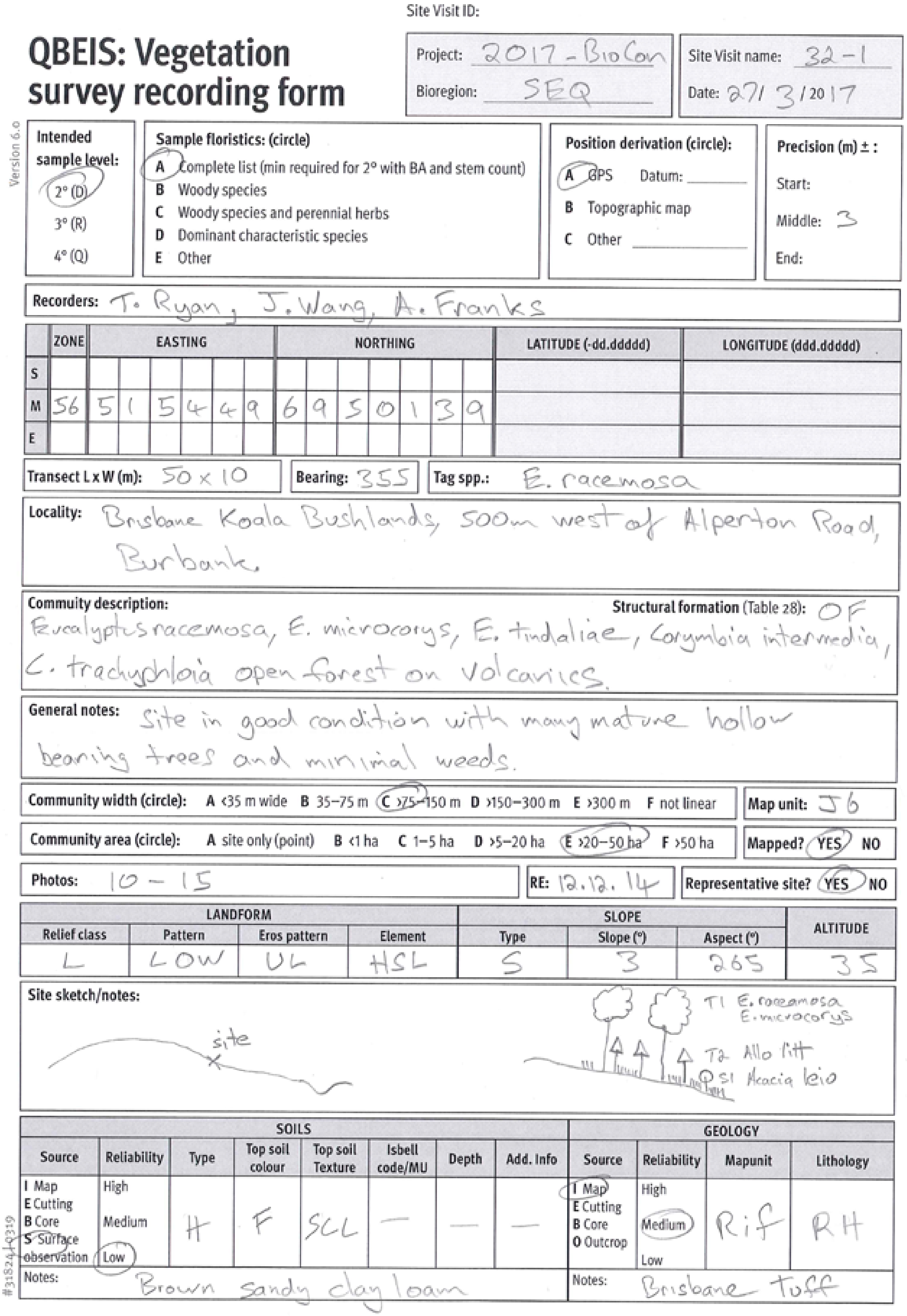
woody grassland vegetation dominated by grasses that at a landform pattern scale consistently has some woody emergent trees or shrubs, being>1% emergent crown cover. Woody grassland regional ecosystems are identified / listed in the Vegetation Management Regional Ecosystem Description Database. (DoR, 2023)

woody vegetation the vegetation for which the ecologically dominant stratum is composed of trees or shrubs.



Ephemeral lagoon (RE 9.3.4), with *Nymphoides indica* and surrounded by *Eucalyptus tereticornis* and *E. platyphylla* woodland (RE 9.3.16) on Gunnawarra Station, south-west of Mt Garnet, Einasleigh Uplands bioregion (M.R. Newton, Queensland Herbarium & Biodiversity Sciences, Queensland Government)

Appendix 7. Completed QBEIS proforma



Site Visit ID:

QBEIS: Vegetation survey recording form

Project: 2017-BioCon
Bioregion: SEQ

Site Visit name: 32-1
Date: 27/ 3/2017

Version 6.0

Intended sample level:
[✓ 2° (D)]
3° (R)
4° (Q)

Sample floristics: (circle)
[✓ A Complete list (min required for 2° with BA and stem count)]
B Woody species
C Woody species and perennial herbs
D Dominant characteristic species
E Other

Position derivation (circle):
[✓ A GPS] Datum: ______
B Topographic map
C Other ______

Precision (m) ± :
Start:
Middle: 3
End:

Recorders: T. Ryan, J. Wang, A. Franks

	ZONE	EASTING						NORTHING							LATITUDE (-dd.ddddd)	LONGITUDE (ddd.ddddd)
S																
M	56	5	1	5	4	4	9	6	9	5	0	1	3	9		
E																

Transect L x W (m): 50 x 10
Bearing: 355
Tag spp.: E. racemosa

Locality: Brisbane Koala Bushlands, 500m west of Alperton Road, Burbank.

Commuity description: Eucalyptus racemosa, E. microcorys, E. tindaliae, Corymbia intermedia, C. trachyphloia open forest on volcanics.

Structural formation (Table 28): OF

General notes: Site in good condition with many mature hollow bearing trees and minimal weeds.

Community width (circle): A <35 m wide B 35–75 m [✓ C >75–150 m] D >150–300 m E >300 m F not linear

Map unit: J6

Community area (circle): A site only (point) B <1 ha C 1–5 ha D >5–20 ha [✓ E >20–50 ha] F >50 ha

Mapped? [✓ YES] NO

Photos: 10 – 15

RE: 12.12.14

Representative site? [✓ YES] NO

LANDFORM				SLOPE			ALTITUDE
Relief class	Pattern	Eros pattern	Element	Type	Slope (°)	Aspect (°)	
L	LOW	UL	HSL	S	3	265	35

Site sketch/notes:

site

T1 E. racemosa
E. microcorys

T2 Allo litt

S1 Acacia leio

SOILS								GEOLOGY			
Source	Reliability	Type	Top soil colour	Top soil Texture	Isbell code/MU	Depth	Add. Info	Source	Reliability	Mapunit	Lithology
I Map E Cutting B Core [✓ S Surface observation]	High Medium [✓ Low]	H	F	SCL	–	–	–	[✓ I Map] E Cutting B Core O Outcrop	High [✓ Medium] Low	Rif	RH
Notes: Brown sandy clay loam								Notes: Brisbane Tuff			

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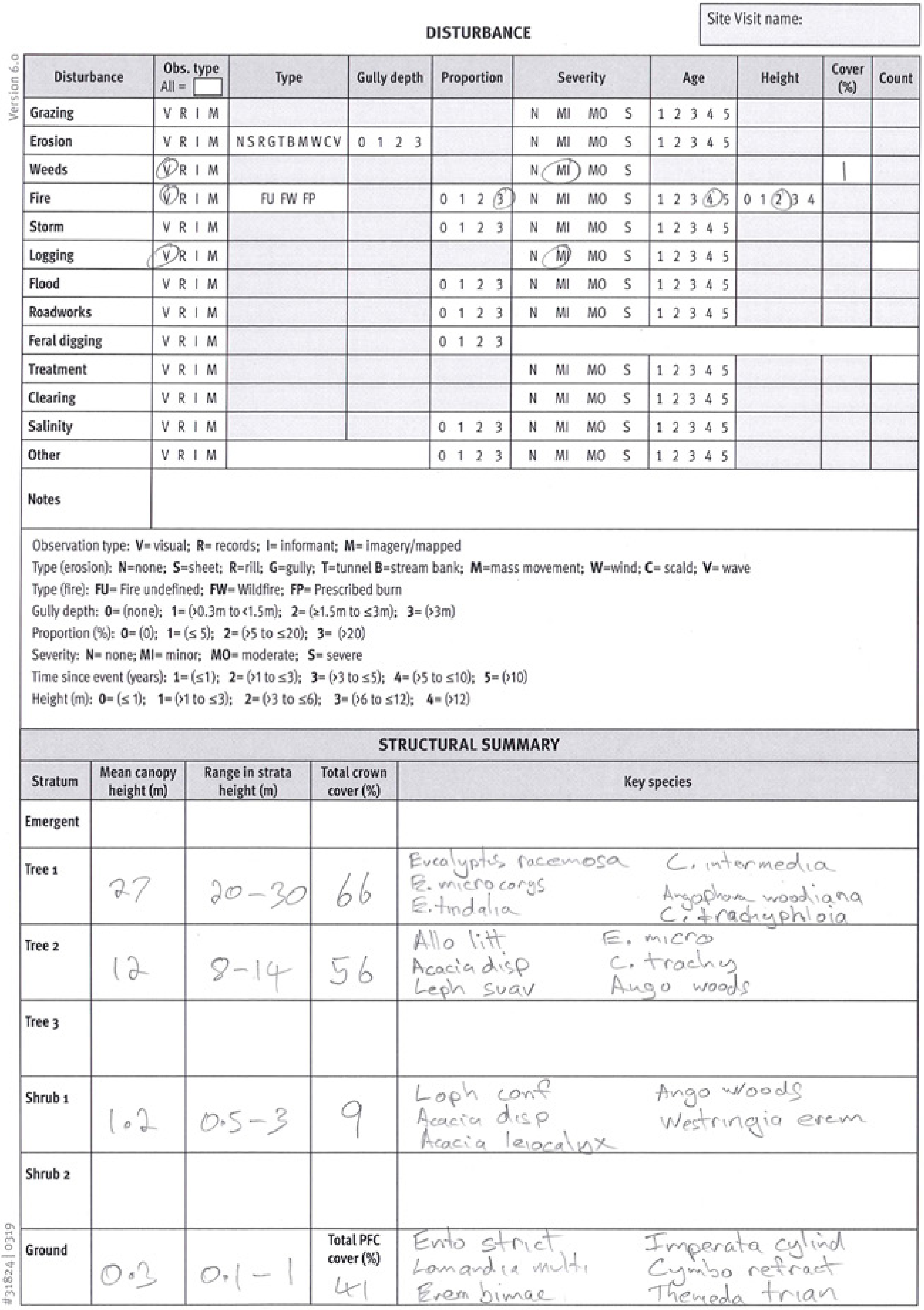

Site Visit name:

Version 6.0

DISTURBANCE

Disturbance	Obs. type All = ☐	Type	Gully depth	Proportion	Severity	Age	Height	Cover (%)	Count
Grazing	V R I M				N MI MO S	1 2 3 4 5			
Erosion	V R I M	N S R G T B M W C V	0 1 2 3		N MI MO S	1 2 3 4 5			
Weeds	[✓ V] R I M				N [✓ MI] MO S			1	
Fire	[✓ V] R I M	FU FW FP		0 1 2 [✓ 3]	N MI MO S	1 2 3 [✓ 4] 5	0 1 [✓ 2] 3 4		
Storm	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Logging	[✓ V] R I M				N [✓ MI] MO S	1 2 3 4 5			
Flood	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Roadworks	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Feral digging	V R I M			0 1 2 3					
Treatment	V R I M				N MI MO S	1 2 3 4 5			
Clearing	V R I M				N MI MO S	1 2 3 4 5			
Salinity	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Other	V R I M			0 1 2 3	N MI MO S	1 2 3 4 5			
Notes									

Observation type: **V**= visual; **R**= records; **I**= informant; **M**= imagery/mapped
Type (erosion): **N**=none; **S**=sheet; **R**=rill; **G**=gully; **T**=tunnel **B**=stream bank; **M**=mass movement; **W**=wind; **C**= scald; **V**= wave
Type (fire): **FU**= Fire undefined; **FW**= Wildfire; **FP**= Prescribed burn
Gully depth: **0**= (none); **1**= (>0.3m to <1.5m); **2**= (≥1.5m to ≤3m); **3**= (>3m)
Proportion (%): **0**= (0); **1**= (≤ 5); **2**= (>5 to ≤20); **3**= (>20)
Severity: **N**= none; **MI**= minor; **MO**= moderate; **S**= severe
Time since event (years): **1**= (≤1); **2**= (>1 to ≤3); **3**= (>3 to ≤5); **4**= (>5 to ≤10); **5**= (>10)
Height (m): **0**= (≤ 1); **1**= (>1 to ≤3); **2**= (>3 to ≤6); **3**= (>6 to ≤12); **4**= (>12)

STRUCTURAL SUMMARY

Stratum	Mean canopy height (m)	Range in strata height (m)	Total crown cover (%)	Key species
Emergent				
Tree 1	27	20–30	66	Eucalyptus racemosa E. microcorys E. tindalia C. intermedia Angophora woodiana C. trachyphloia
Tree 2	12	8–14	56	Allo litt Acacia disp Leph suav E. micro C. trachy Ango woods
Tree 3				
Shrub 1	1.2	0.5–3	9	Loph conf Acacia disp Acacia leiocalyx Ango woods Westringia erem
Shrub 2				
Ground	0.3	0.1 – 1	Total PFC cover (%) 41	Ento strict Lomandra multi Erem bimae Imperata cylind Cymbo refract Themeda trian

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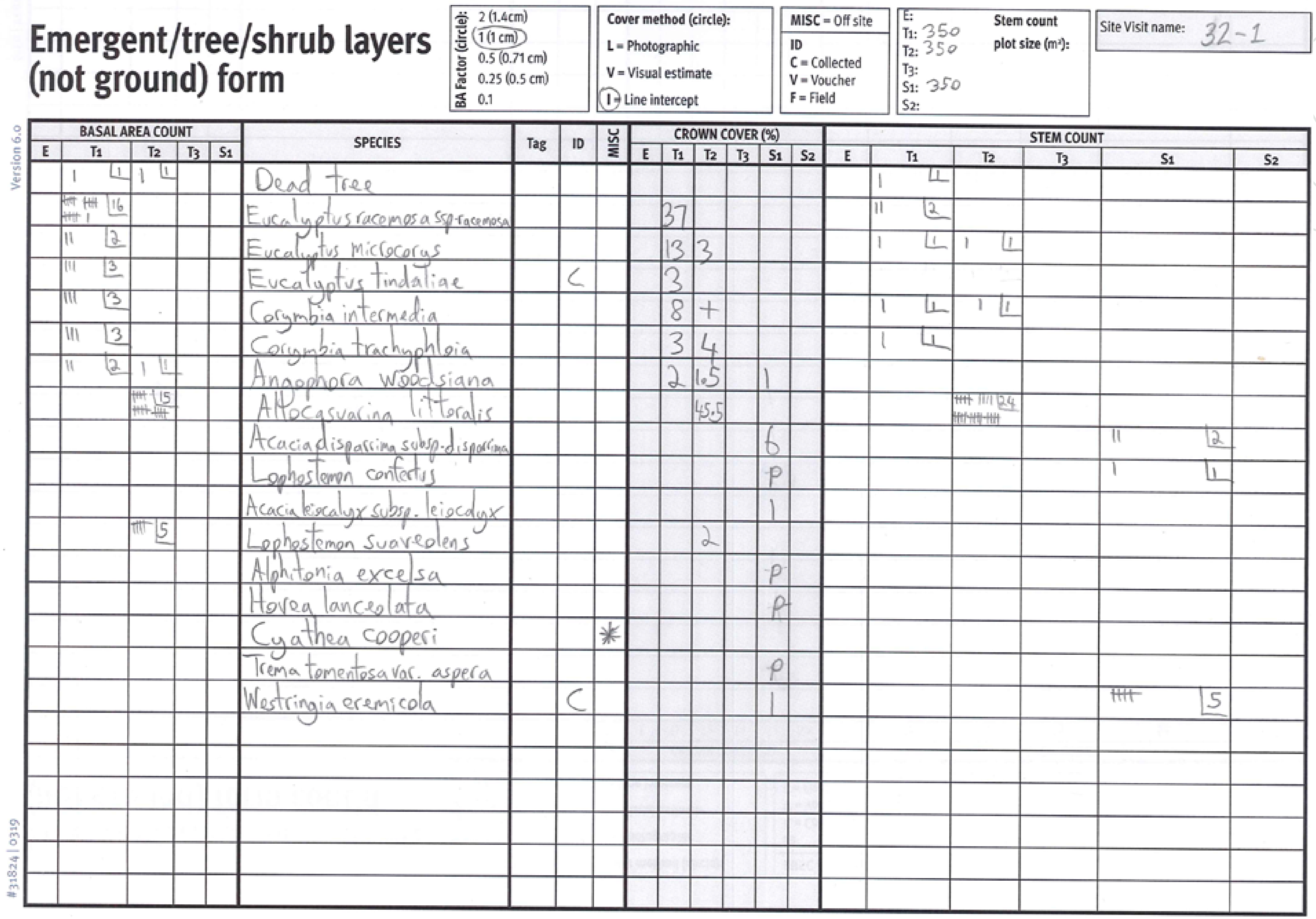

Emergent/tree/shrub layers (not ground) form

BA Factor (circle): 2 (1.4cm) [✓ 1 (1 cm)] 0.5 (0.71 cm) 0.25 (0.5 cm) 0.1

Cover method (circle):
L = Photographic
V = Visual estimate
[✓ I = Line intercept]

MISC = Off site
ID
C = Collected
V = Voucher
F = Field

E:
T1: 350
T2: 350
T3:
S1: 350
S2:
Stem count plot size (m²):

Site Visit name: 32-1

BASAL AREA COUNT									CROWN COVER (%)						STEM COUNT					
E	T1	T2	T3	S1	SPECIES	Tag	ID	MISC	E	T1	T2	T3	S1	S2	E	T1	T2	T3	S1	S2
	| 1	| 1			Dead tree											| 1				
	𝍸 𝍸 𝍸 | 16				Eucalyptus racemosa ssp. racemosa					37						|| 2				
	|| 2				Eucalyptus microcorys					13	3					| 1	| 1			
	||| 3				Eucalyptus tindaliae		C			3										
	||| 3				Corymbia intermedia					8	+					| 1	| 1			
	||| 3				Corymbia trachyphloia					3	4					| 1				
	|| 2	| 1			Angophora woodsiana					2	1.5		1							
		𝍸 𝍸 𝍸 15			Allocasuarina littoralis						45.5						𝍸 |||| 𝍸 𝍸 𝍸 24			
					Acacia disparrima subsp. disparrima								6						|| 2	
					Lophostemon confertus								P						| 1	
					Acacia leiocalyx subsp. leiocalyx								1							
		𝍸 5			Lophostemon suaveolens						2									
					Alphitonia excelsa								P							
					Hovea lanceolata								P							
					Cyathea cooperi			*												
					Trema tomentosa var. aspera								P							
					Westringia eremicola		C						1						𝍸 5	

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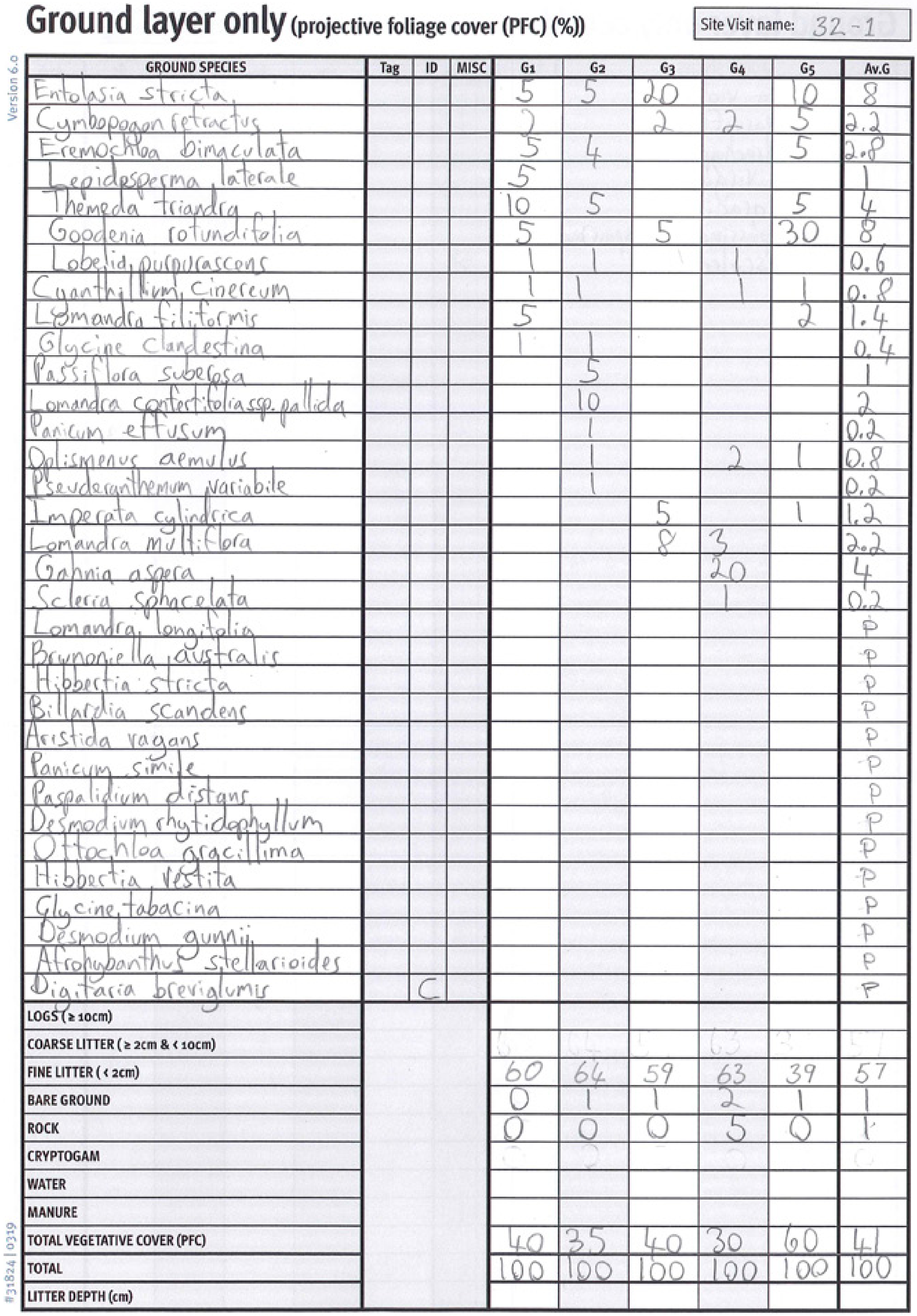

Ground layer only (projective foliage cover (PFC) (%))

Site Visit name: 32-1

GROUND SPECIES	Tag	ID	MISC	G1	G2	G3	G4	G5	Av.G
Entolasia stricta				5	5	20		10	8
Cymbopogon refractus				2		2	2	5	2.2
Eremochloa bimaculata				5	4			5	2.8
Lepidosperma laterale				5					1
Themeda triandra				10	5			5	4
Goodenia rotundifolia				5		5		30	8
Lobelia purpurascens				1	1		1		0.6
Cyanthillium cinereum				1	1		1	1	0.8
Lomandra filiformis				5				2	1.4
Glycine clandestina				1	1				0.4
Passiflora suberosa					5				1
Lomandra confertifolia ssp. pallida					10				2
Panicum effusum					1				0.2
Oplismenus aemulus					1		2	1	0.8
Pseuderanthemum variabile					1				0.2
Imperata cylindrica						5		1	1.2
Lomandra multiflora						8	3		2.2
Gahnia aspera							20		4
Scleria sphacelata							1		0.2
Lomandra longifolia									P
Brunoniella australis									P
Hibbertia stricta									P
Billardia scandens									P
Aristida vagans									P
Panicum simile									P
Paspalidium distans									P
Desmodium rhytidophyllum									P
Ottochloa gracillima									P
Hibbertia vestita									P
Glycine tabacina									P
Desmodium gunnii									P
Afrohybanthus stellarioides									P
Digitaria breviglumis		C							P
LOGS (≥ 10cm)									
COARSE LITTER (≥ 2cm & < 10cm)									
FINE LITTER (< 2cm)				60	64	59	63	39	57
BARE GROUND				0	1	1	2	1	1
ROCK				0	0	0	5	0	1
CRYPTOGAM									
WATER									
MANURE									
TOTAL VEGETATIVE COVER (PFC)				40	35	40	30	60	41
TOTAL				100	100	100	100	100	100
LITTER DEPTH (cm)									

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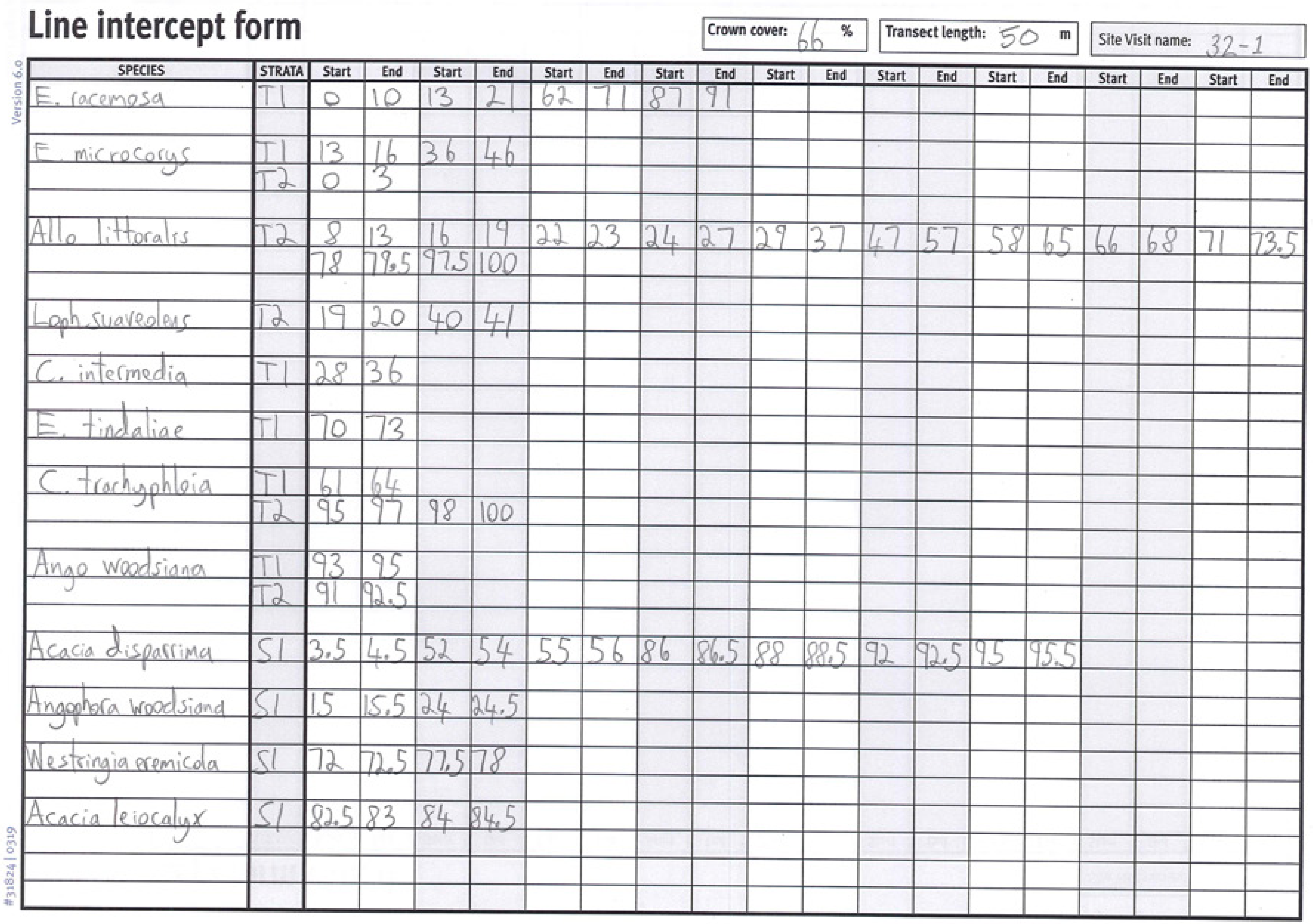
Ground layer only cont'd

Site Visit name: 32-1

GROUND SPECIES	Tag	ID	Misc	G1	G2	G3	G4	G5	Av.G
Hardenbergia violacea									P
Digitaria parviflora		C							P
Corymbia trachyphloia									P
Phyllanthus virgatus									P
Aristida gracilipes									P
Acacia disparrima ssp. disparrima									P
Pteridium esculentum			*						P



Line intercept form

Crown cover: 66 %

Transect length: 50 m

Site Visit name: 32-1

SPECIES	STRATA	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
E. racemosa	T1	0	10	13	21	62	71	87	91								
E. microcorys	T1	13	16	36	46												
	T2	0	3														
Allo littoralis	T2	8	13	16	19	22	23	24	27	29	37	47	57	58	65	66	68	71	73.5
		78	79.5	97.5	100												
Loph. suaveolens	T2	19	20	40	41												
C. intermedia	T1	28	36														
E. tindaliae	T1	70	73														
C. trachyphloia	T1	61	64														
	T2	95	97	98	100												
Ango woodsiana	T1	93	95														
	T2	91	92.5														
Acacia disparrima	S1	3.5	4.5	52	54	55	56	86	86.5	88	88.5	92	92.5	95	95.5		
Angophora woodsiana	S1	1.5	15.5	24	24.5												
Westringia eremicola	S1	72	72.5	77.5	78												
Acacia leiocalyx	S1	82.5	83	84	84.5												

Version 6.0

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BioCondition attributes

Site Visit name: 32-1

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COARSE WOODY DEBRIS

Coarse woody debris (record length in metres of all debris > 10 cm wide, ≥ 0.5 m long, and > 80% in contact with the ground)

Plot size: 50 x 20 m²

1.2, 2.3, 0.65, 4.2, 1.7, 3.8, 1.1

TOTAL (m): 14.95

Tree measures plot size (tick): ☑ 100 x 50 m² ☐ 100 x 20 m² ☐ 100 x 10 m² ☐ 50 x 10 m² ☐ m²

Eucalypts measured greater than : 30 cm

Non-Eucalypts measured greater than : 20 cm

TAG NO.	TREE SPECIES	STRATA	DIAMETER BREAST HEIGHT (DBH) measured at 1.3 m height in cm	HEIGHT (m)	NOTES
	E. racemosa	T1	60.3, 70.8, 50.3, 49		
			55.6, 78		
	E. microcorys	T1	56.2, 60, 72.4, 63		
		T2	43, 36.4, 32.3		
	Allo littoralis	T2	25.1, 32.3, 29.4, 22, 22,		
			29, 21, 26.3, 24.3, 23, 21		
			20.2, 28.2, 23, 25.3, 26		
	Loph suaveolens	T2	55.6, 52.4, 45.8		
	C. intermedia	T1	52.6, 48.9, 54		
	E. tindaliae	T1	49.2, 50.3		
	C. trachyphloia	T1	39.2, 42.3, 49.3, 37		
		T2	31.5, 32		
	Ango woodsiana	S1	21.5, 20.2, 25		
	Acacia disparrima	S1	21, 25.6, 22, 24.2, 30.1, 22		
			32, 20.5		
	Ango woodsiana	S1	22, 21.5		
	Acacia leiocalyx	S1	21		

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Appendix 8. Defining and mapping high-value regrowth (HVR)

The definition of high value regrowth (HVR) vegetation (category C) was amended in the Vegetation Management Act (VMA) on 8 March 2018. Previously it was defined as vegetation not cleared since 31 December 1989. HVR now applies to vegetation not cleared in the last 15 years on freehold land, Indigenous land and occupational licences in addition to leasehold land for agriculture and grazing.

High Value Regrowth is defined in the Dictionary of the VMA: high value regrowth vegetation means vegetation located:

(a) on freehold land, indigenous land, or land subject of a lease issued under the *Land Act 1994* for agriculture or grazing purposes or an occupation licence under that Act; and

(b) in an area that has not been cleared (other than for relevant clearing activities) for at least 15 years, if the area is:
  (i) an endangered regional ecosystem; or
  (ii) an of concern regional ecosystem; or
  (iii) a least concern regional ecosystem.

Remnant vegetation is mapped where the crown cover is at least 50% of the crown cover for that regional ecosystem, as recorded in Benchmark or the mean crown cover value in the technical description for the RE. Regrowth can vary depending on the type of clearing, post-clearing management treatment and seasonal events, hence for high value regrowth (HVR) the constraints of requiring the dominance of native species with at least 50% of the crown cover for that regional ecosystem ensures that the regrowth is a functional regional ecosystem and on the trajectory towards remnant vegetation.

For vegetation to be determined as HVR, the minimum crown cover percentage figures for the appropriate vegetation structure class for the RE given in Table 30 must be met. Each RE is assigned a vegetation structure class (very sparse, sparse, mid-dense and dense) which follow the crown cover classes of Hnatiuk *et al.* 2009, Table 17 in the Regional Ecosystem Description Database (REDD).

Table 30 Structure class thresholds to be used for high value regrowth determination

Vegetation structure classification	Percentage of crown cover representative of that vegetation structure category	Minimum crown cover percentage required
Very sparse	<20%	5%
Sparse	20–50%	10%
Mid-dense	50–80%	25%
Dense	80–100%	40%

A8.2.1 Mapping of high-value regrowth (HVR) vegetation

The high value regrowth map was initially created in 2018 and was produced by first classifying potential or ‘candidate’ HVR woody vegetation using an automated process and data products generated by the Statewide Landcover and Trees Study (SLATS). A simple ruleset was applied to the SLATS clearing data, combined with the SLATS foliage projective cover data, which is an estimate of woody vegetation foliage cover derived from the analysis of a long (~30 year) time-series of Landsat satellite imagery. The 2014 foliage projective cover data set was used for this exercise.

The ruleset applied to identify ‘candidate’ HVR was as follows:

1. The location had been mapped as cleared by SLATS between 1988 and 2002; and,
2. The location had not been mapped as cleared by SLATS since 2002; and,
3. The location had a foliage projective cover of 11% or greater in coastal regions and 5% or greater in inland or western regions; and,
4. The location was Category X in the Regulated Vegetation Map.

Additional exclusions were applied to the derived output to exclude:

- areas covered by a property map of assessable vegetation (PMAV)
- areas of cropping, plantation, orchards or intensive land use
- tenures not covered by VMA (e.g. National Parks, State Forests)

The output of 'candidate' HVR derived from this process was then subject to comprehensive manual visual checking and editing of boundaries using high resolution imagery (2016 and 2017 80cm pixel Earth-i imagery) by botanists from the Department of Environment, Science and Innovation to refine boundaries and remove errors such as small plantations, gardens and areas dominated by weedy non-native vegetation, e.g. invasive species such as camphor laurel (*Cinnamomum camphora*) or lantana (*Lantana camara*). The HVR data has been updated using the most recent SLATS woody vegetation data, Sentinel-2 imagery and higher resolution imagery, together with on-ground site data and visual validation of imagery by botanical experts.

In HVR polygons the preclearing vegetation will generally re-establish and form the regrowth. While this is expected to occur in the majority of cases, a different RE, novel ecosystem or non-native vegetation may regrow at a site. Therefore it is important for a field inspection to be conducted before any clearing to assign the correct RE to the regrowth. Where a HVR polygon intersects with a heterogeneous pre-clearing polygon, the REs attributed to that polygon, represent the most likely potential REs that may form the regrowth. High value regrowth maps can be viewed via Queensland Globe.

In former rainforest areas, *Acacia* species may dominate the regrowth post clearing particularly in areas isolated from remnant vegetation. *Acacia* species are pioneer components of rainforest and scrub ecosystems, which regrow rapidly in response to natural or mechanical disturbances. Where the *Acacia* species dominate regrowth, they form a very distinct canopy and a uniform 'cauliflower' pattern on aerial photos. In these circumstances, other rainforest species may be infrequent. These areas, although dominated by early successional species, can still be considered a functioning regional ecosystem as per the considerations outlined in section 2.3.4 on page 20 of this document.

Low woodland of *Corymbia erythrophloia* and *Eucalyptus similis* on rocky basalt rises (RE 9.5.1) 7 km north of Einasleigh township. (V.J. Neldner, Queensland Herbarium & Biodiversity Sciences, Queensland Government)

Appendix 9. Rainforest site data collection

A9.1 Introduction

The term 'rainforest' in this document follows the definition by Webb (1978) for rainforest in Australia. Rainforests can occur as extensive contiguous forests in the Wet Tropics and Cape York Peninsula bioregions, but more typically occur as scattered patches of varying sizes and interspersed with sclerophyllous elements. The opacity, texture and colour of its closed canopy readily sets it apart from most other vegetation. Rainforest trees are closely spaced with the crowns arranged in one or more layers or strata, the uppermost of which forms the closed canopy, which may be even, uneven or very broken and in places descends to ground level. Rainforest is distinguished from other closed canopy forests by the prominence of characteristic life forms such as epiphytes, lianes, root and stem structures and by the absence of annual herbs on the forest floor.

Lynch and Neldner (2000) have developed a typology for determining if a site is rainforest, mixed forest or non-rainforest. If there is any doubt as to whether a site is rainforest, apply the typology before choosing the data collection methods to use. If the site is not clearly rainforest then collect data according to the non-rainforest methods.

In Queensland, there are two levels of assessment for rainforest site data collection. A detailed one, equivalent to a secondary level site assessment based on methods used by CSIRO and the standard QBEIS plot method, and a less detailed one based on basal area methods, equivalent to Tertiary level site assessment. Data collection for most rainforest sites differs from non-RF sites by not collecting cover data for individual species by strata.

The primary additional data that are collected for rainforest sites are leaf size, leaf fall characteristics, structural complexity and frequency of specialty growth forms. These characteristics are required to classify rainforests into the structural types of Australian rainforests using the Webb (1978) classification (Table 29).

A9.2 Data collection overview

Secondary site assessment

In rainforests a secondary site assessment is based on a 20m x 50m plot centred at the point where the basal area sweep is made. In rainforest sites, the DBH of trees is collected instead of cover data.

Data collected include:

- Locational—as per non-rainforest QBEIS site
- Environmental—as per non-rainforest QBEIS site
- Structural (derived from trees identified in the basal area sweep)—collected using information to allow assignment of the site within the Webb classification scheme. These measures are based on the pro-forma of Goosem (1994)
- Complete floristic list including all vascular plants in all layers
- Species abundance measures of diameter at breast height (DBH), stem density and basal area are applied to all woody species. Canopy cover of each strata is collected rather than canopy cover of individual species.

Tertiary site assessment

In rainforests, a tertiary site assessment is based on a single sweep of basal area using the Bitterlich Stick method, and a 20 x 50 m2 plot centred at the point where the sweep is made.

The flow of data collection is intended to match the steps in the rainforest classification key of Webb 1978 as produced in Table 29.

Data collected include:

- Locational—as per non-rainforest QBEIS site
- Environmental—as per non-rainforest QBEIS site
- Structural (derived from trees identified in the basal area sweep)—collected using information to allow assignment of the site within the Webb classification scheme. These measures are based on the pro-forma of Goosem (1994)
- Complete floristic list including all vascular plants in all layers
- Species abundance collected using a basal area sweep for tree layers (E, T1, T2, T3) and a visual assessment of cover within a 20 x 50 m2 plot

for the S1, S2, G layers. Assigning layers within rainforest can be difficult, and the rules for determining layers from section A2.3.6 should be used to ensure consistency.

Canopy survey

To capture the full diversity of species at a site, a canopy survey for epiphytes is carried out at both secondary and tertiary rainforest sites. The method is the same for both sites. Within the plot area of 50m x 20m conduct a timed random-meander transect with binoculars until the extent of the plot is covered or for up to 30 minutes (whichever is lesser). Record the species present. If a canopy survey is not carried out it must be recorded as “not measured”.

BioCondition attributes

In addition to environmental, structural and species data, biocondition attributes are collected at secondary and tertiary rainforest sites. The same information is collected as at non-rainforest sites, using the same methods.

A9.3 Data collection in secondary rainforest sites

The standard first page of the QBEIS form is completed, followed by the detailed rainforest specific structural data.

A9.3.1 Site selection

The site should be located in an area with a uniform aspect, slope and substrate. The plot should, where possible, follow the contour, and not include changes in slope, creeks or obvious changes in vegetation.

Survey area

All strata are sampled within a 20m x 50m plot (0.1 ha) centred at the point where the basal area sweep is made.

Location and environmental information

This is the same as the standard non-rainforest QBEIS site. Use the front page of the non-rainforest QBEIS site proforma.

A9.3.2 Structural information

This information is collected to accurately use the key in Table 29 to determine the structural classification of a site according to Webb (1978).

Assess the relative abundance of individuals with each characteristic of structure category using:

- Not evident (0)
- Uncommon and/or inconspicuous (1)
- Occasional or uncommon but conspicuous (2)
- Abundant or common (3).

Leaf size

Leaf size of the sun leaves of the tallest stratum (excluding emergent) trees. It is usually easy to decide which two adjacent leaf classes are most common from a visual inspection (Webb, 1978, p356). Where this is difficult the method described by Walker and Hopkins (1990, p81) may be used in which the leaf size of ten adjacent canopy trees is assessed. Another useful field method is to collect a handful of (non-palm) leaves from the ground and measure for size. This can be verified against the species list for the canopy trees at the end of data collection. The leaf size of shaded trees in the lower layers are frequently larger than those of the canopy species and therefore may lead to an overestimate of leaf size.

Complexity

This is assessed using a number of characteristics.

Structural features

- Buttressing: Plank buttresses are those >1 m long. Less than 1 m long are considered spur buttresses.
- Different leaf types

Indicator growth forms

Assess the relative abundance of individuals of different indicator growth forms.

Stem size

A visual assessment of whether the stem sizes of the T1 layer are uniform in size.

Leaf fall characteristics

The proportion of deciduous, semi-deciduous, semi-evergreen and strictly evergreen species in the emergent and canopy strata. This may be recorded after the collection of species data, as species can be scored by leaf-fall class and a proportion calculated. To label the site use the strata that is tallest and allocate leaf-fall classes which are defined in Webb (1978) as follows.

- 'Deciduous' means species or certain individuals of a species that obligatorily lose their leaves completely each year.
- 'Semi-deciduous' indicates that most leafless species are truly deciduous but that some are facultative, i.e. leaf fall is controlled by the severity of the dry season.
- 'Semi-evergreen' means that few or none of the species are truly deciduous and that most of those that shed their leaves do so incompletely depending on the severity of the dry season.
- 'Evergreen' means species that do not loose leaves in a seasonal pattern.

Height of strata

Due to the often dense cover and continuous nature of strata in rainforest plots, it is advisable to determine strata after the DBH and height measures of individuals in the plot area have been measured. Use the 'Structural Summary' table on the first page of the QBEIS pro-forma to record strata height.

The height of each strata present is determined using the rules and guidelines outlined in section A2.5.3. Tree heights may be estimated for low (< 10 m vegetation) or where height estimates have been calibrated with measurements of vegetation with similar heights at other sites on the same field trip.

When using a clinometer, adjustments are also made for the height of the recorder and any slope in the land surface. Also, measure to the point on the ground directly below the highest point of the tree canopy where the top of the tree is not directly above the base of the trunk.

Total cover of tree, shrub and ground layers

The percentage crown cover for each tree, shrub and the ground strata is made using the line-intercept method recommended for non-rainforest sites.

Species Data

Trees >10cm DBH

Measure the DBH for every individual >10cm DBH in the plot. If most trees are just below 10cm then the threshold is adjusted down to get a realistic measure of the plot. For example, if trees are consistently between 9 & 10 cm then threshold is lowered to 9 cm.

For every measured tree, record height, species name and strata.

Heights are initially measured with a range finder or inclinometer to calibrate the botanist's estimation. Once calibrated, estimates may be used.

Trees and shrubs <10cm DBH

Count the number of individuals of each species in each strata in the plot.

As in non-rainforest plots, seedlings of trees and shrubs included in the ground layer are not included in the stem counts.

Basal area

A basal area sweep from the centre of the plot using the same methods as the QBEIS non-rainforest site. The number of individuals of each species in each strata is scored (Strata allocation can be done after strata have been determined as per above). Record all trees that are exactly equal to the gap as a 1

Ground layer

Data for the ground layer is collected as for non-rainforest plots using the ground layer pro-forma. At 0–1 m, construct a 1 m x 1 m ground layer quadrat. Estimate the percentages of each of the species present, with single occurrences being recorded as '0.01'. Continue the species recording, walking slowly and sampling a ground layer quadrat at 10 m intervals, giving a total of five 1 mx 1 m quadrats for the site. If practical, alternate sides of the tape for location of ground layer quadrats. If the ground layer is highly variable measure the ground layer across 10 quadrats at 5m intervals.

Determining the ecologically predominant layer

The ecologically predominant layer is that in which, (the total cross-sectional area of plants) x (the average height of the stratum) is the greatest. This is calculated in three steps:

1. Calculate the ‘cross-sectional area’ of timber at 1.3m for each tree using the formula “π(DBH/2)2”
2. Sum the ‘cross-sectional area’ of each tree in the strata to get the total ‘cross-sectional area’ of the strata
3. Multiply the total ‘cross-sectional area’ of strata x average height of the strata

For example, if the uppermost layer is 15m high and has 10 trees each with a DBH measurement of 50cm each, the ‘ecologically predominant layer metric’ is calculated as

1. ‘corss-sectional area’ of individual tree = π*(25)2 = 1,963
2. ‘cross-sectional area’ of strata = 1,963 * 10 = 19,630
3. ‘Ecologically predominant layer metric’ = 19,630 * 15 = 294,524

If a lower strata (for example the T2) has a higher ‘ecologically predominant layer metric’ then it forms the ecologically predominant layer and the upper strata becomes emergent.

A9.4 Data collection in tertiary rainforest sites

A9.4.1 Site selection

The site should be located in an area with a uniform aspect, slope and substrate. The plot should, where possible, follow the contour, and not include changes in slope, creeks or obvious changes in vegetation.

Survey area

Tree layers are sampled using a basal area sweep, with the dimensions of the sample dictated by the sweep area. The area covered is usually between 0.1 and 0.2 ha.

The shrub and ground layers are sampled within 50x 20 m^2 plot (0.1 ha). The plot is centred on the tree used for the basal area sweep.

Location and environmental information

Use the front page of the standard non-rainforest QBEIS site proforma.

A9.4.2 Structural information

This information is collected to accurately use the key in Table 29 to determine the structural classification of a site according to Webb (1978).

Assess the relative abundance of individuals with each characteristic of structure category using:

- Not evident (0)
- Uncommon and/or inconspicuous (1)
- Occasional or uncommon but conspicuous (2)
- Abundant or common (3).

Leaf size

Leaf size of the sun leaves of the tallest stratum (excluding emergent) trees. It is usually easy to decide which two adjacent leaf classes are most common from a visual inspection (Webb, 1978, p356). Where this is difficult the method described by Walker and Hopkins (1990, p81) may be used in which the leaf size of ten adjacent canopy trees is assessed. Another useful field method is to collect a handful of (non-palm) leaves from the ground and measure for size. This can be verified against the species list for the canopy trees at the end of data collection. The leaf size of shaded trees in the lower layers are frequently larger than those of the canopy species and therefore may lead to an overestimate of leaf size.

Complexity

This is assessed using a number of characteristics.

Structural features

- Buttressing: Plank buttresses are those >1 m long. Less than 1 m long are considered spur buttresses.
- Different leaf types

Indicator growth forms

Assess the relative abundance of individuals of different indicator growth forms.

Stem size

A visual assessment of whether the stem sizes of the T1 layer are uniform in size.

Leaf fall characteristics

The proportion of deciduous, semi-deciduous, semi-evergreen and strictly evergreen species in the emergent and canopy strata. This may be recorded after the collection of species data, as species can be scored by leaf-fall class and a proportion calculated. To label the site use the strata that is tallest and allocate leaf-fall classes which are defined in Webb (1978) as follows.

- 'Deciduous' means species or certain individuals of a species that obligatorily lose their leaves completely each year.
- 'Semi-deciduous' indicates that most leafless species are truly deciduous but that some are facultative, i.e. leaf fall is controlled by the severity of the dry season.
- 'Semi-evergreen' means that few or none of the species are truly deciduous and that most of those that shed their leaves do so incompletely depending on the severity of the dry season.
- 'Evergreen' means species that do not loose leaves in a seasonal pattern.

Height of strata

Due to the often dense cover and continuous nature of strata in rainforest plots, it is advisable to determine strata after the DBH and height measures of individuals in the plot area have been measured. Use the 'Structural Summary' table on the first page of the QBEIS pro-forma to record strata height.

The height of each strata present is determined using the rules and guidelines outlined in section A2.5.3. Tree heights may be estimated for low (< 10 m vegetation) or where height estimates have been calibrated with measurements of vegetation with similar heights at other sites on the same field trip.

When using a clinometer, adjustments are also made for the height of the recorder and any slope in the land surface. Also, measure to the point on the ground directly below the highest point of the tree canopy where the top of the tree is not directly above the base of the trunk.

Total cover of tree, shrub and ground strata

The percentage crown cover for each tree, shrub and the ground stratum is made by visual estimate over the 20m x 50m plot. Cover is estimated for the ground layer litter, bare ground, rock and cryptogams.

A9.4.3 Species information

Tree layers

Species in the tree strata (E, T1, T2, T3) are recorded using a basal area sweep. A basal area factor of 1 is generally used, however a lower factor may be used if less than 20–30 trees are included in the sweep. The sweep assesses the trees at 1.3m (breast height) so if the site is on a slope, ensure the sweep is parallel to the slope uphill and downhill. Where a tree has buttressing at 1.3 m height, the trunk is assessed ignoring the additional width contributed by the buttresses. Lianas are also to be included where they are encountered as part of the sweep, and assigned to the tallest layer they reach. This enables an accurate calculation of basal area.

For each stem counted in the basal area sweep, record its species name, height and strata (Strata allocation can be done after strata have been determined as per above). Record all trees that are exactly equal to the gap as a 1. The dominance of each species in each layer can be calculated by:

$$\frac{\text{basal area of each species}}{\text{total basal area}}$$

Within the sweep area compile a comprehensive list of tree, shrub, climber, ground and epiphytic vascular plants. High-power (10 x 50) binoculars are recommended for assisting in field identification. It is inevitable that some smaller epiphytic orchids and ferns will be overlooked in the canopies of the taller trees.

Shrub and ground layers

Within the 50 m x 20 m plot compile a comprehensive list of all species in each shrub layer and the ground layer. Ground cover estimates and shrub stem counts for individual species are generally not carried out.

Determining the ecologically predominant layer

The ecologically predominant layer is that in which (the number of BA hits) x (the average height of the stratum) is the greatest. For example, if the uppermost layer has BA count of 20 and is 25 m high then the 'ecologically predominant layer metric' is 20 x 25 = 500. If the second layer has a BA count of 50 and is 15 m high, the 'ecologically predominant layer metric' is 50 x 15 = 750. The second layer therefore forms the 'ecologically predominant layer', and the uppermost layer becomes the 'emergent' layer.

Appendix 10. QBEIS rainforest attributes

RAINFOREST ATTRIBUTES

Site visit name:

LEAF SIZE OF CANOPY TREES		COMPLEXITY	
Leaf size	**Proportion (%)**	**Structural feature**	**Abundance**
Macrophyll (> 25 cm long)		Plank buttresses (buttress > 1 m long)	
Macrophyll–mesophyll		Spur buttresses	
Mesophyll (12.5–25 cm long)		Unbuttressed	
Mesophyll–notophyll		Compound leaves	
Notophyll (7.5–12.5 cm long)		Lobed/deeply divided leaves	
Notophyll–microphyll		Simple leaves	
Microphyll (2.5–7.5 cm long)		Strap-like leaves	
Microphyll–nanophyll			
Nanophyll (> 2.5 cm long)			

GROWTH FORM	Abundance	GROWTH FORM	Abundance
Climbing pandans		Banyans	
Climbing aroids		Stranglers	
Epiphytes on tree trunks		Pandans	
Epiphytes in tree crowns		Shrubs	
Hanging vascular epiphytes		Seedlings	
Mosses (replacing epiphytes in canopy and high up tree trunks)		Tree ferns	
Nest vascular epiphytes		Bamboo	
Robust lianes		Ground aroids	
Slender lianes		Ground ferns	
Vines—feather palms leaves		Mosses (on ground)	
Vines—thorns/prickles/hooks		Lichens	
Multi-stem palms		**Stems in canopy trees (circle): Uniform in size?** Yes No	
Single stem palms			
Fan palms			

LEAF FALL CHARACTERISTICS (%)				
Strata	**Evergreen**	**Semi-evergreen**	**Semi-deciduous**	**Deciduous**
E				
T1				

GROUND COVER ESTIMATE (cover assessed over 50 m x 20 m plot)	
Component	**Total PFC cover (%)**
Ground plants	
Fine litter (<2cm diam)	
Coarse litter (≥2cm and <10cm diam)	
Logs (≥10cm diam)	
Rock	
Bare ground	
Cryptogam	
Water	
Manure (feral/non feral)	
Other	
Litter depth (cm)	

Leaf fall characteristics definitions

Evergreen: species that do not lose their leaves in a seasonal pattern

Semi-evergreen: species that are generally evergreen, except in severe dry seasons

Semi-deciduous: species that are generally deciduous, but may not lose their entire canopy

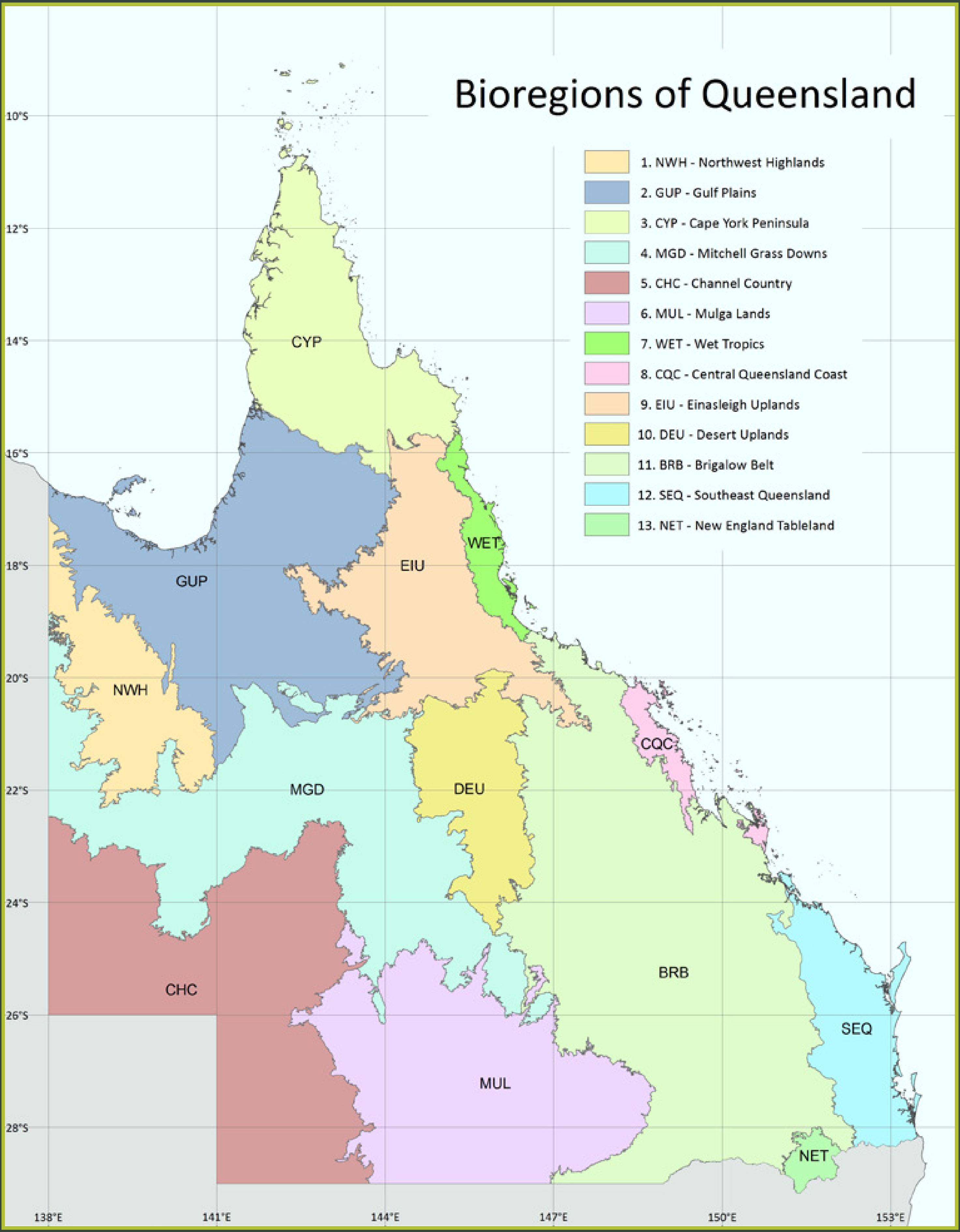
Deciduous: species that always lose their leaves completely each year

Abundance reference

1 - uncommon and/or inconspicuous

2 - occasional or uncommon but conspicuous

3 - abundant or common



Bioregions of Queensland

1. NWH - Northwest Highlands
2. GUP - Gulf Plains
3. CYP - Cape York Peninsula
4. MGD - Mitchell Grass Downs
5. CHC - Channel Country
6. MUL - Mulga Lands
7. WET - Wet Tropics
8. CQC - Central Queensland Coast
9. EIU - Einasleigh Uplands
10. DEU - Desert Uplands
11. BRB - Brigalow Belt
12. SEQ - Southeast Queensland
13. NET - New England Tableland