Native Vegetation Interim Type Standard

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Introduction

The DECCW Native Vegetation Interim Type Standard addresses the scientific processes involved in the gathering, processing and presentation of a range of native vegetation products, the most common being vegetation maps; it is not simply a mapping standard. The Standard is designed to complement other existing DECCW vegetation standards (Definitions and Extent Standards A and B) and incipient DECCW data management and data-basing standards which are being developed under the NSW Vegetation Information System (VIS) project. Development of this standard has also taken account of Australian Government and interstate standards and has achieved a high level of compatibility with these. This summary provides the **Required outcomes** and **Statements of Standard** for each of the chapters in this document. This series of statements comprise the Standard. The text contained within the body of the document is designed to background these statements. The appendices are designed to expand on technical discussion and provide technical detail as to the execution of the Statements of Standard.

Chapter summaries

Metadata, data management and existing data

Required Outcome

1. Metadata, information about the content, and ownership of datasets, is compiled and made available via the NSW Vegetation Information System.
2. All NSW Government funded or sponsored vegetation activities have metadata, which is current, accurate and is stored in the NSW VIS where it is readily accessible to stakeholders.
3. All existing government funded vegetation data are available to the NSW Vegetation Data Custodian in DECCW and included in the NSW Vegetation Information System.

Statements of Standard

1. The metadata elements detailed in Appendix 1 are adopted as the Standard.
2. Each metadata statement has a unique identifier.
3. All native vegetation activities include completion and registration of a metadata statement.
4. All vegetation plot-based data are entered into the YETI database.
5. Any plot data not able to be housed in YETI (no appropriate data fields) are captured electronically in Microsoft Excel or Microsoft Access. In such cases column headings are identical to the datum name on the field data sheets.
6. All spatial data pertaining to vegetation type and extent are entered into the VIS.
7. All spatial files not able to be housed in the VIS during the development phase are archived as ESRI shape or personal geodatabase files.
8. All data entered into databases are checked for errors, miscodings and currency of information.
9. Existing data are assessed against this Standard.
10. All new and re-used government funded vegetation data are available to the NSW Vegetation Data Custodian in DECCW and included in the NSW Vegetation Information System.
11. Each new native vegetation activity includes an assessment of existing spatial and textual data.

Interpretation of remotely sensed imagery

Required Outcome

1. Imagery interpretation outputs can be readily integrated in a GIS environment to inform native vegetation activities and products.
2. Imagery interpretation and analysis yield verifiable data which facilitates multiple uses.

Statements of Standard

1. Visual and computer-based interpretation of remotely sensed imagery for vegetation type activities is based on application of existing vegetation type classes and/or vegetation pattern delineation or type recognition and attribution (detailed in Appendix 2a).
2. Mandatory Attribution fields are completed for all imagery interpretation.
3. The methods of remote image interpretation must be fully documented (see Section 10) to a level of transparency that enables specialists to repeat, assess and augment the interpretation in future development of additional vegetation products.
4. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

Survey design

Required Outcome

1. Field-based vegetation activities are conducted systematically using explicit and repeatable processes.
2. Data are collected with minimum bias and are compatible amongst activities.
3. Field effort is commensurate with the spatial and thematic scales of the project.
4. Field-based activities yield verifiable data which facilitates multiple uses.

Statements of Standard

1. All field surveys, including reconnaissance (rapid survey), are based on an explicit, repeatable and relevant stratification of the project area.
2. Stratification must meet the requirements of randomisation, representation and replication, either by sampling classified Stratification Units **or** by sampling sites ranked highly in a gap analysis until the required number of sites is reached; **or**
3. Where a particular vegetation type is the survey target, plots should be assigned randomly in the known and projected habitats of the target type.
4. Stratification methods and results are published for all projects.
5. Spatial products from this process are archived in the NSW Vegetation Information System.
6. Survey effort reflects scale and project needs.

Plot size

Required Outcome

1. Field data from new and existing sources are compatible; they contribute progressively to a coherent state-wide dataset and allow for consistent and multiple use.

Statements of Standard

1. Measured plots are the basis for all non-reconnaissance field-based vegetation survey.
2. A standard plot size of 0.04 ha is adopted for sampling floristics to maximise compatibility with existing data.

3. Plot sizes larger or smaller than the standard size may be used where explicitly justified (e.g. smaller plots to record floristic variation between wetland microhabitats, larger plots to estimate crown separation in open woodlands). Whenever alternative plot sizes are used, consideration should be given to nested plot designs that include 0.04 ha plots.
4. For rapid survey, location-specific observations are required.
5. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

Field sampling

Required Outcome

1. Investment in field data yields quantitative, primary data to Standard.

Statements of Standard

1. Primary (unclassified), quantitative data is collected in the field, except where otherwise stipulated.
2. Appendix 4 stipulates the data fields for this Standard.
3. Existing data using various cover/abundance classes are used while they are deemed to be relevant to contemporary vegetation activities.

Data analysis

Required Outcome

1. Data analysis is objective, quantitative, systematic and transparent.
2. New data acquisition is based on project needs; existing data are used where appropriate.

Statements of Standard

1. Quantitative, transparent, rigorous and repeatable data analysis is used to underpin derivation of native vegetation types, where such data are available.
2. The data analysis protocol detailed in Appendix 5 is the basis of floristic data analysis unless alternative methods are described and justified.
3. The dataset used to produce a final analysis (see Appendix 5) is clearly identified.
4. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

Classification hierarchy

Required Outcome

1. NSW has an objective, clearly defined, systematic and transparent classification hierarchy for native vegetation types that supports evidence-based natural resource management.

Statements of Standard

1. NSW adopts the hierarchical system of vegetation classes as detailed in Appendix 6.
2. Classification of new quantitative data follows the Standard for data analysis.

Spatial interpolation

Required Outcome

1. The spatial expression of native vegetation types, by modelling their distribution, is underwritten by consistent, comparable and transparent relationships between defined vegetation types and their physical environments.

Statements of Standard

1. The method of interpolation should be transparent, repeatable by other mappers and appropriate to the landscape and data.
2. The choice of spatial variables used in interpolation should have strong demonstrated relationships with floristic composition and be fully justified in documentation of methods for all vegetation survey and mapping projects.
3. Each interpolation has a detailed methodological statement justifying the approach.

Accuracy assessment

Required Outcome

1. The accuracy of spatial products, particularly vegetation maps, is tested and specified.
2. Accuracy assessment is based on clearly explained methods and analyses.

Statements of Standard

1. All accuracy assessment is based on an unambiguous and clearly explained method which is appropriate to the spatial and thematic scales of the product being evaluated.
2. Accuracy is assessed according to an **equal probability sampling design** (Appendix 8) unless an alternative method is justified.
3. All field-based accuracy assessment will deliver basic floristic data pertaining to specific site localities (Appendix 8).
4. All accuracy assessment results in the production of an error matrix, as a minimum, and follows the labelling convention detailed in Appendix 8.
5. Precision and reliability data accumulated during remote sensing interpretation and interpolation processes will be reported as part of the accuracy assessment.

Reporting requirements and summary statistics

Required Outcome

1. All native vegetation survey, classification and mapping projects will provide full documentation of aims, methods and results and provide descriptive and statistical information to define classes and map units.

Statements of Standard

1. Every native vegetation survey, classification or mapping project will culminate in a final technical report which will, at least, be reviewed internally by suitably qualified staff outside the author's Branch (externally peer reviewed and published papers will also satisfy this Standard).
2. The final technical report (or externally published paper) will document key themes and summary statistics, describing methods and results associated with the implementation of this Standard (Appendix 9a).
3. Minimum standard fields, descriptive text and descriptive statistics are required for the final technical report or externally published papers (see Appendix 9 for details).

1 Introduction

1.1 Title of this Standard

This is the **NSW Native Vegetation Interim Type Standard** (the Standard).

1.2 Scope

The Standard applies to all relevant vegetation activities to which the NSW Government makes a financial or in-kind contribution or to which the NSW Government is a signatory.

The Standard addresses the nature and quality of the **scientific processes** for native vegetation type activities (remote sensing interpretation, field survey, data manipulation, data management and mapping). The Standard:

1. adopts consistent, comparable, transparent and quantified science practices for native vegetation type information;
2. specifically **does not** seek to address particular products; a range of products can be produced under this Standard; and
3. is intended to be **scale independent**.

The methodological prescriptions contained within the Environmental Outcomes Assessment Methodology (NSW DNR 2005) remain in force and are not affected by this Standard. However, the NSW Government will only consider data that meets this Standard when considering future amendments to the EOAM.

The custodian of this Standard is the DECCW Executive Director Scientific Services, or delegate. The custodian is responsible for maintaining the integrity and currency of the Standard through liaison with expert staff, from DECCW and externally.

The Native Vegetation Standards have a close relationship to the **Spatial Data Standard** which is in preparation. All data acquired or generated in accordance with the Native Vegetation Standards must also comply with the Spatial Data Standard.

1.3 Context

The Standard complies with the 'NSW Government Standard for Quality Natural Resource Management' (NRC 2005). This Standard is one of a series addressing Native Vegetation Type, Extent and Condition. The documents in this series are:

1. Definition of Native Vegetation (combined definition) and Operational Terms for Reporting its Extent (in preparation)
2. Native Vegetation Extent Standard A (Best Practice), Detectable Woody Native Vegetation (in preparation)
3. Native Vegetation Extent Standard B, Detectable Native Forest (in preparation)
4. Native Vegetation Extent Standard C, Non-woody Native Vegetation (started March 2009, *publication December 2010)
5. Native Vegetation Interim Type Standard [this Standard]
6. Native Vegetation Condition Standard (started June 2009, *publication December 2010).

* Publication dates are targets

Existing standards and guidelines influential in developing the Standard are: *Guidelines for Mapping Native Vegetation* (Sivertsen & Smith 2006), *Australian Soil and Land Survey: Field Handbook* – Vegetation (Hnatiuk *et al.* 2005), *Australian Soil and Land Survey: Guidelines for Conducting Surveys*, Chapter 8 (Thackway *et al.* 2005) and *National Vegetation Information System – Australian Vegetation Attribute Manual Version 6.0* (ESCAVI 2003). Many other documents have also been consulted; these are referenced in the document.

A glossary of terms and acronyms used in the Standard appears at the end of the document.

1.4 How the standards relate

The Definition provides the context for native vegetation activities by defining native vegetation for operational uses. It currently defines a series of operation terms relevant to extent measurement and reporting in New South Wales. (Additional composition-related terms will be added in subsequent versions of the Definition.)

Extent Standard A addresses the complete spectrum of woody native vegetation. It is based on the use of high resolution satellite imagery to quantify the EXTENT of woody native vegetation. CHANGE in extent can be calculated from a time series of extent layers as a secondary product. Methods necessary to produce results under this Standard are being developed. The methods are not ready for routine and repeated use so the NSW Government cannot yet report results based on this Standard.

Extent Standard B addresses CHANGE in dense woody native vegetation as defined under the Montreal Process (FAO 2001) and is an interim standard. Standard B stipulates the use of Landsat medium-resolution satellite data and is thus limited to detectable (dense) woody native vegetation. It adapts well-tested methods, the Queensland SLATS methods (Wedderburn-Bisshop *et al.* 2002), for use in New South Wales. A reliable EXTENT layer can be generated as a secondary product from the change data. It provides the NSW Government with a reliable and quantitative measure of change and extent in the specified part of the woody native vegetation spectrum. When Standard A is available for routine use, Standard B will be phased out or incorporated into Standard A.

Extent Standard C is yet to be written and its methods are in an earlier phase of research and development than Standard A. It will use the same high resolution satellite data as Standard A and will target non-woody native vegetation. Standards A and C will have common data quality standards, the geometric and radiometric corrections of the data will be common to both. Standards A and C are likely to be combined when methods are fully developed.

All the EXTENT standards relate to the Interim Type Standard mainly in regard to survey design, field work and data management. The Type Standard stipulates the necessary quality for these activities. Extent Standards A and C will ensure extent data of a quality that can be used to update extent aspects of vegetation type products.

The Condition Standard is yet to be written. It will be most relevant to the Interim Type Standard, in relation to survey design, field work and data management. The Extent Standards will relate to the Condition Standard to ensure extent data of a quality suitable for calculating condition metrics such as isolation, patch size and fragmentation.

1.5 Purpose of the Standard

The Standard provides a set of quantifiable processes for developing native vegetation TYPE products. It is intended to meet the demands of government, industry and non-government stakeholders for a standard regarding vegetation type recognition, description and reporting.

The Standard provides the flexibility needed to address the many native vegetation data and information needs and scales of endeavour required in New South Wales. The Standard addresses metadata, remote sensing interpretation, native vegetation survey, data management, data analysis, classification and product formulation **processes** rather than focusing on a particular product, scale or end-point. It will be possible to generate product from any process or combination of processes in the Standard. For example, a spatial layer may be produced from imagery interpretation only, or a set of community descriptions from analysed plot data only; both of these are legitimate products with various uses. Neither constitutes a 'vegetation map'.

The Standard seeks to ensure that data are captured using consistent, transparent and repeatable processes. Once captured or created data are suitably housed and are available to a range of users either alone or in combination with other data.

The Standard provides the basis on which government NRM agencies, stakeholders and contractors can ensure the quality of native vegetation activities. By doing this, the Standard will help to achieve the NRC Standard and ensure wise investment of public funds with multiple returns on that investment.

1.6 NSW Government Standard for Quality Natural Resource Management

The NSW Government Standard for Quality Natural Resource Management (NRC 2005) is binding on the NSW Government and its agencies. The NSW Government Standard provides a foundation for all NRM.

The following **Required Outcomes** from the NSW NRM Standard, have been instructive in formulating this Standard because they address due diligence, best-practice, optimising outcomes, risk-assessed decision making and meeting customer needs:

1. use of the best available knowledge to inform decisions in a structured and transparent manner
2. management of natural resource issues at the optimal spatial, temporal and institutional scale to maximise effective contribution to broader goals, deliver integrated outcomes and prevent or minimise adverse consequences
3. consideration and management of all identifiable risks and impacts to maximise efficiency and effectiveness, ensure success and avoid, minimise or control adverse impacts
4. management of information in a manner that meets user needs and satisfies formal security, accountability and transparency requirements.

Practitioners should refer to NRC (2005) for a full description of **guidelines** and **evidence requirements.**

1.7 Relationship with existing vegetation standards

To the extent that it is possible, the NSW Standard accommodates existing national, state and territory guidelines and standards that have been accepted at the relevant jurisdictional level. Compatibility will be pursued via:

- best practice recognised and implemented nationally
- consistency with state and national policy, programs and directions
- quantitative assessment of data and information
- due diligence of procedure and process: rigorous and systematic.

The relationships amongst the Standard and these documents are illustrated in Table 1.1.

Table 1.1 Relationships between the Interim Type Standard and existing documentation

Document	Description	Relationship
Guidelines for mapping native vegetation (Sivertsen & Smith 2006)	Written for the NVMP; developed with input from across government; based on quantified, systematic, rigorous science to deliver quality assured products that meet user needs. Set standards for: a. use of existing data, both spatial and plot b. stratification c. survey design, field sampling and sampling intensity d. remote sensing interpretation; air photo interpretation and satellite image interpretation.	Contributed to the development of the Standard in relation to survey design, field sampling and interpretation of remote sensed imagery.
Australian Vegetation Attribute Manual, V6.0 (ESCAVI 2003)	Contains point-by-point descriptions of the data requirements for the National Vegetation Information System database; constructed through a Commonwealth/state/territory partnership as part of the National Land and Water Resources Audit. Assumes availability of quantitative data about the structure and floristics of the vegetation. Any product entered into the NVIS database at levels II to VI requires some quantitative data.	Contributed to sections on classification and reporting. The NVIS classification has become a national standard. NSW Government has adopted the NVIS database, suitably configured to meet state needs, as a principal component of the NSW Vegetation Information System.
Australian Soil and Land Survey – Field Handbook [Revision of the section on 'Vegetation and Classification' (Hnatiuk, Thackway & Walker 2005)]	This revised and expanded vegetation chapter from the *Australian Soil and Land Survey: Field Handbook* (McDonald *et al.* 1984; 1990) was posted on the web-site in March 2005. Provides guidelines for quantitative vegetation survey including a detailed treatment of the classification hierarchy, survey design and field sampling (site location, sampling methods, structural attributes, floristic attributes and condition).	Contributed to the sections on survey design, field sampling, visual interpretation of remote sensed imagery and classification.
Guidelines for Surveying Soil and Land Resources McKenzie *et al*. (2008) and *Australian Soil and Land Survey Handbook: Guidelines for conducting surveys* (Gunn *et al*. 1988).	McKenzie *et al*. (2008) completely revise Gunn *et al.* (1988). These two books deal with similar subjects but take different approaches; both were valuable in writing the Standard. They provide guidelines for survey design, data acquisition, data analysis and outputs; they canvass the survey methods used in the various states and territories (see Brocklehurst *et al.* 2007, Harris & Kitchener in press, Heard & Channon 1997, McDonald & Dillewaard 1994, Neldner & Howitt 1991, Neldner 1993, Neldner *et al.* 1999, Sivertsen & Smith 2006 and Wilson *et al.* 1990).	Thackway *et al.* (2008) [Chapter 8 in McKenzie *et al*. (2008)] has contributed mainly to the sections on survey design, data management and data.

2 Metadata, data management and existing data

2.1 Required Outcome

1. Metadata, information about the content, and ownership of datasets, is compiled and made available via the NSW Vegetation Information System.
2. All NSW Government funded or sponsored vegetation activities have metadata, which is current, accurate and is stored in the NSW VIS where it is readily accessible to stakeholders.
3. All existing government funded vegetation data are available to the NSW Vegetation Data Custodian in DECCW and included in the NSW Vegetation Information System

2.2 Rationale

1. Metadata, appropriate data storage systems, data quality assurance and data curation are essential for all vegetation-related scientific activity. Without such infrastructure, investment in data and resultant products provides a poor return for Government and stakeholders.
2. Metadata is crucial for modern data management; it provides essential information about the composition, currency and ownership of datasets. In 2008 the NSW Government acquired or generated several terabytes (bytes 10^{12}) of vegetation-related data in hundreds of files. Without metadata data custodians and users cannot identify and access data effectively.
3. The Commonwealth Government through ANZLIC has established a metadata standard which has been adopted Australia-wide. The National Land and Water Resources Audit working group on NVIS identified additional metadata elements pertaining to vegetation information. These metadata elements have been combined to form the NSW Standard (see Appendix 1).
4. An understanding of data quality and currency is essential for Government and its stakeholders to realise the full value of scientific data. Many of the data in existing databases contain errors, miscodings or are out of date; data are also often duplicated.
5. The NSW Government, through DECCW, is building an integrated Vegetation Information System (VIS) for the state which will accommodate all vegetation-related data. Completion of the VIS will trigger a review of relevant parts of the Standard.
6. NSW currently uses three main interrelated and specialised vegetation databases:

   - YETI houses plot-based structural, floristic and environmental data.
   - NVIS is a quantitative spatial and textual database which houses vegetation maps as shape files as well as descriptive statistics about the map units and their component communities.
   - NSWVCA Benson (2006) is a textual database comprising a detailed compendium of information about vegetation communities in New South Wales, both mapped and un-mapped. This database addresses all levels of the NVIS hierarchy although most entries pertain to levels V and VI.

7. NSW, local and Commonwealth government agencies and tertiary institutions have made considerable investments in vegetation-related data over the past 20 years; this includes both spatial and textual data. Many of these data will be useful for contemporary projects.

NSW does not currently have a database which adequately houses spatial data except completed Type maps. There is currently no formal repository for products from image interpretation and computer modelling.

Apart from additional fields to accommodate contemporary data, the YETI database will require fields that allow each plot to be identified with a community and map unit so that their lineage remains explicit. This preserves the integrity of formally analysed outputs.

2.3 Statements of Standard

1. The metadata elements detailed in Appendix 1 are adopted as the Standard.
2. Each metadata statement has a unique identifier*.
3. All native vegetation activities include completion and registration of a metadata statement.
4. All vegetation plot-based data are entered into the YETI database.
5. Any plot data not able to be housed in YETI (no appropriate data fields) are captured electronically in Microsoft Excel or Microsoft Access. In such cases column headings are identical to the datum name on the field data sheets.
6. All spatial data pertaining to vegetation type and extent are entered into the VIS.
7. All spatial files not able to be housed in the VIS during the development phase are archived as ESRI shape or personal geodatabase files.
8. All data entered into databases are checked for errors, miscodings and currency of information.
9. Existing data are assessed against this Standard.
10. All new and re-used government funded vegetation data are available to the NSW Vegetation Data Custodian in DECCW and included in the NSW Vegetation Information System.
11. Each new native vegetation activity includes an assessment of existing spatial and textual data.

* DECCW is currently developing a metadata management system. When this is complete all metadata statements will have to be submitted to a central repository and will require a unique identifier which will be supplied from that central location.

2.4 Additional information

The ANZLIC web site (http://www.anzlic.org.au/asdi/metaelem.htm) contains guidelines and worked examples for completing metadata statements.

3 Interpretation of remotely sensed imagery

Visual and computer-based interpretation of remotely sensed imagery applies to aerial photography and satellite imagery and is referred to hereafter as Remote Image Interpretation (RII). Interpretation of remotely sensed imagery is a highly specialised field; the recognition of spatial patterns is critical in the production of vegetation products.

3.1 Required Outcome

1. Imagery interpretation outputs can be readily integrated in a GIS environment to inform native vegetation activities and products.
2. Imagery interpretation and analysis yield verifiable data which facilitates multiple uses.

3.2 Visual interpretation rationale

1. Two conditions for visual interpretation are addressed by this Standard (see Appendix 2c for more detail):

   a. An *appropriate set of Vegetation Types exists for the study area or has been developed for the study area as part of the project being undertaken.

   b. An appropriate set of Vegetation Types does not exist for the study area and/or traditional stratification/gap analysis is not possible due to the paucity of spatial data.

   ***To determine whether a set of vegetation types is 'appropriate' consider the spatial scale, hierarchical scale, thematic scale and the lineage of the types.**

2. Pattern recognition in remotely sensed imagery is a primary spatial output in several standards and guidelines (e.g. Brocklehurst *et al*. 2007, Sivertsen & Smith 2006, Thackway *et al.* 2005, Neldner *et al.* 2005, Heard & Channon 1997). Spatial layers from imagery interpretation must be readily understood and used to produce other vegetation products.
3. The advent of digital aerial photography (e.g. ADS40) is accompanied by the need for expensive specialised equipment for efficient stereo viewing; however, this new equipment removes the need for separate data capture processes to transfer polygon boundaries into two dimensional digital GIS formats. Traditional API (hard copy photos and a stereoscope) will continue for some time using best available photography. Whilst it is possible to render this digital imagery into hard-copy stereo pairs, it constitutes a sub-optimal use of the data. Alternatively it is possible to transfer traditional film photography into digital imagery suitable for stereo viewing.
4. Spatial data produced from RII may have uses beyond a single project. Attribution must be clear, concise and accessible (similar demands are placed on plot data).
5. Remote sensed polygon classification and attribution must be commensurate with the scale of imagery being interpreted, the final output scale and project outcomes. Attributions generating thousands of unique polygons have proven difficult to use for vegetation type mapping in the past. Similarly, attributions generating only tens of unique polygons may be difficult to use in additional or revised applications.
6. The Standard assumes that individual vegetation activities will be integrated immediately or over time.

3.3 Computer-based interpretation rationale

1. Extent Standard A deals with aspects of spatial analysis and data quality required for calculating and displaying the spatial extent of woody vegetation. Some processes described in Extent Standard A apply; Extent Standard A data quality standards apply to this Standard.
2. Satellite imagery and digital aerial photography are increasingly important in vegetation activities in New South Wales. While they offer significant benefits over traditional aerial photography including synoptic coverage, multispectral bands and ease of manipulation in a GIS environment, they have demerits including affordability, resolution and lack of stereo viewing capabilities without specialised equipment.
3. Newly emerging pattern recognition software (e.g. Definiens 2004) can use texture, colour/tone, vegetation density and neighbour relationships to define and attribute polygons from remotely sensed data (digital aerial photography, high resolution satellite imagery). This software can also incorporate environmental data such as landscape, landform, geology, soils, and geomorphology into its pattern recognition and attribution. Existing vegetation layers can also be used. Pattern recognition software (e.g. Kamagata *et al.* 2006) has shown that it is capable of delivering spatial products similar to those derived from visual API. The software can be applied at any scale.
4. Research and development on the application and rollout of pattern recognition software is essential, particularly given the advent of digital aerial photography.
5. The field of computer-based RII is developing rapidly. The Standard will require revision in the future and therefore comprises an interim statement regarding computer-based interpretation of remote sensed data.

3.4 Statements of Standard

1. Visual and computer-based interpretation of remotely sensed imagery for vegetation type activities is based on application of existing vegetation type classes and/or vegetation pattern delineation or type recognition and attribution (detailed in Appendix 2a).
2. Mandatory Attribution fields are completed for all imagery interpretation.
3. The methods of remote image interpretation must be fully documented (see Section 10) to a level of transparency that enables specialists to repeat, assess and augment the interpretation in future development of additional vegetation products.
4. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

3.5 Additional information

Appendix 2 Part A contains explanations of each of the fields in tabular form.

Appendix 2 Part B contains a data entry proforma which identifies mandatory fields (grey background) and voluntary data fields (no background colour).

Appendix 2 Part C contains a discussion of visual interpretation; Figure App2.1 illustrates the visual interpretation process and table App2.2 details scale-related polygon sizes. Gunn *et al.* (1988) and McKenzie *et al.* (2008) also deal extensively with this subject.

4 Survey design: stratification and survey effort

Rigorous survey design (stratification and survey effort) ensures field-based vegetation activities are efficient, which ensures maximum return on investment.

4.1 Required Outcome

1. Field-based vegetation activities are conducted systematically using explicit and repeatable processes.
2. Data are collected with minimum bias and are compatible amongst activities.
3. Field effort is commensurate with the spatial and thematic scales of the project.
4. Field-based activities yield verifiable data which facilitates multiple uses.

4.2 Rationale

Field survey based on an explicit (*fully and clearly described; leaving nothing merely implied*) survey design is essential for vegetation field sampling or systematic landscape assessment. Unambiguous design and execution of field sampling reduces bias in both sampling and results and allows future workers to build on results rather than restarting processes from the beginning. Starting new projects as if pre-existing work was of no relevance has been relatively common in New South Wales.

Field survey provides one of the main types of vegetation data from which native vegetation products are derived. Absolute numbers of plots will not be stipulated in this Standard as survey effort is determined by a variety of factors that will vary widely across the state.

Random stratified sampling is adopted as best practice by Thackway *et al.* (2005), Sivertsen & Smith (2006), Neldner *et al.* (2005) and Brocklehurst *et al.* (2007) and is adopted for the NSW Standard. Well constructed stratification should adequately address thematic diversity (complexity in vegetation types).

1. A stratified sampling design can be based on either a classification of Environmental Sampling Units (ESUs) (Horner *et al.* 2002) or a gradient analysis of sampling gaps (Ferrier 2002). A classification of ESUs is derived from the intersection of several layers of classified environmental or other spatial information. In contrast, a gradient approach uses a multivariate gap analysis to identify potential sampling locations from a large randomly generated set that are environmentally most dissimilar to those already represented in a set of existing samples.
2. Map-based stratification **may** be augmented by decision rules which are applied in the field. For example, for every site allocated, up to three topographic positions may be sampled (e.g. crest, slope and flat); in this example three plots must be described at each site.
3. The choice of spatial variables is crucial to both classification and gradient approaches to stratification. Examples of stratification variables include substrate type, landform unit and climatic variables, woody/non-woody or crown density classes or other remotely sensed units. All selected stratification variables should have strong inferred relationships with plant species composition.
4. Stratification outputs are valuable products in their own right; they may usefully be accessed for other science-based NRM activities.
5. Three important principals will underpin determination of survey effort in this Standard:

i. **Representation**: ESUs (see above) represent unique combinations of environmental and biotic factors. By sampling each ESU across its geographic range and in proportion to its total area, a representative sample can be compiled.
ii. **Replication**: As a general rule each ESU is sampled at multiple locations (minimum of three) (see Appendix 4).
iii. **Randomisation**: Sites are located randomly within the ESUs but may be subject to rules regarding relationships with boundaries, clumping and access (see Appendix 3).

6. Survey effort depends on scale and theme. The number of plots varies according to the scale of the project and the level of detail demanded. Survey effort also depends on factors such as degree of fragmentation, comparative areas of native and exotic vegetation, and whether exotic or candidate native vegetation is to be sampled.
7. Rapid survey (including 'reconnaissance survey', 'field completion' and 'ground truthing') is, for the purpose of this Standard, defined as *coarse level* (*broad-scale), systematic survey for the purpose of familiarisation or for accuracy assessment of existing spatial layers* (Section 9 of the Standard).

4.3 Statements of Standard

1. All field surveys, including reconnaissance (rapid survey), are based on an explicit, repeatable and relevant stratification of the project area.
2. Stratification must meet the requirements of randomisation, representation and replication, either by sampling classified ESUs **or** by sampling sites ranked highly in a gap analysis until the required number of sites is reached; **or**
3. Where a particular vegetation type is the survey target, plots should be assigned randomly in the known and projected habitats of the target type.
4. Stratification methods and results are published for all projects.
5. Spatial products from this process are archived in the NSW Vegetation Information System.
6. Survey effort reflects scale and project needs.

4.4 Additional information

Appendix 3a explores the applications of this part of the Standard.

5 Survey design: plot size

Quantitative plot-based sampling provides the most robust and flexible data for a state-wide system. The NSW Government must make evidence-based decisions underpinned by high quality data.

5.1 Required Outcome

1. Field data from new and existing sources are compatible; they contribute progressively to a coherent state-wide dataset and allow for consistent and multiple use.

5.2 Rationale

Quantitative, plot-based field data acquisition is best practice (Gunn *et al.* 1988, ESCAVI 2003, Hnatiuk *et al.* 2005, Thackway *et al.* 2005, Sivertsen & Smith 2006 and Brocklehurst *et al.* 2007) and is adopted as the NSW Standard.

1. Measured plots allow for analysis based on unit area from which measured, consistent and comparable statistics and inferences can be drawn. Most current formal analyses pertain to the floristics, their cover and abundance scores and to their relationships with site-specific environmental attributes. Structural data are frequently analysed separately or collated and used descriptively. Structural data need not be confined to the floristic plot only. Hnatiuk *et al.* (2005) suggest determining crown-gap ratios from transects 50m long, rather than the use of extra large plots, whilst the existing NSW *BioMetric* uses a nested 20x20m in 20x50m plot system.
2. Table App 3.5 illustrates that a large majority of existing floristic data in New South Wales have been collected from a ‘standard’ plot size (0.04ha or 20x20m). This has implications for the compatibility of new data collected during future surveys. The few exceptions where different plot sizes have been used relate to specific objectives of those surveys and the structural type of the vegetation being sampled. Hnatiuk *et al.* (2005), for example, suggest a range of plot sizes related to vegetation height (see Appendix 3b), but this could lead to accumulation of data in a wide range of plot sizes, which may introduce artefacts when the data are combined for analysis
3. It may sometimes be necessary to vary plot size to accommodate the environment and the floristic/structural complexity from which data are collected.
4. By convention plots are square or rectangular. Circular plots are frequently difficult to erect in many situations but may be used when circumstances dictate. (**NB** a 0.04ha circular plot has a radius of 11.3m)
5. Plot area must be maintained, external dimensions may change. Plot boundary dimensions may be changed to accommodate linear features if the plot remains wholly within the ESU. For a plot of 0.04ha, 10m x 40m is as valid as 20m x 20m.

5.3 Statements of Standard

1. Measured plots are the basis for all non-reconnaissance field-based vegetation survey.
2. A standard plot size of 0.04 ha is adopted for sampling floristics to maximise compatibility with existing data.
3. Plot sizes larger or smaller than the standard size may be used where explicitly justified (e.g. smaller plots to record floristic variation between wetland microhabitats, larger plots to estimate crown separation in open woodlands). Whenever alternative plot sizes are used, consideration should be given to nested plot designs that include 0.04 ha plots.
4. For rapid survey, location-specific observations are required.
5. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

6 Field sampling

6.1 Required Outcome

1. Investment in field data yields quantitative, primary data to Standard.

6.2 Rationale

1. NSW vegetation activities are frequently hampered by inadequate data. Use of pre-classified data may reduce flexibility of analysis and interpretation. Inconsistency in the field data collected is also a problem. Some of the most important data collected (relative cover/abundance/dominance of species in a plot) is pre-classified (Braun-Blanquet 1932, Poore 1955). The Braun-Blanquet system has up to seven interpretations with 'classes' that vary from 1–4 to 1–7 used in different surveys carried out within New South Wales. When pooled for analysis, these data require standardisation, which results in loss of information, to reduce the influence of methodological artefacts on outcomes of the analysis. Primary (not pre-classified) data on cover and abundance will enhance the flexibility of data for pooled analysis.
2. Field data will be collected for the three themes identified in the NSW targets (NRC 2005): type, extent and condition (including benchmarks). There are many arguments about the prohibitive cost of collecting quantitative rather than qualitative data. **The most expensive component of field data is the cost of putting teams into the field** (travel allowance, travel time, running costs). Field programs should ideally collect the full complement of vegetation data identified in the Standard. However, a lack of resources may mean that compromises must be made when collecting field data. In such cases the data collected will be determined by the activity needs and available resources (see discussion in Appendix 3).
3. Previously collected data are often age-limited in their utility for contemporary vegetation activities. Compositional and structural shifts in native vegetation over time may well limit the validity of old data for contemporary uses. The Standard is intended to allow for the use of existing data in new projects where it is justified. It is also the case that existing data will have historical baseline values well beyond their contemporary utility.
4. Qualitative (observational) information has an important role in native vegetation activities. Such information frequently helps to fill gaps or confirm interpolations in spatial products. Observational information alone should not be the primary form of data used in native vegetation projects and should constitute an adjunct to quantitative data.
5. Rapid survey (see glossary) may be justified in some instances. Rapid survey must yield verifiable data (see Appendix 4 Module 1, minimum requirements).

6.3 Statements of Standard

1. Primary (unclassified), quantitative data is collected in the field, except where otherwise stipulated.
2. Appendix 4 stipulates the data fields for this Standard.
3. Existing data using various cover/abundance classes are used while they are deemed to be relevant to contemporary vegetation activities.

6.4 Additional information

Appendix 4 provides additional background information and discussion.

7 Data analysis

7.1 Required Outcome

1. Data analysis is objective, quantitative, systematic and transparent.
2. New data acquisition is based on project needs; existing data are used where appropriate.

7.2 Rationale

1. Analysis of quantitative plot data to define vegetation types (Appendix 5) is widely accepted as standard practice (Thackway *et al.* in McKenzie *et al.* (2008 [Aust]), Harris & Kitchener (in press [Tas]), Brocklehurst *et al.* (2007 [NT]), Thackway *et al.* (2005 [Aust]), ESCAVI (2003 [Aust]), Neldner *et al.* (2005 [Qld]), Heard & Channon (1997 [SA]). Most recent vegetation surveys in New South Wales have culminated in such data analysis.
2. Numerical ecology, biomathematics and data analysis demand specialised training and skills. The development of the required skill base will require some investment in training and partnerships. Many individuals from government, academia, and increasingly, the contract sector accept, and are well versed in, rigorous data analysis.
3. Analysis outputs and classifications must match the scale of activity being undertaken and the level of abstraction that is implied by that scale (see Gunn *et al.* 1988 pp. 210–232 for further discussion).
4. Data analyses provide powerful tools for pattern and structure recognition in biological data. The results of analyses need to be understood and interpreted; they do not constitute an immutable classification. The results of analyses are affected by the size and nature of the dataset being analysed, the treatment of outliers and ubiquitous species, any masking of data that may be applied and the methods used to judge the rigour and appropriateness of the end results (see Appendix 5).
5. Research and development of new analytical techniques must not be constrained by the Standard.

7.3 Statements of Standard

1. Quantitative, transparent, rigorous and repeatable data analysis is used to underpin derivation of native vegetation types, where such data are available.
2. The data analysis protocol detailed in Appendix 5 is the basis of floristic data analysis unless alternative methods are described and justified.
3. The dataset used to produce a final analysis (see Appendix 5) is clearly identified.
4. Existing data should be used where they meet the Standard and are relevant to contemporary ecological processes and conditions.

8 Classification hierarchy

8.1 Required Outcome

1. NSW has an objective, clearly defined, systematic and transparent classification hierarchy for native vegetation types that supports evidence-based natural resource management.

8.2 Rationale

An unambiguous native vegetation classification system is needed, principally as a communication tool in NRM. Such a system of vegetation classes allows for products to be developed, a clear understanding of how those products are defined and how they relate to each other.

Such a hierarchy does not dictate spatial scale, although there will be a limited range of logical mapping scales for each level of the hierarchy (Table App 6.4). Similarly the hierarchy does not imply product quality. High-level products must convey broader/coarser illustrations of native vegetation type, not poorer quality illustrations.

There are two points of particular note:

1. 'Classification' has different connotations. For example:

   i. a system of related categories, i.e. hierarchical classification *sensu* NVIS (ESCAVI 2003)
   ii. the process of data analysis to identify and describe vegetation types from one or more classes in a hierarchy. This is a process associated with most quantitative vegetation survey and is supported by an extensive published literature
   iii. description and annotation of vegetation types from one or two levels in a classification hierarchy *sensu* Benson *et al.* (2006) and various published vegetation reports (Table App 4.1).

   Under this Standard, a **hierarchy of vegetation classes** (Tables App 6.3a & b) supports native vegetation activities in New South Wales.

2. Catchment Management Authorities (CMAs) and local governments need to position mapping products within a nested native vegetation classification hierarchy. 'Nested' means a specific relationship between map units at different spatial, compositional and temporal scales. Local governments commonly map in the range 1:1 000 to 1:10 000; CMAs in the range 1:10 000 (coastal local assessment) to 1:100 000 (inland regional planning) and State Government at spatial scales of 1:100 000 and above for regional and state-wide applications (scale ranges are approximate).

8.3 Statements of Standard

1. NSW adopts the hierarchical system of vegetation classes as detailed in Appendix 6.
2. Classification of new quantitative data follows the Standard for data analysis.

9 Spatial interpolation

9.1 Required Outcome

1. The spatial expression of native vegetation types, by modelling their distribution, is underwritten by consistent, comparable and transparent relationships between defined vegetation types and their physical environments.

9.2 Rationale

All hard copy or digital representations of vegetation types are models, regardless of how they are derived. The *Oxford Dictionary of Physical Geography* defines a model as a ‘selective approximation which, by the elimination of incidental detail, allows some fundamental relevant or intersecting aspects of the real world to appear in some generalised form’. All vegetation maps are generalisations or simplifications of nature.

Interpolation – mapping the distributions of vegetation types by interpreting their likely occurrence in unvisited parts of the landscape between locations where vegetation types have been observed on the ground. Ground observations may be based on general reconnaissance or spatially explicit vegetation sampling. Interpretation may be based on remote imagery, environmental data or a combination of both, using subjective expert judgement or a range of numerical modelling techniques.

Ground observations must conform to the Standard (see chapters 4 – Survey design, and 5 – Field sampling), i.e. they should be spatially explicit samples wherever possible, with reconnaissance providing supplementary rather than primary observations.

The choice of variables used during interpretation is crucial to the mapping outcomes. Variables chosen should have strong demonstrated relationships with floristic composition and be fully justified in documentation of methods for all vegetation survey and mapping projects.

The method of interpolation should be transparent, repeatable by other mappers, fully justified in the report of the survey and appropriate to the landscape and data.

1. Several interpolation strategies are used in New South Wales. The three main processes are outlined below although it is important to note that large areas of overlap exist between these strategies:

   i. **expert interpretation** undertaken by an individual or expert panel. In its most simple form this method involves the subjective attribution of remotely sensed polygons with vegetation classes, which are either pre-defined or defined progressively during the interpretation process; in its more complex form specific decision rules are developed and adhered to so that the process has some transparency. In some studies, the interpretation may also involve reference to environmental variables (e.g. altitude, substrate type). This process produces traditional deterministic vegetation maps, which are familiar to most users, but involves undocumented levels of subjective bias and limited transparency and repeatability of the mapping process

   ii. **deterministic decision rules** which link occurrence of each vegetation type with a set of spatial variables, which may include maps of remote sensing types, substrate types, climatic variables and/or terrain variables. Spatially explicit site data provide the basis for defining these relationships. Alternative sets of potentially suitable rules may be developed by computer-assisted statistical induction and are then evaluated by an operator with appropriate field experience in a process that may involve several iterations. As above, this process produces traditional deterministic maps. The method is more transparent and repeatable, but may be sensitive to gaps in the coverage of field observations and the choice and quality of spatial data layers

iii. **probabilistic models** quantify the strength of relationships among plant communities and the environmental data in the model and estimate the probability of occurrence of each vegetation type as a function of spatial variables. These may include maps of remote sensing types, substrate types, climatic variables and/or terrain variables. This process uses computer-based methods to quantify the relationships between vegetation types and the spatial variables. A range of modelling techniques are available, including Generalised Linear Models, Generalised Dissimilarity Models and Generalised Additive Models, all of which have been applied previously in New South Wales, as well as Neural Networks, Regression Trees and others. The output may be expressed as a traditional deterministic map showing the most likely vegetation type in each part of the landscape or as a set of probability surfaces that give more detailed information about inherent uncertainties which are ignored in other mapping methods. The method is transparent and repeatable and avoids use of artificially distinct boundaries, but is sensitive to data inputs and may be prone to modelling artefacts if the output is not sufficiently tested and amended.

2. Each modelling process has strengths and weaknesses. Research is needed to improve individual processes and trial the application of strengths from one process in another.
3. Outputs must be produced and used in appropriate ways that are cognisant of embedded uncertainties and errors. For example, when probability surfaces are expressed, interpreted and used in a deterministic way, with only the highest probability community being considered for each grid cell, the apparent level of error is frequently considered to be unacceptably high (although little literature quantifies such errors). Such usage ignores the wealth of information contained in the modelled output and frequently gives rise to misguided judgements of error.

9.3 Statements of Standard

1. The method of interpolation should be transparent, repeatable by other mappers and appropriate to the landscape and data.
2. The choice of spatial variables used in interpolation should have strong demonstrated relationships with floristic composition and be fully justified in documentation of methods for all vegetation survey and mapping projects.
3. Each interpolation has a detailed methodological statement justifying the approach.

10 Accuracy assessment

Accuracy assessment under this Standard includes concepts such as ‘ground truthing’ and ‘field validation’.

10.1 Required Outcome

1. The accuracy of spatial products, particularly vegetation maps, is tested and specified.
2. Accuracy assessment is based on clearly explained methods and analyses.

10.2 Rationale

All maps are produced assuming that they will be accurate or at least fit-for-purpose. This assumption of accuracy is rarely evaluated and if it is, there is no guarantee that the reported accuracy is a true test of the product.

This Standard distinguishes thematic accuracy from the spatial accuracy and precision of spatial products. The latter can be quantified and accounted for largely by reference to data sources and methods without the need for independent field-based assessments. For example, media such as SPOT5 and ADS40 imply a very high level of positional accuracy. This sort of data regarding precision, accuracy and reliability will contribute significantly to understanding limitations of spatial products by users and producers.

In contrast, assessment of thematic accuracy usually requires independent ground data, usually targeted at a finished map product. However, any process coming under the purview of this Standard which produces a spatial product could include an accuracy assessment. For example, a test of a stratification, which examines each ESU against its stipulated environmental parameters, would give map producers and users some concept of how well the stratification captures environmental variation in a study area. Ideally, every spatial product would be tested independently and the level of accuracy reported.

In reality though, accuracy assessments will be restricted to the most important final products (vegetation maps) due to trade-offs between the benefits of accuracy knowledge and the expense of acquiring that knowledge. To maximise return on investment, this Standard aims to ensure that accuracy assessment is carried out in a way that produces valid inferences about variation in map reliability and avoid wasted effort on uninformative fieldwork. Options for accuracy assessment include use of existing data, reuse of data for multiple assessments, data splitting and jack-knifing. Appendix 8 examines some of the ways in which information could be collected for multiple uses.

For an accuracy assessment to be acceptable it **must**:

1. be practical and provide useful information for map users and producers, and
2. be scientifically and statistically valid.

An accuracy assessment which does not satisfy these criteria runs the risk of being irrelevant and/or providing misleading information (either over optimistic or pessimistic) to decision makers, to the point of undermining any map-based planning or management decisions.

Appendix 8 introduces the methods and statistics which underpin accuracy assessment in this Standard.

10.3 Statements of Standard

1. All accuracy assessment is based on an unambiguous and clearly explained method which is appropriate to the spatial and thematic scales of the product being evaluated.
2. Accuracy is assessed according to an **equal probability sampling design** (Appendix 8) unless an alternative method is justified.
3. All field-based accuracy assessment will deliver basic floristic data pertaining to specific site localities (Appendix 8).
4. All accuracy assessment results in the production of an error matrix, as a minimum, and follows the labelling convention detailed in Appendix 8.
5. Precision and reliability data accumulated during remote sensing interpretation and interpolation processes will be reported as part of the accuracy assessment.

11 Reporting requirements and summary statistics

11.1 Required Outcome

1. All native vegetation survey, classification and mapping projects will provide full documentation of aims, methods and results and provide descriptive and statistical information to define classes and map units.

11.2 Rationale

1. Technical reports associated with vegetation survey, classification and mapping projects are frequently the primary source of information that describes the process, effort and results of those projects. To date technical reports have varied widely in format and content. This has diminished the effectiveness of some datasets by restricting third party assessments of data quality and limiting their application as natural resource management tools.
2. Standard reporting on key methods and results in conjunction with critical descriptive and/or summary statistics will increase the utility of final products.(Appendix 9a).
3. Summary statistics derived from quantitative field data are required to adapt vegetation mapping products to NRM regulatory tools such as PVP Biometric and BioBanking.
4. Key summary data are required to facilitate third party map validation and integration into the Native Vegetation Information System.
5. Descriptions of vegetation map units are a critical component of project reporting. These should provide summary information and explanatory data for the derived vegetation map product. They form the primary reference for a wide variety of map users. Current approaches to the documentation of map units are inconsistent. This leads to difficulties in the interpretation of map units between study areas and confuses users applying standard NRM regulatory tools.
6. A selection of minimum standard fields are required so that map unit profiles provide users with equivalent information irrespective of the method used in classification.(Appendix 9b).
7. Third party review of the final project technical report is required to meet this standard.

11.3 Statements of Standard

1. Every native vegetation survey, classification or mapping project will culminate in a final technical report which will, at least, be reviewed internally by suitably qualified staff outside the author's Branch (externally peer reviewed and published papers will also satisfy this Standard).
2. The final technical report (or externally published paper) will document key themes and summary statistics, describing methods and results associated with the implementation of this Standard (Appendix 9a).
3. Minimum standard fields, descriptive text and descriptive statistics are required for the final technical report or externally published papers (see Appendix 9 for details).

11.4 Additional information

Appendix 9 provides additional discussion.

12 Glossary

Term	Definition
Botanical data	In this Standard is used to mean (quantitative) information about the structure and composition of the plants in a defined area (plot)
Composition	The names, forms and relative importance of plant species in a vegetation type
Data	a. recorded, factual information from observation or measurement b. the numbers (digital information) in a computer system which are expressed visually as polygons, lines, grid cells, etc. c. the numbers (digital information) generated by satellite sensors, digital cameras, etc.
Floristic data	Information about plant species, the species present at a site or in a plot; see **botanical data**
Metadata	A precise and concise set of statements about a project or set of data, its nature, extent, quality, currency, custodianship and accessibility (see section 2)
Native vegetation map	One form of **native vegetation model**; map unit polygons represent the spatial expression of a community or group of communities and their landscape relationships to a cartographic standard
Native vegetation model	A simplified representation of natural complexity; **vegetation data and information** products that give spatial expression to native vegetation types (communities) and their landscape relationships. They may express extent as polygons or grid cells; vegetation maps are one form of model
Native vegetation TYPE	An all-encompassing term applying to any classification of native vegetation based on **composition** or composition and **structure** (e.g. plant community; broad floristic type). Vegetation TYPE is differentiated from **vegetation EXTENT** in which (native) vegetation is viewed as two or three broad classes (woody/non-woody or, dense woody/sparse woody/non-woody) for the purpose of measuring and reporting spatial coverage
Plant communities	Repeating and recognisable assemblages of plant species occurring together in the landscape, usually with similar structural characteristics. Communities are often equated to the sub-association of Beadle & Costin (1952) (see section 7 and appendix 6)
Plot	A measured area from which botanical and environmental data are collected as part of a botanical survey
Primary data	The actual value (measured or estimated) of any given metric; data that are not collected and recorded in pre-determined classes
Rapid survey	Any field survey in which the primary purpose is one of the following: familiarisation, checking of remote image interpretation coding/classification, and map field completion. Variously called reconnaissance and ground truthing
Remote Image Interpretation (RII)	Interpretation of remotely sensed imagery and data sourced from, for example, aerial photos, satellite images, Lidar and Radar. This interpretation may be visual or via use of computer programs
Stakeholders	In this document these are primarily: Ministers, executive and employees of NSW and Commonwealth Government natural resource management agencies; NSW land managers requiring vegetation type information; NSW consultants and contractors involved in supplying and interpreting native vegetation type information; academics involved in the supply and use of vegetation type information; NGOs concerned with vegetation type information
Stratification	Partitioning of a landscape (study area) into unique combinations of independent physical environmental attributes which are postulated to determine the distribution of plant species and which may be augmented by the addition of biotic information
Thematic mapping	Mapping of a theme. In natural resource management this term generally applies to mapping of such things as native vegetation, soil landscapes, geology and land systems
Vegetation activity	This term has been adopted in the Standard to minimise the possibility of prejudicial interpretations arising out of more commonly used terms (e.g. vegetation mapping) which imply a specific end point and product type. Vegetation activity includes: survey design, field survey, **rapid survey**, remote image interpretation, data analysis, classification, mapping and reporting.

13 Acronyms

Acronym	Meaning (explanation)
ADS40	A Leica Geosystems digital camera which will progressively replace traditional aerial photography for New South Wales
ANZLIC	Australia and New Zealand Land Information Council
API	Air Photo Interpretation (In this standard this term applies to visual interpretation of hard-copy aerial photography only.)
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	NSW Department of Environment & Conservation (now merged with DNR to form DECCW)
DECCW	NSW Department of Environment, Climate Change and Water
DLWC	NSW Department of Land and Water Conservation; now part of DECCW
DNR	NSW Department of Natural Resources (now merged with DEC to form DECCW)
EOAM	Environmental Outcomes and Assessment Methodology
EPBC	Australian *Environment Protection and Biodiversity Conservation Act 1999*
ESCAVI	Executive Steering Committee on Australian Vegetation Information (Commonwealth convened committee of Commonwealth, state and territory representatives)
ESU	Environmental Sampling Unit (a subdivision of the physical environment relevant to vegetation survey design and sampling; dividing the environment up into discrete and more or less homogeneous units facilitates cost-effective sampling)
FAO	United Nations Food and Agriculture Organization
LiDAR	**Li**ght **D**etection **A**nd **R**anging (light beams are emitted from the platform and the reflectance patterns are detected and interpreted)
NFI	National Forest Inventory
NLWRA	National Land and Water Resources Audit
NPWS	NSW National Parks and Wildlife Service
NRC	NSW Natural Resources Commission
NRM	Natural Resource Management
NVIS	National Vegetation Information System (a spatial and textual database developed through ESCAVI with funding from the National Land and Water Resources Audit)
NVMP	Native Vegetation Mapping Program; a systematic mapping program run by the then Department of Natural Resources
PVP	**P**roperty **V**egetation **P**lan under the NSW *Native Vegetation Act 2003* No. 103
RADAR	**Ra**dio **D**etection **A**nd **R**anging
RII	**R**emote sensed **I**mage **I**nterpretation (This term is intended to encompass visual and computer-based interpretation of aerial photography, airborne imagery and satellite imagery; it does not include interpretation of RADAR or LiDAR data.)
SCALD	**S**tandard **C**lassification for **A**ttributes of **L**an**d** (a standard set of API codes for landcover and landuse interpretation developed by the then Department of Natural Resources)
SEPP	NSW State Environmental Planning Policy (an instrument under the *Environmental Planning and Assessment Act 1979*)
SLATS	Queensland Statewide Landcover And Trees Study
SPOT	**S**atellite, **P**our l'**O**bservation de la **T**erre: French observation satellites, numbered 1 to 5
VIS	NSW Vegetation Information System
YETI	YET 1 more survey database (a Microsoft Access database written in DEC and designed to allow storage of plot-based vegetation and environmental data and retrieval of that data in formats compatible with most common data analysis software)
VCA	NSW Vegetation Classification and Assessment database (provides detailed descriptions of native vegetation types from a number of classificatory levels; provides indicative figures as to current extent and conservation level)

Appendix 1 NSW metadata elements

Metadata category	Core metadata element	Description
DATASET	Title	The name of the dataset
	Custodian	The primary organisation associated with the dataset and responsible for its maintenance
	Jurisdiction	The state or country of the custodian
	Identifier	Unique NSW identifier
DESCRIPTION	Abstract	A characterisation of the dataset, including a brief summary and the intentions for which the dataset was developed
	Search Word(s)	A commonly used word or phrase used to describe the dataset, chosen from a predefined list
	Geographic extent name(s)	A pick list of pre-defined geographic extents, such as map sheets, local government areas, catchments and CMA regions, that reasonably indicate the spatial coverage of the dataset
	Geographic extent polygon(s)	An alternative way of describing geographic extent if no pre-defined area is satisfactory. Defined as a series of coordinate pairs that define the area(s) covered by the dataset
DATA CURRENCY	Beginning date	The earliest date from which information in the dataset is current
	Ending date	The latest date to which the information in the dataset is current
DATASET STATUS	Progress	Progress status of the dataset, e.g. complete, in progress, etc.
	Maintenance and update frequency	The frequency of changes and additions made to the dataset after initial completion
ACCESS	Stored data format	A description of the format in which the data is stored
	Available format types	A description of any format types both digital and non-digital in which the dataset is available
	Access constraints	NFI use only
DATA QUALITY	Lineage	Information about events, parameters and source data used to construct the dataset and information about the responsible parties
	Positional accuracy	An assessment of the accuracy of the positions of spatial objects in the dataset
	Attribute accuracy	An assessment of the accuracy of the identification of entities and the assignment of attribute values in the dataset
	Logical consistency	An explanation of the fidelity or consistency of relationships in the datasets and the checking methods used
	Completeness	Information about omissions, selection criteria, generalisations, definitions used, and other rules used to derive the dataset
CONTACT ADDRESS	Contact organisation	The name of the organisation with which contact may be made to enquire further about the dataset
	Contact organisation jurisdiction	The state or country of the contact organisation
	Contact position	The position title of the individual within the organisation responsible for answering questions about the dataset
	Mail address 1	The mailing address of the contact position
	Mail address 2	Optional extension of mailing address 1
	Suburb/place/ locality	The suburb, place or locality of the mailing address

Metadata category	Core metadata element	Description
CONTACT ADDRESS, continued	State/locality 2	The state of mailing address
	Country	The country of the mailing address
	Postcode	The postcode of the mailing address
	Telephone	The telephone number of the contact position
	Facsimile	The fax number of the contact position
	Electronic mail address	The email address of the contact position or organisation
ADDITIONAL METADATA and DATE	Metadata date	The date that the metadata were created or last updated
	Additional metadata	This section should include: i) name(s) of the author(s) of the metadata sheet; ii) description of the full directory pathway to the data; iii) indication of where additional metadata about the dataset may be accessible, e.g. the name of any other directory system(s) where more detailed metadata are recorded; and iv) other information the author wishes to communicate to users which is not covered by the other proforma fields
EXTENDED DESCRIPTION DETAILS	Type of feature	The type of feature held in the dataset, e.g. point locality records, grid cell, vector or polygon data
	Attribute/field list	A list of the attribute codes or names of the dataset
	Attribute/field description	A description of the attribute codes or names for the dataset
	Attribute percentage completeness	A percentage that represents the level of completeness of each attribute
	Scale/resolution	The scale or resolution at which the dataset has been captured or derived
	Methods	A brief summary of the methods used to acquire or generate the data
	Tenure	Details of land tenure covered by the dataset. This is particularly important where the data are confined to one or two tenure types
DATASET ENVIRONMENT	Software	The name and version of the software in which the dataset has been developed/used
	Computer operating system	Operating system in which the data has been developed/used
	Dataset size	Size of dataset

Existing data

Procedures for assessing existing data

Task 1 – Identify all relevant datasets

Vegetation data relevant to the project, which cover part or all of the study area, are identified and evaluated; e.g. vegetation description, plot data, API, classification, modelling and mapping datasets.

Task 2 – Initial ranking of datasets

Ranking to be based on available METADATA; firstly on data quality relative to project and secondly on the extent of coverage across the project area. Highest rank to be given to datasets with apparently good quality data covering a large proportion of the project area. Some datasets may be eliminated at this stage.

Datasets must be ranked to determine the order of detailed evaluation. The ranking process may identify datasets which will not be useful or relevant and can be excluded from further evaluation.

Task 3 – Detailed evaluation of each dataset

Each identified relevant dataset is to be evaluated and its usefulness assessed by:

a. determining what data type/s the dataset contains (botanical plot data and/or mapped boundaries/line-work for map units and/or attribute coding of mapped units)

b. a detailed evaluation of whether any component data meets the Standard

c. determining whether the data:

    i. are to be used as part of the project (i.e. meet quality and currency standards)
    ii. are not to standard but may be cost-effectively upgraded or useful for validation
    iii. do not meet standards and cannot be cost-effectively upgraded and are not useful for validation.

Note that the evaluation of each dataset often requires contact with original authors.

Appendix 2 Remote sensing interpretation

Part A. Explanatory notes

Header information

Category	Datum	Description
Identification	Recorder	Full name of the person undertaking the Remote Image Interpretation [RII] (recorded in header row)
Project identification	Project code	**Three digit Alpha Code** for the survey area (e.g. NLB = North Lachlan Bogan). This must be unique* (recorded in the header row); allows compatibility with standard survey plot-numbering *A repository for project codes will be established as part of the NSW Vegetation Information System
	Project name	Full descriptive name of the project area
Map sheet identification	1:100 000 map sheet	Required for consistency with any botanical survey
	Map sheet name and number	Designated map sheet name and number
	Other map sheet name & scale	Where remote sensing interpretation is being undertaken on a larger scale map than 1:100 000, nominate the name and scale.
Image/data identification	Primary imagery type	The main type of imagery/data being interpreted. This includes contact prints, digitised contact prints, ADS40, Landsat, SPOT4 or 5, LiDAR and RADAR
	Primary imagery date	Date of the photography or other; record as dd/mm/yy
	Additional imagery type	Secondary or additional imagery/data being interpreted for the same job as the primary imagery type above. This includes contact prints, digitised contact prints, ADS40, Landsat, SPOT4 or 5
	Additional imagery date	Date of the secondary imagery/data; record as dd/mm/yy
Photo ID	CAG#	This is the catalogue number, usually 'NSW' or 'CAG' number that appears in the photo legend. The catalogue number is unique and identifies the photo's scale, date and location
	Run#	As recorded in the photo legend
	Frame/s#	Print number/s, usually recorded in a corner of the aerial photograph and may be recorded in the photo legend
	Date	As displayed in the photo legend
Other imagery ID	Row and path	Record the row and path numbers for any satellite platform data/imagery being used

Polygon specific data

Category	Datum	Description
Polygon identification	Polygon#	The polygon id is a sequential number assigned by the RII person, relating to the designated project and map sheet (see above). Any polygon id number must not repeat for a project code on any given map. If a single person is undertaking interpretation over the map sheet in question, a single numbering sequence will be used. Where two or more people are interpreting parts of a single map sheet, blocks of numbers will be assigned to each person. Alternatively, interpreters may use an alpha prefix (e.g. initials) to distinguish their polygons from others. In either case, the polygons may be re-sequenced on completion of the interpretation
Coarse filter Landcover	Candidate native non-woody vegetation and bare earth Herbaceous communities (woody component <5%)	**cn** non-woody areas **without** a previous cultivation pattern observed **NOTE**: **cn** is the default option; the following code is only used where a prior cultivation pattern is definite
		cl non-woody areas **with** a previous cultivation pattern observed (potential native vegetation)
	Bare earth (total vegetation cover <5%)	**ch** scalds, salt scald, bare fallow
	Woody vegetation	**g** indicating the presence of woody vegetation; any refinement of this code comes from the vegetation density and growth form fields
	Wetlands (natural)	**k** both woody and non-woody
	Artificial water storage and natural open water	**f** lakes, dams, weirs, turkey nest dams **NOTE:** These features identified commensurate with the conceptual scale of the RII
	Rock outcrop	**w1** <20% of area **w2** 20 to 50% **w3** 50 to 70% **w4** 70% of area
	Agricultural landcover	**a** (cropping, exotic pasture, horticulture, plantation)
	Non-natural landcover	**e** all man made landcovers other than water bodies (e.g. mining, quarrying, urban, roads, utilities) **NOTE:** These features identified commensurate with the conceptual scale of the RII
Vegetation cover	Tallest stratum cover (crown cover >5%) **NB Does not apply to emergents**	Cover of the tallest stratum in the polygon. This is defined as the '**dominant stratum**'; to be recorded as a crown cover percent. This, together with the following datum, represents the more-or-less stable cover of the polygon that is likely to change relatively slowly between observation dates. Polygons should be defined on broad cover classes which comply with the NVIS classes except in that they subdivide the Open Woodland and Isolated Trees classes:**<0.1%; >0.1–5%; >5–10%; >10–20%; >20–50%; >50–80%; >80% (see also Table App 2.1 following)**

Category	Datum	Description
Vegetation cover, continued	Additional woody cover (%)	Crown cover percentage of all observable woody vegetation other than the tallest stratum **Emergents** are, by definition, isolated individuals and do not form a stratum or layer. They may occur naturally or be remnants of the original trees in an otherwise cleared area
	Total non-woody cover % (ground cover)	Records the total non-woody and low shrub cover as a percentage of the polygon; to be recorded as cover percentage. This datum is essentially for non-woody polygons which may contain some low shrubby growth forms
Life forms	Growth form – dominant stratum	Records the growth forms of the **dominant** stratum (see Table App 4.5 for a full list)
	Dominant ground cover type/s	Grassy, dry scrub, wet heath, mesic, intermediate
Existing vegetation type	BioMetric communities	Communities as defined in the BioMetric PVP tool; links closely with the VCA. **The BioMetric type ID number is recorded in this field.** In an electronic database (e.g. the NSW Vegetation Information System) this is linked to all information fields
	Other classification	Polygons are attributed with an accredited existing type classification; from a plot-derived classification or other existing classification (e.g. the VCA where not yet incorporated into BioMetric or Regional Vegetation Committees). **NB If the NSW VCA is being used the type ID number will be recorded in this field**
Polygon confidence (reliability)	1	Polygon visited. Remotely observed signature is distinct and will not be confused with other pattern types, no unfamiliar or unexplained elements, relationship between pattern type or predicted species composition and landscape not an issue
	2	Polygon not visited. Remotely observed signature is distinct and will not be confused with other signatures, no unfamiliar or unexplained elements, relationship between pattern type or predicted species composition and landscape not an issue
	3	Polygon not visited. Remotely observed signature is reasonably good, some chance of mistyping, any unfamiliar elements are minor, may be some level of doubt regarding predicted species, vegetation type or pattern type and landforms
	4	Polygon not visited. Remotely observed signature is very similar to other signature/s and may have been mistyped, polygon contains unfamiliar or unexplained elements, polygon pattern, vegetation type or predicted species at odds with other remotely sensed elements
Photo pattern classification	Provisional pattern type	Classification of vegetation pattern types based on remote sensed (and possibly mapped) characteristics. More than one provisional pattern type may be assigned to a polygon where a mosaic is being delineated
	Final pattern type	Revised classification of remotely sensed vegetation pattern types based on plot survey or rapid survey

Category	Datum	Description
Species composition	Emergents	One species only (emergents are by definition isolated individuals and have <5% crown cover)
	Primary component	Species or species codes to be recorded in order of dominance separated by a comma (,); co-dominants to be separated by a dash (–); maximum 3 species
	Secondary component	Species or species codes to be recorded in order of dominance separated by a comma (,); co-dominants to be separated by a dash (–); maximum 3 species
	Tertiary component	Species or species codes to be recorded in order of dominance separated by a comma (,); co-dominants to be separated by a dash (-); maximum 3 species
Landform	Landform pattern	Recorded for landforms within a polygon; refer to: McDonald *et al.* (1990), pp. 34–57; **most frequently used in remote sensing interpretation**
	Landform element	Landform pattern components; refer to: McDonald *et al.* (1990) pp. 24–34; **may be recorded in simple or particularly subtle landscapes**
Condition	Features of the vegetation, observable remotely, which have some bearing on condition assessment	
	Regrowth	Nature of the regrowth (nominated); e.g. natural regeneration, restoration, plantings of single spp. of native plants, post disturbance dense regeneration
	Disturbance type and severity	Type of disturbance (nominated); e.g. fire, logging, storm damage, understorey removed, overstorey removed Low, medium and high severity ratings
Notes	Free text for additional data that will help identify the polygon type or to refine any codings as may be required	

NOTES:

1. Shaded areas are mandatory for all RII exercises. Unshaded areas are optional or used as needed.
2. NULL CODES: In some situations values will not be entered into a given field. No mandatory data fields are to be left blank. The following null codes will be used:

   - NA (not applicable), not logical in the current situation; e.g. woody cover in a non-woody polygon
   - NO (not observed), the attribute is probably present but cannot be observed at the scale/resolution/vegetation type; e.g. ground cover under dense tree or shrub canopies
   - NE (not entered), the attribute has been omitted for an unspecified reason, may require explanation in a free text comment.

3. GROUND COVER is defined as any vegetation less than about 0.5 m in height.
4. EMERGENTS are isolated individuals and do not comprise a stratum or layer. They should not be counted as part of the upper stratum in estimating crown cover percent.
5. ADDITIONAL DATA: Some projects require additional data fields (e.g. old growth, crown condition). The fields in this version of the Standard are considered primary data fields for most routine vegetation activities. If additional fields are used they will be clearly named and defined.

6. Severity codes are often subjective and are specific to a given activity. Severity may refer equally to the size of the impact as well as the frequency of the impact. The following definitions offer guidelines about the meaning of each code. Where a severity rating is called for, the following coding will be used:

   0=no evidence, not discernable, no impact

   1=light, little discernable evidence, low impact, infrequent occurrence

   2=moderate, clear evidence, impact clearly discernable, regular occurrence

   3=severe, inescapable evidence, high impact discernable, frequent occurrence (should be an outstanding feature of the locality).

Table App 2.1 An approximation of the relationship between crown cover (sensu Walker and Hopkins 1984) and foliage projective cover (fpc) (sensu Specht 1970) based on averaged measures.
NB This generalised relationship begins to break down significantly below about 20% crown cover.

CODE **Crown separation**	**D** Closed or dense	**M** Mid dense	**S** Sparse	**V** Very sparse	**Very sparse**	**I** Isolated – sparse	**L** Isolated clumps
Remote sensing criteria	Touching – overlapping	Touching, slight separation	Clearly separated	Well separated	Very well separated	Isolated	Isolated
Crown separation ratio	<0	0 – 0.25	0.25 – 1	1–3	3–20	>20	>20
Crown Cover %	>80	50–80	20–50	5–20	2–5	<5	<5
Foliage projective cover % (approx.)	70–100	30–70	10–30	Relationship with crown cover not reliable			

Part B. Visual interpretation – Data entry

NSW remote sensing data entry

Recorder__________________ Project ID: Code________ Primary imagery type ____________ Additional imagery type ____________________________

Name _____________ Date _ _ /_ _ /_ _

Date _ _ /_ _ /_ _

1:100 000 Map sheet name _________ Map sheet no._____ Air photo CAG# _____ Run# _____ Other imagery: Row#_________

Other map sheet: Name _________ Scale ______________ Frame/s# _____ Path ______

Polygon ID	Coarse filter	Vegetation density			Life forms		Existing veg type		Confidence
Polygon #	Landcover	Tallest stratum % cover	Total veg cover – not tallest stratum	Total non-woody cover % (ground cover)	Growth form – dominant stratum	Ground cover type	BioMetric	Other – name	

Landform		Photo pattern classification		Dominant species			Condition		
Landform pattern	Landform element	Provisional pattern	Final pattern	Primary component	Secondary component	Tertiary component	Regrowth	Disturbance Type	Severity

Part C. Visual interpretation – Discussion

Interpretation of remote sensed imagery can provide a primary spatial data layer and define the spatial extent of patterns in native vegetation through expert systems or computer modelling. This is true for mapping where stratification and GIS based modelling tools have been difficult to implement due to lack of environmental data of a suitable scale and quality.

The primary function of Remote Image Interpretation (RII) in an integrated program of survey and mapping is recognising and delineating spatial patterns in native vegetation, whereas the primary function of the analysed plot data is recognising and classifying floristic groups (communities or types).

There are many perceived advantages and disadvantages of visual image interpretation. Many authors (e.g. Chuvieco & Martinez Vega 1990, Kushwaha *et al.* 1994, Lilliesand & Kiefer 1994, Graetz *et al.* 1995) consider RII to be better than digital techniques because humans can take account of attributes such as:

- texture
- irregular and diffuse boundaries
- spatial relationships
- spectral signatures, colours and grey tones, and
- landscape and landform relationships.

On the other hand, for example, Milne & O'Neill 1989 and Chuvieco & Martinez Vega 1990 suggest RII is:

- time consuming
- imprecise and non-repeatable
- limited to characteristics of the vegetation visible from above, and
- subjective.

Themes

Project aims and themes must be clear when interpreting remote imagery. For example, in undertaking RII for soils mapping, the interpreter searches for combinations of landform, landform relationships and vegetation which, in a localised area, indicate more or less uniform soil characteristics (Gunn *et al*. 1988; pp. 94–95). Polygons are defined and delineated on characteristics which indicated uniform soils. In Land Systems RII, landforms (including geology and geomorphic history) are the main criteria to delineate pattern. In this case, vegetation patterns are a secondary attribute which help to identify the different land units contained in a land system (Gunn *et al.* 1988; pp. 100–104).

In this Standard, native vegetation type is the primary theme in which two main starting circumstances apply:

1. An appropriate set of vegetation types exists for the study area or has been developed for the study area as part of the project being undertaken (condition 1).
2. An appropriate set of vegetation types does not exist for the study area and/or traditional stratification/gap analysis is not possible due to the paucity of spatial data (condition 2).

Condition 1

Polygons are attributed with existing vegetation types. Remotely observed patterns are linked to types based on:

a. prior knowledge of the regional vegetation
b. linkage of plot data, used in defining the types, with remotely observed patterns
c. direct field observation from rapid survey.

This process often requires application of all of the above and close interaction between the RII officer and ecologists.

Any observed and delineated patterns that do not match existing types must be tagged as an UNKNOWN or an UNCERTAIN; see condition 2 below. Ultimately these may be added to an existing type or be further sampled and described as a new type.

Condition 2

Combinations of vegetation density, tone, texture and crown shape are used to recognise uniform vegetation characteristics. These combinations are referred to as pattern types. The interpreter may search for combinations in isolation or can develop a framework in which pattern types can be partitioned. Broad landform types provide one such framework; geology and geomorphology can also be used.

Pattern types can be tagged sequentially (for example 1–n) or can reflect an interpretation framework. Examples of interpretation frameworks include:

> **Landforms sequences**: Riparian Patterns – RIV1, RIV2…, Floodplain Patterns – FLP1, FLP2 …, Peneplain Patterns – PLP1, PLP2 …, Hill Patterns – HIL1, HIL2 ….
>
> **Geological sequences**: Vegetation Patterns on Modern Alluvials – ALL1, ALL2…, Vegetation Patterns on Quaternary Unconsolidated Sediments – QAT1, QAT2…, Vegetation Patterns on Jurassic Sandstone – JST1, JST2…, Vegetation Patterns on Tertiary Basalt – TBA1, TBA2…
>
> **Soil sequences**, **geomorphological sequences** or a combination of several of these.

These pattern types may be used for stratification, survey design and subsequently for defining the extent of recognised vegetation communities.

Remote and field observations

Attributes that can be detected remotely and those which require sighting in the field must be distinguished. Although there is some overlap, remotely sensed attributes include:

- overall vegetation cover
- where trees or shrubs are present:
    - crown density
    - crown colour or grey tone
    - relative height of the stratum
    - crown type or texture
    - relative crown size
- density of herbaceous vegetation (same as overall cover in grasslands, etc.) where visible beneath a canopy
- growth forms (trees, shrubs, etc.)
- background colour or grey tone
- broad landuse types
- landform pattern/element.

From this type of attribute a detailed description of the polygon can be developed.

Attributes requiring field observation include:

- detailed structure (number of strata, heights, densities)
- growth forms
- species composition

- landform element/morphological terrain type
- slope, aspect, runoff
- soil type
- soil surface characteristics
- landuse.

These attributes allow a detailed description of the vegetation type and condition at a site and its immediate environment. The RII data and analysed plot data allow detailed descriptions of vegetation types, accurate representations of their extent (see Section 9), and their relationships with the physical environment, to be formulated.

The current codings have been adapted from the NSW and interstate guidelines and reflect the focus of this process-driven Standard, i.e. pattern recognition and native vegetation mapping. Landuse and landcover codes have been adapted from the DNR SCALD codes.

Attribution levels

The Standard applies a filtering approach to polygon attribution. Application of a coarse filter is designed to distinguish polygons which will be mapped as native vegetation, those that are candidate native vegetation (herbaceous with a previous cultivation pattern), are naturally bare (e.g. rock faces) and non-native landcover.

Having applied the coarse filter and designated a polygon as non-native vegetation, no further attributing is necessary; however, once a polygon has been designated as native vegetation or candidate native vegetation it must be fully attributed.

Application of the fine filter (structural attributes, pattern characteristics, growth form) will help define new polygons (Figure App 2.1).

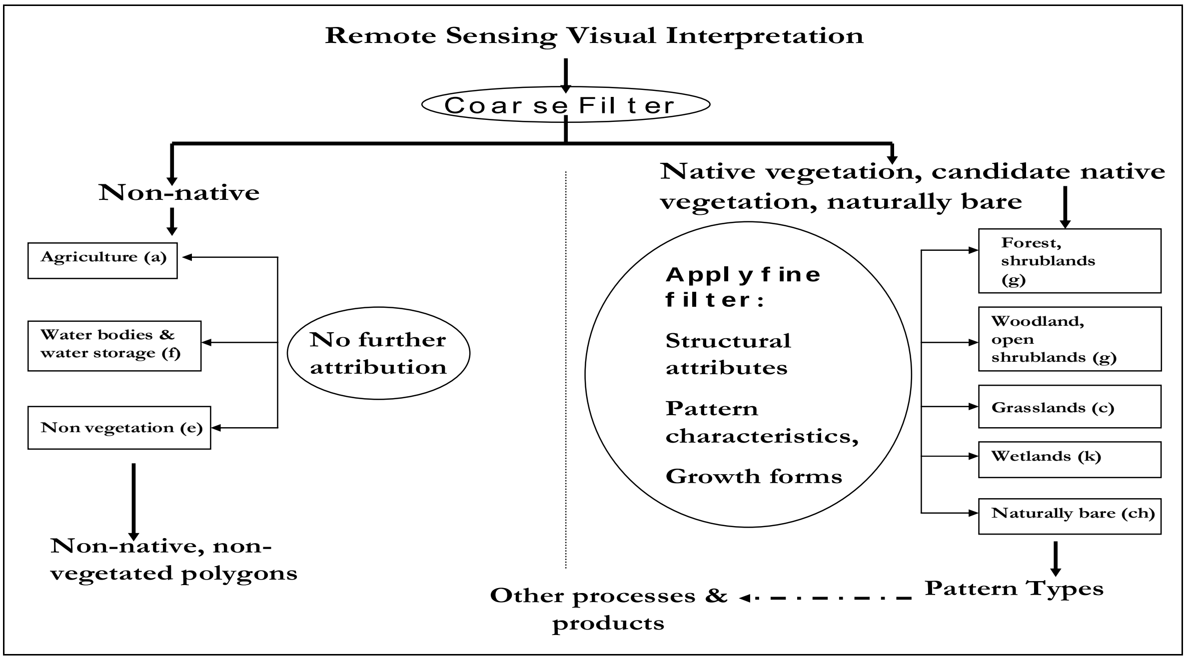

Figure App 2.1 Flow chart showing the level of attribution required for polygons with native and non-native characteristics.

Scale and resolution

The significance of scale is canvassed elsewhere (see Introduction and Appendix 3a). The scale of the project and its outputs also impacts on visual interpretation of remote sensed imagery. Table App 2.2 provides the standard for New South Wales. Increasingly fine resolution remote sensed imagery and apparently scale-less presentation of products in GIS environments does not obviate the need for this Standard. It is increasingly important to clearly set the spatial and thematic limits for spatial products. This standard is based on the BRS (2002) standard and differs from the guideline adopted previously (Sivertsen & Smith 2006), which was based on Gunn *et al.* (1988).

Table App 2.2 Size limits of mapped features due to cartographic constraints (from Bureau of Rural Sciences 2002).

		Cartographic scale			
	Size on map	**1:25,000**	**1:50,000**	**1:100,000**	**1:250,000**
Area of the smallest mapped feature	2mm×2mm	0.25ha	1ha	4ha	25ha
Minimum width for linear features	1mm	25m	50m	100m	250m
Compilation scale (notional)		1:15,000	1:25,000	1:50,000	1:150,000

Appendix 3 Survey design

Part A. Stratification and survey effort

Introduction

The distribution and abundance of most species are non-random and linked to environmental factors (Margules & Scott 1983). All species occur in a characteristic, limited range of habitats. Within their range, species tend to be most abundant around their particular environmental optimum (Ter Braak & Prentice 1988), i.e. the preferred niche. These niches can be quantified using environmental variables (e.g. altitude, rainfall, temperature, solar radiation, substrate, distance to water). The composition of biotic communities changes along environmental 'gradients' (Austin 1991, Austin & Heyligers 1989, Ter Braak & Prentice 1988). The word 'gradient', has a particular meaning in this context. Gradients may or may not be continua in space or time. For example, geology does not necessarily form a gradient in the same way as altitude or rainfall does; changes may be abrupt or incremental depending on spatial scale and lithology. Geology is mapped as discrete types which may be treated as 'classes' in partitioning the physical environment. Thus, the concept of gradients can explain the distribution of organisms in space and time (Ter Braak & Prentice 1988). The spatial relationships between plants and the physical environment is important when undertaking botanical survey or reconnaissance survey. The relationship between plants and environment, even if imperfectly understood, introduces predictability into this process that would be absent if plant distribution was random.

Several guidelines address the amount of sampling effort need to adequately classify and describe vegetation types (Brocklehurst *et al*. 2007, Neldner *et al.* 1999, Reid 1988, FAO 1979). Unfortunately, none of these agree with the survey effort for most botanical surveys across Australia. Survey effort is discussed below.

Stratification

Stratification aims to facilitate efficient and comprehensive vegetation sampling, i.e. in all the component environments of a study area in such a way as to ensure that the variation in vegetation composition is adequately sampled. Stratification can be described in four basic steps:

1. Select independent attributes of the physical environment which are postulated to influence or reflect the distribution of plant species.
2. Select, if appropriate, aspects of the biotic environment which are likewise postulated to influence or reflect the distribution of plant species.
3. The independent physical and biotic classes are intersected to partition the landscape or study area into unique classes. These classes, known as environmental sampling units (ESUs), provide for a field sampling program that covers the range of spatially represented variation for a survey area in an efficient and comprehensive way.
4. If appropriate, devise additional sampling rules to be applied in the field (e.g. sampling of topographic or catenary sequences). Figure App 3.1 illustrates a stratification used in a botanical survey of the Coonabarabran/Gulgong area; it shows the intersection of three environmental layers to produce ESUs.

Alternatively the independent physical variables may be treated as continua and a gap analysis approach taken to assigning sites which sample optimally across all strata.

A flexible approach to stratification is essential. Data availability and regional characteristics dictate that the process varies across the state.

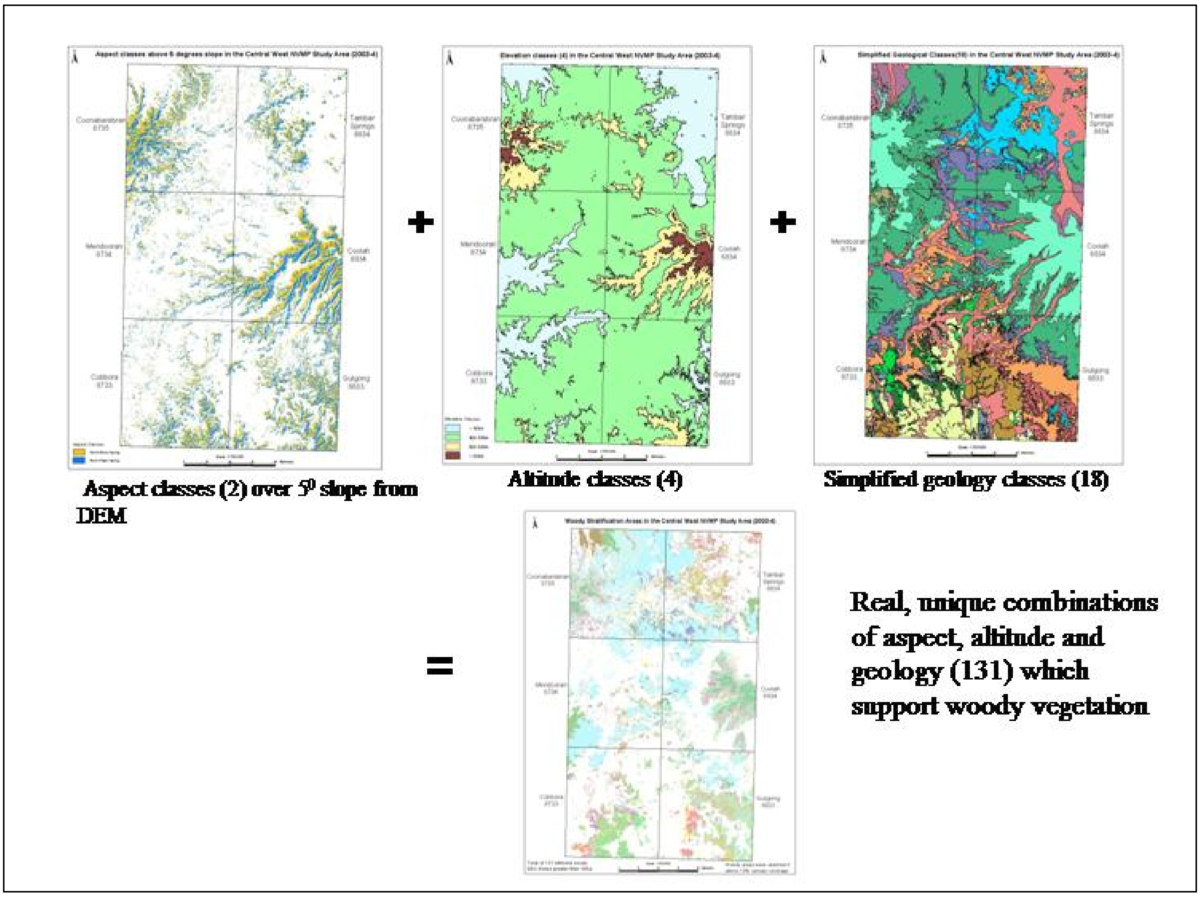

Figure App 3.1 An example of stratification (from Ismay *et al*. 2004).

It is important to understand how plants arrange themselves in relation to one another in the landscape. Plant species may correlate positively or negatively (or be un-correlated) with the chosen environmental gradients; assemblages of species will tend to behave predictably. Different functional groups of species may respond differently one from the other, for example some areas of black box woodland have a grassy understorey, others have a herb understorey whilst still others have a shrub layer and sparse groundcover. Understorey species respond to specific physical conditions (either environmental or related to management history) which may be superficial and not impacting significantly on the growing environment of the tree species. It is possible, therefore, to recognise logical groupings of species (called types, communities, associations or sub-associations, etc.); some species will be common to a number of communities while others will be specific to one.

In summary, most literature suggests that patterns of plant species occurrence reflect physical environmental gradients and that functional groups of plants respond to these gradients differently. Sampling along gradients provides a great deal of information about how various aspects of the physical environment influence species compositions.

Selection of variables

1. Choose environmental layers (variables) that are most likely to influence plant distribution.
2. Choose variables that are informative at the specified scale of data acquisition. A 1:250 000 scale soils layer may not be informative for data acquisition at 1:50 000; a 5m Digital Elevation Model (DEM) will not be informative on riverine plains where local elevation variation is only a few metres.
3. Represent aspects of climate, terrain, substrate and, if necessary, vegetation structure.

4. Select variables for which consistent coverage of spatial data is available across the study area.
5. Avoid duplication or ‘redundant’ variables; variables should be independent.
6. It is legitimate to use variables which are not represented spatially (e.g. landform element, catenary sequence). It is advisable to use only one such variable in any sampling strategy, overuse will complicate area calculations and planning of field work.
7. Generally, the more **independent variables** the better.

Number of environmental sampling units

1. The number of ESUs should allow for comprehensive sampling of the study area at the desired scale.
2. The number of ESUs will depend on the resolution of the spatial data available. In some parts of the state, because of inadequate or poor resolution environmental layers, it may be more efficient to sample based on RII vegetation patterns or to include RII classes as a layer in stratification.
3. There is an iterative relationship between the number of ESUs and the expected number of plot samples. As a **rule of thumb** the maximum number of ESUs should be about one third of the total number of sample localities.

Examples of stratification

By selecting appropriate thematic information about the physical environment, it should be possible to overlay or intersect the various layers and thus produce a set of ESUs. Each ESU may be treated as unique or, with the advent of more sophisticated computer software, it may be possible to articulate degrees of similarity/dissimilarity among ESUs.

To develop a logical and efficient system of sampling it is necessary to know, for each mapping region, information about the physical environment and to understand how that information relates to plant distribution (for example, aspect may be important in some parts of New South Wales but relatively unimportant where seasonal sun angle differences are less marked). Relationships between species distribution and environmental gradients have been used by many authors (Table App 3.1).

Table App 3.1 Stratification strategies from a range of vegetation survey and mapping projects.

Stratification	Study area	Author/s
1. different stages of calcrete formation 2. distance from the coast (surrogate for increasing aridity and occurrence of increasingly siliceous inland dunes, one of the prime determinants of species distribution)	Eyre Peninsula SA	Margules & Nicholls (1987)
1. broad east-west regional transects 2. positioned to sample the greatest possible range of geological map units, altitude, and mean annual rainfall	north-eastern NSW	Austin & Heyligers (1989)
1. parent material 2. topography 3. vegetation structure from API 4. up to three topographic positions in each parent material/vegetation structure combination	O’Hares Creek Catchment	Keith (1994)
API remotely sensed vegetation patterns in the absence of adequate environmental layers	western plains of NSW	Sivertsen & Metcalfe (1995)
1. mapped landform types 2. location (3 latitudinal and 3 longitudinal zones)	Kellerberrin; Western Australian wheatbelt	Brooker & Margules (1996)
1. seven classes of mean daily temperature 2. eight classes of mean annual rainfall 3. 153 soil landscapes (great soil group) 4. up to three topographic locations sampled per site	Central Lachlan	*Austin *et al.*(2000)

Stratification	Study area	Author/s
1. parent material (8 classes) 2. altitude in metres above sea level 0–150; 151–300; 301–450; 451–600; 601–750; 751–900; >900 (7 classes) 3. four terrain classes, - low slope (<5° slope) and three different aspect classes on slopes > 5° 4. aspect classes **north** 30–300°, **south** 120–210°, and **intermediate** 30–120° (**east**) and 210–300° (**west**) – only north and south were postulated to explain the distribution of species	Eden 1:25 000	Keith & Bedward (1999)
As for Keith & Bedward (1999)		NSW NPWS (2000e) and Connolly (2000)
1. five categories of substrate 2. six altitude classes: 900–1000, 1000–1100, 1100–1200, 1200–1300, 1300–1400 and >1400 3. three non-slope topographic classes: Ridge, Flat and Open Depression 4. four aspect classes on slopes >5°: described as north, south, east and west	Guyra 1:100 000	Benson & Ashby (2000)
1. soil landscapes (82 classes) with 2. mean annual temperature (three classes) 3. mean annual rainfall (two classes) This stratification yielded 175 true combinations of the layers; not all theoretical combinations exist in nature. Two biotic masks (woody vegetation with >5% crown cover and candidate non-woody native vegetation) were used to ensure capture of both woody and non-woody vegetation types	six 1:100 000 maps in central western NSW	Lewer *et al*. (2002)

*Note here that two 1:100 000 map sheets in the original study area specifications were abandoned because soil landscape mapping was unavailable. These map sheets, Gindoono and Tullibigeal could not be satisfactorily stratified in a way compatible with the other maps, without the soils data layer.

Stratification area

In all the examples quoted above, with the exception of Benson & Ashby (2000), stratification has been done over a considerable area. Specifically, it has not been done over a single map sheet. For example, Austin *et al.* (2000) stratified over an area covering nine 1:100 000 map sheets. There are considerable efficiencies to be gained in taking this approach. Stratification is time consuming and frequently requires an iterative approach before a satisfactory result is obtained. To have to repeat such a process for each map sheet will be well beyond the resources of most native vegetation surveys.

As a general rule it is advisable to cover the largest feasible area in a single process. In setting limits to stratification area, consideration should be given to availability and consistency of environmental layers and to broad geographic zoning. It may present undue difficulties, for example, to attempt to stratify part of the western slopes in the same exercise as a large area of the western plains. It would be logical to undertake separate stratifications for the slopes and the plains. Similarly, it would not be logical to include areas with inconsistent physical attribute coverages in the same stratification (see the Central Lachlan example above).

Survey effort

The aim of this aspect of survey design it to ensure sampling effort is commensurate with the purpose and scale of the project at hand. Survey effort relates to scale, complexity of the landscape, expected complexity of the vegetation, degree of clearing and plot size (see Neldner *et al.* 2005 p. 26). All of these must be considered in the context of available resources (time, funds and staff). Table App 3.2 contains a number of survey designs which have been taken from recent reports and illustrate the types of sampling effort and rules which may be applied to the survey design. Sampling rules in most of these cases reflect the range of calculated ESU areas and have been applied on a per 1:100k sheet basis.

Scale and its relationship to the Standard

The Standard addresses **process** rather than end-point products and so is intended to be scale independent; however, it is important to understand the language and implications of scale in undertaking vegetation activities (see the text box at the end of this section). There must be an explicit decision regarding the scale of effort and end products in the very early project design phase. The client and provider must discuss what is needed from the job, what notional scale will support the business needs of the client and the resources (time, staff, funding) available to the project. Limits on resources may dictate a smaller scale or a smaller study area; conversely, business need may dictate that more resources be found to undertake the work at the required scale. There may be a need for some trade-off amongst these considerations.

NB In a modern GIS environment products can be presented as scale free, i.e. they can be displayed and interrogated at any scale. It is essential that contemporary vegetation activities are undertaken at a clearly stipulated scale. This will allow the display and interrogation limits of a product to be set, based on clear criteria.

It is not possible to record and map all features of a real landscape; any thematic map represents an abstraction based on a limited number of observations (Gunn *et al.* 1988). Scale is proportional to the level of ecological detail or abstraction that can be represented on a vegetation map or in a database. To produce a reliable map, Reid (1988) suggested a sampling intensity of 0.5–1 plots/cm^2 of the final map area, while the FAO (1979) suggested a minimum sampling intensity of 0.25 plots/cm^2 of map area (note these are scale-independent criteria). Most of this work (Reid 1988, FAO 1979) is based on soil survey and mapping, although the principles are relevant for most themes, including vegetation. To meet these standards, a vegetation survey covering 100 km^2 at a scale of 1:100 000 would require between 25 and 100 plots (a single 1:100 000 sheet covers roughly 2600 km^2.). A survey over the same area conducted at 1:25 000 would require between 400 and 1,000 plots. Because the amount of detail on a 1:100 000 map is less than a quarter of that on a 1:25 000 map, fewer plots are required. Tables App 3.3 and App 3.4 show how recent botanical survey effort compares to the above theoretical plot densities. The information contained in these tables may also serve as a guide in planning future projects. Neldner *et al.* (2005) used a minimum sample density of half the FAO (1979) recommendation. For comparison, see the recommended plot densities taken from the Northern Territory Manual (Brocklehurst *et al.* 2007) (Table App 3.3). All projects appearing in Table App 3.4 may be regarded as high quality regional scale mapping. The great variation in the survey effort reflects the degree of clearing, the complexity of the landscape and vegetation, and the availability of existing data of suitable quality.

Complexity of the study area

Complexity of the study area (e.g. geology, landform and topography) should be reflected in the stratification. If important aspects of environmental diversity cannot be expressed through the stratification, it should be addressed through site-based rules. For example, in a study area with fine-scale topographic variation, it may be necessary to sample two or three aspect classes or landform elements at each designated site; in particularly flat terrain it may be necessary to sample at set distances from water bodies.

Degree of clearing

The number of sites allocated to any given ESU will also depend on the amount of native vegetation it currently supports. Some ESUs may have been totally cleared of native vegetation and will therefore not be sampled. Other ESUs may be in near natural condition and require sampling according to any rules that may be set. Therefore, it will be important to decide prior to embarking on the survey design, the degree to which derived native vegetation is to be sampled. In any agricultural area of the state there is likely to be a spectrum of derived vegetation ranging from mature woodland or forest (which may not appear to be regrowth) to recently fallowed fields with regrowth native grasses, herbs and exotic weeds. This goes back to the pre-survey planning when the product type and scale are decided (see Introduction).

Scale

Scale is a ratio that measures the spatial resolution of mapping. The language of scale may be understood if scale is seen as a fraction. The greater the numerical value of the fraction, the greater the scale and hence the greater the resolution of the mapping. For example, 1/25 000 is a larger fraction than 1/100 000 and therefore 1:25 000 is a larger scale than 1:100 000; the former indicates a larger scale map and greater spatial resolution than the latter.

The level of attribute detail is not necessarily strictly determined by the scale at which real world features can be represented on maps. The locational accuracy of real world features is scale dependent, but the level of attribute detail may be dependent upon the method of data capture. An exception is when the extent of a real world feature is so small that the scale of a map is not capable of discerning that feature. For example, a circular area of vegetation (diameter 2 metres) is impossible to represent as a circular polygon of 0.008 millimetres (2000 mm/250000 mm) diameter on a 1:250 000 scale map. Conversely, vegetation covering a circular area with a diameter of 1 kilometre can be represented (as a polygon of 4 millimetres diameter) on a map of the same scale.

Length and area

Changing from one scale to another has important implications for the representation and analysis of information. A line on a 1:25 000 scale map becomes ¼ its original length on a 1:100 000 scale map (25 000/100 000=1/4) which represents a 75% reduction in the length of any line. The same reduction of scale comprises a 93.75% reduction in the area of any polygon $[(25\,000/100\,000)^2=1/16]$ (Hudson 1992). The inverse is also true; most problems arise in attempting to blow up a small scale map to a larger scale.

Polygon size

The 'on ground' size of vegetation remnants or patches which can be represented also varies with scale. Some debate exists over optimum polygon size for a thematic map. Reid (1988) suggests that a more or less circular polygon should not fall below about 5 mm diameter, while Gunn *et al.* (1988) suggest 10 mm diameter as a lower threshold. Using these rules and at a scale of 1:25 000 it is therefore possible to represent a minimum on-ground area of between 1.25 ha and 4.9 ha. At a scale of 1:100 000, on the other hand, it is possible to represent a minimum on-ground area of between 20 ha (5x4 mm) and 78.5 ha (10x7.8 mm). These are suggested minima only and are challenged by many mappers. Exceptions to these rules also arise in fragmented landscapes; isolated remnants considerably smaller than the theoretical minimum can be successfully shown simply because they are isolated.

Grid cell size

Whilst grid cell size is not, strictly, a measure of scale, it is relevant for electronic databases and geographic information systems. A grid cell size should be chosen that is commensurate with the scale chosen for mapping. Using Reid's (1988) suggestion for minimum polygon size, for example, a 100 m grid cell size is commensurate with 1:25 000 mapping. Spurious precision can be introduced by opting for a very small grid cell size.

Table App 3.2 Summary of survey design and survey effort for some recent projects. All projects are at the same scale.

Survey	Stratification (number of classes)	No. ESUs	Plot allocation (number per ha of ESU)	No. plots	No. plots per sheet	Additional rules
Lewer *et al*. 2002; 6 sheets	Temperature (3), rainfall (2), soil type (83). (woody/non-woody mask)	175	Plots allocated to each map sheet independently 10–500 ha 1 plot 501–1500 ha 2 1501–3000 ha 3 3001–5000 ha 4 5001–7500 ha 5 7501–10 500 ha 6 >10 500 ha 7	850	142	Plots >100 m from ESU boundary Plots >100 m apart Maximum buffer on narrow linear features
Horner *et al*. 2002; 6 sheets	Land capability (5), landscape (13), rainfall variability (6)	101	Plots allocated to each map sheet independently <100 ha 0 101–12 000 ha 3 12 001–25 000 ha 6 25 001–100 000 ha 9	748	125	Plots >100 m from ESU boundary Plots >200 m apart Maximum buffer on narrow linear features
Cannon *et al*. 2002; 4 sheets	Rainfall (4), elevation (6), geology (8)	not given	Plots allocated to each map sheet independently <100 0 100 to 10,000 3 >10,000 6	919	230	Plots >100 m from ESU boundary Plots >200 m apart Maximum buffer on narrow linear features
Ismay *et al*. 2004; 5 sheets	Geology (17), elevation (4), terrain (3) (woody/non-woody mask)	149	Plots allocated to each map sheet independently 10–50 (optional) 1 51–500 2 501–1000 3 1001–3000 4 3001–5000 5 5001–10000 6 10001–25000 7 >25001 12	919	184	Plots >100 m from ESU boundary Plots >1000 m apart Maximum buffer on narrow linear features

Survey	Stratification (number of classes)	No. ESUs	Plot allocation (number per ha of ESU)	No. plots	No. plots per sheet	Additional rules
McNellie 2004; 6 sheets	Land capability (3), geology (6), broad vegetation types (21)	103	Plots allocated to each map sheet independently 101–3000 3 3001–15 000 4 15 001–70 000 6 >70 000 9	563	84	Plots >100 m from ESU boundary Plots >200 m apart Maximum buffer on narrow linear features
Peacock, in prep; 7 sheets	Geology (35), aspect (4), altitude (5), slope (3), landform (5)	?	?	2147	307	
Tindall *et al*. 2004; 15 sheets	Terrain class; aspect; slope; minimum temperature of the coldest period; maximum temperature of the warmest period; annual precipitation; and lithology	not given	Gap analysis tool used	5748	383	not given

Table App 3.3 Northern Territory recommended sampling intensity for various scales of mapping (from Brocklehurst *et al*. 2007).

Scale of published map	Area in hectares represented by 1 cm^2 on map	Recommended sampling density over 1 km^2 Example: mapping 1000 km^2	Number of sites
1:5 000	0.25	100	100,000
1:10 000	1	25	25,000
1:25 000	6.25	4	4,000
1:50 000	25	1	1,000
1:100 000	100	0.25	250
1:250 000	625	0.04	40
1:1 000 000	10,000	0.003	3

Table App 3.4 Plot densities from recent floristic surveys for map production.

Survey	Survey area (ha)	Approx map area (cm^2)	Number of sites	Sites/cm^2 of map area
Lewer *et al.* (2002)	1,576,000	15,760	850	0.054
Horner *et al.* (2002)	1,528,410	15,284	748	0.050
Cannon *et al.* (2002)	1,065,000	10,650	919	0.086
Ismay *et al.* (2004)	1,315,000	13,150	919	0.070
McNellie (2004)	1,509,870	15,100	563	0.037
Tindall *et al.* (2004)	3,016,500	30,165	5,748	0.19
Peacock (in prep)	1,813,100	18,131	2,147	0.12
Benson & Ashby (2000)	267,000	267	312	0.12

Part B. Survey design – Plot size

Recent literature abounds with discussion of plot size, some of which argues for a standard plot size while other argues against it. Thackway *et al.* (2005) point out that there is an inevitable trade-off between plot size and the number of plots that can be recorded. Species-area curves can be used to determine the most efficient plot size for a given vegetation type (capture the majority of the species on site – alpha diversity) and the number of plots needed to capture the full range of species occurring across the extent of the vegetation type (beta diversity) (Mueller-Dombois & Ellenberg 1974, Kent & Coker 1994).

Recent work in New South Wales indicates that characteristics of observers (e.g. local experience, time allowed for plot) may well be more significant than plot size in explaining differences in the number of taxa recorded (NVMP unpublished data); whilst modern analytical techniques can accommodate more than one plot size (see Keith & Bedward 1999, Austin *et al.* 2000).

Various plot sizes have been recommended. Hnatiuk *et al.* (2005) suggest that plot size needs to vary with the height of the vegetation being sampled:

- >20 m high; 900 m^2 (30 m x 30 m) plots
- <20 m high; 400 m^2 (20 m x 20 m) plots
- <1 m high; plots from 25 m^2 (5 m x 5 m) to 4 cm^2 (2 cm x 2 cm).

Field data from many sources was collated and assessed by Tindall *et al.* (2004) who report the plot size and type of data collected in their assessment of existing data. Sivertsen (2001) collated similar data from published survey reports around New South Wales. Table App 3.5 illustrates that a plot size of 0.04 ha (20x20 m) is the most frequently used. The exceptions are usually smaller plot sizes used in grassland or heathland surveys, or larger plots sizes used in open woody communities where overstorey is the main focus.

Table App 3.5 Plot sizes from a range of NSW surveys; principally those used in recent mapping projects [compiled from Tindall *et al.* 2004 & Sivertsen 2001].

Quadrat size (ha)	Type of data	Reference
0.04	Full floristics	Andrew (2001), Bell & Douglas (2002), Benson & Ashby (2000), Benson & Howell (1994), Clements *et al*. (2000), Douglas & Bell (2002), ESP (2001), Fisher & Ryan (1994), Fisher *et al*. (1995), French *et al*. (2000), Hibberd & Taws (1993), James, Lembit, Burcher & Ecograph Consulting (2002), Keith & Bedward (1999), Keith & Benson (1988), Keith *et al*. (2000), Lembit (2002), Lembit (in prep. 2001), Leonard (1999), Lockwood *et al*. (1997), NSW NPWS (2000a), NSW NPWS (2000b), NSW NPWS (2000d), NSW NPWS (2000c), NSW NPWS (2001), NSW NPWS (2002), NSW NPWS (2003a), NSW NPWS (2003b), Payne (1996), RBG (misc. data sheets 1974–1987), Sivertsen & Metcalfe (1995), Smith & Smith (2000), Steenbeeke (1990), Taws (1997), Thomas (2001), Thomas (undated), Thomas *et al*. (2000), Tindall *et al*. (2004), Tozer (2003)
0.1	Full floristics	Binns (1997), Gilmour (1985), Helman (1983), Jurskis *et al*. (1995), Portners *et al*. (1997)
0.04-0.1	Full floristics	Beukers (undated), Black (2000a), Black (2000b), Proust Bushland Surveys (2002)
0.04 & 0.0025	Full floristics	Keith (1994)
0.01	Full floristics	Benson (1994) Monaro grasslands
unknown	Full floristics	CSIRO (1999a), CSIRO (1999b), NPA (1998)
0.04	Presence/absence	Skelton & Adam (1994), Smith & Smith (1996)
0.04	Partial floristics	Togher (1996)

Appendix 4 Field sampling

Field data – Explanatory notes and definitions

NB There is a key to superscripts after the tables.

Module 1 Minimum requirements

Location

Datum	Explanation	
Date	dd/mm/yy.	
Plot identification	Plot identification is in two parts (**NB The limit on the number of characters is dictated by software limitations on row labels.**)	
	Survey ID	Three digit alpha code for the survey area (e.g. NLB = North Lachlan Bogan), do not repeat codes already in central database.
	Plot no.	The plot number is a three digit numeric, as assigned by the field staff. Plot numbers must not be repeated within a Survey ID.
Recorders	Official codes for each person involved in description of the plot. Field staff must check with the central database to ensure no duplication occurs. The ID code will be the first three letters of the Surname followed by the person's initials or the first two letters of their first given name, e.g. Peter L. Smith will be SMIPL.	
Grid reference	**NB** Grid reference is chosen as the standard in order to accommodate old and new technologies. The DECCW survey database automatically converts grid references to latitude and longitude and can export plot locations in either form. The NSW Department of Lands Geodetic standard is GDA94. **By convention grid references are recorded from the SW corner of the plot.**	
	Zone – NSW contains three grid zones; the correct zone must be chosen.	
	Datum – Record the datum being used. The Standard datum is GDA94 (Geocentric Datum Australia) which is the same as WGS84 (World Geodetic System); some GPS may not be programmed for GDA94 but all will be programmed for WGS84. If grid references are calculated from an existing map the DATUM may not be GDA94 and must be specified.	
	Easting and Northing are read off the GPS or calculated from a topo-cadastral or topographic map.	
	Position in quadrat – record the position of the GPS in general terms, e.g. SW corner, centre (note the above convention).	
Base plot dimensions	External dimensions of the plot (metres).	
Plot orientation	Rectangular plot – compass bearing of the long axis (in a square plot the orientation is the same as the aspect).	
Marked	Has the quadrat position been marked for later re-visiting? YES or NO **NB** By convention the SW corner of the plot is marked (otherwise location must be specified); markers should be of a type that will not injure livestock and will be locatable after fire or other disturbance.	
Photo number/s	The frame or sequence numbers for each photo taken at the site. A ‘Photo-board’ may be placed in the plot, so that relevant details (number and date) are recorded on the photograph.	
Plot photo orientation	Compass bearing of the plot photos.	

Existing classifications

Datum	Explanation
Keith class	See Keith 2004.
Regional veg class	Existing regional vegetation type class where these exist.
BioMetric type (or NSWVCA)	Current BioMetric community list current at the time; Benson *et al.* (2006) and subsequent publications.
Type: other	Any other classification or community name relevant to the site.
[1]Confidence	Level of certainty that the site is representative of the nominated type.

Structure and composition

Datum	Explanation
[2]Stratum	A stratum is a distinct height class in the vegetation and must have a crown cover of 5% or more. The descriptors **Upper**, **Mid** and **Ground** reflect the major expected growth forms. In non-woody vegetation only the Ground stratum is present and will be confined to the lowest three entries on the form. A stratum may contain more than one layer (e.g. the mid-stratum may consist of shrubs comprising two or three distinct height classes); the Standard allows for up to three **layers** in each stratum (layers do not have to be present).
Growth form	Record the dominant growth form in each stratum/layer (see Table App 4.5). In some cases it may be necessary to record more than one growth form, e.g. where grasses and low shrubs are of equal height and importance in a stratum.
Dominant species	List the three most common species in decreasing rank order in each stratum.
[3]Cover	Record the percent cover for each recorded species
Height	Record the height of each stratum. Height is always measured to the top of the crowns, tussocks, etc. Record the tallest height (max), the lowest height (min) and the most commonly occurring (mode) height for each stratum/layer.

Condition

Datum	Explanation
Native richness	Number of native species found in each stratum – species such as mistletoe should be counted for the stratum they inhabit.
Native cover	Total cover of native species in each stratum.
Exotic cover	Total cover of exotic species in each stratum.
Cover non-vegetation	The percent area of the plot covered by litter and bare ground respectively.
Number of trees with hollows	Estimated by counting the number of trees with hollows visible from the ground.
Woody debris	Total length of woody material on the ground in the plot; >10 cm in diameter.
Woody regeneration	Two measures are required: 1) The number of overstorey species regenerating (this includes shrubs when they comprise the overstorey), 2) Combined abundance of regenerating individuals (as per floristics sheet).
Woody stem sizes	Measured as diameter at breast height (DBH) – this is defined as the diameter of a tree at 1.37 m above the ground, measured from the high side of slope. Two options are available for recording this data: 1. Measure and count the stems in each size class and record a total number of stems for each class; all stems over 30 cm DBH must be measured and recorded individually. 2. Measure and record the DBH of each tree in the plot individually (preferred).
Tree health	An assessment of tree health in the plot, expressed in terms of observable dieback from larger to smaller branches. Tick the appropriate boxes; do not count dead branches, etc. See Figures App 4.1 and App 4.2 for a visual guide.

Landuse and landcover

Datum	Explanation
Age structure	Relative age classes of the vegetation in the plot; more particularly the ages of trees and shrubs present (Table App 4.1 and Figure App 4.1).
Landuse (dominant)	Dominant landuse as per options available. If 'other' specify landuse.
Landcover (upper stratum)	Cover percent of the tallest stratum. For the purposes of this field the upper stratum is defined as the tallest stratum in the plot, independent of its growth form.
Landcover (ground stratum)	[4]Foliage projective cover percent of the ground stratum.

Site history ([5]frequency and [6]age)

Datum	Explanation
Site history is intended to be gleaned from land managers or owners; subjects must be familiarised with the nature of the questions prior to interview; **no data can be guaranteed as confidential** and is intended for entry into a public database.	
Grazing management	Refers to domestic stock only (not feral or native species).
Farming	All forms of cropping and horticulture.
Erosion control	All forms of erosion control and conservation farming.
Pasture improvement rates kg/ha (fertilizer)	Rates of application (see data sheet).
Pasture improvement rates kg/ha (dolomite or lime)	Rates of application (see data sheet).
Timber extraction	All forms including fence post and firewood..
Regrowth management	Any way in which regrowth is managed (e.g. grazing, burning, slashing).
Weed control	Any way in which weeds are managed.
Pest animal control	Poisoning, shooting, ripping.
Burning	Any burning used as a deliberate management tool (weeds, stubble).
Other	Record any other factors nominated by the interviewee.

Plot disturbance ([7]severity and age)

NB Severity and age units are defined below the tables.

Datum	Explanation
Clearing	Includes logging of individual stems. Evidence of past logging/clearing.
Cultivation	Includes existing crops, exotic (improved) pastures and recently cropped land (may be evidence of recent cropping, e.g. plough lines).
Soil erosion	Accelerated, human-induced erosion. Observational evidence to include the main type/s of erosion: sheet, rill, gully, and a subjective assessment of severity.
Grazing	Estimate total impact of domestic and feral grazing.
Fire damage	Estimate impact of fire; observations re severity (heat) of fire.
Storm damage	Estimate impact of storm damage.
Other	Nominate and estimate any other major plot disturbance impacts (for a more comprehensive list see Table 20, App 5.2 in Hnatiuk *et al.* 2005).

Focal taxa

Datum	Explanation
Focal taxa	These are taxa of particular note in judging the overall condition of the plot and include: disturbance sensitive species, grazing sensitive species and species listed under the *Threatened Species Conservation Act 1995*. Data as for structure.

Physiography

Datum	Explanation
Morphological type	The form of the land at the plot site. Refer to McDonald *et al.* (1990), p. 13; Table App 4.2, for the relationship between morphological type and landform element.
Landform element	Recorded for landforms within a 20 m radius of the plot centre. Refer to McDonald *et al.* (1990) pp. 24–34; Table App 4.2 for the relationship between morphological type and landform element.
Landform pattern	Recorded for landforms within a 300 m radius of the site. Refer to McDonald *et al.* (1990), pp. 34–57; see also Table App 4.3.
Microrelief	Localised, naturally occurring, small (<1 m approx.) and abrupt changes in relief; conditions such as gilgai, mound springs and hummocking. Refer to McDonald *et al.* (1990), pp. 88–92; see also Table App 4.4.
Site lithology	Rock type/s observed at the site.
Soil surface texture	This indicates the ratio of sand, silt and clay sized particles in the soil. Field texture is determined by the behaviour of a ball of moistened soil (see McDonald *et al.* 1990, p. 118).
Soil colour	Record the colour of the soil (describe or use Munsell colour chart standard colour).
Soil depth	Estimate the depth of soil at the site.
Site soil type	Broad descriptive name for the soil observed at the site (e.g. grey clay, red earth, sand).
Slope	The angle of slope in degrees of the survey site.
Slope method	Method of measuring slope (e.g. clinometer, Abney level).
Aspect	The compass bearing of slope in degrees.
Aspect method	Method of measuring aspect (e.g. compass on site, topographic map).
Site drainage (runoff)	0 = no runoff (ponding).
	1 = very slow (free water on surface for long periods, or water enters soil immediately. Soils usually either level to nearly level or loose and porous).
	2 = slow (free water on surface for significant periods or water enters soil relatively rapidly. Soils usually either nearly level to gently sloping or relatively porous).
	3 = moderately rapid (free water on surface for short periods only; moderate proportion of water enters soil).
	4 = rapid (large proportion of water runs off; small proportion enters soil. Water runs off nearly as fast as it is added. Soils usually have moderate to steep slopes and low infiltration rates).
	5 = very rapid (very large proportion of water runs off; very small proportion enters soil. Water runs off as fast as it is added. Soils usually have steep to very steep slopes and low infiltration rates).
Distance to water	Distance from the plot centre to the nearest point of the water body.
Distance to water type	Record whether permanent or ephemeral; stream or still water; natural or manufactured.

Module 2 Floristics

Floristics

Datum	Explanation
Stratum (& layer)	Stratum & layer in which each species occurs: U1, U2, U3, M1, M2, M3, G1, G2, G3.
Growth form	Growth form for each recorded species (see Table App 4.5).
Field name	Scientific name or a descriptive field name where the plant identity is uncertain or unknown. Descriptive names are expected to be used consistently until formal identification is known. **NB** Descriptive name will not be entered into the database.
Species name	Scientific name confirmed by a suitably experienced individual or herbarium identification staff.
[1]Cover	A measure or estimate of the appropriate cover measure for each recorded species; recorded from 1–5 and then to the nearest 5%. If the cover of a species is less than 1% & it is considered important then the estimated cover should be entered (e.g. 0.4).
Abundance rating (Abund)	A relative measure of the number of individuals or shoots of a species within the plot. Use the following intervals, numbers above about 20 are estimates only: 1,2,3,4,5,6,7,8,9,10,20,50,100,500,1000 or specify a number greater than 1000 if required.
Field #	A number supplied for each collection made in a plot (use adhesive labels or jewellery tags).
Royal Botanic Gardens number (RBG#)	Individual collector's numbers which identify specimens sent to the Botanic Gardens Trust for identification.

Additional overstorey species are significant overstorey species observed outside the plot but within the same sampling unit (ESU). Observations should only be recorded within about 50 m of the plot in any direction, i.e. a one hectare area surrounding the plot.

Module 3 Ground cover monitoring

Location

Date, site number, recorders, grid reference & photo number and orientation as for Module 1

Datum	Explanation
Transect start	Grid reference for the starting point of the transect.
Transect end	Grid reference for the end-point of the transect.
Transect length	Length of the transect in metres, the standard length is 50 m.

Groundcover

Tally the first point of contact, for plants less than 1 m in height, every 50 cm along the 50 m transect (100 points in total).

Datum	Explanation
Litter	Includes leaf litter, twigs, branches, bark and fallen timber (logs).
Bare ground	Areas not covered by above features or living vascular plants.
Cryptogams	All recognisable ground lichens and other bryophytes (e.g. mosses, liverworts and cryptogams).
Woody debris	Total length of woody material on the ground in the plot; greater than 10 cm in diameter.
Rock	Rocky outcrops, boulders and transported fragments / surface strew (lag gravel).
Exotic – annual	Annual exotic species; any growth form.

Datum	Explanation
Exotic – perennial	Perennial exotic species; any growth form.
Shrub	Any native shrub under 1 m in height.
Grass – hummock	Native hummock grasses.
Grass – other	Other native grasses.
Forb	Any native forb under 1 m in height.
Sedge/rush	Any native sedge or rush under 1 m in height.
Fern	Any native fern under 1 m in height.
Other	See Table App 4.5 for a fuller list of growth forms.

Other

Datum	Explanation
Dung – stock	Tally in a 25 cm radius every 50 cm along the 50 m transect (total 100 points).
Dung – exotic pests	Tally in a 25 cm radius every 50 cm along the 50 m transect (total 100 points).
Dung – native	Tally in a 25 cm radius every 50 cm along the 50 m transect (total 100 points).
Woody seedlings	Tally in a 25 cm radius every 50 cm along the 50 m transect (total 100 points).

Module 4 Data required for the YETI database – not acquired on site

Context

Datum	Explanation
1:100 000 map name	As displayed on the map.
1:100 000 map number	As displayed on the map.
Other map used	Scale, name and number of any additional map used in the field.
ESU sampled	Environmental sampling unit identifier OR, other sample design identifier (e.g. vegetation pattern type) in which the plot is located. This is required so that the sample design facilitated by the chosen stratification can be properly assessed.
Breach ID	For compliance staff who are attending an alleged breach.
Botanical subdivision	Botanical subdivision of NSW in which the plot is located; see Harden (2000).
Elevation	Height above sea level of the plot.
Elevation method	Source of the elevation (e.g. 1:100 000 map, GPS). **NB** Elevations taken from a single GPS are not accurate.
Map geology	Mapped geology. Required to compare with the site lithology. Mapped geology is often used in stratification. If mapped geology is at odds with field observations analyses may need to be adjusted accordingly.
Map soil	Mapped soil type if available. Same argument as above.

Air photo and other remote imagery or data

Datum	Explanation
NSW or CAG no.	This is the NSW catalogue number which is recorded on the photo legend of all hard copy air photos. This number is unique to the particular photo-capture project.
Run no.	Identifies the photo run.
Frame no.	Identifies the individual photo.
Photo date	Record as dd/mm/yy.
Scale	Contact print scale. This allows some assessment of the maximum level of interpretation detail that may be expected.

Other remote imagery or data

Datum	Explanation
Data type	Specify the imagery or data type used (e.g. SPOT5 image; Lidar data).
Date	dd/mm/yy.
Row number	Row number if appropriate.
Path number	Path number if appropriate.
Pixel size	Pixel size of the imagery or data as used. Most contemporary data can be expressed in a number of pixel sizes.
Hit rate/density	This is specifically for LiDAR or RADAR data and will be specified by the data supplier.

Post survey

Datum	Explanation
Community ID	Community type to which the plot is allocated.
Map unit ID	Name and number of the map unit in which the plot is found.

Explanation of superscripts – Definitions, tables and figures

[1]Confidence (reliability) classes

1 Polygon or map unit visited. Remotely observed signature is distinct and will not be confused with other pattern types, no unfamiliar or unexplained elements, relationship between pattern type or predicted species composition and landscape not an issue.

2 Polygon or map not visited. Remotely observed signature is distinct & will not be confused with other signatures, no unfamiliar or unexplained elements, relationship between pattern type or predicted species composition and landscape not an issue.

3 Polygon not visited. Remotely observed signature is reasonably good, some chance of mistyping, any unfamiliar elements are minor, may be some level of doubt regarding predicted species, vegetation type or pattern type and landforms.

4 Polygon not visited. Remotely observed signature is very similar to other signature/s and may have been mistyped; polygon contains unfamiliar or unexplained elements, polygon pattern, vegetation type or predicted species at odds with other remotely sensed elements.

[2]**Stratum** (plural **Strata**) is a major horizontal structural division of a stand of vegetation. In this Standard three major strata are recognised: the Upper (tree), Mid (small trees and shrubs) and Ground (herbaceous and small shrubs). It is possible in some situations to observe further horizontal divisions within these major strata; these divisions within strata are called **layers**. The Standard recognises up to three layers in each stratum. **A stratum or a layer must comprise at least 5% crown cover.**

[3]**Cover** refers to the area of a plot or polygon covered by vegetation of various types. The Standard recognises two cover measures: crown cover and foliage projective cover.

Crown cover	Extent of individual crowns defined by the crown perimeter (applies to woody species); the area covered by a crown which is treated as a solid object; the area of a plot or polygon covered by the combined total of individual crowns.
[4]**Foliage projective cover (fpc)**	Equivalent to the vertical shadow cast by an individual crown's photosynthetic material only (leaves, phyllodes, needles); the area covered by the sum of photosynthetic material in a crown; the area of a plot or polygon covered by the combined total fpc of individual crowns.
Canopy cover	**Not used in this Standard**; equivalent to the vertical shadow cast by a individual crown (includes trunk, branches, branchlets, twigs and foliage); the area covered by the sum of all plant material in a crown; the area of a plot or polygon covered by the combined total canopy cover of individual crowns.

[5]**Severity** is a relative measure or estimate of the degree to which a site or reference point has altered from a natural or benchmark condition. The following are a series of statements intended to guide field practitioners in assigning one of four severity classes.

None	No departure from the natural or benchmark state; no observable evidence.
Light (slight)	Small departure from the natural or benchmark state; no major alteration of composition or structure; evidence of change not immediately obvious; careful observation needed to ascertain change at the site.
Moderate	Clearly observable (conspicuous, common) departure from a natural or benchmark state; some departure in terms of composition and/or structure; clear evidence of change; a readily recognisable characteristic of the site.
Severe	A major observable (very conspicuous, heavy, extensive) departure from a natural or benchmark state; major departures in terms of composition and/or structure; compelling evidence of a specific change; an inescapable characteristic of the site.

[6]**Age** is an arbitrary set of time classes to provide guidance as to the likely degree of recovery of the native vegetation towards a natural or benchmark state following disturbance. Three age classes are recognised:

Recent	Less that about three years
Not recent	About three to ten years
Old	Greater than about ten years

[7]**Frequency** is an arbitrary set of time classes intended to provide a relative guide to the repeat cycle of various land management activities.

Not done	Not done; not ever repeated
Rare	Repeated about once every five (5) years
Occasional	Repeated on a cycle of about two (2) to five (5) years
Frequent	Repeated on a cycle of less than two (2) years

Maturity of timber stands

Table App 4.1 contains definitions of accepted terms for describing the relative maturity of timber stands. Figures App 4.1 and 4.2 illustrate these terms.

Table App 4.1 Age structure classes

1	Early regeneration	Dominated by small, dense to open regenerating plants, with few older, emergent plants.
2	Advanced regeneration	Dominated by dense to open regenerating plants, with scattered larger plants (NB In treed habitats, if there are reasonable numbers of large ‘habitat’ trees scattered amongst smaller regenerating plants this may be better described as ‘uneven-aged’).
3	Uneven age	Mixture of different sizes and age classes present amongst species recorded in the tallest stratum.
4	Mature age	Well-spaced mature-sized plants, but with few ‘over mature’ plants.
5	Senescent	Dominated by ‘over mature’ plants, evidence of senescence in many plants, some with no disturbance evident. Stags (i.e. large dead trees) may be present.

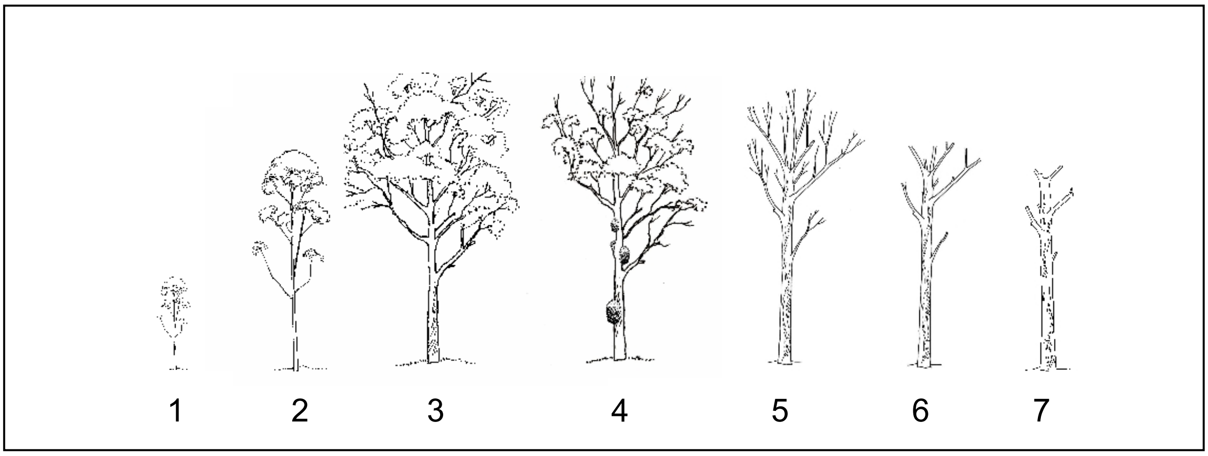

Figure App 4.1 Growth stages (from Eyre *et al.* 2002) illustrating 1. sapling, 2. juvenile, 3. mature and 4–7 stages of senescence.

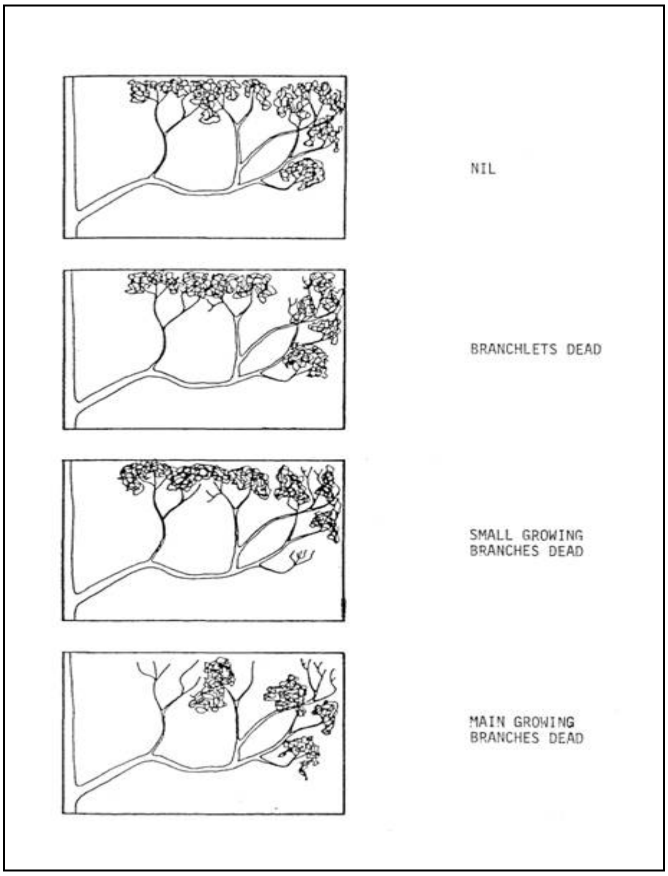

Figure App 4.2 Assessment of dead branches for judging tree health (after Grimes 1978).

Table App 4.2 Morphological types and potential landform elements (after McDonald *et al.* 1990).

Morphological type	Possible landform elements
Crest	Hillcrest
	Summit surface
	Dunecrest
Hillock	Tor
	Tumulus
	Dune
	Cone mound
Ridge	Levee
	Bar
	Scroll
	Prior stream
	Dune
	Foredune
	Lunette
	Beach ridge
	Embankment
	Dam
Slope – unspecified	Cliff
	Scarp
	Hillslope
	Cut face
	Landslide
	Embankment
Simple slope	Bank
	Beach
	Duneslope
Mid slope	Breakaway
	Cliff-foot slope
	Scarp-foot slope
	Bench
	Berm
Lower slope	Cliff-foot slope
	Scarp-foot slope
	Pediment
	Footslope
	Talus
Flat	Plain
	Rock flat
	Rock platform

Morphological type	Possible landform elements
Flat, continued	Cut-over surface
	Scald
	Pediment
	Fan
	Valley flat
	Terrace flat
	Channel bench
	Back plain
	Scroll plain
	Flood out
	Terrace plain
	Tidal flat
	Intertidal flat
	Supratidal flat
	Fill top
	Berm
	Reef flat
Open depression	Alcove
	Gully
	Cirque
	Drainage depression
	Stream channel
	Stream bed
	Tidal creek
	Estuary
	Swamp
	Swale
	Trench
Closed depression	Lake
	Playa
	Doline
	Ox-bow
	Lagoon
	Swamp
	Blow out
	Cirque
	Maar
	Crater
	Pit

Table App 4.3 Landform patterns showing expected slope and relief (after McDonald *et al.* 1990).

Slope class codes are: L= level <1%; VGI= very gently inclined 1–3%; VI= gently inclined 3–10%; MI= moderately inclined 10–32%; S= steep 32–56%; VS= very steep 56–100%.
Relief class codes are: EL= extremely low <9m; VL= very low 9–30m; L= low 30–90m; H= high 90–300m; VH= very high >300m

Landform pattern	**Typical slope class**	**Typical relief**
Alluvial plain	L	EL
Anastamotic plain	L	EL
Badlands	L	EL
Bar plain	L	EL
Chenier plain	L	EL
Covered plain	L	EL
Delta	L	EL
Floodplain	L	EL
Lacustrine plain	L	EL
Longitudinal dunefield	L	EL
Made land	L	EL
Marine plain	L	EL
Meander plain	L	EL
Parabolic dunefield	L	EL
Pediplain	L	EL
Plain	L	EL
Plateau	L	EL
Playa plain	L	EL
Sheet-flood fan	L	EL
Stagnant alluvial plain	L	EL
Terraced land	L	EL
Tidal flat	L	EL
Peneplain	L	VL
Terrace	L	VL
Alluvial fan	VGI	EL
Pediment	VGI	EL
Sand plain	VGI	EL
Beach ridge plain	GI	EL
Coral reef	GI	VL
Dunefield	GI	VL
Lava plain	GI	VL
Rise	GI	VL
Karst	MI	VL
Low hill	MI	L
Meteor crater	MI	H–L
Hills	S	H
Caldera	VS	H
Escarpment	VS	EL–VH
Mountain	VS	VH
Volcano	VS	VH, H, L

Table App 4.4 Microrelief which may be encountered in NSW (after McDonald *et al.* 1990).

Microrelief	Types	
Gilgai	Crabhole	
	Normal	
	Linear	
	Lattice	
	Melonhole	
	Contour	
Hummocky	Swamp hummock	
Other	Mound/depression	
	Karst	
	Sinkhole	
	Mass movement	
	Terracettes	
	Contour trench	
	Spring mound	
	Spring hollow	
	Other	
Biotic	**Agent**	**Component**
	Animal	Mound
	Human	Elongate mound
	Bird	Depression
	Termite	Elongate depression
	Ant	Hole
	Vegetation	Terrace

Table App 4.5 Growth forms likely to be encountered in NSW (after Hnatiuk *et al.* 2005).

Code	Name	Description
T	Tree	Woody plant >2 m tall with a single stem or branches well above the base.
M	Tree mallee	Woody perennial plant usually of the genus *Eucalyptus*. Multi-stemmed with <5 trunks of which at least 3 exceed 100 mm diameter at breast height (DBH), usually >8 m tall.
S	Shrub	Woody plant, multi-stemmed at the base (or within 200 mm from ground level) or, if single stemmed, <2 m tall.
Y	Mallee shrub	Commonly <8 m tall, usually with >5 trunks, of which at least 3 of the largest do not exceed 100 mm DBH.
Z	Heath shrub	Shrub usually <2 m tall, commonly with ericoid leaves (nanophyll or smaller categories).
C	Chenopod shrub	Xeromorphic single or multi-stemmed halophyte exhibiting drought or salt tolerance.
G	Tussock grass	Forms discrete but open tussocks usually with distinct individual shoots, or if not, then not forming a hummock, e.g. *Poa*.
H	Hummock grass	Coarse xeromorphic grass with s mound-like form, often dead in the middle e.g. *Triodia*.
D	Sod grass	Grass of short to medium height forming compact tussocks in close contact at their base and uniting as a densely interfacing leaf canopy e.g. couch and kikuyu.
V	Sedge	Herbaceous, usually perennial, erect plants generally with a tufted habit and of the families Cyperaceae and Restionaceae.
R	Rush	Herbaceous, usually perennial erect plants. Rushes are grouped in the families Juncaceae, Typhaceae, Restionaceae and the genus *Lomandra*.
F	Forb	Herbaceous or slightly woody annual or sometimes perennial plant; not a grass.
E	Fern	Characterised by large usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on leaves.
L	Vine	Climbing, twining, winding or sprawling plant usually with a woody stem.
A	Cycad	Palm-like plant, stemless to arborescent with fruit in cones.
P	Palm	Arborescent monocotyledon with pinnate to palmate leaves.
X	Xanthorrhoea	Stemless to arborescent grasstrees.
U	Samphire shrub	Leafless Chenopods of the genus *Halosarcia* (samphire) with fleshy, jointed stems.

DECCW VEGETATION FIELD SURVEY FORM

Module 1 (Minimum requirements)

Location

				Survey code	Plot no.	Recorders		
Date		**Plot ID.**						
AMG grid reference	zone 54 55 56	datum		Easting		Northing		Position in quadrat
Base plot size		**Orientation of 0.1ha plot**			**marked**	yes no	**photo # / orientation**	

Structure & composition (within 0.04 ha quadrat)

Keith class		Confidence: high mod low N.A
Regional veg class (BVT)		Confidence: high mod low N.A
BioMetric type (or NVCA)		Confidence: high mod low N.A.
Other:		Confidence: high mod low N.A.

NVIS level V (within 0.04 ha quadrat)

Stratum	Growth form	Species name	Cover	Abund.	For the entire			Field
Upper					Upper stratum Height to crown (m)			
Upper					min	mode	max	
Upper								
Mid					Mid stratum Height to crown (m)			
Mid					min	mode	max	
Mid								
Ground					Ground stratum Height to crown (m)			
Ground					min	mode	max	
Ground								

Growth form: T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub, G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern

Cover: 0–1,1,2,3,4,5,10,15,20,25,30,35, etc. Abundance: 1,2,3,4,5,6,7,8,9,10,20,50,100,500,1000,>1000

DECCW VEGETATION FIELD SURVEY FORM

Site no.

Condition

(within 0.04 ha)	Upper stratum	Mid stratum	Ground stratum Grasses	Ground stratum Shrubs	Ground stratum Other	Cover %		(within 0.1 ha quadrat)		
Native richness						**Litter**		**No. trees with hollows**		
Native cover						**Bare ground**		**Woody debris** lineal metres		
Exotic cover						**Cryptogam**		**Woody regeneration** No. upper stratum sp. & abundance.		

(within 0.1 ha quadrat)

Woody stem-sizes (DBH) (tally within category)	≥ 5– <10	≥10– <20	≥20– <30	≥30 cm DBH measure all
(or, measure all ≥5cm DBH)				

Tree health	no evidence	branchlets dead	small branches dead	main branches dead	trees dead

Landuse and landcover

Age structure	early regeneration	advanced regeneration	uneven age	mature	senescent	
Landuse (dominant)	nature conservation	travelling stock route	forestry	grazing	cropping	other:
Landcover (upper stratum)	none	native	environmental planting	native plantation	exotic other:	
Landcover (ground stratum)	none	native	environmental planting	native plantation	exotic other:	

Site history

	Freq. code	Age code	Land manager survey: categories, quantities, comments
Grazing management			not grazed; set stocked; rotational / cell grazing
Farming			none; direct drill; disc plough tyned implement; mouldboard rotary hoe
Erosion control			none; contour cultivation; mulching banks; other
Pasture improvement rates (fertiliser) kg/ha			none; <125; 126–250; >250
Pasture improvement rates (lime/dolomite) t/ha			none; <2; 2–4; 4–7; >7
Timber extraction (incl. firewood)			

Site history, continued

	Freq. code	Age code	Land manager survey: categories, quantities, comments
Regrowth management			
Weed control			
Pest animal control			
Burning			
Other			

Frequency: 0=no record, 1=rare (>5yrs), 2=occasional (2–5yrs), 3=frequent (<2yrs)   Age: R=recent (<3yrs), NR=not recent (3–10yrs), O=old (>10yrs)

Plot disturbance

	Severity code	Age code	Observational evidence:
Clearing (inc. logging)			
Cultivation (inc. pasture)			
Soil erosion			
Firewood collection			
Grazing			
Fire damage			
Storm damage			
Other			

Severity: 0=no evidence, 1=light, 2=moderate, 3=severe   Age: R=recent (<3yrs), NR=not recent (3–10yrs), O=old (>10yrs)

Focal taxa

(e.g. disturbance sensitive spp., ROTAPS, etc. within 0.04 ha quadrat)

Stratum	Growth form	Field name	Species name	Cover	Abund.	Field no.	RBG no.

Physiography

Morphological Type	Landform Element	Landform Pattern	Microrelief
Lithology	Soil surface Texture	Soil Colour	Soil Depth
Slope	Aspect	Site drainage	Distance to nearest water and type

DECCW VEGETATION FIELD SURVEY FORM

Module 2 Full floristics

Site no.

Floristics

(within 0.04 ha quadrat)

Stratum	Growth form	Field name	Species name	Cover	Abund.	Field no.	RBG no.

Growth form: T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub, G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern, F=forb, L=vine, A=cycad, P=palm, X=xanthorrhoea, U=samphire shrub.

Cover: (<1%see explanatory notes) 1,2,3,4,5,10,15,20,25,30,35, etc. crown cover %

Abund: 1,2,3,4,5,6,7,8,9,10,20,50,100,500,1000 (>1000 see explanatory notes)

DECCW VEGETATION FIELD SURVEY FORM

Site no.

Floristics (cont.)

(within 0.04 ha quadrat)

Sub-stratum	Growth form	Field name	Species name	Cover	Abund.	Field no.	RBG no.

Additional overstorey species (within ESU to a maximum of 1 ha area)

Stratum	Growth form	Field name	Species name	Cover	Abund.	Field no.	RBG no.
AdU							
AdU							
AdU							
AdU							
AdU							

Growth form: T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub, G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern, F=forb, L=vine, A=cycad, P=palm, X=xanthorrhoea, U=samphire shrub.

Cover: (<1%see explanatory notes) 1,2,3,4,5,10,15,20,25,30,35, etc. crown cover %

Abund: 1,2,3,4,5,6,7,8,9,10,20,50,100,500,1000 (>1000 see explanatory notes)

DECCW VEGETATION FIELD SURVEY FORM

Site no.

Module 3 Ground cover monitoring

Location

				Survey name		Plot no.	Recorders		
Date		**Site no.**							
AMG grid reference	zone 54 55 56	datum		Transect start (0m) E N			Transect end (50m) E N		
Transect length			**orientation**			**marked**	yes no	**photo # / orientation**	

Ground cover

	Tally first point of contact (<1m), every 50cm along 50m transect (0.5m to 50m = 100 points)	TOTAL
Litter		
Bare ground		
Cryptogam		
Woody debris		
Rock		
Exotic – annual		
Exotic – perennial		
Shrub (crown height <1m)		
Grass – hummock *		
Grass – other *		
Forb *		
Sedge / rush *		
Fern *		
Other *		

* native species

Other

	Tally presence within 25cm radius, every 50cm along 50m transect (0.5m to 50m = 100 points)	TOTAL
Dung – stock		
Dung – exotic pests		
Dung – native		
Woody seedlings		

Module 4 Data required for the YETI database – not acquired on site

Context

1:100 000 map name		100k map no.	
Other map used 25k or 50k & number			
ESU sampled			
Breach ID			
Botanical subdivision			
Elevation		Elevation method	
Map geology		Map soil	

Aerial photo

NSW or CAG no.		Run no.	
Frame no.		Photo date	____/____/_______
Scale		Photo pinned	Y/N

Other remote sensed data or imagery

Data type		Date	____/____/_______
Row no.		Path no.	
Pixel size (actual)		Hit rate/density	

Post survey

Community ID		Map unit ID	

Appendix 5 Data analysis

General principles

Floristic analyses aim to provide an objective and rigorous basis to recognise, describe and map vegetation communities by deriving a numerical classification of the plot samples.

This Standard does not mandate particular software or analysis pathways. Numerical techniques are developing so rapidly that stipulating a single analysis pathway is unrealistic. Nonetheless, the techniques described in this appendix adopt rigorous approaches which have been available in most software packages since the 1980s and provide robust and repeatable results. The protocols below are intended to provide guidelines and a minimum standard for data analyses.

Eleven data analysis principles have been identified. Reporting methods and results against these principles will help ecological practitioners judge their adherence to the Standard.

NOTE: It is important to engage experts in the field of numerical analysis when planning, conducting and interpreting the results of data analysis.

1. Develop an intuitive floristic classification for the study area

This step searches for pattern and structure in the data. It should be completed after the formal survey and remote sensing interpretation are complete whilst patterns of occurrence are fresh in the minds of practitioners. If more than one botanical expert is involved in the survey, this task is best undertaken independently and the results compared as a group. The opinion of one expert may not agree with that of another. The output from this analysis can be a hierarchical diagram exploring the relationship between vegetation units or an annotated list of vegetation plots and their prospective vegetation units.

2. Ensure data are 'clean' (see Table App 5.6 Group A tasks)

Ensure all species records:

- are at appropriate levels of taxonomic classification: species, subspecies, variety, form (are subspecific taxa informative?)
- are at the same level of taxonomic classification (if subspecific taxa are to be retained, have all occurrences of all affected species been identified to that level?)
- use the same version of taxonomic nomenclature (are all name changes and taxonomic revisions accounted for?)
- use a single system of nomenclature (interstate spellings & acceptance of revisions vary)
- use the same scoring system of relative importance at the site.

3. Describe and understand the descriptive statistical properties of the whole dataset

The descriptive statistical properties of the data are those that expose all relevant features of the data to the analysis and the interpretation of the analysis. For example:

- species accumulation, how the number of species encountered changes in relation to the number of plots described (can indicate adequate or inadequate sampling based on the number of new species encountered per plot)
- minimum and maximum values of species cover, vegetation structure, etc. (indicating possible outliers or miscoding)
- column and row summaries of species and plot attributes (indicating possible outliers)
- data distribution (skewed distribution may need special consideration in the data analysis).

4. Identify and remove (where appropriate) outliers or otherwise problematic samples from the data matrix

It is not appropriate to remove data simply because they are inconvenient or may deliver an inconvenient result. Data may be removed for statistical or ecological reasons, or both. Outliers in this context refers to a quadrat whose composition is inconsistent with the expected composition of quadrats in the dataset, and most likely represented anomalous field conditions during sampling. Outliers can dramatically affect the moment characterisations of data, introducing noise and obscuring the structure in the data. For example, a flush of new growth following a rain event or at the change of season may cause otherwise similar plots to appear different (annual and ephemeral species are often removed from analyses for such reasons). Typically clustering, ordination and distance matrices are used to identify outliers.

It is also common practice to remove uninformative complexity from the dataset. In a typical survey dataset, up to about 30% of species occur infrequently (less than 3–5 times, Figure App 5.1). Infrequently occurring species will have little role in determining pattern and structure in the data. For example, in the software package PATN (Belbin 1994), where every plot is compared with every other plot based on species composition (and relative importance of each species in the plot), any species that occurs only once in the dataset, and therefore cannot be compared with occurrences in other plots, does not contribute to any plot-to-plot relationship and therefore cannot contribute to the final analysis. Similarly, species that only occur infrequently in the dataset contribute little to the result.

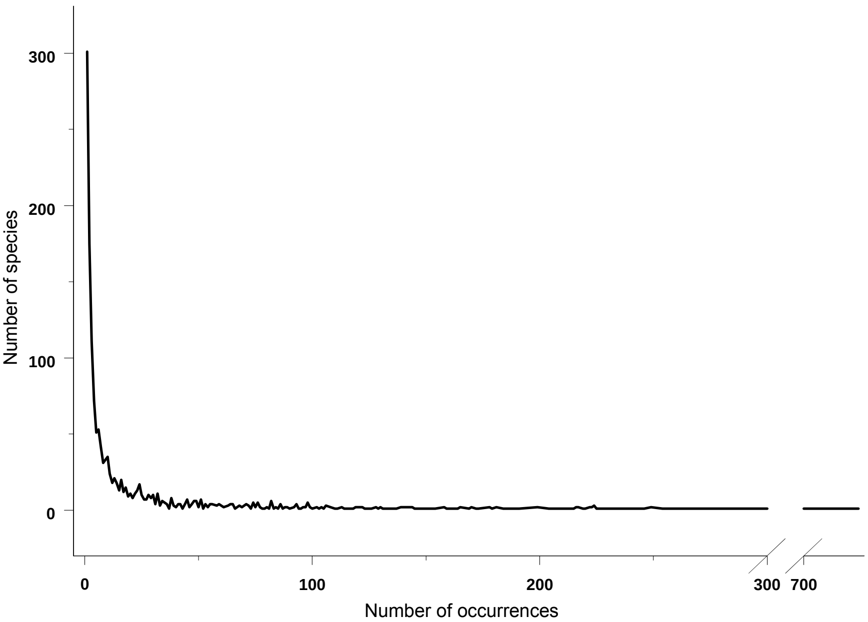

Figure App 5.1 Frequency of occurrence of species in a dataset consisting of 1292 quadrats and 1495 species.

Note: 301 species occurred only once [genus only records removed] (from Peacock and Law unpubl).

5. Create different derivations of the full floristic dataset by masking combinations of frequency, life form, native and exotic species

Analysis of data sub-sets helps to identify the contribution of those sub-sets in determining the final analysis results. The tables below **illustrate** the sub-setting of data from a recent vegetation mapping exercise (Peacock and Law unpubl). Every species was identified by life form/life stage (Table App 5.1) and this was then used to inform the data sub-setting of the data for analysis (Table App 5.2). Sub-setting the data was performed to minimise the 'noise' resulting from the large number of rarely encountered taxa, the influence of annual taxa reflecting variation in survey seasons, and the influence of disturbance reflected by the presence of exotic weedy taxa.

Table App 5.1 Broad life form classes for plant species recorded in the survey dataset consisting of 1292 plots.

Life form class	Total count	Native	Exotic
Annual	198	69	129
Annual or perennial (incl. facultative perennials)	111	70	41
Biennial	11	1	10
Opportunistic / ephemeral	2	2	0
Perennial	1107	994	113
Seasonal perennial	66	64	2
Total	**1495**	**1200**	**295**

Table App 5.2 Masking options explored in the survey dataset using 1292 plots.

Masking option	Number of taxa
Full dataset (genus only records excluded)	1495
Native taxa only	1200
Native taxa only, single occurrence taxa removed	983
Native taxa only, single and dual occurrence taxa removed	851
Native taxa only, single and dual occurrence taxa removed, all annual taxa removed	817

6. Apply hierarchical and non-hierarchical classification models to each of the floristic data sub-sets

Extending the above example, RIND analysis (in PATN, Belbin 1994) is conducted for all pair-wise combinations of hierarchical and non-hierarchical floristic data sub-sets. The RAND statistic calculated for each combination enabled a distance matrix to be compiled for all masking alternatives. The distance matrix was represented as a dendrogram to help select the optimal data sub-sets for full analysis (see Fig App 5.2).

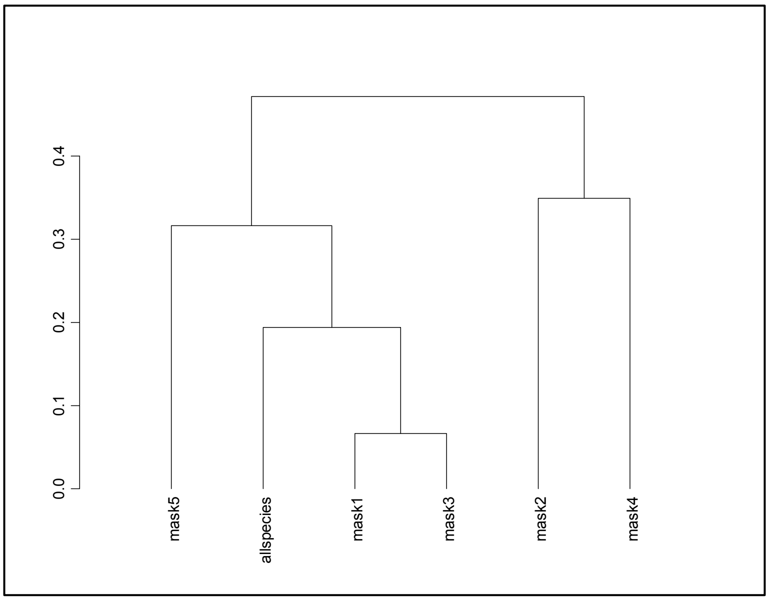

Figure App 5.2 Dendrogram displaying the relationships amongst several data masking options.

7. Derive output products from these classification models

These products help practitioners understand and visualise the results. Examples of such products are dendrograms (Figure App 5.3), two-way tables, group membership lists and spatial representations of the groups.

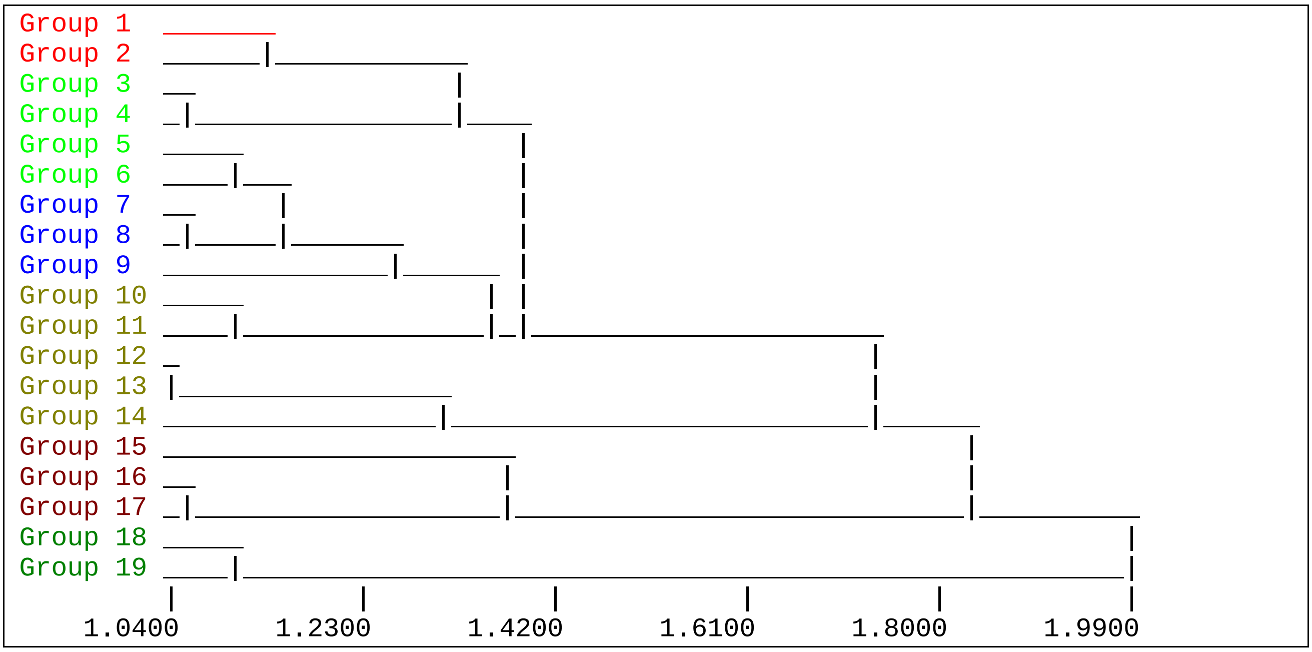

Figure App 5.3 Dendrogram displaying the dissimilarity relationship for a hierarchical analysis.

8. Apply statistical tests and procedures to validate the robustness of the classification model and the classification groups using both internal (to the model) and external criteria.

Apply a series of comparative tests of each classification model based on object group membership. These tests include homogeneity analysis (Figure App 5.4), which helps to determine the optimal number of groups and, within group distance analysis (Figure App 5.5), which exposes the within-group ecological distance compared to ecological distance between groups.

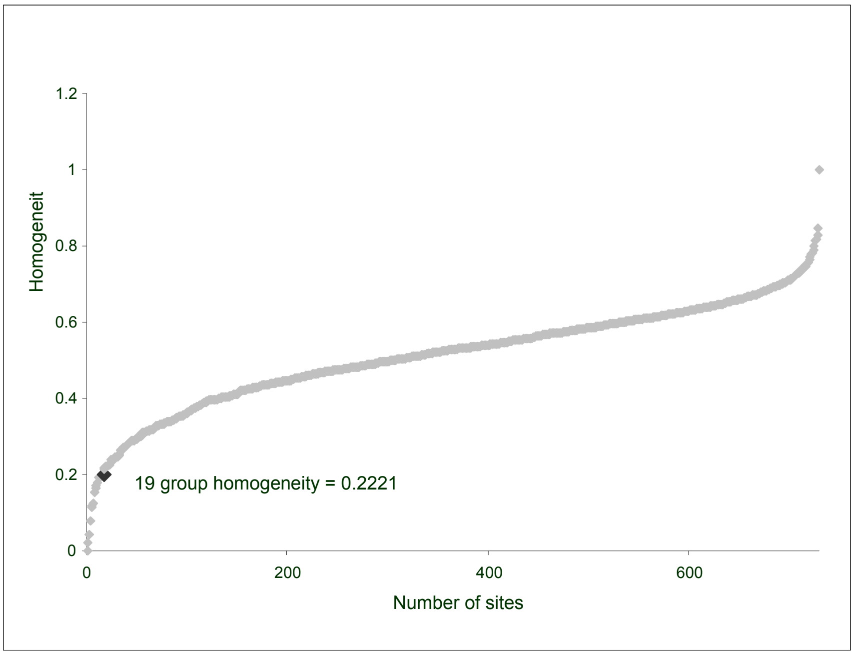

Figure App 5.4 Homogeneity curve for the site classification.

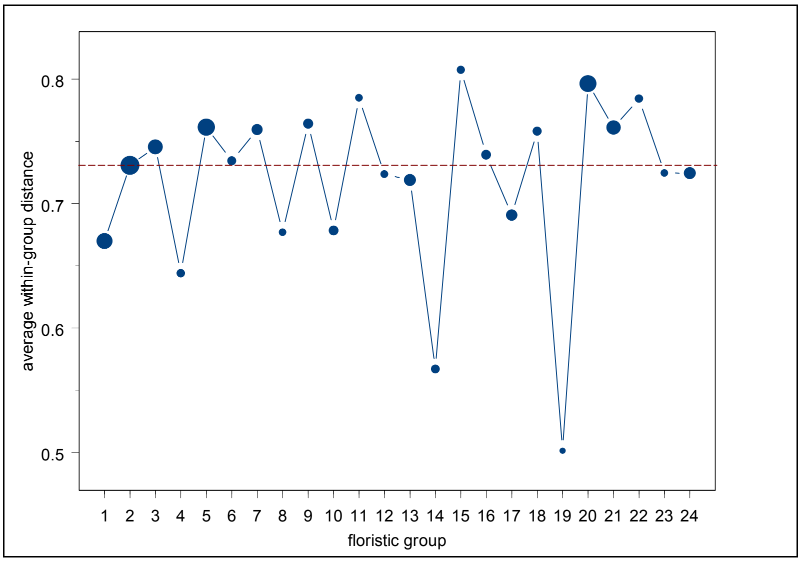

Figure App 5.5 **Weighted mean within-group distances for the 24 floristic groups from MRPP (McCune & Mefford 1999).**

9. Apply indirect gradient analysis (ordination) of both the quadrats and species (species ordination) to recover underlying patterns of species distribution (in multi-dimensional space) and its relationship to plot environmental variables and derived classificatory groups.

10. Provide appropriate output products to facilitate an expert review of the classificatory groups by botanists familiar with the data, the study area and the floristic analysis process (see examples below in Figure App 5.6).

```
      0.8050      0.9980      1.1910      1.3840      1.5770      1.7700
           |           |           |           |           |           |
POPLAR BOX ON STAGNANT ALLUBIAL PLAINS
  Group  1 __                                       HERB UNDERSTOREY
  Group  2 _|___                                    GRASSY
  Group  3 ____|_____                               YELLOW BOX
  Group  4 ______   |                               HERB UNDERSTOREY
  Group  5 __   |   |                               SHRUBBY UNDERSTOREY
BELAH ON FLOODPLAINS
  Group  6 _|___|___|___
MYALL/BOREE ON STAGNANT ALLUVIAL PLAINS
  Group  7 ___________ |
AUSTROSTIPS ARISTIGLUMIS & MIXED BELAH AND POPLAR BOX ON FLOODPLAINS
  Group  8 ____      | |
PINE, GREY BOX AND POPLAR BOX ON PENEPLAINS
  Group  9 ___|______|_|__________
  Group 10 _                     |
  Group 11 |__                   |
  Group 12 __|____               |
LIGNUM; BLACK BOX & RIVER RED GUM (FLOODPLAINS)
  Group 13 ______|_______________|___________________
LIGNUM & BELAH (FLOODPLAINS)
  Group 14 ____                                     |
BLACK BOX (FLOODPLAINS)
  Group 15 ___|___                                  |
RIVER RED GUM (FLOODPLAINS)
  Group 16 ______|__________________                |WITH OTHER EUC SPEC
  Group 17 ________                |                |WITH YELLOW BOX
  Group 18 _______|__              |                |PURE STANDS OVER GRASS

  Group 19 _________|_________     |                |
  Group 20 __________________|_____|________________|___________________
  Group 21 __                                                          |
  Group 22 _|____________                                              |
  Group 23 _____________|______________                                |
  Group 24 _______                    |                                |
  Group 25 ______|_______________     |                                |
  Group 26 _                    |     |                                |
  Group 27 |_________           |     |                                |
  Group 28 __       |           |     |                                |
  Group 29 _|_______|___________|_____|________________________________|
           |           |           |           |           |           |
      0.8050      0.9980      1.1910      1.3840      1.5770      1.7700
```

Figure App 5.6 **Annotated dendrogram (for comparison with the intuitive classification and interpretation of analysis results).**

11. Derive a range of tabular and graphical statistical reporting products for the floristic groups and map units (see examples below).

Table App 5.3 Structural summary for a community derived from the plot data.

Growth form	Mean height (m) (+/-se)	Height range (m)	Mean crown cover (%) (+/-se)	Crown cover range (%)
Tree	15.6 (0.93)	10–24	36.3 (4.61)	5–60
Tall shrub / small tree	7.0 (0.64)	2–12	7.0 (2.42)	2–15
Shrub	1.2 (0.07)	0.5–2	7.2 (4.68)	0.5–35
Groundcover	0.04 (0.03)	0.01–1	54.4 (8.31)	5–95

Table App 5.4 Example of a diagnostic species output for a community.

Life form	Name	Group score (50 percentile)	Group frequency	Non-group score (50 percentile)	Non-group frequency	Fidelity class
Tree	*Eucalyptus camaldulensis*	6	1	5	0.0473	positive
Shrub	*Einadia nutans*	0	0	2	0.6079	negative
Tussock grass	*Amphibromus nervosus*	5	0.5	6	0.0052	positive
Tussock grass	*Austrodanthonia bipartita*	5	0.5	2	0.0868	positive
Tussock grass	*Austrostipa scabra*	0	0	4	0.6526	negative
Tussock grass	*Enteropogon acicularis*	0	0	2	0.5658	negative
Sedge	*Eleocharis plana*	5	0.5	3	0.0157	positive
Rush	*Juncus flavidus*	2	0.5	2	0.0421	positive
Forb	*Calotis cuneifolia*	0	0	2	0.5842	negative
Forb	*Centipeda cunninghamii*	2	0.5	1	0.0157	positive
Forb	*Mentha satureioides*	3	0.5	1	0.0078	positive
Forb	*Oxalis perennans*	0	0	2	0.55	negative

Table App 5.5 Example of a characteristic species output for a community.

Species	Relative abundance	Relative frequency	Indicator value
Eucalyptus camaldulensis	33	100	33
Rumex brownii	14	100	14
Alternanthera denticulata	10	100	10
Sonchus oleraceus	9	100	9
Bothriochloa macra	25	80	20
Carex inversa	7	80	5
Oxalis perennans	7	80	6
Cynodon dactylon	73	70	51
Verbena gaudichaudii	24	70	17
Solanum nigrum	21	70	15
Lolium rigidum	17	70	12
Conyza bonariensis	12	70	8
Pratia concolor	38	60	23

River Red Gum Forests on Floodplains

Floristic group 19

Floristic group name: Very Tall Open *Eucalyptus camaldulensis* Forest with a forb understorey

Number of sites in group: 36

Total number of species recorded in group: 197

Mean number of species recorded per quadrat: 20 (+/–0.88)

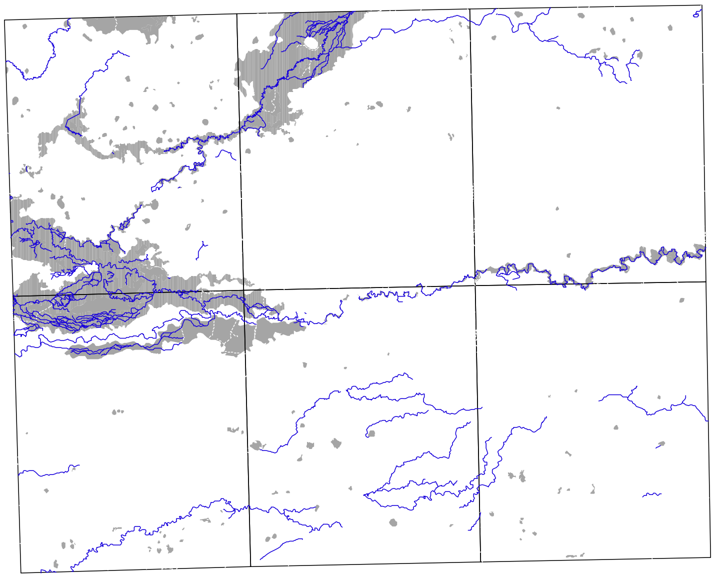

Figure App 5.7 Distribution of quadrat locations for floristic group 19.

Plot data analysis protocol

The plot data analysis blueprint developed for the Native Vegetation Mapping Program [NVMP] (Peacock 2004) is outlined below.

NB: The database for plot data (YETI) was a stand-alone product on individual computers. Tasks 1 to 8 (Principal step A) below were devised and described for individual computers. New South Wales is moving to a networked YETI database system (.net or equivalent) which requires different ways of approaching these tasks. Instead of replicating site records and creating an 'analysis dataset', virtual tables will be created and any changes that 'correct' the base data will automatically be incorporated into the affected records. This will avoid confusing data replication and keep existing data up-to-date.

Table App 5.6 Plot data analysis protocol – providing a guideline and minimum standard.

Principal steps	Analysis	Tasks	Software
A. Floristic data preparation	Data checking and cleaning	1. Compile all plots into a YETI project for the purposes of building a single analysis project dataset.	ACCESS
		2. Ensure all 'objects' are labelled consistently (including case) and are 8 or less characters in length.	ACCESS
		3. Examine plots not meeting minimum standards (guidelines) and justify with documentation on why they are excluded from analyses.	ACCESS Visual
		4. Taxonomic review: a. ensure consistency among surveys internal and external to survey b. verify species identifications and the status of infrequent taxa c. examine for consistent level of taxonomic identification (e.g. sub-species and varieties).	ACCESS
		5. Scoring systems: a. ensure consistency among projects b. prepare min-max summaries c. relativisation, i.e. place all species on a single consistent scoring system.	PC-ORD ACCESS
		6. Does every species entry have a cover and abundance? Await data export to PATN and PC ORD formats for final checking.	ACCESS
		7. All unidentified species (unknown species 1-n) must be named or removed.	ACCESS
		8. Eliminate all non-plot species and remove to 'incidental records table'.	ACCESS
B. Floristic data matrix compilation	Export data matrix for initial analyses	9. Export floristics cover score to PC-ORD and PATN formats.	ACCESS PC-ORD PATN
		10. Export floristics abundance to PC-ORD and PATN formats.	ACCESS PC-ORD PATN
	Matrix validation species – species	11. Run SCAN, check minimum and maximum values for species and for objects, richness per plot; examine cover and abundance values separately.	PATN
		12. Run row and column summaries.	PC-ORD
	Matrix validation – outliers	13. Run outlier analysis to check for unusual sites. Unusual plots to be checked against field sheets to determine if they are outliers. Consider removing these sites from pattern analysis. If removed, document in methods the rationale for removal. If they are outliers due to data errors, then correct in YETI and repeat the first 8 steps above.	PC-ORD
		14. Feed corrections or object deletions to YETI and repeat steps 1–8. Re-compile the matrix.	
C. Descriptive statistics	Species accumulation	15. Determine whether the species accumulation has plateaued.	PATN PC ORD
	Data distribution	16. Run HIST (in PATN) to determine if the data distribution is skewed and needs transformation before full analysis	PATN PC ORD SPLUS

Principal steps	Analysis	Tasks	Software
D. Association matrix comparisons	Compare association matrices	17. Mantel test association matrices derived from cover score and abundance measures.	SPLUS
E. Species masking table compilation	Export full species list and compile with species attributes	18. Set up masking tables: a. Display name b. Species number c. Family d. Growth form e. Life stage f. Native exotic g. Identification level. Frequency masking is completed via an ACCESS query run on demand.	ACCESS
F. Floristic data matrix export(s)	Export floristic data matrices for final analyses	19. Export floristics cover score or abundance to PC-ORD and PATN formats: a. Export several different options, e.g. native only, annuals removed, frequency <3 removed, etc. b. Name export files with a clear convention. c. Record dimensionality of each export file (number of objects and attributes) in a table. d. Ensure required number of species and attributes is being compiled in ACCESS and read into PC-ORD and PATN.	PC-ORD PATN ACCESS
G. Cluster analysis of quadrats	Create initial cluster outputs using both hierarchical (UPGMA) and…	20. PATN analysis: a. start PATN b. DATN (read in archive file) c. ASO (create association matrix) d. FUSE (select fusion strategy) e. DEND (view results graphically) f. GDF (create group definition file as a vector, i.e. *.gav). As a first cut, define the number of groups as sqrt (N) *1.3, i.e. 900 objects = 30 groups + (1.3 x 30) is 39 groups g. write *.gav file out to a spreadsheet with each row containing the object label and group label.	PATN
	Non-hierarchical (ALOC) methods	21. PATN analysis: a. start PATN b. ALOC (set parameters for non-hierarchical analyses, i.e. number of groups = number chosen in GDF run above) c. GDF as above d. write *.gav file out to a spreadsheet with each row containing the object label and group label.	PATN PC ORD
	Analysis outputs	22. Derive outputs for each classification to aid in comparison (two-way tables, dendrograms, etc.).	PATN
	Classification robustness	23. Run a series of statistical tests to validate the robustness of each classification (homogeneity, MRPP).	PATN
		24. Run ordination of both quadrats and species to recover underlying patterns.	PC ORD
	Select best possible analysis model	25. Compare output with intuitive classification. 26. Run RIND to compare association scores and determine differences between classification models.	PATN

Principal steps	Analysis	Tasks	Software
H. Quadrat (object) vegetation structure data compilation	Vegetation structure summaries by floristic group	27. Clean and validate data. 28. Min-max summaries on each stratum & min-max summaries on cover scores. 29. Min-max summaries on heights. 30. Check stratum heights do not overlap. 31. Check for consistent use of ground stratum versus tallest stratum, especially for grasslands.	XLS ACCESS SPLUS
I. Quadrat and vegetation structure tables	Two-way table	32. Compile the two tables into a single file.	XLS ACCESS SPLUS
J. Quadrat (object) variables matrix compilation	Co-variables analysis of environmental relationships of floristic groups	33. Validate sites table in YETI.	XLS ACCESS SPLUS
K. Derive reporting products	Fidelity analysis	34. Run FIDEL to help determine the diagnostic power of each species.	PATN
	Character species analysis	35. Run Dufréne & Legendre (1997) in PC ORD to determine the characteristic species for each group.	PC ORD

Appendix 6 Classification

Introduction

The debate about the classification and nomenclature of vegetation communities began early in the 20th century. Shimwell (1971) provides a comprehensive international review up to that date. Contemporary and Australian-focused reviews of community classification have been published by Keith (2002 & 2004) and Benson (2006).

Beadle & Costin (1952) proposed a system of classification for Australian vegetation. Their classification is still used and influences the debate significantly.

A system of classification was developed by a joint state/territory/Commonwealth working group for a National Vegetation Information System (NVIS) under the National Land and Water Resources Audit between 1988 and 2002 (ESCAVI 2003). The NVIS classification system is based on vegetation structure and dominant floristics and has a lineage back to Specht (1970) via Walker & Hopkins (1990).

The NVIS hierarchy is a strictly linear (nested one-to-one) hierarchy. Each level in the hierarchy can be summarised by a simple rule set to populate the next highest level. Below is an extract from ESCAVI (2003, page 7) which summarises the NVIS information hierarchy.

The NVIS information hierarchy

The NVIS information hierarchy has six levels as shown in the table below. The purposes of the information hierarchy are to:

- define and therefore standardise the structural and floristic information needed within the different levels of the information hierarchy
- provide a framework for quality control and assurance of vegetation description information
- provide a framework for generating outputs (e.g. map products) at the various levels.

Table App 6.1 The NVIS information hierarchy. The levels below the dark line are the levels recommended for data compilation.

Hierarchical level	Description	NVIS structural/floristic components required	Example
I	**Class***	Dominant growth form for the ecologically or structurally dominant stratum	Woodland
II	**Structural formation***	Dominant growth form, cover and height for the ecologically or structurally dominant stratum	Tall Open Woodland
III	**Broad floristic formation****	Dominant growth form, cover, height and dominant genus for the upper most or the ecologically or structurally dominant stratum	Eucalyptus Tall Open Woodland
IV	**Sub-formation****	Dominant growth form, cover, height and dominant genus for each of the three traditional strata (i.e. Upper, Mid and Ground)	Eucalyptus Tall Open Woodland with a grassy understorey
V	**Association****	Dominant growth form, height, cover and species (3 species) for the three traditional strata (i.e. Upper, Mid and Ground)	*Eucalyptus populnea/Eucalyptus conica* Tall Open Woodland over mid-dense *Austrostipa scabra* grassland
VI	**Sub-association****	Dominant growth form, height, cover and species (5 species) for all layers/sub-strata	*E. populnea/E. conica* Tall Open Woodland over sparse *Acacia deanii* over mid-dense *A. scabra* and *Enteropogan acicularis* grassland

* Walker & Hopkins 1990 ** NVIS (defined for the NVIS Information Hierarchy)

The United States hierarchy

The US Native Vegetation Classification is demonstrative of Northern Hemisphere classifications and differs markedly from the NVIS hierarchy in that it is non-linear; any given level cannot be simply summarised to populate the next highest level as new definitional criteria are often required. The upper levels of the hierarchy incorporate the concept of naturalness (Formation Sub-group); leaf morphology and macroclimate types (Formation Group) and leaf penology (Formation Sub-class). The uppermost hierarchical layer (Formation Class) is defined very similarly to the NVIS Structural Formation.

The US NVC nominates the Association as the basic unit for vegetation classification (Grossman *et al.* 1998 p. 24) and defines Association as 'a plant community type of definite floristic composition, uniform habitat conditions and uniform physiognomy' (Grossman *et al.* 1998 p. 24). This is very similar to Beadle & Costin (1952) except with respect to the 'uniform habitat condition' being definitional.

Table App 6.2 A summary of the US National Classification System (Maybury 1999).

Level	Primary basis for classification	Example
Class	Structure of vegetation	Woodland
Sub-class	Leaf phenology	Evergreen Woodland
Group	Leaf types, corresponding to climate	Temperate or Sub-polar Needle-Leaved Evergreen Woodland
Sub-group	Relative human impact (natural/semi-natural, or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Saturated Temperate or Sub-polar Needle-Leaved Evergreen Woodland
Alliance	Dominant/diagnostic species of the uppermost or dominant stratum	Longleaf Pine -- (Slash Pine, Pond Pine) Saturated Woodland Alliance
Association	Additional dominant/diagnostic species from any strata	Longleaf Pine / Little Gallberry / Carolina Wiregrass Woodland

The NSW hierarchy

New South Wales adopts a four-tiered hierarchy. It is linear (nested one-to-one) in the lower three tiers. The highest level introduces new definitional criteria (structure, growth form and physiognomy).

The four tiers of the hierarchy deal with different levels of recognition and definition of vegetation units; they are not intended to represent different levels of quality or reliability and do not automatically equate to a spatial scale (see Table App 6.4).

This Standard expects that descriptions/definitions at any level of the hierarchy will be challenged and improved by advances in data quality and quantity, techniques and technology.

New South Wales will comply with NVIS because it defines the reporting levels for the state. New South Wales will principally report at levels V and VI (with some possibility of level III). The terminology for the NSW hierarchy has deliberately moved away from Beadle & Costin (1952) and NVIS (ESCAVI 2003) terms such as Association and Alliance, since the technical meanings of such terms have become clouded.

Table App 6.3a **defines** each level in the hierarchy as well as **definitional notes** and **equivalents and examples** designed to illustrate and further describe the definition. Table App 6.3b contains information relating to process and possible applications. These tables are presented separately for convenience only.

Table App 6.4 lists the logical mapping scales for each level in the hierarchy. These may be related to the Products Table classes used in the NSW Native Vegetation Mapping Strategy.

Table App 6.3a Definitions, definitional notes and equivalences for the NSW classification hierarchy.

Level	Name	NSW Interim Type Standard	NSW Interim Type Standard	Relationship with other classifications
		Definition	**Definitional notes**	**Equivalents & examples[1]**
A	**Vegetation structural types**	A broad grouping of finer-levels types which share: a. [2]structural similarities b. similar [3]growth forms c. similar [4]physiongnomic characteristics	This is a NON-FLORISTIC level which is least related to finer-level floristic types. **NB** Some finer-level floristic types may equate to more than one structural type. Generally, the most commonly expressed mature structural type will be chosen; in some cases a one to many relationship will remain	This is analogous (but not identical) to the: Formations of Beadle and Costin (1952); Structural Formations of Walker & Hopkins (1990); Structural Formations of Hnatiuk *et al.* (2005); Sub-Formations of Keith pp. 26–28 (2004) and the Structural Classes of Benson (2006)
B	**NSW vegetation classes**	Groupings of finer-level types which share all of the following: a. dominant genus or genera in the upper stratum b. dominant growth form/s in the upper and ground strata c. broad structural similarities d. a broadly similar physical environment	This is what Beadle & Costin (1952) refer to as a Synthetic Unit; there would be no expectation to map these units from analysis and classification of plot data. Implies some functional similarity which **may** provide a logical framework for benchmarks. Some benchmarks may be set at lower levels	Formation Groups: Benson 2006 Vegetation Classes: Keith 2004 Major Groupings: Beadle 1981
C	**NSW broad floristic types**	An assemblage of species occurring in a particular area that corresponds to the basic unit for catchment or similar assessment (see 'required effort') **OR,** groupings of finest-level types which share similar species, particularly those that characterise and define the finer types	A coarser level of type recognition based on the same information requirements as Level D (Plant community types) but at a coarser level of resolution	Alliance (Beadle & Costin 1952); Broad Vegetation Map of Central West and Lachlan CMAs (DEC 2006), Regional Vegetation map of Border Rivers Gwydir CMA (Eco Logical PL 2008); Wheatbelt Mapping (Sivertsen & Metcalf 1995)
D	**Plant community types**	An assemblage of plant species, often defined through groups of samples (releves) that are suitable for local scale site assessment (e.g. PVP and EIS). Mandatory attributes include: a. based on floristic compositional information that is classified using clearly described methods b. contain at least some species that occur more frequently in the unit than outside it c. distinguishable from other communities by the frequency and abundance of characteristic species d. contain a description that includes a list of characteristic species, salient structural and physiognomic features of the vegetation, a range of environmental conditions (climate, substrate and terrain) and geographical area where the community is likely to occur	A floristically classified type that may contain a number of vegetation structures (structure is not homogeneous). The species composition may alter over its distribution but not substantially. Method of classification is stated and qualifications bound data quality	Vegetation Community Keith 2004; *BioMetric* Types (part); Benson 2006 (=/- Sub-association) Benson *et al.* 2006 (part); NVMP, Guyra (Benson & Ashby 2000), some LGA Does not equate to the B&C classification; quite a different concept

Table App 6.3b Process and possible applications for the NSW classification hierarchy.

Indicative associated activities and products				
Level	**Required effort**	**Indicative applications**	**Indicative NVIS reporting level**	**NSW tool applications**
A	Not intended for mapping; auto generated in the Vegetation Information System	State-wide overview; bushfire fuel assessments and national reporting	II (indicative; no NSW entered at this level)	No tool applications
B	An amalgamation of finer level types based on the definitional rule set; **OR** an appropriate existing classification in which the **worst case** equates to this level; appropriate levels of remote sensing interpretation, extrapolation and rapid survey	Broad context; some state reporting; SoF; NVIS/NFI integration; national reporting. Relates finer-level types at the generic level	III (indicative; some NSW data entry at this level)	Some current *BioMetric* types; regional vegetation types; may be suitable for *BioMetric* benchmarks if function is similar; assist with EEC definitions
C	Similar demands as level D at a coarser level of classification and a lower data density; **OR** An appropriate existing classification in which the worst case equates to the level; appropriate levels of remote sensing interpretation, extrapolation and rapid survey	Some PVP activities (incentives); BioBanking, CAP, SoE, state planning and reporting	V/VI (indicative)	Some current *BioMetric* types; regional vegetation types; may be suitable for *BioMetric* benchmarks if function is similar; assist with EEC definitions
D	See definition for required effort; implies very high data density and detailed interpolation	PVP tools, EIS, Biocertification, local government planning. **NB** This is the aspirational goal for all BioMetric types, it is **not** the current level of many BioMetric types	VI	Many of the *BioMetric* types but not all. This is the aspirational aim for Biometric types as the NSWVCA; useful for threatened species habitat recognition and definitions of EECs

Table App 6.4 Possible mapping scales for the NSW classification hierarchy.

Hierarchy / Scale	Vegetation structural types	NSW vegetation classes	NSW broad floristic types	Plant community types
2,000	Not recommended for routine mapping			X
4,000				X
5,000				X
10,000				X
15,000				X
20,000				X
25,000			X	X
50,000			X	X
75,000			X	X
100,000		X	X	X
250,000		X	X	
500,000		X		
1,000,000		X		

Appendix 7 Spatial interpolation

Producing a final spatial product from a combination of processes (stratification, plot and spatial data acquisition, data analysis and interpretation) requires a mapping team to move from the known (locations where data have been acquired) to the unknown (unvisited parts of the study area). If the plot or observation density is high, this process, known as 'interpolation' should fill gaps between known points. Moving from a set of known and sampled locations into a new environmental space outside the sampled envelope would comprise extrapolation, a riskier strategy.

Each modelling process described attempts to do the same task although methods employed and the definition of spatial units vary considerably. Table App 7.1 displays a simplified example of the type of matrix to be filled to complete a spatial interpolation. The 'spatial unit type' could be an API polygon, an environmental envelope defined by several environmental variables or, grid cells defined by dozens of environmental variables. The main point to observe is that most of the cells in the matrix require attribution (i.e. there are many more spatial units that need to be attributed than those that have been sampled) and the communities do not distribute themselves neatly among the available unit types. For example, community A is distributed across most unit types and is possibly defined by species with broad environmental tolerances, whereas community B is specific to one unit type and is the only community occurring in that type. Community B probably defines a map unit whereas community A does not. Community C is confined to two unit types; only one other community occurs in those types (one site in A). Community C is indicating that unit types Riverine2 and Riverine7 are compositionally similar enough to be joined into one map unit. Community A would comprise the reported heterogeneity in that map unit.

Table App 7.1 Part of a conceptual information matrix indicating 'known' units (polygons, grid cells or ESUs) and 'unknown' units requiring attribution (shading separates adjacent spatial unit types).

Defined vegetation communities		A	B	C	D	E
Spatial unit number	Spatial unit type					
0001	Riverine1	X				
0009	Riverine1	X				
0020	Riverine1					X
0036	Riverine1					
0105	Riverine1					
0213	Riverine1					
0002	Riverine2	X		X		
0008	Riverine2			X		
0034	Riverine2			X		
0037	Riverine2					
0104	Riverine2					
0003	Riverine3		X			
0117	Riverine3					
0200	Riverine3		X			

Defined vegetation communities		A	B	C	D	E
Spatial unit number	**Spatial unit type**					
0004	Riverine4	X				
0063	Riverine4					
0107	Riverine4					X
0005	Riverine5	X				X
0007	Riverine5	X				
0006	Riverine6					X
0071	Riverine6	X				
0083	Riverine6					
0215	Riverine6					
0008	Riverine7			X		
0107	Riverine7			X		
0223	Riverine7					
0010	Riverine8	X			X	
0122	Riverine8				X	
0125	Riverine8					
0500	Riverine8					
0013	Riverine9	X				
0027	Riverine9	X				
0091	Riverine9					
0137	Riverine9					X
0112	Riverine9					
0063	Riverine9					
0081	Riverine9	X				
0018	Riverine10				X	
0040	Riverine10					
0053	Riverine10				X	

Decision trees

A simple interpolation method based on subjective expert judgement involving the assignment of each pre-existing floristic class to remotely observed and delineated polygons is perhaps the simplest form of decision tree in current use. This can be thought of as a system of decision rules.

Table App 7.2 shows a more complex decision tree used by an expert panel to derive vegetation mapping units (after Sivertsen & Peacock 2003). This protocol was informed by a spatial intersection of sampled points assigned to floristic groups with mapped polygons assigned to API classes. In these instances the decision rules seek to define a robust relationship between remotely sensed pattern classes and vegetation communities derived from classified, quantitative plot data. It would be possible to refine this decision tree by adding specific environmental relationships which are likely to define the occurrence of a given vegetation type where the relationship between remote image interpretation and vegetation types is unclear or amorphous. For example, particular geologies or soils could be specified.

At the more complex end of the spectrum a decision tree will comprise multiple binary nodes which express critical (significant) points of departure in physical and remotely sensed attributes. For example, groups of vegetation types may split on whether they occur on plains or hills, rolling downs or mountains. Plains communities may then be subdivided on the basis of non-alluvial (red and brown earth soils) or alluvial plain (alluvial and clay soils). The alluvial group may then subdivide on whether they are floodplain or riparian (e.g. bank, levee and backplain) and the riparian then split on the alluvial sediment type (sandy or clayey). Finally, the communities of the sandy alluvials may then align with two (or more) pattern groups based on remotely observed characteristics which reflect differences in overstorey composition (for a detailed example see Keith & Bedward 1999. At this more complex end of the spectrum, end points define an environmental-remote sensing type envelope which can be given spatial expression by a GIS package.

Table App 7.2 Simple decision tree used to interpolate among vegetation types defined from analysis of plot data and independently derived air photo interpretation classes (after Sivertsen & Peacock 2003).

Relationship	Actions to create map unit	Map unit
1. One to one correspondence between a floristic group and an API class (possibly with minor occurrences of sites from other floristic groups)	Create map unit defined by one floristic group and one API class	Single community map unit (heterogeneity specified by any sites from other floristic groups occurring in the API class)
2. Single floristic group relates strongly to two or more API classes (possibly with some sites from other floristic groups)	Collapse API classes into one for the purposes of map unit creation	Map unit with a single dominant community (heterogeneity specified by any sites from other floristic groups occurring in the API classes)
3. Several floristic groups relate to two or more API classes	1. Examine other environmental factors (e.g. altitude, geology, soils) to determine if relationships can be refined. If NO/YES…. 2. Determine most robust separation of floristic groups and API classes based on relevant environmental factors	1. If NO create one map unit with more than one principal community (heterogeneity specified by the number of component communities) 2. If YES create more than one map unit as indicated by floristic/API/environmental relationships. These map units may have one or more principal communities (heterogeneity as above)
4. API classes which do not relate strongly to any floristic group. (may result from: poor or inadequate sampling & survey design OR highly detailed API which is not commensurate with the scale of classification, mapping and/or the survey design OR poor site location georeferencing)	1. API polygons are too small for the final map; collapse into most closely related neighbouring polygon 2. API polygon large enough for final map and closely related to an API class that has a designated map unit 3. API polygon large enough for final map & displays no close relationship with existing map units or other API classes	1. API polygon becomes part of an existing map polygon 2. API polygon becomes part of an existing map polygon or creates a new polygon of an existing map unit 3. Consider creation of a map unit on this basis alone. Such cases usually arise where the API signature is unique and distinctive and where the principal canopy species are known qualitatively (heterogeneity not specified)
5. A floristic group that does not relate strongly to any API class or classes (frequently the result of a floristic group consisting of common and widespread species)	Re-examine all relationships	Commonly defines part of the heterogeneity of a number of map units
6. A floristic group that relates strongly to a few API polygons but does not seem to relate well to the API class as a whole	Examine API polygon group for differences from the norm; look for refinements defined by physical environmental factors	If there is a basis for subdividing the API class then create a new map unit; if there is no basis for subdividing API class this becomes a special case of Relationship 3 above (heterogeneity specified as in 3)

Appendix 8 Accuracy assessment

Introduction

The accuracy and precision of spatial products can be quantified and accounted for in a number of ways; not all require field-based assessments. In the disciplines of remote sensing interpretation and spatial analysis, for example, geodatabase fields can be designed which record source and methods for a given field. Where media are specified as high resolution orthorectified images, a high positional accuracy is implied. Similarly, a method comprising a three-dimensional appreciation of tree canopy cover or a credible calculation of tree canopy spacing, implies that canopy data is reliable. This sort of data regarding precision, accuracy and reliability will contribute significantly to informing the expectation of both users and producers of spatial products.

Accuracy assessment is a necessary and an integral part of mapping. Contemporary scientific, legal and planning processes demand increasingly quantitative underpinning of spatial products.

For example, in circumstances where vegetation maps are to be used for **biocertification**, a high level of accuracy is assumed and expected of that mapping. The accuracy of such mapping is almost certain to be tested in a legal sense in the not-too-distant future.

Similarly, since the advent of SEPP 46 and the subsequent native vegetation Acts, NSW natural resource management agencies have relied increasingly on quantitatively-based mapping in legal disputes. See, for example, the numerous cases in which the NSW Northern Wheatbelt mapping has gone virtually unchallenged in the Land and Environment Court, in cases of illegal clearing, because of its quantitative base.

The increasing sophistication of both prosecution and defence is beginning to demand justification (read ‘accuracy assessment’ and ‘methodological certainty’) of such mapping, as has been evidenced in recent cases where, for example, the validity of Ramsar wetland mapping has been challenged. Whilst the reputation of individual experts may continue to carry some weight in such circumstances, quantitative evidence is increasingly relied upon.

The scientific literature abounds with discussions on the methods and need for accuracy assessment (e.g. Landis & Koch 1977, Story & Congalton 1986, Congalton 1991, Fitzgerald & Lees 1994, Gopal & Woodcock 1994, Green & Strawderman 1994, Hammond & Verbyla 1996, van Deusen 1996, Stehman 1997, Milliken *et al*. 1998, Stehman & Czaplewski 1998, Stehman 2005), specifically in vegetation mapping and the interpretation and use of vegetation maps (e.g. Regan *et al*. 2002, Elith *et al*. 2002, Keith in press). While accuracy assessment of vegetation maps has not been common practice in Australia (see Keith & Bedward 1999, Tozer 2003, for exceptions), published habitat distribution maps of species and communities are rarely published in overseas journals without a quantitative assessment of their accuracy.

Accuracy assessment must be relevant to the current and envisaged uses of a spatial product. For example, mid-scale mapping (e.g. 1:100 000) is used for regional planning, catchment report cards, CAPs, SoE and context for PVP as well as many other similar uses. Such products must portray the spatial extent of vegetation types accurately at the sub-regional scale but would not be expected to be accurate at any given point 100% of the time. Such mapping may be judged on a per polygon basis and, taking into consideration acceptable (stated) levels of heterogeneity, may be expected to be accurate somewhere between 60 and 80% of the time. On the other hand, fine-scale mapping undertaken in development areas (e.g. 1:25 000 or finer) may be used for biocertification, local area planning, site allocation (for a particular development activity) and other related uses; it is expected by the user to be accurate at any given point or plot most of the time. In practical terms this means that, as the demands on the mapping increase, additional expense and effort will be required to test, establish and improve the accuracy of that mapping.

The basic concept

In an accuracy assessment **mapped landcover classes** (e.g. community types, photo pattern types) are compared to a set of **classified reference localities** (validation data) that are regarded as 'true'; **the extent to which these two classifications agree is defined as map accuracy** (Stehman & Czaplewski 1998). However, there are many ways in which the two classifications can be derived and compared. The ways in which the reference sampling and classification are designed will affect the results of any accuracy assessment.

Accuracy assessment

Stehman & Czaplewski (1998) identify three basic components of an accuracy assessment: the **sample design**, the **response design** and the **estimation and analysis protocol**.

Sample design

The **sample design** states the methods by which the reference sample units are selected. The sample design is important because within it is specified how the sites will be approached and the nature of the sampling units.

1. **Unless otherwise justified, accuracy assessment undertaken for spatial products is to be based on a proportional sampling of each class. In the case of non-spatial products sampling will be based on a list of localities or general areas for each described class.**
2. **The sampling unit is to be specified. In most cases a fixed area plot will be the sampling unit (e.g. 20mx20m or 20mx50m area). In other cases individual pixels, pixel clusters or whole polygons may be selected as the sampling units. The whole sampling unit is to be assessed.**
3. **The location of sampling units is to be chosen at random either as:**

    - **a series of random points, defining the localities of sampling units, which will be visited and data recorded that will enable a variety of accuracy assessments, or**
    - **a series of random points, stratified by map class, which define the localities of sampling units at which data will be recorded, to test the map classes.**

NB A high degree of accuracy is demanded of the location data; an important component of the rigour of accuracy assessment comes from comparing a map location and the equivalent ground location with a high degree of precision.

Response design

The response design is the protocol for determining the reference land-cover classification of a sampling unit. The response design comprises an **evaluation protocol** and a **labelling protocol**.

Evaluation

Under the evaluation protocol the type of information collected in the sampling unit is specified. Given the definitions in the DECCW draft Classification Hierarchy, it would be logical to record dominant species and also to qualitatively compare the sample unit to the mapped landcover class with respect to general floristics, structure, landforms and substrates.

4. **As a minimum, identify and record the three numerically dominant species in each stratum present. A qualitative assessment of the following is also to be made before a label is assigned.**

   Ascertain whether or not the recorded species are identified as ***characteristic species*** *in the mapped or described class.*

   Assess the 'goodness of match' between the observed and mapped/described class based on characteristic species, salient structural and physiognomic features of the vegetation, the range of described environmental conditions (e.g. climate, substrate and terrain) and geographical area where the community occurs.

Labelling

The labelling protocol assigns the reference classification (or classifications) to the sample unit based on the information obtained from the evaluation protocol (Stehman & Czaplewski 1998).

There are a number of ways in which the sample unit may be labelled. The most common is to assign a single label chosen from the available **mapped landcover class** labels (see for example Story & Congalton 1986, Congalton 1991, Green & Strawderman 1994 and Fitzgerald & Lees 1994). In some instances more than one label is assigned (see for example Stehman & Czaplewski 1998, Milliken & Beardsley 1998 and Gopal & Woodcock 1994). This often involves the application of more than one **mapped landcover class** label or the application of a range of labels from 'absolutely right' to 'absolutely wrong'. This latter scale of correctness is referred to as a fuzzy set and could be used to distinguish between the levels of accuracy required for regional mapping as opposed to that required for very detailed, high expectation mapping.

Where a field plot is being compared to a mapped class the 'ground truth' expert is asked to assign each sample unit a degree of correctness based on the **evaluation protocol**. In the example cited by Gopal & Woodcock (1994), four degrees of correctness are recognised:

a. Absolutely Wrong: absolutely unacceptable. Very wrong.
b. Understandable but Wrong: Not good; there is something about the site that makes the answer understandable but there is clearly a better answer. This answer would pose a problem for users of the map. Not Right.
c. Reasonable or Acceptable Answer: May not be the best possible but is acceptable; this does not pose a problem to the user if it is seen on the map. Right.
d. Absolutely Right: no doubt about the match. Perfect.

5. **Based on the results of the evaluation protocol a single label is assigned to each sample unit. If no appropriate label exists in the mapped or described classes, an 'unknown 1….n' label is assigned.**
6. **The degree of 'goodness of fit' between the mapped or described and the observed labels is specified in terms of the Gopal & Woodcock (1994) scale (see above).**

Analysis and estimation

This is a complex area and one in which the statistics and mathematics are evolving rapidly. It would undoubtedly be a mistake to mandate one analysis pathway or estimator in this Standard. There are some basic, and relatively simple calculations that are generally agreed upon in the literature; to progress beyond these, however, should involve the input of one of the numerically literate ecologists, biometricians or statisticians that DECCW is blessed with.

The most important and most basic tool is the **error matrix**, also know as the **confusion matrix**. A simple example of an error matrix is shown below (Table App 8.1, from Congalton 1991).

An error matrix effectively summarises the key information obtained from the sampling and response designs. In the example copied from Congalton (1991) whole numbers, representing numbers of observations, have been used; the same matrix has been reproduced with the cells displaying proportions of effort, which is more in line with Stehman (1997). In this example there are a total of 434 observations. By convention the ROWS represent the map or described classes and the COLUMNS represent the observed, reference or true classes.

7. **In this Standard all accuracy assessment undertaken will, as a minimum, produce an error matrix derived from the sampling and evaluation protocols.**
8. **Overall accuracy, user's accuracy and producer's accuracy comprise the minimum accuracy reporting estimators under this Standard.**

Table App 8.1 An error matrix showing comparisons between four mapped classes and four reference classes (from Congalton 1991).

		Reference				
		1	**2**	**3**	**4**	**Row total**
Map	**1**	65	4	22	24	**115**
	2	6	81	5	8	**100**
	3	0	11	85	19	**115**
	4	4	7	3	90	**104**
	Column total	**75**	**103**	**115**	**141**	**434**

A number of important accuracy indicators can be derived from this matrix:

a. The ROW SUM represents the proportion of the area mapped in each class, whereas the COLUMN SUM represents the true proportion of the area in each land class.

b. **Overall accuracy** (Congalton 1991), or the **overall proportion of area correctly classified** (Stehman & Czaplewski 1998), which represents the probability that a randomly selected point location is classified correctly by the map, is calculated by adding all cell values where the map and reference labels agree (main diagonal) and dividing by the total effort. In the case of the table above this is (65+81+85+90)/434=321/434=0.74 OR 74%.

c. **User's accuracy** for any given class ***x*** is the conditional probability that a randomly selected point classified as category ***x*** by the map is classified as category ***x*** by the reference data (Stehman & Czaplewski 1998). This is calculated for each map class by dividing the number correctly classified by the row sum for that class, usually expressed as a percentage. In the table above the **user's accuracy** for class 1 is 65/115=57% whereas the **user's accuracy** for class 4 is 90/104=87%.

d. **Producer's accuracy** for any given class ***y*** is the conditional probability that a randomly selected point classified as category ***y*** by the reference data is classified as category ***y*** by the map (Stehman & Czaplewski 1998). This is calculated for each reference class by dividing the number correctly classified by the column sum for that class, usually expressed as a percentage. In the table above the **producer's accuracy** for class 1 is 65/75=87%, whereas the **producer's accuracy** for class 4 is 90/141=64%.

e. **Omission errors** for any given class ***w*** is the conditional probability that a randomly selected point classified as category ***w*** by the reference data is classified as category ***k*** by the map (Stehman & Czaplewski 1998). This is calculated by dividing the number incorrectly classified for the reference class ***w*** by the column sum for that class. In the table above the **omission error** for class 1 is calculated by (6+0+4)/75=10/75=13%**. NB** Omission errors are the residual of the user's accuracy.

f. **Commission errors** for any given class ***z*** is the conditional probability that a randomly selected point classified as category ***z*** by the map is classified as category ***k*** by the reference data (Stehman & Czaplewski 1998). This is calculated by dividing the number incorrectly classified for the map class z by the row sum for that class. In the first table above the **commission error** for class 1 is calculated by (4+22+24)/115=50/115=43%. **NB** Commission errors are the residual of the producer's accuracy.

Appendix 9 Reporting requirements

Part A Requirements for technical reports

Introduction

The primary function of a technical report is to describe the methods and results for any process or series of processes covered by this Standard. Discussion of the implications of results may or may not be appropriate and may need to be discussed with management. Having said that, this appendix deals with discussion as a normal part of reporting.

The technical report is the key user reference which enables an assessment of:

1. the purpose for which the product was developed
2. the standards and effort applied to different stages of the project
3. methods employed to achieve standards
4. the results arising from the application of methods
5. implications of the results in relation to key themes such as understanding landscape vegetation patterns, conservation status of vegetation communities, application and utility of data and further work.

Reporting requirements

An example of a standard vegetation report structure is presented in Table App 9.1. The report should clearly demonstrate a relationship between the application of method and the description of results. Each section within the chapter represents a theme or process involved in the construction of the classification and map. Each theme must be addressed in both methods and results sections.

Each theme has its own reporting criteria and requirements; these are outlined in Table App 9.1. Each reporting summary is designed to provide an outline of the reporting requirements; the nature of an individual project may necessitate other reporting criteria. Reporting is only required for the themes actually addressed in the project.

Table App 9.1 Example report structure with reference to theme reporting tables.

Section	Theme	Reporting summary
Authorship		Authorship is given to those people who are responsible for the execution and reporting of a project or who have contributed substantial original work (intellectual property) to the project. See Acknowledgements, below, for comparison.
Introduction		Includes rationale for study and proposed uses of the products
Background	Study area	Brief description of the location (<200 words) + map if needed
	Climate	Brief description (<200 words) of temperature and rainfall ranges & seasonality + tables if needed
	Geology/geomorphology	Brief description (<300 words) of the main features known (thought) to affect the distribution of vegetation communities + map if needed
	Previous vegetation studies	Documentation of all vegetation studies of relevance
Methods	Existing data	Describes the use and modification of any existing data in the current project
	Remote sensing interpretation	Describes the attributes collected and methods used. Refer to Appendix 2 of this Standard. Report on: • all imagery types, dates and scales • method(s) of interpretation used (e.g. human interpretation using 2d or 3d methods; computer-based (image classification, pixel based supervised/unsupervised classification) • mapping criteria (thematic scale, etc.) • effort (e.g. staff days per unit area [map sheet] in assigning boundaries, field days by interpretation staff, total rapid assessment sites completed) • role in interpolation and map production • criteria on which confidence classes are assigned
	Survey stratification and site selection	Describes the design and allocation of new survey effort. Refer to Appendix 3. Report: • stratification method (creation of unique sampling units, gap analysis, etc.) • stratification layers used • date and scale of stratification layers
	Field survey methods	Describes the field survey techniques. Refer to Appendix 4. Report: • plot size • cover and abundance scoring system used • relative use of full floristic sampling and of rapid assessment sites • any rules used to help locate plots in the field • use of site photography, general descriptions, etc.

Section	Theme	Reporting summary
Methods, continued	Data analysis and community classification	1. Describes the use of an existing classification and the criteria for assigning any given class to any given polygon type. Report: • the source and lineage of the classification • criteria used to assign classes to remotely sensed types • the contingency used if the above criteria fail to apply (e.g. encountering undescribed types, mismatch between remote sensing and described types) 2. Describes the analytical techniques used to develop a classification from plot data. Refer to Appendix 5 and 6. Report: • outline of the data, its intended use and intended level of classification • data checking and cleaning protocols • masking and transformation options explored • method(s) employed to derive classes • method(s) used to check and refine classes
	Spatial interpolation	Describes the method(s) used to integrate all data to produce final spatial product(s), usually map units. Refer to Appendix 7. Report: • interpolation method(s) and rule sets (e.g. expert panel; decision tree; probability calculation) • any smoothing techniques to be used for the final product • contingency for anomalous results • use of mosaics and mixtures
	Accuracy assessment	Describes the design and implementation of an independent map accuracy assessment. Refer to Appendix 8. Report: • source of independent data • proportional sampling (sub-sampling) rules • any emphasis for sampling (some classes may have been previously assessed; alternatively some classes may be so problematic as to require extensive sampling) • types of analyses to be undertaken additional to the minimum required by the Standard
	Conservation status assessment	Describes the data and analysis used to assess the conservation status of the classes and/or spatial types
Results	Existing data	Describes any unique contribution of existing data to the results. Report: • data sets used • data sets rejected and reasons • contribution of existing data to the outcomes

Section	Theme	Reporting summary
Results, continued	Remote sensing	Provides results on spatial patterns and attribute performance • number of remotely sensed types identified and defined • number of polygons defined • modal polygon area, upper and lower limits • overall confidence (this is important when judging the accuracy assessment). Where computer-based techniques have been used, in addition to the above, all analytical pathways are outlined and the results reported. Details of abandoned methods or models are not required but some brief description would be informative.
	Stratification	Reports the results of the stratification: • number of sampling units (theoretical maximum, real number, number supporting native vegetation) • proportional sampling rules and method of application
	Field survey	Provides results of the field survey program in relation to the survey design. Indicates performance of sampling strategy. Report: • number of full floristic plots • plot density per unit area; per map sheet; per sampling unit • number of rapid assessment sites • density of rapid assessment sites per unit area, etc. • number of floristic families, genera and species encountered • numbers of notable species encountered (threatened, new records, etc.)
	Data analysis and classification	Describes the outputs of the analysis described in methods above. Identifies the dominant vegetation patterns that emerge from the analysis. Report: • reconciliation between remotely sensed types and existing classification • results of treatment of anomalous circumstances • results of all the data analyses performed that are used in defining the final classes [usually vegetation communities] (do not describe abandoned analyses in detail but a brief description may be informative); this will include class definition, strength and coherence, etc. • final number of classes to be used and rationale • detailed description of each class (see part B of this appendix)

Section	Theme	Reporting summary
Results, continued	Spatial interpolation	Describes the results of the spatial interpolation used in generating the final vegetation mapping product. Report: • number of spatial types (e.g. map units) produced • the contribution of each vegetation class to each spatial type (non contributory types are often not reported except in probability modelling) • total area of each spatial type across the study area and for subdivisions of the study area (e.g. individual map sheets) if required. • detailed description of each spatial type
	Accuracy assessment	Results of independent accuracy assessment for all map units. Report: • error matrix • user's accuracy (degree of agreement between the map and the reference data) • producer's accuracy (degree of agreement between the reference data and the map) • errors of omission and commission
	Conservation status	Provides results of the conservation status assessment for each type
Discussion	Vegetation patterns in the landscape	Provides a synthesis of the relationship between map units and landscape patterns in the study area. Describes the relationship between map units
	Conservation status and endangered ecological community listings	Provides a synthesis of the protected area status of map units in the landscape and the threatening processes impacting upon them. Identifies relationships between listed EECs under the NSW *TSC Act 1995* and Commonwealth *EPBC Act 1999*
	Relationship to other vegetation classification systems	Relationships between other equivalent vegetation classifications within or adjoining the study area. Also refers to other relevant higher or lower order classification systems
	Further work	Describes any processes or localities that would benefit from future investment to improve the usefulness of the vegetation products
	Users guide to data and maps	Describes appropriate uses and applications of data derived from the study
Project Management	Project products and metadata	Location and storage of all products including hardcopy and digital data collected and derived for the project
Acknowledgements		Acknowledge any person who has: assisted with the project, provided financial support, been a mentor, or commented on draft reports
Authorship		Authorship is given to those people who are responsible for the execution and reporting of a project or who have contributed substantial original work (intellectual property) to the project
References		All references must be cited; citations are to be in accordance with any DECCW publications standards
Appendices	Text and tables that are not appropriate or required for the body of the report. NB Short reports are usually best.	Items such as: species lists; detailed map unit or community descriptions and examples of remote sensing interpretation or plot survey data sheets are frequently appended to a report. This keeps the body of the report brief and to the point whilst supplying appropriate information for specialist users.

Part B Map unit profile requirements

Introduction

Description of map units is required for all vegetation projects. The aim of a profile is to:

1. provide vegetation structural and floristic information to assist with field identification and to discriminate among map units
2. provide habitat descriptions that define the distribution of map units
3. understand the hierarchical relationship between the unit and other classification systems
4. contribute summary data that can be used to assist with the implementation of natural resource regulatory tools (e.g. Biometric, PVP, BioBanking)
5. understand the robustness of the community in terms of the survey effort (sampling adequacy), internal heterogeneity (natural or unmapped variations) and reliability of mapped distributions (interpolations)
6. provide summary conservation assessment and protected area status data for the map unit.

The Standard recognises that information contained within map unit profiles will vary depending on the type and scope of vegetation survey, classification and mapping methods. For example, projects utilising extensive systematic field data (product classes 4 and 5) are able to apply more robust statistical procedures to summarise floristic and structural information. Alternatively qualitative data may be gleaned from methods that rely on a priori classifications (product class 3) using existing literature, field experience or remote sensing.

Table App 9.2 Map unit profile fields.

Theme	Field	Description
Relationships to other vegetation classifications	*BioMetric* vegetation type	Identify equivalent *Biometric* vegetation type to describe the regional classification unit
	Statewide formation and class	Based on Keith (2004)
	Endangered ecological communities (EEC) listings	Community falls within the definition of an EEC listed under the NSW *Threatened Species Conservation Act 1995* and/or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
	Other significant classifications	Might include existing classification systems or mapping studies adjoining or proximate to study area
Vegetation community structure	Upper height of each stratum (metres)	Modal upper height in metres of each stratum. Systematic datasets should include standard error bounds
	Height range of each stratum (metres)	Identify maximum and minimum heights in metres. Systematic datasets should include standard error bounds

Theme	Field	Description
Vegetation community structure, continued	Cover and cover range of each stratum (%)	Modal percentage crown cover or foliage projective cover of each stratum. Systematic datasets should include standard error bounds
	Crown cover range	Identify maximum and minimum cover values (%).Systematic datasets should include standard error bounds
Floristic summary	Species richness	Mean number of taxa per site (include standard error bounds)
	Total number of species in community	All native species recorded at sites used to define the vegetation community
	Species composition within each stratum	A summary of commonly encountered, dominant or other characteristic species found within each stratum of the community
	Diagnostic and characteristic species	Note, these two terms have specific statistical meanings. If the appropriate analyses are not performed then these terms should either be avoided or a clear explanation of the method used must be provided
Habitat summary	Substrate	Primary soil, geological features associated with the distribution of the community
	Climate	Primary climatic features (annual rainfall, temperature)
	Topographic features	Slope, aspect, topographic position, elevation
Conservation assessment	Estimate of pre clearing area	Extrapolated distribution of pre-clearing extent of community found in the study area
	Extant area	Extrapolated distribution of vegetation community to current extent of native vegetation cover in the study area
	Estimated percentage cleared	Proportion of the extant distribution to the pre clearing area expressed as a percentage value
	Threats	Summary of known key threatening processes listed under the NSW TSC Act 1995 or other known significant impacts

Theme	Field	Description
Protected area status	Area in conservation reserves (hectares)	Area (hectares) found in lands managed under the NSW *NPWS Act 1994*, flora reserves under the *Forestry Act 1912,* Commonwealth *National Parks and Wildlife Conservation Act 1975*
	Proportion of extant area in conservation reserves	Proportion of extant area found on lands managed under the NSW *NPWS Act 1994*, flora reserves under the *Forestry Act 1912*, Commonwealth *National Parks and Wildlife Conservation Act 1975* expressed as percentage value
	Proportion of pre-clearing area in conservation reserves	
	Other lands managed for conservation	Project specific needs (land zoning, informal reservation, etc.)
Other	Number of sites	Number of sites used to define community
	Example locations	Typical representation of community at identifiable location accessible to the public
	Example photograph	
	Significant flora	May include threatened or other significant taxa recorded within the map unit

NB The structural and floristic summaries described are essential for data entry into both the state and national Vegetation Information Systems.

Recent examples of community presentation in technical reports and published papers

Example 1 – from Sydney Metropolitan Catchment Management Authority (unpublished)

Wet Sclerophyll Forests

Shrubby sub-formation

Illawarra Escarpment Blackbutt-Bangalay Forest

Blue Gum High Forest

Grassy sub-formation

Sydney Turpentine Ironbark Forest

O'Hares Creek Shale Cap Forest

Illawarra Escarpment Blackbutt-Bangalay Forest MU33

Statewide class: North Coast Wet Sclerophyll Forests
PVP biometric type: Blackbutt – Turpentine – Bangalay moist open forest on sheltered slopes and gullies, southern Sydney Basin

Equivalent regional class: Illawarra Gully Wet Forest (WSF p. 99)

Description

This section provides a user friendly description of the floristic and structural features of the vegetation community. It provides details on the habitat characteristics of unit distribution in the study area that might include substrate (soil and geology), climate (annual rainfall and temperature), and topographic features (slope, aspect, topographic position, elevation).

Floristic summary*

	Average height and height range (m)	Average cover and cover range (m)	Typical species
Trees	21.2m ±11.9 5.0–40.0	45.2% ± 18.1 10–80	*Eucalyptus botryoides, Syncarpia glomulifera, Eucalyptus pilularis, Banksia integrifolia, Leptospermum laevigatum*
Small trees	7.2m ±4.0 2.0–15	24.3% ± 16.9 4–60	*Livistona australis, Pittosporum undulatum, Acacia maidenii, Tristaniopsis collina, Banksia integrifolia, Glochidion ferdinandi*
Shrubs	3.3m ±1.5	20%±5	*Acacia floribunda, Acacia irrorata, Livistona australis*
Ground covers	1m	70%±20	*Lomandra longifolia, Calochlaena dubia, Imperata cylindrica* var. *major, Poa affinis, Gymnostachys anceps, Polystichum australiense, Indigofera australis, Pteridium esculentum, Poa labillardierei, Doodia aspera*
Vines & climbers	N/A	N/A	

*Compiled from 17 of 34 sites with structural data recorded.

Threats

Simple summary of primary threats

Conservation status

Highlights legal status (discuss EPBC Act 1999, TSC Act 1995, representation in reserves, distribution and status in neighboring or adjoining regions). NOTE: Actual figures were not available at the time of publication.

	Within SMCMA	Total known distribution
Estimate of pre-clearing area	xxx hectares	xxx hectares
Extant area	xxx hectares	xxx hectares
Estimated percentage cleared	xxx %	xxx %
Area in conservation reserves	xxx hectares xxx % of extant area xxx % of pre-clearing area	xxx hectares xxx % of extant area xxx % of pre-clearing area

Example locations

Identify reference points that are accessible to public if possible.

Known variations:

Describes floristic or structural variations that are currently recognised in this map unit.

Relationship to other communities

Identifies units that have similar floristic and/or structural characteristics in the study area. Also identify units that are often spatially proximate.

Accuracy

Mapping accuracy based on validation.

Robustness of community classification based on number of replicates, observed variations within unit.

Species richness

Number of plots	34
Total species	318
Average species per plot	43.6 ±8.5

Diagnostic species

Species name	Group score (60 percentile)	Group frequency	Non-group score (60 percentile)	Non-group frequency	Fidelity class
Acacia parramattensis	2	83%	2	11%	positive
Adiantum aethiopicum	2	50%	2	20%	positive
Calochlaena dubia	2	50%	2	7%	positive
Carex appressa	2	83%	6	0%	positive
Cladium procerum	2	17%	0	0%	positive
Cyclosorus interruptus	1	17%	0	0%	positive
Dichondra repens	2	67%	2	19%	positive
Entolasia marginata	2	83%	2	11%	positive
Eucalyptus amplifolia subsp. *amplifolia*	4	83%	3	3%	positive
Geitonoplesium cymosum	2	50%	1	7%	positive
Huperzia australiana	2	17%	0	0%	positive
Hydrocotyle laxiflora	2	50%	2	6%	positive
Lomandra longifolia	2	50%	1	32%	positive
Melaleuca linariifolia	4	100%	3	3%	positive
Microlaena stipoides var. *stipoides*	6	67%	2	29%	positive
Oplismenus imbecillis	4	50%	2	20%	positive
Phragmites australis	2	17%	0	0%	positive
Pratia purpurascens	2	83%	2	32%	positive
Prostanthera lanceolata	2	33%	0	0%	positive
Pteridium esculentum	2	50%	2	31%	positive
Ranunculus plebeius	1	33%	0	0%	positive
Rubus parvifolius	2	50%	2	8%	positive
Sigesbeckia orientalis subsp. *orientalis*	2	50%	2	9%	positive

Example 2 – from Lewer *et al.* (2002, out of print)

Riparian woodlands and open forests (FLP)

***Eucalyptus camaldulensis* (+/– mixed eucalypts) Tall Woodlands**

Group no:	16
No in group:	10
Species richness:	42 ± 2
Map units:	FLP1

Plate 13.1 *Eucalyptus camaldulensis* (+/– mixed eucalypts) Tall Woodlands

Group 16 is a Tall Woodland dominated by *Eucalyptus camaldulensis* sometimes with *Eucalyptus melliodora*, *Eucalyptus largiflorens* and *Eucalyptus populnea* subsp. *bimbil* to a mean height of 17.4 m. There is a sparse understorey of regenerating eucalypts, notably *Eucalyptus camaldulensis* (to a mean height of 9.2 m) or scattered shrubs: *Acacia salicina*, *Geijera parviflora* and *Myoporum montanum*. The shrub layer is sparse and characterised by scattered *Muehlenbeckia florulenta* and *Eucalyptus camaldulensis* saplings (to a mean height of 1.2 m). The lower stratum is dense (76% cover), mid-high (40 cm high), and is comprised of a variety of tussock and sod grasses, native forbs and sedges. The characteristic native species in this stratum are *Paspalidium jubiflorum*, *Rumex brownii*, *Alternanthera denticulata*, *Bothriochloa macra*, *Carex inversa*, *Oxalis perennans*, *Cynodon dactylon*, *Verbena gaudichaudii*, *Pratia concolor*, *Carex appressa*, *Paspalidium jubiflorum*, *Eragrostis parviflora*, *Dichondra repens*, *Marsilea drummondii*, *Einadia nutans* and *Enteropogon acicularis*. The exotic prostrate forb *Phyla canescens* is a common component of the lower stratum. Other common exotic species include: *Sonchus oleraceus*, *Solanum nigrum*, *Lolium rigidum*, *Conyza bonariensis*, *Cirsium vulgare*, *Chondrilla juncea*, *Xanthium spinosum* and *Medicago polymorpha*. Additionally, a couple of exotic small tree species were also noted *Melia azedarach* and *Schinus areira*. This association occurs predominantly on the lighter textured clay soils on the flood plains and alluvial plains, mainly in open depressions, stream channel banks or on seasonally wet flats.

Table 13-1 Structure—Group 16

Growth form	Mean height (m) (+/-se)	Height range (m)	Mean crown cover (%)(+/-se)	Crown cover range (%)
Tree	17.4 (1.73)	(12–28)	45.5 (7.76)	(5–80)
Tall shrub / small tree	9.2 (1.42)	(6–16)	13.3 (2.10)	(5–20)
Shrub	1.2 (0.11)	(0.6–1.5)	10.6 (5.35)	(1–35)
Groundcover	0.4 (0.15)	(0.05–1.7)	76.3 (5.62)	(40–95)

Table 13-2 Diagnostic species – Group 16

Life form	Name	Group score (50 percentile)	Group frequency	Non-group score (50 percentile)	Non-group frequency	Fidelity class
Tree	*Eucalyptus camaldulensis*	6	1	5	0.0321	positive
Shrub	*Einadia nutans*	1	0.5	2	0.6043	negative
Tussock grass	*Austrostipa scabra*	1	0.1	4	0.6604	negative
Tussock grass	*Bothriochloa macra*	2	0.8	2	0.0401	positive
Tussock grass	*Enteropogon acicularis*	1	0.5	2	0.5615	negative
Tussock grass	*Paspalidium jubiflorum*	4	0.5	2	0.0829	positive
Sod grass	*Cynodon dactylon*	2	0.7	2	0.0160	positive
Sedge	*Carex appressa*	2	0.3	0	0	positive
Sedge	*Carex inversa*	2	0.8	2	0.2861	positive
Forb	*Calotis cuneifolia*	0	0	2	0.5936	negative
Forb	*Oxalis perennans*	2	0.8	2	0.5374	constant
Forb	*Pratia concolor*	3	0.6	1	0.0321	positive
Forb	*Rumex brownii*	2	1	1	0.2219	positive

Table 13-3 Character species—Group 16

Species	Relative abundance	Relative frequency	Indicator value
Eucalyptus camaldulensis	33	100	33
Rumex brownii	14	100	14
Alternanthera denticulata	10	100	10
Sonchus oleraceus	9	100	9
Bothriochloa macra	25	80	20
Carex inversa	7	80	5
Oxalis perennans	7	80	6
Cynodon dactylon	73	70	51
Verbena gaudichaudii	24	70	17
Solanum nigrum	21	70	15
Lolium rigidum	17	70	12
Conyza bonariensis	12	70	8
Pratia concolor	38	60	23
Cirsium vulgare	17	60	10
Muehlenbeckia florulenta	5	60	3
Chondrilla juncea	28	50	14
Xanthium spinosum	24	50	12
Paspalidium jubiflorum	15	50	7
Medicago polymorpha	13	50	6
Eragrostis parviflora	7	50	4
Dichondra repens	5	50	2
Marsilea drummondii	4	50	2
Einadia nutans	3	50	1
Enteropogon acicularis	3	50	2

Example 3 – from Keith & Bedward 1999

Map Unit 21: Candelo Dry Grass Forest

Candelo Dry Grass Forest is dominated by *Eucalyptus tereticornis, E. globoidea* and *Angophora floribunda,* usually with *E. melliodora ca*. 22 m tall*. Acacia mearnsii* is the most frequent species in sparse strata of small trees and shrubs 2–8 m tall. The distinctive and diverse grassy groundcover is dominated by *Themeda australis, Notodanthonia racemosa*, *Dichanthium sericeum, Eragrostis leptostachya, Microlaena stipoides* and *Dichelachne micrantha,* with forbs including *Dichondra repens, Desmodium varians, Hydrocotyle laxiflora, Geranium solanderi* and *Gnaphalium gymnocephalum. Glycine tabacina* and *G. clandestina* trail amongst the groundcover. Candelo Dry Grass Forest occurs on undulating terrain in the driest western parts of the Bega and Towamba valleys below 300 m elevation on granitoid substrates or rarely Ordovician mudstones. Frost hollows near Candelo support stands of *E. pauciflora*, but these persist only as small highly modified remnants. This assemblage is part of a complex of grassy ecosystems (map units 18–21) in the Bega valley and associated rainshadow areas. It is distinguished from other assemblages by the inclusion of *E. melliodora* in the tree stratum and groundcover elements such as *Dichanthium sericeum* and *Glycine tabacina*. It generally grades from west to east into Bega Dry Grass Forest (map unit 20), and the precise boundary between these units is somewhat arbitrary, although an outlying stand of Candelo Dry Grass Forest has been recorded between Bega and Wolumla. No similar assemblages have been described in adjacent regions (Austin 1978, Woodgate *et al*. 1994). Over 90% of this vegetation has been cleared for agriculture and almost all of the remaining 1500 ha is highly fragmented on private land where is it threatened by further clearing, grazing and weed invasion (Keith 1995).

Species richness: 35 ± 3 (0.04 ha)

Extant area: 1571 ha

Proportion cleared: 91%

Number of samples: 28

Table A21.1. Diagnostic plant species of map unit 21.

Species	Target frequency	Target C/A	Residual frequency	Residual C/A	Fidelity class
Angophora floribunda	0.679	3 (1–4)	0.084	2 (1–3)	positive
Brachycome ciliata var. *ciliata*	0.071	1 (1–1)	0	0 (0–0)	positive
Chloris ventricosa	0.036	2 (2–2)	0	0 (0–0)	positive
Notodanthonia racemosa var. *racemosa*	0.679	2 (1–2)	0.039	1 (1–2)	positive
Dichanthium sericeum	0.429	1 (1–2)	0	0 (0–0)	positive
Dichondra repens	0.893	2 (2–3)	0.272	1 (1–2)	positive
Eragrostis leptostachya	0.75	2 (2–3)	0.033	1 (1–2)	positive
Eucalyptus globoidea	0.643	3 (1–3)	0.235	3 (1–3)	positive

Species	Target frequency	Target C/A	Residual frequency	Residual C/A	Fidelity class
Eucalyptus tereticornis	0.786	3 (1–3)	0.033	3 (1–3)	positive
Glycine tabacina	0.536	2 (1–2)	0.024	1 (1–2)	positive
Hydrocotyle laxiflora	0.75	2 (1–2)	0.195	2 (1–2)	positive
Microlaena stipoides var. *stipoides*	0.857	2 (2–3)	0.344	1 (1–2)	positive
Plantago hispida	0.036	4 (4–4)	0	0 (0–0)	positive
Themeda australis	0.821	4 (3–4)	0.1	2 (1–3)	positive
Zornia dyctiocarpa	0.036	1 (1–1)	0	0 (0–0)	positive
Acacia mearnsii	0.607	1 (1–3)	0.154	2 (1–3)	frequent
Desmodium varians	0.679	1 (1–2)	0.242	1 (1–2)	frequent
Dichelachne micrantha	0.714	1 (1–2)	0.073	1 (1–2)	frequent
Geranium solanderi	0.714	1 (1–2)	0.081	1 (1–2)	frequent
Glycine clandestina	0.786	1 (1–2)	0.319	1 (1–2)	frequent
Gnaphalium gymnocephalum	0.714	1 (1–1)	0.173	1 (1–1)	frequent
Eucalyptus baueriana	0.036	1 (1–1)	0.026	2 (1–3)	uninformative
Eucalyptus bosistoana	0.071	1.5 (1–2)	0.053	2 (1–3)	uninformative
Eucalyptus elata	0.071	1 (1–1)	0.114	3 (2–3)	uninformative
Eucalyptus maidenii	0.107	3 (3–3)	0.062	3 (2–3)	uninformative
Eucalyptus melliodora	0.429	1.5 (1–3)	0.003	2 (1–3)	uninformative
Eucalyptus viminalis	0.036	1 (1–1)	0.057	3 (1–3)	uninformative
Lomandra longifolia	0.321	1 (1–1)	0.553	2 (1–2)	negative
Poa meionectes	0.429	1.5 (1–3)	0.541	2 (1–3)	negative
Pteridium esculentum	0.179	1 (1–2)	0.585	2 (1–3)	negative

Table A21.2. Vegetation structure of map unit 21. Frequency is the proportion of samples in which strata were present. Height and cover data are means with standard errors in parentheses (n=28).

Stratum	Frequency (%)	Height (m)	Cover (%)
Tree	100	22.4 (0.8)	24 (2)
Small tree	50	8.4 (0.8)	20 (4)
Shrub	89.3	1.9 (0.2)	12 (3)
Ground cover	100	0.3 (0.0)	77 (4)

Table A21.3. Habitat characteristics of map unit 21. Means and interquartile ranges for altitude and slope were calculated from n field samples, while those for annual rain were calculated from ESOCLIM predictions (see Table 5, text). Frequency terrain and parent material refers to number of samples (n) recorded in respective classes. Terrain classes: flat (slope≤5°); north (slope>5° and aspect<30° or >300°); intermediate (slope>5° and aspect 30–120° or 210–300°); and south (slope>5° and aspect 120–210°).

	Frequency (%)	Mean	Interquartile range	n
Annual rain (mm)		792	774–816	28
Altitude (m)		149	105–183	28
Slope (degrees)		14	8–21	28
Terrain class				
North	14			4
Intermediate	61			17
South	18			5
Flat	7			2
Parent material				
Devonian granitoids	86			24
Ordovician high quartz sedimentary formations	14			4

References

Andrew, D (2001) *Post fire vertebrate fauna survey, Royal National Park and Heathcote National Park and Garrawarra State Recreation Area*. NSW National Parks and Wildlife Service, Hurstville.

Austin, MP (1978) 'Vegetation', in MP Austin & KD Cocks (eds), *Landuse on the south coast of New South Wales*, pp. 44–67. CSIRO, Canberra.

Austin, MP (1991) 'Vegetation theory in relation to cost-efficient surveys', in CR Margules & MP Austin (eds), *Nature conservation: cost effective biological and data analysis*, pp. 17–22. CSIRO, Melbourne.

Austin, MP, Cawsey, EM, Baker, BL, Yiaeloglou, MM, Grice, DJ & Briggs, SV (2000) *Predicted vegetation cover in the Central Lachlan region*. CSIRO Division of Wildlife and Ecology, Canberra.

Austin, MP & Heyligers, PC (1989) 'Vegetation survey design for conservation: Gradsect sampling of forests in North-eastern New South Wales'. *Biological Conservation*, vol. 50, pp. 13–33.

Beadle, NCW (1981) *The vegetation of Australia*. Cambridge University Press, Sydney.

Beadle, NCW & Costin, AB (1952) 'Ecological classification and nomenclature'. *Proc. Linn. Soc. NSW*, vol. 77, pp. 61–82.

Belbin, L (1994) *PATN pattern analysis package*. CSIRO Sustainable Ecosystems, Canberra.

Bell, S & Douglas, S (2002) *Clyde River National Park vegetation survey*. Report to the NSW National Parks and Wildlife Service, Sydney.

Benson, DH & Howell, J (1994) *Hawkesbury-Nepean catchment vegetation mapping: explanatory notes for the Wollongong 1:100 000 map sheet*. Ecology Section, National Herbarium, Royal Botanic Gardens, Sydney.

Benson, JS (1994) 'Monaro grasslands'. *Cunninghamia*, vol. 3, no. 3, pp. 609–650.

Benson, JS (2006) 'New South Wales vegetation classification and assessment: Introduction – the classification, database, assessment of protected areas and threat status of plant communities'. *Cunninghamia*, vol. 9, no. 3, pp. 329–382.

Benson, JS & Ashby, EM (2000) 'Natural vegetation of the Guyra (NSW) 1:100 000 map sheet'. *Cunninghamia*, vol. **6,** no. 3, pp. 747–872.

Benson, JS, Allen, CB, Tougher, C & Lemmon, J (2006) 'New South Wales vegetation classification and assessment: Part 1 plant communities of the NSW Western Plains'. *Cunninghamia*, vol. 9, no. 3, pp. 383–450.

Beukers, M (undated) Unpublished vegetation survey data, Ecologically Sustainable Forest Management Program. NPWS Far South Coast Region, NSW National Parks and Wildlife Service, Eden.

Binns, DL (1997) 'Floristic and vegetation patterns of Coolah Tops, New South Wales'. *Cunninghamia*, vol. 5, no. 1, pp. 233–274.

Black, D (2000a) Unpublished vegetation plot data, Budderoo National Park. NSW National Parks and Wildlife Service, Sydney.

Black, D (2000b) Unpublished vegetation plot data, Morton NP; Bugong Area, Burma FT Burning Block. NSW National Parks and Wildlife Service, Sydney.

Braun-Blanquet, J (1932) *Plant sociology*. McGraw Hill, New York.

Brocklehurst, P, Lewis, D, Napier, D & Lynch, D (2007) *Northern Territory guidelines and field methodology for vegetation survey and mapping*. Technical report 02/2007D, Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory.

Brooker, MG & Margules, CR (1996) ‘The relative conservation value of remnant patches of native vegetation in the wheatbelt of Western Australia: I. Plant diversity’. *Pacific Conservation Biology*, vol. 2, pp. 268–278.

BRS—*see* Bureau of Rural Sciences

Bureau of Rural Sciences (2002) *Land use mapping at catchment scale, principles, procedures and definitions*, 2nd edition. Bureau of Rural Sciences, Canberra.

Cannon, G, Cannon, M, Harding, W, McCosker, R, Spunner, B, Steenbeeke, G & Watson, G (2002) *Native vegetation of the Bellata, Gravesend, Horton and Boggabri 1:100 000 map sheets*. Native Vegetation Map Report Series, NSW Department of Natural Resources, Sydney.

Chuvieco, E & Martinez Vega, J (1990) ‘Visual versus digital analysis for vegetation mapping: some examples on central Spain’. *Geocarto International*, vol. 3, pp. 21–30.

Clements, A, Rodd, T, Rodd, J & Moore, R (2000) ‘Shale/sandstone transition forest within the Blue Mountains local government area’. Anne Marie Clements & Associates, unpublished report to Blue Mountains City Council.

Congalton, RG (1991) ‘A review of assessing the accuracy of classifications of remotely sensed data’. *Remote Sens. Environment*, vol. 37, pp. 35–46.

Connolly, D (2000) *Vegetation survey, classification and mapping – Lower Hunter & Central Coast region*. NSW National Parks and Wildlife Service, Sydney.

CSIRO (1999a) Unpublished survey data: Clyde Mountain and environs. CSIRO, Canberra.

CSIRO (1999b) Unpublished survey data: Kosciusko survey sites. CSIRO, Canberra.

Department of Environment and Conservation (2006) *Broad vegetation maps of Central West and Lachlan CMAs*. Internal report, Department of Environment and Conservation, Dubbo.

Definiens (2004) *eCognition professional user guide 4.* Definiens AG, Munich, Germany.

Douglas, S & Bell, S (2002) *Bimberamala National Park vegetation survey*. NSW National Parks and Wildlife Service, Sydney.

Dufréne, M & Legendre, P (1997) ‘Species assemblages and indicator species: the need for a flexible asymmetrical approach’. *Ecological Monographs*, vol. 67, no. 3, pp. 345–366.

Ecological Surveys and Planning Pty Ltd (2001) *Native vegetation mapping of areas 1 to 5 in Blue Mountains City local government area*. Report to BMCC by Ecological Surveys & Planning Pty Ltd, Hornsby.

Elith, J, Burgman, MA & Regan, HM (2002) ‘Mapping epistemic uncertainties and vague concepts in predictions of species distributions’. *Ecological Modelling*, vol. 157, pp. 313–329.

ESCAVI—*see* Executive Steering Committee for Australian Vegetation Information

ESP—*see* Ecological Surveys and Planning Pty Ltd

Executive Steering Committee for Australian Vegetation Information (2003) *National vegetation information system – Australian vegetation attribute manual,* version 6.0. Department of Environment and Heritage, Canberra.

Eyre, TJ, Kelly, AL, Sutcliffe, T, Denham, R, Jermyn, D & Venz, M (2002) *Forest condition assessment and implications for biodiversity – final report*. Queensland Department of Natural Resources, Indooroopilly, Queensland.

FAO—see Food and Agriculture Organization of the United Nations

Ferrier, S (2002) 'Mapping spatial pattern in biodiversity for regional conservation planning: where to from here?'. *Systematic Botany*, vol. 51, pp. 331–363.

Fisher, M & Ryan, K (1994) *Hawkesbury–Nepean catchment vegetation mapping: explanatory notes for the Taralga and Oberon 1:100 000 map sheets*. Ecology Section, National Herbarium, Royal Botanic Gardens, Sydney.

Fisher, M, Ryan, K & Lembit, R (1995) 'The natural vegetation of the Burragorang 1:100 000 map sheet'. *Cunninghamia*, vol. 4, no. 2, pp. 143–215.

Fitzgerald, RW & Lees, BG (1994) 'Assessing the classification accuracy of multi-source remote sensing data'. *Remote Sens. Environment*, vol. 47, pp. 362–368.

Food and Agriculture Organization of the United Nations (1979) 'Soil survey investigation for irrigation'. *Soil Bulletin*, no. 42.

Food and Agriculture Organization of the United Nations (2001) *State of the world's forests*. Food and Agriculture Organization of the United Nations, Rome, Italy.

French, K, Pellow, B & Henderson, M (2000) 'Vegetation of the Holsworthy Military Area'. *Cunninghamia*, vol. 6, no. 4, pp. 893–940.

Gilmour, PM (1985) 'Vegetation survey of Deua National Park'. Unpublished report to NSW National Parks and Wildlife Service, Narooma.

Gopal, S & Woodcock, C (1994) 'Theory and methods for accuracy assessment of thematic maps using fuzzy sets'. *Photogrammetric Engineering and Remote Sensing*, vol. 60, no. 2, pp. 181–188.

Graetz, RD, Wilson, MA & Campbell, SK (1995) *Land cover disturbance over the Australian continent, a contemporary assessment*. Biodiversity series paper no.7, Department of the Environment, Sport and Territories, Canberra.

Green, EJ & Strawderman, WE (1994) 'Determining accuracy of thematic maps'. *The Statistician*, vol. 43, no. 1, pp. 77–85.

Grimes, RF (1978) *Crown assessment of natural spotted gum ironbark forest*. Technical paper no. 7, pp. 1–16, Department of Forestry, Queensland.

Grossman, DH, Faber-Langendoen, D, Wealkey, AS, Anderson, M, Bourgeron, P, Crawford, R, Goddin, K, Landaal, S, Metzler, K, Patterson, K, Pyne, M, Reid, M & Sneddon, L (1998) 'International classification of ecological communities: terrestrial vegetation of the United States', in *Volume 1, The national vegetation classification system: development, status and applications*. The Nature Conservancy, Arlington, Virginia, USA.

Gunn, RH, Beattie, JA, Reid, RE & van de Graaff, RHM (1988) *Australian soil and land survey handbook: guidelines for survey*. Inkata Press, Melbourne.

Hammond, TO & Verbyla, DL (1996) 'Optimistic bias in classification accuracy assessment'. *International Journal of Remote Sensing*, vol. 17, no. 6, pp. 1261–1266.

Harden, GJ (2000) *Flora of New South Wales*; volume 1. University of NSW Press, Sydney.

Harris, S & Kitchener, K (in press) *Tasmania's vegetation – a technical manual for TASVEG: Tasmania's vegetation map, version 1.0*. Tasmanian Department of Primary Industries, Water and Environment, Hobart.

Heard, L & Channon, B (1997) *Guide to a native vegetation survey (agricultural region) using the Biological Survey of South Australia methodology*. SA Department of Housing & Urban Development, Adelaide.

Helman, CE (1983) 'Inventory analysis of southern NSW rainforest vegetation'. Unpublished doctoral dissertation, MSc Thesis, University of New England, Armidale.

Hibberd, J & Taws, N (1993) 'The Long Paddock revisited 15 years on: a comparative study of the condition and use of travelling stock reserves in the Southern Tablelands 1977–1993'. Unpublished report for the Nature Conservation Council, Sydney.

Hnatiuk, RJ, Thackway, R & Walker, J (2005) 'Vegetation', in *Australian soil and land survey: field handbook*, 3rd edition. Department of Agriculture, Fisheries and Forestry, Canberra.

Horner, G, McNellie, M, Nott, TA, Vanzella, B, Schliebs, M, Kordas, GS, Turner, B & Hudspith, TJ (2002) *Native vegetation of the Dry Lake, Oxley, Hay, One Tree, Moggumbill and Gunbar 1:100 000 map sheets*. Native vegetation map report series, NSW Department of Natural Resources, Sydney.

Hudson, JC (1992) 'Scale in space and time', in R Abler, M Marcus & J Olen (eds), International Geography Congress, *Geography's inner worlds: pervasive themes in contemporary American geography*, pp. 208–297. Rutgers University Press, New Brunswick, NJ.

Ismay, K, Lewer, S, Deluca, S, McKenzie-Gay, M, Powrie, S, Burns, M, Ryan, C & Chaffey, D (2004) Draft report: *Native vegetation of the Cobbora, Coolah, Coonabarabran, Mendooran, Tambar Springs 1: 100 000 map sheets*. Native vegetation map report series, NSW Department of Natural Resources, Sydney.

James, T, Lembit, R, Burcher, P & Ecograph Consulting (2002) *Natural asset mapping for Baulkham Hills Shire Council – plant communities in Baulkham Hills Shire*. Report commissioned by BHSC, Baulkham Hills.

Jurskis, V, Shields, R & Binns, D (1995) 'Flora survey, Queanbeyan/Badja Environmental Impact Statement Area, Southern Region, New South Wales'. Supporting document 3, in *Environmental Impact Statement for Queanbeyan & Badja Management Areas*. Research Division, State Forests of NSW, Beecroft.

Kamagata, N, Hara, K, Mori, M, Akamatsu, Y, Li, Y & Hoshino, Y (2006) 'A new method of vegetation mapping by object-based classification using high resolution satellite data'. Proceedings of the 1st International Conference on Object-Based Image Analysis, ISPRS Commission V1, WG V1/4, Salzburg, Austria.

Keith, DA (1994) 'Floristics, structure and diversity of natural vegetation in the O'Hares Creek catchment, south of Sydney'. *Cunninghamia*, vol. 3, no. 3, pp. 543–594.

Keith, DA (1995) 'Involving ecologists and local communities in survey, planning and action for conservation in a rural landscape: an example from the Bega Valley, New South Wales', in DA Saunders, JL Craig & EM Mattiske (eds), *Nature conservation 4: The role of networks*, pp. 385–400. Surrey Beatty and Sons, Chipping Norton, Sydney.

Keith, DA (2002) *A compilation map of native vegetation for New South Wales*. NSW National Parks and Wildlife Service, Hurstville.

Keith, DA (2004) *Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT*. Department of Environment and Conservation, Hurstville.

Keith, DA (2009) 'The interpretation, assessment and conservation of ecological communities'. *Ecological Management & Restoration*, vol. 10, no. s1, pp s3–s15.

Keith, DA & Bedward, M (1999) 'Native vegetation of the South East Forests region, Eden, New South Wales'. *Cunninghamia*, vol. 6, no. 1, pp. 1–218.

Keith, DA & Benson, DH (1988) 'The natural vegetation of the Katoomba 1:100 000 map sheet'. *Cunninghamia*, vol. 2, no. 1, pp. 107–144.

Keith, DA, Tozer, M & Hunter, S (2000) *An evaluation of vegetation mapping data for the DSNR Priority 5 mapping area*. Internal report to DSNR, National Parks and Wildlife Service, Sydney.

Kent M & Coker P (1994) *Vegetation description and analysis. A practical approach*. John Wiley and Sons Ltd, Chichester, UK.

Kushwaha, SPS, Kuntz, S & Oesten, G (1994) ‘Applications of image texture in forest classification’. *International Journal of Remote Sensing*, vol. 15, pp. 2273–2284.

Landis, JR & Koch, GG (1977) ‘The measurement of observer agreement for categorical data’. *Biometrics*, vol. 33, pp. 159–174.

Lembit, R (2001) *Vegetation mapping of Hornsby Shire*. Unpublished report to Hornsby Shire Council, Gingra Environmental Consultants, Campsie.

Lembit, RS (2002) *Vegetation survey of Marramarra National Park, Muogamarra Nature Reserve & Maroota Historic Site*. Report for Sydney North Region, NSW National Parks and Wildlife Service, Mt Colah.

Leonard, G (1999) *Survey and description of vascular plant species and assemblages, brush-tailed rock-wallaby sites, Kangaroo Valley colony 1, west of Hampden Bridge, Kangaroo Valley, NSW, Australia*. Unpublished report for NSW National Parks and Wildlife Service, Sydney.

Lewer, S, Ismay, K, Grounds, S, Gibson, R, Harris, M, Armstrong, R, Deluca, S & Tindall, D (2002, out of print) *Native vegetation of the Bogan Gate, Boona Mount, Condobolin, Dandaloo, Tottenham and Tullamore 1:100 000 map sheets*. Native vegetation map series, NSW Department of Land and Water Conservation, Sydney.

Lilliesand, TM & Kiefer, RW (1994) *Remote sensing and image interpretation*. John Wiley & Sons, New York.

Lockwood, M, Wise, P, Lane, M, Williams, J, Godd, L & Costello, D (1997) *Eurobodalla National Park flora survey*. Recreation and heritage report no. 84, Charles Sturt University, Johnstone Centre of Parks, Albury Campus Library, Albury.

Margules, CR & Nicholls, AO (1987) ‘Assessing the conservation value of remnant habitat 'islands': mallee patches on the Western Eyre Peninsula, South Australia’, in DA Saunders, GW Arnold, AA Burbidge & AJM Hopkins (eds), *Nature conservation: the role of remnants of native vegetation*, pp. 89–102. Surrey Beatty & Sons Pty Ltd; CSIRO; CALM, Sydney.

Margules, CR & Scott, RM (1983) ‘Review and evaluation of integrated surveys for conservation’, in K Myers, CR Margules & I Musto (eds), *Survey methods for nature conservation*. CSIRO, Canberra.

Maybury, KP (1999) *Seeing the forest and the trees: ecological classification for conservation*. The Nature Conservancy, Virginia, USA.

McCune, B & Mefford, MJ (1999) *PC-ORD for Windows*. Multivariate analysis of ecological data, version 4.17. MjM Software, Gleneden Beach, Oregon, USA.

McDonald, RC, Isbell, RF, Speight, JG, Walker, J & Hopkins, MS (1984) *Australian soil and land survey – field handbook*. Inkata Press, Melbourne.

McDonald, RC, Isbell, RF, Speight, JR, Walker, J & Hopkins, MS (1990) *Australian soil and land survey – field handbook*, 2nd edition. Australian Collaborative Land Evaluation Program, Canberra.

McDonald, WJF & Dillewaard, HA (1994) *CORVEG* vegetation and flora database for Queensland, version 2.0. Queensland Herbarium, Queensland Department of Environment and Heritage, Brisbane.

McKenzie, NJ, Grundy, MJ, Webster, R & Ringrose-Vogse, AJ (2008) *Guidelines for surveying soil and land resources*, 2nd edition. CSIRO, Melbourne.

McNellie, M (2004) Draft *Native vegetation of the Moulamein, Wanganella, Conargo, Cohuna, Mathoura and Tuppal 1:100 000 map sheets*. Native vegetation map report series, NSW Department of Natural Resources, Sydney.

Milliken, J, Beardsley, D & Gill, S (1998) *Accuracy assessment of a vegetation map of north-eastern California using permanent plots and fuzzy sets*. United States Department of Agriculture Forest Service, available at www.fs.fed.us/r5/rsl/publications/.

Milne, AK & O'Neill, A (1989) *Feasibility study for using Landsat imagery to monitor landcover change in the Willandra Lakes World Heritage Region*. University of NSW, Sydney.

Mueller-Dombois D & Ellenberg H (1974) *Aims and methods of vegetation ecology*. John Wiley and Sons, New York.

Natural Resources Commission of NSW (2005) *Standard for Quality Natural Resource Management*. Natural Resources Commission of NSW, Sydney.

Neldner, VJ (1993) 'Vegetation survey and mapping in Queensland'. *Queensland Botany Bulletin*, no. 12.

Neldner, VJ & Howitt, CJ (1991) 'Comparison of an intuitive mapping classification and numerical classifications of vegetation in south-east Queensland, Australia'. *Vegetatio*, vol. 94, pp. 141–152.

Neldner, VJ, Thompson, EJ, Bean, AR & Dillewaard, HA (1999) *Methodology for survey and mapping of vegetation communities and regional ecosystems in Queensland*. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Neldner, VJ, Wilson, BA, Thompson, EJ & Dillewaard, HA (2005) *Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland*, version 3.1, updated September 2005. Queensland Herbarium, Environmental Protection Agency, Brisbane.

National Parks Association (1998) 'Benandera State Forest biodiversity survey'. Unpublished report, National Parks Association, Sydney.

NPA—*see* National Parks Association

NRC—*see* Natural Resources Commission of NSW

NSW Department of Natural Resources (2005) *Native Vegetation Regulation 2005: environmental outcomes assessment methodology*. NSW Department of Natural Resources, Sydney.

NSW National Parks and Wildlife Service (2000a) *Vegetation survey, classification and mapping: Lower Hunter and Central Coast Region*. A project undertaken for the LHCC Regional Environmental Management Strategy, NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2000b) *Biodiversity study for the Georges River Catchment, volume 1: native vegetation*. Background study for stage 2 of the Georges River Catchment Regional Environmental Plan, prepared for Department of Urban Affairs & Planning, NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2000c) *Terrestrial ecosystems of the Eurobodalla local government area*. A project undertaken with Eurobodalla Council and the Lower South Coast Catchment Management Committee, NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2000d) Unpublished survey data. Southern CRA vegetation surveys 1997–2000, NSW National Parks and Wildlife Service, Queanbeyan.

NSW National Parks and Wildlife Service (2000e) *The native vegetation of the Cumberland Plain, Western Sydney*. Technical Report, Comprehensive Regional Assessment Unit, Sydney Zone, NSW National Parks and Wildlife Service, Sydney.

NSW National Parks and Wildlife Service (2001) Unpublished data for survey of Umina Coastal Sands Woodland for nomination before Scientific Committee. NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2002) *Native vegetation of the Illawarra Escarpment and Coastal Plain – bioregional assessment study part I*. NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2003a) *The native vegetation of the Warragamba Special Area*. Report to the Sydney Catchment Authority, NSW National Parks and Wildlife Service, Hurstville.

NSW National Parks and Wildlife Service (2003b) *The native vegetation of the Woronora, O'Hares and Metropolitan Catchments*. Unpublished report to the Sydney Catchment Authority, NSW National Parks and Wildlife Service, Hurstville.

NSW DNT—*see* NSW Department of Natural Resources

NSW NPWS—*see* NSW National Parks and Wildlife Service

Payne, R (1996) Unpublished vegetation plot data from Bouddi Peninsula.

Peacock, R (2004) *Data analysis blueprint*. Internal discussion paper for the Native Vegetation Mapping Program, Department of Natural Resources, March 2004, Sydney.

Peacock, R (in prep) Unpublished data: Yalleroi, Bingara, Inverell, Ashford, Cobbadah, Bundarra, Manilla and Tamworth 1:100 000 map sheets. NSW Department of Environment, Climate Change and Water, Sydney.

Poore, MED (1955) 'The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet system'. *Journal of Ecology*, vol. 42, pp. 216–224.

Portners, MF, Ashby, EM & Benson, JS (1997) 'The natural vegetation of the Pooncarie 1:250 000 map'. *Cunninghamia*, vol. 5, no. 1, pp. 139–232.

Proust Bushland Surveys (2002) 'Unpublished vegetation survey of Barren Grounds Nature Reserve'. NSW National Parks and Wildlife Service, Hurstville.

RBG—*see* Royal Botanic Gardens

Regan, HM, Colyvan, M & Burgman, MA (2002) 'A taxonomy and treatment of uncertainty for ecology and conservation biology'. *Ecological Applications*, vol. 12, no. 2, pp. 618–628.

Reid, RE (1988) 'Soil survey specifications', in RH Gunn, JA Beattie, RE Reid & RHM van de Graaff (eds), *Australian soil and land survey handbook: guidelines for survey*, pp. 60–72. Inkata Press, Melbourne.

Royal Botanic Gardens (1974–1987) Miscellaneous unpublished vegetation survey data Ku-Ring-Gai Chase National Park. Royal Botanic Gardens, Sydney.

Shimwell, DW (1971) *Description and classification of vegetation*. Sidgwick & Jackson biology series, Sidgwick & Jackson, London.

Sivertsen, DP (2001) *Guidelines for mapping native vegetation: part 3 background papers*. Department of Natural Resources, Sydney.

Sivertsen, DP & Metcalfe, LM (1995) 'Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1:250,000 map sheets)'. *Cunninghamia*, vol. 4, no. 1, pp. 103–128.

Sivertsen, DP & Peacock R (2003) *Guidelines for mapping native vegetation: part 2 data storage, analysis, map creation and reporting*. Internal technical report for the Native Vegetation Mapping Program, Department of Natural Resources, Sydney.

Sivertsen, DP & Smith, PL (2006) *Guidelines for mapping native vegetation*. Department of Natural Resources, Sydney.

Skelton, NJ & Adam, P (1994) *Beecroft Peninsula vegetation survey*. Australian Nature Conservation Agency, Canberra.

Smith, PJ & Smith, JE (1996) 'Vegetation survey of the Kedumba Valley'. Unpublished report to Sydney Catchment Authority, Penrith.

Smith, P & Smith, J (2000) *Survey of the Duffys Forest vegetation community*. Report to NSW National Parks and Wildlife Service & Warringah Council, P & J Smith Ecological Consultants, Blaxland.

Specht, RL (1970) ‘Vegetation’, in GW Leeper (ed.), *The Australian environment*. CSIRO and Melbourne University Press, Melbourne.

Steenbeeke, GL (1990) *An investigation into the flora and vegetation of the middle Kowmung River Valley, eastern NSW*. University of Sydney School of Biological Sciences, Camperdown.

Stehman, SV (1997) ‘Selecting and interpreting measures of thematic classification accuracy’. *Remote Sensing of Environment*, vol. 62, pp. 77–80.

Stehman, SV (2005) ‘Comparing estimators of gross change derived from complete coverage mapping versus statistical sampling of remotely sensed data’. *Remote Sensing of Environment*, vol. 96, pp. 466–474.

Stehman, SV & Czaplewski, RL (1998) ‘Design and analysis for thematic map; accuracy assessment: fundamental principles’. *Remote Sensing of Environment*, vol. 64, pp. 331–344.

Story, M & Congalton, RG (1986) ‘Accuracy assessment: a user's perspective’. *Photogrammetric Engineering and Remote Sensing*, vol. 52, no. 3, pp. 397–399.

Sydney Metropolitan Catchment Management Authority (unpublished) *The native vegetation of the Sydney Metropolitan Catchment Management Authority area*. Sydney Metropolitan CMA, Parramatta.

Taws, N (1997) *Vegetation survey and mapping of Jervis Bay Territory*. A report to Environment Australia, Canberra.

Ter Braak, JF & Prentice, IC (1988) ‘A theory of gradient analysis’, in GW Snedecor & WG Cochran (eds), *Statistical methods*, vol. VIII, pp. 272–317. Iowa State University Press, AMES, IOWA.

Thackway, R, Neldner, VJ & Bolton, M (2005) ‘Vegetation’, in NJ McKenzie, MJ Grundy, R Webster & AJ Ringrose-Vogse (eds), *Australian soil and land survey field handbook: guidelines for conducting surveys*. Australian Department of Agriculture, Fisheries and Forests, Canberra.

Thackway, R, Neldner, VJ & Bolton, M (2008) ‘Vegetation’, in NJ McKenzie, MJ Grundy, R Webster & AJ Ringrose-Vogse (eds), *Australian soil and land survey field handbook: guidelines for conducting surveys*, 2nd edition. Australian Department of Agriculture, Fisheries and Forests, Canberra.

Thomas D (2001) Unpublished vegetation survey data, Warragamba Catchment. Collected for the Sydney Catchment Authority, Penrith.

Thomas, D (undated) Unpublished vegetation survey data.

Thomas, V, Gellie, N & Harrison, T (2000) *Forest ecosystem classification and mapping for the Southern CRA Region*. Report for the NSW CRA/RFA Steering Committee, Project No. NS 08EH, NSW National Parks and Wildlife Service, Queanbeyan.

Tindall, D, Pennay, C, Tozer, M, Turner, K & Keith, D (2004) *Araluen, Batemans Bay, Braidwood, Burragorang, Goulburn, Jervis Bay, Katoomba, Kiama, Moss Vale, Penrith, Port Hacking, Sydney, Taralga, Ulladulla and Wollongong 1:100 000 mapsheets*. Native vegetation map report series, no. 4, NSW Department of Environment and Conservation, Hurstville.

Togher, C (1996) *A report on the biodiversity and land management of the Abercrombie River Catchment*. National Parks Association Inc, Sydney.

Tozer, M (2003) ‘The native vegetation of the Cumberland Plain, western Sydney: systematic classification and field identification of communities’. *Cunninghamia*, vol. 8, no. 1, pp. 1–75.

van Deusen, PC (1996) ‘Unbiased estimates of class proportions from thematic maps’. *Photogrammetric Engineering and Remote Sensing*, vol. 62, no. 4, pp. 409–412.

Walker, J & Hopkins, MS (1984) ‘Vegetation’, in RC McDonald, RF Isbell, JR Speight, J Walker & MS Hopkins (eds), *Australian soil and land survey – field handbook*, 1st edition, pp. 58–77. Inkata Press, Melbourne and Sydney.

Walker, J & Hopkins, MS (1990) 'Vegetation', in RC McDonald, RF Isbell, JR Speight, J Walker & MS Hopkins (eds), *Australian soil and land survey – field handbook*, 2nd edition, pp. 58–77. Inkata Press, Melbourne and Sydney.

Wedderburn-Bisshop, GR, Walls, J, Senerath, UG & Stewart, AJ (2002) 'Methodology for mapping change in woody landcover in Queensland from 1999 to 2001 using Landsat ETM+', *Proceedings of the 11th Australasian Remote Sensing and Photogrammetry Conference*, Brisbane.

Woodgate, PW, Peel, WD, Ritman, KT, Coram, JE, Brady, A, Rule, AJ & Banks, JCG (1994) *A study of the old-growth forests of East Gippsland*. Department of Conservation and Natural Resources, Melbourne.

Wilson, BA, Brocklehurst, PS, Clark, MJ & Dickinson, KJM (1990) *Vegetation survey of the Northern Territory, Australia*. Technical report no. 49, Conservation Commission of the Northern Territory, Darwin.

Additional reading consulted in compiling the Standard

Andrews, J & Flemons, P (1997) *Murray Darling Basin Project M305, methodology for mapping structural vegetation.* Occasional paper no. 29, NSW National Parks and Wildlife Service, Sydney.

Australian National Parks and Wildlife Service (1991) *Remnant Vegetation in Australia*. Australian National Parks and Wildlife Service, Canberra.

Armston, JD, Danaher, TJ & Collett, LJ (2004) 'A regression approach for mapping woody Foliage Projective Cover in Queensland with Landsat data', *Proceedings of the 12th Australasian remote sensing and photogrammetry conference*, Fremantle.

Armstrong, P, Park, GN & Molloy, BPJ (1981) 'Towards a national classification of New Zealand vegetation and landforms'. *New Zealand Journal of Ecology*, vol. 4, pp. 129–130.

Austin, MP (2002) 'Spatial prediction of species distribution: an interface between ecological theory and statistical modelling'. *Ecological Modelling*, vol. 157, pp. 101–118.

Austin, MP & Cawsey, EM (1996) *A preliminary forest community classification for south-eastern NSW.* A report for the NSW National Parks and Wildlife Service, CSIRO, Canberra.

Austin, MP, Cunningham, RB & Good, RB (1983) 'Altitudinal distribution of several eucalypt species in relation to other environmental factors in southern New South Wales'. *Australian Journal of Ecology*, vol. 8, pp. 169–180.

Beadle, NCW (1948) *The vegetation and pastures of western New South Wales: with special reference to soil erosion.* NSW Department of Soil Conservation, Sydney.

Bean, AR, Sparshot, KM, McDonald, WKF & Neldner, VJ (1998) *Forest ecosystem mapping and analysis of south-eastern Queensland Biogeographic Region A, vegetation survey and mapping.* Report for the Queensland CRA/RFA Steering Committee, Queensland Herbarium, Queensland Department of Environment and Heritage and Environment Australia, Department of Environment, Sport and Territories, Brisbane.

Beard, JS & Webb, MJ (1974) *Vegetation survey of Western Australia: Great Sandy Desert – Part 1 aims, objectives and methods.* University of Western Australia Press, Nedlands.

Belbin, L (1990) 'The analysis of pattern in bio-survey data', in CR Margules & MP Austin (eds), *Nature conservation: cost effective biological survey and data analysis,* pp. 176–190. CSIRO, Melbourne.

Belbin, L (1995) *Technical reference: PATN pattern analysis package.* CSIRO, Sustainable Ecosystems, Canberra.

Benson, DH & Keith, DA (1990) 'The natural vegetation of the Wallerawang 1:100 000 map'. *Cunninghamia*, vol. 2, no. 2, pp. 305–336.

Berryman, AA (1992) ‘On choosing models for describing and analysing ecological time series’. *Ecology*, vol. 73, no. 2, pp. 694–698.

Chapman, SB, Clarke, RT & Webb, NR (1989) ‘The survey and assessment of heathland in Dorset, England, for conservation’. *Biological Conservation*, vol. 47, pp. 137–152.

Cochran, WG (1977) *Sampling techniques.* John Wiley and Sons, New York.

Cottam, G & Curtis, JT (1956) ‘The use of distance measures in phytosociological sampling’. *Ecology*, vol. 37, pp. 451–460.

Delaney, JL & Skidmore, AK (1998) ‘Discrepancy or error in forest type classification’. *Australian Forestry*, vol. 61, no. 2, pp. 82–88.

de Gruijter, JJ (1977) ‘Choosing a numerical method for soil classification’, in JJ Gruijter (ed.), *Numerical classification of soils and its application in survey*, pp. 25–50. Centre for Agricultural Publishing and Documentation, Wageningen, Netherlands.

Donnelly, P (2006) *Vegetation/habitat mapping: NSR spatial vegetation inventory and monitoring handbook*, 1st edition. US Fish & Wildlife Service; NWR Remote Sensing Laboratory, New Mexico.

Duncan, RP, Norton, DA & Woolmore, CB (1990) ‘The lowland vegetation pattern, south Westland, New Zealand. 2. Ohinemaka Forest’. *NZ Journal of Botany*, vol. 28, pp. 131–140.

Elmore, AJ, Mustard, JF, Manning, SJ & Lobell, DB (2000) ‘Quantifying vegetation change in semiarid environments: precision and accuracy of spectral mixture analysis and the Normalised Difference Vegetation Index’. *Remote Sensing of Environment*, vol. 73, pp. 87–102.

Equihua, M (1990) ‘Fuzzy clustering of ecological data’. *Journal of Ecology*, vol. 78, pp. 519–534.

Faber-Langendoen, D, Aaseng, N, Lew-Smith, M & Drake, J (2007) ‘Vegetation classification, mapping and monitoring at Voyageurs National Park, Minnesota: an application of the U S National Vegetation Classification’. *Applied Vegetation Science*, vol. 10, pp. 361–374.

Faith, DP (1991) ‘Effective pattern analysis methods for nature conservation’, in CR Margules & MP Austin (eds), *Nature conservation: cost effective biological survey and data analysis*, pp. 47–53. CSIRO, Australia.

Goodchild, MF (1994) ‘Integrating GIS and remote sensing for vegetation analysis and modelling: methodological issues’. *Journal of Vegetation Science*, vol. 5, pp. 615–626.

Greenberg, JA, Dobrowski, SZ, Ramirez, CM, Tuil, JL & Ustin, SL (2006) ‘A bottom-up approach to vegetation mapping of the Lake Tahoe Basin using hyper-spatial image analysis’. *Photogrammetric Engineering and Remote Sensing*, vol. 72, no. 5, pp. 581–589.

Hallsworth, EG (1978) *Benefits and costs of land resource survey and evaluation.* Commonwealth and State Government Collaborative Soil Conservation Study 1975–77, Australian Department of Environment, Housing & Community Development, Canberra.

Harris, S & Kitchener, K (2005) *From forest to fjaeldmark: descriptions of Tasmania's vegetation.* Tasmanian Department of Primary Industries, Water and Environment, Hobart.

Hill, MO & Gauch, HGJ (1980) ‘Detrended correspondence analysis: an improved ordination technique’. *Vegetatio*, vol. 42, pp. 47–58.

How, D (1982) ‘The recreational value of forests’. *Australian Parks & Recreation*, February 1982, pp. 53–57.

Jeffers, JNR (1979) *Sampling*. Institute of Terrestrial Ecology, Cambridge.

Jennings, M, Faber-Langendoen, D, Peet, R, Loucks, O, Glen-Lewin, D, Damman, A, Barbour, M, Pfister, R, Grossman, D, Roberts, D, Tart, D, Walker, M, Talbot, S, Walker, J, Hartshorn, G, Waggoner, G, Abrams, M, Hill, A & Rejmanek, M (2004) *Guidelines for describing associations and* *alliances of the US National Vegetation Classification.* The Ecological Society of America Vegetation Classification Panel, Washington DC.

Jennings, M, Loucks, O, Peet, R, Faber-Langendoen, D, Glen-Lewin, D, Grossman, D, Damman, A, Barbour, M, Pfister, R, Walker, M, Talbot, S, Walker, J, Hartshorn, G, Waggoner, G, Abrams, M, Hill, A, Roberts, D, Tart, D & Rejmanek, M (2003) *Guidelines for describing associations and alliances of the US National Vegetation Classification.* The Ecological Society of America Vegetation Classification Panel, Washington DC.

Jensen, ME (1990) 'Interpretation of environmental gradients which influence sagebrush community distribution in north-eastern Nevada'. *Journal of Range Management*, vol. 43, no. 2, pp. 161–167.

Kalkhan, MA, Reich, RM & Stohlgren, TJ (1998) 'Assessing the accuracy of Landsat Thematic Mapper classification using double sampling'. *International Journal of Remote Sensing*, vol. 19, no. 11, pp. 2049–2060.

Keith, DA & Sanders, JM (1990) 'Vegetation of the Eden region, south-eastern Australia: species composition, diversity and structure'. *Journal of Vegetation Science*, vol. 1, pp. 203–232.

Kikkawa, J, Webb, LJ, Dale, MB, Monteith, GB, Tracey, JG & Williams, WT (1981) 'Gradients and boundaries of monsoon forests in Australia'. *Proceeds of the Ecological Society of Australia*, vol. 11, pp. 39–52.

Kinsey, RH (1981) 'Small format aerial photography'. *AQUA*, June 1981, pp. 15–16.

Laut, P, Hyeligers, PC, Keig, G, Loffler, E, Margules, CR & Scott, RM (1977) *Environments of South Australia.* CSIRO Division of Land Use Research, Canberra.

Lord, JM & Norton, DA (1990) 'Scale and the spatial concept of fragmentation'. *Conservation Biology*, vol. 4, no. 2, pp. 197–202.

McLaughlin, SP (1989) 'Natural floristic areas of the western United States'. *Journal of Biogeography*, vol. 16, pp. 239–248.

Metcalfe, LM, Sivertsen, DP, Tindall, D & Ryan, KR (2003) 'Natural vegetation of the New South Wales wheatbelt (Cobar–Nyngan–Gilgandra, Nymagee–Narromine–Dubbo 1:250 000 vegetation sheets)'. *Cunninghamia*, vol. 8, no. 2, pp. 253–284.

Mitchell, PB (2002) *NSW ecosystems study: background and methodology.* A report for the NSW Biodiversity Strategy, NSW National Parks and Wildlife Service, Hurstville.

Murphy, DD (1989) 'Conservation and confusion: wrong species, wrong scale, wrong conclusion'. *Conservation Biology*, vol. 3, no. 1, pp. 82–84.

NSW NPWS (1999) *Forest ecosystem classification and mapping for the upper and lower north east.* Unpublished report prepared by NPWS for the Resource and Conservation Assessment Council, NSW National Parks and Wildlife Service, Sydney.

O'Neill, AL (1989) 'Land system mapping using Landsat multispectral scanner imagery in the Willandra Lakes Region of western New South Wales'. *Australian Geographer*, vol. 20, no. 1, pp. 26–35.

Penridge, LK & Walker, J (1988) 'The crown-gap ratio (C) and crown cover: derivation and simulation study'. *Australian Journal of Ecology*, vol. 13, pp. 109–120.

Queensland Environmental Protection Agency (2002) *Biodiversity assessment and mapping methodology.* Queensland Environmental Protection Agency, Brisbane.

Ruggiero, M, McNiff, M, Olson, A & Wheeler, B (2005) *Strategic plan for the US Geological Survey Biological Informatics Program: 2005–2009.* US Geological Survey; Biological Resources Discipline, Virginia, USA.

Schwind, B, Warbington, R & Brohman, R (2004) 'USDA Forest Service mapping standards for existing vegetation – a test of base level mapping standards', *Proceedings of the Tenth Remote Sensing Applications Conference.* United States Department of Agriculture Forest Service, Washington State, USA.

Seddon, J, Briggs, S & Doyle, S (2002) *Little River Catchment biodiversity assessment.* A report for the TARGET project, NSW National Parks and Wildlife Service, Canberra.

Shepherd, DPBGR & Hopkins, AJM (2002) *Native vegetation in Western Australia: extent, type and status.* Resource Management Technical Report 249, Department of Agriculture, Western Australia, South Perth.

Sivertsen, DP (1983) 'Ecological survey in the Northern Territory', in K Meyers, CR Margules & I Musto (eds), *Survey methods for nature conservation, volume 2.* CSIRO, Canberra.

Sivertsen, DP (1994) *Standard data collection and survey methods – a practical possibility?* NSW National Parks and Wildlife Service, Sydney.

Sivertsen, DP (1995) 'Habitat loss – its nature and effects (including case studies from NSW)', in RA Bradstock, TD Auld, DA Keith, RT Kingsford, D Lunney & DP Sivertsen (eds), *Conserving biodiversity: threats and solutions,* pp. 29–42. Surrey Beatty & Sons, Chipping Norton.

Sivertsen, DP & Smith, PL (2001) *Native vegetation management targets B – setting goals and targets.* Internal report, NSW Department of Land and Water Conservation, Sydney.

Skirvin, SM, Drake, SE, Maingi, JK, Marsh, SE & Kepner, WG (2000) *An accuracy assessment of 1997 Landsat thematic mapper derived land cover for the Upper San Pedro Watershed (USA/Mexico).* US Environmental Protection Agency, Washington DC, USA.

Smith, PL & Sivertsen, DP (2001) *Native vegetation management targets A – landscape composition for the maintenance of biodiversity in production-oriented landscapes.* Internal report, NSW Department of Land and Water Conservation, Sydney.

Soué, ME & Sanjayan, MA (1998) 'Conservation targets: Do they help?' *Science*, vol. 279, pp. 2060–2061.

Specht, RL (1981) 'Conservation of vegetation types', in RH Groves (ed.), *Australian vegetation*. Cambridge University Press, Cambridge, UK.

Specht, RL (1981) 'Major vegetation formations in Australia', in A Keast (ed.), *Biogeography of Australia*. Junk, The Hague, Netherlands.

United States Department of Agriculture (1966) *Aerial-photo interpretation in classifying and mapping soils.* United States Department of Agriculture, Washington DC, USA.

Walker, J, Crapper, PF & Penridge, LK (1988) 'The crown-gap ratio (*C*) and crown cover: the field study'. *Australian Journal of Ecology*, vol. 13, pp. 101–108.

Walker, J, Thompson, CH, Reddell, P & Rapport, DJ (2001) 'The importance of landscape age in influencing landscape health'. *Ecosystem Health*, vol. 7, no. 1, pp. 7–14.

Wison, BA, Neldner, VJ & Accad, A (2002) 'The extent and status of remnant vegetation in Queensland and its implications for state-wide vegetation management and legislation'. *Rangeland Journal*, vol. 24, no. 1, pp. 6–35.