   

THE VEGETATION OF THE KOWEN, MAJURA AND JERRABOMBERRA DISTRICTS OF THE AUSTRALIAN CAPITAL TERRITORY

Prepared for:

Conservation Planning and Research, ACT Government

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The Vegetation of the Kowen, Majura and Jerrabomberra Districts of the Australian Capital Territory

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EXECUTIVE SUMMARY

Over 20,000 hectares of vegetation was mapped in the Kowen, Majura and Jerrabomberra Districts. Remnants down to 0.05 hectares in area were correctly classified at an overall accuracy of 83%. Eleven remnant native vegetation communities were identified in the study area, and vegetation dominated by native species comprised over 58% of the study area.

The project demonstrated the feasibility and cost effectiveness of using aerial photo interpretation (API) in a digital three dimensional environment (3D) environment to map the vegetation communities recently described by NSW Office of Environment and Heritage (Armstrong *et al.* 2013) at a scale that enables management decisions to be made about individual properties or reserves.

The mapping met the requirement of Product Class 5: Fine Classification/High Spatial Resolution/Full Floristic Vegetation Map (DECC 2009). This is the highest resolution vegetation community mapping available for the study area and is suitable for use at scales ranging from broad regional planning to local planning and property planning.

The mapping was based around a multi-attribute spatial database that also provided information about the cover of vegetation and dominant tree species allowing it to be used for purposes other than those displayed in the community mapping.

1. INTRODUCTION

The Kowen, Majura and Jerrabomberra districts of the Australian Capital Territory (ACT) (latitude 35˚ 09’-35˚ 25’S; longitude 149˚ 05’-149˚ 20’E) cover an area of approximately 21,000 hectares north-east of the city of Canberra.

The main landscape features of the study area include the: Kowen escarpment, a steep north-south orientated range of hills formed during the Cullarin Uplift; Molonglo Gorge, a deep valley carved by the Molonglo River through the ordovician metasediments of the Pittman Formation; steep to gently rising rounded hills, flats and depressions on silurian volcanics and sediments of the Canberra Formation (Jenkins 2000 & Finlayson 2008).

Land use in the study area is dominated by plantation forestry along with areas devoted to conservation management, broad-acre agriculture, military training, airport infrastructure and small urban and industrial sites. Numerous roads border or cross the study area including the Federal Highway, Kings Highway and Monaro Highway.

Native vegetation has been fragmented across the study area during various phases of agricultural, forestry and urban development. Even within the areas managed for conservation the majority of the vegetation has undergone some form of disturbance in the form of clearing or ringbarking. Ingwersen *et al*. (1974) observed that changes in vegetation composition in Mt Ainslie and Mt Majura Nature Reserves followed the boundaries of 19th century land tenure maps, indicating that they were an artefact of human disturbance and management. The authors of this report also observed widespread evidence of ringbarking in Kowen Escarpment and Molonglo Gorge Nature Reserves as well as within remnant native vegetation within the Kowen Forest plantation. Partly due to this widespread disturbance and alteration of native vegetation this project aimed to map vegetation as it currently exists in the landscape not as it would have been prior to European settlement.

A number of authors have previously undertaken vegetation classification and mapping in the study area, commencing with Lindsay Pryor (1938) who compiled the first vegetation map of the ACT. Later studies included: Ingwersen *et al*. (1974) who classified and mapped the vegetation on Mt Ainslie and Mt Majura; National Capital Development Commission (1984) who mapped and classified all of the area; National Capital Planning Authority (1991) mapped vegetation structure in the Majura Valley; Thomas *et al*. (2000) modelled the vegetation communities of the area, this information was later updated by Gellie (2005). A number of other studies have been completed for development activities and some unpublished mapping was undertaken by the ACT Government at more local scales.

The existing vegetation mapping was no longer suitable for making planning decisions due to the following reasons; the vegetation cover had changed substantially since some of the previous mapping was completed, a new classification had been produced by Armstrong *et al.* (2013) for the Upper Murrumbidgee region that provided an opportunity for New South Wales and the Australian

Capital Territory to use common terminology, the resolution of some of the previous mapping was not sufficiently detailed (e.g. Thomas *et al*. 2000) or the coverage of the mapping was too limited (e.g. ACT Government unpublished data). Urban and infrastructure planning decisions required new detailed mapping that used the most up to date classification.

1.1 Climate

The climate of the area was described by Jenkins (2000) as moderately dry with warm dry summers and cool winters. Jenkins also notes that a possible rain shadow may exist over Queanbeyan which lies in the lee of the same escarpment that dominates the Kowen district, therefore it is possible that areas immediately west of the Kowen escarpment experience less precipitation. Cold air drainage is a feature of the climate (Jenkins 2000) that has a strong influence on vegetation structure and composition, especially in the lowlands of the Canberra Formation and silurian volcanics where this characteristic has resulted in the formation of grasslands by inhibiting tree growth (ACT Government, 2005).

The Canberra Airport weather station is sited within the study area. The climate data for this site is given in Table 1.

Table 1. Climate data for the study area (BOM 2013). Canberra Airport (elevation 578m ASL)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Temperature															
Mean maximum temperature (°C)	28.0	27.1	24.5	20.0	15.6	12.3	11.4	13.0	16.2	19.4	22.7	26.1	19.7	72	1939 2010
Mean minimum temperature (°C)	13.2	13.1	10.7	6.7	3.2	1.0	-0.1	1.0	3.3	6.1	8.8	11.4	6.5	72	1939 2010
Rainfall															
Mean rainfall (mm)	58.5	56.4	50.7	46.0	44.4	40.4	41.4	46.2	52.0	62.4	64.4	53.8	616.4	72	1939 2010
Decile 5 (median) rainfall (mm)	48.6	55.2	31.6	30.2	38.0	31.4	36.4	45.6	52.3	54.7	60.3	44.0	616.6	72	1939 2010
Mean number of days of rain ≥ 1 mm	5.6	5.1	4.8	4.8	5.1	5.7	5.8	7.0	7.0	7.8	7.5	5.9	72.1	72	1939 2010
Other daily elements															
Mean daily sunshine (hours)	9.5	9.0	8.1	7.3	6.0	5.2	5.8	7.0	7.7	8.6	8.9	9.4	7.7	32	1978 2010
Mean number of clear days	9.3	7.5	8.7	8.4	8.1	7.5	8.5	8.9	9.4	8.3	7.1	8.7	100.4	70	1939 2010
Mean number of cloudy days	9.8	10.0	9.9	9.5	11.7	12.2	11.0	10.0	9.7	10.6	11.0	9.9	125.3	70	1939 2010

1.2 Geology and soil landscapes

The majority of the study area is comprised of ordovician siltstone, sandstone and shale of the Pittman Formation. Volcanic, dacitic ignimbrite of silurian age occurs in bands in the west of the study area along with associated patches of granitic porphyry and rhyodactic lava (Bureau of Mineral Resources 1992).

The Pittman Formation has given rise to a number of soil landscapes. These are: vestigial soil landscapes which are formed in-situ from resistant parent materials; erosional soil landscapes formed by the erosional process of running water; colluvial soil landscapes formed by mass movement and transferral landscapes consisting of deep deposits of eroded parent material (Jenkins 2000). The Pittman Formation is predominantly comprised of vestigial and erosional soil landscapes along with small portions of colluvial and transferral landscapes. The silurian volcanics are dominated by transferral soil landscapes with minor areas of colluvial soil landscapes (Jenkins 2000).

The Cullarin Uplift formed the range of hills and areas of higher elevation of the Kowen escarpment. Volcanism during the silurian gave rise to the ranges of Mt Ainslie and Mt Majura in the west of the study area. The erosion of the Molonglo River and floodplain kept pace with the Cullarin Uplift to form Molonglo Gorge (Finlayson 2008).

2. METHODS

2.1 Vegetation Classification

Armstrong *et al*. (2013) produced the classification: *Plant communities of the upper Murrumbidgee catchment in New South Wales and the Australian Capital Territory.* That classification was used by the current project as the basis for describing and naming remnant native vegetation with a woody cover of greater than 10% (crown cover). Three additional native vegetation communities (AFV, q1, q6) not described by Armstrong *et al.* (2013) were also described and mapped following field reconnaissance and spatial analysis by the authors (unpublished data). The 11 remnant native vegetation communities identified and mapped in this project are shown in Table 2. Additional mapping units were created (see Table 3) for polygons not dominated by remnant woody vegetation or comprising native grasses with less than 10% woody crown cover.

Table 2. Native vegetation communities mapped in the study area. (note AFV, q1 and q6 are additional to Armstrong *et al.* (2013)).

Community name
p14: Red Stringybark - Scribbly Gum – *Rytidosperma pallidum* tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands Bioregion
u178: Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands Bioregion
u19: Blakely's Red Gum - Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands Bioregions
q1: Drooping She-oak low woodland to open forest on shallow infertile hillslopes in the Australian Capital Territory and surrounds
u29: Apple Box - Broad-leaved Peppermint tall shrub-grass open forest primarily on granitoids of the South Eastern Highlands Bioregion
u181: *Callistemon sieberi – Kunzea ericoides* rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes Bioregions
u191: Black Cypress Pine - Brittle Gum tall dry open forest on hills primarily in the Cooma Region
u78: Snow Gum grassy mid-high woodland of the South Eastern Highlands Bioregion
q6: Red Box tall grass-shrub woodlands primarily on hillslopes and footslopes in the Australian Capital Territory
NTG: Natural Temperate Grassland
AFV: Aquatic Fringing Vegetation

Table 3. Mapping units dominated by planted or highly modified native vegetation or exotic vegetation.

Mapping unit label
PLE: Plantation Exotic
NG: Native Grassland
EXG: Exotic Grassland
URB: Urban and Developed Areas
DNS: Derived Native Shrubland
APE: Amenity Planting Exotic
APN: Amenity Planting Native
EXS: Exotic Shrubland
EPN: Environmental Planting Native
Water: Water Surfaces
EXF: Exotic Forests
EXW: Exotic Woodland
DNW: Derived Native Woodland
Rock: Rock Surfaces
ARB: Arboriculture

2.2 Aerial Photo Interpretation

In this project aerial photo interpretation (API) and field reconnaissance were used to classify and map vegetation community boundaries. An experience interpreter can readily recognise some vegetation types, for example pine plantation, while other distinctions such as variations in grassland associations are far more difficult, at times impossible, to confidently identify from photo appearance alone. To improve mapping accuracy in grasslands this project incorporated mapping from previous ecological surveys and assessments (see Figure 2 for locations). This mapping was supported by intensive fieldwork that allowed grassland units to be identified and mapped with greater accuracy than is possible from API alone, the process of integrating pre-existing mapping into the project is discussed in more detail below.

The photo interpreter (MW) also undertook extensive fieldwork to inform the interpretation and attribution process (see Figure 3 for locations). In this project large areas east of Majura Lane and south of Pialligo Avenue were not accessible to the photo interpreter. However some of these areas were able to be included in the accuracy assessment or were covered by the pre-existing mapping.

Areas of public land such as Kowen Forest, Mt Ainslie and Mt Majura Nature Reserves were subject to more intensive field work which involved driving most tracks and undertaking walks. The Military Training Area was available for inspection by both the photo interpreter and the accuracy assessment field workers.

Integration of pre-existing mapping

This mapping project incorporated existing detailed grassland mapping carried out by other authors (Biosis 2010, Biosis 2012, Biosis 2013, Osborne *et al*. 2009, Rowell 2009, SMEC 2008, URS 2010). These pre-existing maps were generated for ecological assessments and generally conformed to the *Survey guidelines for determining lowland vegetation classification and condition in the ACT* (Conservation Research and Planning 2011). These guidelines require the collection of canopy cover estimates well as recording cover/abundance of all plant species present with a 20 by 20 metre quadrat.

Using these guidelines a mapping unit is considered to be native vegetation if;

- 1(a) not less than 10% of the area is covered with vegetation (whether dead or alive); and
- 1(b) more than 50% of the perennial plant understorey is comprised of indigenous species; or
- Trees or shrubs indigenous to the area have a canopy cover of 10% or greater in any stratum.

Mapping units classified as Natural Temperate Grassland (NTG) meet the four key defining characteristics (location, tree cover, native vegetation and diversity) of Natural Temperate Grassland according to the *National Recovery Plan for Natural Temperate Grassland of the Southern Tablelands* (Environment ACT 2005).

Mapping units that meet these criteria are then to be scored, using the quadrat data, according the Method to Assess Grassy ecosystem sites (Rehwinkel 2007).

In the ACT mapping units are generally considered to be NTG under both the EPBC and NC Act if they meet the defining characteristics of the community and have a FVS of 7 or higher. Where multiple quadrats are taken for a mapping unit the range of scores should be reported with the highest FVS being used to determine if a mapping unit meets the definition of NTG.

The spatial data contained in the pre-existing mapping was copied into the final mapping produced in this project. That data included all boundaries and associated attributing. The boundaries of the existing mapping were only altered where they were immediately adjacent to a polygon of the same mapping unit and could be merged with this mapping unit to create a larger polygon.

The all pre-existing mapping had already been attributed to indicate its structure and composition relative to the criteria described above. All site determined by the pre-existing mapping to be Natural Temperate Grassland were attributed as NTG in current project. All grasslands attributed as being dominated by native species in the pre-existing mapping but not meeting the NTG criteria were attributed as NG in the current project. All grasslands attributed as being dominated by exotic species in the pre-existing mapping were attributed as EXG in the current project.

Technology

During fieldwork, routes followed were recorded using the Ozi Explorer application on a Global Positioning System (GPS) enabled Android tablet. Vegetation observations were recorded as waypoints in the same software. The use of Ozi Explorer allowed viewing of partially completed mapping versions in the field and increased field work efficiency. Observations were recorded against GPS waypoint numbers in an android comma-separated text file. These were then imported into ESRI ArcGIS software to aid interpretation.

Office-based mapping was carried out in concert with fieldwork to assist in the interpretation of vegetation communities using Stereo Analyst for ArcGIS (SAfA) by Intergraph. This software facilitates viewing of stereo 3D imagery in a geo-referenced environment. Historically, API was recorded directly onto photo prints (or overlays on prints) which were then sent to specialist photogrammetrists to capture the polygons and codes in a digital Geographic Information System (GIS) format. This led to longer project timeframes and the potential for transcription errors. The availability of 3D GIS workstations represents a significant improvement to the process.

The GIS environment also allowed existing mapped information, such as roads, creeks and drainage lines to be displayed in the 3D space at the same time as the 3D imagery, which assists in interpretation. The software also has the capacity to adjust colour balance and zoom levels which can be used to improve recognition of vegetation communities – a significant advantage over use of photographic prints. Additionally, partially completed maps were exported in formats compatible with Ozi Explorer and used to assist fieldwork.

Photography

The photography used in this study is described below:
Date Captured; September 2008

Sensor;	Leica ADS40
Sensor Type;	Push-Broom airborne
Ground Sample Distance (Pixel Size);	50 cm
Bands;	Red, Green, Blue, Infrared
Supplier;	NSW Land and Property Information

Hardcopy stereo prints were also produced to facilitate viewing stereo 3D images using a stereoscope during fieldwork.

The 2008 photography used in the 3D environment was also supported by more current 2D digital aerial orthophotography of similar or greater resolution (to 10cm pixel size) that covered the entire study area. This 2D imagery was collected in 2009 and 2012 and was used to determine if there had been any significant changes in vegetation structure and distribution since the 3D imagery had been collected.

Field Observation Points

Waypoints from GPS were registered where observations were made in the field, see Figure 3 for locations. Information recorded at observation points included:

- Accurately locating individual tree crowns and noting species
- Recording the vegetation community on the site
- Making notes on vegetation ecotones, and understorey species and structure

2.3 Mapping Processes

The "mapping process" refers to the means by which field-collected information in the form of GPS points, routes and observations were combined with expert interpretation of stereo 3D digital images to create polygons and populate related attribute tables.

All waypoints and routes were converted to 3D shapefiles to allow viewing in the same 3D space as the ADS40 imagery. This imagery was subject to a range of digital colour manipulations (e.g. standard deviation stretch), which improved the recognition of communities. It was advantageous to vary the colour display characteristics depending on which community was being mapped.

Polygons were initially created to define patches of vegetation based on structural characteristics, prior to extensive field work. This gave the interpreter an overview of landforms and vegetation structure throughout the study area and facilitated targeted fieldwork. The minimum polygon size to be delineated was 500 square metres. However polygons used from previous field surveys in grassland included some polygons smaller than 500 sqm. Crown cover percent was the primary factor in deciding where polygons were delineated. The woodland/grassland threshold was nominated as ten percent crown cover. Roads were generally ignored in polygon delineation, except where an area dominated by a road formation met minimum polygon specifications.

Fieldwork was then undertaken following a process of observation, prediction and confirmation. Where predictions were consistently accurate fieldwork intensity was reduced. Where predictions were not attempted due to different landform/photo-appearance or where predictions were inconsistent, fieldwork intensity was increased.

Where delineated patches were large and contained different communities, they were subsequently subdivided. Field observations of vegetation communities were interpolated or extrapolated based on the image appearance and topographic variables. Image appearance included features such as: height; density; three dimensional texture of crowns and canopy; crown size; crown shape, and; colour. Topographic variables used to guide extrapolation/interpolation included: altitude; topographic position; slope and; aspect.

Interpolation involved taking field observations within a delineated area and interpreting the observations to attribute characteristics such as vegetation community classification and dominant species. Extrapolation involved using field observations from other areas to inform the attribution of sites with similar image and topographic appearance where field observations had not been made.

Mapping Attributes

Each mapping polygon had an associated entry in a 'feature attribute table'. The following attributes were assigned to each polygon:

Preferred Vegetation Community Classification
Vegetation Community code from Armstrong *et al.* (2013), e.g. u78 (Snow Gum grassy mid-high woodland of the South Eastern Highlands Bioregion) or map unit code for grassland or non-remnant vegetation (see Table 3).

Alternate Vegetation Community Classification
A second vegetation community code that was used when vegetation within the polygon shared characteristics with two communities. Also used for derived communities as an indication of the likely community prior to major alteration (generally clearing).

Reliability Code
Polygons were assigned a reliability code as an indication of the level of confidence in the interpretation of the preferred vegetation community classification and species dominance. The level of confidence for species dominance was generally lower than for community classification.

> 1 – Very high confidence: e.g. polygon was visited, or easily recognisable such as pine plantation, urban areas, and water surfaces.
>
> 2 – High confidence: e.g. polygon was close to areas visited in the field, and shared characteristics such as 3D image appearance – colour, texture, crown shape, canopy height

and density variation - slope, aspect, altitude, landform.

3 – Moderate confidence: e.g. polygon was some distance from field observations, but shared characteristics such as slope, aspect, 3D image appearance.

4 – Low confidence: extrapolation was based on photo-appearance and topography but the polygon was a long way from field survey areas and was not a readily recognisable community.

Dominant species
Up to three dominant species in the tallest stratum (McDonald *et al.* 1998) (not attributed for grasslands).

Total Cover
Estimated percent vegetation cover of all vegetation in the polygon in the following classes:
z =0, a = <1%, b = 1-5%, c = 5-10%, d = 10-20%, e = 20-50%, f = 50-80%, g = 80%+

Tall Cover
Estimated percentage crown cover (as defined by McDonald *et al*. 1998) of the tallest stratum:
z = 0, a = <1%, b = 1-5%, c = 5-10%, d = 10-20%, e = 20-50%, f = 50-80%, g = 80%+

Regrowth
Regrowth crown cover (as defined by McDonald *et al*. 1998) as a percentage of tall cover:
a = virtually nil (< 1%), b = trace 1 - 10%, c = 10 – 30%, d = 30 – 50%, e = 50 – 80%, f = virtually all regrowth > 80%+

Height
Estimated height class of the canopy species. Height estimates were informed by on-screen measurements in the stereo 3D environment. Height class was classified into 5 metre intervals, where the recorded attribute was the tallest expected height within the polygon. For example 20m represents 15-20 metre maximum canopy height.

Crown Condition
Crown condition, including health:
0 = n/a, 1 = Healthy; dieback <10% of trees, 2 = Moderate; dieback in up to 10-50% of trees (including recently dead trees), 3 = Poor; dieback in over 50% of trees (including recently dead trees)

Previous mapping
Where polygons were derived from existing data this attribute was assigned a value greater than zero.

Comments
Any relevant comments.

Shape Length
Standard ESRI attribute being the length of line that encompasses the polygon.

Shape Area
Standard ESRI attribute being the area of the polygon in square metres.

2.4 Accuracy Assessment Methods

The NSW DECCW *Native Vegetation Interim Type Standard* (Sivertsen 2009) details the processes involved in producing information relating to native vegetation, including mapping. This standard has provided the framework for this study and requires that accuracy of all spatial products is tested and specified and that such analysis and methods are clearly explained. Components of the accuracy assessment must include an unambiguous method, appropriate scale, equal probability sampling design, site specific floristic data, an error matrix and reporting of precision and reliability results.

Consistent with recommendations from both Sivertsen (2009) and Eco Logical Australia (2011), the assessment of the mapping in this study was undertaken "blind", i.e. field assessors had access to the mapping linework but not the attributing. Therefore they were not biased towards or against any pre-existing classification of the mapping unit.

This accuracy assessment involved the following steps:

- Random selection of polygons in prescribed mapping units. The number of polygons in each mapping unit was proportional to their frequency in the total study area.
- Field inspection of the selected polygons was then undertaken with no knowledge of what the mapped attributes were for each polygon.
- Data was collected on the dominant species in each structural layer and the surveyor labelled each polygon with up to three mapping unit labels that could be applied to the polygon (in descending order of correctness).
- Data from the inspected polygons was then compared with the mapped data for that polygon to determine if the mapping unit given in the map corresponded with one of those given in the field.
- An error matrix was constructed to determine overall, user and producer accuracy for the map.

This process was only completed for determining the accuracy of assigning of vegetation types to polygons, not for an estimate of accuracy in attributing dominant species.

Reference polygon allocation

Reference polygons (i.e. ground truthing sites) were allocated proportionally based on the number of polygons of each mapping unit. Both Eco Logical Australia (2011) and Sinclair Knight Merz (2009) used 100 sampling plots in their accuracy assessment of vegetation mapping of 1:100,000 map sheets and Eco Logical Australia (2011) used 50 sampling plots in assessing a 1:50,000 map sheet. It was envisaged that for this study 200 reference polygons would be collected, the high sample rate reflects the fine scale (1:25,000) of the mapping being produced. The identification and classification of pine plantations is relatively simple and because pine plantations cover a large part of the study area it was assumed that this vegetation classification was correct and this unit was not proportionately sampled in this assessment. Pine plantations were therefore allocated a smaller number of reference sites and these sites were among the first to be sampled to determine if this assumption was correct.

The mapping units were analysed in GIS to calculate the total number of polygons in each mapping unit. This total was converted into a percentage of the total number of polygons in the study area. The percentage was multiplied by 200 to determine how many reference polygons were allocated to each community.

A random number table was used to create a subset of 400 numbers with values between 1 and 2000 (the range of the FID values contained in the mapping layer), polygons with corresponding feature identity (FID) numbers were then selected for sampling. The "create centroid" tool within ArcGIS was used to create a centre point within the reference polygon to allow identification of the sample site in the field using a hand held GPS. Each polygon centroid was at least 100 metres from any other polygon centroid. Reference polygons locations were not restricted by tenure, polygons were inspected on ACT Government, Commonwealth and private land.

Field Methods

Reference polygons were assessed by observing the vegetation visible from the polygon centroid. Copies of the mapping linework were used in the field to confine observations within the reference polygon and a GPS was used to locate centroids in the field. The following attributes were collected at each polygon centroid;

1. Plot number
2. Date
3. Observer
4. Coordinates of the observation point in Geographic Datum Australia 94 (AMG Zone 55)
5. The three species with the greatest cover in each stratum
6. Total percent cover of each stratum
7. The vegetation community or mapping unit observed to be present on the reference site
8. Best alternative vegetation community or mapping unit (if appropriate)
9. Second alternative (if appropriate)
10. Landform element
11. A portrait and landscape photo of the vegetation in each reference polygon

Evaluation and labelling protocol for reference polygons

All reference polygons were then evaluated using the field data to determine the appropriate label to be used in the analysis. Evaluation and labelling followed the process shown in Figure 1.

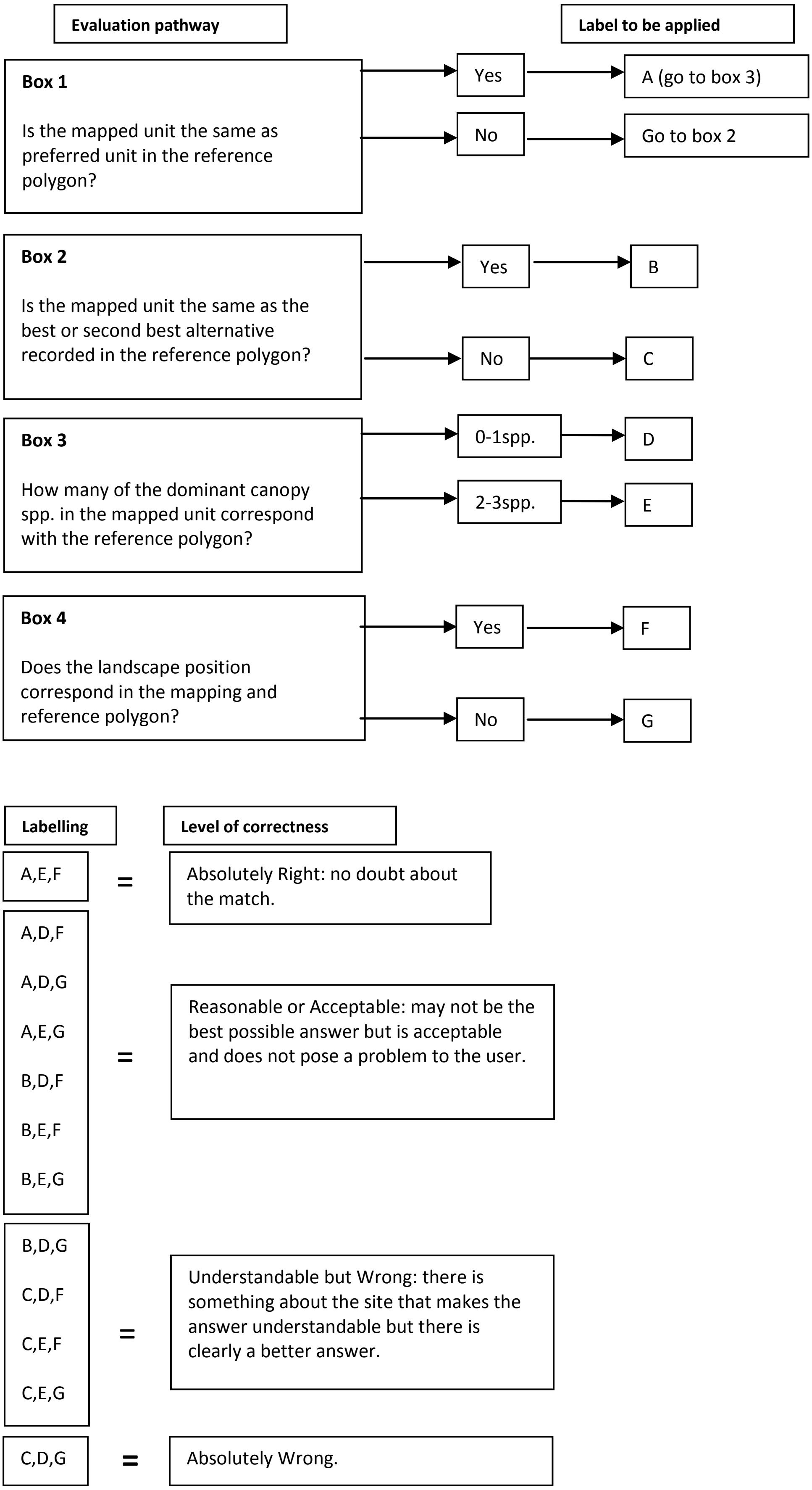

Figure 1. Evaluation and labelling protocol for accuracy assessment.

Analysis

Each reference polygon was given one of the labelling options shown in Figure 1, depending upon its label the mapping unit for each reference polygon was then determined to be correct or incorrect. This classification was made according to the rule shown in Table 4:

Table 4. Correct and incorrect labelling classes

Correct labels	Incorrect labels
• A,E,F	• B,D,G
• A,D,F	• C,D,F
• A,D,G	• C,E,F
• A,E,G	• C,E,G
• B,D,F	• C,D,G
• B,E,F	
• B,E,G	

The level of correlation between the map label and the label given to the mapped unit by the field visit was analysed using an error matrix to calculate overall accuracy, user accuracy, producer accuracy, omission errors and commission errors, as defined in the Appendix 8 of the *Native Vegetation Interim Type Standard* (Sivertsen, 2009).

Rectification of errors

Erroneous polygons identified by the accuracy assessment were rectified in the final map but the statistics contained in this report are those collected during the accuracy assessment prior to any rectification of the final map.

3. RESULTS

3.1 Mapping unit areas

Table 5 shows the total area for each mapping unit, sorted by greatest extent. Table 6 displays how much of the vegetation in the study area is remnant (i.e. the original vegetation community is still identifiable in the polygon), derived native (dominated by native species but displaying major structural or compositional alteration), exotic (introduced species have replaced native species as dominants in the tallest stratum) and not vegetated. This can only be considered indicative because for example the q1 community is called native but some areas may be derived, and much of the woodland communities contain significant exotic ground layer vegetation.

Table 5. Mapping unit areas (total area of each mapping unit)

Mapping unit	Area (hectares)	Percentage of study area
PLE	5548.6	26.6
NG	4906.3	23.5
p14	2784.2	13.3
EXG	1650.6	7.9
u178	1594.3	7.6
URB	1183.5	5.7
u19	1180.3	5.6
q6	516.9	2.5
NTG	423.6	2.0
q1	164.9	0.8
u29	155.3	0.7
APN	152.3	0.7
APE	129.2	0.6
DNS	123.1	0.6
u181	107.7	0.5
EXS	102.7	0.5
ARB	57.4	0.3
DNW	36.7	0.2
AFV	20	0.1
u78	19.9	0.1
EPN	15.5	0.1
u191	8.5	0.04
EXF	5.7	0.03
Water	5.4	0.03
EXW	1.4	0.01
Rock	0.5	0.002
Total	20894.6	100

Table 6. Area of native and exotic vegetation in the study area.

Native/Non-native	Area (hectares)	Percentage of study area
Remnant native	6975.7	33.4
Derived native	5234.0	25.0
Exotic vegetation	7495.5	35.9
Not vegetated	1189.4	5.7
Total	20894.6	100

3.2 Pre-existing data

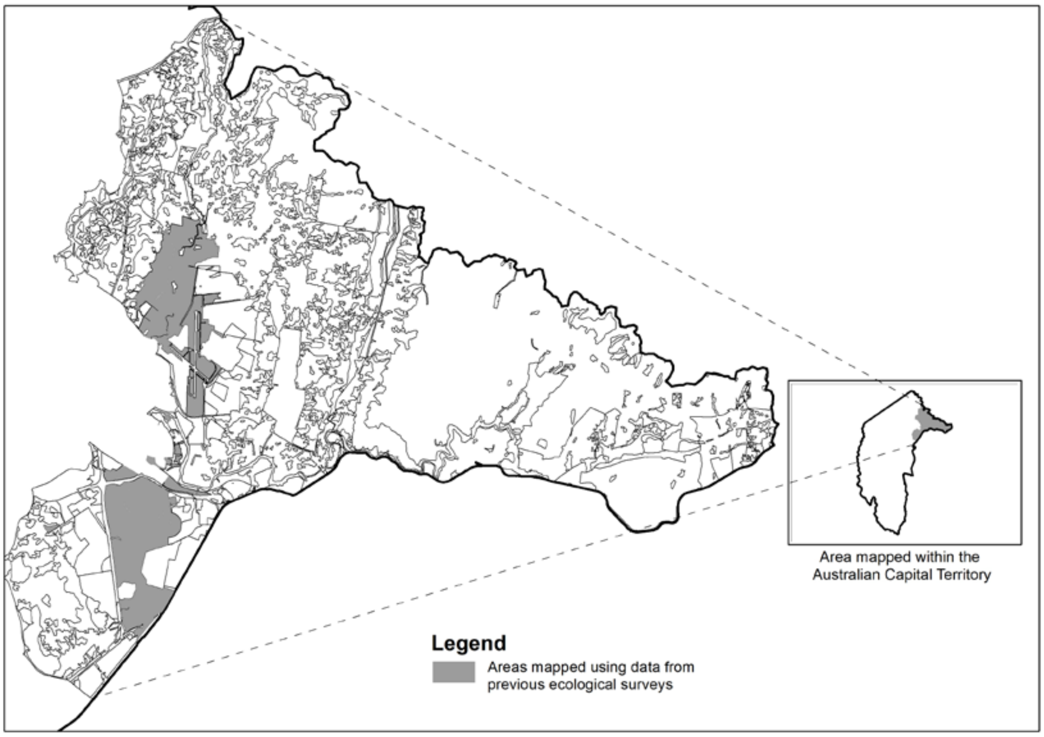

Figure 2. Areas mapped using data from previous ecological surveys.

The pre-existing mapping that was copied into this project and shown in Figure 2 covered an area of 1462 hectares and primarily composed different grassland types which are described below.

3.3 Interpretation fieldwork locations

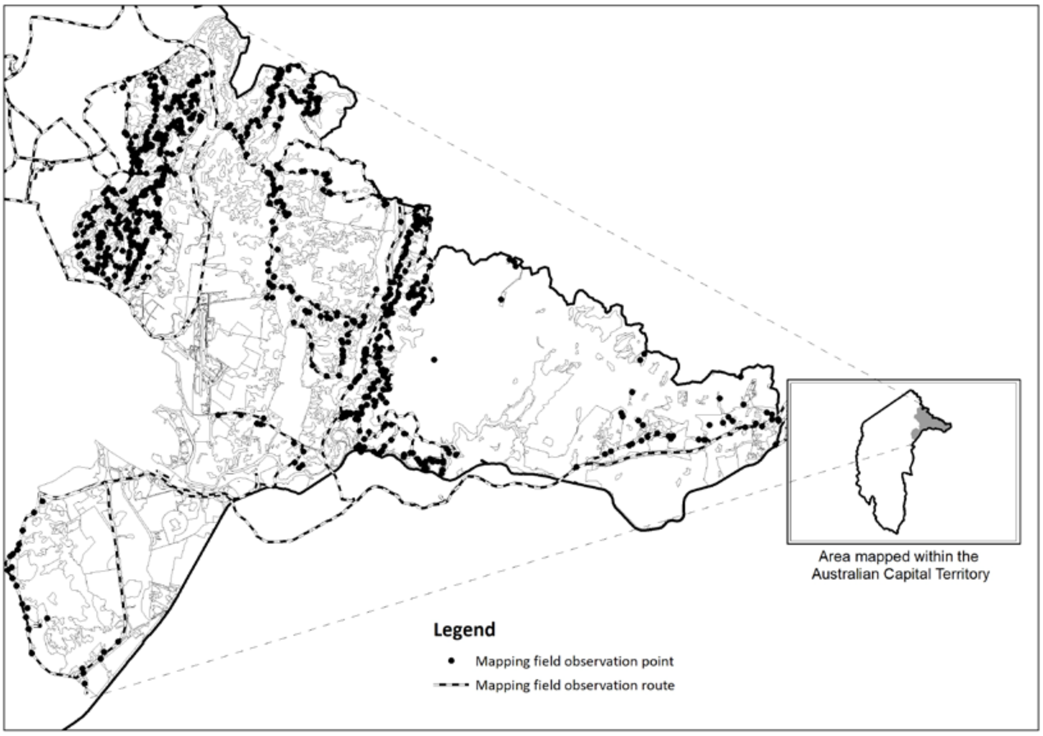

Figure 3. Field observation points and routes used to inform the aerial photo interpretation process.

The fieldwork undertaken to support the aerial photo interpretation process involved the collection of data on 1473 observations points and 1641 kilometres of routes driven or walked as shown in Figure 3.

3.4 Detailed descriptions of mapping units

p14: Red Stringybark - Scribbly Gum –* Rytidosperma pallidum *tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands Bioregion

The most extensive remnant native vegetation community was p14 (Figure 4) which covers approximately 2,784 hectares (Table 5). Within the study area p14 was dominated by a variety of eucalypts such as *Eucalyptus macrorhyncha, Eucalyptus rossii, Eucalyptus polyanthemos* and *Eucalyptus mannifera*. The understorey was quite variable with a range of sclerophyllous shrubs and grasses notably *Rytidosperma pallidum*. Within the study area this community had a preference for hill slopes and ridges and was spread across the north and east of the study area, including the Kowen Escarpment Nature Reserve, Majura Military Training Area, and Mt Ainslie and Mt Majura Nature Reserves.

P14 had a variable overstorey with the dominant species varying from location to location however within the Kowen area, south facing slopes were generally dominated by *Eucalyptus macrorhyncha*, and the small dense crowns of this species were observable using API. *Callitris endlicheri* was occasionally present in this mapping unit, particularly near the Molonglo Gorge.

P14 commonly graded into u178 and u29. A typical pattern had p14 on the ridges and extending down the slopes to where it grades into u29. Where hill slopes level out into undulating topography p14 often had broad ecotones with u178. These ecotones could include a p14 overstorey with a grassy understorey typical of u178, or u178 overstorey with p14 *Rytidosperma pallidum/*sclerophyllous understorey. In these situations polygons were labelled according to the dominant overstorey species.

Figure 4. P14 dry sclerophyll open forest.

u178: Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands Bioregion

U178 (Figure 5) was a grassy woodland community dominated by *Eucalyptus melliodora* and *Eucalptus bridgesiana*, with *Eucalyptus blakelyi* a common associate. Shrubs were uncommon, with grasses such as *Themeda triandra, Austrostipa scabra* and *Poa sieberiana* dominating the ground layer along with a range of forbs. The total area mapped as u178 was 1,594 hectares. This vegetation community was recognised as good grazing country soon after the arrival of Europeans and has been heavily utilised for grazing and/or cropping. Areas which were dominated by a native tree overstorey but had an exotic grass understorey were labelled u178. Areas which were likely to have been u178 and had been cleared of trees to below the threshold 10% crown cover percent, but retained a ground layer dominated by native grasses and herbs were labelled Native Grassland (NG). U178 was ecotonal with u19 and q6. Distinction of these communities rested upon the relative proportion of *Eucalyptus bridgesiana, Eucalyptus polyanthemos* and *Eucalyptus blakelyi*. U178 was dominated by *Eucalyptus melliodora* and/or *Eucalyptus bridgesiana* with *Eucalyptus polyanthemos* and *Eucalyptus blakelyi* being absent or subdominant. U178 appeared to favour more productive sites than q6, and sites with better drainage than those that supported u19.

Figure 5. u178 grassy woodland.

u19: Blakely's Red Gum - Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands Bioregions

U19 (Figure 6) was a grassy woodland community with an overstorey dominated by *Eucalyptus melliodora* and *Eucalyptus blakelyi*. At a regional level *Eucalyptus albens* is also a dominant species in this community but it does not occur in the study area. Shrubs were uncommon or absent. The groundlayer was dominated by grasses and herbs including *Themeda triandra*, *Rytidosperma* spp., *Poa sieberiana* and *Austrostipa scabra*.

The total area mapped to u19 within the study area was 1,180 hectares, 810 hectares (69%) of which were identified as being significantly affected by dieback, a condition almost exclusively effecting *Eucalyptus blakelyi*. Areas dominated by *Eucalyptus blakelyi* with or without *Eucalyptus melliodora*, with *Eucalyptus bridgesiana* being infrequent or absent were mapped as u19. This community often occurs in sites of impeded drainage.

Figure 6. u19 grassy woodland

q1: Drooping She-oak low woodland to open forest on shallow infertile hillslopes in the Australian Capital Territory and surrounds

This community was not described by Armstrong *et al.* (2013) but had been included in earlier classifications that covered the study area (Sharp *et al.* 2007, Ingwersen *et al.* 1974). The authors considered this community required description and mapping due to the strong dominance of *Allocasuarina verticillata*, and its consistent affinity for the Campbell, and to a lesser degree Burra, Soil Landscapes. This community needs to be managed in specific ways to retain its habitat values for certain species listed as threatened in the ACT such as *Arachnorchis actensis* (ACT Spider Orchid) and *Calyptorhynchus lathami* (Glossy Black-Cockatoo).

Within the study area q1 (Figure 7) was mapped exclusively in the Mount Ainslie and Mount Majura Nature Reserves. A total of 165 hectares was mapped as q1, although other polygons in which *Allocasuarina verticillata* was the most common species were mapped as other communities due to the combined crown cover percentage of other species.

The second and third dominant species in this community included a wide range of trees including *Eucalyptus melliodora*, *Eucalyptus blakelyi*, *Eucalyptus mannifera*, *Eucalyptus rossii*, *Brachychiton populneus* and *Acacia parramattensis*. Midlayer and groundlayer diversity was typically lower in this community though it was always dominated by native species.

Figure 7. q1 low woodland.

u29: Apple Box - Broad-leaved Peppermint tall shrub-grass open forest primarily on granitoids of the South Eastern Highlands Bioregion

Community u29 (Figure 8) was a tall eucalypt woodland to open forest characterised by the presence of *Eucalyptus bridgesiana*, *Eucalyptus dives, Eucalyptus nortonii* and/or *Eucalyptus melliodora* on granite hills with a shrubby, grassy or herbaceous understorey. Shrub species include *Cassinia longifolia, Bursaria spinosa* and the tall shrub *Acacia dealbata*. The ground layer was grassy/herbaceous with the main grass species being *Poa sieberiana, Elymus scaber* and *Themeda triandra* along with a range of forbs.

Within the study area u29 was mapped over an area of 155 hectares. It typically occurred in an environmental zone in between u178 grassy woodland and p14 dry open forest on undulating topography. Where drainage lines were broad u178 woodland often extended into the more dissected topography of the Kowen escarpment, at some point up the drainage line a distinct midlayer of shrubs became evident and *Eucalyptus melliodora* became less common. This was where a polygon delineating u178 from u29 was placed. *Eucalyptus dives* was typically only present as an occasional associate in u29 within the study area. At times, apparently due to more favourable soil or moisture conditions, u29 extended up protected slopes and merged into p14 where environmental conditions become drier. At other locations u178 merged directly into p14 without the intermediate u29 community.

Figure 8. u29 tall woodland

u181: **Callistemon sieberi – Kunzea ericoides *rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes Bioregions***

U181 (Figure 9) in the study area often formed a tall dense shrub layer dominated by *Leptospermum obovatum* and *Kunzea ericoides* along with *Callistemon sieberi*, *Acacia rubida* and *Bursaria spinosa*. *Lomadra longifolia* was often a conspicuous component of the sometimes sparse groundlayer. The community was restricted to exposed bedrock and associated gravely sediments within the riparian zone of the Molonglo River through Molonglo Gorge. This community graded into the AFV community and mapped areas of u181 also included patches of AFV, particularly where *Phragmities australis* was dominant.

Figure 9. u181 riparian tall shrubland in the foreground

u191: Black Cypress Pine - Brittle Gum tall dry open forest on hills primarily in the Cooma Region

U191 (Figure 10) was identified over a 8.6 hectares area of north facing slopes that dipped steeply into Molonglo Gorge. The site contained *Callitris endlicheri*, *Eucalyptus polyanthemos* and *Acacia doratoxylon* in the overstorey. This community shared a number of characteristics with u66 but generally had a relatively higher cover of *Callitris enderlicheri*, with a sparser groundlayer and lower overall plant diversity. According to Armstrong *et al.* (2013) u191 was also more strongly associated with earthy sands and lithosols derived from metasediment, a description that fitted the characteristics of the mapped area.

Figure 10. u191 tall dry open forest

u78: Snow Gum grassy mid-high woodland of the South Eastern Highlands Bioregion

Both Mount Majura and Mount Ainslie Nature Reserves had small patches of *Eucalyptus pauciflora* dominated woodland (Figure 11) with a grassy groundlayer that had a combined total of 20 hectares. *Eucalyptus bridgesiana* was a common associate. In the study area u78 occurred, somewhat atypically, on hilltops and ridgelines, where it was restricted to south and south-east facing slopes that probably have lower mean temperatures than other aspects.

Figure 11. u78 mid-high woodland

q6: Red Box tall grass-shrub woodlands primarily on hillslopes and footslopes in the Australian Capital Territory

The q6 mapping unit (Figure 12) was not identified by Armstrong *et al.* (2013), who classified woodlands with a grassy understorey that contained *Eucalyptus polyanthemos* as a dominant species as being part of community u178. Detailed mapping in the ACT using the Armstrong *et al.* (2013) classification revealed that large areas of woodland were dominated by *Eucalyptus polyanthemos* and that these areas could be identified using API. These areas (mapped as q6) occupied areas with a distinct combination of soil landscapes, aspect and topographic position that was both consistent and distinct from that of u178 and u19.

In the ACT, field observations by the authors suggested that soil landscape was the strongest predictor of occurrence. The Queanbeyan, Pialligo (aeolian) and Winnunga Soil Landscapes had much higher probability of containing woodlands dominated by *Eucalyptus polyanthemos* than other soil landscapes. Within these landscapes areas with north to northeasterly aspects were more likely to support the q6 community. Lower and midslope topographic positions were more likely to support this community than flats and crests.

Eucalyptus polyanthemos woodlands could usually be identified from other woodland communities by a fairly rapid change in the dominant tree species that sometimes resulted in monospecific stands of *Eucalyptus polyanthemos* over large areas. At lower positions in the landscape the q6 unit transitioned into u19, u178 and grasslands. Higher in the landscape where the slopes were steeper and soils shallower it transitioned into p14 open forest. Where aspect became distinctly southerly and slope increased, *Eucalyptus polyanthemos* woodlands also transitioned into u29.

As with the other woodland communities most of the original distribution of *Eucalyptus polyanthemos* woodland had been heavily altered by grazing and changed fire regimes. The midlayer and groundlayer composition had been greatly simplified and it was generally impossible to distinguish characteristics of this layer that were distinct from other woodlands. Shrubs may have once been a major component of this woodland judging by some small less disturbed remnants, but it was difficult to determine how widespread a shrubby understorey would have been.

Figure 12. q6 grass-shrub woodland in the Majura Valley

PLE: Plantation Exotic

The PLE (Figure 13) mapping unit was used where plantation forestry was the main land use, as distinct from amenity plantings that may have been planted with the same species but for different purposes. The structure of the vegetation in this mapping unit varied greatly from newly logged areas that may have been devoid of trees at the time of the imagery being flown, to areas with very large pines that had been retained as buffers through multiple logging cycles. *Pinus radiata* was the dominant overstorey species in this unit though other plantation species may have been present in some locations. This mapping unit was the most widespread in the study area covering 5,549 hectares.

Figure 13. PLE plantation forestry

NG: Native Grassland

NG (Figure 14) was the second most common vegetation type, covering 4,906 hectares. NG has been mapped where tree or shrub cover was less than 10%, grasses were the dominant upper stratum (90% or more) and there was no evidence of recent cultivation. API was used to identify if there were land use artefacts, such as plough lines, that may provide information about whether a site was predominantly exotic or native dominated. Manipulating the colour displays in the imagery also aided in determining the relative abundance of native species, for example drainage lines dominated by exotic species appeared bright green when the colour histogram of the imagery was manipulated in the correct manner. API was not however able to determine what particular grass species dominate a site or if there was any diversity of native forbs at a site. As a result this mapping unit did not separate native grasslands into the various Temperate Montane Grasslands classified in Armstrong *et al.* (2013).

API is not the best way for determining if a site is naturally treeless or if the site had been cleared by humans. For this reason the NG mapping unit included a mixture of sites that may have been naturally treeless grasslands, such as those defined as Natural Temperate Grasslands of the Southern Tablelands in the South East Highlands Bioregion (*Environment Protection and Biodiversity Conservation ACT, 1999*), and grasslands that may have been derived from woodlands or forests by land clearing.

Where detailed fieldwork indicated that sites naturally had a tree or shrub cover of less than 10%, and were dominated by native grasses and supported a diversity of forbs; they were mapped as NTG. No sites were mapped as NTG from API alone.

Figure 14. NG in the foreground grading into p14 on the hill on the right.

EXG: Exotic Grassland

These polygons were dominated by exotic grasses such as *Phalaris* spp., *Dactylis glomerata, Vulpia* spp. and *Bromus* spp. (Figure 15). The total area mapped as EXG was 1,651 hectares. This vegetation was derived from the modification of NTG or one of the woodland or forest mapping units. Through various processes the tree and shrub cover had been reduced to less than 10% and the dominant groundcover species were exotic perennial and/or exotic annual grasses. Areas have been mapped as EXG where API identified evidence of cultivation, such as plough lines, or where image manipulation techniques displayed regular patterns such as colour changes characteristic of exotic grasses in drainage lines.

Figure 15. EXG represented by cultivated land

URB: Urban and developed areas

URB (Figure 16) was defined by areas dominated by construction or other development, to the effective exclusion of native vegetation communities. The total area of this mapping unit was 1,184 hectares and included some narrow road verges, small vacant areas between roads and buildings and smaller areas of amenity planting around buildings.

Figure 16. URB characterised by vegetation in an urban setting

NTG: Natural Temperate Grassland

NTG (Figure 17) mapping units were all derived from spatial data generated by previous field surveys. This vegetation type is thought to have been treeless (i.e. <10% tree or shrub cover) grassland at the time of European settlement and being dominated by native grasses and possessing a diversity of native forbs it meets the definition of “Natural Temperate Grasslands of the Southern Tablelands in the South East Highlands Bioregion Endangered Ecological Community” (EPBC 1999). In some cases vegetation mapped as NTG may have been modified through cultivation, grazing or fertilising but the level of modification had not diminished the vegetations condition to a stage where it did not meet the EPBC definition at the time of survey.

Figure 17. NTG in Jerrabomberra West Nature Reserve

DNS: Derived Native Shrubland

DNS (Figure 18) comprised 123 hectares of the study area. DNS generally occured where open forest or woodland had been cleared and then allowed to regenerate to native shrubs with a tree (overstorey) cover of less than 10% and a midstorey cover of greater than 10%. The groundlayer in these areas may be exotic but was more commonly dominated by native grasses and forbs. Dominant shrub species were typically *Acacia parramattensis, Leptospermum* spp.*, Kunzea ericoides, Acacia dealbata* or *Acacia dawsonii. Acacia parramattensis* was variable in appearance on the imagery, apparently due to being in various stages of senescence and hence variable leaf cover. The imagery was four years old at the time of mapping, and field inspection found that many of these areas were completely senescent. In the absence of fire these stands will probably develop into grassland, either derived native or exotic.

Figure 18. NG in the foreground grading into DNS in the midground.

APN: Amenity Planting Native

APN (Figure 19) was mapped where Australian native trees and tall shrubs (not necessarily indigenous to the ACT) had been planted for amenity value and had a cover of greater than 10%. Small or narrow polygons that may fit this definition have also been mapped as URB where they were too small to be indentified separately. This mapping unit was common around houses and other buildings which sometimes may be incorporated within the APN unit.

Figure 19. APN along Canberra Avenue.

APE: Amenity Planting Exotic

APE (Figure 20) was mapped where trees and tall shrubs not native to Australia had been planted for amenity value and had a cover of greater than 10%. Small or narrow polygons that may fit this definition have also been mapped as URB where they were too small to be indentified separately. This mapping unit was common around houses and other buildings which sometimes may be incorporated within the APE unit.

Figure 20. APE of Sequoia species.

EXS: Exotic Shrubland

EXS (Figure 21) covered a total of 103 hectares within the study area. These areas were most often dominated by exotic *Rubus* spp. and were associated with watercourses. A range of native species may also have been present, such as *Leptospermum obovatum* and *Phragmites australis. Salix* spp. were also present but at the time of imagery, most were dying as a result of chemical control. The dominant species and structure of areas mapped as EXS may change quickly over time due to flooding and attempted control of blackberry. Given that the imagery was taken in September 2008, these areas may have expanded or contracted significantly at the time of reporting.

Figure 21. EXS Rubus shrubland beside the Molonglo River.

EPN: Environmental Planting Native

EPN (Figure 22) was comprised of areas with an overstorey cover of greater than 10%, generally of tree species indigenous to ACT and most likely planted for environmental enhancement. Visual clues such as trees planted in lines and even age structures and tree spacing, along with the species composition of the vegetation were used to determine if the vegetation had been planted. This mapping unit typically comprised erosion control plantings and biodiversity enhancement revegetation.

Figure 22. EPN at the intersection of Majura Road and the Federal Highway.

AFV: Aquatic Fringing Vegetation

AFV (Figure 23) was a community identified by ACT Conservation Planning and Research (ACT Government unpublished data 2013) and is additional to the native vegetation communities described in Armstrong *et al.* (2013). Generally AFV occurred in stream or in adjacent overflow channels. This unit was dominated by many different species, many of which are ephemeral depending on stream conditions. In the study this mapping unit was predominantly used for areas dominated by *Phragmites australis* or *Typha* spp. as these species can be identified by API. Sites dominated by *Juncus* spp. and *Carex* spp. have been mapped as NG as they predominantly occur outside of streams.

Figure 23. AFV dominated by *Phragmites australis*

Water: Water Surfaces
These surfaces were covered by water at the time the imagery was collected.

EXF: Exotic Forests
EXF (Figure 24) contained areas dominated by exotic trees with a crown cover estimated to be over 30 percent that were not planted but have self-sown. This mapping unit included Salix spp. along drainage lines, and self-sown *Populus* spp. and *Pinus radiata*.

Figure 24. EXF dominated by *Populus* sp. beside the Monaro Highway

EXW: Exotic Woodland
EXW (Figure 25) was mapped in areas dominated by exotic trees with a crown cover estimated to be between 10 and 30 percent, that were not planted but have self-sown. This mapping unit included *Salix* spp. along drainage lines and self-sown *Pinus radiata*.

Figure 25. EXW dominated by *Salix* sp. adjacent to Majura Road.

DNW: Derived Native Woodland

DNW (Figure 26) was restricted to individual patches in Mount Majura and Mount Ainslie Nature Reserves. The overstorey was dominated by *Brachychiton populneus* with a canopy cover estimated to be 10 – 30 percent and a grassy understorey. *Brachychiton populneus* was thought to be planted on these sites (Coltheart 2011, Ingwersen *et al.* 1974) making this a derived community.

Figure 26. DNW dominated by *Brachychiton popluneus* on Mt Majura

Rock: Rock Surfaces

Rock was mapped as comprising a single polygon on Mount Ainslie where the vegetation cover was less than 10%.

ARB: Arboriculture

ARB (Figure 27) was mapped where species of introduced trees and vines with a cover of 10% or more were grown for food production purposes. This mapping unit included *Vitis vinifera, Olea* sp. and *Corylus* sp. plantations.

Figure 27. ARB dominated by *Olea* sp. beside Hindmarsh Drive.

3.5 Accuracy Assessment

Sampling for the accuracy assessment collected data on 193 reference polygons, with an initial focus on plantation pines to determine if that mapping unit was as easily interpreted as had been assumed. The results of these early surveys supported the assumption that plantation pine did not need to be proportionally surveyed. However the Microsoft Excel files that contained the first 23 reference polygons was subsequently corrupted and was not able to be used in the generation of the error matrix. Table 6 shows the relative area and frequency of each mapping unit in the spatial layer along with how many reference polygons were required for each unit and how many polygons were actually sampled from each unit.

The accuracy assessment did not assess the ARB and q6 mapping units as both of these were identified after the assessment was completed. In the accuracy assessment areas mapped as q6 were treated as part of u178 in line with the classification of Armstrong *et al.* (2013).

Table 7. Comparison of the number of required reference polygons to the number actually surveyed

Mapping unit	Hectares**	Total number of polygons**	% of area	% of polygons	Number of reference polygons required	Number of reference polygons surveyed
PLE	5547.5	18	27	2	3	2
NG	5035.4	281	24	23	47	33
p14	2774.7	163	13	14	27	19
u178	2133.3	253	10	21	42	52
EXG	1580.2	63	8	5	11	2
URB	1262.7	71	6	6	12	9
u19	1106.2	65	5	5	11	11
NTG	472.5	60	2	5	10	0
u29	161.6	38	1	3	6	5
q1	155.8	35	1	3	6	11
DNS	155.5	37	1	3	6	11
APE	126.1	44	1	4	7	5
APN	109.3	28	1	2	5	4
u181	107.7	3	1	0	1	2
EXS	99.9	7	0	1	1	0
u191	23.2	3	0	0	1	0
u78	19.9	5	0	0	1	2
EPN	14.6	3	0	0	1	1
AFV	13.0	8	0	1	1	1
Water	5.4	2	0	0	0	0
EXF	4.8	5	0	0	1	0
EXW	3.8	3	0	0	1	0
DNW	2.1	3	0	0	1	0
Rock	0.5	2	0	0	0	0
Grand Total	20915.6	1200	100	100	200	170*

*Table 7 excludes the 23 polygons for which the data was lost.

**Values in Table 7 are based on the interim map at the time the accuracy assessment was undertaken, Table 5 and Table 6 report the hectares of each mapping unit presented in the completed map.

Following Sivertsen (2009) an error matrix was used to analyse overall accuracy, producer accuracy and user accuracy as well as omission and commission errors. Table 8 shows the error matrix used to generate these parameters. Mapping unit combinations that did not occur in this accuracy assessment are shown as blank cells. The rows represent the mapped or described units and the columns represent the observed, reference or true units (Sivertsen, 2009).

Table 8. Error matrix comparing the classification of polygons from API (mapped polygon units) with the classification of polygons from field referencing (reference polygon units) as part of the accuracy assessment process.

Reference Polygon Units

Mapped polygon units

	AFV	APE	APN	DNG	DNS	EPN	EXG	p14	PLE	q1	u178	u181	u19	U29	u78	URB	Row Total
AFV	1																1
APE		5															5
APN			4														4
DNG				28	1		4										33
DNS					9					2							11
EPN						1											1
EXG							2										2
p14								18			1						19
PLE		1							1								2
q1										11							11
u178						1		3		1	38		9				52
u181												2					2
u19													11				11
U29								2		2				1			5
u78															2		2
URB		1	1													7	9
Column total	1	7	5	28	10	2	6	23	1	16	39	2	20	1	2	7	170

Sivertsen (2009) defines the following values that can be calculated from Table 8;

- Overall accuracy (the overall proportion of area correctly classified), 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 diving by the total effort. The overall accuracy of the map is 141/170 or 83%.
- 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. This is calculated for each map unit by dividing the number correctly classified, by the row sum for that unit, usually expressed as a percentage. Table 9 contains the user's accuracy values for all of the referenced map units.
- 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. This is calculated for each reference unit by dividing the number correctly classified, by the column sum for that unit, usually expressed as a percentage. Table 9 contains the producer's accuracy values for all of the referenced map units.
- Omission errors for any given unit ***w*** is the conditional probability that a randomly selected point classified as unit ***w*** by the reference data is categorised as unit ***k*** by the map. Omission errors are the residual of the user's accuracy. These are provided in Table 9.
- Commission errors for any given class ***z*** is the conditional probability that a randomly selected point classified as unit ***z*** by the map is classified as unit ***k*** by the reference data.

Commission errors are the residual of the producer's accuracy. These are provided in Table 9.

Table 9. Accuracy levels for each mapping unit

Mapping unit	User's accuracy	Omission errors	Producer's accuracy	Commission errors
AFV	100%	0%	100%	0%
APE	100%	0%	71%	29%
APN	100%	0%	80%	20%
NG	85%	15%	100%	0%
DNS	82%	18%	90%	10%
EPN	100%	0%	50%	50%
EXG	100%	0%	66%	34%
p14	95%	5%	78%	22%
PLE	50%	50%	100%	0%
q1	100%	0%	69%	31%
u178	73%	27%	97%	3%
u181	100%	0%	100%	0%
u19	100%	0%	55%	45%
u29	20%	80%	100%	0%
u78	100%	0%	100%	0%
URB	78%	22%	100%	0%
Overall accuracy			83%	

The labelling and evaluation protocols detailed in Figure 1 allowed a finer resolution of analysis to be made of the capacity of the API method to correctly classify each mapping unit. Table 10 displays the detailed level of correctness for each mapping unit included in the accuracy assessment. Note that NG was never considered to be absolutely correct, this is because API could not determine the dominant species in the groundlayer, so following the labelling protocols this mapping unit could never be classed as absolutely correct.

Table 10. The number of each mapped unit that fell into each category of correctness (see Evaluation and Labelling Protocols).

Mapped Unit	Absolutely right	Acceptable	Understandably wrong	Absolutely wrong
AFV	0	1	0	0
APE	3	2	0	0
APN	2	2	0	0
NG	0	28	5	0
DNS	2	7	2	0
EPN	0	1	0	0
EXG	0	2	0	0
p14	9	9	1	0
PLE	0	1	1	0
q1	5	6	0	0
u178	16	22	12	2
u181	0	2	0	0
u19	4	7	0	0
u29	0	1	4	0
u78	2	0	0	0
URB	1	6	1	1
Totals	44	97	26	3

4. DISCUSSION

4.1 Vegetation Classification

Armstrong *et al.* (2013) provided the basis for the classification of remnant native vegetation. This classification was applicable to the majority of native vegetation mapped during this study. However difficulties were encountered in applying the classification in the following situations;

- **Aquatic Fringing Vegetation** – this community was not described by the Armstrong *et al.* (2013) classification. This vegetation community was very difficult to sample and map as the dominant species can change both temporally and spatially in very short periods of time. In addition the community was often restricted to small areas with very specific habitat characteristics, typically these areas are too small to be included in vegetation mapping however the fine resolution of this map did allow the largest areas to be defined. Dominant aquatic species are often not discernible using API, for example it was very difficult to differentiate Schoenoplectus, Bolboschoenus, Typha or Phragmites using API. In the ACT seven associations within this community have been recognised and described from field survey (Johnston and Skinner 2013 – unpublished data). Due to the rapid changes in dominance and composition of this community it is often not useful to map down to the association level as this is likely to change often over the life of a mapped product.

- **Grasslands** – this vegetation formation was the most difficult to map and describe in the study area. This was due to a number of factors such as the limited ability of API to determine between grass species, the effects of human disturbance that have broken the abiotic determinants of species distribution resulting in a landscape that is very difficult to interpret, and the dynamic nature of grasslands where dominance and structure of the grasslands can change rapidly through time. Benson *et al.* (1997) noted in their description of the grasslands of the NSW Riverine Plain, that relative abundance of species and structure of patches could change year to year depending on environmental factors such as rainfall or human factors such as grazing intensity. The same dynamic changes occur in the temperate grasslands of ACT.

  Human disturbance has resulted in grasslands with differing evolutionary origins, often with similar species compositions, existing in different seral stages depending on the type, frequency, duration and intensity of disturbance. Costin (1954) states that terms such as association (which corresponds to the term community used in this report) and alliance were not applicable to grasslands that had been extensively modified (pastures as defined by Costin). Armstrong *et al.* (2013) and ACT Government (2005) reflect the difficulty in dealing with the continuum of states that grasslands now exist in. Armstrong *et al.* (2013) has described 7 "natural" temperate grassland communities. ACT Government (2005) included 5 natural grassland floristic associations and defined other modified grasslands such as "native pasture", "degraded native pasture" and "secondary grasslands". These classifications do not include grasslands dominated by exotic species which themselves may vary from desirable agricultural grasslands dominated by *Phalaris* spp., to weedy perennials such as *Eragrostis curvula* and annual dominated grasslands where grasses like *Vulpia* spp. may dominate for short periods before being replaced by exotic broadleaf species. The fact that few of these variations can be identified by API (as noted by Benson *et al*. 1997) makes creation of a complete vegetation map at the community level very difficult for this formation.

  In this study grasslands were mapped as Native Grasslands (NG) unless there was evidence that an area had been pasture improved or there was field based information about the composition of an area. Native Grasslands included sites that were naturally treeless and those where the tree cover had been cleared to below 10%. It included a variety of condition classes, some sites may have had a diversity of native species that would have allowed them to be classed as part of the Natural Temperate Grassland (NTG) endangered ecological community if field data had been available. Likewise others would have been more accurately described as degraded native pasture (ACT Government 2005). This unit also included sites that at different times would have been better mapped as Exotic Grassland (EXG) but at the time the imagery was flown there was no evidence for this classification. Other authors have dealt with these issues in differing ways, for example

Porteners (1993) used mapping units such as "Open Areas" and "Cleared" to describe disturbed vegetation where the groudlayer composition was variable. Westbrooke and Miller (1995) mapped *Bromus rubens/Hordeum marinum* herbland noting that the dominance varies and may include native forbs.

The decision to make Native Grassland the default unit for grasslands, unless evidence existed indicating that Natural Temperate Grassland or Exotic Grassland should be used, was taken on the basis of field observation that native grasses tended to dominate except in areas of restricted drainage or active cultivation.

- ***Eucalyptus polyanthemos*** woodlands – these woodlands predominantly occurred in the central part of the study area on the Majura Military Training Area as well as on the western edge of the study area in Callum Brae Nature Reserve. In line with Armstrong *et al.* (2013) these woodlands were initially included as part of u178 Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands Bioregion due to the grassy nature of the groundlayer, lack of a midlayer and the co-dominance or sub-dominance of *Eucalyptus melliodora* and *Eucalyptus bridgesiana* (along with occasional *Eucalyptus blakeyli*). This classification was problematic because *Eucalyptus polyanthemos* is not regarded as a characteristic species of Apple Box – Yellow Box woodlands (u178) (Armstrong *et al*. 2013). This species is a co-dominant in two other locally occurring communities, Red Stringybark – Scribbly Gum open forest (p14) and Norton's Box – Red Stringybark open forest (u66). However both these communities had more sparse groundlayers, more developed midlayers and different co-dominant eucalypts than *Eucalyptus polyanthemos* dominated woodlands in the study area.

  Following the initial mapping and accuracy assessment, more analysis was undertaken of the distribution of the *Eucalyptus polyanthemos* dominated areas in comparison to those dominated by *Eucalyptus melliodora*, *Eucalyptus blakelyi* and *Eucalytpus bridgesiana*. Cluster analysis of woodland data restricted to ACT sites and supplemented with new sites, displayed that grassy woodlands, where *Eucalyptus polyanthemos* was the only canopy species, clustered separately from other vegetation communities. Principal component analysis of these results displayed that this cluster was more strongly influenced by aspect and topographic position than other woodland clusters. The distribution of *Eucalyptus polyanthemos* dominance was most strongly influenced by soil landscape, aspect and landscape position. Field observations confirmed that changes in these environmental gradients led to abrupt changes in canopy dominance. As a result the authors determined to create an additional community: q6 Red Box tall grass-shrub woodlands primarily on hillslopes and footslopes in the Australian Capital Territory.

  Woodlands mapped as Red Box woodlands (q6) typically occurred on slopes below Red Stringybark – Scribbly Gum open forest (p14) and Apple Box – Broad-leaved Peppermint open forest (u29). They then transitioned into Apple Box – Yellow Box woodlands (u178) or Blakely's Red Gum – Yellow Box woodland (u19) on the lowest footslopes and flats. In many areas where clearing had occurred Red Box woodlands (q6) now transitioned into Native Grassland and Exotic Grassland. Figure 12 shows a typical remnant of q6, large trees with a canopy typical of a woodland species, strongly dominated by *Eucalyptus polyanthemos* with a grassy ground cover on relatively gentle slopes.

It is possible that this community had a distinct shrublayer in its original state. A remnant stand in the Bullen Range Nature Reserve that occupied a footslope topographic position, was almost completely dominated by *Eucalyptus polyanthemos* but had a sparse to mid-dense shrub layer. The absence of stumps or coppice regrowth trees and the presence of some rare shrub species indicated that this remnant was relatively undisturbed and potentially representative of the original community, at least in this location. How widespread this shrubby form of the community may have been is now difficult to determine.

The accuracy assessment did not include Red Box woodlands (q6) because the presence of this community had been overlooked at this point in the study. The later identification of the q6 community displayed the value of mapping and accuracy assessment projects that lead us to question existing classifications and acknowledge aspects of the biodiversity that have previously gone undocumented.

- *Callitris endlicheri* – this species was a component of two vegetation communities that occur in the local area; Black Cypress Pine – Brittle Gum open forest (u191) and Norton's Box – Red Stringybark open forest (u66). Armstrong *et al.* (2013) stated that Black Cypress Pine – Brittle Gum open forest (u191) commonly occurred on earthy sands derived from metasediments, a characteristic that reflects the conditions where the community was mapped in Molonglo Gorge. Norton's Box – Red Stringybark open forest (u66) occurs on acid volcanics and is usually dominated by *Eucalyptus nortonii*, neither characteristic applies in the gorge. Therefore the geology and composition of the *Callitris endlicheri* woodlands support them being mapped as Black Cypress Pine – Brittle Gum open forest (u191).

4.2 Technical Constraints

During the course of the project numerous difficulties were encountered in the interface between ArcGIS Desktop 10 (Service Pack 2) and Stereo Analyst. These difficulties were all resolved but did extend the time required to generate and attribute the mapping

The imagery used was collected in 2008. This effectively made the map four years old at the time of production. Whilst the 2008 image was still representative of the vegetation over the vast majority of the study area in 2012, there were sites where vegetation cover had changed significantly since the imagery was flown. For example a vineyard and a truffle farm had been established in the north east of the study area and some forestry coupes had been logged. The latter example does not change the mapping unit classification but it does change the structural attributes that were also collected in the mapping process. More recent tiled imagery was not available for this project area. To improve the currency of the mapping 2012 2D imagery was used to check for obvious changes in the vegetation structure that had occurred since the 3d imagery was collected. This project found that when imagery reaches about five years old (or if major changes to vegetation are known to have occurred) consideration should be given to acquiring new photography or other remote sensing data.

API was used to estimate certain structural attributes such as percentage of tallest cover, percentage of total cover and height of tallest stratum. The interpreter developed protocols for estimating percentage cover and 3D imagery was used to estimate height. However this method is not the best means of determining structural attributes. Lidar (Light image detection and ranging) is an alternative method likely to produce improvements in efficiency and accuracy in the collection of structural attributes. Lidar-derived canopy height models (in the form of grids or rasters) provide estimates of canopy height that are routinely better than one or two metres in accuracy (Webster 2013) and can also be used to generate crown cover percentage and stratify crown cover percent by height. Understorey information can also be generated, though the accuracy of this data is in part determined by canopy cover and the number of pulses emitted by the Lidar. Lidar point clouds can now be viewed in 3D stereo simultaneously alongside geospatially linked 3D stereo imagery, giving the ability to measure 3D structure of vegetation rather than estimate these attributes using API.

4.3 Map Product Class

The vegetation classification used in this study described the plant communities to Level D (Armstrong *et al.* 2013) in the hierarchy described in Sivertsen (2009). The minimum polygon size to be displayed on this map is 0.25 hectares, at a scale of 1:25,000 this represents an area 2 mm by 2 mm square. This scale is generally suitable for uses such as Biobanking, property scale planning and local government planning (Sivertsen 2009). The scale of the mapping combined with the level of the classification means that the mapping met the requirement of Product Class 5: Fine Classification/High Spatial Resolution/Full Floristic Vegetation Map (DECC 2009).

4.4 Mapping Accuracy

Overall accuracy

The overall mapping accuracy of 83% achieved the main objective of the project: being an accuracy of 80% or greater. This level of overall accuracy is comparable to other mapping performed in parts of NSW such as Narrandera 82%, Lockhart/Urana 85%, Cootamundra/Junee 91% and Yanco/Yoogali 93% (Eco Logical Australia, 2011).

In contrast to the mapping described by Ecological Australia (2011) the ACT mapping had a finer spatial and classification resolution, characteristics that may result in a higher level of mapping error. In addition the ACT mapping was subject to a relatively intense accuracy assessment that may have been more likely to identify mapping errors. In light of these influences the 83% accuracy level is a strong confirmation of the methods used in this study.

User accuracy

User accuracy was generally above 70% for the assessed mapping units. The two exceptions were Plantation Exotic and Apple Box – Broad-leaved Peppermint open forest (u29). The Plantation Exotic error was a result of small sample size due to the loss of data collected on this unit earlier in the project. The results from the lost data could not be incorporated into this report but it did indicate that Plantation Exotic was generally accurately attributed, had this data been available the user accuracy for this unit would have been much higher.

User accuracy in Apple Box – Broad-leaved Peppermint open forest (u29) was more problematic. In the Kowen district this community was restricted to the lower slopes of very narrow scarp streams on the Kowen escarpment. Many of these areas were ecotones with floristic elements of Apple Box – Broad-leaved Peppermint open forest (u29), Yellow Box – Apple Box woodland (u178), Red Stringybark – Scribbly Gum open forest (p14) and Drooping She-oak woodland (q1). *Eucalyptus bridgesiana* which is one of the definitive species of Apple Box – Broad-leaved Peppermint open forest (u29) was the dominant upper canopy species at all of the reference polygons incorrectly allocated to map unit Apple Box – Broad-leaved Peppermint open forest (u29). The reference plots were classified as being incorrectly labelled because the associated dominant species were not characteristic of Apple Box – Broad-leaved Peppermint open forest (u29). The low level of user accuracy was understandable given the small, narrow areas occupied by this community and the fact it shared a dominant upper canopy species with other mapping units.

Producer accuracy

Producer accuracy was generally above 70%, with a 100% producer accuracy achieved for 7 of the 16 mapping units in the accuracy assessment. The lowest accuracy levels were achieved in the Environmental Planting Native (EPN) (50%) and Blakely's Red Gum – Yellow Box tall grassy woodland (u19) (55%). Only two reference polygons were classified as Environmental Planting Native in the reference data and it is likely that this low sample size contributed to the low accuracy rate for this mapping unit. One polygon predicted to be Yellow Box – Apple Box tall grassy woodland (u178) by the mapping was classified as Environmental Planting Native (EPN) by the reference data so it is possible that the mapping slightly underestimates the distribution of Environmental Planting Native in the study area.

Blakely's Red Gum – Yellow Box tall grassy woodland (u19) had low producer accuracy but high user accuracy. All of the polygons predicted by the mapping to be Blakely's Red Gum – Yellow Box tall grassy woodland (u19) were confirmed as correct by the reference data (thus the 100% correct user accuracy) but 9 additional polygons, all predicted by the mapping to be Yellow Box – Apple Box tall grassy woodland (u178), were classified as Blakely's Red Gum – Yellow Box tall grassy woodland (u19) by the reference data (thus the 55% producer accuracy). This indicates that the mapping underestimates the distribution of Blakely's Red Gum – Yellow Box tall grassy woodland (u19) by misclassifying it as Yellow Box – Apple Box tall grassy woodland (u178). Much of the error in these parameters can be attributed to the difficulty in separating these very similar mapping units both in the field and using API. These mapping units had formerly been classified as one community (Yellow Box – Blakely's Red Gum Grassy Woodland) by Sharp *et al*. (2007). Both Yellow Box – Apple Box woodland (u178) and Blakely's Red Gum – Yellow Box woodland (u19) have Yellow Box (*Eucalyptus melliodora*) as a dominant species in the upper stratum, share a similar structure and species composition and are in similar landscape positions. For the purpose of classifying reference and mapping polygons this project used the relative proportion of *Eucalyptus blakelyi* and *Eucalyptus bridgesiana* to determine which mapping unit the polygons should be classified as. Based on the error matrix in Table 8 it is possible that up to 17% of the polygons mapped as Yellow Box – Apple Box woodland (u178) could be Blakely's Red Gum – Yellow Box woodland (u19). It is not possible to estimate how many hectares this represents and the later addition of Red Box tall grass-shrub woodlands to the classification may further effect the producer and user accuracy of these woodlands.

Producer accuracy for Drooping She-oak woodland (q1) was 69%, the mapping appeared to underestimate the distribution of this mapping unit. Drooping She-oak woodland (q1) is confined to the ACT and may be a seral community resulting from the disturbance of other communities (Ingwersen *et al*. 1974). For the purpose of classifying reference and mapping polygons this project used the dominance of *Allocasuarina verticillata* to determine how polygons should be classified. *Allocasuarina verticillata* can be a component of many vegetation types including, Red Stringybark – Scribbly Gum open forest (p14), Yellow Box – Apple Box woodland (u178), Apple Box – Broad-leaved Peppermint open forest (u29), Norton's Box – Red Stringybark open forest (u66), Black Cypress Pine – Brittle Gum open forest (u191) and Derived Native Shrubland. Disturbed patches within any of these communities could be classified as Drooping She-oak woodland (q1). It was probable that some of the producer error resulted from disagreement between the mapping and reference data regarding dominance of *Allocasuarina verticillata*, as this species was identified in the dominance attribute field of nearly all the polygons classed as q1 by the reference polygons but incorrectly classified as other units by the mapping.

Other mapping units

Not all mapping units were included in the accuracy assessment, Table 11 lists these units.

Table 11. Mapping units for which no reference data was collected

NTG	Natural Temperate Grassland
ARB	Arboriculture
EXS	Exotic Shrubland
q6	Red Box grass-shrub woodland
u191	see Armstrong et. al.(2013) community
Water	Water surfaces
EXF	Exotic Forest
EXW	Exotic Woodland
DNW	Derived Native Woodland
Rock	rock surfaces

As discussed earlier, mapped Natural Temperate Grassland polygons had been imported from other fully groundtruthed mapping data. As these polygons had not been interpreted from the aerial photography and were already supported by field data they were excluded from the accuracy assessment. It was assumed that the original surveys that mapped this vegetation community were correct because they were based on field visits.

Table 7 shows Exotic Shrubland required one reference polygon however the polygon that was randomly selected was not accessible. This mapping unit could be groundtruthed in the future but this is not considered a high priority.

Black Cypress Pine – Brittle Gum open forest (u191) was predicted by the mapping to occur in three locations and required one reference polygon. Whilst this reference polygon was not collected during the accuracy assessment, earlier fieldwork associated with the interpretation did include a site supporting this vegetation community so its existence in the study was confirmed. This mapping unit could be groundtruthed in the future but this is not considered a high priority.

Only two locations were mapped as water and no reference polygon was required to sample this unit. Water is relatively easy to interpret from API and it is expected this unit will be mapped to at least the overall level of accuracy achieved in the study area.

Exotic Forest and Exotic Woodland are structurally different versions of units dominated by self seeded exotic trees, usually *Populus* spp., *Pinus radiata* and *Salix* spp. A reference polygon was required for each unit. The data for both of these reference polygons was corrupted. Given the small number of polygons and areas of each unit, collecting more field data is not considered a priority and would not significantly affect overall accuracy.

The Derived Native Woodland mapping unit relates to portions of Mt Majura and Mt Ainslie Nature Reserves where *Brachychiton populneus* was the dominant canopy species. It is understood that these trees were planted early in the 20th century as part of a revegetation program (Ingwersen *et. al*. 1974). Only one reference polygon was required. The canopy of these trees is quite distinctive so the mapping of this unit was likely to be at least as good as the overall accuracy for the map. Given the small number of polygons and areas of this mapping unit, collecting more field data is not considered a priority and would not significantly affect overall accuracy.

The Rock mapping unit was recorded only on Mt Ainslie. No reference polygons were required, the unit is easily identified by API and given the small number of polygons and areas of this mapping unit, collecting more field data is not considered a priority and would not significantly affect overall accuracy.

Adequacy of the 3-D API method

The 3-D API method was applied to the study area as a trial to determine if its application was feasible, cost effective, and acceptably accurate to apply to the remainder of the ACT for the production of 1:25,000 scale vegetation maps.

The method proved relatively easy to apply, partly due to the ease of accessing the study area for field interpretation. More effort was required in the fragmented agricultural areas where the natural drivers of vegetation distribution had been disrupted making the landscape harder to interpret. Such an issue is also likely to provide difficulties to alternative methods such as automated segmentation and attributing.

Cost effectiveness has not been measured relative to other mapping projects, partly because the scale of use of this product (1:25,000) is not comparable with mapping done in similar vegetation in NSW.

Accuracy was comparable with other mapping undertaken on the NSW South-west Slopes and was greater than the 80% overall accuracy target set for the project. At a map unit scale only Environmental Planting Native (EPN) and Yellow Box - Blakely's Red Gum Woodland (u19) were significantly difficult to interpret and it appeared that the method was suitable for the range vegetation types encountered in the study area.

In summary the method achieved the aims of the project and is suitable for application in the remainder of the ACT.

Conservation Status

The Yellow Box – Apple Box woodland (u178) and Blakely's Red Gum – Yellow Box woodland (u19) communities are both components of the White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and derived Grasslands listed under the EPBC Act and Yellow Box-Red Gum Grassy Woodland listed under the ACT *Nature Conservation Act (1980)*. At the time of writing 8,151 hectares of vegetation in the ACT was regarded as meeting the *Environment Protection and Biodiversity Conservation Act (1999)* criteria and 13,765 hectares met the *Nature Conservation Act*

(1980) criteria (Maguire & Mulvaney 2011). Conservation reserves within the ACT contained 3,364 hectares of the EPBC Act listed community and 5,699 hectares of the NC Act listed community (Maguire & Mulvaney 2011).

In the study area 2,778 hectares were mapped as Yellow Box – Apple Box woodland (u178) or Blakely's Red Gum – Yellow Box woodland (u19), this figure excluded areas of Native Grassland which may be classified as part of the endangered community under certain conditions. Not all of the area mapped as Yellow Box – Apple Box woodland (u178) or Blakely's Red Gum – Yellow Box woodland (u19) would meet the requirements for classification as an endangered ecological community under either piece of legislation and it is not possible to determine this classification from API. Despite this, it is clear that the study area is important for the conservation of Yellow Box – Apple Box woodland (u178) and Blakely's Red Gum – Yellow Box woodland (u19) due to their extent in the study area. Within the study area these woodlands were found in Mt Ainslie, Mt Majura, Kowen Escarpment, Callum Brae and West Jerrabomberra Nature Reserves. They were also found on other land managed by the ACT Government such as Kowen Forest.

Natural Temperate Grasslands of the Southern Tablelands are listed as endangered under the EPBC Act and Lowland Native Grassland is listed as endangered under the NC Act. The NC Act listing only applies to grasslands below 625m ASL and had been estimated to cover 991 hectares (ACT Government 2005). The area of Natural Temperate Grassland that meets the EPBC Act criteria in the ACT has not been determined. It is possible that portions of the Native Grassland mapping unit identified in this study may have qualified as Natural Temperate Grassland though any such areas were likely to be small as Natural Temperate Grassland has been the focus of extensive survey work in the ACT over the past 15 years.

Within the study area 424 hectares of Natural Temperate Grassland that did meet the NC Act criteria had been mapped using pre-existing field data. This mapping unit occurred in West Jerrabomberra Nature Reserve and other ACT Government land such at East Jerrabomberra and west of Majura Road.

Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions is listed as an endangered ecological community under the NSW *Threatened Species Conservation Act (1995)*. Within the study area 20 hectares were mapped as Snow Gum woodland (u78), a woodland community that is contained within the NSW TSC Act definition. All Snow Gum woodland (u78) mapping units were within the Mt Ainslie and Mt Majura Nature Reserves.

River Bottlebrush – Burgan riparian shrubland (u181) and Aquatic Fringing Vegetation mapping units occurred within the riparian zone and is subject to Action Plan no. 29 – ACT Aquatic Species and Riparian Zone Conservation Strategy gazetted under the NC Act (ACT Government 2007).

This is the first phase of vegetation mapping in the ACT, funding has been secured to map a further 135,000 hectares of vegetation using this method.

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Appendix 1. Map of the vegetation of the Kowen, Majura and Jerrabomberra districts of the Australian Capital Territory.