Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps

Gretchen Brownstein[1], Caitlin Johns[2], Ray Blick[3], Andrew Fletcher[4], Peter Erskine[5]
Centre for Mined Land Rehabilitation,
Sustainable Minerals Institute,
University of Queensland

April 7, 2014

[1]Ecologist: g.brownstein@uq.edu.au
[2]Ecologist: caitlin.johns@uq.edu.au
[3]Ecologist: r.blick@uq.edu.au
[4]Corresponding Author: andrew.fletcher@uq.edu.au
[5]Program Leader: p.erskine@uq.edu.au

This handbook outlines the datasets, analyses and reporting required to conduct a statistically rigorous and sensitive flora monitoring program to detect change in Newnes Plateau Shrub Swamps and Hanging Swamps (hereafter refered to collectively as swamps), at an individual swamp community scale, due to underground mining. It is proposed as a replacement for the current Centennial Coal Newnes Plateau Temperate Highland Peat Swamps on Sandstone (THPSS) vegetation monitoring program as it contains the following improvements: 1) sufficient replication at the swamp scale such that analysis of key indicators of community composition and health can be assessed in a statistically rigorous manner, 2) clearly defined and ecologically meaningful trigger values and 3) a clear framework outlining required management actions.

Contents

List of Figures

List of Tables

List of Appendices

1. Monitoring handbook outline

1.1 Overview of the handbook

This document outlines a statistically rigorous and ecologically meaningful method for flora monitoring of Newnes Plateau Shrub and Hanging Swamps that is suitable for use across Centennial Coal's Angus Place, Springvale and Clarence collieries. The proposed monitoring program would replace the existing flora monitoring outlined (and currently applied across the three collieries) in the Angus Place Colliery Subsidence Management Plan and Environmental Monitoring Program (specifically Section 7.3, see Appendix C) that in its current form is unable to determine if vegetation in a Newnes Plateau swamp has been impacted (or not) by mining. In addition the flora monitoring methodology outlined in this document addresses the requirements of the Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC) condition 7 of approval 2011/5949 (Appendix B). As a result this program may be applied to meet the monitoring requirements of both state and federal governments for evaluating potential mining related impacts to Newnes Plateau swamps that fit the definition of Temperate Highland Peat Swamps on Sandstone (THPSS).

Sections 2 and 3 of this document provide a brief background and context of historic flora monitoring on the Newnes Plateau. Section 4 gives an overview of the objectives and trigger values of the recommended flora monitoring. Sections 5 and 6 detail the sampling design and protocols required for data collection and analysis. Reporting and data management procedures are outlined in Sections 5.4 and 6.4. The appendices contain supporting information including background on why the existing monitoring program requires adjustment, justification for the revised sampling design and trigger values, and example data sheets.

The flora monitoring program recommended here relies on data from the subsidence and groundwater/surface water monitoring to inform areas that require monitoring and to produce a complete assessment of impacts of mining activity by Centennial Coal on the Temperate Highland Peat Swamps on Sandstone (THPSS). The subsidence and groundwater/surface water monitoring are detailed in the "Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan for LWs 415 - 417" and the above mentioned Angus Place Colliery management plans, hence are not discussed further in this document.

This flora monitoring program follows an adaptive approach with data collection informing revisions to ensure scientific rigor and to meet future site management requirements. Procedures for flora monitoring program revisions are detailed in Section 4.

1.2 Monitoring objectives

The Newnes Plateau Flora monitoring program aims to detect negative impacts on the vegetation structure and condition of TPHSS as a result of subsidence and/or changes to ground and surface water flows associated with mining activity by Centennial Coal. A negative impact is defined as a value(s) exceeding the trigger(s) outlined in Section 4. The measures of vegetation structure and condition are summarised in Section 4, these measures develop a multivariate approach to assessing swamp health. Based on the DSEWPAC condition 7 (Appendix B), the Newnes Plateau Flora monitoring program includes the following:

- A focus on vegetation community structure and diversity, including biological indicator species
- Trigger values focused on detecting impacts of subsidence or/and changes in groundwater and surface water flows associated with ongoing mining activity
- Information about how the trigger values were derived
- Reference sites in THPSS that will never be impacted by subsidence
- A method for defining and describing baseline conditions of individual THPSS for both impacted and reference sites
- Details of the parameters monitored along with the methods, timing, frequency and locations of both baseline and ongoing monitoring of reference and impacted sites
- A sampling design which is statistically capable of detecting changes in the defined indicator variables
- A description of how potential impacts arising from the monitoring and mitigation measures themselves will be minimised or avoided
- An outline of the data management and analysis procedures required to maintain and report verifiable data and results
- An adaptive management mechanism for refining trigger values and determining the length of time a THPSS site is monitored.

2. Newnes Plateau THPSS overview

The Newnes State Forest (encompassing the Newnes Plateau) is an economically, environmentally and socially significant area. Managed by the Forestry Corporation of NSW for harvesting of native and introduced timbers, this area is ecologically significant due to the presence of the Newnes Plateau Shrub Swamps (NPSS), an Endangered Ecological Community (EEC) listed under the Threatened Species Conservation Act 1995. Also present are Newnes Plateau Hanging Swamps (NPHS), which together with NPSS form part of the threatened ecological community 'Temperate highland peat swamps on sandstone' (THPSS), protected under the Environmental Protection and Biodiversity Conservation Act 1999.

DEC (2006) list the key features of the NPSS vegetation type as: a moderately dense to open shrub layer with very dense understorey of sedges. The NPSS are found on semi-permanently saturated soils with high organic content in the lowest footslopes, broad valley floors and alluvial flats (DEC 2006). The key features described for the NPHS vegetation type include: a low dense fern-dominated community usually perched on a hillside with few trees present and; groundwater dependence (DEC 2006). However, in reality NPSS and NPHS are diverse plant communities, often with few species in common between swamps. For example, during the spring 2013 survey, of the 185 species recorded, 56% were recorded in five plots or less (Blick et al., 2013).
The vegetation patterns of the NPSS and NPHS are closely associated with local hydrology and are currently classified into two broad swamp categories: Type A and Type C. The type A are periodically wet with rainwater as the main source of water, while the Type C are permanently wet with groundwater as the main source of water. Conceptual models of these shrub and hanging swamp systems are shown in Figures 2.2 and 2.1. Due to the underlying geology, a single swamp can contain both type A and C areas leading to heterogeneity in vegetation composition. This difference in hydrological regime effects predictions of impacts from changes to ground and surface water flows. Regardless of type, due to close links between vegetation and hydrology, changes to the hydroplogy will effect the vegetation.

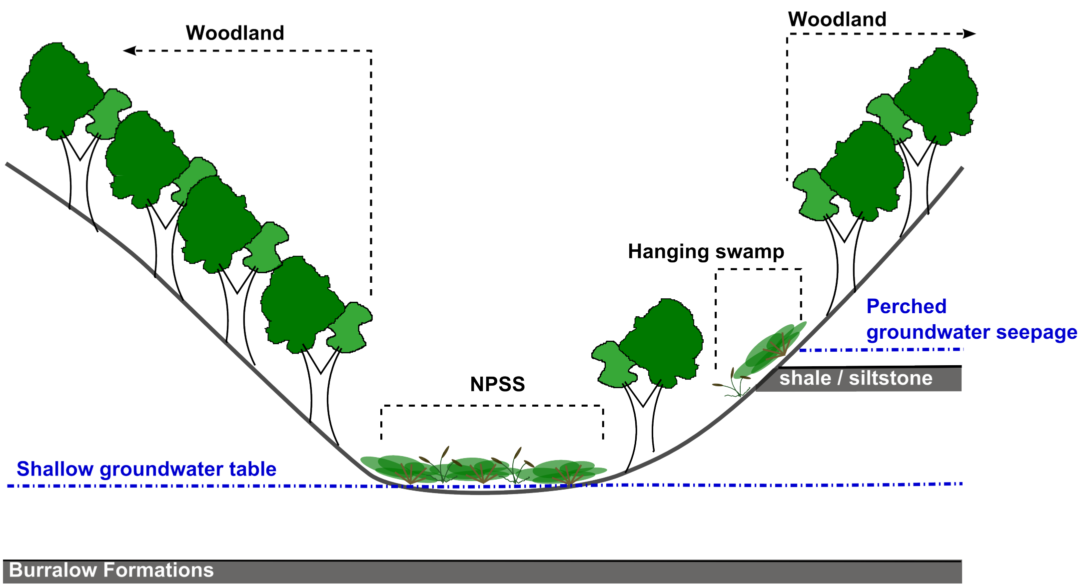

Figure 2.1: Conceptual model of Type C THPSS.

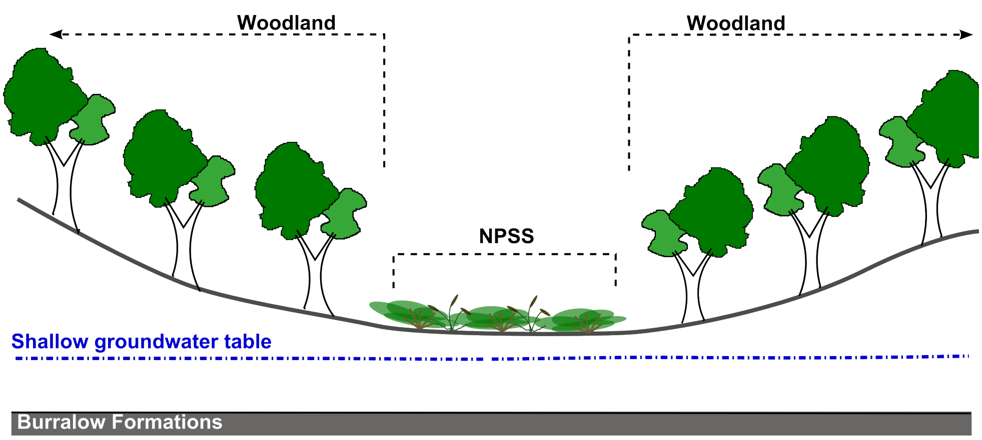

Figure 2.2: Conceptual model of Type A THPSS.

3. Why monitoring is required

Newnes Plateau vegetation experiences a range of disturbances (*e.g.* forestry, fire, mining and recreational uses). The monitoring program outlined here focuses on detecting impacts of underground mining on the THPSS. Active coal mining started in the Newnes Plateau and Lithgow area in 1838 and three mines operated by Centennial Coal are currently located beneath the Newnes State Forest. Two are longwall mines (Angus Place and Springvale Collieries) while the third is a bord and pillar mine (Clarence Colliery). Longwall underground mining is considered a key threatening process to wetlands by State and Federal governments. As such this requires Centennial Coal to demonstrate that mining activities are not impacting on overlying THPSS.

3.1 Primary objective

The primary objective of the monitoring program is to determine whether mining activities impact the condition, species composition and/or extent of Newnes Plateau THPSS plant communities. Undermining results in subsidence, which in turn has potential to alter ground and surface water hydrology. As THPSS are hydrologically restricted communities there is a clear link between changes in hydrology and potential impacts on swamp vegetation. However, these communities exist across a range of hydrological conditions and the plant species comprising these communities are generally thought to be tolerant of a fluctuating water table and moisture availability. Therefore, 1) vegetation impacts are likely to occur where hydraulic modifications are sufficiently large and 2) a time lag between change in hydrology and change vegetation is likely. Identifying this change is the goal of the monitoring program (Figure 3.1). Changes in vegetation patterns are inextricably linked with changes in surface and groundwater availability, therefore hydrological data (e.g. piezometer data) are essential to interpreting changes in Newnes Plateau THPSS vegetation.

3.2 The existing monitoring program

Flora monitoring of shrub swamps by Centennial Coal commenced in 2003 with seasonal monitoring protocols beginning in 2005 following the listing of the swamp communities by

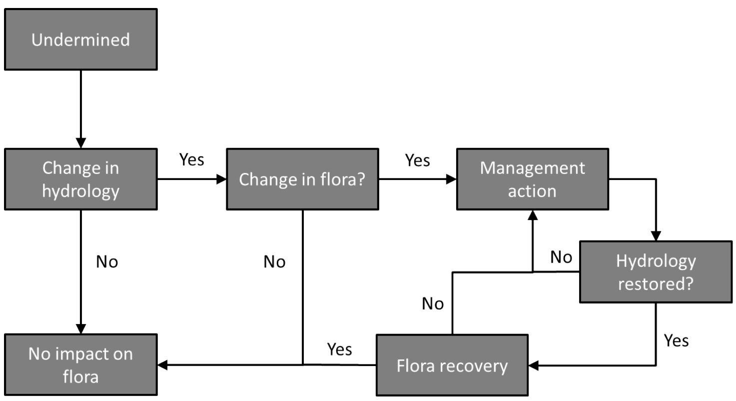

Figure 3.1: Conceptual model of how mining associated changes to hydrology could potentially impact the THPSS and the role of monitoring.

State and Federal governments (NPSS and THPSS respectively). A review and redesign of the program was initiated in 2012 after the existing monitoring program failed to identify a number of obvious community impacts, primarily to East Wolgan and Narrow shrub swamps. Most likely reasons for failure to detect change were 1) a lack of clear connection and feedback linking the mine operational plan with monitoring and management of environmental risk, 2) absence of clearly defined and ecologically meaningful trigger values and 3) the inability of the sampling design to detect adverse impacts. Until 2012 monitoring was only required by the New South Wales Government. In 2010 the Federal Government determined that mine water discharge by Centennial Coal into Newnes Plateau THPSS was a threatening process that had failed to be reported to the appropriate federal regulatory bodies. As a result, federally imposed monitoring of Newnes PlateauTHPSS has been conducted since 2012 (Appendix B).

Currently the monitoring program 1) lacks replication at the individual swamp scale, 2) involves large sampling errors related to plot size and abundance estimation, 3) lacks parameters for defining changes in vegetation structure, 4) lack of understanding of the variability within and between swamps, and 5) includes no plan for defining when and how long monitoring must continue (Appendix D, Brownstein et al. (2013)). Also of concern are the cumulative impacts introduced by flora monitoring activities; adjustments to the status quo are required to limit impacts of monitoring while collecting appropriate data to detect change. Appendix A contains a summary of research conducted by the University of Queensland in 2012-2013 to determine the limitations of the current vegetation monitoring program and how these limitations can be overcome. Table 3.1 broadly outlines how the recommended method addresses the issues identified above.

Table 3.1: Comparison of current statutory monitoring and reporting activities with the method recommended here.

Component	Current State	Current Federal	Recommended
Quantification of vegetation cover	visual cover/abundance estimation within 400m^2 plots	Point intercept (frequency) within 400m^2 plots	Cover in cross community transects
Replication within community	NIL or variable	Nil or variable	3 or more, scaled to community size
Monitoring Interval	3 seasons (spring, summer, autumn)	4 seasons	Annual (spring)
Statistical Analyses	SIMPER, PERMANOVA	1 tail t-test	1 tailed t-test
Trigger values	Significant decline in condition/health; decline in population numbers compared to baseline (not related to rainfall); increase in exotic species compared to last year; major dieback of flora compared to baseline monitoring (not related to climate, bushfire or other anthropogenic cause not associated with subsidence); significant change in species diversity; significant increase in exotic species	Species assemblage >30% change in 3 yrs; increase in eucalypts 3 plants in 1yr period; 1.5 unit decline in average condition in one year; increase in bare ground more than 100m^2 over 3yr; increase in exotic biodiversity of four in one year at BB score 4 or higher	Significant: increase in non-vegetated area; decrease in live vegetation cover; decrease in proportion amphibious species cover; change in terrestrial damp species cover; increase in exotic vegetation cover; increase in establishment of eucalyptus or pine (Table 6.2)
Remote sensing	Nil	Nil	5-15cm resolution, 4 band covering community, 4 seasons
Field measures concurrent with Remote Sensing	N/A	N/A	Fixed random 1m plots at minimum 100m separation across community
Reporting	Seasonal and Annual	Annual	Annual, trigger event
Duration	none specified	Minimum 10 years, intensity decrease after 3yrs	Minimum 10 years, intensity decrease after 3yrs

4. The proposed monitoring design

To meet the requirements outlined in Section 1.2 the new monitoring program must clearly link data from floristic surveys with the data derived from hydrological and subsidence monitoring programmes. The information from subsidence risk maps will inform which areas are more intensively surveyed and areas considered as appropriate reference sites. As mining progresses, hydrological data combined with floristic data will be used to assess if changes in floristic data are linked with mine related impacts, e.g. changes in hydrology (Figure 3.1). The types of data required for each of the environmental components is outlined in Table 4.1.The proposed flora monitoring program will follow an adaptive management approach. Data from monitoring will be analysed to inform successive monitoring activity relative to potential environmental risks of Centennial Coal operations (Figure 4.1).

Table 4.1: The data types required for effective flora monitoring

Environmental Component:	Data required:
Geology	Subsidence
Hydrology	Water chemistry Rainfall Stream flow Groundwater
Flora	Community composition Community condition

4.1 Overview of the performance indicators

The performance indicators cover three broad groups: vegetation composition, vegetation condition and community condition, Table 4.2 outlines the parameters measured for each performance indicator and the trigger levels to be reported for vegetation. These measures and trigger values capture vegetation structure and condition changes that THPSS could undergo due to undermining impacts. These measures and trigger values can only be meaningfully assessed in conjunction with hydrological data (e.g. piezometer data).

4.2 Overview of the survey methods

The sampling methodology consists of two components: a seasonal aerial survey and an annual intensive ground survey; designed to assess the full extent of each community under investigation. The aerial seasonal monitoring measures vegetation and swamp condition by capturing changes in live canopy cover and the extent of non-vegetated areas. In addition the seasonal aerial mapping will detect rapid changes in the environment from direct and indirect impacts (*e.g.* 4x4 activity). The time series of air photos will provide a clear record of change throughout the duration of the monitoring program. The annual intensive ground survey will measure parameters associated with vegetation composition and condition by recording individual species abundance and the extents of non-vegetated areas. The annual survey records trends in species presence and abundance at an ecologically relevant time scale. It is

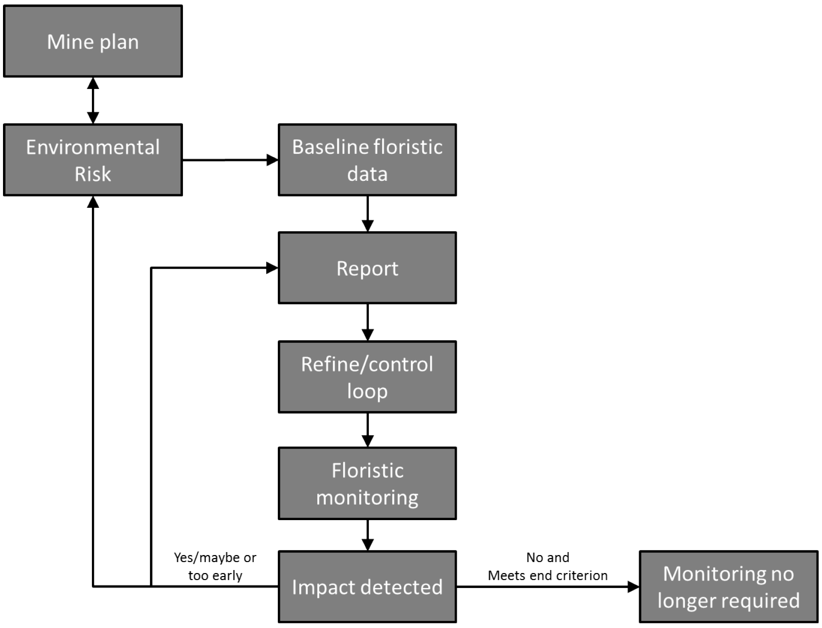

Figure 4.1: Conceptual framework showing how data from flora monitoring informs the environmental risk assessment and monitoring conclusions.

recommended that ground surveys are carried out when species are most easily identified (i.e. summer). This approach increases the quantity and quality of floristic information recorded while minimising impact from trampling.

4.3 Overview of the sampling design

The sampling design and data analysis is based on a Before-After-Control-Impact (BACI) approach. This approach is commonly used to monitor for potential environmental impacts and allows for unrelated changes (*e.g.* temporal variability due to rainfall) to be assessed in the analyses. This type of analysis requires that 'impact' and 'control' sites are monitored with similar methods over similar periods of time. Here a potential 'impact' site is defined as a community that is within the subsidence zone. A 'control' site is a community that has not been and is not expected be undermined in the future and is not within 200m of mine activity (as per SEWPAC condition 7 of approval 2011/5949).

Terminology:
Site is a mapped NPSS or NPHS (*i.e.* MU 50 or MU51) community (VISMap 2231)
Control sites have not been and will not be undermined and are beyond measurable subsidence associated with mine activity.
Impact sites will be or have been undermined or are within an area of measurable subsidence.

Sites will be classified using a subsidence risk map (high, medium or low risk) and hydrological information (type A, type C or combination A/C swamp). Subsidence related risks are predicted and measured deformations associated with mining activities including (*a*) subsidence, (*b*) tilt and (*c*) strain, that are combined with surface topography and geology which may magnify impacts. Hydrological information will be based on natural fluctuations in ground water levels prior to mining recorded in shallow piezometers. This classification will inform the distribution of sampling plots within the community. Effective selection of

Table 4.2: Performance indicators for shrub swamp vegetation monitoring.

Performance indicators	Parameter measured	Trigger level
Hydrology	Water table depth and stability	Evidence of a reduction in water table depth or stability, due to underground mining, from piezometers located in impact sites (refer to hydrology monitoring reports)
	Flow path	Evidence of a change in flow path due to subsidence, based on aerial imagery and field observations
Vegetation structure	Abundance of native wetland species	A statistically significant reduction in the abundance of native wetland species in impacted community relative to the previous survey
	Live Shrub cover	A statistically significant reduction in the percent live cover of native shrub species in impacted community relative to the previous survey
	Abundance and diversity of exotic species	A statistically significant increase in abundance and/or diversity in the ratio of exotic to native species in an impacted community relative to the previous survey
Vegetation condition	Live native canopy cover	A statistically significant reduction in the percent live cover of native species in impacted community relative to the previous survey
Swamp condition	Non-vegetated areas	A statistically significant increase in the percent area of non-vegetated (bare ground) in impacted community relative to the previous survey

control and impact sites absolutely requires:

1. Information on when and where new areas will be undermined.
2. Accurate and up to date undermining extents.
3. Predicted and measured subsidence zone extents and magnitudes.
4. Up-to-date piezometer and surface water data from control and impact communities.

Control sites should be selected that are as similar as practical to impact sites in terms of hydrology (type A, C or A/C) and vegetation structure (e.g. shrub-dominated, sedge-dominated or mixed). There should be at least three control sites for each impact site to provide a reasonable basis for statistical comparison. However, control sites may be used for comparisons across multiple impact sites (i.e. unique control sites are not required for matching with each impact site). Consideration also needs to be given to the potential for fire or other impacts to affect the comparability of some control and reference sites over time. Therefore, it is good practice to include some additional control sites as insurance against temporary or permanent loss of controls due to unforseen impacts.

4.3.1 Rationale underpinning data analysis

There are multiple possible ways of analysing the data collected. Univariate analyses are recommended as the preferred option in the current context (i.e. where there is a need to demonstrate a specified statistical power) because it is much easier to calculate power for these tests than for their multivariate alternatives. We also recommend a very simple approach to Before-After-Control-Impact (BACI) data analysis, based on one-tailed paired-sample t tests, for the following reasons:

- For some of the more complex BACI analyses (e.g. the beyond BACI design), formal power analysis procedures have not been published and are very complicated (Downes et al., 2002)).
- Paired-BACI designs require a single reference site to be allocated to each impact site. The results of tests conducted using this design may vary depending on which reference site is selected.
- In a multiple-BACI design (i.e. comparing multiple reference sites to multiple impact sites), power will depend on the extent that similar changes occur across each group. This test may be a less suitable option if we are more interested in detecting cases where just one site has been impacted by drying.
- All, except the most basic BACI designs (i.e. one control site, one impact site, one before impact survey, one after impact survey), require multiple monitoring surveys to be conducted in both the before and after impact periods. These tests are also based on the assumption that surveys are conducted at large enough time intervals that they are independent. Historically, it has not always been possible to conduct multiple surveys before undermining has occurred. If logistical constraints are similar in future, it would be useful to select a data evaluation method that does not depend on this level of replication in time.

4.4 Overview of sampling frequency and duration

The Before—After component of the BACI analysis requires that site data is collected before mine activities occur; the recommendation made here is that baseline data is collected for one year prior to impact so that "before impact" imagery is available for all four seasons and one intensive on ground survey has been conducted. Monitoring at a site is recommended to continue for three years post undermining, at that time if no impact has been detected within the site, monitoring is reduced to an annual aerial survey. If no impacts are detected after 10 years, monitoring ceases at the site. Impacts in this case include anomalous changes in hydrology and/or where a flora monitoring trigger value is reached at the site.

4.5 Overview of reporting structure and adaptive monitoring

The monitoring reports will focus on determining if any changes have occurred at the impacted sites related to hydrological changes caused by mining. In addition the annual report will include a review of the current trigger values based on monitoring data from reference sites and recommendations for any adjustments required. The report should be more than a simple report card, rather it should include actionable management options in regards to THPSS.

5. Seasonal monitoring

The season monitoring proposed here is composed of two components: remote sensing and a low-impact ground-truthing survey. Current intensive ground monitoring at seasonal intervals (4 times per year) causes significant and visible trampling of swamp vegetation, opens up bare ground and potentially introduces exotic species by creating habitat niches. This is particularly so with quantitative measures requiring revisits to specific points within a fixed area on a seasonal basis. A remote sensing approach at sufficient spatial and spectral resolution provides coverage at a whole community scale. When combined with a minimal access quantitative ground based observation protocol at a community scale, applied concurrently by a trained ecologist, the result is a comprehensive and sensitive monitoring program. The direct comparison of ground based observation and remotely sensed imagery provides a report that can be interpreted with a high level of confidence. The main components of the seasonal monitoring and their processes are outlined in Table 5.1 and the workflow is outlined in Figure 5.2.

5.1 Remote sensing

Image source is less important than the spatial and temporal resolution of the imagery collected. A spatial resolution lower limit of 15cm is required to effectively track change within a community using object based image analysis. Temporal resolution must align with concurrent field observation which is used to confirm aerial imagery interpretation. The development of this handbook utilised a small UAV (Unmanned Aerial Vehicle, <5kg) to demonstrate capture of imagery at a community scale. The Newnes Plateau is a rugged location for the operation of small UAS (Unmanned Aerial Systems), however, seasonal aerial imagery collection by traditional methods is likely to be prohibitively expensive. As this is a monitoring program routine collection of imagery is essential to change detection, particularly where it is desirable to limit physical access.

Imagery collection must result in generation of a georeferenced orthophoto mosaic and digital surface model in traditional colour and near infrared bands. Where a UAV is applied to capture remote sensed imagery it must be capable of GPS guided flight paths with dual digital SLR camera payload. The experimental airframe used for developing this handbook was a flying wing design with battery powered pusher propeller and 2m wingspan. During development Sony NEX-5 mirrorless DSLR digital cameras with Sony 16mm pancake lenses were used. Image processing was conducted using computer vision software (Pix4UAV, Pix4D, Lausanne, Switzerland). At 400ft above ground level this resulted in approximately 5cm resolution aerial photography. A spatial resolution between 5-10cm improves object detection by clearly delimiting vegetation features within a community.

The othromosaic image is segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) and segments are converted to geospatial features as a shape file and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation is applied to each segment to assign a class of shrub vegetation, or bare ground/dead vegetation.

- Dead vegetation is characterized by high reflectance while bare peat in eroded areas

Table 5.1: Detail of resources, sources and data types required to perform seasonal converged remote sensing and field monitoring.

Components	Description and sources of resources
Metadata (from CEY)	Subsidence Model Controlled Action Area: (a geospatial file provided by CEY outlining area of surface potentially affected by subsidence) Measured Subsidence: Monitoring line locations and measurement point elevation changes where these intersect swamp communities (.xls or geospatial file of high precision GPS records) Local Precipitation: Plateau temperature and rainfall data from CEY weather station (.xls or .csv) Groundwater Depths: current piezometer records of depth to groundwater within monitored plots (.xls file) Mine Workings: updated monthly production and mine face locations (.shp or .dxf).
Wetland Extent Polygons (publicly available spatial data)	OEH data download VISMap 2231: Vegetation communities of the Western Blue Mountains (.shp or .tab)
GME Spatial Ecology	Geospatial Modelling Environment (www.spatialecology.com) (free software that uses ArcGIS and R statistics) genrandompnts: tool to generate random sampling points within polygons, settings (polygon from VISMap 2231, mindist 100)
Locating/ Marking Plots	Centroid of plot requires star picket inserted to 1m depth to ensure permanency, a $1m^2$ plot is centred on the star picket and 3m from swamp boundary by on ground observation of vegetation Use foam or flagging tape to ensure picket is visible in imagery
Ground control	Proportion of plot vertical projection representing (a) live vegetation, (b) dead vegetation, (c) bare ground (d) exotic species in each $1m^2$ plot Identify exotic species in plot
Imagery Collection	Red Green Blue and Near Infrared at 5-15cm ground sampling distance, extent of imagery cover is mapped polygon with 30m buffer, imagery overlap sufficient to produce orthophoto mosaic and digital surface model
Image Processing	Four band Orthophoto (geotiff) digital surface model (geotiff or 3D point cloud) Object segmentation (recommend eCognition but not essential, segment image based on colour and texture at scale that captures individual button grass tussocks (30:20:30 settings in multiresolution segmentation algorithm eCognition)
Analyses	Ground control: plot repeat measure trend analysis of cover proportions, exotic species richness change over time, correlates: historic rainfall, mine workings/subsidence. Mapped community mean and variance for proportional cover 1-tail t-test. Remote sensing: buffer ground plot centroid markers with a 0.5m buffer, compare with plot measures from field. Segment image and compare polygon boundaries and extents with premining. Map expanded bare ground or perennial vegetation senescence. Correlate changes with piezometer depths to ground water, recreational and forestry impacts, rainfall data and mine workings.
Reporting	Ground control: trends in bare, dead vegetation, exotic cover/richness Correlation between plot and imagery (mean, SE/Variance) Comparison of premining thematic cover type with current imagery Change in vegetation live cover correlation with mine workings, piezometer depths, rainfall and other non-mining impacts

was dark in colour.

- Shrub vegetation is defined by a combination of colour, surface elevation (digital surface model to assess canopy height) and texture.

Original data collection and image processing is then used to evaluate aerial imagery from subsequent seasons (tabulate, overlap or intersect using ArcGIS). This is summarised in Table 5.2

5.2 Ground control surveys

To both validate the aerial imagery and collect additional information on exotic species, a minimum of five plots should be assigned to each community. These should be randomly located prior to going in to the field using a minimum distance between points function (GME Spatial Ecology for ArcGIS) to ensure community coverage (Figure 5.1). As each wetland is typically a long and narrow ecological community, the minimum distance set between each plot defines the spatial extent and plot placement. Therefore, plot location is stratified to ensure broad spatial coverage of the whole community and to operate as ground control points for image validation, rather than focusing on a cross-sectional interpretation of geomorphology or hydrological patterns.

The THPSS boundaries delineated in VISMap2231 should be used initially to randomly locate the plots. Once on the ground the location of the plots may need to be adjusted to correct for THPSS boundary mapping and/or GPS location inaccuracies. Where random points are on or outside the boundary of the THPSS, plots should be moved the minimum distance required to fall 3m inside the boundary of swamp vegetation (as a useful guideline, we consider the boundary to be the point at which shrub and/or understorey vegetation cover in a sampling quadrat is dominated by amphibious and/or terrestrial damp habitat vegetation, see Section 6 below).

Minimum distance between plots should never exceed 100m to retain coverage, however, oversampling will lead to trampling and vegetation impacts due to the frequency of monitoring. Sampling number is therefore derived as a function of swamp dimensions rather than area. Plots are 1m^2 centred on a star picket. Pickets should have post top markers so as they can be identified in the aerial imagery. This approach allows direct correlation of field observations with UAV imagery and also ensures on-ground observations are conducted at the extents of the community in all seasons. In each plot, an ecologist will record three variables:

1. percentage live vegetation (photosynthetically active plant material)
2. percentage non-vegetated area (bare ground, water, litter and standing dead biomass)
3. percentage cover of each exotic plant species

The percentages of live and non- vegetated area should sum to 100%. The plot data should be collected each time, and within a few days of collecting, the aerial imagery. Additional information should be collected where other possible changes are observed throughout the community using the data sheet in Appendix I.

5.3 Data analysis and trigger values

For each season, the newly derived orthomosaic image will be compared to the baseline thematic map to calculate the intersection between images (carried out using ArcGIS v10.1, ESRI, CA, U.S.A.). For each community the change in the variables related to trigger levels 1 and 2 listed below will be calculated from the maps and expressed as a percentage of total community area. Trigger level 3 is calculated using the exotic species cover from the ground control plot data. For each trigger level variable a single sample t-test comparing baseline with current data will be conducted, any significant differences ($p \leq 0.10$) will be reported.

Trigger level:

1. A reduction in live vegetation cover of more than 20% within the community compared with baseline data.
2. A single patch of non-vegetative cover greater than 400m^2 doubles in size compared with baseline data.
3. A significant increase in exotic species cover compared with the baseline data.

It is important to compare current with baseline values with each community as these are highly variable systems. For example the total amount of land cover classified as non-vegetated can be similar between impacted and non-impacted sites. Sunnyside Swamp (control) has an estimated non-vegetated land cover of 29-34%, while East Wolgan (impacted by mine-waterdischarge) has an estimated non-vegetated land cover of 26% within the map boundary line (Appendix E). Therefore, we recommend that values for each community are compared with baseline (pre-undermining) data from that community, the differences between the pre- and post-impact values is the measure of change. A key performance indicator will be the relative change in bare ground between seasons, in the context of change experienced in other wetlands considered to be a suitable control.

5.4 Reported information and management actions

The reported information should include the change in values related to trigger levels (live vegetation cover, non-vegetated cover and exotic species cover). Values from both impacted and control swamp need to be reported to examine if the magnitude of change in the impacted swamps is outside the natural range.

If a trigger value is exceeded there are several measures to inspect prior to initiating a management action. The first is to investigate if a sudden increase in bare ground may have occurred from a tree falling into the community, or the development of 4x4 tracks. Secondly, investigate the aerial imagery as an explanation for a change in vegetation cover(*e.g.* ground sampling distance, flight conditions and camera equipment). A final course of action will be to initiate intensive sampling to ensure that a structural change has occurred. Seasonal variation is the exception and is expected, especially between winter and summer, to avoid change due to seasonal variation between-year comparisons should only be made within season (e.g. between summer—summer).

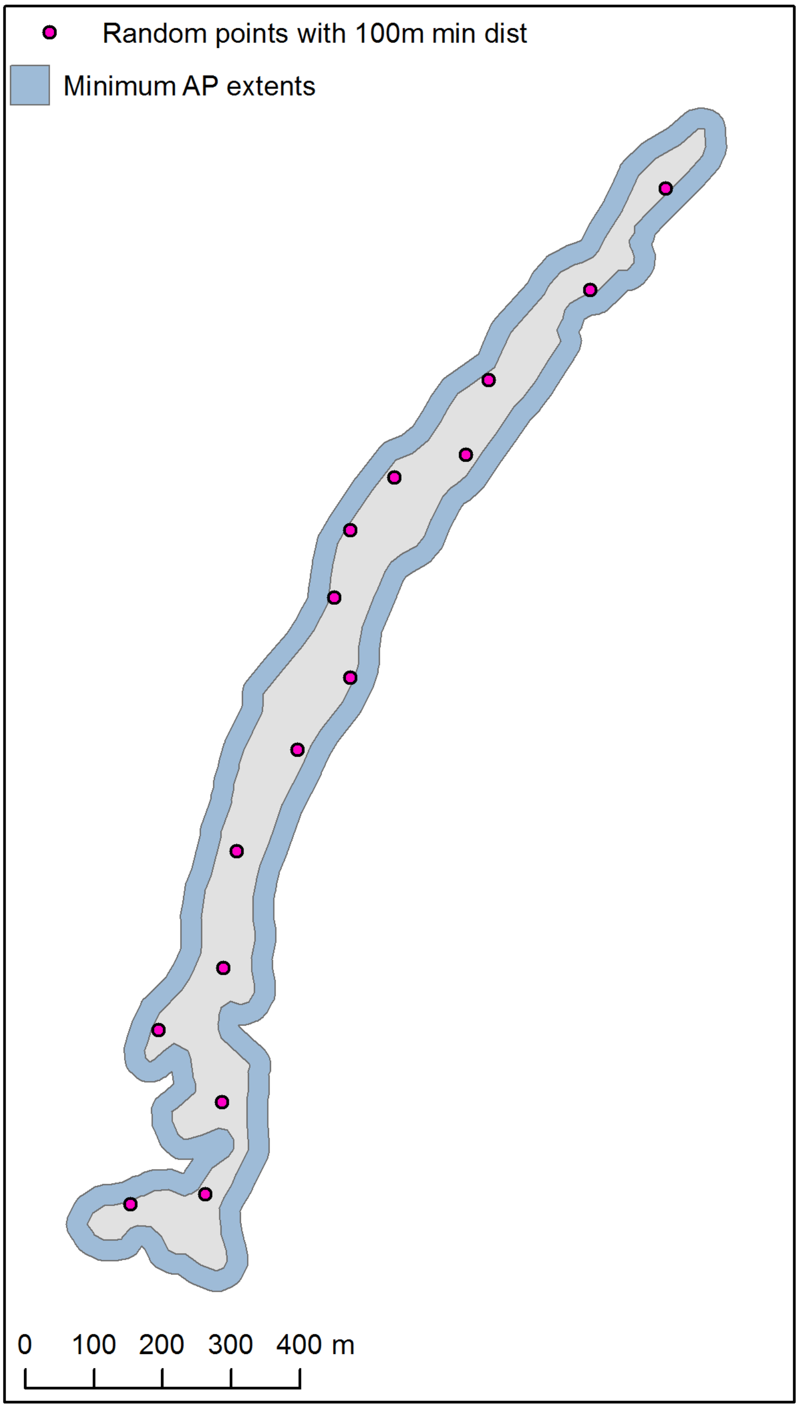

Figure 5.1: Diagram illustrating ground sampling protocols for each community. West Carne shrub swamp is provided as a case study. AP refers to the spatial extent of aerial photography. Monitoring plots are placed randomly at 100m minimum distance throughout each community. At each location, a single assessment plot sized 1m^2 is inspected for live vegetation cover, dead/bare ground cover and exotic plant cover.

Table 5.2: Remote sensing collection and analysis parameters for the season monitoring program.

Remote Sensing Component	**Specifications**
Spatial Resolution	<15cm
Temporal Resolution	Seasonal
Spectral Resolution	R,G,B,NIR
Products	Orthophoto, digital surface model
Object Based Image Analysis	eCognition multiresolution segmentation
Segmentation parameters	Scale 30, Shape 20, Compactness 30
Change Detection	Pre-impact thematic polygons

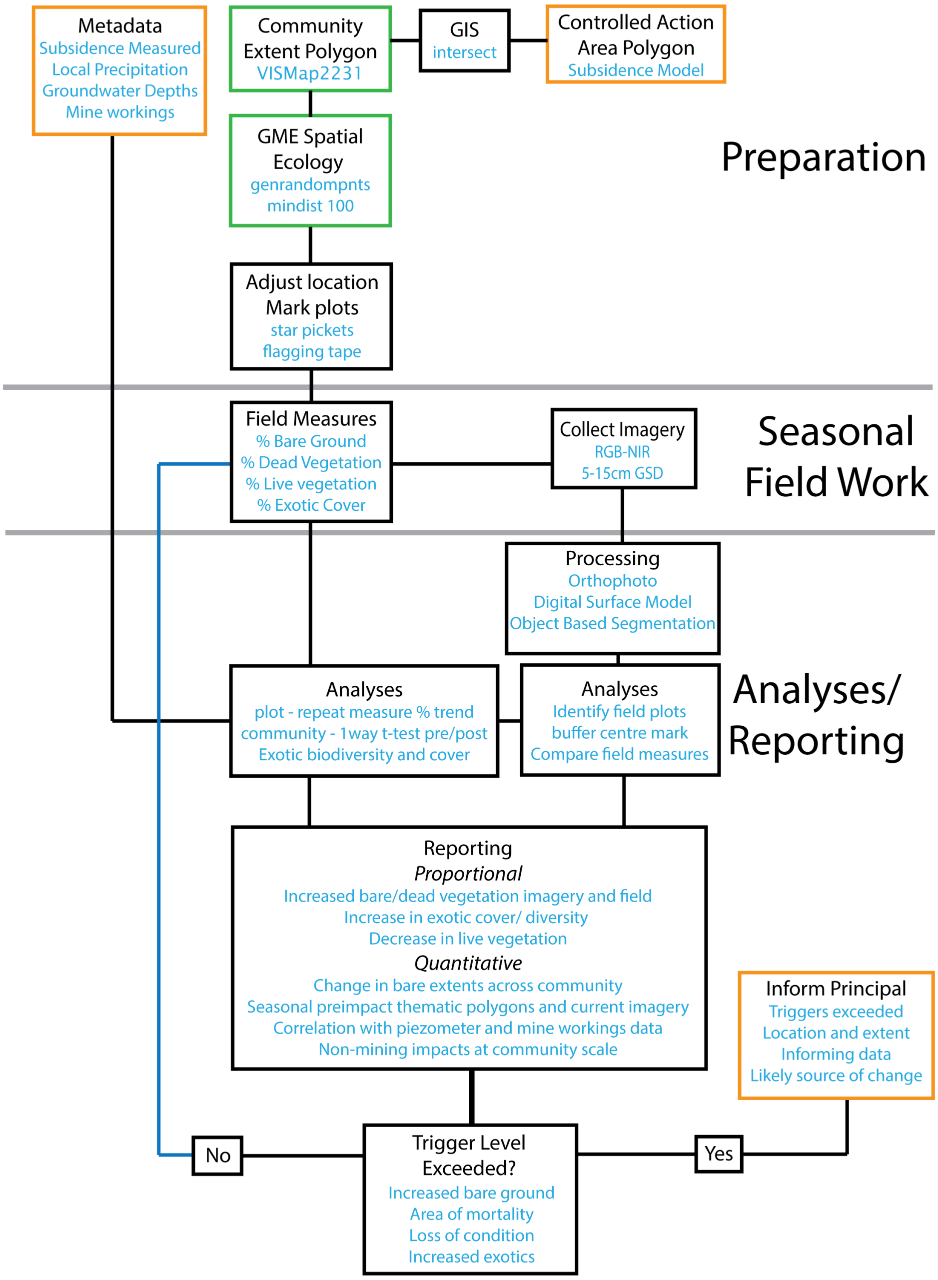

Figure 5.2: Work flow for monitoring preparation, seasonal monitoring and reporting. Orange boxes outline input required from or reporting to Centennial Coal. Green boxes are publicly available data or resources required. Black boxes are monitoring works conducted by contracted ecological/remote sensing service.

6. Annual monitoring

The annual monitoring is an intensive ground-based sampling effort. The sampling design is a series of 3 or more permanently marked transects spanning the width of each community. Along each transect, $1m^2$ plots are placed at set intervals. Within each plot, the percentage cover of each species is recorded along with percentage cover of bare ground. These data are then used to calculated changes in the indicator values to assess if triggers have been exceeded (Table 6.1). The work flow for the annual monitoring is outlined in Figure 6.1 and detailed below.

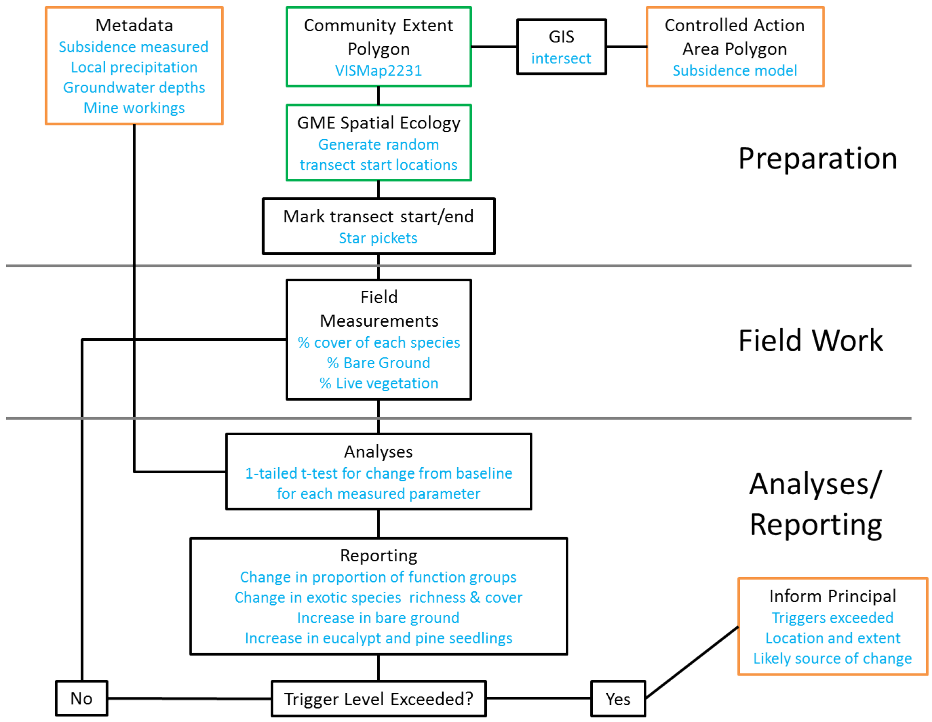

Figure 6.1: Work flow for annual monitoring preparation, monitoring and reporting. Orange boxes outline input required from or reporting to Centennial Coal. Green boxes are publicly available data or resources required. Black boxes are monitoring works conducted by contracted ecological/remote sensing service.

6.1 Transect sampling method

The sampling regime we outline here involves floristic data collection in small quadrats distributed along a number of fixed transects that span the full soil moisture gradient (from edge to edge) in each community, instead of the large fixed plots used in previous monitoring. Our reasons for recommending this transect-based method for future vegetation monitoring are outlined in Appendix F.

6.1.1 Initial site set-up and pilot study to determine required sampling intensity

When setting up new sites the sampling design should adhere to the following general principles:

- A minimum of 3 replicate samples (i.e. transects) are necessary per swamp to be able to detect changes in vegetation at specific swamps between surveys, or to compare vegetation between different swamps, using standard statistical methods.
- The initial number of transects set up per swamp to collect baseline data should be proportional to swamp area to ensure representative sampling of vegetation across the whole swamp i.e. replication will be higher in larger swamps. (One randomly positioned transect for every 200m of swamp length was found to be sufficient for this purpose in the pilot study outlined in Appendix G.)
- Transect start points should be positioned at the swamp edge using a stratified random sampling approach (e.g. after dividing the length of the swamp into sections, transect start positions should be located at a random point along the swamp edge, within each section).
- Transect start points should be determined before going into the field, to avoid unintentional sampling bias.
- During the initial baseline survey, 100cm x 100cm quadrats should be positioned at a sampling interval of approximately one quadrat per 4m. This sampling intensity has been demonstrated to be sufficient for detecting changes in the proposed indicator variables based on pilot study data (refer to Appendix G)

Transect setup:

- In the field, transect start points determined using wetland map layers in ArcGIS (e.g. VISMap 2231, New South Wales Office of Environment and Heritage; Information and Assessment Section, 2006) may need to be adjusted to correct for wetland boundary mapping and/or GPS location inaccuracies. Transect start and end points should be located at or just inside the swamp edge. As a useful guideline, we consider this to be the point at which shrub and/or understorey vegetation cover in a sampling quadrat is dominated by amphibious (Amp) and/or terrestrial damp habitat (Tda) vegetation (i.e. more than 50% of the vegetation cover present belongs to one of these categories).
- Transect start and end points should always be the same between monitoring surveys to ensure that comparable data are collected. Start and endpoints should therefore be marked with both stakes and waypoints during site set-up.
- A compass bearing should also be recorded from the start point and taken in the field for reference in future surveys, in case the end point is obscured by vegetation and/or GPS location accuracy is poor.
- Assessors should avoid walking directly through the areas where quadrats will be placed, for example by always placing quadrats slightly offset (e.g. 50cm upslope) of the walked transect line.

Data to be collected: An example data sheet is provided in Appendix H.

- **Metadata** including Date; Swamp ID; Transect ID; Quadrat No; Assessor; Photo number.
- **Identity and percent canopy cover of each shrub and understorey species present.** Total canopy cover per quadrat may sum to greater than 100% due to layering. Canopy cover should not be assessed for established trees (i.e greater than approximately 6m in height)
- **Extent of non-vegetated area (i.e. % of total quadrat area), divided into to the following sub-categories:**
    1. **The % of bare ground only** (i.e. areas with no overhanging shrub or understorey species present)
    2. **The % of leaf litter only** (i.e. only scored when there are no overhanging shrub or understorey species present)
    3. **The % of large woody debris only** (i.e. only scored when there is no overhanging or underlying shrub or understorey vegetation present)
    4. **The % of standing water only** (i.e. open water with no shrub or understorey vegetation present)
- **Extent of live green vegetation cover** (i.e. % of quadrat area that is covered by photosynthetically-active material)
- **Eucalypt and/or pine seedling presence and abundance** (i.e. % cover and total count of seedlings less than 1m height per quadrat)
- **Photos:** Photos should be captured from each transect start point, focused along the length of the transect. Photo location and direction must be the same for all survey times. Where the end stake is not visible, a compass should be used to ensure consistency in photo direction across surveys.
- **Site condition report:** At each swamp an overall appraisal of condition should be made, including any evidence of potential mining-related impacts not captured by transect-based sampling or indirect impact from recreational or forestry related surface activities. Where potential impacts are noted, GPS waypoints and photographs should be recorded along with a description of any evidence. A *pro forma* for recording site condition is provided in Appendix I.

6.2 Key indicator variables

Two types of indicators are proposed here: 1) changes in water plant functional group (WPFG) cover and 2) changes in vegetation structure and condition. Appendices L, N, M give detailed background information about how and why these indicators were chosen. Table 6.1 contains a summary of all variables recommended for monitoring understorey vegetation in Newnes Plateau swamps, and the directions in which these variables are expected to change if mining leads to a reduction in groundwater or surface flows. The preliminary trigger levels are defined in Table 6.2, with details on defining and revising trigger levels in Appendix K.

Table 6.1: Summary of indicator variables and changes to test for

Indicator of drying	**Apply to:**	**Notes**
Increase in the extent of non-vegetated area	All sites	Does not include areas covered by standing water.
Decrease in the proportion of spatial area sampled that is scored as green (i.e. live photosynthetic) vegetation cover.	All sites	
Reduction in amphibious (A) vegetation as a proportion of total vegetation cover	All sites	
Increase in terrestrial dry habitat (Tdr) vegetation as a proportion of total vegetation cover	All sites	
Increase in terrestrial damp habitat (Tda) vegetation as a proportion of total vegetation	Sites dominated by amphibious vegetation before mining (i.e. wetter sites)	At these sites, drying would be expected to cause an increase in Tda and/or Tdr cover.
Decrease in Tda vegetation as a proportion of total vegetation cover	Sites dominated by Tda vegetation before mining (i.e. damp/dry sites)	At these sites drying would be expected to cause a reduction in Tda cover and/or an increase in Tdr cover.
Increase in exotic vegetation as a proportion of total vegetation cover	All sites	
Increased establishment of eucalypt and/or pine seedlings ($\leq$1m in height)	All sites	The validity of this variable as an indicator of drying in NPHS and NPSS requires further testing.

Table 6.2: Preliminary trigger levels defined

Indicator of drying	**Trigger level (preliminary only*)**	**Notes**
Increase in the extent of non-vegetated area (excluding areas covered by standing water)	20% increase	
Decrease in the proportion of spatial area sampled that is scored as green (i.e. live photosynthetic) vegetation cover.	20% reduction	
Reduction in amphibious (A) vegetation as a proportion of total vegetation cover	30% reduction	At NS, SSE and BN, smaller changes i.e. =15% were able to be detected using the sampling regimes tested (Appendix G).
Increase in terrestrial dry habitat (Tdr) vegetation as a proportion of total vegetation cover	10% increase	Pilot study data indicate that a change of this magnitude should be detectable across a range of sites.
Increase in terrestrial damp habitat (Tda) vegetation as a proportion of total vegetation	10% increase	
Decrease in Tda vegetation as a proportion of total vegetation cover	10% decrease	
Increase in exotic vegetation as a proportion of total vegetation cover	10% increase	
Increased establishment of eucalypt and/or pine seedlings ($\leq$1m in height)	30% increase in frequency (presence/absence in quadrats)	The validity of this variable as an indicator of drying in NPHS and NPSS requires further testing (refer to notes in previous section outlining rationale for indicator value selection).

*Because these trigger values were derived using data from a small number of sites, they should currently be considered as preliminary only. While indicative of the range of effect sizes we can expect to detect at the sites that were surveyed, they will be refined when transect data have been obtained from a larger number of sites.

A management response will be triggered if the following criteria are met:

1. There is evidence from of a change in ground or surface water depth and stability or flow path at the site due to mine subsidence.
2. Analysis of vegetation survey data from an impact site demonstrates that a significant ($p \leq 0.10$) change has occurred, between surveys conducted before and after mining, that exceeds the trigger levels specified for one (or more) of the indicators of drying outlined in Table 6.2, and
3. Changes of an equivalent type, magnitude and direction have not occurred at any of the reference sites over the same time period.

6.3 Power analysis and optimisation of the sampling design

Power analysis of pilot study data is important at the initial stages of monitoring, both for ensuring that sampling is adequate to detect a change of the magnitude desired and also for streamlining, to ensure that sampling effort is not unnecessarily high (Downes et al., 2002). After the initial baseline survey is complete, the sampling regime can be refined based on the results of post-hoc power analyses (Downes et al., 2002; Quinn and Keough, 2002). For example, in very wide swamps, it may be possible to reduce transect length to half the swamp width (i.e. from edge to centre) to reduce sampling time. Such adjustments to sampling design (numbers of transects per site, sampling intervals within transects and full vs half width transects) may be made, provided it can be demonstrated that enough statistical power is retained to detect if a trigger level has been exceeded.

Conversely, if analysis of pilot study data shows that power to detect a change is poor and that additional sampling is required, these adjustments should be made and data collected according to the finalised monitoring design at least once before any potential mining impact occurs. Before/After comparisons testing for changes over time at the within-swamp scale should be made using equivalent numbers of samples per monitoring survey. On this basis, it is better to deliberately oversample during the initial baseline/preliminary/pilot survey than to under sample. If it is found that a site has been under-sampled (i.e. the design is not sensitive enough to detect if a trigger level has been exceeded), an additional survey will be required (preferably in the same season/year) to set up more transects. However, if surplus samples are collected some of these may be discarded later to reduce the field sampling time required in subsequent surveys, once it has been shown via a post-hoc power analysis that this will not have an impact on ability to detect change (Downes et al., 2002).

6.4 Guidelines for data analysis and reporting

The power analyses we have trialled, using Newnes Plateau transect data, were based on testing for differences between two points in time (i.e. monitoring surveys) at the individual site scale, using one-tailed paired-sample t tests (i.e. before vs after). A t-test was selected here because it is simple to perform and has greater power to detect (before/after impact) changes than an equivalent ANOVA test (Downes et al., 2002). We recommend analysing future monitoring data using a similar approach, as follows:

- Total values for each indicator variable should be determined at the individual transect scale, as per the methodology outlined in Appendix J. **(Note: When assessing**

changes in vegetation cover, only shrub and understorey cover are included. Canopy cover from overhanging trees (e.g. mature eucalypts) should be excluded.)

- For each impact swamp, a one-tailed t test should be used to test for significant differences between indicator values obtained in the current survey and those obtained from the baseline before-impact survey.
- If a significant change is detected between these times at an impact site, then data collected from reference sites at the same time points should also be tested (i.e. site by site, comparing the same two survey times) to determine if a change of the same direction and magnitude has occurred in the same time period at any of these non-mining-impacted sites.

The report should include what (if any) change in indicator value(s) was found for both impact and control swamps, with an indication of which (if any) swamps exceed the trigger values. In addition any recommendations for adjustments to trigger values required should also be listed. The preliminary trigger levels are defined in Table 6.2, with details on defining and revising trigger levels in Appendix K.

7. Time and Resources required

7.1 Seasonal monitoring

Initial (manual) classification of imagery is time consuming (approx. 2 days per swamp community $\times$ 1 person), however subsequent analysis is rapid (1 hour per swamp community $\times$ 1 person). Each season, four swamp communities per day (two people) for the field work and five office days (1 person) to carry out data analysis and report writing (Table 7.1).

7.2 Annual monitoring

The initial intensive on the ground monitoring will require roughly 1 day (2 people) of field time per community. However once the initial data have been analysed and the number of transects and the quadrat spacing adjusted (roughly 1 hour of office time per community, 1 person), the subsequent surveys should only require half day (2 people) of field time per community. Data analysis and reporting will require five office days (1 person, Table 7.1).

Table 7.1: Estimated number of person days required for each component of the monitoring method

Survey type	Location	Component	Person days required per swamp
Seasonal	Field	Image capture	0.25
		Ground survey	0.25
	Office	Initial image classification	2
		Image re-classification	0.1
		Data analysis and reporting	0.1
Annual	Field	Initial transect survey	2
		Re-survey of transects	1
	Office	Initial data analysis	0.1
		Data analysis and reporting	0.1

8. Data management and storage

Maintaining data integrity is a key component of a long term monitoring program. For all data types, *e.g.* imagery and floristic data, it is very important to have the complete meta-data including date of collection, location of collection, assessor/recorder, how the data were collected and what post-collection processing was conducted. In the case of species data a link to a voucher specimen and which species identification keys were used to identify the plant should also be included. Great care should be taken in maintaining consistent species names as variation in naming protocols can lead to false change in the data set. For the imagery, metadata should also include altitude and camera information.

Before the data are stored and/or analysed they should be checked for completeness (have all data been collected and have the metadata been filled in completely) and accuracy (*e.g.* species percentage cover values are within a realistic range). Data should be stored in a digital format that is easily assessed by non-proprietary software (*e.g.* .txt or .csv file types) and in multiple locations (*e.g.* in different buildings and/or different computer systems).

9. Summary

This document proposes a monitoring program for the NPSS and NPHS that is robust and statistically valid. The proposed method vastly improves the current method employed for monitoring (Appendix C) and more than meets the requirements laid out in the DSEWPAC condition 7 (Appendix B). As a result this program may be applied to meet the monitoring requirements of both state and federal governments for evaluating potential mining related impacts to swamps on the Newnes Plateau.

The two components, named here ”Seasonal” and ”Annual” for their suggested timing together make up a very robust program. An alternative application of these two components is the Annual intensive ground based method is applied once before undermining and then again once a trigger value has been reached in the Seasonal aerial monitoring. We do not recommend the Annual intensive ground survey being conducted more than once per year as this is likely to cause negative impacts to the NPSS and NPHS vegetation.

10. Acknowledgments

Funding for development of this manual was provided by Centennial Coal Pty Ltd.
Field ecologists Phill McKenna, Vanessa Glenn, Cameron Kilgour, Nic McCaffrey and Helen Vickers have contributed to the collection of data used to inform this manual.

Bibliography

Alexander, P., Nielsen, D. L., and Nias, D. (2008). Response of wetland plant communities to inundation within floodplain landscapes. *Ecological Management & Restoration*, 9(3):187–195.

Benson, D. and Baird, I. R. C. (2012). Vegetation, fauna and groundwater interrelations in low nutrient temperate montane peat swamps in the upper blue mountains, new south wales. *Cunninghamia*, 12(4):267–307.

Blick, R., Brownstein, G., Johns, C., Fletcher, A., and Erskine, P. (2013). Spring and annual flora monitoring report for centennial coal operations. Technical report, Centre for Mined Land Rehabilitation, University of Queensland, St Lucia,.

Boulton, A. J. and Brock, M. A. (1999). Australian freshwater wetlands: Processes and management.

Britton, D. L. and Brock, M. A. (1994). Seasonal germination from wetland seed banks. *Australian Journal of Marine and Freshwater Research*, 45.

Brock, M. and Casanova, M. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. In Klomp, N. and Lunt, I., editors, *Frontiers in ecology: Building the links*, pages 181–192. Elsevier Science, Oxford.

Brownstein, G., Blick, R., Johns, C., Bricher, P., Fletcher, A., and Erskine, P. (Submitted November 2013). Many small vs few large: Applying species-area relations in sampling heterogeneous wetlands. *Wetlands*, In review.

Campbell, C., Johns, C., and Nielsen, D. (2014). Vegetation responses to environmental flows: The value of plant functional groups in demonstrating and communicating outcomes. *Freshwater Biology*, 59:858–869.

Casanova, M. (2011). Using water plant functional groups to investigate environmental water requirements. *Freshwater Biology*, 56(12):2637–2652.

Casanova, M. and Brock, M. (2000). How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? *Plant Ecology*, 147(2):237–250.

Cole, C. A. and Kentula, M. E. (2011). Monitoring and assessmentwhat to measure and why. In LePage, B. A., editor, *Wetlands*, pages 137–152. Springer Netherlands.

Downes, B. J., Barmuta, L. A., Fairweather, P. G., Faith, D. P., Keough, M. J., Lake, P. S., Mapstone, B. D., and Quinn, G. P. (2002). *Monitoring ecological impacts: Concepts and practice in flowing waters*. Cambridge University Press, Cambridge.

DSEWPAC (2012). Approval: Mining of longwalls 415, 416 and 417 at springvale colliery, nsw, epbc 2011/5949.

Keddy, P. (2010). *Wetland ecology: Principles and conservation.* Cambridge University Press, Cambridge, second edition edition.

Leck, M. A. and Brock, M. A. (2000). Ecological and evolutionary trends in wetlands: Evidence from seeds and seed banks in new south wales, australia and new jersey, usa. *Plant Species Biology*, 15(2):97–112.

Liu, G. H., Li, W. E. I., Li, E. H., Yuan, L. Y., and Davy, A. J. (2006). Landscape-scale variation in the seed banks of floodplain wetlands with contrasting hydrology in china. *Freshwater Biology*, 51(10):1862–1878.

OEH (2013). Atlas of nsw wildlife census of australian plant species taxa.

PlantNET (2013). Plantnet: Nsw flora online. national herbarium of new south wales.

Quinn, G. and Keough, M. (2002). *Experimental design and data analysis for biologists.* Cambridge University Press.

Reid, M. and Quinn, G. (2004). Hydrologic regime and macrophyte assemblages in temporary floodplain wetlands: Implications for detecting responses to environmental water allocations. *Wetlands*, 24:586–599.

Robertson, H. A. and James, K. R. (2007). Plant establishment from the seed bank of a degraded floodplain wetland: a comparison of two alternative management scenarios. *Plant Ecology*, 188(2):145–164.

Tiner, R. W. (1999). *Wetland indicators: A guide to wetland identification, delineation, classification and mapping.* CRC Press, New York.

A Research completed by the University of Queensland underpinning the methodology proposed in the draft Newnes swamp vegetation monitoring handbook:

Research completed by the University of Queensland underpinning the methodology proposed in the draft Newnes swamp vegetation monitoring handbook:

Testing the effectiveness of subjective estimates of cover/abundance using BB methodology for change detection in Newnes plateau swamp vegetation. Manuscript submitted Dec 2013(Blick et al. In prep.-a).

Experimental methods for detecting and quantifying weed abundance at a community scale (strip adaptive, transect intercepts, 1m2, large plot searches). Work completed October 2012 - June 2013. Manuscript to be submitted early 2014 (Blick et al. In prep.-c).

East Wolgan UAV ground survey proof of concept (July 2013). Manuscript in review *Biodiversity and Conservation* (Blick et al. In prep.-b)

Pilot study: eCognition for vegetation cover and condition for monitoring handbook recommendations (November 2013)

Cleaning and compilation of historical BB and PIM monitoring data into a relational database, to ensure comparability of nomenclature across datasets and facilitate statistical comparison of data between surveys (mid-late 2012) These data were subsequently supplied to Centennial Coal for Envirosys, to comply with SEWPaC conditions for Longwall panels 415-417.

Classification of Newnes Plateau wetland plant species into functional groups based on water requirements (literature & herbarium database records review, completed late 2012-mid 2013).

Validation of wetland plant functional group (WPFG) classification in glasshouse experiment: Effects of water table depth and stability on germination, establishment and survival of native and exotic macrophytes in highland temperate peat swamps (soil collection early 2013, experiment mid-late 2013, manuscript in preparation for submission mid 2014 (Johns et al. In prep.-b)).

Demonstrated effectiveness of WPFG as indicators for detecting differences in swamp vegetation due to differences in hydrology, using Newnes field data (late 2013). Manuscript in preparation for submission early 2014 (Johns et al. In prep.-c).).

Testing methodology for statistically rigorous ecological monitoring of shrub swamp communities using quantitative data:

> (a) Mini-plots- seven swamps assessed with approximately 350 1m2 plots (data collected in summer 2012-2013, including species abundance, soil moisture and peat depth).
>
> (b) Transects - 4 swamps at two time points with two observers, six plot sizes and 20 transects in total (data collected Autumn 2013).
>
> (c) Test of plot size and distribution required for biodiversity capture - manuscript demonstrating BB plots only capture general characteristics, suitable for mapping but not monitoring (submitted to *Wetlands*, late 2014 (Brownstein et al. In review)).

(d) Ecotones as indicators: Manuscript examining changes across swamp edge as a monitoring tool to detect community change. In preparation for submission to *Journal of Vegetation Science* in early 2014 (Brownstein et al. In prep.).

(e) Expansion of current 400m^2 to demonstrate monitoring capacity of current method under replication (4 swamps sampled with up to 8 new plots each, Autumn 2013). Manuscript submitted to *Wetlands* late 2014 (Brownstein et al. In review).

(f) Comparison of functional group classification methods for describing vegetation differences associated with hydrology on the Newnes Plateau. Manuscript in preparation for submission to *Freshwater Biology* in early 2014 (Johns et al. In prep.-c).

(g) Transect based sampling regime to detect hydrological change in shrub swamp communities: Sampling design and statistical power considerations. Manuscript in preparation for submission to *Applied Vegetation Ecology*, mid 2014 (Johns et al. In prep.-a).

Manuscripts in preparation or submitted:

Blick, R.A.J., Brownstein, G., Johns, C.V., Bricher, P., Fletcher, A. & Erskine, P. In prep.-a. Should ecologists have access to site information prior to floristic surveys? *In preparation for submission to Methods in Ecology and Evolution*.

Blick, R.A.J., Fletcher, A. & Erskine, P. In prep.-b. Assessing vegetation impacts and informing restoration: A role for unmanned aerial systems. *Submitted to Biodiversity and Conservation December 2013*.

Blick, R.A.J., Johns, C.V., Brownstein, G., Fletcher, A. & Erskine, P. In prep.-c. Are adaptive sampling strategies appropriate for monitoring weed abundance in subalpine shrub swamps? *In preparation for submission to Ecological Management and Restoration*.

Brownstein, G., Blick, R., Johns, C., Bricher, P., Fletcher, A. & Erskine, P. In review. Many small vs few large: Applying species-area relations in sampling heterogeneous wetlands. *Submitted to Wetlands*.

Brownstein, G., Johns, C.V., Pritchard, D., Fletcher, A. & Erskine, P. In prep. Ecotones as indicators: Do they have potential as a monitoring tool for wetland plant communities? *In preparation for submission to Journal of Vegetation Science*.

Johns, C., Brownstein, G., Blick, R., Fletcher, A. & Erskine, P. In prep.-a. Development of a transect-based sampling regime to detect changes in shrub swamp communities: Sampling design and power considerations. *In preparation for submission to Applied Vegetation Ecology*.

Johns, C., Fletcher, A. & Erskine, P. In prep.-b. The effects of water table depth and stability on establishment and persistence of wetland macrophytes from Newnes Plateau wetland soil seed banks. *Manuscript being prepared for submission to Aquatic Botany*.

Johns, C.V., Brownstein, G., Blick, R., Fletcher, A. & Erskine, P. In prep.-c. Detecting the effects of water regime on wetland plant communities: Which plant functional groups perform best? *In preparation for submission to Freshwater Biology*.

B Flora Monitoring Requirements Springvale EPBC

Approval

Mining of Longwalls 415, 416 and 417 at Springvale Colliery, NSW, EPBC 2011/5949

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Proposed action

person to whom the approval is granted	Springvale Coal Pty Ltd
proponent's ACN (if applicable)	052096769
proposed action	Coal extraction using longwall mining techniques of three longwall panels at the existing Springvale Mine, including Longwalls 415–417 [See EPBC Act referral 2011/5949].

Approval decision

Controlling Provision	Decision
Listed threatened species and communities (sections 18 & 18A)	Approved

Conditions of approval

This approval is subject to the conditions specified below.

expiry date of approval

This approval has effect until 19/03/2032

Decision-maker

name and position	The Hon Tony Burke MP Minister for Sustainability, Environment, Water, Population and Communities
signature	Tony Burke
date of decision	14.3.12

Conditions attached to the approval

1. Unless agreed by the minister in writing, longwall mining is not to be undertaken in areas directly below known **high quality** sites of temperate highland peat swamps on sandstone or within approved buffer zones (as per condition 2). If at any time the person taking the action seeks the **minister's** agreement to vary this condition the person taking the action must demonstrate in writing that a proven technology or engineering methodology will be used for the proposed longwall mining that prevents **severe impacts** of **subsidence** on temperate highland peat swamps on sandstone, or that would allow any **severe impacts** on temperate highland peat swamps on sandstone to be successfully remediated.

2. Within three months of the date of this approval, the person taking the action must submit details of proposed buffer zones around **high quality** temperate highland peat swamps on sandstone for the **minister's** approval. The buffer zones must be approved by the **minister** before mining of longwalls 416 and 417 can commence.

3. The person taking the action must monitor **subsidence** resulting from the proposed longwall mining in accordance with the *Springvale Colliery Subsidence Management Plan: Proposed Subsidence Monitoring and Reporting program LW415 to 417* to monitor **subsidence** effects on the endangered temperate highland peat swamps on sandstone ecological community.

4. If **anomalous subsidence** is detected within 200 metres of an area of temperate highland peat swamps on sandstone ecological community using the method defined in condition 3, the person taking the action must submit to the **department** a report detailing:

   a) the extent and level of **subsidence** recorded

   b) likely reasons for the **anomalous subsidence**

   c) potential **impacts** on the temperate highland peat swamps on sandstone ecological community resulting from the **anomalous subsidence**.

5. The report in condition 4 must be submitted to the **department** within 10 business days of detecting the **anomalous subsidence**.

6. Within six months of the date of this approval, the person taking the action must submit a Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan ('Monitoring and Management Plan') for the **minister's** approval, to define clear, quantifiable and measurable criteria for monitoring the **impact** of longwall mining on temperate highland peat swamps on sandstone.

7. The Monitoring and Management Plan must include prevention, monitoring, mitigation and management actions for all potential **impacts** on the temperate highland peat swamps on sandstone ecological community arising from the action. The Monitoring and Management Plan must be a stand-alone document and include but not be limited to:

   a) monitoring must take into account the geological and hydrological context in which the swamps sit, i.e. monitoring must include methods to detect potential geological and hydrological impacts upstream of temperate highland peat swamps on sandstone

   b) monitoring must focus on surface and groundwater hydrology (including at least one piezometer per swamp), surface and groundwater quality, vegetation community structure and diversity, and biological indicator species

   c) monitoring must include at least one sample per season (four samples per year) at each sampling location for each parameter measured, though more frequent sampling may be required for some parameters

   d) monitoring post-mining must continue for a period of at least 10 years. Monitoring frequency may be reduced once three years of post-mining swamp monitoring has been undertaken if swamp condition has not degraded as a result of mining activity

e) monitoring must include all temperate highland peat swamps on sandstone (including but not limited to both Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps) potentially affected by the proposed action (**impact sites**) as well as **reference sites**. **Reference sites** must include temperate highland peat swamps on sandstone that have never been subjected to, or are not predicted to be impacted by, **subsidence** impacts

f) details of the parameters monitored, methods, timing, frequency and location of baseline monitoring within the temperate highland peat swamps on sandstone ecological community

g) definition and description of baseline conditions of individual temperate highland peat swamps on sandstone (including both **impact** and **reference sites**), including biological processes, condition, threats and the range of natural variability observed in parameters monitored

h) trigger levels sufficient to detect potential **impacts** of **subsidence** on the temperate highland peat swamps on sandstone ecological community, including information on how the triggers were derived using baseline monitoring and desktop study data. Triggers should be specific and measureable

i) details of the parameters monitored, methods, timing, frequency and location of **reference site** monitoring within the temperate highland peat swamps on sandstone ecological community

j) allowance and methods for trigger levels to be refined as more monitoring data is collected

k) details of the parameters monitored, methods, timing, frequency and location of **impact site** monitoring within the temperate highland peat swamps on sandstone ecological community, sufficient to detect changes in the defined trigger levels

l) corrective actions to be taken should the defined trigger levels (as at condition 7h) be exceeded. These should be clear, measurable, auditable and include specific timing (e.g. within 6 months of **impact** detection). Implementation of a Response Strategy (as required at condition 13) should be included as a corrective action should **severe impacts** be detected.

m) details of how data collected by the proposed monitoring methods will be analysed. This must include a method to analyse data sets in an holistic manner to produce an overall indication of swamp health

n) description of how potential **impacts** arising from the monitoring and mitigation measures themselves will be minimised or avoided

o) maps illustrating the location of the longwall mining activity, past mining activities, expected **subsidence** limits, location of temperate highland peat swamps on sandstone within a 5 kilometre radius of the longwall mining activity, and past and proposed monitoring locations for all parameters

p) description of record keeping and reporting procedures

q) the plan must clearly state the person responsible, including their position or status

r) the plan must include a timeline for review, and provision for revisions to be approved by the **department** prior to their implementation

8. The Monitoring and Management Plan must be reviewed by two **independent reviewers** approved by the **department** prior to the submission to the department for approval.

9. If the **minister** approves the Monitoring and Management Plan then the approved Monitoring and Management Plan must be implemented.

10. A report detailing the results of actions carried out under the Monitoring and Management Plan must be prepared and provided to the **department** annually on the anniversary of the date of this approval. The **minister** may request that the report be reviewed by an **independent reviewer** approved by the **department**.

11. The person taking the action must, when first becoming aware of an **impact** to temperate highland peat swamps on sandstone:

    a) when the **impact** is a defined trigger level (as defined in condition 7h) being exceeded, report the **impact** to the Department within five business days

    b) when the **impact** is a defined trigger level (as defined in condition 7h) being exceeded, report the implementation of the corrective action (as defined at condition 7l) within such time as is reasonable in the circumstances, unless required to report outcomes within a time frame specified in writing by the department

    c) when exceedence of a trigger level is not detected, but an **impact** is apparent, report the **impact** to the department within 20 business days with details of proposed corrective actions

    d) in all of the above cases (conditions 11a to 11c inclusive), provide the results of monitoring data relating to the **impact** and an explanation of the expected cause of the impact.

12. If at any time the **minister** determines that data provided in the report at condition 10 or 11 indicates that the action has had a **severe impact** on the temperate highland peat swamps on sandstone ecological community and/or any associated threatened species, the **minister** will inform the person taking the action in writing ('the **severe impact** notification letter'), particularising all **severe** impacts. Once the person taking the action receives the **severe impact** notification letter, conditions 13 to 18 (inclusive) will apply.

13. When the person taking the action receives a **severe impact** notification letter, the person taking the action must prepare and submit a Temperate Highland Peat Swamps on Sandstone Response Strategy (the 'Response Strategy') for the **minister**'s approval within three months of the date of the letter.

14. The Response Strategy must include measures for remediating or offsetting all **severe impacts** particularised by the Minister on the temperate highland peat swamps on sandstone ecological community arising from the action. The Response Strategy must be a stand-alone document and include but not be limited to:

    a) a description of the **severe impact** including extent, duration, and expected cause. This should include a description of how the **impact** may affect temperate highland peat swamps on sandstone

    b) the objectives of the Response Strategy

    c) the proposed response actions to be taken and how the proposed actions will be implemented

    d) a description of how the strategy will deliver an overall conservation outcome that improves or maintains the viability of temperate highland peat swamps on sandstone and associated threatened species

    e) the estimated cost of all proposed response actions

    f) the strategy must clearly state the person responsible for implementing remediation actions, including their position or status and contact details

    g) description of record keeping and reporting procedures

15. The Response Strategy must be reviewed by two **independent reviewers** approved by the **department** prior to the submission to the department.

16. If the **minister** approves the Response Strategy then the approved Response Strategy must be implemented.

17. A report detailing the results of actions carried out under the Response Strategy must be prepared and provided to the **department** at a time agreed to in writing by the **department** upon receiving the Response Strategy. The report must be reviewed by an **independent reviewer** within a timeframe determined in agreement with the department prior to being provided to the department.
18. The person taking the action must, if required in writing by the minister, stop all work associated with the proposed action within sixty days of the date of the letter referred to in condition 12. Work may be resumed if indicated in writing by the **minister**.
19. If at any time the **minister** determines in writing that s/he is not satisfied that adequate financial arrangements are in place to ensure that a Response Strategy (as required under condition 13) could be implemented, the **minister** may require the person taking the action to provide an arrangement (in the form of a bond, financial guarantee or similar arrangement (in these conditions 'a bond')), as directed by the **minister**.
20. The value of a bond that may be required by the **minister** under condition 19 is the amount determined by the **minister** as required to implement of a Response Strategy.
21. The **minister** may increase or decrease the bond amount required where the person taking the action has increased or decreased, respectively, the liability.
22. In providing for or varying a bond amount in accordance with these conditions, the **minister** may request the person taking the action to obtain written quotes for the cost of potential actions under the Response Strategy from a third party approved by the **minister** within a timeframe determined in agreement with the department.
23. The bond is to remain in force until the **minister** is satisfied that no claim is likely to be made on the assurance.
24. The person taking the action must meet all the charges and costs in obtaining and maintaining the bond.
25. The person taking the action must meet all the charges and costs associated with independent review of documents required under these conditions.
26. The person taking the action must publish all documents required under these conditions on their website, except where agreed in writing with the **department** on grounds of potentially sensitive commercial information.
27. Within 30 days after the **commencement** of the action, the person taking the action must advise the **department** in writing of the actual date of **commencement**.
28. The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, including measures taken to implement the management plans, report, strategy, etc. required by this approval, and make them available upon request to the **department**. Such records may be subject to audit by the **department** or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the **department**'s website. The results of audits may also be publicised through the general media.
29. Within three months of every 12 month anniversary of the **commencement** the person taking the action must publish a report on their website addressing compliance with each of the conditions of this approval, including implementation of any management plans, report, strategy etc. as specified in the conditions. Documentary evidence providing proof of the date of publication and non-compliance with any of the conditions of this approval must be provided to the **department** at the same time as the compliance report is published. The person taking the action must also notify any non-compliance with this approval to the department in writing within two business days of becoming aware of the non-compliance.
30. Upon the direction of the **minister**, the person taking the action must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the **minister**. The independent auditor must be approved by the **minister** prior to the commencement of the audit. Audit criteria must be agreed to by

the **minister** and the audit report must address the criteria to the satisfaction of the **minister**.

31. If the person taking the action wishes to carry out any activity otherwise than in accordance with the management plans report, strategy etc, as specified in the conditions, the person taking the action must submit to the **department** for the **minister**'s written approval a revised version of that management plan, report, strategy etc. The varied activity shall not commence until the **minister** has approved the varied management plan, report, strategy etc in writing. The **minister** will not approve a varied management plan, report, strategy etc unless the revised management plan, report, strategy etc would result in an equivalent or improved environmental outcome over time. If the **minister** approves the revised management plan, report, strategy etc that management plan, report, strategy etc must be implemented in place of the management plan, report, strategy etc originally approved.

32. If the **minister** believes that it is necessary or convenient for the better protection of threatened species and communities to do so, the **minister** may request that the person taking the action make specified revisions to the management plan, report, strategy etc specified in the conditions and submit the revised management plan, report, strategy etc for the **minister**'s written approval. The person taking the action must comply with any such request. The revised approved management plan, report, strategy etc must be implemented. Unless the **minister** has approved the revised management plan, report, strategy etc. then the person taking the action must continue to implement the management plan, report, strategy etc. originally approved, as specified in the conditions.

33. If, at any time after two years from the date of this approval, the person taking the action has not substantially **commenced** the action, then the person taking the action must not substantially commence the action without the written agreement of the **minister**.

34. Unless otherwise agreed to in writing by the **minister**, the person taking the action must publish all management plan, report, strategy etc referred to in these conditions of approval on their website. Each management plan, report, strategy etc must be published on the website within one month of being approved.

Definitions

Anomalous subsidence: any and all ground movements that result from mining in excess of that predicted to impact the temperate highland peat swamps on sandstone ecological community (Longwall 415: 1.5 metres of subsidence, 6-10 millimetres per metre of maximum panel tilt, maximum compressive strains of 18 millimetres per metre and maximum tensile strains of 15 millimetres per metre. Longwalls 416 and 417: 1.1 metre of subsidence, 4–7 millimetres per metre of maximum panel tilt, 3–6 millimetres per metre maximum compressive strain [with a maximum of 14 millimetres per metre maximum compressive strain in alluvium-filled valleys] and 2–5 millimetres per metre of maximum tensile strain).

Commencement: The extraction of coal associated with the proposed longwalls.

Department: The Australian Government Department administering the *Environment Protection and Biodiversity Conservation Act 1999*.

High quality: pertaining to temperate highland peat swamps on sandstone, this means those parts of Sunnyside East and Carne West swamps as marked on the map at Appendix 1 to this approval.

Impact/s: as defined in section 527E of the EPBC Act.

Impact site/s: a site/s potentially subject to impacts of the action.

Independent Reviewer/s: third party/parties with relevant experience and background, not associated with any party involved in the action.

Minister: The Minister administering the *Environment Protection and Biodiversity Conservation Act 1999* and includes a delegate of the Minister.

Reference site/s: a site/s not likely to be subject to impacts of the action

Severe Impacts: Impacts to temperate highland peat swamps on sandstone that indicate a long-term change in swamp hydrology, water quality or flora composition. This includes fracturing of the rock strata beneath the swamp, evident through an extended (longer than that recorded in reference sites during the same time period) reduction in groundwater levels.

Subsidence: any and all ground movements that result from mining.

C Flora monitoring statutory conditions Angus Place including East Wolgan shrub swamp March 2006

- Ridge between Narrow Swamp and East Wolgan Swamp - 1 piezometer to a depth of 54 m.

All groundwater piezometers are shown on **Figure 2**.

Frequency

All swamp piezometers are monitored continuously for water level, and the logged data is downloaded manually every two months. The ridge piezometers will initially be monitored for water level at two monthly intervals. When one of these bores is within the zone of influence of an active longwall panel, instrumentation will be installed to allow continuous water level monitoring until the influence of mining (if any) has ceased.

Angus Place currently engages Connell Wagner to download, manage and analyse data.

Analysis of Results

The results from the monitoring program will identify potential effects from longwall mining or rainfall and will be correlated with the results from the relevant subsidence line monitoring results and the relative position of the longwall. All this data will assist in explaining any changes in groundwater levels.

Connell Wagner will prepare a short report every two months to present the analysis of the monitoring results. A more detailed report presenting all the data from the year will be prepared on an annual basis.

It is worth noting that the new piezometer within the West Wolgan North Extension area was installed approximately eight weeks prior to its affectation by subsidence. Consequently, there will be minimal baseline data to compare results and understand the response to climatic variations. The objective of installing the piezometer and subsequent gathering of data is to understand the potential impact from subsequent longwall extraction. It is noted that should drought conditions continue to prevail, the monitoring results will be complicated in terms of fulfilling the original objective.

7.3 Flora

Location

Vegetation monitoring will continue to be carried out in each swamp using manual inspection of quadrats ($400m^2$). Flora monitoring locations, parameters and reporting details are detailed in the EMP (**Appendix 1**, **Section 6.2**). The number of quadrats per swamp is summarised below.

- West Wolgan Swamp – 2 vegetation monitoring quadrats established in 2002.
  2 additional vegetation monitoring quadrats established in 2004
- West Wolgan North Ext.[4] – 2 vegetation monitoring quadrats to be established in 2006
- Narrow Swamp – 4 vegetation monitoring quadrats established in 2004 (one located at edge).
- East Wolgan Swamp – 2 vegetation monitoring quadrats established in 2005

Frequency

Monitoring is carried out seasonally during Summer, Autumn, Winter and Spring.

Rationale

This special sub-section has been included as a request by DEC during the consultation process.

[4] The DEC Draft vegetation mapping identified this area to be a further potential swamp. Upon confirmation of this mapping, consider review of West Wolgan North Extension area. The monitoring sites have been installed as requested by DEC.

The experimental design seeks to ensure that there is sufficient power to effectively detect changes in vegetation structure, composition and condition. Paired quadrats are used at sampling sites to allow comparison between quadrats located within and at the margin of swamp vegetation. Regionally there are a number of control swamp quadrats including four at Carne West Swamp, two at Sunnyside Swamp and two at Prickly Swamp. The two quadrats at Kangaroo Creek Swamp, whilst already the subject of mining, provide a level of control as they provide an indication of the response of swamp vegetation to ongoing climatic conditions. Relevant literature regarding vegetation dynamics and monitoring have been reviewed in an effort to ensure that the techniques applied will meet the monitoring objectives.

Careful thought was given to the potential application of more intensive flora monitoring (including the tagging of individual plants), but this has not been adopted to date as it was considered that it would not lead to any significant additional power in terms of detection of the relatively localised and temporary changes predicted in the risk assessment process, and there would be a disproportionate increase in the amount of time involved in collecting and maintaining data. Flora monitoring techniques will be further reviewed in light of future survey results and as new techniques for analysis emerge.

Indicator species will be determined as part of the review of monitoring results up until the end of 2005. In identifying indicator species, regard will be paid to those species which are increasing or decreasing in abundance, exotic species and species which typically occur along swamp margins or in woodland communities close to swamp margins.

Analysis of Results

Flora monitoring results will be analysed to determine species diversity and abundance. These results will be correlated with the groundwater monitoring results, photographic monitoring results, rainfall records, subsidence line survey results and the relative locations of the longwalls. All this data will assist in explaining any potential changes in species diversity, composition and vegetation health. If threatened species are located/reported within the Swamps, specific monitoring for each species will be conducted during subsequent surveys.

Angus Place currently engages Gingra Ecological Services (Roger Lembit) to undertake the monitoring detailed in this Section. A report will be prepared following each monitoring session with a more comprehensive report prepared annually.

7.4 Fauna

Location

Fauna monitoring will be carried out in each swamp using trapping techniques, call broadcasting and manual inspections. Fauna monitoring locations, frequency and reporting details are detailed in the EMP (**Appendix 1**). The number and locality of sites is summarised below:

- West Wolgan Swamp – 1 site.
- Narrow Swamp – 1 site.
- East Wolgan Swamp – 1 site.

Additional detail on the Fauna monitoring program (including GPS locations of quadrats can be found in **Section 6.3** of the EMP (**Appendix 1**).

Frequency

The sites are surveyed during Autumn (good for mammals – March), Spring (good for birds, mammals and reptiles – September/October) and Summer (good for birds, amphibians and reptiles – December/January). Additionally, targeted searches will be carried out for threatened species during the seasons where they are most active.

Analysis of Results

D Addressing the limitations of the current methodology

Could small adjustments to the current monitoring design address the short falls?

Brief Outline of Problem: A key objective of the monitoring program is to detect change in the Newnes Plateau THPSS. The current monitoring design consists of 53 400m^2 plots spread over 27 swamps, with between one and six plots per swamp. At each plot all species are recorded and assigned a cover/abundance category (based on a modified Braun-Blanquet scale).

Replication is currently missing in 12 of the 27 swamps, and nine of the 27 swamps have only two plots. Replication is needed to test for statistically significant changes in any vegetation parameter. When sampling from a homogeneous area three replicates are considered the minimum, though the data have shown that these swamps not homogeneous. We ask the question; would 3 to 10 replicate 400m^2 plots (scaled to size of swamp) provide sufficient replication to detect a change in vegetation structure of 20%, with a power of ≥ 0.80 at a significance level of $p \leq 0.10$?

A second problem requiring assessment is the use of a modified Braun-Blanquet scale (ordinal data type), which restricts the statistical methods and analysis. For example, it is not possible to add scores together to get a total cover value using categorical data. We addressed this problem by testing if the categorical estimates are precise enough for this monitoring program.

Question 1: Can increasing the number of 400m^2 plots in a swamp provide enough detail to meet the requirements of the monitoring program?

Question 2: Are the measurements obtained from 400m^2 plots sufficiently precise to allow detection of an ecologically appropriate effect size (i.e. are statistically significant changes able to be detected while impacts remain small to moderate)? The vegetation measures examined:

- Species diversity
- Proportional abundance of wetland vs non-wetland species
- Weed species diversity and abundance
- Eucalypt seedling encroachment
- Extent of bare ground

Methods: The number of 400m^2 plots per swamp was increased to one plot for every 100m swamp edge, with a minimum of three plots per swamp. Due to the area of the plot, in the smaller swamps (West Wolgan North and Bungleboori North) the sampling area was nearly equal to the swamp area. Original refers to plots included in the current monitoring program. Expanded refers to the combination of original and the additional plots sampled for this test. For the purpose of this test weeds and weedy species are defined as exotic species, eucalyptus seedlings and native species that often colonise disturbed areas.

Results:
Species Richness: The total number of species found across all swamps was 152 species. With the increase in number of plots, the total number of species found per swamp increased

(on average by 25 species), with the greatest increase seen in Sunnyside East where the greatest number of plots were added and new habitat types were sampled (Table 1).

The mean number of species per plot tended to be slightly higher in the expanded data set (Table 10.1). With the expanded data set, the variance in number of species per plot increased (again due to sampling a greater number of habitats).

The mean constancy (the number of plots in which a species occurs) was lower in the expanded data set (Table 10.1). The two larger swamps (Sunnyside East and Narrow Swamp) had the lowest constancy. The habitat in Sunnyside East naturally ranges from wet at the low north end to dry at the upper south end, with wet habitat species in the lower end and dry habitat species in the upper end of the swamp. Roughly two thirds of Narrow Swamp has been impacted by mine water discharge, with different vegetation communities found in the affected and unaffected portions. Increasing the number of plots does not lower the overall variance.

Proportional abundance of wetland vs non-wetland species: Given the ordinal nature of the data, calculations like addition and subtraction are not possible, hence total cover or proportional abundance of species or groups of species cannot be calculated; though counts of species or groups of species within the cover/abundance categories is possible. Figure 10.1 shows the frequency of each cover/abundance category for the function groups in each swamp using the original plots (left) and the expanded plots (right). The main difference is the higher number of low cover/abundance terrestrial species in both Narrow Swamp (NS) and Sunnyside East (SSE). The two small swamps show little difference in cover/abundance distribution between data sets (this is probably due to similar habitat throughout out the swamp). The proportion of wetland species per plot is similar for all but Sunnyside East, again due to the extended plots sampling the drier areas of the swamp (Table 10.2).

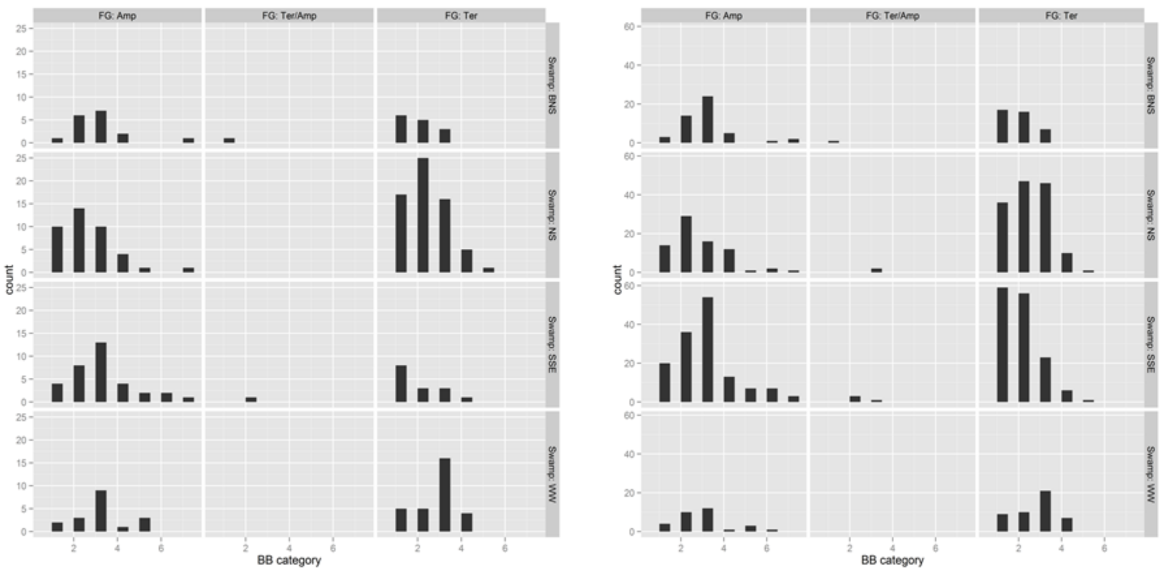

Figure 10.1: The frequency of species in each cover/abundance category for each functional group and swamp. The original plots (left) and the expanded plots (right).

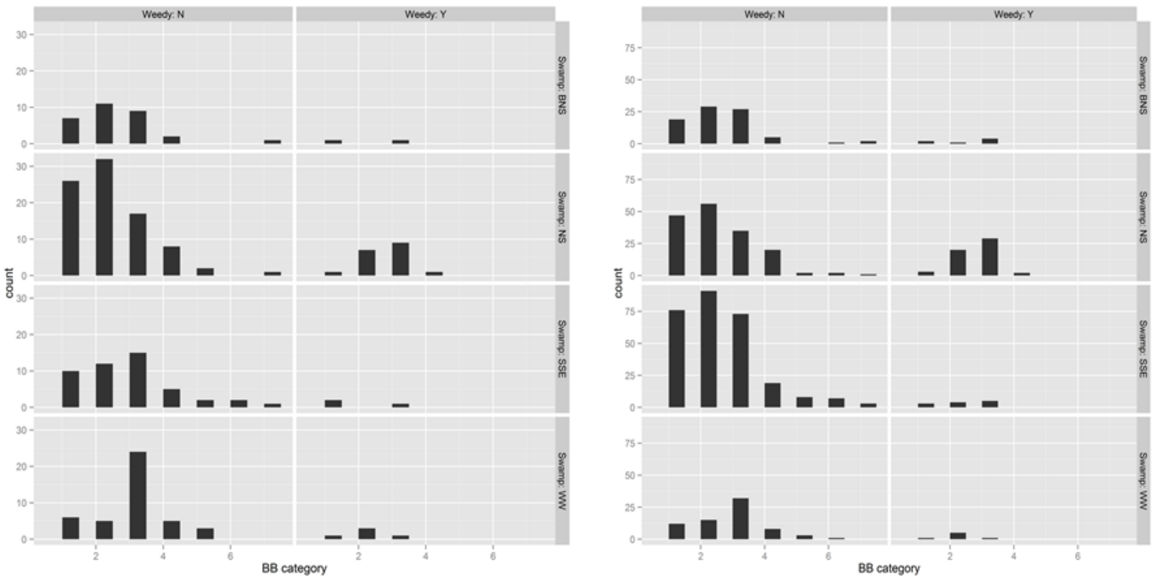

Figure 10.2: The frequency of species in each cover/abundance category for weedy and non-weedy species for each swamp. The original plots (left) and the expanded plots (right). N=no, Y=yes

Weed diversity and abundance The number of weed species per swamp ranged from one to 13, with more weed species found with the expanded data set (Table 10.3). The trends in weed number, abundance and proportion in the original and expanded data sets are similar (Figure 10.2 and Table 10.3). Note the lower standard deviation in the expanded data set for Narrow Swamp and Sunnyside East (Table 10.3).

Eucalypt seedling encroachment Eucalypt seedlings were found in every swamp in the expanded data set but only three of the four swamps with the original data set. The percentage of plots where eucalypts were present ranged from 29% to 100% in the expanded data set and 0% to 50% of the plots in the original data set (Table 10.4).

Extent of bare ground The bare soil/litter was recorded in all four swamps in both the original and expanded data set (Table 10.4). Though the maximum and minimum cover/abundance scores for bare soil/litter remained similar between the two data sets (Table 10.5).

The multivariate approach: A dissimilarity measure can be used to summarise the differences between plots within a swamp (the modified Gower dissimilarity is often used for ordinal data). To assess variance the average distance to the group centroid is calculated (here a group is all plots in a swamp); in addition distances of individual plots from the group centroid can be examined. Greater variance (larger distances to group centroid) could indicate a greater number of habitats within the swamp. Forming hypotheses about how the mean and variance will change due to undermining is difficult. Determining what a significant level of change in the mean consists of and predicting how the mean will change are very difficult. Both an increase and decrease in variance could indicate impact depending on the extent of the impact (e.g. part vs. all plots affected). An analysis examining the dissimilarity could be used as a starting point or summary but changes in these values cannot be used as indicators, hence we leave this out.

Are the measurements obtained from 400m^2 plots sufficiently precise enough to allow detection of a meaningful effect size? As is evident from the summary of the main indicators power analysis for this data set is only possible when examining numbers (or proportions) of species. Calculating a meaningful variance in abundance (hence effect size) is not possible with this data set. The tables below show the effect size (delta) that could be detected with the original and expanded data sets, with a power of 0.80 at a significance level of 0.10 using a one-sample two-tailed test. In nearly all cases, increasing the sample size decreased the minimum detectable effect size. The exception is the proportion of wet and dry habitat species in Narrow Swamp. The analysis suggest that using 400m^2 plots detecting a 30% to 50% change in the indicators would be the best could be achieved with the expanded number of plots (though in many cases its much worse!).

Conclusions: Increasing the number of 400m^2 plots in a swamp does not provide enough detail to meet the requirements of the monitoring program. The measurements obtained from 400m^2 plots are not sufficiently precise enough to allow detection of small to moderate changes in vegetation cover (whether due to altered hydrology or any other cause).

Table 10.1: Summary stats for the 400m^2 plots (BNS, NS, SSE and WW) ± 1 standard deviation.

	Number of plots sampled per swamp		Number of species found per swamp		Mean number of species per plot		Mean constancy per swamp (%)	
Swamp	Original	Expanded	Original	Expanded	Original	Expanded	Original	Expanded
BNS	1	3	32	52	32	32 ± 5	100	58 ± 27
NS	3	7	67	78	36 ± 3	32 ± 5	53 ± 24	40 ± 28
SSE	2	10	36	100	27± 3	30 ± 11	70 ± 25	29 ± 25
WW	2	3	32	38	25 ± 1	27 ± 4	75 ± 25	68 ± 30

Table 10.2: The proportion of wet habitat and dry habitat species per plot in the original plots and expanded plots, ± 1 standard deviation. Tdr = Terrestrial dry group; Tda = Terrestrial damp group

	Proportion Amphibious		Proportion Tdr		Proportion Tda	
Swamp	Original	Expanded	Original	Expanded	Original	Expanded
BNS	0.5	0.51 ± 0.02	0.29	0.25 ± 0.1	0.09	0.07 ± 0.04
NS	0.37 ± .01	0.33 ± 0.05	0.24 ± 0.12	0.19 ± 0.1	0.19 ± 0.08	0.25 ± 0.09
SSE	0.63 ± 0.07	0.5 ± 0.19	0.17 ± 0.04	0.28 ± 0.17	0.04 ±0.004	0.05 ± 0.04
WW	0.37 ± 0.05	0.38 ± 0.05	0.24 ± 0.05	0.25± 0.04	0.2 ± 0.006	0.19 ± 0.02

Table 10.3: Weed diversity in each swamp for the original plots and expanded plots.

	Number of weed species in a swamp		Mean number of weed species per plot		Mean proportion of weed species per plot	
Swamp	Original	Expanded	Original	Expanded	Original	Expanded
BNS	1	2	1	1.3 ± 0.58	0.03	0.05 ± 0.02
NS	10	13	6.0 ± 4.4	7.4 ± 2.9	0.17 ± 0.13	0.24 ± 0.11
SSE	2	3	1.0 ± 1.4	0.5 ± 0.85	0.04 ± 0.05	0.01 ± 0.02
WW	2	2	1.5 ± 0.7	1.3 ± 0.58	0.06 ± 0.03	0.05 ± 0.03

Table 10.4: Eucalypt seedling and extent of bare ground in each swamp for the the original plots and expanded plots.

	Percentage of plots with eucalypts in a swamp		Percentage of plots with bare soil/litter in a swamp		Percentage of plots with bare water in a swamp	
Swamp	Original	Expanded	Original	Expanded	Original	Expanded
BNS	100%	100%	100%	67%	100%	67%
NS	0	29%	100%	85%	0	0
SSE	50%	60%	100%	100%	0	0
WW	100%	100%	50%	67%	0	0

Table 10.5: The minimum and maximum cover/abundance scores for bare ground in each swamp.

	Min and Max score for bare ground in a swamp	
Swamp	Original	Expanded
BNS	1	1-3
NS	3-4	3-4
SSE	1-4	1-4
WW	2	2-3

Table 10.6: Detectable effect size for species richness and constancy

		Mean number of species per plot		Mean constancy per swamp (%)		Mean number of weed species per plot		Mean proportion of weed species per plot	
	Swamp	Avg	Effect	Avg	Effect	Avg	Effect	Avg	Effect
Original	BNS	32	na	100	na	1	na	0.03	na
Expanded	BNS	32	11.48	58	62.03	1.3	1.33	0.05	0.05
Original	NS	36	6.89	53	55.1	6	10.1	0.17	0.3
Expanded	NS	32	5.3	40	29.86	7.4	3.1	0.24	0.12
Original	SSE	27	17.34	70	144.8	1	8.1	0.04	0.29
Expanded	SSE	30	9.3	29	21.3	0.5	0.72	0.01	0.017
Original	WW	25	5.79	75	144.8	1.5	4.1	0.06	0.17
Expanded	WW	27	9.19	68	68.9	1.3	1.33	0.05	0.07

Table 10.7: Detectable effect size for the wetland species indicators. Tdr = Terrestrial dry group; Tda = Terrestrial damp group

		Proportion of amphibious species		Proportion Tdr		Proportion Tda	
	Swamp	Mean	Effect size	Mean	Effect size	Mean	Effect size
Original	BNS	0.5	na	0.29	na	0.09	na
Expanded	BNS	0.51	0.046	0.258	0.23	0.07	0.092
Original	NS	0.37	0.023	0.24	0.27	0.19	0.18
Expanded	NS	0.33	0.053	0.19	0.01	0.25	0.096
Original	SSE	0.63	0.4	0.17	0.23	0.04	0.023
Expanded	SSE	0.5	0.16	0.28	0.14	0.05	0.03
Original	WW	0.37	0.29	0.24	0.29	0.2	0.035
Expanded	WW	0.38	0.12	0.25	0.09	0.19	0.04

E A pilot study providing details of the image classification process

We evaluated image classification by testing (i) the accuracy of the segmentation process and the detection of indirect impact, (ii) the accuracy of image classification between seasons of a single shrub swamp, and (iii) we compared an automatic classification process (Nearest neighbour analysis NN: eCognition Developer v8.7 scale 30, shape 20, compactness 30, spectral difference 5) with manual classification using an orthodem and orthomosaic.

The segmentation process was tested using imagery covering 6.2ha in *Sunnyside Swamp* (Figure 10.3). When we evaluated tree trunks (white linear objects) as a separate category we estimated 23-37% bare ground (Figure 10.3c; n=15 trials). By including tree trunks in the same category as bare ground we decreased variation and improved the accuracy in estimating non-vegetated areas (i.e., **29-34%**; n=5 trials). Live vegetation and shadows were easily discriminated (Figure 10.3d-e). These results suggest that shrub swamp habitat can be reliably classified in three categories (live vegetation, non-vegetative and unknown/shadows/canopy).

Between season variation was tested using imagery covering 7ha in *Carne Central* (Figure 10.4). We found a substantial decrease in live vegetation cover and an increase in non-vegetated areas between February 2012 and June 2013 (Figure 10.4c; n=5 trials). Even though bare ground was estimated at **16.2%** in February 2012 and **21.1%** in June 2013, only 4.6% of the total area of bare ground was estimated in both years. This discrepancy between years could be due to stretching of vegetation (image stitching error) and/or shadows that were present in 13% of the target area (June 2013 image). Ground surveys are needed to validate this change.

We evaluated the classification algorithm using imagery covering 4.1ha in *East Wolgan* (Figure 10.5). The NN algorithm revealed on average **41%** of bare ground in East Wolgan (95% confidence interval = **38-44%**; n= 10 trials). However, just **25%** of East Wolgan was classified consistently with bare ground. Using a manual classification, 47,095 polygons were evaluated and classified according to three categories described above (live, dead/bare, unknown). Within the mapped boundary of East Wolgan we considered **26%** to have bare ground indicating high correspondence with NN classification. However, on further inspection only 17% agreement was found between NN and manual classification.

Overall, results support manual classification of three categories (live vegetation, non-vegetative areas and other). Ground surveys are needed to validate imagery. Primary classification (baseline data) should be used to investigate the spatial structure of bare ground each season. Importantly, indirect impact from (i) forestry, (ii) recreational activity, (iii) mine related surface activity (e.g. subsidence lines) can be monitored using UAS imagery.

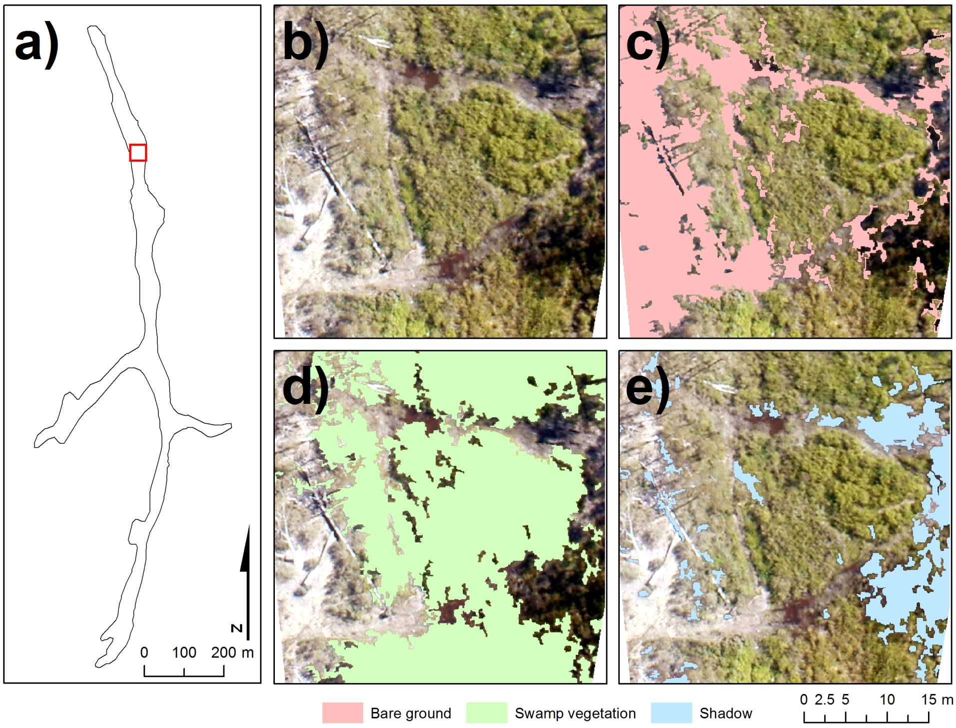

Figure 10.3: Figure showing the classification of indirect impacts (4x4 track) in Sunnyside Swamp. Environmental conditions can cause shadows to appear in the aerial imagery (e).

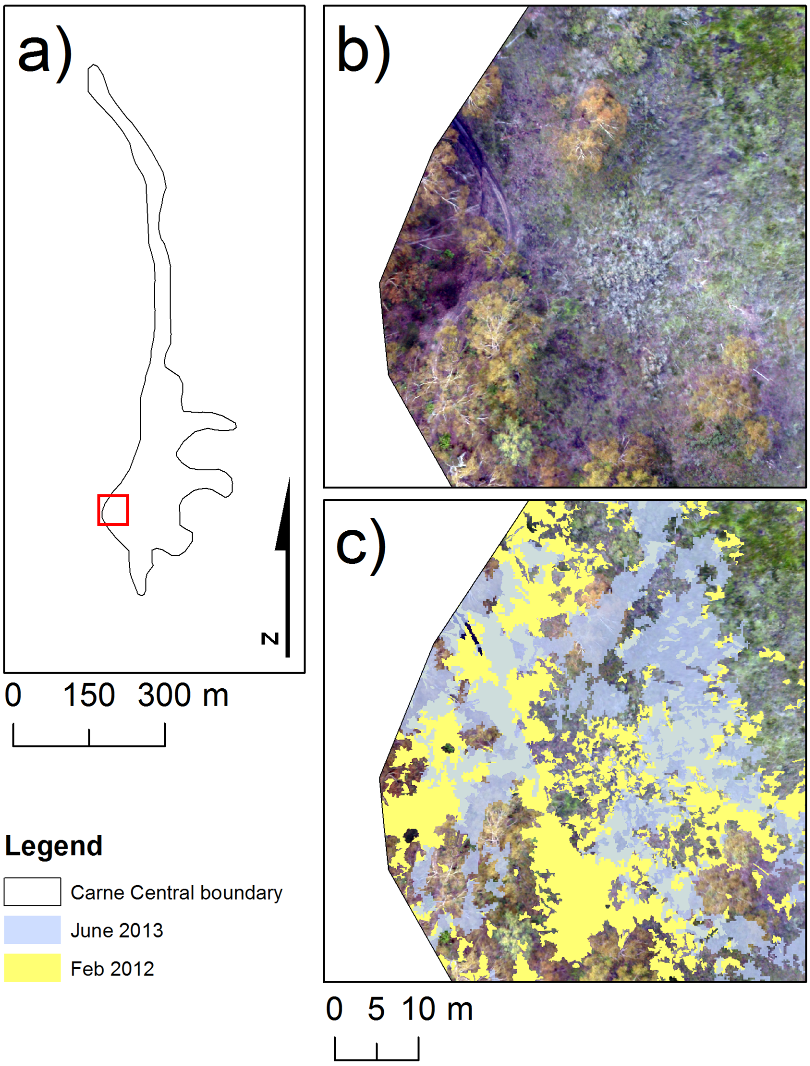

Figure 10.4: Figure showing the classification of non-vegetated areas in Carne Central over two years (a). Bare ground and the formation of a motorbike trail was visible along the western side of Carne Central in February 2012 (b). The thematic map (image classification) had poor correspondence (5% overlap) between years (c) including sections of a motorbike trail which remains clearly visible from the ground. Ground surveys are required to validate a change in dead trees and bare ground in Carne Central during June 2013.

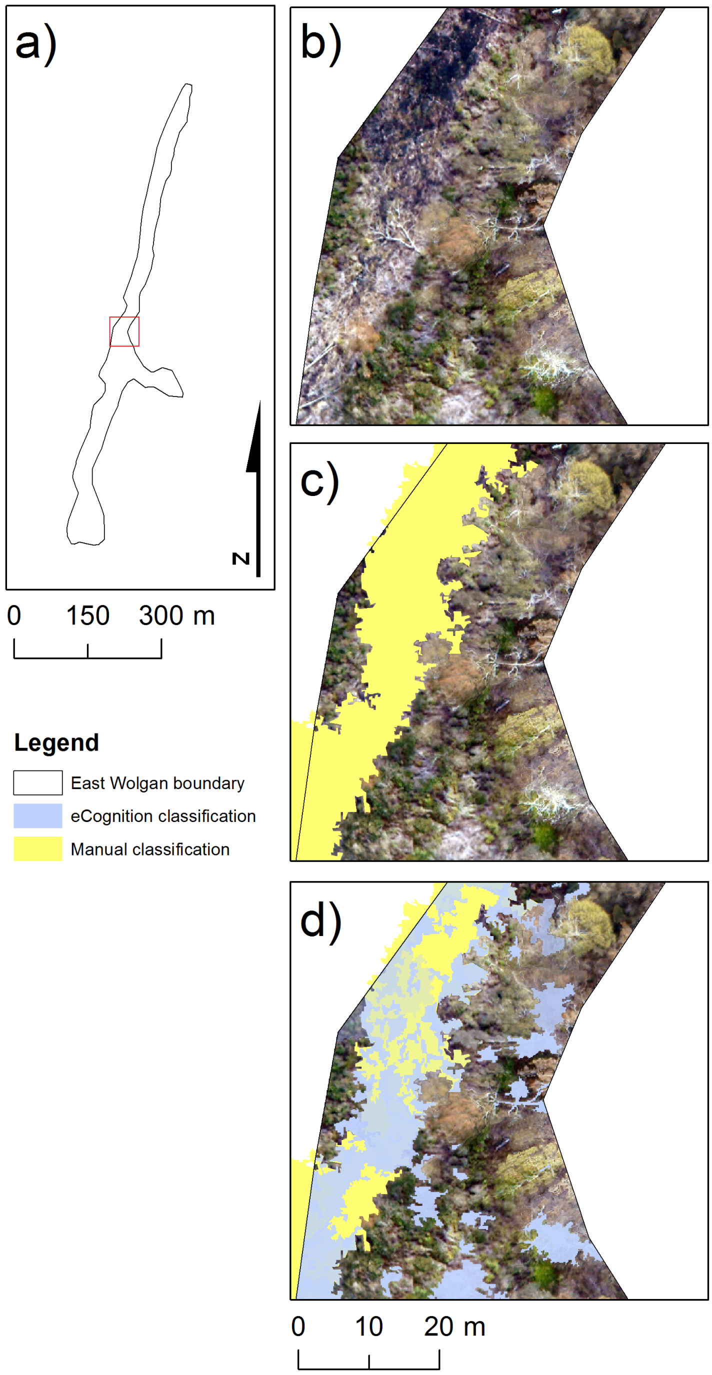

Figure 10.5: Figure illustrating two methods of classifying East Wolgan Swamp (ab). Manual classification (c; yellow fill) shows a continuous band of impact indicating channelization of shrub swamp habitat. Classification using a nearest neighbour (NN) algorithm indicates a less continuous band of non-vegetated area (d; purple fill) and has omitted low reflectance objects as they were mistaken for shadows, and detected high reflectance objects such as standing eucalypts along the boundary line. Manual classification is recommended to provide baseline data and deviations each season can be used to qualify impacted areas of swamp habitat. Initial (manual) classification is time consuming (2 days per swamp), however subsequent analyses could be rapidly assessed (1 hour per swamp).

F Justification for the use of cross-swamp transects

Why transects? Hydrologic variables including the depth, frequency and duration of inundation are key factors affecting the establishment, growth and reproduction of wetland macrophytes (Casanova and Brock, 2000; Keddy, 2010). Within wetlands, species composition is rarely uniform. Instead wetland vegetation communities are typically characterised by zonation along a water availability gradient, with species occupying different ranges along this gradient according to their relative tolerance to waterlogging, inundation and drying (Keddy, 2010). Other abiotic and biotic factors also affect zonation patterns e.g. substrate type, interspecific competition and herbivory.

If mining activities have an impact on ground water or surface flow paths, vegetation condition and abundance effects may differ according to gradient position and impact type. For example, during a prolonged drying event it is likely that encroachment of non-wetland species into wetland plant communities would initially be most detectable in edge zones. In contrast, at sites affected by previous mine water discharge (e.g. East Wolgan Swamp and Narrow Swamp), the effects of alterations to surface and groundwater flows on the plant communities including localised vegetation dieback and increases in bare ground and weed establishment are most apparent close to the drainage line i.e. at lower elevations. Sampling restricted to fixed plots located at a single elevation increase the risk that changes could be missed due to plot placement. Sampling vegetation at regular intervals along transects that span the full wetland elevation gradient, from edge to middle, will help to reduce this risk.

Advantages of small plots It has been demonstrated that subjective estimates of species abundances in large plots (including modified Braun-Blanquet scores derived 20 x 20m plots used in the previous monitoring program design) lack precision and repeatability (Appendix Sampling size). Use of small (1m x 1m) quadrats will allow more precise estimates of cover to be obtained.

G Pilot study: Optimisation of transect sampling regimes and determination of minimum detectable effect sizes, using post-hoc power analysis

A transect survey pilot study was conducted in 2013 with the following aims:

1. To determine the optimum sampling regime (quadrat size x sampling interval) for measuring the abundance of each of the following vegetation indicator variables, at the swamp scale
   - Extent of non-vegetated area
   - Proportion of quadrat area scored as "green" vegetation cover
   - Amphibious (Amp) vegetation as a proportion of total vegetation cover
   - Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover
   - Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover
   - Exotic vegetation as a proportion of total vegetation cover
   - Frequency of eucalypt seedling detection (proportion of quadrats sampled)
   - Frequency of exotic species detection (proportion of quadrats sampled)
2. To quantify the extent of variability between repeat surveys using this optimum sampling regime.
3. To determine minimum detectable effect sizes for each indicator variable, by conducting a *post-hoc* power analysis.

Site selection

We selected four wetlands that broadly spanned the range of hydrological states (from permanently wet with standing water to predominantly damp to dry), vegetation types (from shrub-dominated to open) and wetland sizes present in the Centennial Coal mine lease areas (Table 1).

Table 1 Overview of sampling site traits

Swamp	Hydrological class	Size	Vegetation
Bungleboorie North (BNS)	Wet swamp	Small	Uniformly dense, shrubby, vegetation community
West Wolgan, northern subsection (WW)	Dry swamp	Small	Heterogeneous vegetation, consisting of a mixture of grasses, sedges and forbs with a patchy shrub layer
Narrow Swamp (NSN)	Dry swamp, affected by previous mine-water discharge	Intermediate	Heterogeneous vegetation. Dense shrub cover at upstream end and low shrub cover downstream. Weed cover and extent of bare ground high compared to other swamps.
Sunnyside East Swamp (SSE)	Mixed: Surface water present at downstream end, dry at upstream end	Large	Vegetation community dominated by *Gleichenia dicarpa* and *Baloskion* spp. at top end, with higher cover of *Baumea rubiginosa* and various shrub species downstream.

Vegetation survey 1: Comparing sampling regimes

The first transect survey was conducted in April 2013. For each swamp between 3 and 10 transects were sampled, spanning the width the swamp. The number of transects surveyed per swamp (Table 1) was determined based on wetland size. Transects locations were determined before going into the field by using ArcGIS to divide the length of each swamp into 200m sections, then randomly position a transect start point within each of these sections along the edge of the mapped swamp boundary. The resulting transects were spaced between 50m to 175m apart. A hand-held GPS device was used to locate the start location of each transect in the field.

We collected vegetation and bare ground data along these transects using: 1) a point intercept sampling method, 2) presence/absence data collected from small quadrats of two sizes and 3) % cover data (including % green vegetation cover) from nested quadrats that could be aggregated to create and compare % cover scores and variability for six different quadrat sizes (sizes ranging from 50 x 50cm, to 100cm x 400cm), at a range of different sampling intervals (from 1 to 4 quadrats per 8m of transect length). The nested point and quadrat sampling design is illustrated in Fig. 1.

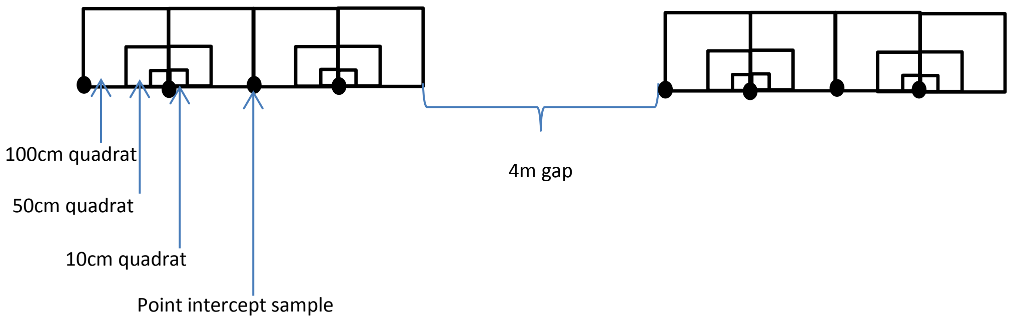

Figure 1. Nested sampling design repeated along transects

Vegetation survey 2: Variability in results between two surveys

In September 2013, 18 of the 24 transects surveyed in April 2013 were resampled so that variability between the two survey times could be assessed. Waypoints and photos were used to relocate the original transect start and end points in the field. Percentage cover scores were recorded in 100cm x 100cm quadrats, using the first and third quadrat per set of four (refer to Fig. 1). In total, half of the quadrats sampled per transect in April were resampled in September 2013 (refer to Figure 1).

Data analysis

In total, 17 sampling regimes (i.e. quadrat sizes x sampling intensities) were compared. For each sampling regime, abundance scores were calculated at the transect level for every indicator variable. For each variable, the mean values obtained per swamp and standard deviations between transects from each of the sampling regimes were plotted and compared (e.g. Figure 2). The optimum sampling regime, for the total number of transects surveyed, was then determined per variable by identifying the quadrat size x sampling interval combinations that:

- Were sufficient to detect the variable of interest across all four swamps (including groups with low and/or patchy cover at some sites i.e. exotic species and eucalypt seedlings).
- Appeared to provide a robust approximation of the mean (i.e. values did not change substantially with further increases in quadrat size and/or sampling intensity)
- Resulted in the lowest overall variability between transects, across the four swamps.

Power analyses were conducted using the power.t.test function in the statistical package R and were conducted in two stages using slightly different methods:

First, after the initial survey in April, the data obtained were used to calculate the minimum detectable effect size for each variable, per swamp. This initial power analysis was based on analysing the data with a one-tailed **two-sample t test**, with a specified statistical power of 0.80 and significance level of $p = 0.10$. For this test, minimum detectable effect sizes are determined by the number of transects surveyed (n) and the extent of variability between transects (i.e. standard deviation) (Downes et al. 2002, Quinn and Keough 2002).

After the September survey, we used the results obtained from both surveys to calculate the extent of variability between survey times. This allowed minimum detectable effect sizes to be calculated for a one-tailed **paired-sample t test**, based on data from the two time points with a specified power of 0.80 and significance level of p = 0.10. Paired sample t tests were used for the comparison between survey times because samples obtained from the same transect location at different time points are not independent (i.e. vegetation cover observed in one survey is expected to influence the cover found at the same transect in subsequent surveys). Unlike two-sample t tests, paired-sample t tests do not require independent samples and are therefore more appropriate for comparing repeated measurements from the same transects. Minimum detectable effect sizes for this test are affected by the number of transects surveyed (n) and the variability in the extent of change recorded between survey times, per transect (Downes et al. 2002, Quinn and Keough 2002).

Results and interpretation

Selection of optimum sampling regime

Of the 17 sampling regimes compared, the use of 100cm x 100cm quadrats, at a sampling intensity of two quadrats per set of four, was identified as the optimum design for sampling the majority of indicator variables across the four swamps. This sampling regime was sufficient to detect weeds and eucalypt seedlings and eucalypt seedlings across all four wetlands, despite the low cover and patchy distribution of these groups at most sites. This sampling regime also minimised variability between transects for most indicator variables (i.e. proportional cover of key water plant functional groups, non-vegetated area and live green vegetation). Increases in quadrat size and sampling intensity also led to no appreciable change in mean % cover scores recorded for these variables; this was verified using one-way ANOVAs, where no significant changes were detected.

Power analysis 1: Minimum detectable effect sizes based on data from a single time point

Swamps that displayed a high degree of spatial heterogeneity in indicator variables had higher minimum detectable effect sizes for those variables than swamps that were less heterogeneous. Minimum detectable effect sizes were often higher for WW than for the other swamps, due to a combination of heterogeneity in the vegetation community and the lower number of transects surveyed. Minimum detectable effect sizes for each indicator variable, per swamp, based on a two-sample t test on April survey data only are shown in **Table 2.** These values are based on data obtained using the sampling regime selected above. The minimum detectable effect sizes calculated for the % cover based indicator variables (e.g. non-vegetated area, wetland plant functional group abundance and live green vegetation extent) were generally quite low, indicating that this sampling regime should be rigorous enough to detect small to moderate changes in these indicator variables (i.e. 10-30%).

In contrast, the minimum detectable effect sizes for the two frequency-based variables (i.e. frequency of tree seedling and exotic species detection) were much higher. This was because detection frequencies varied extensively between transects (Table 2). For the 17 sampling regimes we tested, frequency scores did not appear likely to be effective for detecting changes over time in the abundance of vegetation indicator groups characterised by low abundances and patchy distributions. Therefore, a different method may be required to detect changes in exotic species and tree seedling abundance (e.g. % cover scores or seedling counts). The results of this pilot study also indicate that frequency of eucalypt seedling detection may not be a reliable indicator of site dryness, because eucalypt seedling detection frequencies in the two wet swamps (BNS and SSE) were similar or higher than those in the dry swamps (WW and NSN).

Power analysis 2: Accounting for effect of variability between survey times on minimum detectable effect sizes

The minimum detectable effect sizes calculated in paired-sample t tests increased with variability in the extent of change (per transect) between surveys and decreased with the number of transects surveyed (Table 3). For BNS, NSN and WW, this paired-sample power analysis used the same number of transects in total as the earlier power analysis (April survey data only), while at SSE fewer transects were compared in the second analysis. For BNS and NSN and SSE, detectable effect sizes were quite similar in magnitude to those derived from the initial baseline data analysis, despite the lower number of transects surveyed in SSE. This suggests that 4 to 7 transects should be sufficient for detecting small to moderate changes in key indicator variables at these sites.

WW had the smallest number of transects and quadrats per transect sampled and the highest heterogeneity in the extent of change per transect between surveys for a number of variables.

This resulted in low power to detect changes in a number of indicator variables, including the extent of non-vegetated areas, terrestrial dry (Tdr) vegetation cover and terrestrial damp (Tda) vegetation cover (refer to minimum detectable effect sizes in Table 3).

The results demonstrate that more than three transects will be required to detect small to moderate changes in key indicator variables at this site, at the specified power and significance levels. Further power analyses were conducted on the data from WW to demonstrate how increasing the number of transects would affect minimum detectable effect sizes (Figure 3).

Caveats and additional recommendations re optimising sampling design:

The extent of variability observed at West Wolgan is likely to have been driven, in part, by the lower number of quadrats sampled per transect in this wetland. The area sampled was very small and transects were consequently both few in number and short compared to the other sites. Vegetation within the area was also quite heterogeneous, potentially contributing to differences in the extent of change over time between individual transects.

We have not determined whether similar results (i.e. means, extent of variability between transects and minimum detectable effect sizes) can be obtained by spacing quadrats further apart if sampling in very wide shallow wetlands with broader zonation patterns (e.g. Carne Central, West Wolgan main section). This should be tested, because increasing the sampling interval in wider swamps would potentially greatly reduce the amount of time needed to complete surveys in these larger swamps.

Results: Figures and tables

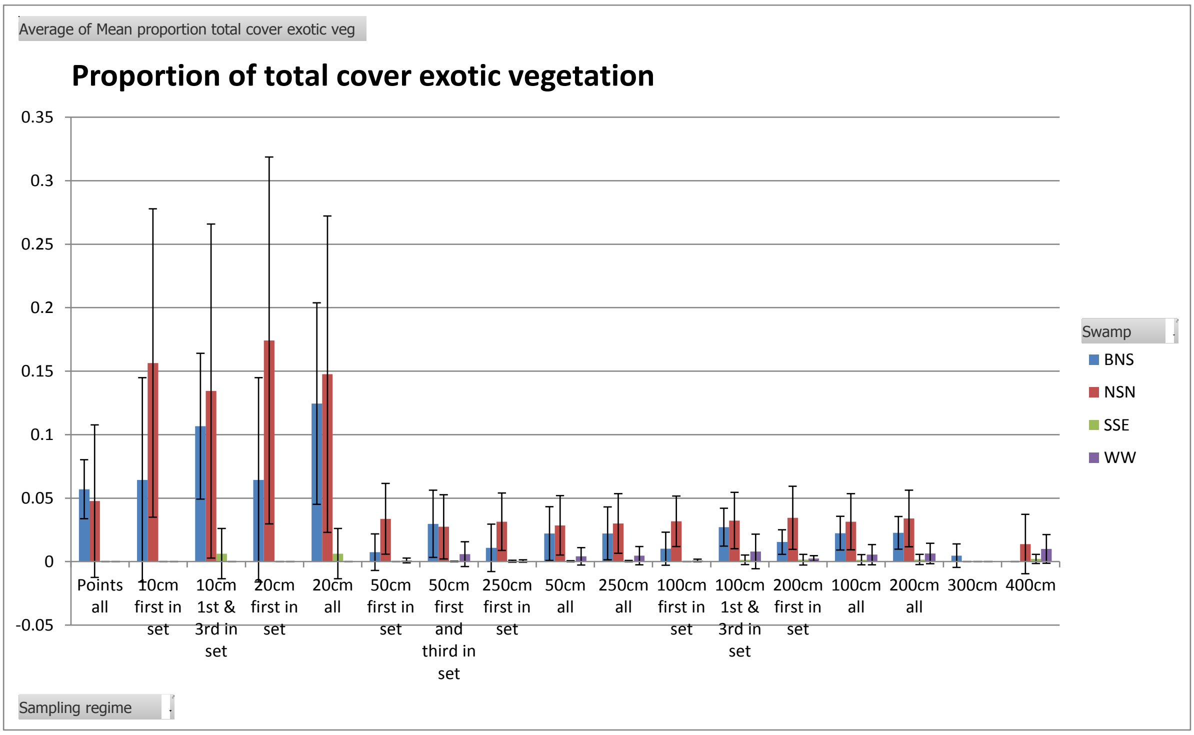

Figure 2. Mean proportion exotic vegetation cover detected (± standard deviation) using each sampling regime, per swamp.

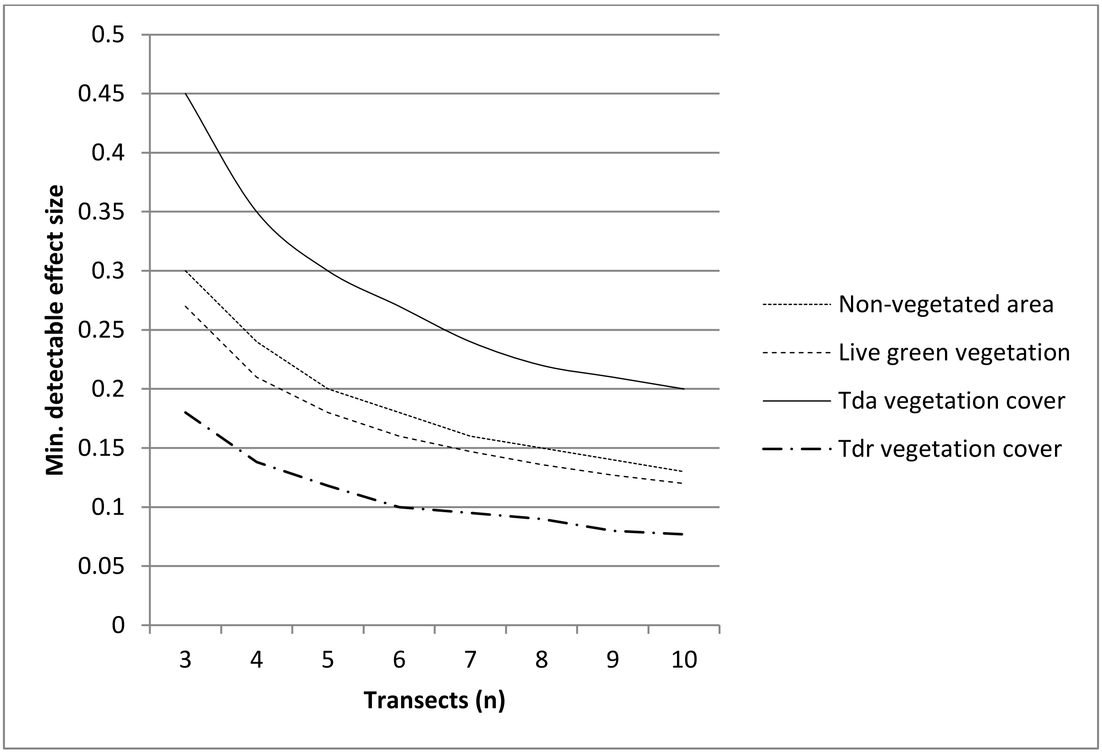

Figure 3. West Wolgan - the effects of increasing total transect number on minimum detectable effect sizes (based on the std.dev. of the change per transect between April & September surveys, a power of 0.80 and *p* = 0.10).

Table 2. Indicator variable baseline values (April 2013) and minimum increase or decrease that could be detected at the swamp scale, using a one-tailed two sample t test, with power = 0.80 and p = 0.10.

Indicator variable	Wetland (n = transects)	Mean	Std. dev.	Min. detectable effect size (i.e. absolute change detectable)	Min. detectable effect size as a proportion of the mean
*Extent of non-vegetated area (includes bare ground, leaf litter, large woody debris and water)	BNS (n = 4)	0.09	0.05	0.09	1.01
	NSN (n = 7)	0.34	0.11	0.12	0.36
	SSE (n = 10)	0.30	0.15	0.14	0.48
	WW (n = 3)	0.15	0.07	0.14	0.97
Proportion of quadrat area scored as "green" vegetation cover	BNS (n = 4)	0.79	0.08	0.13	0.17
	NSN (n = 7)	0.48	0.14	0.16	0.34
	SSE (n = 10)	0.57	0.15	0.15	0.26
	WW (n = 3)	0.60	0.05	0.09	0.16
Amphibious (Amp) vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.84	0.06	0.10	0.12
	NSN (n = 7)	0.71	0.12	0.15	0.21
	SSE (n = 10)	0.90	0.09	0.08	0.09
	WW (n = 3)	0.48	0.13	0.26	0.53
Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.09	0.04	0.07	0.85
	NSN (n = 7)	0.15	0.06	0.07	0.49
	SSE (n = 10)	0.08	0.08	0.07	0.91
	WW (n = 3)	0.09	0.02	0.04	0.45
Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.04	0.04	0.06	1.31
	NSN (n = 7)	0.13	0.08	0.09	0.72
	SSE (n = 10)	0.01	0.03	0.03	2.11
	WW (n = 3)	0.21	0.01	0.02	0.08
Exotic vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.00	0.00	NA	NA
	NSN (n = 7)	0.10	0.06	0.07	0.75
	SSE (n = 10)	0.00	0.00	0.00	1.96
	WW (n = 3)	0.00	0.00	0.00	1.83
Disturbed habitat vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.01	0.01	0.01	1.44
	NSN (n = 7)	0.15	0.08	0.10	0.65
	SSE (n = 10)	0.02	0.04	0.04	2.58
	WW (n = 3)	0.01	0.01	0.01	1.76
†Frequency of eucalypt seedling detection (proportion of quadrats sampled)	BNS (n = 4)	0.10	0.11	0.18	1.90
	NSN (n = 7)	0.01	0.04	0.04	3.11
	SSE (n = 10)	0.09	0.11	0.11	1.22
	WW (n = 3)	0.15	0.13	0.26	1.72
†Frequency of exotic species detection (proportion of quadrats sampled)	BNS (n = 4)	0.00	0.00	NA	NA
	NS (n = 7)	0.30	0.15	0.18	0.59
	SSE (n = 10)	0.02	0.05	0.05	2.07
	WW (n = 3)	0.17	0.14	0.28	1.69

*NB: Extent of non-vegetated area differs from extent of bare ground because other types of cover were included in this category in this pilot study. These include areas that lacked standing vegetation cover due to dense leaf litter, large woody debris and standing water.

†For low abundance x patchily distributed species, frequency data was typically highly variable between transects (i.e. more variable than % cover data), leading to low power to detect a change.

NA indicates inability to specify minimum detectable effect size because calculation requires a standard deviation >0.

Table 3. Minimum detectable effect sizes obtained after accounting for between-survey variability. (Power analysis based on one-tailed paired-sample t tests, with power = 0.80, p = 0.10, n = transects surveyed and standard deviation as indicated.)

Variable	Wetland (n = transects)	Mean score April 2013	Mean score Sept 2013	Mean change per transect (April to Sept)	Std. dev. (change per transect)	Min. detectable effect size
Extent of non-vegetated area (water not included)	BNS (n = 4)	0.073	0.14	0.07	0.12	0.15
	NSN (n = 7)	0.354	0.42	0.08	0.10	0.09
	SSE (n = 4)	0.306	0.29	0.08	0.12	0.15
	WW (n = 3)	0.151	0.14	0.15	0.19	0.30
Proportion of quadrat area scored as "green" vegetation cover	BNS (n = 4)	0.74	0.78	0.04	0.14	0.18
	NSN (n = 7)	0.49	0.51	0.02	0.08	0.07
	SSE (n = 4)	0.53	0.62	0.09	0.11	0.14
	WW (n = 3)	0.60	0.75	0.15	0.17	0.27
Amphibious (Amp) vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.85	0.87	0.03	0.13	0.16
	NSN (n = 7)	0.71	0.76	0.05	0.11	0.10
	SSE (n = 4)	0.92	0.92	0.00	0.03	0.04
	WW (n = 3)	0.49	0.60	0.11	0.09	0.14
Terrestrial dry (Tdr) habitat vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.08	0.07	-0.01	0.07	0.09
	NSN (n = 7)	0.08	0.08	0.00	0.06	0.05
	SSE (n = 4)	0.03	0.03	0.01	0.03	0.04
	WW (n = 3)	0.12	0.21	0.08	0.11	0.18
Terrestrial damp (Tda) habitat vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.05	0.03	-0.02	0.06	0.08
	NSN (n = 7)	0.14	0.08	-0.05	0.07	0.06
	SSE (n = 4)	0.10	0.10	0.00	0.01	0.01
	WW (n = 3)	0.50	0.24	-0.27	0.28	0.45
Exotic vegetation as a proportion of total vegetation cover	BNS (n = 4)	0.01	0.00	-0.01	0.02	0.03
	NSN (n = 7)	0.10	0.07	-0.03	0.04	0.03
	SSE (n = 4)	0.00	0.00	0.00	0.00	NA
	WW (n = 3)	0.01	0.01	-0.01	0.01	0.02
Frequency of eucalypt seedling detection (proportion of quadrats sampled)	BNS (n = 4)	0.11	0.09	-0.02	0.16	0.20
	NSN (n = 7)	0.00	0.06	0.06	0.06	0.05
	SSE (n = 4)	0.12	0.09	-0.03	0.12	0.15
	WW (n = 3)	0.15	0.11	-0.04	0.19	0.30
Frequency of exotic species detection (proportion of quadrats sampled)	BNS (n = 4)	0.12	0.07	-0.05	0.07	0.09
	NSN (n = 7)	0.54	0.57	0.02	0.10	0.09
	SSE (n = 4)	0.08	0.00	-0.08	0.06	0.08
	WW (n = 3)	0.71	0.39	-0.32	0.16	0.26

NA indicates inability to specify minimum detectable effect size because calculation requires a standard deviation >0.

References

Downes, B. J., L. A. Barmuta, P. G. Fairweather, D. P. Faith, M. J. Keough, P. S. Lake, B. D. Mapstone, and G. P. Quinn. 2002. Monitoring ecological impacts: Concepts and practice in flowing waters. Cambridge University Press, Cambridge.

Quinn, G. P. and M. J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press.

H Transect survey datasheet

Transect sampling

Swamp:

Transect no:

Assessor:

Date:

Camera:

Notes:

Start point:

Direction:

Photo no:

% cover per quadrat

Species / Non-vegetated category	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Etc
E.g. Live “green” veg cover																					
Bare ground																					
Standing water																					
Species 1																					
Species 2																					
Species 3																					
Etc																					

I Site condition datasheet

Site Condition Summary Sheet

Ground-based Vegetation Monitoring

Date: Assessors: Site:

Camera:

Photo location / waypoint:	Photo No:	Description:

Reference or Impact site (R/I):

Any evidence of possible mining-related disturbance since last survey? (Y/N):

Category	Present/absent	Waypoint
Change in water level/flow path		
Localised vegetation dieback		
Recent tree fall		
Other		

Comments

Evidence of other types of disturbance since last survey? (Y/N):

Comments

Overall appraisal of site condition

Condition score 1-5 (1 = poor, 5 = high quality): Reason:

Figure 10.6: A site condition datasheet used to summarise swamp condition.

J Transect data analysis method

Transect data analysis method

Step 1 For ease of analysis, compile the raw data from all swamps, transects and quadrats into a single file per monitoring survey as shown in the example below:

Year	Season	Assessor	Swamp	Transect	Quadrat	Field name	Scientific name / final determination	WPFG	Exotic?	% cover score
2013	Spring	A.B.	Sunnyside	1	1	Grass 1	Austrostipa rudis	Tdr		3
2013	Spring	A.B.	Sunnyside	1	1	Baum_rubi	Baumea rubiginosa	Ate		50
2013	Spring	A.B.	Sunnyside	1	1	Prunella	Prunella vulgaris	Tda	Y	1
2013	Spring	A.B.	Sunnyside	1	1	Bare area	Non-vegetated (bare)	Non-vegetated (bare)		30
2013	Spring	A.B.	Sunnyside	1	1	Bare area, inundated	Non-vegetated (inundated)	Non-vegetated (inundated)		20
2013	Spring	A.B.	Sunnyside	1	1	Total live green veg cover	% Green	% Green		
2013	Spring	A.B.	Sunnyside	1	2	.....	....	......	......	......Etc
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Once compiled all survey data should be retained in a database for use in future data analyses.

Step 2 Calculate the following summary statistics for each swamp, per transect:

Summary statistic	Description
Proportion of total area sampled that is non-vegetated (excluding inundated areas)	Sum of non-vegetated % cover scores across whole transect / Number of quadrats sampled
Proportion of area scored as live vegetation cover	Sum of all % green cover scores across transect / Number of quadrats sampled

Summary statistic	Description
Total vegetation cover	Sum of all individual species % cover scores for the whole transect. (Exclude cover scores for % green cover and non-vegetated area classes.)
Proportion amphibious vegetation cover	Sum of all A, Amp, Ate, Atl, Atw & Arp species % cover scores / Total vegetation cover
Proportion Tdr vegetation cover	Sum of all Tdr species % cover scores / Total vegetation cover
Proportion Tda vegetation cover	Sum of all Tda species % cover scores / Total vegetation cover
Proportion exotic vegetation cover	Sum of all exotic species % cover scores / Total vegetation cover
*Frequency of eucalypt &/or pine seedling detection	Total quadrats with eucalypt seedlings present / Number of quadrats sampled
*Abundance of eucalypt &/or pine seedlings	Total eucalypt seedling count

*If eucalypt seedlings are found not to be a useful indicator of drying, these may be dropped (i.e. if numbers of eucalypt seedlings present at wet sites is not found to be lower than numbers at drier sites, based on baseline transect surveys).

Step 3 For each variable, conduct a one-tailed paired sample t-test, comparing data between surveys at the swamp scale:

E.g. Test for increase in proportion non-vegetated area at Sunnyside Swamp after undermining.

Data: Sunnyside Swamp, proportion non-vegetated area per transect

Transects	Sample 1 (Before undermining)	Sample 2 (Current monitoring survey – After undermining)
1	0.10	0.20
2	0.15	0.15
3	0.20	0.24
4	0.05	0.04
5	0.10	0.20
6	0.11	0.19

Results: t = 2.57, degrees of freedom = 5, p-value = 0.025.   Mean increase in proportion non-vegetated area = 0.052 (i.e. ~5% of the area surveyed)

Interpretation: The proportion of non-vegetated area recorded in the current monitoring survey was significantly higher than recorded in the baseline survey (p = 0.025). However, the magnitude of the change was small and did not exceed the trigger level for this variable.

K Methods for defining and revising trigger levels

Defining trigger levels Here we have defined some preliminary trigger levels for the indicator variables listed in Table 6.2. These are based on analysis of transect data collected during a pilot study, involving a limited number of sites (n = 4). The four swamps selected included one swamp impacted by previous mine water discharge (Narrow Swamp), two reference swamps that have not been undermined (Sunnyside East and Bungleboorie North) and one site that has been undermined but does not exhibit obvious signs of hydrological disturbance (West Wolgan, northern section). The preliminary trigger levels shown here were selected on the basis that pilot study data demonstrated changes of these magnitudes, or lower, could be detected using the methodology outlined in this handbook, across all four pilot study sites, with a statistical power of 0.80 and a significance level of $p \leq 0.10$.

For further details of the pilot study, including methods, the data collected (means and standard deviations for each indicator variable per swamp) and minimum detectable effect sizes based on power analysis, for each site, refer to Appendix G.

Revision of trigger levels For each of the indicators described in the above section, trigger levels will be reviewed and updated on an individual monitoring report basis, by comparing the values of each indicator variable recorded at potential impact sites with those recorded at reference sites as defined by DSEWPAC (2012). This model complies with an adaptive management framework and will ensure that trigger levels are kept up to date on an ongoing basis, as new data are collected and as additional sites are added.

L Justification of indicator selection

Changes in water plant functional group (WPFG) cover Freshwater wetland plant communities are often highly variable in species composition and abundance, at both the local and regional scale (Boulton and Brock, 1999). Monitoring reports produced to date have shown that this is also true for Newnes Plateau THPSS plant communities (Brownstein et al., 2013). The inherent variability in vegetation composition and structure found both between swamps and between different areas within swamps on the Newnes Plateau makes it difficult to: i) make overarching predictions about the changes in species composition likely to occur if water regimes are altered, ii) choose indicator species to monitor, or iii) define management response triggers, based on species composition, that will be relevant across the full range of wetlands involved. Assessments of plant functional group composition, rather than species composition, have been recommended for addressing these issues by a number of researchers both in Australia and overseas (Reid and Quinn, 2004; Casanova, 2011; Cole and Kentula, 2011).

Classifying species into groups based on their hydrological requirements (e.g. hydrophytes versus non-hydrophytes) makes it easier to identify and describe differences in vegetation community composition linked to differences in water availability. The water plant functional group (WPFG) classification developed by Brock et al. (Britton and Brock, 1994; Brock and Casanova, 1997; Casanova, 2011) is widely recognised and has been successfully used to demonstrate the effects of differences in water regime on wetland plant communities in a range of contexts (Leck and Brock, 2000; Liu et al., 2006; Robertson and James, 2007). WPFG composition and abundance have been used specifically as indicators for monitoring wetland condition in other, past and current/ongoing, Australian wetland monitoring programs (Reid and Quinn, 2004; Alexander et al., 2008; Campbell et al., 2014) and are recommended here. In Appendix N we demonstrate that WPFG categories are effective for demonstrating differences in NPSS and NPHS vegetation composition based on differences in water availability between monitoring sites.

Table 10.8 contains a list of WPFG categories that are applicable to Newnes Plateau swamp species and their definitions. Details of how to classify species into these categories can be found in Britton and Brock (1994), Reid and Quinn (2004) and Casanova (2011). A list of NPSS and NPHS species recorded in previous monitoring surveys and their applicable WPFG categories is also provided in Appendix N.

Other vegetation condition indicators Other indicator variables to detect the effects of drying on Newnes Plateau swamp vegetation include senescence of vegetation, increases in the extent of bare ground, increases in the abundance of opportunistic pioneer species and increases in eucalypt seedling establishment. Increases in bare ground could occur in swamps that are subject to large and/or sudden surface or groundwater level fluctuations, as seen in East Wolgan swamp following the cessation of mine-water discharge (see Appendix E). Senescence of wetland vegetation (i.e. reduction in the extent of live, green vegetation cover) may occur before increases in bare ground become apparent. Changes in the extent of bare ground and in live green vegetation cover are therefore both recommended here as indicators of severe and/or rapid drying. For these variables cover scores can also be used to ground-truth and classify high-resolution aerial imagery (refer back to 5).

Increases in exotic and/or opportunistic species abundance can provide a useful indicator of change because early-successional invasive plants are often the first to colonise after a

Table 10.8: Water plant functional groups applicable to Newnes Plateau swamp species (from Brock and Casanova, 1997; Casanova, 2011)

Functional group	**Definition**
Terrestrial (T)*	Species that do not possess adaptations that will help them withstand flooding while in the vegetative state.
Terrestrial, damp habitat (Tda)	Terrestrial species that characteristically inhabit damp habitats.
Terrestrial, dry habitat (Tdr)	Terrestrial species that typically occur in drier habitats.
Amphibious (A)*	Species that tolerate (AT) or respond (AR) to fluctuations in surface water presence/absence.
Amphibious emergent (ATe) (fluctuation tolerator)	Emergent species, including sedges and rushes, that tolerate fluctuations in surface water availability without changing growth form.
Amphibious low growing (ATl) (fluctuation tolerator)	Low-growing species that tolerate both immersion and drawdown/damp conditions.
Amphibious woody (ATw) (fluctuation tolerator)	Woody perennial species that require flooding during some stage of their life cycle, but tolerate fluctuations in surface water availability.
Amphibious plastic (ARp) (fluctuation responder)	Species that respond to changes in surface water availability with morphological plasticity (i.e. change growth form substantially depending on water presence/absence and depth).

*During preliminary classification some species may be placed in the overarching categories A or T if there is insufficient information available to classify them into a more specific WPFG subcategory. Classifications may be revised and refined as additional information becomes available.

disturbance. However, it should be noted that while such increases could occur due to altered hydrology, increases in exotic and opportunistic species abundance can also occur due to a range of other types of disturbance. It is therefore important that such changes, if detected, are interpreted in conjunction with other evidence of wetland drying and are not taken as conclusive evidence of drying in the absence of other supporting information (such as direct evidence of a reduction in groundwater depth) .

In previous monitoring assessments of weedy species diversity and abundance have not always explicitly defined which species should be included in this weedy species category and why. Both exotic and native species can be considered weeds depending on location and context and the criteria for native species inclusion/exclusion in this category are somewhat subjective. In future monitoring we recommend focusing on the abundance of exotic species only, as listed in the Atlas of NSW Wildlife - Census of Australian Plant Taxa (OEH, 2013) and defined on the National Herbarium of NSW website (PlantNET, 2013). Nomenclature follows CHAH (2011) (NB: Those native species that have been listed as weedy in previous monitoring reports are terrestrial dry and damp habitat species (i.e. Tdr and Tda functional groups). Increases in the abundance of these species will be detected as an increase in Tdr and/or Tda vegetation cover at monitoring sites.

Newnes Plateau swamps occur adjacent to eucalypt forest (and/or radiata pine plantations) and waterlogging is thought to have an environmental filtering effect, limiting the establishment of eucalypt seedlings in wetland areas (Benson and Baird, 2012). Woody species encroachment has also been demonstrated to be a useful indicator of wetland drying in wetlands elsewhere (Tiner, 1999; Keddy, 2010). Increases in eucalypt and/or pine seedling abundance are recommended as a potential indicator of drying here. However, it should be noted that further work needs to be done to determine whether or not eucalypt seedling abundance (i.e. number of recently established seedlings <1m in height) actually differs between wet and dry sites.

While mature tree numbers within swamp boundaries are low, data have not yet been collected across enough swamps to determine if the abundance of tree seedlings shows a similar trend. Evidence from a pilot study, comparing eucalypt detection frequencies between two wet swamps (Bungleboorie North and Sunnyside East) and two drier swamps (West Wolgan and Narrow Swamp) indicates that frequency of eucalypt seedling detection may not be an effective indicator of site dryness, because seedling detection frequencies in the two wet swamps (BNS and SSE) were similar or higher than those in the dry swamps (WW and NSN).

M Demonstration of relationship between the vegetation indicator variables selected for ground-based monitoring and site wetness

Data collection

Point intercept data were collected from all existing seasonal vegetation monitoring plots in Newnes Plateau Shrub Swamps (MU50) and Newnes Plateau Hanging Swamps in Spring 2012. Species composition was recorded at points spaced every 50cm along four transects per 20 x 20m plot and along eight transects per 10 x 40m plot, summing to a combined total transect length of approx. 80m per plot.

Classification of plots based on relative water availability

Each of the 20m x 20m monitoring plots was classified into one of two hydrology groups, 'Wet' or 'Dry'. These were allocated based on water permanence, as determined from field observations over the previous four years of seasonal vegetation monitoring surveys (McKenna pers. comm.). Plots characterised by the presence of standing water throughout the year were classified as 'Wet', while those with permanently low, or variable, water tables were classified as 'Dry'. Plots were also classified into two groups based on their location within the wetland, 'Edge' or 'Middle'. Edge plots were located in the wet/dry ecotone at the wetland/forest boundary, while middle plots were located near the midpoint, or lowest elevation of the wetland vegetation community.

Data analysis

All species were classified into water plant functional groups (WPFG). Next, cover scores (i.e. total number of times encountered) were calculated for each species, per transect, and summed at the WPFG level to obtain a total cover score per group. Total cover was also calculated for non-vegetated area (i.e. total number of sample points where no vegetation was detected).

The data were analysed using the statistical package PRIMER v.6. A Bray-Curtis dissimilarity matrix was calculated, using WPFG cover scores to for between-transect comparisons. This dissimilarity matrix was used to produce an non-metric multi-dimensional scaling (nMDS) plot to display differences in indicator variable scores according to hydrology group (Wet/Dry) and plot position (Edge/Middle). We then averaged indicator variable scores at the plot scale (i.e. pooled all transects per plot) and used a permutational multivariate analysis of variance PERMANOVA to determine if indicator variable scores differed significantly according to plot hydrological category (Wet/Dry) or position (Edge/Middle), and if there was any interaction between these terms. Hydrological category and plot position were treated as fixed factors and the test was run with permutation of residuals under a reduced model and 999 permutations of the raw data. Where significant differences were detected between categories of plots, similarity percentage (SIMPER) analyses was performed to determine the nature and extent of these differences.

Results

Significant differences were detected in indicator variable scores, both between “Wet” and “Dry” plots (p = 0.001) and between “Edge” and “Middle” plots (p = 0.001). There was no significant interaction between these terms (Table 1).

The main differences detected between these plot categories, as reflected in the SIMPER analysis and in Figure 1 are as follows:

Edge plots, on average, contained a higher abundance of points scored as non-vegetated, lower abundance of inundation-tolerant shrubs (Atw) and sedges and rushes (Ate) and a higher abundance of terrestrial dry (Tdr) habitat vegetation than middle plots (Figure 1, Table 2).

Wet plots, on average, contained a higher abundance of amphibious vegetation (Ate, Atw and Arp groups) and much lower average abundance scores for terrestrial dry (Tdr) and terrestrial damp (Tda) habitat vegetation, and areas scored as non-vegetated, than dry plots (Figure 1, Table 2).

Figures and tables

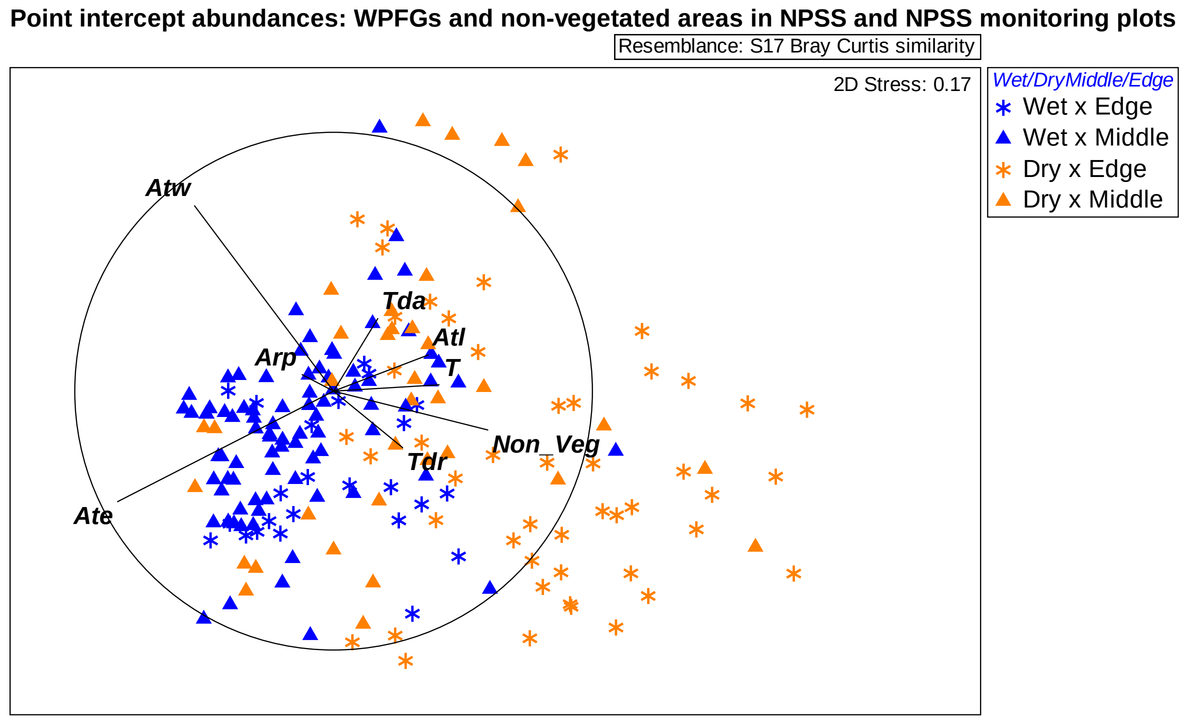

Figure 1. Relationship between indicator variable scores and plot class (Wet/Dry and Edge/Middle)

Table 1. PERMANOVA output

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors

Name	Abbrev.	Type	Levels
Wet/Dry	We	Fixed	2
Middle/Edge	Mi	Fixed	2

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
We	1	5706.6	5706.6	11.883	**0.001**	999
Mi	1	2561	2561	5.3329	**0.001**	998
WexMi	1	250.1	250.1	0.52081	0.717	999
Res	42	20169	480.22			
Total	45	30106				

Details of the expected mean squares (EMS) for the model

Source	EMS
We	1*V(Res) + 18.806*S(We)
Mi	1*V(Res) + 18.806*S(Mi)
WexMi	1*V(Res) + 9.403*S(WexMi)
Res	1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares

Source	Numerator	Denominator	Num.df	Den.df
We	1*We	1*Res	1	42
Mi	1*Mi	1*Res	1	42
WexMi	1*WexMi	1*Res	1	42

Estimates of components of variation

Source	Estimate	Sq.root
S(We)	277.91	16.671
S(Mi)	110.64	10.519
S(WexMi)	-24.473	-4.947
V(Res)	480.22	21.914

Table 2. SIMPER output

Section 1. Examines Wet/Dry groups (across all Middle/Edge groups)

Characteristics of plots within "Wet" group
Average similarity: 76.75

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ate	182.89	49.05	4.03	63.92	63.92
Atw	93.11	24.09	2.57	31.39	95.30
Tda	8.61	1.44	0.88	1.87	97.17
Tdr	14.31	1.18	0.43	1.53	98.71
Atl	5.08	0.54	0.46	0.71	99.41
T	3.06	0.29	0.60	0.37	99.79
Non_Veg	1.89	0.14	0.31	0.18	99.97
Arp	1.06	0.03	0.14	0.03	100.00

Characteristics of plots within "Dry" group
Average similarity: 64.34

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%

Ate	114.54	32.20	3.22	50.04	50.04
Atw	61.87	13.00	1.26	20.21	70.25
Tda	28.18	5.70	1.31	8.87	79.12
Tdr	23.69	5.53	1.06	8.60	87.72
T	21.06	4.34	0.92	6.75	94.47
Atl	17.62	3.09	1.03	4.80	99.26
Non_Veg	4.49	0.47	0.39	0.74	100.00

Comparision of groups WET & DRY
Average dissimilarity = 35.71

Species	Group WET Av.Abund	Group DRY Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ate	182.89	114.54	14.03	1.44	39.29	39.29
Atw	93.11	61.87	8.20	1.34	22.96	62.25
Tda	8.61	28.18	4.31	1.40	12.06	74.31
T	3.06	21.06	2.93	1.23	8.21	82.53
Atl	5.08	17.62	2.63	1.20	7.38	89.90
Tdr	14.31	23.69	2.49	0.87	6.97	96.88
Non_Veg	1.89	4.49	0.93	0.63	2.59	99.47
Arp	1.06	0.04	0.19	0.34	0.53	100.00

Section 2. Examines Middle/Edge groups (across all Wet/Dry groups)

Characteristics of plots within "Edge" group
Average similarity: 67.75

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ate	128.91	37.09	4.05	54.74	54.74
Atw	58.39	11.24	1.37	16.59	71.33
Tdr	37.91	8.28	1.59	12.22	83.56
T	16.02	4.41	0.83	6.52	90.07
Tda	15.28	3.83	1.19	5.65	95.73
Atl	12.13	2.36	0.78	3.48	99.21
Non_Veg	3.95	0.52	0.37	0.77	99.98
Arp	0.17	0.01	0.22	0.02	100.00

Characteristics of plots within "Middle" group
Average similarity: 74.86

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ate	168.39	46.42	3.29	62.01	62.01
Atw	91.84	23.57	2.37	31.49	93.50
Tda	17.45	2.26	0.71	3.02	96.52
Atl	9.26	0.94	0.52	1.25	97.77
Tdr	7.67	0.88	0.52	1.17	98.94
T	7.55	0.61	0.46	0.82	99.76
Non_Veg	2.44	0.16	0.35	0.21	99.97
Arp	0.88	0.02	0.12	0.03	100.00

Comparison of groups Edge & Middle
Average dissimilarity = 31.23

Species	Group Edge Av.Abund	Group Middle Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ate	128.91	168.39	9.94	1.35	31.83	31.83
Atw	58.39	91.84	8.27	1.34	26.49	58.32
Tdr	37.91	7.67	5.55	1.30	17.77	76.09
Tda	15.28	17.45	2.72	0.98	8.72	84.81
Atl	12.13	9.26	1.89	0.94	6.05	90.86
T	16.02	7.55	1.84	0.77	5.90	96.76
Non_Veg	3.95	2.44	0.86	0.63	2.75	99.51
Arp	0.17	0.88	0.15	0.33	0.49	100.00

N Classification of Newnes Plateau plant species into water plant functional groups (WPFG)

This Appendix contains a list of plant species recorded previously in Newnes Plateau THPSS and details of their functional group classification, including information sources used. Where species had been classified into WPFG previously based on experimental data or on extensive field observations (Brock and Casanova 1997, Casanova and Brock 2000, Reid and Quinn 2004), we allocated species to the same groups. The remaining species were classified as per the methods of Britton and Brock (1994), Reid and Quinn (2004) and Casanova (2011), based on morphology, ecological information obtained from; scientific publications, herbarium records (i.e. AVH 2013), observations from seasonal field monitoring surveys and the results of a seed-bank germination and growth experiment conducted by CMLR in 2013 (C. Johns, unpublished data). Details of references are provided at the end of this appendix. **NB**: For some species, WPFG classifications may be updated as more information becomes available. We have flagged classifications that we consider to be borderline based on the information currently available.

References

AVH. 2013. Australia's Virtual Herbarium: A database of herbarium record information from the collections held in Australias major state and territory herbaria (http://avh.chah.org.au/).
Britton, D. and M. Brock. 1994. Seasonal germination from wetland seed banks. Marine and Freshwater Research 45:1445-1457.
Brock, M. and M. Casanova. 1997. Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. Pages 181-192 in N. Klomp and I. Lunt, editors. Frontiers in ecology: Building the links. Elsevier Science, Oxford.
Casanova, M. 2011. Using water plant functional groups to investigate environmental water requirements. Freshwater Biology 56:2637-2652.
Casanova, M. and M. Brock. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? Plant Ecology 147:237-250.
Cunningham, G. M., W. E. Mulham, P. L. Milthorpe, and J. H. Leigh. 1992. Plants of Western New South Wales. Inkata Press, Marrickville, NSW.
Johns, C., Fletcher, A. and Erskine. In prep. The effects of water table depth and stability on establishment and persistence of wetland macrophytes from Newnes Plateau wetland soil seed banks. (Manuscript in prep. for submission to Aquatic Botany.) PlantNET. 2012. PlantNET: NSW flora online. National Herbarium of New South Wales. (http://plantnet.rbgsyd.nsw.gov.au/floraonline.htm).
Reid, M. and G. Quinn. 2004. Hydrologic regime and macrophyte assemblages in temporary floodplain wetlands: Implications for detecting responses to environmental water allocations. Wetlands 24:586-599.
Romanowski, N. 1998. Aquatic and wetland plants: A field guide for non-tropical Australia. UNSW Press, Sydney, NSW.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Acacia acicularis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry sclerophyll forest, heath and woodland in sandy and clay loam soils. Occoasionally recorded at the edges of wetlands or creeklines (approx 7% of herbarium records, 154 assessed in total).
Acacia buxifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in dry sclerophyll forest, woodland and heath, often on hillslopes on sandy or gravelly areas.
Acacia dorothea	Shrub	Perennial	Ter	Tdr		F		AVH (2013)	Chiefly collected from scrub and dry sclerophyll forest habitats.
Acacia longifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in sclerophyll communities and coastal heath and scrub, often collected from sand on foredunes. Grows to 8m high (described as shrub or tree).
Acacia melanoxylon	Tree	Perennial	Ter	Tdr	Tdr/Tda	F		PlantNET (2013); AVH (2013)	Frequently occurs as a fringing species rather than a true wetland species. Often collected from sites on creek banks and occasionally from dry creek beds or similar. Described as widespread, particularly at higher altitudes and grows in a variety of habitats, chiefly in wet sclerophyll forest and in or near cool rainforest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Acacia obtusifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in dry and wet sclerophyll forest, woodland and heath, in sandy and loam soils, mostly on sandstone but also on basalt. Only very occasionally collected from dry water courses i.e. areas that may be inundated at times. Grows to 8m high (described as tree or shrub).
Acacia spp.	Shrub or Tree	Perennial	Ter	T		F		PlantNET (2013)	
Acacia terminalis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in dry sclerophyll forest, woodland and heath, usually on sandstone.
Acacia ulicifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry sclerophyll woodland and forest, usually in sandy soil.
Acaena ovina	Forb	Perennial	Ter	Tdr		F	D	Cunningham et al (1992); PlantNET (2013); AVH (2013)	Most frequently collected from disturbed areas, including roadsides. Occasionally collected in moist drainage lines, creek beds and similar moist habitats.
Agrostis bettyae	Grass	Perennial	Amp	ATe	ATe/Tda	F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	Described as occurring in montane woodland, but has often been collected from areas described as damp ground or as seasonally wet areas, at the edges of wetlands or drainage lines or in areas with poor drainage.
Agrostis spp.	Grass	Perennial	Ter/Amp	T		F		PlantNET (2013)	Some species occur in bogs.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Allocasuarina littoralis	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in woodland or occasionally tall heath, on sandy or otherwise poor soils. Very occasionally collected from (intermittently wet?) creek beds or drainage lines.
Allocasuarina nana	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in heath on sandstone, especially in exposed situations such as ridges.
Amperea xiphoclada	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as widespread in heath, woodland and forest on low-fertility sandy soils.
Amyema pendulum	Mistlet oe	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Mistletoe. Described as parasitic on Eucalyptus and locally common on several Acacia species.
Amyema spp.	Mistlet oe	Perennial	Ter	Tdr		F		PlantNET (2013)	Classification based on habitat of host spp. found in Newnes Plateau surveys.
Anagallis arvensis	Forb	Annual or Perennial	Ter	Tda		F	D	PlantNET (2013); AVH (2013)	Described as perennial or annual and widespread in pastures, disturbed sites and creek banks (PlantNET 2012). Similar habitat to Conyza bonariensis, which was classified as Tda by Reid & Quinn (2004).
Aristida ramosa	Grass	Perennial	Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Described as occurring in woodland on poor soils. Often collected from roadsides, pastures, cleared areas.
Aristida spp.	Grass	Annual or Perennial	Ter	Tdr		F		PlantNET (2013)	Described as frequenly ocurring in low rainfall areas and on poor soils.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Arrhenechthites mixta	Forb	Perennial	Ter	Tdr		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Name change to A. mixtus. Established inUQ glasshouse experiment under free-draining conditions only.
Arthropodium milleflorum	Forb	Perennial	Ter	Tda	Tda/ATl	F		PlantNET (2013); AVH (2013)	Described as occurring in a variety of habitats (quite common in grasslands and woodlands i.e. dry to moist sites, but occasionally in boggy/swampy areas too).
Arthropodium minus	Forb	Perennial	Ter	Tda	Tda/Tdr	F		PlantNET (2013); AVH (2013)	Described as occurring in a variety of habitats.
Arthropodium spp.	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as occurring in a variety of habitats
Asplenium flabellifolium	Fern	Perennial	Ter	Tda		F		Cunningham et al (1992); PlantNET (2013); AVH (2013)	A trailing terrestrial species, occurring in sheltered, moist shady conditions, mainly found in rock crevices but sometimes epiphytic in rainforest.
Astrotricha spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2012); AVH (2013)	Described habitats include wet sclerophyll forest, rainforest margins and dry sclerophyll forest. (Hydrophyte classification based on species found in following IBRA Bioregions: Sydney Basin, South Eastern Highlands, NSW Southwestern Slopes)
Austrodanthonia eriantha	Grass	Perennial	Ter	Tdr		F	D	PlantNET (2012); AVH (2013)	Described as occurring in a variety of habitats, including moderately disturbed areas e.g. roadsides and pastures. Now called Rhytidosperma erianthum.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Austrodanthonia penicillata	Grass	Perennial	Ter	T		F		PlantNET (2012); AVH (2013)	Now Rytidosperma penicillatum. Described as occurring in grassland and open woodland, often on slopes.
Austrodanthonia pilosa	Grass	Perennial	Ter	T		F		PlantNET (2012); AVH (2013)	Described as occurring in a variety of habitats. Now called Rhytidosperma pilosum.
Austrodanthonia setacea	Grass	Perennial	Ter	T		F		PlantNET (2012); AVH (2013)	Now Rhytidosperma setaceum. Occurs in a variety of habitats, including in moist areas e.g. roadside drains.
Austrodanthonia spp.	Grass	Perennial	Ter	Tdr		F		PlantNET (2012)	Described as occurring in a variety of habitats. Now Rhytidosperma.
Austrostipa pubescens	Grass	Perennial	Ter	Tdr		F		PlantNET (2012); AVH (2013)	Described as growing in woodland and heath on sandstone.
Austrostipa rudis	Grass	Perennial	Ter	Tdr		F		PlantNET (2012); AVH (2013)	Described as occurring in woodland.
Austrostipa spp.	Grass	Perennial	Ter	Tdr		F		PlantNET (2012)	

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Baeckea linifolia	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2012); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs; P. McKenna pers. obs.	Typically recorded in wet heath and in damp places, such as in riparian vegetation along creek banks, near waterfalls, in drainage lines or similar habitats. Observed in wetland areas subject to shallow surface inundation by UQ field staff. Seedlings established in both free-draining and waterlogged conditions in UQ glasshouse and Tolerated subsequent shallow inundation (3-5cm, ~8 weeks), maintaining growth even when completely submerged.
Baeckea spp.	Shrub	Perennial	Ter/Amp	T/ATw		F		PlantNET (2013)	Some species primarily occur in wet areas, while others are found in drier places.
Baeckea utilis	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2012); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs; P. McKenna pers. obs.	Described as occurring in heath or sclerophyll forest, typically in wet places. Often found at the edges of swamps, creeks or drainage lines. Observed in wetland areas subject to shallow surface inundation by UQ field staff. Seedlings established in free-draining and waterlogged conditions in UQ glasshouse and Tolerated subsequent shallow inundation (3-5cm, ~8 weeks even when completely submerged.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Baloskion australe	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	Usually described as occurring in wet peaty, sandy or gravelly soil and in Sphagnum bogs. Sometimes found in forest and/or extending upslope from drainage lines into drier areas. Has been seen growing in a few cm of water at some Newnes Plateau wetland sites.
Baloskion fimbriatum	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Described as occurring in wet and poorly drained, deep sandy soils. Frequently found at wetland edges, in the ecotone between the wet swamp edge and surrounding drier habitat vegetation.
Baloskion gracile	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Described as occurring in wet and poorly drained deep, sandy or peaty soils. Also often collected from non-wetland sites.
Baloskion spp.	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013)	Described as generally occurring in swampy, peaty areas.
Banksia cunninghamii	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry sclerophyll forest
Banksia ericifolia	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs.	Described as occurring in heath, dry sclerophyll forest and woodland. Also sometimes found in swampy situations (c. 10% of AVH records from NSW & ACT). Observed growing in waterlogged soil at one Newnes Plateau wetland monitoring site.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Banksia marginata	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry sclerophyll forest
Banksia spinulosa	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in heath, dry sclerophyll forest and woodland.
Banksia spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Classified based on distribution records of other species listed in this table only.
Bauera spp.	Forb/S hrub	Perennial	Ter	T		F		PlantNET (2013)	Only three species described for this genus in NSW. Habitats range from open heath to wet areas.
Baumea rubiginosa	Sedge/ Rush	Perennial	Amp	ATe		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as occurring in swamps and other damp areas, on sandy soils. Established inshallow water (3-5cm deep) in UQ glasshouse experiment.
Baumea spp.	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013)	Described variously as occurring in permanently moist areas, in standing water, along streams and in swamps.
Billardiera scandens	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as common in open eucalypt forest and woodlands.
Blechnum ambiguum	Fern	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as common on wet rocks, near waterfalls, on cliff faces and in similar situations.
Blechnum cartilagineum	Fern	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as widespread and hardy, occurring in open forest and rainforest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Blechnum minus	Fern	Perennial	Amp	ATe	ATe/Tda	F		PlantNET (2013); Romanowski (1998); AVH (2013)	Described most often as forming colonies along creek banks on wet to waterlogged soil just above the water line and in seasonally waterlogged swamps, usually in partly shaded places.
Blechnum nudum	Fern	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998); AVH (2013); N. McCaffrey pers. obs.; C. Johns pers. obs.	Occurs in moist to waterlogged areas including rainforest gullies, stream banks and sometimes in swamps, in forested places, often partly shaded. Has been observed in wet areas in a few cm of water on the Newnes Plateau.
Blechnum patersonii	Fern	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998); AVH (2013)	Described as being found often along creeks or in rock crevices, in rainforest and moist gullies.
Blechnum spp.	Fern	Perennial	Amp	ATe	ATe/Tda	F		PlantNET (2013)	
Boronia deanei	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013); P. McKenna pers. obs.	Described as growing in wet heath and mainly collected from around the margins of swamps.
Boronia microphylla	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in heath and dry sclerophyll forest on sandstone. Approx. 5% of collection records from riparian or poorly drained areas.
Boronia spp.	Shrub	Perennial	Ter	T		F		PlandNET (2013)	
Bossiaea heterophylla	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as common on sandy soils in a variety of habitats.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Bossiaea lenticularis	Shrub	Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); C. Johns pers. obs	Described as occurring in dry sclerophyll forest, often in moist sites. Sometimes collected around edges of swamps. Single specimen Established infree-draining conditions in UQ glasshouse experiment.
Brachyloma daphnoides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in heath, dry sclerophyll forest and woodland, usually on sandy soils.
Brachyscome graminea	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Often described as occurring on moist or swampy ground.
Brachyscome scapigera	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring in sclerophyll forest, frequenly on swampy ground.
Brachyscome spathulata	Forb	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as occurring on heavy soils in open areas, including in woodlands, grasslands and alpine meadows.
Brachyscome spp.	Forb	Annual or Perennial	Ter	T		F		PlantNET (2013)	
Caesia parviflora	Forb	Perennial	Ter	Tdr	Tdr/Tda	F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs.	Described as occurring in heath (including wet and dry heath), woodlands and dry sclerophyll forests on sandstone-derived soils. Sometimes observed at damp/waterlogged sites by UQ staff.
Caladenia spp.	Forb		Ter	Tdr		F		PlantNET (2013)	Generally described as occurring most commonly in dry sclerophyll forests or woodlands.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Callicoma serratifolia	Shrub or Tree	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring mainly in rainforest and being common along creeks and rocky gullies.
Callistemon pityoides	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013)	Described as occurring in wet places, including wet heath and riparian scrub as well as in swamps. Typically collected from boggy areas, often in peaty granitic heathland or sometimes in shallow and/or running water in open sites.
Calochilus spp.	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Most spp occur mainly in dry sclerophyll forest and similarly dry/terrestrial environments, but C. paludosis is also often found in swampy heaths and on damp peaty soils. Calochilus grandiflorus is also occasionally found in peaty, swampy areas.
Calochlaena dubia	Fern	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Decribed as widespread in tall open forest, usually on poorer soils. Often found in moist to wet areas, including lining creeks.
Calytrix tetragona	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occcurring in heath, woodland and dry sclerophyll forest, particularly on skeletal and sandy soils.
Carex gaudichaudiana	Sedge/ Rush	Perennial	Amp	ATe		F		Reid & Quinn (2004); PlantNET (2013); Romanowski (1998); AVH (2013)	Described as occurring in swamps, in shallow water and on creek banks.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Carex inversa	Sedge/ Rush	Perennial	Amp	ATe		F		Cunningham et al (1992); PlantNET (2013)	Described in PlantNET as being widespread in grassland and open forest (drier sites), but according to Cunningham et al (1992), it grows in moist situations such as swamps, river flats and regularly flooded roadside drains (i.e. areas that have standing water some of the time).
Carex spp.	Sedge/ Rush	Perennial	Amp	ATe		E,F		Brock & Casanova (1997); Casanova & Brock (2000); PlantNET (2013); C. Johns pers. obs	Brock & Casanova may not be referring to the same Carex sp., but the UQ survey team have recorded this Carex in swampy areas only on the Newnes Plateau (i.e. subject to wetting and drying) and it should have a broadly similar life-history.
Cassinia aculeata	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occuring in sclerophyll forest, woodland and heath on sandy or gravelly soils.
Cassinia compacta	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in sclerophyll forest and wooldand on sandy and clay soils and rocky sandstone ridges.
Cassinia uncata	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in mallee or dry sclerophyll forest, on ridges in gravelly or silty soil.
Cassytha glabella	Vine	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Parasitic twiner.
Caustis recurvata	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in coastal sandy heath and mountain heath.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Celmisia longifolia	Forb	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013); P. McKenna pers. obs.	Described as usually occurring in bogs or seepages. Often observed in wet swamps on the Newnes Plateau by UQ staff.
Celmisia spp.	Forb	Perennial	Ter	Tda		F		PlantNET (2013)	
Centaurium erythraea	Forb	Annual or Biennial	Ter	Tda	Tda/Tdr	E,F	D	PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as widespread, especially in pastures. Frequently an early coloniser of floodplain areas and wetland margins after drawdown. Occurs in similar situations to *Cirsium vulgare* (classified as Tda by Brock & Casanova 1997). Established in damp free-draining conditions in UQ glasshouse experiment and did not survive subsequent immersion.
Centaurium spp.	Forb	Annual or Biennial	Ter	Tda	Tda/Tdr	F	D	PlantNET (2013); AVH (2013)	Described as widespread, especially in pastures and/or settled areas.
Centaurium tenuiflorum	Forb	Annual or Biennial	Ter	Tda	Tda/Tdr	F	D	PlantNET (2013); AVH (2013)	Described as widespread in settled areas but uncommon. Frequently an early coloniser of floodplain areas and wetland margins after drawdown. Occurs in similar situations to Cirsium vulgare (classified as Tda by Brock & Casanova 1997).
Centella asiatica	Forb	Perennial	Ter	Tda		F	D	PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	Described as growing mainly in damp places.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Centipeda minima	Forb	Annual	Amp	ATl		E,F		Casanova & Brock (2000); Reid & Quinn (2004); PlantNET (2013); AVH (2013)	Common in damp areas, including areas subject to flooding where it typically germinates during drawdown.
Centipeda spp.	Forb	Annual or Perennial	Amp	ATl		E,F	D?	PlantNET (2013)	PlantNET describes these species as occurring in damp places or areas subject to flooding. Centipeda minima and C. cunninghamii can germinate underwater (own unpublished experimental results).
Characeae indeterminate	Macroalgae		Aqu	Sr		E,F		Casanova (2011); AVH (2013)	
Chiloglottis spp.	Forb		Ter	T		F		PlantNET (2013)	Described as occurring in various habitats, from damp to dry.
Cirsium vulgare	Forb	Biennial	Ter	Tda	Tda/Tdr	E,F	D	Brock & Casanova (1997); PlantNET (2013); AVH (2013); Johns et al (In prep.)	Classified as Tda by Brock & Casanova (1997). However, often occurs in dry locations and disturbed habitats. Established in free-draining conditions only in UQ glasshouse and did not survive subsequent inundation.
Clematis aristata	Vine	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Occurs in moist or sheltered sites, usually in forests.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Clematis spp.	Vine	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Mostly climbers.
Comesperma ericinum	Shrub	Perennial	Ter	Tda	Tdr/Tda	F		PlantNET (2013); AVH (2013)	Described as occurring mainly in or on the edges of dry sclerophyll forest on sandstone.
Comesperma retusum	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Described as mainly occurring in permanently wet places, including wet hillsides, moist soil in wet heath, in swamps and along creeklines.
Comesperma spp.	Shrub or Vine	Perennial	Ter/Amp	T/ATw		F		PlantNET (2013)	Habitats range from dry to wet, depending on species.
Conospermum taxifolium	Shrub	Perennial	Ter	Tda	Tda/Tdr	F		PlantNET (2013); AVH (2013)	Described as occurring in heath and dry sclerophyll woodland, typically in dry heath on deep sand dunes, but occasionally collected in swamps (i.e. <7% of AVH records).
Conyza bonariensis	Forb	Annual	Ter	Tda		E,F	D	Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013); AVH (2013)	Common in disturbed areas.
Conyza spp.	Forb	Annual	Ter	Tda		E,F	D	Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013)	Most species found in NSW are annuals (PlantNET 2012). Classification based on distribution records of species found in Newnes Plateau sites.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Conyza sumatrensis	Forb	Annual	Ter	Tda		F	D	PlantNET (2013); AVH (2013)	Common in disturbed areas.
Coronidium scorpioides	Forb	Perennial	Ter	Tda		E,F	D	PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as generally growing in stringybark forest, often on disturbed sites and generally on clay-loam soils. Established inUQ glasshouse experiment under damp free-draining conditions. Established plants did not survive waterlogging or immersion (8 weeks).
Craspedia spp.	Forb	Annual or Perennial	Ter	T		F		PlantNET (2013)	WPFG depends on species. The species found so far in the Blue Mountains west of Sydney occur in habitats ranging from dry to wet situations such as in swamps.
Crepis capillaris	Forb	Perennial	Ter	T		F	D	PlantNET (2013); AVH (2013)	Described as a common weed of roadsides and disturbed areas.
Cryptandra spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	The species occurring in the Blue Mountains west of Sydney generally occur in drier habitats, e.g. rocky sites in open forest.
Cryptostylis spp.	Forb		Ter	T		F		PlantNET (2013)	Some described as occurring commonly in swamp heath, others usually found in sclerophyll woodland or forest.
Cyathea australis	Fern	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as widespread in rainforest or open forest in gullies or on hillsides in moist shady situations.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Cyperaceae indeterminate	Sedge/Rush		Amp	Ate		F		Reid & Quinn (2004); Casanova (2011)	
Cyperus spp.	Sedge/ Rush	Annual or Perennial	Amp	ATe		E,F		Reid & Quinn (2004); Casanova (2011)	Cyperus spp classified as Ate by Brock & Casanova (1997) based on experimental data.
Dampiera stricta	Forb	Perennial	Ter	Tdr		E, F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Described as usually occurring in heath on sandy soils. Established inUQ glasshouse experiment under free-draining conditions only.
Darwinia fascicularis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in heath or dry sclerophyll forest.
Daviesia latifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as widespread in dry sclerophyll communities.
Daviesia spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Most described as occurring mainly in dry sclerophyll forest and many mainly found on sandy or skeletal soils.
Daviesia ulicifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as mainly occurring in dry sclerophyll forest.
Derwentia blakelyi	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Name updated to Veronica blakelyi. Described as occurring mainly in eucalypt forest.
Deyeuxia brachyathera	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring in forest and mountain gullies, especially in cool, damp places.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Deyeuxia gunniana	Grass	Perennial	Ter	Tda	Tda/ATe	F		PlantNET (2013); AVH (2013)	Described as occurring in shady or damp areas in forest or swamps. Typically collected from areas described as damp to wet e.g. at waters edge beside creek or on moist peat, rather than in standing water.
Deyeuxia innominata	Grass	Perennial	Ter	Tda	Tda/ATe	F		PlantNET (2013); AVH (2013)	Described as often growing on hillsides or slopes, usually in wet places (e.g. wet herbfield) often by creeks or in swamps.
Deyeuxia quadriseta	Grass	Perennial	Ter	Tda	Tda/ATe	F		PlantNET (2013); AVH (2013)	Often found in moist to wet areas, including on floodplains, along creeks and drainage lines and in swamps, but also collected in other situations (e.g. on slopes in eucalypt woodand or in grassland areas).
Deyeuxia spp.	Grass	Perennial	Ter/Amp	Tda/A		F		PlantNET (2013)	Most species occurring in the Blue Mountains are described as growing in moist, shady areas with many found growing in swamps.
Dianella caerulea	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Described as occurring in heath, dry sclerophyll forest and rainforest. Very occasionally recorded in swampy areas (<2% of herbarium records of 157 assessed).
Dianella prunina	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in sclerophyll forest on sandy soils.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Dianella revoluta	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in sclerophyll forest, woodland and mallee.
Dianella spp.	Forb	Perennial	Ter	T		F		PlantNET (2013)	Most species occur in dry sclerophyll forest, but D. tenuissima is a moist habitat specialist.
Dianella tasmanica	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in sclerophyll forest on shallow, often sandy soils.
Dichelachne inaequiglumis	Grass	Perennial	Ter	Tda	Tda/ATe	F		PlantNET (2013); AVH (2013)	Described as widespread in woodland on better soils. 24% (of 67) herbarium records assessed referred to specimens collected from wetlands or damp habitats (e.g. drainage lines and soaks).
Dichelachne micrantha	Grass	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as common in dry or wet sclerophyll forest. Just over 1% (of 205) herbarium records assessed were from specimens collected in wetland habitats.
Dichelachne parva	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as growing in wet habitats in montane areas on sandy or granitic soil or in shale woodland in higher rainfall areas. Often collected from moist (rather than inundated) areas e.g. wet scleropyll forest.
Dichelachne spp.	Grass	Perennial	Ter/Amp	T/A		F		PlantNET (2013)	Some described as occurring in wet habitats and others described as being common in wet or dry sclerophyll forest or woodlands.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Dichondra repens	Forb	Perennial	Ter	Tda		F		Cunnningham et al (1992); PlantNET (2013); AVH (2013); C. Johns pers. obs.	Described as growing in damp shaded places on a variety of soil types. Frequently found in damp areas in Newnes Plateau wetlands by UQ survey team.
Dichondra sp. (Glabrous leaves)	Forb	Perennial	Ter	Tda		F		Cunnningham et al (1992); PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	This taxon referred to as *D. newengland* in a draft manuscript by the late Bob Johnson (*D. newengland* currently used as the provisional name for this taxon by the National Herbarium of New South Wales- McCaffrey pers. comm.). Often observed on damp soils or mud at Newnes Plateau wetland sites by UQ field staff.
Dichondra spp.	Forb	Perennial	Ter	Tda		F		PlantNET (2013)	
Dillwynia phylicoides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry sclerophyll forest on acidic, well-drained soils.
Dipodium punctatum	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Saprophytic orchid. Described as occurring in wet sclerophyll forest to dry sclerophyll woodland on a variety of soils.
Dipodium roseum	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Saprophytic orchid. Described as occurring in wet sclerophyll forest to dry sclerophyll woodland on a variety of soils.
Dittrichia graveolens	Forb	Perennial	Ter	Tda		F	D	Cunnningham et al (1992); PlantNET (2013); AVH (2013)	Described as common in disturbed areas, particularly areas that receive extra moisture, along rivers, creeks, roadsides and in low-lying areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Diuris spp.	Forb		Ter	T		F		PlantNET (2013)	Orchids. Mostly described as occurring in dry sclerophyll forest, though some mainly occur in moist habitats.
Drosera binata	Forb	Annual or Perennial	Amp	ATe		E,F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs; P. McKenna pers. obs.; Johns et al (In prep.)	Described as occurring in wet sand and sandy peat in swamps, on creek banks and on seepage lines. Often observed in shallow water by UQ field staff. Established inUQ glasshouse under damp or waterlogged conditions and Tolerated subsequent shallow inundation (>8 weeks) provided emergent stems were present (otherwise senesced).
Drosera peltata	Forb	Annual or Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs; P. McKenna pers. obs.; Johns et al (In prep.)	Described as widespread in moist areas. Established in UQ glasshouse under damp or waterlogged conditions.
Drosera pygmaea	Forb	Annual or Perennial	Ter	Tda				AVH (2013); N. McCaffrey pers. obs.	Observed growing in moist areas by UQ staff but not necessarily in the presence of surface water.
Drosera spatulata	Forb	Annual or Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns et al (In prep.)	Described as occurring in wetlands and heath. Observed growing on mud and in drier areas by UQ staff, but not in standing water. Established in UQ glasshouse under damp or waterlogged conditions

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Drosera spp.	Forb	Annual or Perennial	Ter	Tda		F		PlantNET (2013); C. Johns pers. obs.	*Drosera* spp that are not identified to species level in Newnes Plateau wetlands are most likely to be *D. spathulata* or *D. peltata or D. pygmaea.*
Echinopogon ovatus	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring in wet sclerophyll woodland and along creeks.
Eleocharis spp.	Sedge/ Rush	Annual or Perennial	Amp	ATe		E,F		Reid & Quinn (2004); Casanova (2011); AVH (2013); Johns et al (In prep.)	Established inUQ glasshouse under waterlogged or inundated (3-5cm depth) conditions.
Eleocharis gracilis	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Described as occurring in seasonally wet situations.
Emilia sonchifolia	Forb	Annual	Ter	T		F	D	PlantNET (2013); AVH (2013)	Described as a common weed of roadsides and open areas. Few herbarium records for this state.
Empodisma minus	Sedge/ Rush	Perennial	Amp	ATe		E,F		PlantNET (2013); Romanowski (1998); Johns et al (In prep.)	Described as common in bogs, swampy places and on wet creek banks including areas that may be shallowly flooded at times, always in acid soils. Established inUQ glasshouse under damp, waterlogged or inundated (3-5cm depth) conditions.
Entolasia marginata	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	Described as occurring in scrub in slightly damper areas on sandy or sandstone-derived soils. Observed growing in damp areas by UQ staff but not in standing water.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Entolasia spp.	Grass	Perennial	Ter	T		F		PlantNET (2013)	Described as occurring in dry scrub or in damper areas on sandy or sandstone-derived soils.
Entolasia stricta	Grass	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as occurring in scrub in dry areas, on sandy or sandstone-derived soils, though occasionally collected from moist or swampy areas. Established in UQ glasshouse under damp, waterlogged or inundated (3-5cm depth) conditions. Plants remained healthy during surface inundation (3-5cm depth) for >8 weeks (i.e. til end of experiment).
Epacris microphylla	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013)	Described as occurring in swampy heath but also in drier coastal heath and dry sclerophyll forest on sandstone and granite.
Epacris obtusifolia	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013)	Described as usually occurring in swampy situations or in wet heath.
Epacris paludosa	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as occurring in swamps, bogs and wet heath on sandstone and granite. Established in UQ glasshouse under damp free-draining or waterlogged conditions.
Epacris spp.	Shrub	Perennial	Ter/Amp	T/ATw		F			
Epilobium billardierianum	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as being widespread in moist habitats.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Eriochilus cucullatus	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Orchid. Described as being widespread in open habitats.
Eucalyptus blaxlandii	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Habitat described as wet or dry sclerophyll forest on moderately fertile sandy soil in elevated sandstone country.
Eucalyptus dalrympleana	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Approx. 4% (of 129) herbarium records referred to specimens growing on swampy ground, with another 10% collected from riparian areas.
Eucalyptus dives	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring on shallow soils on rises.
Eucalyptus fastigata	Tree	Perennial	Ter	Tda	Tdr/Tda	F		PlantNET (2013); AVH (2013)	Described as occurring in wet sclerophyll forest in cold wet areas on fertile soils.
Eucalyptus mannifera	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Approx 3% (of 361) herbarium records assessed referred to specimens growing on swampy ground.
Eucalyptus oreades	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as sporadic but locally frequent in wet or dry sclerophyll forest, usualy on poor skeletal or sandy soils on high sloping country.
Eucalyptus pauciflora	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Less than 0.5% (of 465) herbarium records assessed were from specimens described as occurring in swamps. However, approximately 7% of records were from specimens growing at the edges of swamps or in riparian situations.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Eucalyptus radiata	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Approx. 10% of herbarium records indicate occurrence near creeks or swamps, but rarely actually recorded in swamps (i.e. two records, of 307).
Eucalyptus sieberi	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as dominant in wet or dry sclerophyll forest and woodland areas.
Eucalyptus sp. (seedling)	Tree	Perennial	Ter	Tdr	Tdr/Tda	F		PlantNET (2013)	
Eucalyptus spp.	Tree	Perennial	Ter	Tdr		F		PlantNET (2013)	
Eucalyptus stricta	Tree	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	A small number of herbarium records were for specimens growing close to water, with one record (of 325) of a specimen occurring in a permanent bog.
Euchiton involucratus	Forb	Perennial	Ter	Tda		E,F		PlantNET (2013); Campbell et al (2014); AVH (2013); Johns et al (In prep.)	Described as occurring on moist ground. Often found in areas subject to periodic inundation (33% of herbarium records referred to occurrence in wetland areas). Established in UQ glasshouse under free-draining conditions only and did not survive subsequent inundation (8 weeks).
Euchiton sphaericus	Forb	Perennial	Ter	Tda		F		PlantNET (2013); Campbell et al (2014); AVH (2013)	Described as being widespread in various habitats. Occurs in similar situations to *Cirsium vulgare which was* classified as Tda in previous studies.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Euchiton spp.	Forb	Perennial	Ter	T		F		PlantNET (2013)	Most species described as occurring in shady or moist areas, but some are not.
Gahnia aspera	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in drier situations in rainforest, dry sclerophyll forest and woodland.
Gahnia filifolia	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in open woodland on hillsides, often on drier sites, on sandy soils. Occasionally collected in swamps.
Gahnia melanocarpa	Sedge/ Rush	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as growing in wet sclerophyll forest and rainforest.
Gahnia microstachya	Sedge/ Rush	Perennial	Ter	Tdr				PlantNET (2013); AVH (2013)	Occurs in sclerophyll forest and woodland in drier situations.
Gahnia sieberiana	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998); AVH (2013); P. McKenna pers. obs.	Described as growing in damp places including creek edges or areas that may flood in winter as well as on drier hillsides in woodland, usually on sand or silt. Approx. 15% (of 110) herbarium records refer to swampy habitats.
Gahnia spp.	Sedge/ Rush	Perennial	Ter/Amp	T/ATe		F		PlantNET (2013)	
Galium gaudichaudii	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as being widespread, particularly in relatively dry sites.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Galium propinquum	Forb		Ter	Tdr		F		Cunningham et al (1992); PlantNET (2013); AVH (2013)	Little information provided about habitat. Was recorded on a mountaintop near Ardlethan, in a mallee gum community (Cunningham et al (1992)).
Galium spp.	Forb	Annual or Perennial	Ter	Tdr		F		PlantNET (2013)	
Genoplesium spp.	Forb		Ter	T		F		PlantNET (2013)	Congeners described as occurring in habitats ranging from damp 'moss-gardens' to ridgetops in sclerophyll forest.
Geranium homeanum	Forb	Annual or Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as usually occurring in damper sites.
Geranium neglectum	Forb	Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); Johns *et al* (In prep.)	Described as occurring on creek banks and in swamps. Only established in free-draining pots in UQ glasshouse experiment.
Geranium spp.	Forb	Annual or Perennial	Ter	T		F		PlantNET (2013)	
Gleichenia dicarpa	Fern	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998); AVH (2013); N. McCaffrey pers. obs.	Described as often forming large colonies in sunny damp to waterlogged sites, including in swamps and sumplands. Observed from damp to shallowly inundated conditions by UQ field staff.
Glossodia major	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in sclerophyll forest, woodland and coastal heath.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Gnaphalium spp.	Forb	Annual or Perennial	Ter	T		F	D	PlantNET (2013)	Some species described as occurring on periodically inundated ground, some described as colonisers of bare ground, occurring on sites subject to periodic disturbance (whether dry or damp), others habitat unspecified.
Gompholobium huegelii	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as widespread in dry sclerophyll forest and heath on sandy to gravelly soils.
Gonocarpus micranthus	Forb		Amp	ATl		E,F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns et al (In prep.)	Described as occurring in swamps and damp places in heath or open forest. Observed multiple times in damp to shallowly inundated areas by UQ field staff. Established in damp free-draining or waterlogged conditions in UQ glasshouse experiment. Established plants maintained growth during shallow inundation (3-5cm) over 8 weeks even when completely immersed.
Gonocarpus oreophilus	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring in the understory of wet scleropyll forest or rainforest.
Gonocarpus tetragynus	Forb	Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013) ; Johns et al (In prep.)	Described as occurring in dry sclerophyll forest, heath and shrubstone, normally on sandstone. Established in free-draining or waterlogged conditions in UQ glasshouse and did not survive subsequent immersion (8 weeks).

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Goodenia bellidifolia	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occuring in heath or sclerophyll forest, often on sandstone.
Goodenia hederacea	Forb		Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as growing in various habitats from forest to alpine woodland and grassland.
Goodenia ovata	Shrub	Perennial	Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Described as occurring in forest and woodland and sometimes in exposed rocky situations near sea.
Goodenia spp.	Forb		Ter	Tdr		F		PlantNET (2013)	
Goodenia stelligera	Forb		Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as growing in swamps on sandstone.
Gratiola peruviana	Forb	Perennial	Amp	ATl		F		Casanova (2011); PlantNET (2013); AVH (2013)	Classified as Tda by Casanova (2011), but described as growing in shallow water in the silt and mud of swamps and stream banks by PlantNET (2013). Of 87 AVH records assessed, 100% referred to damp, riparian or aquatic habitats.
Grevillea acanthifolia	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as occurring in swampy areas or wet rock shelves, sand or peat over sandstone. Often collected from riparian areas e.g. on creek banks close to water, rather than in permanently inundated areas. In UQ glasshouse germinated from free-draining damp (and occasionally waterlogged) soil and once established tolerated shallow surface inundation (8wks), forming a dense network of surface roots extending into the water column.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Grevillea laurifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in open woodland or dry sclerophyll forest on ridges and slopes. Sometimes found growing in the ecotone between eucalypt forest and swamp.
Grevillea x gaudichaudii	Shrub	Perennial	Ter	T		F		AVH (2013); Mt Tomah Botanic Gardens website www.mounttomahbotanicgarden.com.au	Described as occurring on sandstone cliffs, rocky gullies and swampy areas.
Gymnoschoenus sphaerocephalus	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998); AVH (2013)	Described as occurring in permanent swamps, on seasonally wet plains, on wet slopes and along shallow ephemeral creeks.
Haemodorum spp.	Forb		Ter	T		F		PlantNET (2013)	Congeners described as occurring in habitats from dry sclerophyll forest to swamps.
Hakea dactyloides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring on sandy soils in heath, dry sclerophyll forest and woodland. Occasionally occurs in or near wetlands or watercourses.
Hakea laevipes	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring on sandy soils in heath, dry sclerophyll forest and woodland.
Hakea microcarpa	Shrub	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Generally found in wet situations including in heathy swamps, riparian zones and hillside soaks.
Haloragis heterophylla	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring in moist areas, especially around creeks and drainage lines.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Hemarthria uncinata	Grass	Perennial	Amp	ATe		E,F		PlantNET (2013); Romanowski (1998); AVH (2013); Johns et al (In prep.)	Grows in swamps and damp places. Tolerant of flooding. Established in UQ glasshouse under free-draining (and occasionally waterlogged) conditions. Established plants tolerated shallow surface inundation 3-5cm (8 weeks).
Hibbertia acicularis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as widespread in heath and dry forest on infertile sands.
Hibbertia cistiflora subsp. cistiflora	Shrub	Perennial	Ter	Tda	Tdr/Tda	F		PlantNET (2013); AVH (2013)	Occurs on sandstone, in dry sclerophyll forest and heath. Sometimes found in or beside swampy areas.
Hibbertia empetrifolia subsp. empetrifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in woodland or sclerophyll forest scrambling over other vegetation.
Hibbertia linearis	Shru	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in heath and dry sclerophyll forest on sands. Often found on or near coastal sand dunes.
Hibbertia rufa	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as widespread in sedgeland or heath. Of 40 herbarium records assessed, approx. 45% referred to specimens collected from heath swamps and another 45% were collected from habitats not described as wetland.
Hibbertia spp.	Shrub	Perennial	Ter	T		F		PlantNET (2013)	
Hibbertia vestita	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll forest on shallow, infertile soils.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Histiopteris incisa	Fern	Perenial	Ter	Tda		F		PlantNET (2013); N. McCaffrey pers. obs.; AVH (2013)	Described as widespread in moist, sheltered situations. Only occasionally collected in swamps (i.e. in 2 of 104 AVH records assessed).
Holcus lanatus	Grass	Perennial	Amp	ATe	ATe/Tda	E,F	D	Cunningham et al (1992); PlantNET (2013); AVH (2013); Johns et al (In prep.)	Described as uncommon in Western NSW, found only from a damp site. More common in wetter climates and generally regarded as a weed in pastures, irrigation land and gardens. In UQ glasshouse experiment established under damp/free-draining conditions only, but Tolerated subsequent flooding and maintained growth provided emergent stems were present.
Hookerochloa hookeriana	Grass	Perennial	Amp	ATe	ATe/Tda	F		PlantNET (2013); AVH (2013)	Occurs in open forest or grassland in moist, swampy or waterlogged places.
Hovea heterophylla	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll woodland; widespread and common.
Hovea linearis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in sands derived from sandstone in forest and woodland habitats.
Hydrocotyle laxiflora	Forb	Perennial	Ter	Tda	Tda/ATl	F		Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013);	Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes H. laxiflora as commonly growing in moist areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Hydrocotyle peduncularis	Forb	Perennial	Amp	ATl		E,F		Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013); Johns et al (In prep.)	Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes this species as commonly growing on wet mud. Some AVH (2013) records indicate this species collected below the water line in creeks. Frequently collected from damp or wet areas (including riparian zones and swamps). Established under free-draining or waterlogged conditions in UQ glasshouse. Established plants tolerated immersion (8 weeks) by increasing petiole lengths.
Hydrocotyle triparitata	Forb	Perennial	Amp	ATl		E,F		Brock & Casanova (1997); Casanova (2011); PlantNET (2013); AVH (2013)	Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl; PlantNET (2013) describes this species as commonly growing on wet mud. Some AVH (2013) records indicate this species collected below the water lline in creeks. Frequently collected from damp or wet areas (including riparian zones and swamps).
Hydrocotyle spp.	Forb	Perennial	Amp/Ter	ATl/Tda		E,F		Brock & Casanova (1997); Casanova (2011); PlantNET (2013)	Brock & Casanova (1997) classified Hydrocotyle triparitarta as Atl; Casanova (2011) classified Hydrocotyle verticillata as Atl

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Hypericum gramineum	Forb		Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Described as occurring in well-drained soils of open forest and grassland.
Hypericum japonicum	Forb		Amp	ATl		E,F		PlantNET (2013); AVH (2013); C. Kilgour pers. obs.; N. McCaffrey pers. obs.; Johns et al (In prep.)	Described as growing on damp to wet soils. Of 71 herbarium records assessed, 51% specimens were collected in wetlands, 14% were from drier sites and 35% were from damp areas adjacent to wetlands or similar habitats. Established in UQ glasshouse under free-draining, waterlogged or shallowly-inundated (3-5cm) conditions and tolerated immersion (8 weeks) by reducing leaf size and increasing internode length.
Hypericum spp.	Forb	Annual or Perennial	Ter/Amp	T/ATe		F		PlantNET (2013)	Various habitats from well-drained soils to 'semi-aquatic' in water along river margins.
Hypochaeris glabra	Forb	Annual	Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Common in disturbed habitats.
Hypochaeris radicata	Forb	Annual	Ter	Tdr		E,F	D	PlantNET (2013); AVH (2013); Johns et al (In prep.)	Common in disturbed habitats. Established in UQ glasshouse under free-draining conditions only and did not survive subsequent immersion (8 weeks).
Hypochaeris spp./Leontodon taraxacoides	Forb	Annual	Ter	Tdr		F	D	PlantNET (2013)	Common in disturbed habitats. (Difficult to distinguish between taxa when immature.)
Hypolepis muelleri	Fern	Perennial	Ter	Tda		F		PlantNET (2013)	Occurs along creeks and swamps in open forest or margins of rainforest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Hypoxis hygrometrica	Forb	Perennial	Ter	Tdr		F		Cunningham et al (1992); PlantNET (2013)	Described as common in open grassland areas including pastures. Dies back soon after seeding.
Isachne globosa	Grass	Perennial	Amp	ATe		F		PlantNET (2013); Romanowski (1998)	Described as usually growing in and beside fresh water and as an aquatic or semi-aquatic perennial to ~0.7m high.
Isolepis cernua	Sedge/Rush		Amp	Ate		F		N. McCaffrey pers. obs.; AVH (2013)	Only observed growing on damp to wet soils by UQ staff (i.e. not observed in dry areas).
Isolepis habra	Sedge/ Rush	Perennial	Amp	ATl		F		PlantNET (2013); AVH (2013)	Occurs on damp ground or in shallow water.
Isolepis inundata	Sedge/ Rush	Perennial	Amp	ATe		E,F		Casanova (2011); PlantNET (2013); AVH (2013); Johns *et al* (In prep.)	Described as widespread in moist habitats. Typically collected from areas of shallow water or wet mud (AVH 2013). Profuse germination and establishment in Newnes soil seedbank glasshouse experiment under waterlogged, free-draining moist and submerged (3-5cm depth) conditions. Inundation tolerant.
Isolepis spp.	Sedge/ Rush	Annual or Perennial	Ter/Amp	Tda/ATe		F		PlantNET (2013)	Described as occurring in moist situations.
Isolepis spp./Schoenus spp.	Sedge/ Rush	Annual or Perennial	Amp	ATe		F		C. Johns pers. obs.	Typically found growing in shallow water, or on wet mud and has an emergent growth form. (Difficult to distinguish between these taxa in the field when small/immature.)

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Isopogon anemonifolius	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as widespread in dry sclerophyll forest and heath.
Joycea pallida	Grass	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Now Rhytidosperma pallidum. Described as generally occurring on upland, acid soils of low fertility.
Juncus bufonius	Sedge/ Rush	Annual	Amp	ATe		E,F	D	PlantNET(2014); Johns *et al* (In prep.)	Described as common in seasonally wet disturbed habitats. Established in UQ glasshouse under waterlogged or submerged conditions. Inundation tolerant.
Juncus continuus	Sedge/ Rush	Perennial	Amp	ATe		E,F		Reid & Quinn (2004); AVH (2013)	Described as common in moist places with sandy soils.
Juncus planifolius	Sedge/ Rush	Annual or Perennial	Amp	ATe		E,F		PlantNET (2013); Reid & Quinn (2004); AVH (2013); Johns *et al* (In prep.)	Frequent germination and establishment in Newnes soil seedbank glasshouse experiment under waterlogged, free-draining moist and submerged (3-5cm depth) conditions. Inundation tolerant.
Juncus spp.	Sedge/ Rush	Perennial	Amp	ATe		E,F		Reid & Quinn (2004)	Juncus spp. classified as Ate by Reid & Quinn (2004).
Juncus usitatus	Sedge/ Rush	Perennial	Amp	ATe		E,F		Reid & Quinn (2004), Campbell *et al* (2014)	Described as common on stream banks and in other moist areas.
Lachnagrostis filiformis	Grass	Annual or Perennial	Ter	Tda		F	D	PlantNET (2013); AVH (2013)	Described as often occurring on heavy soils or in moist areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Lachnagrostis spp.	Grass	Annual or Perennial	Ter	Tda		F		PlantNET (2013); N. McCaffrey pers. obs.	Described as often occurring on heavy soils or on moist sites.
Lactuca serriola	Forb	Biennial	Ter	Tdr		F	D	PlantNET (2013)	Described as common and widespread weed of gardens, roadsides, wasteland, cultivation and degraded pastures.
Lagenophora stipitata	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in grassland, tall alpine herbfield, woodland and sclerophyll forest.
Leontodon taraxacoides	Forb	Perennial or Biennial	Ter	Tda		E,F	D	PlantNET (2013); AVH (2013); Johns *et al* (In prep.)	A weed of lawns and wasteland. Frequently found in damp areas. Single plant established in UQ glasshouse under waterlogged conditions (none in other treatments).
Lepidosperma gunnii	Sedge/ Rush	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Occurs in woodland and heath, often in damper areas.
Lepidosperma laterale	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in a range of habitats, especially woodland and forest, mostly on sandy soils, often on rocky hillsides.
Lepidosperma limicola	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Described as occurring in swamps.
Lepidosperma tortuosum	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013)	Occurs in mountain heath and woodland habitats. Frequently found around the edges of wetlands, as well as in higher, drier locations.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Lepidosperma spp.	Sedge/ Rush	Perennial	Ter/Amp	T/ATe		F		PlantNET (2013)	Congeners found in a range of habitats, from dry to swampy.
Leptospermum arachnoides	Shrub	Perennial	Ter	T		F		PlantNET (2013)	Occurs in moist heath and sclerophyll forest on shallow soils.
Leptospermum continentale	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013) ; Johns *et al* (In prep.)	Occurs in forest or open sandy, swampy places. Established in UQ glasshouse under waterlogged conditions (none in other treatments).
Leptospermum grandifolium	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Mostly collected from riparian habitats. Occurs in sandy swamps and in riparian zones along rocky streams. Established in UQ glasshouse under moist free-draining or waterlogged conditions.
Leptospermum obovatum	Shrub	Perennial	Amp	ATw	ATw/Tda	E,F		PlantNET (2012); AVH (2013); Johns et al (In prep.)	Often occurs in swamps, generally toward the margins, but mostly found in riparian communities among granite or sandstone rocks along the edges of swift-flowing streams. Established in UQ glasshouse under free-draining or waterlogged conditions.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Leptospermum polygalifolium	Shrub	Perennial	Amp	ATw	ATw/Tda	E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Occurs in sandy soil or on sandstone, but also on basalt derived soils. Commonly found in riparian areas and occasionally collected in swamps, but frequently occurs in other situations. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks).
Leptospermum sphaerocarpum	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in heath or dry sclerophyll forest on ridges or escarpments.
Leptospermum spp.	Shrub	Perennial	Ter/Amp	T/ATw		F		PlantNET (2013)	Various habitats.
Leptospermum trinervium	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in dry sclerophyll forest, heath and scrub in deep or shallow sandy soil.
Lepyrodia anarthria	Sedge/ Rush	Perennial	Amp	ATe		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Occurs in or near swamps and in wet or damp peaty soils. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks).
Lepyrodia scariosa	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013); AVH (2013); C. Kilgour pers. obs.; N. McCaffrey pers. obs.; C. Johns pers. obs.	Occurs in moist sand or peaty soil in heath and woodland and near margins of swamps. Sometimes observed in shallowly inundated wetlands by UQ staff.
Lepyrodia spp.	Sedge/ Rush	Perennial	Ter/Amp	Tda/ATe		F		PlantNET (2013)	Described as occurring in moist/wet soil or in swampy areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Leucopogon lanceolatus	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Often found on hillsides in wet or dry sclerophyll forest. Occasionally collected near wetland margins or along creeklines.
Leucopogon microphyllus	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as widespread in heath, scrub and dry sclerophyll forest on sandy or rocky soils.
Lindsaea linearis	Fern	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as widespread in moist areas, often amongst rocks in open forest or heath or near swamps.
Logania albiflora	Shrub	Perennial	Ter	T		F		PlantNET (2013)	Occurs in wet sclerophyll forest and woodland
Lomandra confertifolia subsp. rubiginosa	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Usually occurs in dry sclerophyll forest.
Lomandra filiformis	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils.
Lomandra filiformis subsp. coriacea	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils.
Lomandra filiformis subsp. filiformis	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Usually occurs in dry sclerophyll forest, on well drained sandy or rocky soils.
Lomandra glauca	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in heath to dry sclerophyll forest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Lomandra longifolia	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Found in a variety of habitats. Most herbarium records indicate non-wetland habitat, but approx. 3% (of 244) referred to areas that wet and dry (e.g. stream beds) and another 8% indicated damp and/or riparian zone habitats.
Lomandra multiflora subsp. multiflora	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in woodland and forest.
Lomandra spp.	Sedge/ Rush	Perennial	Ter	T		F		PlantNET (2013)	Some species occur near waterways or in rainforest.
Lomatia myricoides	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Often occurs along watercourses or in sclerophyll forest (approx. 50% of herbarium records riparian).
Lomatia myricoides x silaifolia	Shrub	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Hybrid.
Lomatia silaifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Widespread in heath, sclerophyll forest and woodland.
Lomatia spp.	Shrub	Perennial	Ter	T		F		PlantNET (2013)	Various habitats, from dry to moist areas.
Ludwigia spp.	Forb or Shrub		Ter/Amp	T/A		F		PlantNET (2013)	Most species occur in wet or seasonally wet places, with many spreading into areas of standing water with floating stems.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Luzula flaccida	Forb	Perennial	Ter	Tda		F	D	PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; Johns *et al* (In prep.)	Described as common in moist grassy understory in eucalypt woodland, in grassy margins of wet sclerophyll forest and also disturbed sites such as road banks. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks).
Luzula spp.	Forb		Ter/Amp	T/ATe		F		PlantNET (2013)	Various habitats described, from open grassy areas to swamps.
Lycopodiella lateralis	Clubmoss	Perennial	Ter	Tda	Tda/ATl	F		PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.	Almost always found in moist to wet and boggy areas, e.g. slopes near streams. Observed on damp ground to mud by UQ staff but not in standing water.
Lycopodium deuterodensum	Clubmoss	Perennial	Ter	T		F		PlantNET (2013)	Widespread in various situations, often on sandy soils.
Microlaena stipoides	Grass	Perennial	Amp	Tda		F		PlantNET (2013); AVH (2013); Johns *et al* (In prep.)	Occurs in a variety of habitats including wet and dry sclerophyll forest, damp ground along creeks and in pastures and suburban lawns. Established in UQ glasshouse under free-draining or waterlogged conditions. Tolerated subsequent inundation (3-5cm depth, 8 weeks).
Microtis unifolia	Forb		Ter	Tdr		F		PlantNET (2013)	Widespread in a variety of habitats including rock outcrops in semi-arid areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Mirbelia platylobioides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in heath or eucalypt woodland on sandy soils.
Mirbelia rubiifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in heath or eucalypt woodland on sandy soils.
Mirbelia spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Mostly found in heath or woodland on sandy soils.
Mitrasacme polymorpha	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Widespread, typically on sandy soil overlying sandstone.
Mitrasacme serpyllifolia	Forb	Perennial	Ter	Tda		E,F		AVH (2013); C. Kilgour pers. obs.; C. Johns pers obs. ; Johns *et al* (In prep.)	Observed in damp areas but not in standing water by UQ staff. Established in UQ glasshouse under free-draining or waterlogged conditions. Established plants did not survive inundation (3-5cm depth, 8 weeks).
Mitrasacme spp.	Forb	Annual or Perennial	Ter	T		F		PlantNET (2013); C. Kilgour pers. obs.; C. Johns pers. obs.	Some species prefer damp habitats, while others primarily found in drier areas.
Monotoca scoparia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Usually found in dry sclerophyll forest, woodland or heath on sandy soil.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Myriophyllum pedunculatum	Forb	Perennial	Amp	ARp	ARp/ATl	E,F		Casanova (2011); Reid & Quinn (2004); PlantNET (2013); AVH (2013) P. McKenna pers. obs.; N. McCaffry pers. obs.; C. Johns pers obs.; Johns *et al* (In prep.)	Neither reference classified this particular species but its congeners were classified as Arp. This species is also described as ranging from aquatic to fully emergent. Established in UQ glasshouse under waterlogged or submerged (3-5cm depth) conditions. Inundation tolerant.
Nertera granadensis	Forb	Perennial	Amp	ATl	ATl/Tda	E,F		PlantNET (2013); AVH (2013) ; Johns *et al* (In prep.)	Occurs in bogs and wet soil or on rocks near water. Established in UQ glasshouse under free-draining or waterlogged conditions. Established plants survived immersion but leaves were yellow after 8 weeks.
Notochloe microdon	Grass	Perennial	Amp	ATe		F		PlantNET (2013); N. McCaffrey pers. obs.	Grows in moist shady areas. Observed on damp soils and in up to 5cm of standing water by UQ field staff (N. McCaffrey has only ever seen this species in the middle of swamps).
Notodanthonia longifolia	Grass	Perennial	Ter	T		F		PlantNET (2013)	Now Rhytidosperma longifolium. Grows in open forest on rocky or sandy soils, occasionally in damp places.
Ochrosperma oligomerum	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Grows in dry sclerophyll forest and heath on sandstone ridges or outcrops.
Olearia erubescens	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013); C. Johns pers. obs.	Grows in dry sclerophyll forest. Occasionally recorded around edges of swamps.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Olearia quercifolia	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013); P. McKenna pers. obs.; C. Johns pers. obs.; N. McCaffrey pers. obs.	Grows in swampy or moist terrain.
Opercularia hispida	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Usually occurs on sandy soils, often among rocks and on creek banks.
Opercularia spp.	Forb or Shrub	Perennial	Ter	T		F		PlantNET (2013)	Some species occur on creek banks.
Orchidaceae indeterminate	Forb		Ter	T		F		PlantNET (2013)	
Oxalis spp.	Forb		Ter	Tda		E,F	D	PlantNET (2013); Johns *et al* (In prep.)	A common weed occurring in a variety of habitats. Often found in disturbed areas. Established under waterlogged conditions in UQ glasshouse.
Panicum decompositum var. tenuius	Grass	Perennial	Ter	T		F		PlantNET (2013)	Described as widespread on good soils.
Panicum spp.	Grass	Annual or Perennial	Ter/Amp	Tda/ATe		F	D: some spp.	PlantNET (2013)	Habitats vary, from standing water to cultivated areas.
Paspalidium spp.	Grass	Annual or Perennial	Ter	T		F		PlantNET (2013)	Most described as occurring in dry habitats, but some associated with river banks etc.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Patersonia fragilis	Sedge/ Rush	Perennial	Amp	ATe		E, F		PlantNET (2013); AVH (2013); C. Johns pers. obs.; Johns *et al* (In prep.)	Occurs in wet heath. Established under free-draining or waterlogged conditions in UQ glasshouse. Established plants tolerated inundation (3-5cm, 8 weeks).
Patersonia longifolia	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Grows in dry sclerophyll forest and heath on sandy soil.
Patersonia sericea	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Grows in dry sclerophyll forest, woodland and heath. Sometimes found in or around swampy areas.
Patersonia spp.	Sedge/ Rush	Perennial	Ter	T		F		PlantNET (2013)	Various habitats.
Persoonia chamaepitys	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll forest or heath on sandstone. Sometimes found at the edges of wetlands.
Persoonia hindii	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013); C. Johns (pers. obs.)	Occurs in sclerophyll forest to woodland. Only 15 habitat records available that could be assessed. Often observed on slopes above swamps on the Newnes Plateau by UQ staff, but not within swampy areas.
Persoonia laurina	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in dry sclerophyll forest or heath on sandstone.
Persoonia levis	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in heath to dry sclerophyll forest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Persoonia mollis	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Occurs in heath to wet sclerophyll forest.
Persoonia mollis subsp. mollis	Shrub	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Occurs in wet to dry sclerophyll forest.
Persoonia myrtilloides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in heath to dry sclerophyll forest on sandstone.
Persoonia myrtilloides subsp. myrtilloides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in heath to dry sclerophyll forest on sandstone.
Persoonia recedens	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll forest on sandstone.
Persoonia spp.	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Most described as occurring in dry sclerophyll forest, woodland or heath, often on sandstone. Small number occur in wet sclerophyll forest.
Petrophile canescens	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in dry and wet heat and dry sclerophyll forest on deep sandy soils.
Petrophile pulchella	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring in heath and dry sclerophyll forest on shallow sandy soils.
Phyllanthus hirtellus	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Common in heath and dry sclerophyll forest.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Phyllota phylicoides	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll forest on sandstone. Occasionally collected from swampy areas (7 of 231 habitat records assessed i.e. 3%).
Pimelea linifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Wide range of habitats. Occasionally occurs in swampy areas.
Pinus radiata	Tree	Perennial	Ter	Tdr		F		PlantNET (2013)	Exotic plantation forestry species.
Platysace lanceolata	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in woodland and heath, often on sandy soil.
Platysace linearifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Grows in dry sclerophyll forest on sandy soil.
Poa affinis	Grass	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in woodland on sandstone.
Poa labillardierei	Grass	Perennial	Ter	Tda		F		PlantNET (2013)	Occurs on river flats and moist situation, and in forests extending up open sheltered slopes
Poa labillardierei var. labillardierei	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Occurs on river flats and moist situation, and in forests extending up open sheltered slopes
Poa sieberiana var. cyanophylla	Grass	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013); C.Johns pers. obs	Described as occurring in a wide range of habitats. Less than 1% of 104 herbarium records assessed, specified a periodically inundated habitat. Only observed in dry areas (i.e. above the wetland edge) in Newnes Plateau wetland vegetation surveys.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Poa sieberiana var. sieberiana	Grass	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013) C.Johns pers. obs	Various habitats. Approx. 4% of (211) herbarium records assessed were from wetland habitats and another 6% specified other damp habitats. Frequently observed in damp areas in Newnes Plateau wetland vegetation surveys (i.e. often abundant in drainage lines / tends not to occur in drier areas).
Polygonum plebeium	Forb	Annual or Perennial	Ter	Tda			D	PlantNET (2013); AVH (2013)	Common on disturbed sites. Typically found around the margins of waterways and wetlands in areas which have recently undergone drawdown.
Polyscias sambucifolia	Shrub	Perennial	Ter	T		F	D	PlantNET (2013); AVH (2013)	Common on disturbed sites in wet or dry sclerophyll forest or rainforest margins.
Pomaderris andromedifolia subsp. andromedifolia	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Mainly occurs in open forest along escarpment. Sometimes found in riparian zones.
Poranthera microphylla	Forb	Annual	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Widespread in forest and woodland.
Prasophyllum spp.	Forb		Ter	T		F		PlantNET (2013)	Habitats vary; some prefer moist to wet areas, others only recorded in drier habitats.
Pratia spp.	Forb	Perennial or Annual	Ter/Amp	Tda/ATl		F		PlantNET (2013)	Habitats typically include wet, muddy areas e.g. swamps.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Pratia surrepens	Forb	Perennial	Amp	ATl		F		PlantNET (2013); AVH (2013)	Occurs in or near swamps, in moist grassland and on mud in depressions.
Prunella vulgaris	Forb	Perennial	Ter	Tda	Tda/ATl	E,F	D	PlantNET (2013); AVH (2013); Johns et al (In prep.)	Widespread weed, often found in disturbed areas, particularly moist sites. Single plant established in UQ glasshouse under free-draining conditions. Survived subsequent immersion but leaves were yellow after 8 weeks.
Pseudanthus divaricatissimus	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); Atlas of Living Australia (2013)	Occurs on rocky sandstone sites on sandy soils.
Pseuderanthemum variabile	Forb	Perennial	Ter	T		F		PlantNET (2013)	Occurs in a variety of coastal habitats, especially rainforest and wet sclerophyll forest.
Pseudognaphalium luteoalbum	Forb	Annual	Ter	Tda		E,F		Brock & Casanova (1997); Reid & Quinn (2004); PlantNET (2013); own unpublished experimental results	Widespread species described as occurring in most plant communities, on various soils.
Pteridium esculentum	Fern	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as occurring in open forest or cleared land.
Pterostylis longifolia	Forb		Ter	Tda		F		PlantNET (2013)	Decribed as common in moist areas of sclerophyll forest and coastal scrubs.
Pterostylis spp.	Forb		Ter	T		F		PlantNET (2013)	Orchids. Various habitats.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Pultenaea canescens	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013)	Occurs in swamp-heath on sandstone, mostly around margins when found near wetlands, but also frequently recorded in drier habitats.
Pultenaea capitellata	Shrub	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as occurring in swamp heath to dry sclerophyll forest on acidic substrates. When occurring in swamps, generally found around the higher, drier margins.
Pultenaea divaricata	Shrub	Perennial	Amp	ATw		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Collection records indicate that this species has almost always been collected from areas with damp to very wet ground, usually in swamp heath (sometimes with surface water) or associated with hillside seepages (e.g. hanging swamps). Established in UQ glasshouse under waterlogged conditions.
Pultenaea scabra	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as occurring in heath to dry sclerophyll forest, usually on sandy soils
Pultenaea spp.	Shrub	Perennial	Ter			F		PlantNET (2013)	
Pultenaea tuberculata	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as occurring in dry sclerophyll forest to heath on sandstone.
Ranunculus spp.	Forb	Annual or Perennial	Ter/Amp	T/ATl/ATe		F		Reid & Quinn (2004)	Reid & Quinn (2004) classified R. inundatus as Ate and R. amphitrichus as Tda. Most species described as occurring on moist ground/wet mud.
Restionaceae indeterminate	Sedge/Rush		Amp	Ate		F			Classification based on own field observations.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Rhynchosia minima	Forb		Ter	Tdr		F		PlantNET (2013)	Occurs in a variety of habitats, mostly on heavy soils in grassland.
Rhytidosporum procumbens	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in heath, scrub and sclerophyll forest. Often occurs in moister areas, including near swamps.
Rubus spp.	Shrub	Perennial	Ter	Tda		F	D	PlantNET (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs.	Categorisation based on field observations of species occurring at Newnes Plateau wetland sites.
Rubus ulmifolius	Shrub	Perennial	Ter	Tda		E,F	D	PlantNET (2013); AVH (2013); N. McCaffrey pers. obs.; P. McKenna pers. obs.; Johns et al (In prep.)	Occurs in wetter areas of southern to central eastern NSW. Established in UQ glasshouse experiment under waterlogged conditions.
Schoenus apogon	Sedge/ Rush	Perennial	Amp	ATe		F	D	Cunningham et al (1992); PlantNET (2013); Romanowski (1998); AVH (2013)	Described as occurring in seasonally wet habitats. Often occurs in the fringing zone around wetlands or on creek banks, in moist but not necessarily inundated areas. Also occurs in disturbed sites e.g. pastures, roadsides, lawns and construction sites, where conditions are damp.
Schoenus brevifolius	Sedge/ Rush	Perennial	Amp	ATe		F		PlantNET (2013)	Described as occurring in swamps and damp heath.
Schoenus imberbis	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as growing in dry sclerophyll forest and heath on sandy soils.
Schoenus maschalinus	Sedge/ Rush	Perennial	Amp	ATe/ATl		F		PlantNET (2013)	Occurs in damp to swampy places.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Senecio diaschides	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as growing in moist sites in sclerophyll forest.
Senecio hispidulus	Forb		Ter	Tdr		F	D	PlantNET (2013)	Described as growing mainly in disturbed sites.
Senecio linearifolius	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring mostly in wet sclerophyll forest. Sometimes recorded in areas adjacent to wetlands or creeklines.
Senecio madagascariensis	Forb	Annual or Biennial	Ter	Tdr		F	D	PlantNET (2013)	Described as a widespread opportunistic weed, especially in degraded pasture and disturbed sites.
Senecio minimus	Forb	Annual	Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Described as a widespread opportunistic weed, mainly in wet sclerophyll forest.
Senecio prenanthoides	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as growing in eucalypt woodland.
Senecio spp.	Forb	Annual, Biennial or Perennial	Ter	T		F	D - some spp.	PlantNET (2013)	
Sonchus asper	Forb	Annual	Ter	Tdr		F	D	PlantNET (2013); AVH (2013)	Described as a weed of most habitats, including pastures, cultivation, roadsides, gardens, wasteland and disturbed areas.
Sonchus oleraceus	Forb	Annual	Ter	Tdr		E,F	D	Brock & Casanova (1997); Own unpublished experimental data; AVH (2013)	Brock & Casanova (1997) classified this as Tdr, but other species that commonly occur in disturbed areas on moist soil e.g. Conyza spp have been classed as Tda.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Sonchus spp.	Forb	Annual	Ter	Tdr		E,F	D	PlantNET (2013); AVH (2013)	Brock & Casanova (1997) classified S. oleraceus as Tdr.
Sowerbaea juncea	Forb	Perennial	Ter	Tda		F		PlantNET (2013)	Described as occurring in heath on damp and intermittently water-logged soils.
Sphaerolobium spp.	Shrub	Perennial	Ter	Tda		F		PlantNET (2013)	Only two species found in NSW. Often occurs in moister habitats, including wet heath to swampy areas.
Sphagnum cristatum	Moss	Perennial	Amp	ATl		F		AVH (2013); Whinam & Chilcott (2002); N. McCaffrey pers. obs.; P. McKenna pers. obs.	Only observed by UQ staff in permanently wet areas, including bogs.
Sphagnum spp.	Moss	Perennial	Amp	ATl		F		N. McCaffrey pers. obs.; P. McKenna pers. obs.	Only observed by UQ staff in permanently wet areas, including bogs.
Sphaerolobium minus	Shrub	Perennial	Ter	Tda		F		PlantNET (2013)	Described as widespread in wet heath or sometimes forest on sandy or peaty soils.
Sphaerolobium vimineum	Shrub	Perennial	Ter	Tda		F		PlantNET (2013); C. Johns pers. obs.	Described as widespread in heath and forest, often in swampy places. Observed growing on damp ground by UQ field staff but not in inundated areas.
Sprengelia incarnata	Shrub	Perennial	Amp	ATw		F		PlantNET (2013); AVH (2013)	Described and typically collected from areas described as swampy shrubland and in heath, frequently on wet sandy and/or peaty soil.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Stackhousia monogyna	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as growing in heath, grassland, woodland and sclerophyll forest, often on slopes, rarely in swamps.
Stackhousia spp.	Forb	Annual or Perennial	Ter/Amp	T/ATw		F		PlantNET (2013)	Habitat varies according to species.
Stellaria pungens	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as common in shady places.
Sticherus lobatus	Fern	Perennial	Ter	Tda		F		PlantNET (2013); N. McCaffrey pers. obs.	Often forms colonies in open forest or on margins of rainforest.
Stylidium graminifolium	Forb	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Occurs in dry sclerophyll forest.
Stylidium lineare	Forb	Perennial	Ter	Tda		F		PlantNET (2013)	Occurs in heath and dry sclerophyll forest on sandstone and open poorly-drained plateau areas.
Stylidium productum	Forb	Perennial	Ter	T		F		PlantNET (2013)	Occurs in dry sclerophyll forest on sandstone.
Stylidium spp.	Forb	Perennial	Ter	T		F		PlantNET (2013)	
Taraxacum officinale	Forb	Perennial	Ter	Tda		E,F	D	Brock & Casanova (1997); PlantNET (2013); AVH (2013)	Classified as Tda in previous experimental study. Described as a widespread weed of lawns, roadsides, wasteland and cultivated and pasture areas.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Telopea speciosissima	Shrub	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Described as occurring on deep sandy soils with brown or yellow clay over sandstone in dry slerophyll forest.
Tetrarrhena spp.	Grass	Perennial	Ter/Amp	T/ATe		F		PlantNET (2013)	Habitats range from heath on sandstone, to wet heaths, peat swamps, watercourse fringes and damp tussock grasslands.
Thelionema caespitosum	Forb	Perennial	Ter	T		F		PlantNET (2013)	Described as widespread.
Thelymitra spp.	Forb		Ter	T		F		PlantNET (2013)	Orchids. Habitats range from open forest to wetter sites e.g. seepage areas.
Trachymene spp.	Forb	Annual, Biennial, Perennial or Ephemeral	Ter	T		F	D - some spp.	PlantNET (2013)	Habitats range from sclerophyll forest to swampy areas.
Tricoryne elatior	Forb	Perennial	Ter	T		F		PlantNET (2013)	Habitat ranges from sclerophyll forest, heath and woodland to swamps on sandy loam and lateritic soils.
Utricularia dichotoma	Forb	Perennial	Amp	ATl	ATe/ATl	E,F		Reid & Quinn (2004); PlantNET (2013); AVH (2013); Johns et al (In prep.)	Reid & Quinn (2004) classified Utricularia australis as Arp, but it grows in fully immersed situations whereas U. dichotoma grows in shallow water. Established in UQ glasshouse under waterlogged or submerged conditions. Inundation tolerant.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Utricularia spp.	Forb	Annual or Perennial	Amp	ATe/ARp		E		Reid & Quinn (2004); PlantNET (2013); AVH (2013)	Reid & Quinn (2004) did not classify this whole genus, but Utricularia australis was classified as Arp.
Velleia montana	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Described as occurring mainly in subalpine grassland and woodland.
Vellereophyton dealbatum	Forb	Annual or Biennial	Ter	Tda		F	D	PlantNET (2013)	Occurs on disturbed moist sites.
Veronica plebeia	Forb	Perennial	Ter	T		F	D	PlantNET (2013); AVH (2013)	Occurs in eucalypt forest, grassland, on rainforest margins and as a weed in lawns and gardens.
Veronica spp.	Forb or Shrub	Annual or Perennial	Ter/Amp	Tda/ATl		F	D - some spp.	PlantNET (2013)	Habitats range from eucalypt forest to disturbed pasture to growing in running water along stream banks.
Viola betonicifolia	Forb	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as widespread in woodland and forest.
Viola hederacea	Forb	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Occurs in sheltered moist places.
Viola sieberiana	Forb	Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep.)	Grows on moist ground on more exposed sites. Established in UQ glasshouse experiment under free-draining or waterlogged conditions.
Viola spp.	Forb	Annual, Biennial or Perennial	Ter	Tda		F		PlantNET (2013); C. Johns pers. obs.	This taxon observed growing in damp conditions by UQ field staff.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Wahlenbergia gracilis	Forb	Perennial	Ter	Tda		F		Cunningham et al (1992); PlantNET (2013)	Described as occurring in many situations, often in the vicinity of watercourses.
Wahlenbergia luteola	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in woodland grassland and along roadsides.
Wahlenbergia spp.	Forb	Annual or Perennial	Ter	T		F		PlantNET (2013)	
Wahlenbergia stricta	Forb	Perennial	Ter	Tdr		F		PlantNET (2013)	Occurs in a variety of plant communities.
Xanthorrhoea media	Sedge/ Rush	Perennial	Ter	Tdr		F		PlantNET (2013)	Described as occurring on sandstone, usually on drier, more exposed ridges and hillsides.
Xanthosia dissecta	Forb	Perennial	Ter	Tda		E,F		PlantNET (2013); AVH (2013); Johns et al (In prep)	Described as usually occurring in damp situations, in woodland, wet heath and swamp. Germinated in UQ glasshouse experiment under waterlogged conditions.
Xanthosia pilosa	Shrub	Perennial	Ter	T		F		PlantNET (2013); AVH (2013)	Described as occurring in heath and sclerophyll forest, occasionally along watercourses, on rocky and sandy sites.
Xanthosia spp.	Forb or Shrub	Perennial	Ter	T		F		PlantNET (2013)	Various habitats, from sclerophyll forest to swamps.
Xanthosia stellata	Forb	Perennial	Ter	Tdr		F		PlantNET (2013); AVH (2013)	Occurs in eucalypt forest on sandstone.

Scientific name	Life form	Longevity	Terrestrial (Ter), amphibious (Amp) or aquatic (Aqu) WPFG	WPFG subcategory	WPFG classification borderline?	Classified using experimental data (E) or field observations (F)	Described as common in disturbed areas (D)	References	Comments
Xyris complanata	Sedge/ Rush	Perennial	Ter	Tda		F		PlantNET (2013); AVH (2013)	Often described as growing in damp or seasonally wet areas, including at the edges of swamps, but also occurs in heath on sandy soil.
Xyris gracilis	Sedge/ Rush	Perennial	Ter	Tda		F		PlantNET (2013); Romanowski (1998); AVH (2013)	According to AVH records, many X. gracilis specimens collected from damp or wet areas on sandy or peaty soils i.e. intermittently wet or waterlogged ground such as in hanging swamps or near the margin of a wetland. Sometimes described as occurring in a swamp.
Xyris spp.	Sedge/ Rush	Perennial	Ter/Amp	Tda/ATe		F		PlantNET (2013); Romanowski (1998)	Most Xyris spp. described as occurring on seasonally moist/wet ground, with only X. operculata growing regularly in permanently waterlogged soils.
Xyris ustulata	Sedge/ Rush	Perennial	Amp	ATe	N	F		AVH (2013); PlantNET (2013); Romanowski (1998)	Often seen growing in shallowly inundated areas in Newnes Plateau wetlands by UQ field staff. Typically collected from wet swampy areas (i.e. wetlands and/or seepage zones)