***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (s266B)**
Conservation Advice (including listing advice) for
Coastal Upland Swamps in the Sydney Basin Bioregion

1. The Threatened Species Scientific Committee (the Committee) was established under the EPBC Act and has obligations to present advice to the Minister for the Environment (the Minister) in relation to the listing and conservation of threatened ecological communities, including under sections 189, 194N and 266B of the EPBC Act.
2. The Committee provided the attached listing and conservation advice on the **Coastal Upland Swamps in the Sydney Basin Bioregion** ecological community to the Minister in April 2014. The Minister accepted the Committee's advice, adopting it as the approved conservation advice.
3. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to include the **Coastal Upland Swamps in the Sydney Basin Bioregion** ecological community in the endangered category. It is noted that the ecological community is listed as endangered under the New South Wales *Threatened Species Conservation Act 1995*.
3. The draft description for this ecological community was made available for expert and public comment for a minimum of 30 business days. The Committee and Minister had regard to all public and expert comment that was relevant to the consideration of the ecological community.
4. This approved conservation advice has been developed based on the best available information at the time it was approved; this includes scientific literature, advice from consultations, existing plans, records or management prescriptions for this ecological community.

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1. DESCRIPTION OF THE ECOLOGICAL COMMUNITY

The Coastal Upland Swamps in the Sydney Basin Bioregion ecological community (hereafter referred to as Coastal Upland Swamps or the ecological community) includes a range of vegetation and fauna associated with periodically waterlogged soils on the Hawkesbury sandstone plateaux. Vegetation types include open graminoid heath, sedgeland and tall scrub. The national ecological community corresponds with the ecological community of the same name that is listed under the NSW *Threatened Species Conservation Act 1995*. Information regarding the NSW- listed ecological community can be found at: http://www.environment.nsw.gov.au/determinations/coastaluplandswampfd.htm.

1.1 Name of the ecological community

The name of the ecological community is Coastal Upland Swamps in the Sydney Basin Bioregion. The name is consistent with the name for the ecological community on the New South Wales list of Threatened Ecological Communities.

1.2 Location and physical environment

The Coastal Upland Swamps in the Sydney Basin Bioregion ecological community is endemic to NSW, occurring within the eastern part of the Sydney Basin IBRA bioregion[1].

In the south the ecological community primarily occurs on the Woronora plateau, and in the north, predominantly on the Somersby-Hornsby plateaux. The southern part of this distribution is separated from the north by areas characterised by non-sandstone substrates, lower effective rainfall, lower elevation, and the extensive urban development of Sydney.

Geology and Altitude

The community occurs primarily on poorly permeable sandstone plateaux in the low relief headwater valleys of streams and on sandstone benches with abundant seepage moisture (Buchanan, 1980; Young, 1986; Keith and Myerscough, 1993; Keith et al., 2006). They are occasionally associated with weathered shale lenses and ironstone (Buchanan, 1980; Keith, 1994). Soils are generally acidic and vary from yellow or grey mineral sandy loams with a shallow organic horizon to highly organic spongy black peats with pallid subsoils (NSW Scientific Committee, 2012).

The majority of swamps occur at elevations of 200-450 metres above sea level (ASL). However, the elevation of some swamps in the region can vary from as low as 20 metres to around 600 metres ASL (NSW Scientific Committee, 2012).

Hydrology

There are strong hydrological controls on the distribution of the Coastal Upland Swamps community, both regionally and locally. Geomorphic development of the swamps is driven by positive feedbacks that operate when there is significant excess of precipitation over evaporation. This, along with high run-on from catchments and low rates of percolation and run-off, promotes soil water logging (Young, 1982; 1986). Lateral transportation and deposition of sediment via overland flows lead to the choking of headwater valleys, impeding drainage (NSW Scientific Committee, 2012). Higher levels of soil moisture lead to increased density of ground cover, thereby trapping more sediment and further impeding drainage and killing trees that are unable to tolerate raised water tables (NSW Scientific Committee, 2012). Drainage of the swamps is mainly via lateral seepage through the sediments with some possible

[1] Interim Biogeographic Regionalisation of Australia Version 7. IBRA regions are large geographically distinct areas of similar climate, geology, landform, vegetation and animal communities. Version 7 divides Australia into 89 bioregions and 419 subregions, including offshore islands. More information regarding IBRA, including maps are available at: http://www.environment.gov.au/topics/land/nrs/science-maps-and-data/australias-bioregions-ibra

very slow vertical percolation into the underlying poorly permeable bedrock. Channels, if present, are discontinuous and usually are very shallow and linking a series of deep pools at the downstream end of large valley-floor swamps.

Climate

The ecological community shows a strong relationship to a climatic gradient, reaching its greatest development on the central portion of the Woronora plateau. In this location the Illawarra escarpment (the seaward side of the Woronora plateau) produces orographic rainfall[2], fogs, and enhanced cloud cover, which in turn reduce evaporation (NSW Scientific Committee, 2012). The orographic climatic effects rapidly diminish with distance inland from the escarpment and the occurrences of swamps are much reduced on the westernmost third of the plateau (NSW Scientific Committee, 2012).

1.3 Vegetation

The formation of swamps and wetlands are dependent on a range of factors including location in the landscape, underlying geology, and climate. These play an important role in determining the level of water-logging and sedimentation levels in the swamps. Swamp vegetation can be highly variable depending on water flows, substrates, rainfall and altitude. Fire history also plays an important role in the development and persistence of swamp boundaries.

The Coastal Upland Swamps community is characterised by highly diverse and variable mosaics of vegetation depending on soil conditions, size of the site, recent rainfall conditions, fire regimes and disturbance history (NSW Scientific Committee, 2012). The total number of vascular plants species for the community is likely to exceed 200 (NSW Scientific Committee, 2012). An indicative list of vascular plant species characteristic of the Coastal Upland Swamps is given in Table 1. The ecological community also includes a wide range of micro-organisms, fungi, and cryptogamic plants (NSW Scientific Committee, 2012) that are not listed here.

Larger swamps in the ecological community may consist of a range of structural forms which include tall open scrubs, tall closed scrubs, closed heaths, open graminoid heaths, sedgelands and fernlands. Smaller swamps are more typically characterised by open graminoid heaths and/or sedgelands, but may include tall scrub (NSW Scientific Committee, 2012).

Coastal Upland Swamps are characterised by a diverse assemblage of vegetation and are essentially treeless, although trees may be present as scattered individuals or isolated clumps of eucalypts, including mallees (Keith and Myerscough, 1993; NSW Scientific Committee, 2012). Many plant species within the swamps are absent from or uncommon in the surrounding landscape, making the Coastal Upland Swamps distinctive and recognisable (Keith and Myerscough, 1993; Keith, 2013).

[2] Orographic rainfall refers to rainfall produced when moist air rises over a mountain range and cools.

Table 1: Characteristic native plant species for the Coastal Upland Swamps in the Sydney Basin Bioregion ecological community (NSW Scientific Committee, 2012).

SCIENTIFIC NAME	COMMON NAME(S)
Shrubs	
Almaleea paludosa	-
Baeckea imbricata	Heath Myrtle
Baeckea linifolia	Swamp Baeckea
Banksia ericifolia	Heath Banksia
Banksia oblongifolia	Dwarf Banksia
Banksia robur	Swamp Banksia, Broad-leaved Banksia
Bauera microphylla	Dog Rose
Boronia parviflora	Swamp Boronia, Small Boronia
Cryptandra ericoides	Heathy Cryptandra
Dillwynia floribunda	Showy Parrot Pea
Epacris microphylla	Coral Heath
Epacris obtusifolia	Blunt-leaf Heath
Epacris paludosa	Swamp Heath
Grevillea oleoides	Red Spider Flower
Grevillea parviflora	Small-flower Grevillea
Hakea teretifolia	Dagger Hakea, Narrow-fruited Needlebush
Hibbertia serpyllifolia	Hairy Guinea Flower
Leptospermum grandifolium	Mountain Tea-tree, Woolly Tea-tree
Leptospermum juniperinum	Prickly Tea-tree, Juniperinum Tea-tree
Leptospermum squarrosum	Pink Tea-tree
Melaleuca squarrosa	Scented Paperbark
Mirbelia rubiifolia	Heathy Mirbelia
Petrophile pulchella	Conesticks
Pultenaea aristata	Bearded Bush-pea
Sphaerolobium vimineum	Leafless Globe-pea
Sprengelia incarnata	Pink Swamp-heath
Symphionema paludosum	-
Viminaria juncea	Golden Spray, Native Broom
Xanthorrhoea resinosa	Grass Tree
Forbs, ferns and twiners	
Actinotus minor	Lesser Flannel-flower
Blandfordia nobilis	Christmas Bells
Burchardia umbellata	Milkmaids
Cassytha glabella	Dodder Laurel, Devil's Twine
Dampiera stricta	-
Drosera binata	Forked Sundew
Drosera spatulata	Spoon-leaved Sundew
Gleichenia microphylla	Scrambling Coral-fern
Gonocarpus micranthus	Creeping Raspwort
Gonocarpus salsoloides	-
Gonocarpus tetragynus	-
Goodenia dimorpha	-
Haemodorum corymbosum	Bloodroot
Lindsaea linearis	Screw Fern, Necklace Fern
Mitrasacme polymorpha	-
Opercularia varia	Variable Stinkweed
Selaginella uliginosa	Swamp Selaginella
Sowerbaea juncea	Rush Lily, Vanilla Plant
Stackhousia nuda	-
Stylidium lineare	Narrow-leaved Triggerplant
Thysanotus juncifolius	Fringe-lily
Xanthosia tridentata	Rock Xanthosia
Xyris gracilis subsp. *laxa*	-
Xyris juncea	Dwarf Yellow-eye
Xyris operculata	Tall Yellow-eye

Graminoids	
Baumea acuta	-
Baumea teretifolia	Twigrush
Chorizandra sphaerocephala	Roundhead Bristle-sedge
Empodisma minus	Spreading Rope Rush
Entolasia stricta	Wiry Panic
Eurychorda complanata	-
Gahnia sieberiana	Sword Grass, Sawsedge
Gymnoschoenus sphaerocephalus	Button Grass
Lepidosperma limicola	Razor Sedge
Lepidosperma neesii	-
Leptocarpus tenax	-
Lepyrodia scariosa	-
Plinthanthesis paradoxa	Wiry Wallaby-grass
Ptilothrix deusta	-
Schoenus brevifolius	Zig-zag Bog-rush
Schoenus pachylepis	-
Schoenus paludosus	-
Tetraria capillaris	-
Tetrarrhena turfosa	-

1.4 Fauna

The ecological community provides habitat to a wide variety of vertebrate and invertebrate fauna. The swamps provide shelter from predators and essential resources such as sources of permanent water during drought, and sources of food (e.g. nectar from flowers or invertebrate prey). Some fauna may be transient through the community; for instance pollinating birds such as honeyeaters are likely to visit during flowering season, and other animals may use the swamps as stepping stones to more preferred habitats.

Mammals likely to inhabit the ecological community include: *Wallabia bicolor* (swamp wallaby), *Cercartetus nanus* (eastern pygmy possum), *Antechinus stuartii* (brown antechinus) and *Rattus lutreolus* (swamp rat). Birds present in the ecological community include: *Dasyornis brachypterus* (eastern bristlebird) (nationally listed), *Phylidonyris novaehollandiae* (New Holland honeyeater), *Phylidonyris niger* (white-cheeked honeyeater), *Neophema pulchella* (turquoise parrot), *Stipiturus malachurus* (southern emu-wren), *Malurus cyaneus* (superb fairy-wren), *Malurus lamberti* (variegated fairy-wren), *Rhipidura albiscapa* (grey fantail), *Stagonopleura bella* (beautiful firetail) and *Pezoporus wallicus wallicus* (eastern ground parrot).

The Coastal Upland Swamps community provides important habitat for frogs. A number of threatened species have been recorded as occurring within the ecological community including the nationally vulnerable *Litoria aurea* (green and gold bell frog) and *Heleioporus australiacus* (giant burrowing frog) (NSW Scientific Committee, 2012). *Pseudophryne australis* (red-crowned toadlet), which is listed as vulnerable in NSW, is also known to be present. In addition, the lizard *Varanus rosenbergi* (Rosenberg's goanna), listed as vulnerable in NSW, inhabits the ecological community.

A range of invertebrates occur in the ecological community. Stygofauna within the groundwater are abundant and comprise relatively few co-occurring species, exhibiting high levels of local endemism (Hose, 2008; 2009). Key invertebrate species commonly present include the crustaceans: *Euastacus australasiensis* (Australian crayfish), *E. hirsutus* (hairy crayfish) and *E. spinifer* (Sydney crayfish) (NSW Scientific Committee, 2012). The ecological community also provides habitat for the NSW listed endangered insect *Petalura gigantea* (giant dragonfly) (Baird, 2012), which is now uncommon in the coastal regions of NSW (NSW Scientific Committee, 2012).

Further detail on faunal roles and interactions is contained in *Detailed description of biology and ecological processes*, Appendix A.

1.5 Additional Considerations

Boundaries between the Coastal Upland Swamps and adjacent communities can be quite distinct across distances of a few metres or more diffuse transitions across tens of metres, and may not follow tree lines precisely (NSW Scientific Committee, 2012). Substantial shifts may occur in swamps and adjoining woodland boundaries over decadal time scales (Keith et al., 2010).

Each swamp of the ecological community needs to be considered. Ecological, geological, surface water and groundwater conditions and how these factors relate to the function of individual swamp systems must be understood before potential impacts can be assessed (Coffey Geotechnics, in publication).

Buffer zone: A buffer zone is a contiguous area adjacent to swamp systems that is important for protecting the integrity of the swamp. As the buffer zone lies to the outside, around the swamp, it is not part of the national ecological community and is not formally protected as a matter of national environmental significance. However, practical application of a buffer zone is strongly recommended.

The purpose of the buffer zone is to help protect and manage the national ecological community. The edges of a swamp are considered particularly susceptible to disturbance and the presence of a buffer zone is intended to act as a barrier to further direct disturbance. For instance, a buffer zone may help to protect the ecological community from altered water flows, pollution and other threats.

There are a number of factors influencing the function and persistence of swamp systems. Many of the threats to the community involve surface hydrology and hydrologically transported pollutants, including urban runoff. It is therefore recommended that a surface buffer zone be considered using sub-catchment boundaries. With respect to mitigating threats from underground mining, subterranean buffers and other features of underground mine design should be addressed to avoid adverse impacts to the ecological community. A preliminary analysis of case histories shows that predicted subsidence parameters and mine design features indicate the likelihood of adverse impacts. These include vertical subsidence, tilt, strain, upsidence and valley closure, as well as longwall panel width, pillar width and depth of overburden cover (Krogh, 2012). Consistent with this understanding, the NSW Planning and Assessment Commission (PAC, 2010) adopted a set of thresholds in predicted subsidence parameters to identify swamps that may be at risk of negative environmental consequences (Appendix C).

Additional information on ecological processes can be found in Appendix A.

No condition thresholds have been applied to this ecological community.

1.6 Area critical to the survival of the ecological community

The landscape distribution of swamp ecosystems is a function of local climate, landform, substrate variables and sub-catchment features and activities which influence hydrological regimes. Given the very specific set of variables required for the Coastal Upland Swamps to develop and persist, the areas currently occupied and the associated sub-catchment are considered to be areas critical to the survival of the community.

1.7 Geographic extent and distribution

The ecological community is endemic to New South Wales, being restricted to the Hawkesbury sandstone plateaux of the Sydney Basin Bioregion. The northern occurrences of the ecological community lie on and around the Somersby-Hornsby plateaux. The southern occurrences lie on the Woronora plateau west to the Robertson region. The Woronora plateau accounts for the majority (about 83%) of known swamps in the ecological community (NSW Scientific Committee, 2012).

Swamps are naturally small, with approximately 42% of those mapped being less than 1 ha. The largest 5% of swamps (>14 ha) account for just under half of the total area of the community (NSW Scientific Committee, 2012).

1.8 National context and other existing protection

The Sydney sandstone basin is an identifiable geological entity that is recognised nationally as a discrete area supporting specialised and significant native flora and fauna.

Relationships to other listed ecological communities

The Coastal Upland Swamps was listed in 2012 as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act 1995* (TSC Act).

Three other swamp ecological communities are listed under the TSC Act:

- Blue Mountains Swamps in the Sydney Basin Bioregion – vulnerable;
- Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion – endangered; and
- Montane peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions – endangered.

The Blue Mountains Swamps and the Newnes Plateau Shrub Swamps, along with some swamps in the Southern Highlands region are incorporated within the nationally endangered Temperate Highland Peat Swamps on Sandstone ecological community. These swamp communities share some plant species with the Coastal Upland Swamps, and some occurrences are also found in headwaters of streams on Sydney sandstone plateaux. However, these communities occur further inland and occur primarily on sandstones other than the Hawkesbury Formation (e.g. the Narrabeen Group) as well as a range of other substrates in the case of Temperate Highland Peat Swamps. The Coastal Upland Swamps also usually contains a much higher diversity of plant species than these other communities (Keith & Myerscough, 1993) and many of its dominant and less common species are not found in either Blue Mountains Swamps or Newnes Plateau Shrub Swamp (e.g. *Banksia robur, B. oblongifolia, Grevillea parviflora, Pultenaea aristata*) (NSW Scientific Committee, 2012).

The NSW Montane peatlands community shares some geomorphic and hydrological characteristics, but has relatively few species in common with the Coastal Upland Swamps. These montane swamps are found on more fertile non-sandstone substrates, generally in cooler

climatic environments, and lack many of the sclerophyllous floristic components which characterise the other swamp communities (NSW Scientific Committee, 2012).

Level of protection in reserves

The ecological community occurs in a number of reserves, including Royal, Heathcote, Ku-ring-gai Chase, Brisbane Water, Garigal, Popran, Sydney Harbour and Yengo National Parks, Dharawal and Muogamarra Nature Reserves and Garawarra State Conservation area. Of these, Dharawal Nature Reserve and National Park contain the largest occurrences (Tozer et al., 2010). On the Woronora plateau, where the majority of the ecological community occurs, only 179 of the estimated total 1003 swamps of the ecological community are within National Park reserve (M Krogh pers comm. February 2014). The reserved swamps cover 383.5 ha or only 8.6% of their extent on the Woronora plateau. Overall approximately 1552 ha of the ecological community occur within conservation reserve and around 4000 ha occurs within land managed by the Sydney Catchment Authority. It is acknowledged that many threats, notably impacts of subsidence, inappropriate fire regimes and climate change still pose significant risks to the ecological community, even where it occurs on conservation tenure.

Further information on similar or intergrading ecological communities and other protection measures can be found in Appendix B *Detailed description of national context.*

2. SUMMARY OF THREATS

There are past and ongoing threats to the Coastal Upland Swamps and the key threats are outlined below (for detailed information see Appendix C):

- Clearing, for example, that associated with infrastructure, roads, quarries, surface facilities and recreational facilities.
- Altered hydrological processes.
- Fracturing and drainage of shallow groundwater aquifers as a result of land subsidence.
- Changes in climatic conditions and fire frequency associated with climate change.
- High frequency fire threatening structurally dominant species and low variability fire regimes, potentially threatening non-dominant species.
- Localised disturbances, for example, those associated with unauthorised access by vehicles, trail bikes, mountain bikes and horses.

Further details about the threats can be found at Appendix C *Description of threats*.

3. SUMMARY OF ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

Criterion1: Decline in geographic distribution

A comparison of recent mapping and high resolution photography with historical mapping and imagery suggests a decline in the distribution of the Coastal Upland Swamps of up to 10% since European settlement. Therefore the ecological community is **not eligible** for listing under this criterion.

Criterion 2: Small geographic distribution coupled with demonstrable threat

As nearly half of the mapped swamps that make up the Coastal Upland Swamps are less than 1ha in size, the community's distribution is considered restricted. The ecological community is subject to demonstrable threats, as outlined in Appendix C, which may cause it to be lost in the near future. The ecological community meets relevant elements of Criterion 2 to make it **eligible** for listing as **endangered**.

Criterion 3: Loss or decline of functionally important species

The Coastal Upland Swamps community is not characterised by a single dominant species or group of dominant species. Groups of species, geomorphic features and climatic condition, rather than individual species, appear to support the major functions within this ecological community. It is difficult to assess declines of functionally important species. As such, there is **insufficient information** to determine the eligibility of the ecological community for listing under any category of this criterion.

Criterion 4: Reduction in community integrity

There is evidence that woody resprouter species have declined by 37% across 72% of swamp sites over past decades, within the core of the range of the ecological community. Significant declines have also been observed in non-woody resprouting species. As these resprouter species are key components of the community with important roles in post-fire recovery, their decline is indicative of substantial declines in ecological integrity of the community. Given the slow rates of natural restoration, the absence of effective remediation techniques and the potential threats to the community's persistence, the ecological community is considered to have undergone at least a substantial reduction in its integrity. It is therefore **eligible** for listing as **vulnerable** under Criterion 4.

Criterion 5: Rate of continuing detrimental change

Bioclimatic modelling by Keith et al. (2014) projects a decline of 56 % (median) in both area and suitability of environments in which the ecological community occurs over the next 50 years. This estimate does not include declines that may be attributable to effects of underground mining or directly to adverse fire regimes. Given the continuing and potential threats to the ecological community, the projected rate of decline is reasonably indicative of a severe rate of continuing detrimental change. The ecological community, therefore, is **eligible** for listing as **endangered** against this criterion.

Criterion 6: Quantitative analysis showing probability of extinction

There are no quantitative data available to assess this ecological community under this criterion. Therefore, there is insufficient information to determine eligibility for listing under this criterion.

Full details of how the ecological community was assessed against the EPBC Act listing criteria can be found at Appendix D *Eligibility for listing against the EPBC Act criteria.*

4. PRIORITY CONSERVATION ACTIONS

4.1 Research and monitoring priorities

Research priorities that would inform future regional and local priority actions for the Coastal Upland Swamps include:

High priorities:

- Undertake or support existing research into methods of prescribing effective buffers to protect the ecological community from the impacts of subsidence associated with longwall mining.
- Undertake or support and enhance existing survey programs to locate and map occurrences of the ecological community, identify threatened species that utilise the habitat, and identify priority areas for conservation.
- Undertake research into the processes related to environmental variability and determine their roles in maintaining the diversity of the ecological community.
- Undertake or support existing research into the hydrological budget of swamps and its sensitivity to climate change and underground mining.
- Undertake or support existing research into the use of fire as a management tool and identify appropriate fire regime requirements of both flora and fauna in the ecological community for biodiversity conservation.
- Monitor the predicted changes in climatic moisture and fire regimes associated with climate change to better inform management of the ecological community.

Other priorities:

- Design and implement a monitoring program or support and enhance existing monitoring programs for the ecological community, including determining the relative biodiversity and conservation benefits of particular swamps.
- Undertake or support and enhance existing basic research of the biology and ecology of the ecological community.
- Undertake or support analysis of the hydrological processes of the ecological community.
- Undertake or support research into the ecosystem services provided by Coastal Upland Swamps, the change in services through time and their sensitivities to disturbance.

4.2 Priority recovery and threat abatement actions

The following priority recovery and threat abatement actions should be implemented to stop the decline of, and support the recovery of, the Coastal Upland Swamps:

<u>Habitat loss, disturbance and modification</u>

- Protect and conserve remaining areas of the ecological community.
- Avoid disturbances to hydrology that may result in changes to the natural hydrological regime of the community.
- Avoid impacts arising from proposed developments, in particular longwall coal mining on the Woronora Plateau.
- Liaise with mining companies to ensure application of ‘best practice’ planning/implementation to avoid adverse impacts on the ecological community.

- Liaise with local councils, State authorities and other land managers to ensure that roads, infrastructure and maintenance activities (e.g. associated with transport, energy or water supply, mining and rural or residential development) in areas where the ecological community occurs do not adversely impact on the ecological community.
- Manage unauthorised access (e.g. horse riding, off-road vehicles), through appropriate fencing and improved signage.

Invasive species

- Manage swamps to prevent the introduction of new, or further spread of, invasive weeds.
- Control invasive pest animals and avoid grazing and/or trampling damage to swamps, and to protect native fauna, through coordinated landscape-scale control programs.

Fire

- Develop and implement appropriate fire management strategies that take into account how key species in the ecological community respond to fires, acknowledging the role of appropriate fire regimes in maintaining the diversity of the community.
- Manage fire regimes to avoid subsurface fires in peat soils.
- Liaise with local fire brigades and agencies and engage their support in managing the impacts of fire on the ecological community.
- Avoid impacts related to hazard reduction and fire suppression operations and post-suppression 'mop-up' activities, particularly through vehicular access and installation of control lines within the extent of Coastal Upland Swamps.

Conservation information

- Maintain liaison with managers of land on which the ecological community occurs.
- In consultation with land managers, local and state authorities and Aboriginal groups, develop management guidelines and technical material to assist land managers, including measures to address inappropriate fire regimes, changes to hydrology and health and maintenance of the ecological community.
- In consultation with land managers, local and state authorities and Aboriginal groups, develop or support appropriate existing education programs, information products and signage to help the public recognise the presence and importance of the ecological community, and their responsibilities under state and local regulations and the EPBC Act.
- Promote opportunities for inclusion of the ecological community in any proposed reserve tenure or other conservation management arrangements.

4.3 Existing plans/management prescriptions

There is no approved state recovery plan for the ecological community, as defined in this listing. However, relevant management prescriptions exist in various forms. These include NSW Parks and Wildlife Plans of Management for the following areas:

- Brisbane Water National Park
- Dharawal National Park, State Conservation Area and Nature Reserve
- Finchley Aboriginal Area, Yengo National Park and Parr State Conservation Area

- Garigal National Park
- Ku-ring-ga Chase National Park and Lion Island, Long Island and Spectacle Island Nature Reserves
- Marrararra National Park, Muogamarra Nature Reserve and Maroota Historic Site
- Popran National Park
- Royal National Park, Heathcote National Park and Garawarra State Recreation Area
- Sydney Harbour National Park.

Current management plans are available from the NSW Office of Environment and Heritage website at: http://www.environment.nsw.gov.au/parkmanagement/ParkManagementPlans.htm.

The Woronora plateau, where the majority of the Coastal Upland Swamps occurs, is within protected catchment land. The Sydney Catchment Authority (SCA) and the Office of Environment and Heritage jointly manage Special Areas, declared under the *Sydney Water Catchment Management Act 1998* for their value in protecting the quality of the raw water used to provide drinking water to Sydney, the Illawarra and the Blue Mountains, and for their ecological integrity.

Relevant SCA plans and policies include the:

- Special Areas Strategic Plan of Management 2007; and
- The revised Special Areas Strategic Plan of Management 2013 (draft for public consultation),

Available from the Sydney Catchment Authority website at: http://www.sca.nsw.gov.au/search?query=special+areas+strategic+plan+of+management&collection=sca-meta

- Sydney Catchment Authority Principles for Managing Mining and Coal Seam Gas Impacts

Available at: http://www.sca.nsw.gov.au/__data/assets/pdf_file/0017/40850/SCA-Mining-Principles.PDF

Relevant Commonwealth threat management documents include:

- Novel biota and their impact on biodiversity Threat Abatement Guidelines 2013

4.4 Recovery plan recommendation

Although there is no specific state recovery plan for the Coastal Upland Swamps, there are a number of existing planning documents for conservation and threat abatement that align with the ecological community (see existing management plans above). Taking into account the recovery and threat abatement priorities and actions specified in this conservation advice, a recovery plan for the ecological community is not required at this time.

APPENDICES

APPENDIX A – DETAILED DESCRIPTION OF BIOLOGY AND ECOLOGICAL PROCESSES

Hydrology

Hydrological processes are crucial to the development of the ecological community. The development and persistence of the Coastal Upland Swamps is reliant on an excess of precipitation over evapotranspiration along with high surface run-on and low rates of percolation and run-off. This promotes soil water-logging, the development of dense vegetation and sediment build-up, with positive feedback leading to further deposition and restriction of surface and subsurface flows (Young, 1982; 1986, Keith, 2013). Soils of the Coastal Upland Swamps are formed under periods of prolonged inundation and associated plants are adapted to tolerate oxygen-poor, wet substrate conditions (DECC, 2007a).

The ecological community and associated groundwater aquifer function are essential in protecting downstream ecosystems during periods of low rainfall. Decreases to groundwater levels in swamp habitats are likely to reduce and/or change the location of baseflow discharges, affecting groundwater dependent ecosystems, stream ecosystems and catchment water supply needs (Krogh, 2012).

Fire

An important biotic interaction within the ecological community is the fire-mediated competition between overstorey shrubs and understory plants that promotes the persistence of characteristic native biota (Keith, 2013) (Figure 1). Fire regimes that promote the development of dense overstorey strata result in declines in diversity of understorey flora, especially woody resprouters that are intolerant of shade and have low growth rates, fecundity and recruitment (Keith, 2013). Conversely, short fire intervals can result in rapid declines of some species that have slow maturation times or require habitat features that are slow to develop after fire. Fire regimes that involve substrate fires (peat fire) can also be detrimental to the characteristics of the ecological community. Such fires can result in the death of seedbanks, lignotubers and other underground organs, lead to erosion, and promote a transition into non-swamp vegetation.

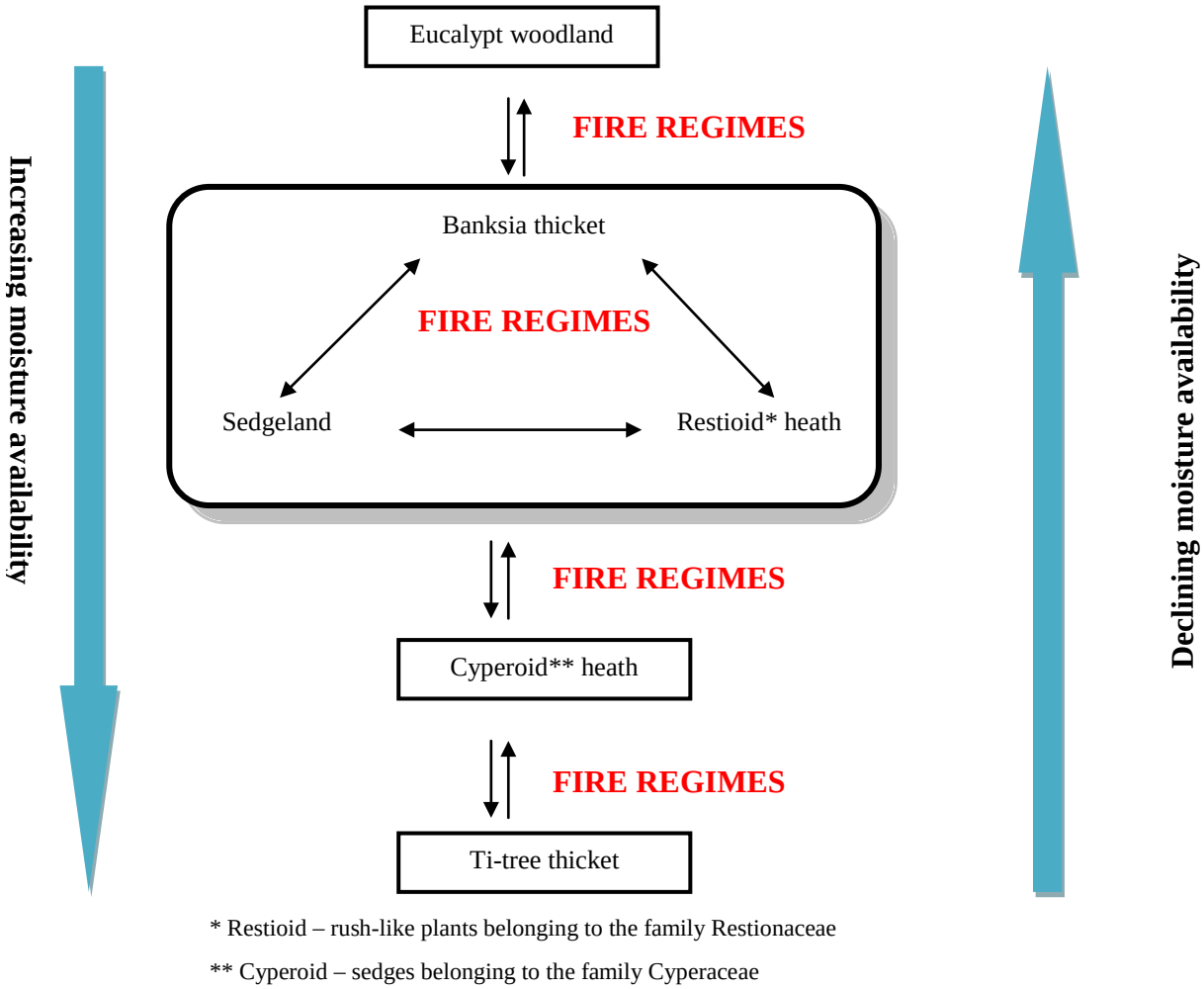

Figure 1: A cause-effect process model summarising ecosystem dynamics in the Coastal Upland Swamps (adapted from Keith, 2013). The states within the boxes are different sub-communities within the ecosystem (see Keith & Myerscough, 1993 for description), with fire regimes and moisture regimes deriving transitions between them.

Examples of faunal roles and interactions

Fossorial groundwater dependent organisms, such as the freshwater crayfish and giant dragonfly (Benson and Baird, 2012) have a unique functional role within the ecological community.

Freshwater burrowing crayfish such *Euastacus australasiensis* have been identified as a significant component of Australian swamp ecosystems (Benson and Baird, 2012). Their groundwater filled burrows provide refuge sites against fire and predation (for example, skinks) (Benson and Baird, 2012). Giant dragonfly burrows may also be similarly utilised by other species within the ecological community. For example spiders, insects, frogs have been observed within the entrance of a dragonfly burrow (Benson and Baird, 2012) in the ecological community.

In Tasmania, burrowing crayfish are known to increase respiration of surrounding soil (Richardson, 1983), and may affect vegetation through soil aeration and root grazing (Richardson and Wong, 1995).

APPENDIX B – DETAILED DESCRIPTION OF NATIONAL CONTEXT

Landuse history

Indigenous occupation

There is ongoing debate about the nature, range and territories of Aboriginal language groups in the greater Sydney region existing prior to European contact (Biosis, 2009). Attenbrow (2002) suggests the main language groups of the greater Sydney region were: Darug (coastal and hinterland), Gundungarra and Dharawal.

Widespread archaeological artefacts and art sites provide evidence of extensive use of the Woronora Plateau by the Dharawal people at the time of European arrival, (NPWS, 2003). Table 3 summarises some of the indigenous uses of species found specifically in the ecological community. Axe grinding grooves are often found at the outflow points from Coastal Upland Swamps where water flows continuously from the swamp through open sandstone pavements.

Table 3: Traditional Aboriginal plant resources and likely use within the Coastal Upland Swamps of the Sydney Basin Bioregion (adapted from Biosis, 2009).

Species	Indigenous uses
Acacia rubida	Seeds were ground for flour
Banksia ericifolia	The flowers were sourced for their sweet nectar and were sucked or soaked
Banksia paludosa	The nectar of the flowers was sucked or soaked to make a sweet beverage. The cones were used for retaining fire as they remained alight for a considerable period.
Banksia robur	
Dodonaea triquetra	The leaves were chewed for toothache and used as a poultice for stonefish and stingray
Gahnia sieberiana	The seeds were pounded to produce flour and the bases of the leaves are edible
Lomandra longifolia	The seeds were ground for flour. The flowers and the base of the leaves are edible. The tough leaves were also used to make baskets.
Pteridium esculentum	The rhizome of this plant was a staple food source – roasted first to destroy toxins.
Xanthorrhoea resinosa	Resins were extracted and used as adhesive. Inflorescences were used as spear shafts.

Mining

While much of the Woronora plateau was unsuitable for agriculture because of infertile soils (NPWS, 2003), the discovery of coal in the Illawarra region in 1796 established mining as one of the main industries of the area (Krogh, 2007). There are currently eight operational coal mines in the southern coalfields, six of which have leases underlying the Woronora plateau (Krogh, 2007). In addition, there is a network of ventilation shafts across the plateau, along with a plethora of transmission line easements, pipelines, access routes and fire trails (NPWS, 2003) servicing the mines.

Sydney Water Catchment

The development and population growth of Sydney over 1788 - 1888 necessitated the provision of a clean, safe and reliable water supply for the city and the surrounding region (Krogh, 2007).

Between 1900 and 1935, five dams were constructed flooding the Avon, Nepean, Cataract, Cordeaux and Woronora River valleys.

Since 1999, responsibility for dams, reservoirs and catchments of Sydney and the Illawarra has been held by the Sydney Catchment Authority (SCA) (Krogh, 2007). The SCA is governed by the NSW *Sydney Water Catchment Management Act 1998.* The SCA acknowledge that mining in the catchments is likely to continue until at least 2050 and that large areas of Sydney's drinking water catchment are subject to mining production and titles (SCA, 2014b).

Relationships to other protected matters

Relationships to nationally-listed ecological communities

The Temperate Highland Peat Swamps on Sandstone ecological community (Temperate Highland Peat Swamps on Sandstone) was listed as 'endangered' under the EPBC Act in 2005. It comprises temporary or permanent swamps occurring on sandstone in the temperate highlands region in NSW (DEH, 2005), typically at elevations between 600 metres and 1100 metres above sea level (ASL). The wetter parts of Temperate Highland Peat Swamps on Sandstone are occupied by sphagnum bogs and fens, while sedge and shrub associations occur in the drier parts (TSSC, 2005). The level of waterlogging and amount of sedimentation are influenced by the location of the swamps: hanging swamps (occurring on steep valley sides) have low levels of sedimentation, and accumulate organic material slowly; valley swamps and those along watercourses have greater levels of sedimentation, and accumulate organic material more quickly (TSSC, 2005). The thicker vegetation often found around the peat swamps provides 'islands' of good habitat for a diverse range of fauna, such as in the Blue Mountains (EA, 2001; NPWS, 2001).

While many of the characteristics (e.g. geology, vegetation types) of the Coastal Upland Swamps appear to be consistent with the Temperate Highland Peat Swamps on Sandstone they are distinguished by species composition and environmental features such as elevation. The Coastal Upland Swamps ecological community occurs at elevations between 20 m to 600 m ASL. However, the majority of the swamps occur at elevations between 200 m to 450 m ASL. Temperate Highland Peat Swamps on Sandstone ecological community occurs at elevations between 600 metres and 1100 metres ASL.

Relationships to World or National Heritage places

The ecological community occurs within the Royal National Park, Ku-ring-gai National Park, Lion, Long and Spectacle Island Nature Reserves and Garawarra State Conservation Area, each of which is included on the National Heritage List.

Relationships to State-listed ecological communities

In NSW, the ecological community is listed under the *Threatened Species Conservation Act 1995* as Coastal Upland Swamps in the Sydney Basin Bioregion in the 'endangered' category.

Relationships to other vegetation classifications

Caveat

Ecological communities are complex to classify. Each State/Territory jurisdiction applies its own system to classify ecological communities which can present challenges when cross-referring amongst systems. They may also vary in accuracy in representing the on-the-ground situation, particularly if based on maps and modelling. Any reference to vegetation and mapping units as equivalent to a national ecological community, at the time of listing, should be taken as indicative rather than definitive. A unit that is generally equivalent may include elements that do not meet the description. Conversely, areas mapped or described as units other than those referred to may sometimes meet the description. Judgement of whether an EPBC-protected

ecological community is present at a particular site should focus on how an area meets the description, particularly the key diagnostic characteristics for the national ecological community.

Relationships to national and state vegetation systems

The ecological community encompasses a range of other vegetation classifications which are summarised in Table 4.

Table 4: Units of other vegetation classifications which make up the Coastal Upland Swamps ecological community (adapted from NSW Scientific Committee, 2012).

Vegetation Type	Reference
'Sedge swamps' and 'Shrub swamps'	Pidgeon (1938)
'Extensive Swamp or Moor Communities'	Davis (1941)
'Swamps'	Buchanan (1980)
'Sedgeland (Community 12)'	Benson & Fallding (1981)
'Sedgeland/Shrubland (Community 21)'	Thomas & Benson (1985) [reproduced in Benson & Howell (1994)]
'Open-scrub (Community 4a)' 'Open-heath (community 4b)' 'Sedgeland (Community 5)'	Fallding & Benson (1985)
'Ti-tree Thicket'(TT) 'Cyperoid Heath' (CH) 'Restioid Heath' (RH) 'Sedgeland' (SL) 'Banksia Thicket' (BT)	Keith & Myerscough (1993) and Keith (1994)
'Upland Swamps Banksia Thicket' (MU42) 'Upland Swamps Tea-tree Thicket' (MU43) 'Upland Swamps Sedgeland-Heath Complex' (MU44)	NPWS (2003)
'Sydney Hinterland Sandstone Upland Swamp' (MU43)	DECC (2008a)
'Coastal Upland Damp Heath Swamp' (map unit S_FrW01) 'Coastal Upland Wet Heath Swamp' (map unit S_FrW02)	DECCW (2009)
'Coastal Upland Swamp' (map unit FrWp129) parts of 'Blue Mountains - Shoalhaven Hanging Swamps' (map unit FrWp130)	Tozer et al. (2010)

The latter two units tend to intergrade on the Woronora Plateau (Tozer et al., 2010), with overall floristic differences relating to increasing plant diversity as altitude declines and some local endemism in the upper altitudinal range of Blue Mountains - Shoalhaven Hanging Swamps (FrW p130). Various other published and unpublished studies have also recognised the Coastal Upland Swamp as a distinctive community (NSW Scientific Committee, 2012)

APPENDIX C – DESCRIPTION OF THREATS

Interactions between hydrological processes and fire regimes are crucial to the development of the Coastal Upland Swamps. The main mechanisms leading to altered hydrological processes are the fracturing of rock strata associated with subsidence and climate change. Other threats include fire, clearing and localised disturbances.

Altered hydrological processes

Any activity that leads to subsidence, warping of the land surface, fracturing of bedrock layers or valley closures thereby changing hydrological processes involving groundwater and/or surface water will change conditions necessary for the persistence of swamps. The conversion of perched water table flows into subsurface flows significantly changes the water balance of upland swamps (Benson and Baird, 2012). Additionally, changes to surface morphology may lead to development of nick points which then result in significant erosion (Young, 1982). Unlike other threats (fire, clearing, disturbance) for which remediation may be possible, changes which alter catchment hydrology pose an irreversible threat to the integrity of swamp ecosystems (Benson and Baird, 2012; Davey et al., in publication).

Where the underlying strata of a swamp is fractured and water levels drop, species adapted to moister conditions and periodic or prolonged inundation are likely to be replaced by those species better adapted to drier conditions (DECC, 2007a). For example, frogs are likely to suffer significant adverse impacts as a result of changes to swamp habitats because of their reliance on water for foraging and breeding within these areas. The Coastal Upland Swamps also provides habitat for the NSW listed giant dragonfly, which is now uncommon in coastal regions (NSW Scientific Committee, 2012), largely as a result of loss and degradation of swamp habitats.

The technique of longwall mining is recognised as a cause of subsidence and this is reflected by the fact that the 'Alteration of habitat following subsidence due to longwall mining' is listed as a Key Threatening Process in NSW (NSW Scientific Committee, 2005). Longwall mining is considered the only viable high production mining method in the majority of Australian underground coal mines (Davey et al., in publication).

The Woronora plateau contains approximately 83% of the ecological community, and of this, approximately 78% (4029 ha) is located wholly or partially over current mining leases (Krogh, 2007; J Dawson pers comm., 2014). Only 179 (383.5 ha) of the estimated 1003 swamps in the ecological community are within the NSW National Park reserve system, thereby providing them with protection from direct mining impacts (M Krogh pers comm., 2014).

A review of impacts on Coastal Upland Swamps located over the Dendrobium mine by Krogh (2012) has concluded that there have clearly been adverse impacts on the ecological community (fracturing of underlying strata, alteration of groundwater levels and desiccation of swamps). The similarity of impacts in Dendrobium swamps 12 and 15b to impacts measured in Kangaroo Creek swamp on the Newnes Plateau as a result of longwall mining highlight consistent patterns of longwall mining impacts on upland swamps generally (Krogh, 2012). Vegetation changes have also been detected in some of the affected swamps (Krogh, 2012).

It is difficult to predict impacts of an activity on the Coastal Upland Swamps due to complex dependencies on geological features, time lags in hydrological and ecological responses, and influences such as rainfall variation during and after subsidence events (NSW Scientific Committee, 2012). Where swamps are small, located in areas of relatively flat topographic relief and contained wholly within the boundaries of the longwall panel, non-systematic subsidence may be sufficiently low for impacts to be considered negligible, and it is possible that swamp integrity can/will be maintained (M Krogh pers comm., 2014). This also appears to

be true for swamps undermined by older bord and pillar style techniques[3] where subsidence levels were far lower than contemporary longwall subsidence levels (M Krogh pers comm., 2014).

However where mining and subsidence impacts are significant, ground displacements resulting from mining activities can occur up to 3 km outside of the disturbance site, most occurring soon after, although they may continue to become evident for several years (NSW Scientific Committee, 2005; 2012). Davey et al., (in publication) noted that:

> '*Numerous upland peat swamps located above longwall mined sections have been impacted by changes to the hydrological regime. Due to the lack of monitoring data, the discrete causal mechanisms and specific timeframes are difficult to quantify. Detailed descriptions of various sites before and after mining activities provide strong qualitative data. Observations from these sites indicate that changes to the hydrological regime can result in declines in groundwater quality, desiccation of organic matter, slumping and void formation, creation of knick points, increased erosion, severe impacts to flora and fauna and increased susceptibility to extreme weather events (drought, floods, fire). Further information is required on the specific time lags between mining and likely impacts and the role of mine plan layout and proximity to the extent of the onsite damage.'*

A preliminary analysis of case histories by Krogh (2012) shows that predicted subsidence parameters and mine design features influence the likelihood of adverse impacts. In that analysis, the predicted vertical subsidence, tilt, strain, upsidence and valley closure, as well as longwall panel width, puillar width and depth of overburden cover were key factors found to be useful in predicting whether a longwall mine will result in impacts on upland swamps (Krogh, 2012). The NSW Planning and Assessment Commission, in its assessment of a proposal for longwall mining beneath major occurrences of Coastal Upland Swamps on the Woronora plateau (PAC, 2010) concluded that at the present state of knowledge, six criteria should be applied individually to identify swamps that may be a risk of negative environmental consequences based on whether the swamps are predicted to be subject to: i) systematic tensile strains >0.5 mm/m; ii) systematic compressive strains >2 mm/m; iii) depth of cover less than 1.5 times longwall panel width; iv) tilt (transient or final) >4 mm/m; v) predicted valley closure of >200 mm; and vi) a 'maximum observed closure strain' >7.0 mm/m (PAC, 2010), p120).

In addition to coal mining activities, there is potential for coal seam gas exploration and extraction to occur in these areas. While no coal seam gas projects are currently under way within the region of the ecological community, the introduction of these activities could potentially adversely impact upon the hydrological processes of the swamps in the future.

Climate change

The Coastal Upland Swamps community has a strong association with high levels of climatic moisture. The development of swamps and their persistence depends on an excess of precipitation over evapotranspiration combined with high surface run-on and low rates of low percolation and run off (Young, 1982; 1986). Available climate modelling, to date for the region, predicts that temperatures will become warmer and that rainfall patterns will be drier (NSW Scientific Committee, 2012).

It has been shown that boundaries of upland swamps and surrounding woodlands are sensitive to temporal changes in hydrology over decadal time scales (Keith et al., 2010). However, until recently, little was known about how climatic changes might impact the distribution of the swamps or what parts of the landscape may act as refuges under future climates

[3] This does not apply to older bord and pillar operations which have subsequently experienced pillar extraction (sometimes referred to as total extraction) which are effectively acting as very wide and long longwalls.

(Keith et al., 2014). To address this issue Keith et al. (2014) used correlative bioclimatic models to estimate rates of change in the extent and distribution of environments suitable for the development and persistence of the ecological community under future climates. Results suggest that in response to climate change, hydrologically suitable environments for the Coastal Upland Swamps will contract and shift in a south-west direction, with the northern boundaries moving south more rapidly than southern margins (Keith et al., 2014).

The range of estimated decline of the ecological community over the next 50 yrs (2010-2060) varies from 37 to 86% based on these bioclimatic models, regionally appropriate global climate models and emissions scenarios (Keith et al., 2014). The projected median decline in distribution of the ecological community is 56% (Keith et al., 2014). Some of the modelled scenarios projected a reversal of expansion of swamp environments, followed by rapid decline commencing in the early 21st century, consistent with observed changes in swamp distribution in the late 20th century (Keith et al 2010). Note that these predictions do not take into account declines exacerbated by changes in hydrological regimes resulting from mining activities (Keith et al., 2014) or impacts from more frequent fire events, or other disturbances.

Inappropriate fire regimes

Fire plays an important role in the development and persistence of the characteristic vegetation structure of the Coastal Upland Swamps. Fire regimes that promote prolonged persistence of dense overstorey strata lead to declines in the diversity of understory flora, especially the woody resprouters that are intolerant of shade, and have low rates of growth fecundity and recruitment (Keith et al., 2013).

High frequency fires may threaten species, including plants that are structurally dominant, such as *Banksia ericifolia, Hakea teretifolia, Leptospermum squarrosum, Melaleuca squamea and Petrophile pulchella* (NSW Scientific Committee, 2012). *B. ericifolia* is an important winter food source and nesting substrate for a range of fauna therefore declines could potentially impact on some populations of animals reliant on this resource (NSW Scientific Committee, 2012).

The severity and extent of decline in woody resprouters were assessed from data collected at 53 sites in 1983 and 2009 (Keith, 2013). During this period, the summed abundance of woody resprouters declined by a mean of 37% at 72% of sampled sites (Keith, 2013). In their study examining wetland dynamics, Keith et al. (2010) concluded that fire frequency parameters on their own are a poor predictor of spatial patterns in swamp vegetation changes. However when mean fire interval was combined in a two-factor model with solar radiation (an indicator of regional patterns of climatic moisture) the patterns were stronger (Keith et al., 2010).

Destruction of peat substrates as a result of fire has been reported in the ecological community on the Woronora plateau (Keith et al., 2006; Krogh, 2007). Substrate fires consume not only the peaty base, but can kill soil seed-banks, underground regenerative organs such as lignotubers and rhizomes, as well as fauna (NSW Scientific Committee, 2012). Damage to the substrate can also cause nick-points and result in erosion beyond the immediate area of the fire. These may be further exacerbated by heavy rainfall events, which are not infrequent within the distribution of this ecological community (NSW Scientific Committee, 2012).

A project investigating the terrestrial vertebrate fauna of the Greater Southern Sydney region concluded that the Woronora, O'Hares Creek and Metropolitan Special Areas include the largest and most significant areas of upland swamps in the region (DECC, 2007b). The swamps surveyed in this project included some swamps from the ecological community, but also others not part of the ecological community. The faunal survey highlighted some decline in faunal abundance related to changes in vegetation and habitat thought to be due to overly frequent fires in this area. The eastern bristlebird, previously known to occur in these habitats has not

been seen for over 20 years (DECC, 2007b). The long-nosed potoroo, often seen around the swamps of Barren Grounds Nature Reserve, have also disappeared (DECC, 2007b). The eastern ground parrot was once common on Maddens Plains and thought to be locally extinct until recently when it was discovered within upland swamp landscapes on the Woronora plateau (NSW Scientific Committee, 2012). The eastern pygmy-possum, southern emu-wren and beautiful firetail are additional species from the upland swamps that may be threatened by fire (DECC, 2007b).

It is not known why fauna species from upland swamps on the Woronora Plateau, are particularly susceptible to inappropriate fire regimes (DECC, 2007b). It is clear that the patchy distribution of swamps makes recolonisation difficult in the event of local extinction (DECC, 2007b). However widespread fires would have occurred prior to European settlement, so it may be that there is a synergistic effect of fire and the introduction of feral predators (DECC, 2007b). It is also likely that the diverse range of species found in these swamp habitats are particularly vulnerable to predation after an area has been opened up by fire (DECC, 2007b).

Clearing and localised disturbance

It is estimated that up to 10% of the historic distribution of the Coastal Upland Swamps ecological community has been lost due to clearing (NSW Scientific Committee, 2012). Overall the scope for further clearing appears to be limited as much of the remaining distribution occurs on public land managed by Sydney Catchment Authority and NSW National Parks (NSW Scientific Committee, 2012). However future habitat loss could still result from rural and residential development on unprotected tenures. This is of particular relevance to the northern parts of the ecological community's range, in the Somersby-Hornsby Plateau (David Keith pers. comm., 2013). On protected tenures, there remains a possibility of habitat loss due to specific developments associated with transport, clay and sand quarries, energy or water supply infrastructure and surface facilities servicing underground mining activities (NSW Scientific Committee, 2012). In some areas (e.g. Lizard Creek catchment) swamp species have been impacted by alkaline mine water discharges (DECC, 2007a).

Localised areas of the community could potentially be impacted by disturbances associated with earthworks within swamps or their catchments. These could lead to changes in drainage, sedimentation and weed invasion (NSW Scientific Committee, 2012). Exploration and extraction of coal seam gas could also threaten the ecological community in the future.

Key threatening processes

The following listed key threatening processes are most relevant to the ecological community:

National (EPBC Act):

- Land clearance
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases
- Novel biota and their impact on biodiversity

NSW (TSC Act):

- Anthropogenic climate change
- Alteration of habitat following subsidence due to longwall mining
- Clearing of native vegetation
- Herbivory and environmental degradation caused by feral deer

APPENDIX D – ELIGIBILITY FOR LISTING AGAINST THE EPBC ACT CRITERIA

Criterion 1 – Decline in geographic distribution

There are insufficient data to estimate historical (since 1750) changes in swamp area in detail. However by comparing recent mapping from high resolution aerial photography (Tozer et al., 2010) and historical imagery and mapping of headwater valleys in relevant areas, the decline in distribution of the community since 1750 is estimated to be up to 10 % (NSW Scientific Committee, 2012).

For a measure of more recent change, Keith et al. (2010) looked at changes in the extent of upland swamps in a sample catchment based on mapping derived from aerial photographs taken between 1961 and 1998. It was found that there was a net expansion of sample swamps (mean increase of 10.2%; range 3-32%) into surrounding woodland, likely attributable to increasing climatic moisture during this period. Within the same area it is estimated that approximately 5-7% of the area of the swamps had been destroyed in the past 50 years as a result of clearing for quarries, mines, rural residential development and roads (Keith et al., 2013; NSW Scientific Committee, 2012).

Given that the study area of Keith et al. (2010) is located within the core range of the ecological community and includes areas of protected and unprotected tenures, it is reasonably assumed that the results of the study are representative of changes in the extent of the ecological community as a whole (Keith et al., 2013). There are significant concerns regarding future declines in geographic distribution (Keith et al., 2014) but these are not relevant to this criterion and dealt with under other criteria, particularly criterion 5.

As the ecological community has not been demonstrated to have met the required elements of Criterion 1, it is **not eligible** for listing under this criterion.

Criterion 2 – Small geographic distribution coupled with demonstrable threat

This criterion aims to identify ecological communities that are geographically restricted to some extent. Three indicative measures apply:

1) extent of occurrence, an estimate of the total geographic range over which the ecological community occurs;

2) area of occupancy, an estimate of the area actually occupied by the ecological community (which generally equates with its present extent); and

3) patch size distribution, an indicator of the degree of fragmentation of the ecological community.

It recognises that an ecological community with a distribution that is small, either naturally or that has become so through modification, has an intrinsically higher risk of extinction if it continues to be subjected to ongoing threats that may cause it to become lost in the future. There are demonstrable and ongoing threats to the ecological community, as detailed in Appendix C.

A minimum convex polygon enclosing all mapped occurrences of the ecological community estimated its extent of occurrence to be about 496 000 ha (NSW Scientific Committee, 2012).

The area of occupancy of the Coastal Upland Swamps was estimated from an amalgamation of fine-scale vegetation mapping throughout the range of the ecological community. The mapped area of swamps is approximately 5360 ha (NSW Scientific Committee, 2012). Approximately 83% of this area occurs on the Woronora Plateau (NSW Scientific Committee, 2012). Due to

the small size of individual swamps, a scattered occurrence in the landscape, and the small mapped area totalling 5360 ha, the ecological community is therefore considered to have a **restricted** geographic distribution.

The swamps naturally occur in small patches. Approximately 42% of individual mapped swamps are less that 1 ha in size. Collectively, they make up only around 6% of the total mapped area (Keith, 2013). Larger swamps (>14 ha) account for only 5% of individual swamps but just under half (47%) of the total area of the community (NSW Scientific Committee, 2012). The catchments for individual swamps also are small and rarely exceed 200 ha (Keith et al., 2014). Given a majority of mapped individual swamps are less than 1 ha in size, the ecological community's geographic distribution is also consistent with being **restricted** on the basis of individual patch (swamp) size.

Keith et al. (2010) demonstrated that swamp-woodland boundaries shift markedly in response to climatic moisture and possibly in concert with fire events, over decadal periods of time. If the contraction of wetlands occurs as rapidly as the expansion that was observed in the late 20th century, then an observable response may well be detectable within the next 20 to 30 years. In addition, the ecological community is at threat from sudden loss due to impacts from subsidence. Such impacts are difficult to predict but can include desiccation, decreased water quality, increased erosion and increased susceptibility to extreme weather events. Based on this information the Committee considers that an ecologically sensible timeframe of 50 years for '*near future'* is appropriate when applied to this ecological community. This is consistent with the findings of the NSW Scientific Committee in 2012, notably that the nature of the ecological community and the threatening processes to which it is exposed are such that it is likely that it will undergo a large reduction in geographic distribution over a timeframe appropriate to its life cycle and habitat characteristics.

Over its entire range, these threats may cause the ecological community to be lost in the *near future* (in this case, 50 years being a relevant timescale), due to the combined impacts of hydrological change resulting from geological subsidence, inappropriate fire regimes and the predicted decline in climatic moisture as a result of climate change (Keith, 2013). Therefore the ecological community has been demonstrated to meet the relevant elements of Criterion 2 to make it **eligible** for listing as **endangered**.

Criterion 3 – Loss or decline of functionally important species

The ecological community is characterised by highly diverse and variable mosaics of vegetation related to variability in soil conditions and fire regimes (NSW Scientific Committee, 2012). Groups of species, geomorphic features and climatic conditions, rather than individual species appear to support the major functions within this ecological community. It is difficult to assess declines of functionally important species. As such, there is **insufficient information** to determine the eligibility of the ecological community for listing under any category of Criterion 3.

Criterion 4 – Reduction in community integrity

This criterion recognises that an ecological community can be threatened with 'functional' extinction through on-going modifications that do not necessarily lead to total destruction of all elements of the community. The severity of the reduction in community integrity is assessed by considering the changes being such, that restoration is unlikely within the immediate, near or medium-term future.

Changes in integrity

The main threats that contribute to a reduction in the integrity of the Coastal Upland Swamps are altered hydrological processes as a result of longwall mining, inappropriate fire regimes and the potential impacts of climate change. Biological (ecological) responses to changes in hydrological regimes may involve considerable time lags, due to potential interactions with climatic conditions and fire regimes.

As outlined in Appendix B, fire-mediated competition between overstorey shrubs and understorey species is important to maintaining the characteristic swamp biota. Understorey flora, especially woody resprouters, can decline as a result of being outcompeted by an increased density of the overstorey strata (Keith, 2013). The severity of decline in woody resprouter species (which includes species of *Banksia, Epacris, Grevillea, Baeckea, Leptospermum* and *Xanthorrhoea* (Keith et al., 2007)), was assessed by Keith (2013) who observed a mean reduction of 37% across all woody resprouters in 72% of sites samples over a 26 year period. There were also significant declines in non-woody resprouting species (Keith et al., 2007) This represents a considerable shift in the diversity of understorey species and lifeforms as a consequence of altered fire-hydrological regimes and interactions. In addition, the decline in woody resprouters could result in a loss of resources available to a range of fauna.

Restoration timeframes

The ecological community is slow to recover after disturbance. The aggradation rates of natural upland swamps in the Sydney Basin suggest that complete restoration following significant damage would likely require tens to hundreds of years (Davey et al., in publication). Additional research is required to determine whether, in fact, subsidence impacts (fracturing of rock substrate) to the ecological community are reversible, and if so, what the associated time frames for restoration are. Current remediation strategies appear insufficient to effectively combat vertical seepage through fracture networks and direct remediation of upland peat swamps has not been attempted to date (Davey et al., in publication).

Conclusion

The reduction in integrity experienced by the ecological community, as indicated by the loss of woody resprouters, with consequent degradation of habitat values, is substantial. This is likely to continue into the future across most of its distribution. The nature of the change in integrity within the ecological community is such that restoration of swamps is unlikely to be possible within the *medium-term future,* even with positive human intervention. Therefore, the ecological community is **eligible** for listing as **vulnerable** under this criterion.

Criterion 5 – Rate of continuing detrimental change

A continuing change refers to a recent, current or projected future change whose causes may be known or either not known or not adequately controlled, so is liable to continue unless remedial measures are taken.

Generally, future changes in ecological systems may be predicted by extrapolating current trends or by modelling future environmental scenarios using established relationships between the biota and its environment. Thus, depending on the circumstances, continuing declines may be predicted even when the ecosystem is apparently stable at the present time (Keith, 2013). Keith et al. (2014) applied a range of plausible alternative climate models and emissions scenarios to predict distribution changes in the Coastal Upland Swamps. These models and scenarios predict declines in the area of suitable environments for Coastal Upland Swamps ranging between 37 - 86% (median 56%) over the 50 years from 2010 to 2060. None of the

modelled scenarios predicted stability or increases in environmentally suitable area over future decades (Keith et al., 2014). Further, the effects of climate-related declines may be exacerbated by changes to hydrological regimes resulting from mechanical damage to the substrate leading to increased permeability (Keith et al., 2014). Given these considerations, the projected median decline of 56% is indicative of a severe rate of continuing detrimental change. Therefore the ecological community is **eligible** for listing as **endangered** under this criterion.

Criterion 6 – Quantitative analysis showing probability of extinction

There is no quantitative data available to assess this ecological community under this criterion. Therefore, there is **insufficient information** to determine the ecological community's eligibility for listing under this criterion.

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