Assessment of Swamp Sclerophyll Forest on Coastal Floodplains TEC on NSW Crown Forest Estate (South Coast Region)

Survey, Classification and Mapping Completed for the NSW Environment Protection Authority

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1 Overview

Swamp Sclerophyll Forest on coastal floodplains is one of several Threatened Ecological Communities associated with coastal floodplains with a potential distribution that spans the entire NSW coastal region. The most widespread and abundant dominant tree species throughout most of its range are *Eucalyptus robusta* (swamp mahogany) and *Melaleuca quinquenervia* (paperbark) but *E. robusta* is uncommon and localised south of Nowra, and *M. quinquenervia* does not occur south of Sydney. For this report we focus on a study area south of Sydney where dominant trees are stated to include *Eucalyptus robusta*, *Eucalyptus botryoides* (bangalay) and *Eucalyptus longifolia* (woollybutt). There are three communities cited in the final determination relevant to our study area: in the Illawarra, Swamp Sclerophyll Forest includes 'Alluvial swamp mahogany forest' (map unit 35) of NPWS (2002); on the south coast, it includes 'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175) of Thomas et al. (2000) and 'Coastal Sand Swamp Forest' (map unit 45) of Tindall et al. (2004). FE 175 is not defined from plot data so we were not able to use it in our analyses. Map unit 45 is the most relevant for our study, but this includes occurrences on sand plains and there is an inconsistency in the final determination which omits map unit 34 of NPWS (2002) which occupies similar environments.

We used a combination of an existing map of coastal landforms and geology and several models of alluvial landform features to determine the likely extent of floodplains and alluvial soils in our study area. We used aerial photograph interpretation to map vegetation patterns within floodplain and alluvial areas and to map photo patterns likely to indicate the presence of Swamp Sclerophyll Forest outside modelled areas. Our study area includes over 350,000 hectares of state forest.

Our analyses of plot data assigned 19 plots (including one partial floristic plot) out of 6635 to a previously defined Swamp Sclerophyll Forest community (p45) dominated by *Eucalyptus robusta*. We confirm that this species is strongly characteristic of the assemblage and concluded that any stand at which it was dominant in the study area is likely to represent the TEC. We also assigned a further three plots with ambiguous relationships to Swamp Sclerophyll Forest. These plots were floristically more closely aligned to another forested wetland community identified by Tozer et al. (2010), p107 (Estuarine Creekflat Scrub), but were also related to p45 and had *Eucalyptus botryoides* as the dominant overstorey species. Despite statements in the final determination, we did not find any evidence of forest dominated by *Eucalyptus longifolia* belonging to Swamp Sclerophyll Forest TEC, although the species was found associated with stands dominated by *E. robusta*. Out of 22 plots, we identified two plots in state forest (one in Nowra State Forest and one in Termeil State Forest) which we assessed as Swamp Sclerophyll Forest TEC. We used plot data, verified records of *E. robusta* locations in the study area and a selection of environmental and remote-sensing variables to develop a Boosted Regression Tree (BRT) model of the probability of occurrence of Swamp Sclerophyll Forest. We assigned our mapped polygons to Swamp Sclerophyll Forest based on plot data, overstorey and understorey patterns, landform features and modelled probabilities. We used the BRT model to ensure that all areas of potential Swamp Sclerophyll Forest had been checked using API and mapped as appropriate.

From these assignments, in our study area we identified approximately 32 hectares of Swamp Sclerophyll Forest in state forest. Given the strength of association between the species assemblage presented and the cited map unit p45, we believe that our mapping of Swamp Sclerophyll Forest TEC in state forest closely represents the true extent, because of the very limited occurrence in state forest and because the distinctive photo pattern of stands dominated by *E. robusta* are reliably interpreted by mappers.

2 Introduction

2.1 Project Rationale

This project was initiated by the NSW Environment Protection Authority (EPA) and Forestry

Corporation of NSW (FCNSW) as a coordinated approach to resolve long standing issues surrounding the identification, extent and location of priority NSW Threatened Ecological Communities (TECs) that occur on the NSW State Forest estate included within eastern Regional Forest Agreements.

2.2 Final Determination

This is one of several determinations relating to vegetation associated with coastal floodplains. An assessment of the characteristics and conservation status of vegetation on coastal floodplains and associated landforms in NSW was initially made by Keith and Scott (2005). While it was *in press* at the time, this assessment provided important information for the final determination of Swamp Sclerophyll Forest (SWSF) on coastal floodplains. SWSF on coastal floodplains was first gazetted as an Endangered Ecological Community on 17 December 2004. Minor amendments were subsequently made and the determination to make a minor amendment was gazetted on 8 July 2011.

Paragraph 1 of the final determination (NSW Scientific Committee, 2011) states that SWSF occurs on *'...waterlogged or periodically inundated alluvial flats and drainage lines associated with coastal floodplains.'* and that the community is 'typically open forest' but sometimes occurs as shrubland, fernland, reedland or sedgeland. This is somewhat inconsistent with Paragraph 4 which states that SWSF *'...has an open-to-dense tree layer of eucalypts and paperbarks...'.* Widespread and abundant dominant tree species are listed as including *Eucalyptus robusta* (swamp mahogany), *Melaleuca quinquenervia* (paperbark) and, south from Sydney, *Eucalyptus botryoides* (bangalay) and *Eucalyptus longifolia* (woollybut).

Paragraph 6 of the final determination (NSW Scientific Committee, 2011) cites Keith and Scott (2005) as identifying a group of vegetation samples which belong to the community. The particular group is not explicitly stated, but it may be inferred from the context of the report and the name of the group that the determination refers to Keith and Scott's group 1, Swamp Sclerophyll Forest on Coastal Floodplains.

It is ambiguous whether all of the 79 samples allocated to Keith and Scott's group 1 are considered to belong to the community, as 57 of them are assessed as not floodplain vegetation.

Paragraph 7 of the final determination (NSW Scientific Committee, 2011) refers to other Endangered Ecological Communities which may adjoining or intergrade with SWSF and states that these collectively cover all remaining native vegetation on the coastal floodplains of New South Wales. However, no evidence is provided to support this statement. It appears to be an assumption rather than a statement of fact.

Paragraph 8 of the final determination (NSW Scientific Committee, 2011) refers to communities or map units described by previous studies, which include, are included within or are otherwise related to SWSF. These offer important information of potential diagnostic value, although in some cases there is only a partial relationship and the limits of the relationship are not clear. Although not explicit, it may be inferred from paragraph 8 that a community or map unit which is described in a cited study but not mentioned in the final determination is not referable to Swamp Sclerophyll Forest. This inference is consistent with the extent estimates provided in paragraph 9, but may not be consistent with statements in paragraph 7 pertaining to intermediate assemblages and transitional habitats, depending on how the terms 'intermediate' and 'transitional' are interpreted.

2.3 Initial TEC Reference Panel Interpretation

Under the *Threatened Species Conservation Act 1995* (TSC Act), TECs are defined by two characteristics: an assemblage of species and a particular location. The TEC Panel agreed that the occurrence of SWSF is constrained to the IBRA bioregions stated in the final determination, but that contiguous areas within adjacent bioregions should be included in analysis and mapping where appropriate. The panel agreed that SWSF is a TEC which has been defined primarily from previous quantitative floristic analyses. Accordingly, the assemblage of species is interpreted by reference to vegetation communities which have been previously described from quantitative floristic analysis and which have been explicitly listed in the final determination. From the final determination for SWSF, Table 1 summarises the key determining features of SWSF and how they have been used in the assessment reported here, based on the interpretation of the features by the Panel.

Table 1: Key features of Swamp Sclerophyll Forest of potential diagnostic value. Numbers in the left-hand column refer to paragraph numbers in the final determination.

	Feature	Diagnostic value and use for this assessment
1	NSW occurrences fall NSW North Coast, Sydney Basin and South East Corner bioregions	Explicitly diagnostic, but used with some allowance for occurrence outside. For this report we focus on the area south of Sydney and adopt the South East Corner bioregion and the southern areas of the Sydney Basin bioregion
1	Associated with humic clay-loams and sandy loams	Indicative, not used
1	On waterlogged or periodically inundated alluvial flats and drainage lines and river terraces associated with coastal floodplains.	Potentially diagnostic, depending on agreed definition of landform features
1	Generally occurs below 20 m though sometimes up to 50 m	Implicitly diagnostic; 50m elevation used as a threshold unless there is clear evidence otherwise
1,4	Structure of the community either open forest, shrubland, fernland, reedland or sedgeland (para 1) or with an open-to-dense tree layer of eucalypts and paperbarks	Indicative, but the two paragraphs are not consistent
1	Characterised by the listed 59 plant species, including 4 eucalypts	Potentially diagnostic, in the context of previously described communities cited in the determination
2	Known from 29 LGAs but may occur elsewhere.	Indicative, not used.
4	The most widespread and abundant dominant trees include *Eucalyptus robusta* (swamp mahogany), *Melaleuca quinquenervia* (paperbark) and, south from Sydney, *Eucalyptus botryoides* (bangalay) and *Eucalyptus longifolia* (woollybut). Other trees may be scattered throughout at low abundance or may be locally common at few plots, including *Callistemon salignus* (sweet willow bottlebrush), *Casuarina glauca* (swamp oak) and *Eucalyptus resinifera* subsp. *hemilampra* (red mahogany), *Livistona australis* (cabbage palm) and *Lophostemon suaveolens* (swamp turpentine). It is implied that *Melaleuca ericifolia* may be dominant	Indicative, but used to distinguish SWSF from other related EECs where floristic composition is otherwise ambiguous
4	Description of understorey, listing 6 small tree species, 5 shrub species, 3 vine species and 9 ground cover species which may be present	Indicative, not used

	Feature	Diagnostic value and use for this assessment
6	Description of differences in tree species composition and environmental differences from other EECs on coastal floodplains	Indicative, but used to distinguish areas which are floristically similar to two or more EECs
8	On the south coast, this community includes 'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175) of Thomas et al. (2000) and 'Coastal Sand Swamp Forest' (map unit 45) of Tindall et al. (2004).	There is no floristic plot data for forest ecosystem 175, which appears to be based on dominance by *Eucalyptus robusta*. Map unit 45 is used as the main comparative diagnostic feature, though the inclusion of this map unit, which is not always alluvial, may not be consistent with the environmental descriptors in paragraph 1.

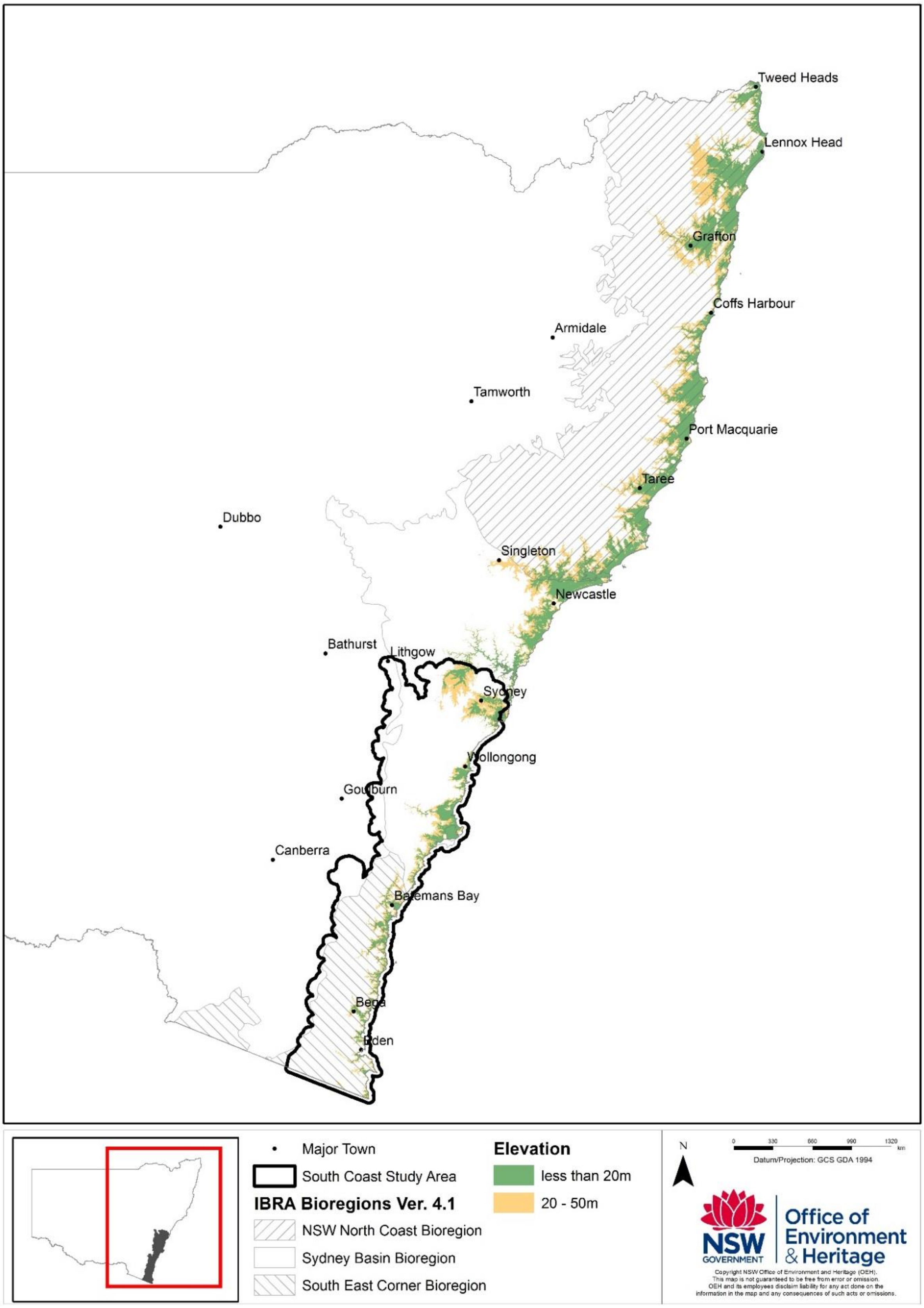
2.4 Assessment Area

2.4.1 Location and study area boundaries

We partitioned the assessment of Swamp Sclerophyll Forest on coastal floodplains TEC into two study areas: the North Coast and South Coast. We did this to minimise the risk that relationships between regional vegetation communities and the TEC would be confounded or masked by geographical variation or other major ecological gradients, which might otherwise be a significant risk if we had treated the full latitudinal range of the TEC as a single study area. For our purpose, the Sydney metropolitan area provides a convenient boundary because it approximates a significant ecological boundary and because it is a highly modified landscape which does not contain any state forest to be assessed for our project.

Our South Coast study area is shown in Map 1. This area includes all of the South East Corner bioregion, all IBRA subregions south from the Hawkesbury River in Sydney Basin bioregion, a 5 kilometre wide perimeter zone on these areas, and areas below 250 metre elevation in river valleys in South East Highlands bioregion. We considered that this would include all vegetation relevant to any TEC likely to occur in state forests on the NSW South Coast, from Sydney down to the Victorian border. Within our South Coast study area, there are no lowland state forests north of Nowra and most of our assessment of floodplain TECs, including Swamp Sclerophyll Forest, was concentrated on the area south of Nowra. Many of the maps in this report show only the most relevant section of our study area, south of Nowra.

<u>Map 1</u>: South Coast assessment area showing bioregions and elevation thresholds.



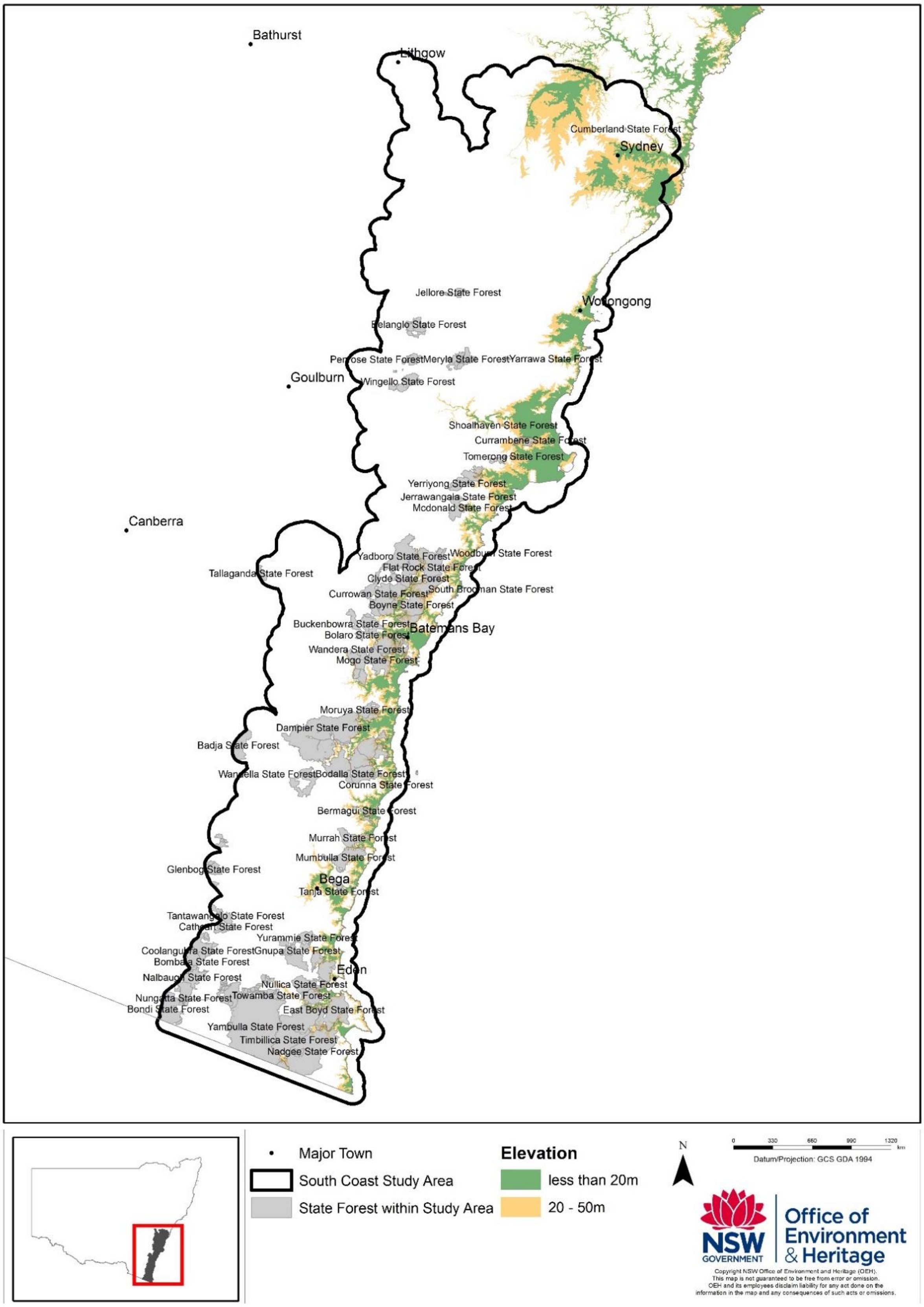
2.4.2 State forests subject to assessment

The South Coast study area includes Crown forest estate situated within Southern and Eden Integrated Forestry Operations Approval (IFOA) regions. A total of 61 state forests were included in this assessment (Table 2). State forests excluded from the assessment include those areas defined as Forest Management Zones 5 (Hardwood Plantations) and Zone 6 (Softwood Plantations). Small areas of native forest wholly enclosed or adjoining Forest Management Zone 6 (Softwoods) are also excluded from this assessment as they are considered to be outside of the authority of the IFOA.

Table 2: List of candidate state forests assessed in the South Coast study area.

State Forest	Area (Ha)	State Forest	Area (Ha)
Badja State Forest	4839	Moruya State Forest	4059
Bateman State Forest	1	Mumbulla State Forest	6137
Belanglo State Forest	3891	Murrah State Forest	4215
Benandarah State Forest	2761	Nadgee State Forest	20537
Bermagui State Forest	1861	Nalbaugh State Forest	4396
Bodalla State Forest	24079	Newnes State Forest	281
Bolaro State Forest	1779	North Brooman State Forest	3631
Bombala State Forest	620	Nowra State Forest	521
Bondi State Forest	12742	Nullica State Forest	18298
Boyne State Forest	6161	Nungatta State Forest	887
Broadwater State Forest	167	Penrose State Forest	1986
Bruces Creek State Forest	791	Shallow Crossing State Forest	3855
Buckenbowra State Forest	5193	Shoalhaven State Forest	104
Cathcart State Forest	1735	South Brooman State Forest	5587
Clyde State Forest	3587	Tallaganda State Forest	1363
Coolangubra State Forest	8489	Tanja State Forest	867
Corunna State Forest	183	Tantawangalo State Forest	2466
Cumberland State Forest	40	Termeil State Forest	698
Currambene State Forest	1695	Timbillica State Forest	9144
Currowan State Forest	11977	Tomerong State Forest	212
Dampier State Forest	33746	Towamba State Forest	5471
East Boyd State Forest	21010	Wandella State Forest	5492
Flat Rock State Forest	4896	Wandera State Forest	5198
Glenbog State Forest	4641	Wingello State Forest	3975
Gnupa State Forest	1318	Woodburn State Forest	10
Jellore State Forest	1411	Yadboro State Forest	10750
Jerrawangala State Forest	268	Yambulla State Forest	47108
Kioloa State Forest	171	Yarrawa State Forest	179
Mcdonald State Forest	3684	Yerriyong State Forest	6604
Meryla State Forest	4554	Yurammie State Forest	4050
Mogo State Forest	15498	**Total**	**352971**

<u>Map 2</u>: Candidate state forests assessed in the South Coast study area.



2.5 Project Team

This project was completed by the by the Ecology and Classification Team in the OEH Native Vegetation Information Science Branch. It was initiated and funded by the NSW Environment Protection Authority under the oversight of the Director Forestry.

The project was managed by Daniel Connolly. Doug Binns undertook the floristic analysis of survey plots, and has interpreted the relationships and relatedness between relevant vegetation communities. Allen McIlwee performed the spatial analysis including fine scale modelling of alluvial floodplain extent, and broad scale predictive distribution modelling. Owen Maguire and Bob Wilson undertook API mapping using 3D stereo imagery across the study area. Flora survey plots were completed by Jackie Miles and Paul McPherson (Eden area), with additional samples completed by Ken Turner, Jedda Lemmon and Doug Binns. Field assistance was provided by Paula Pollock (EPA) Alex Waterworth (EPA), Ken Turner, Daniel Connolly and Philip Gleeson. Dan Bowles provided GIS, mapping and technical support.

3 Methodology

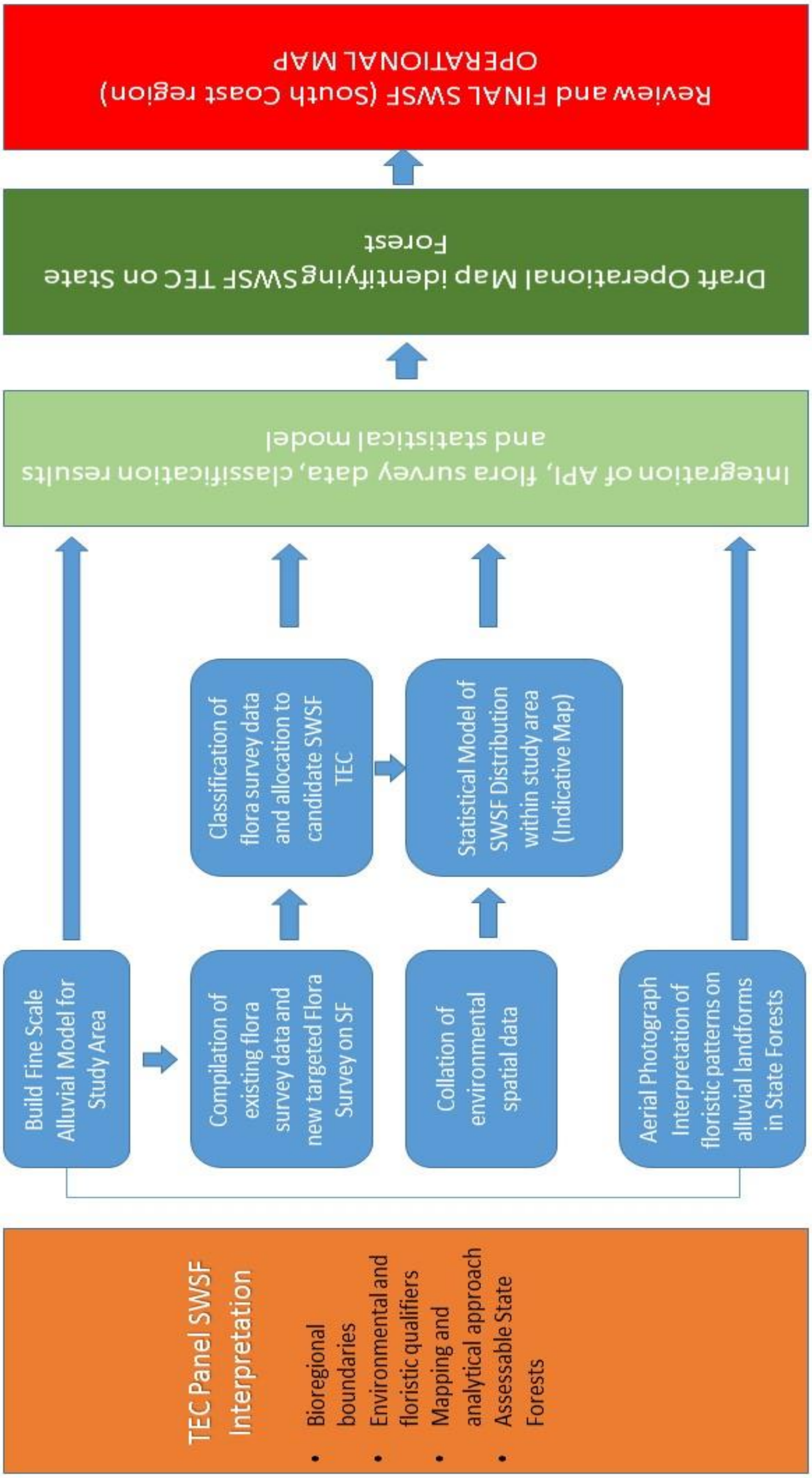
3.1 Approach

Diagram 1 provides a schematic overview of our approach. Analysis and mapping was guided by the general principles and particular interpretation of Swamp Sclerophyll Forest (SWSF) TEC adopted by the TEC Reference Panel, described in Section 2.3. For the purpose of this project, SWSF is interpreted to be defined primarily by floristic plot data previously allocated to vegetation communities which have been previously described from quantitative floristic analysis and which have been explicitly listed in the final determination. The following statements from the final determination provide the basis for comparative analysis In the Illawarra, this community includes 'Alluvial swamp mahogany forest' (map unit 35) of NPWS (2002). On the south coast, this community includes 'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175) of Thomas et al. (2000) and 'Coastal Sand Swamp Forest' (map unit 45) of Tindall et al. (2004).

Plots in which standard floristic data have been collected (comprising data already held in the OEH VIS flora survey database over all tenures and data collected specifically for this project in state forests) were compared with plots previously allocated to the communities' equivalent to those listed in the SWSF final determination. A number of methods were used for comparison, comprising both dissimilarity-based methods and methods based on multivariate regression. The results were then used to assess the likelihood that plots in state forests belonged to one or more of the communities listed in the final determination. There is no single preferred method of making these comparisons and no objective threshold to determine whether or not a plot belongs to a community (and thus SWSF). Options for different methods and thresholds represent narrower or broader interpretations of SWSF, but this approach using plot-based floristic comparison provides a means of consistently allocating plots to being either SWSF or not for a range of interpretation options.

The final determination does not cite a map resource that can be used as a primary layer to guide the location of suitable landscape features used in the TEC definition, Since the date of the final determination, a set of maps of landform features has been developed which allows parts of the cited communities that are mapped on floodplains or mapped on alluvial soils to be distinguished to some extent, although the scale is not always suitable for our purpose and finer-scale alluvial features are omitted (Troedson & Hashimoto 2008). There is no reference to these maps in the final determination. In addition to these maps, we have developed a fine scale alluvial model, described in Section 3.2.2, to map areas of potential alluvial features.

<u>Diagram 1</u>: Schematic overview of approach.



3.2 Identifying Alluvial Landforms

3.2.1 Coastal comprehensive assessment floodplain maps

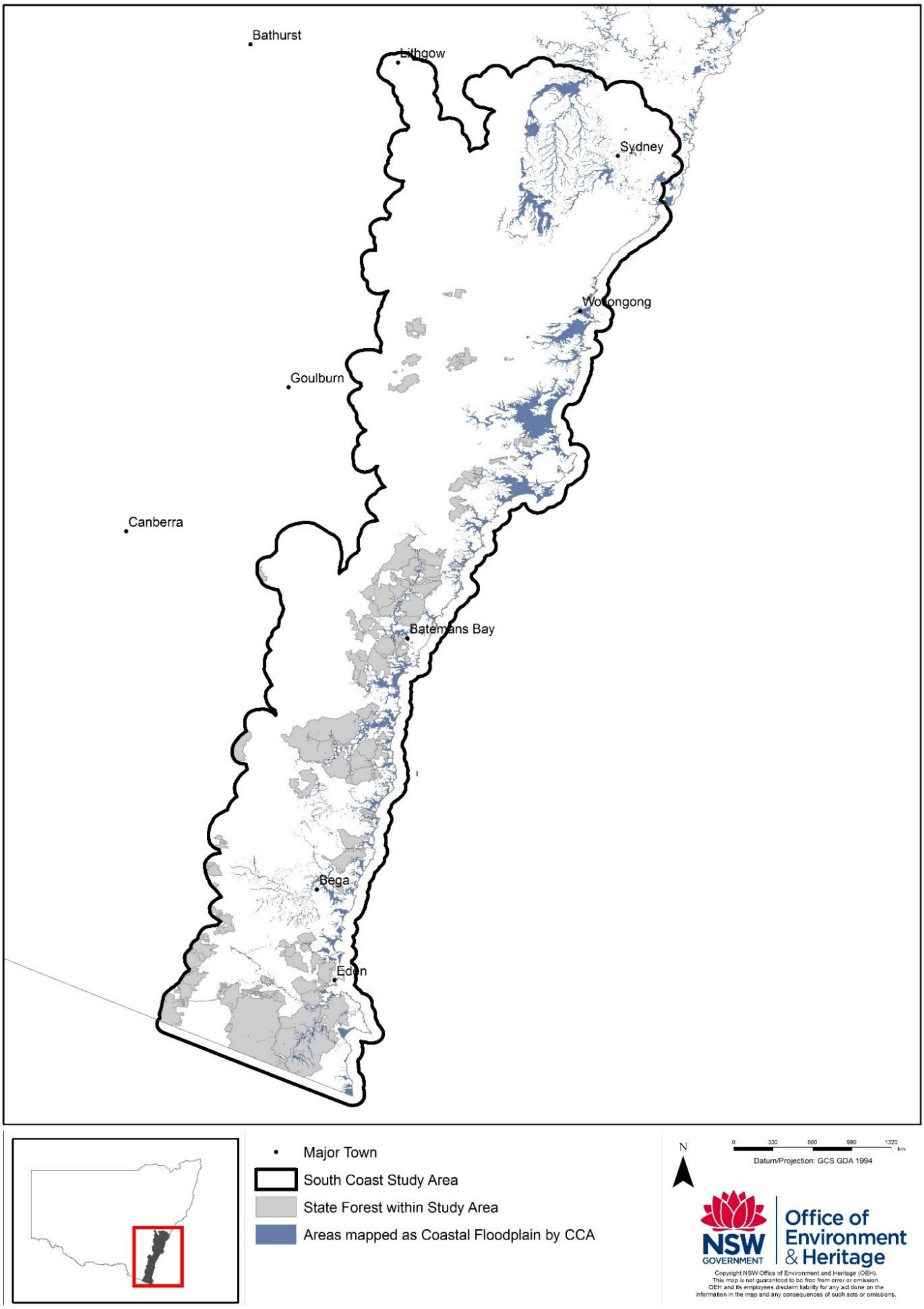
Troedson and Hashimoto (2008) describe a series of maps of Quaternary geology and related features, used for a comprehensive coastal assessment. We have used all the alluvial surface geology units from these maps to define areas of mapped alluvium and we have used map unit descriptors to define areas of coastal floodplains at 1:25 000 scale (shown at a smaller scale in Map 2).

3.2.2 Fine scale alluvial model

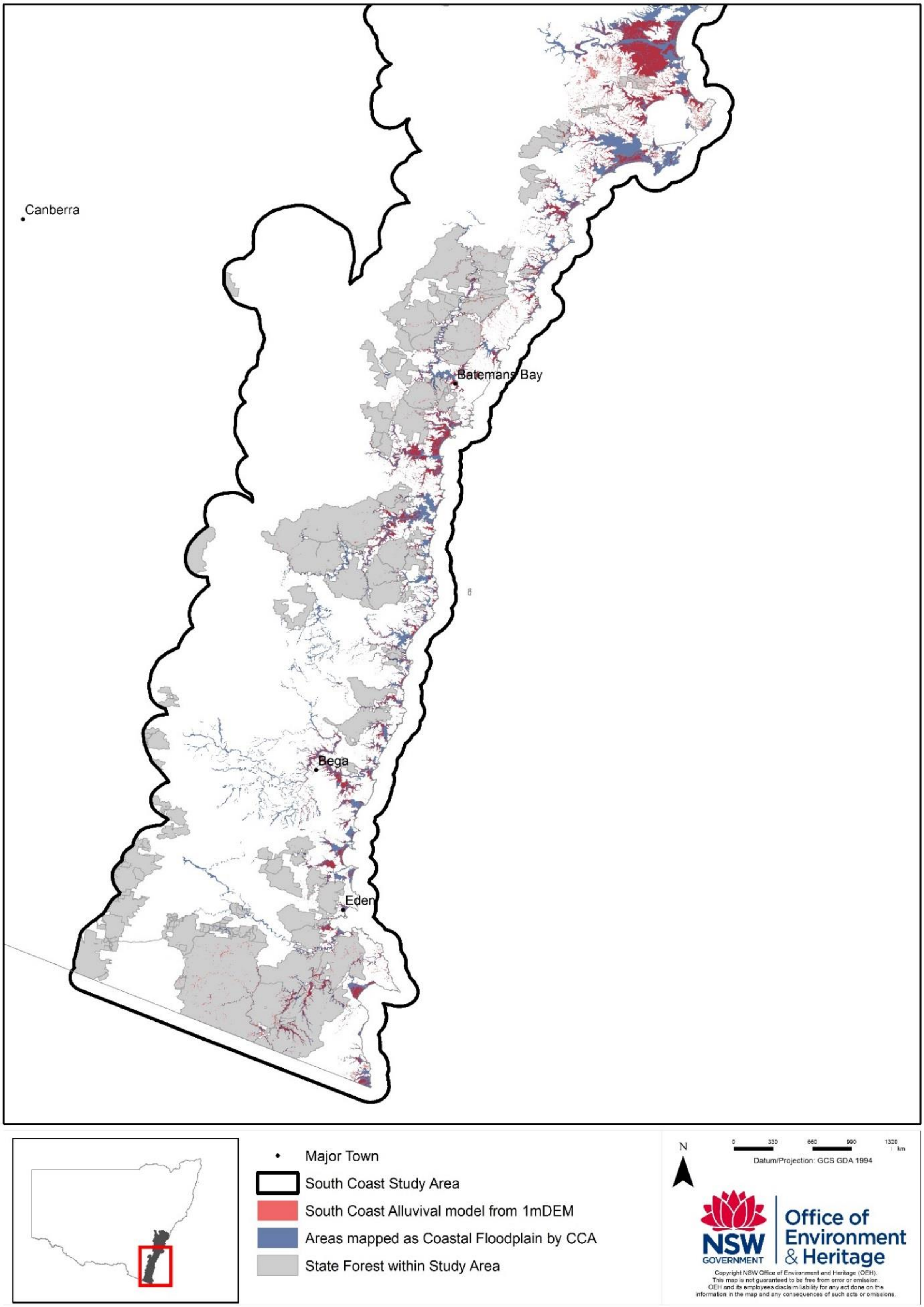
We generated a fine scale digital representation of landscape elements in the study area that are likely to be associated with the range of floodplain and alluvial descriptors offered by the final determination for SWSF (Map 3). The concept for the model is that floodplain and alluvial environments relevant to SWSF occur in areas which are flat or have low slope and which receive either run-on flow, pooling or overbank flow at above particular thresholds, which vary with slope and catchment size. The model uses a 1 m resolution, filled DEM derived from LiDAR data to calculate flow accumulation, elevation above stream channels along the lines of flow, and slope. Stream channels are defined at catchments >= 0.5 ha. Thresholds are applied to combinations of the three variables to delineate areas alluvial /floodplain EECs. This includes River-Flat Eucalypt Forest, Swamp Oak Forest and Swamp

Sclerophyll Forest. The actual occurrence of these EECs is likely to be less than the model indicates, since some areas will have vegetation composition which is not consistent with the determinations for any of these EECs. The set of mapped polygons in map 3 were used as a starting point to identify sites for new floristic surveys, as well as API digitising and mapping.

Map 3: Coastal floodplain mapped by the comprehensive coastal assessment (CCA) for the South Coast study area.



<u>Map 4</u>: Alluvial model overlaid on top of floodplain mapping by CCA.



3.3 Compilation of Existing Vegetation Data

3.3.1 Existing vegetation classification

The two classifications cited in the final determination which are most relevant to SWSF in state forests south of Sydney are those of Thomas et al. (2000) and Tindall et al. (2004). The absence of quantitative data precluded further quantitative assessment of forest ecosystem 175 (Thomas et al. 2000), though it is described as being dominated by *Eucalyptus robusta*, so we examined relationships to previous classifications of all plots in which this species was dominant or had a cover score of at least 3. Also, it can be noted that some overlap in mapped distribution occurs between units defined by Tindall et al. (2004) and Thomas et al. (2000). Subsequent to the final determination, each of these studies has been superseded by more recent studies (Gellie 2005 in place of Thomas et al. 2000, and Tozer et al. 2010 in place of Tindall et al. 2004) using a larger pool of data. Previously-defined communities cited in the final determination can be traced to equivalent communities in the more recent classifications, so plot allocations for the latter are used in this project for floristic comparison. The relevant communities from the final determination and their more recent equivalents are listed in Table 3.

Table 3: Communities defined from recent analyses which are equivalent to those cited in the final determination.

Community listed in determination	Recent equivalent
'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175)	VG 175: Northern Coastal Lowlands Swamp Forest – *E. robusta* (Gellie 2005)
'Alluvial swamp mahogany forest' (map unit 35) (NPWS 2002)	
MU 45 Coastal Sand Swamp Woodland (Tindall et al. 2004)	FoW p45 Coastal Sand Swamp Woodland (Tozer et al. 2010)

3.3.2 Existing vegetation data

A recent review of OEH systematic flora survey data holdings in eastern NSW (OEH in prep) was available for the project. The review identified a subset of data suitable for use in quantitative vegetation classification on the basis that it met a set of predefined criteria, namely that plots:

- provided location co-ordinates with a stated precision of less than 100m in accuracy
- covered a fixed survey search area of approximately 0.04 hectares
- supported an inventory of all vascular plants
- provided a documented method that assigns a quantitative and/or semi quantitative measure of the cover and abundance of each species recorded

A total of 15487 plots within the study area, including 171 plots surveyed specifically for our project, were in the OEH VIS Flora Survey Database at 22 July 2015. 11,558 of these had floristic data suitable for analysis.

3.3.3 Analysis data set

We chose our pool of data to ensure that it included all plots which had previously been allocated to any community that we considered relevant to south coast SWSF or to any of the other coastal TECs covered by our broader project and all other plots which had not previously been analysed or allocated to a community in a regional study. Plots were omitted which had previously been allocated to communities which we considered not relevant to the group of TECs under consideration in our study area. Communities were assessed as not relevant for one of the following reasons: tablelands communities occurring on ridges or slopes mostly above 600 m; ridgetop dry shrubby forests; heaths with few species in common with communities of interest; communities recorded only north of the Illawarra area and not listed in any of the relevant determinations; communities which were clearly floristically and environmentally distinct from communities of interest. Appendix A indicates all communities from which plot data were included. We also included all plots for which no previous community allocations were available and all plots which had not previously been classified or allocated to a community.

3.3.4 Data preparation and taxonomic review

All species in the pooled dataset was standardised for analysis using a review completed for all flora survey data compiled for the Eastern NSW Classification (OEH in prep). Nomenclature was standardised to follow Harden (1990-93; 2000-2002) and updated to reflect currently accepted

revisions using the PlantNETWebsite (Royal Botanic Gardens 2002). The data was also amended to:

- exclude exotic species
- exclude species identified to genus level only
- maintain consistency in assignment of subspecies or varieties to species.

Cover and abundance score data extracted from the pooled data set was standardised to a six class modified braun-blanquet score. The transformation algorithm available within the OEH VIS Flora

Survey data analysis module was applied to the analysis dataset.

3.3.5 Swamp Mahogany locality records

All records of *Eucalyptus robusta* were extracted from the Atlas of NSW Wildlife (Bionet access 10 Nov 2015). Identification accuracy and spatial precision were assessed in a number of steps. Observations with a stated spatial accuracy of more than 100 metres were initially identified then excluded from the modelling dataset. Records that were situated outside currently defined distributional limits (Plantnet 2015) were field checked and rejected or accepted on the basis of new field information. Remaining records were then closely reviewed in GIS against recent aerial imagery and topographic data to confirm that stated location descriptions and landscape characteristics matched. Records which recorded inconsistent details between georeferenced data and plot description were resolved by contacting the observer to confirm location details or in the absence of additional information were then excluded from the modelling dataset.

3.4 New Survey Effort

3.4.1 Survey stratification and design

New flora survey effort targeted habitats within state forests likely to support alluvial and related low lying landscapes. State forests considered to be candidates for survey and assessment were identified using guidance from the TEC interpretation panel to discriminate bioregional and elevation thresholds. The purpose of new survey effort was to ensure that all candidate state forests identified included replicated samples of target habitats in order to assess relationships to the species assemblage presented in the final determination. Approaches to plot selection differed slightly by region.

Nowra to Bega Valley

Candidate state forests were assessed by using a geographic information system to display 10 metre contour lines within and adjoining state forest boundaries. Low relief landscapes adjacent to drainage channels, including creeks, streams and rivers were marked. Existing flora samples within state forests were displayed to assess existing survey effort. Digital aerial imagery was then assessed at each point to ensure that the sample was located within woody native vegetation relatively free of disturbance. A selection of samples was then chosen from the pool of identified plots based on road and trail access.

Bega Valley to Victorian Border

A detailed alluvial model highlighting low relief drainage channels and adjoining terraces was available for the Eden region. Existing flora survey samples were intersected with the model to assess the current survey effort within state forest.

A set of 1000 randomly located notional sample points were then generated across the distribution of the model within state forest tenures. Samples were then assessed manually for accessibility and whether the vegetation was dominated by native woody vegetation and relatively free of visible disturbance. If samples failed to satisfy the criteria the plot was discarded. Iterations of random sample points was stopped when a minimum of five samples were located within each state forest. Selected samples were then chosen to ensure that the range in elevation across the modelled area within each state forests was sampled. Final sampled plots depended upon the access constraints and time available to field teams.

3.4.2 Survey Method

Systematic surveys

Systematic flora survey were conducted in accordance with OEH standard methods (Sivertsen 2009). Preselected sample points were located in the field using a global positioning system (GPS). In the field, plots were assessed for the presence of heavy disturbance (such as severe disturbance through clearing or weed infestation) and were either abandoned or moved to an adjoining location in matching vegetation.

Systematic floristic sample plots were fixed to 0.04 hectares in size. The area was marked out using a 20 by 20 metre tape, although in some communities (such as riparian vegetation) a rectangular configuration of the plot (e.g. 10 by 40 metres) was required. Within each sample plot all vascular plant species were recorded and assigned estimates for foliage cover and number of individuals. Raw scores were later converted to a modified braun-blanquet scale (Poore 1955) as shown in Table 4.

Table 4: BB-to-cover abundance conversion table.

Modified braun-blanquet 6 point scale	Raw Cover Score	Raw Abundance Score
1 (<5% and few)	<5%	≤3
2(<5% and many)	<5%	≥3
3 (5-25%)	≥5 and <25%	any
4 (25%-50%)	≥25% and <50%	any

5 (50%-75%)	≥50% and <75%	any
6 (75%-100%)	≥75%	any

Species that could not be identified in the field were recorded to the nearest possible family or genus and collected for later identification. Species that could not be identified confidently were lodged with the NSW Herbarium for identification. At each plot, estimates were made of the height range, projected foliage cover and dominant species of each vegetation stratum recognisable at the plot. Measurements were taken of slope and aspect. Notes on topographic position, geology, soil type and depth were also compiled. Evidence of recent fire, erosion, clearing, grazing, weed invasion or soil disturbance was recorded. The location of the plot was determined using a hand held GPS or a topographic map where a reliable reading could not be taken. Digital photographs were also taken at each plot.

Non-systematic surveys

Non-systematic survey techniques were employed by survey teams to record observations of flora species present in likely habitat. Survey observations were made against a standard proforma which recorded a minimum of three dominant species in each of the upper, middle and ground stratum.

These partial floristic plots were identified as rapid field sites. No fixed assessment area was used and the number of species recorded was subject to time and visibility constraints. Observations were supported by a georeferenced position and a digital photograph. In addition brief descriptions of vegetation composition and pattern were also made intermittently by field crews to identify vegetation patterns of interest. These were retained as free text descriptors attached to a georeferenced point and are known as 'Field Note Points'.

3.5 Classification Analyses

3.5.1 Clustering

There is a range of methods available for quantitative classification of vegetation communities.

Results may vary depending on which method is used and which parameters are chosen for a particular method. There is no single best method, but the most widely used method is clustering of plots based on pairwise dissimilarities. As results vary with varying dissimilarity measures, comparisons with previous classification require use of the same measures. Relationships among plots vary depending on the data pool used, so that introducing additional data may change the composition of previously defined groups.

Most clustering methods result in a plot being allocated to a single vegetation community. A plot may also be related to other communities, but these interrelationships are not evident from allocations. As an alternative, fuzzy clustering methods assign a membership value to each plot for each community, which provides a measure of the likelihood that a plot belongs to any particular community. For this project, Noise Clustering (De Cáceres et al. 2010; Wiser & De Cáceres 2013) was selected as the most appropriate fuzzy clustering method for three reasons: it allows specification of fixed clusters defined from previously described groups and provides direct allocations to those groups; it is relatively robust to outliers (which have a large difference from all previously defined groups or communities) and allows clustering into new groups; and it is robust to the prevalence of transitional plots with relationships to two or more previously defined communities. The latter are both characteristic of data for the study area. Noise Clustering requires specification of a fuzziness coefficient (where a coefficient of 1 is equivalent to hard clustering which allocates each plot to only one community) and a threshold distance for outliers. Following a number of trial runs with different subsets of data, different fixed groups and different parameters, we chose a fuzziness coefficient of 1.1 and an outlier threshold of 0.85. These parameters resulted in results which were relatively robust to different sets of data and which had a high degree of consistency with previous classifications. Analyses were done using functions in the 'vegclust' package in R 3.1.1.

We conducted a number of analyses using different subsets of data and different sets of previously defined communities, as follows:

1. A subset of 1345 plots which comprised all plots previously allocated to a relevant vegetation group by Gellie (2005) plus previously unallocated plots in state forest or surveyed for this project. Relevant vegetation groups are listed in Appendix A. This provided an assessment of the membership of all state forest plots to communities which could be related to those defined by Thomas et al. (2000) which were explicitly listed in the final determination.
2. A subset of 2708 plots which comprised all plots previously allocated to a relevant vegetation group ('SCIVI' community) by Tozer et al. (2010) plus previously unallocated plots in state forest or surveyed for this project. Relevant vegetation groups are listed in Appendix A.
3. This provided an assessment of the membership of all state forest plots to communities which could be related to those defined by Tindall et al. (2004) and Keith & Bedward (1999) which were explicitly listed in the final determination.
4. A subset of 6234 plots comprising all suitable plots available in VIS up to 22 July 2015 which either previously had been allocated to a relevant community by either Gellie (2005) or Tozer et al. (2010), or had not previously been allocated. This subset included all previously unallocated plots regardless of occurrence in state forests. Two fuzzy clustering analyses were applied to this subset, one using Gellie (2005) allocations as fixed groups and the other using Tozer et al. (2010). These analysis were designed to investigate allocations in a broader context.
5. A traditional hard clustering, using ALOC in PATN, was applied to the same subset of 6234 plots for comparison with fuzzy clustering results.

3.5.3 Multivariate regression

We used multivariate regression to make pair-wise comparisons of selected pairs of communities to test their degree of floristic similarity to other pairs, using the 'mvabund' package in R3.1.1 (Warton et al. 2012). This method does not rely on calculation of dissimilarities so provides an independent comparison with distance-based methods. For each pair, the difference in summed AIC is calculated, summed across all species in both communities combined, between a null model and a model using community as the factor. The difference in summed AIC provides a relative measure of the extent to which recognising two separate communities provides a better model of species occurrence than does a single combined group. A higher difference indicates communities which are more clearly distinct. A difference close to zero, or negative, indicates no distinction between groups. We also used the results of multivariate regression to identify species which are most strongly characteristic of difference between groups. Species with the highest difference between AIC for the group model and that for the null model are those with most diagnostic value.

3.5.3 Other methods

We made a comparison between the assemblage as listed in the final determination and the various communities either cited in the final determination or otherwise floristically similar or occurring in similar environments. For this comparison we used plots which could be allocated to a community with a high degree of confidence (membership >=0.5 from fuzzy clustering results) and excluded ambiguous plots. We based the comparison simply on the number and proportion of the species listed as the SWSF assemblage which were present in the group of plots comprising the community to be compared. The number in the group depends on both the degree of concordance and the number of plots from which the pool of species is drawn. To allow a valid comparison among communities, we calculated the number as the mean of the numbers from 100 repeated equal-sized random samples. This comparison was restricted to communities with at least ten plots. We also calculated the mean proportion of the assemblage species per plot for each community. These measures cannot be used in an absolute since because the final determination does not provide any indication of thresholds. However, they are potentially useful in a relative sense, in the context of communities listed as SWSF in the final determination.

3.5.4 Allocation of plots to SWSF and other communities

We assessed plots as being SWSF if their membership of any floristic community cited in the final determination was 0.5 or above. The only such community relevant to State Forests in our study area was p45. We classified plots as belonging to SWSF regardless of whether they were on mapped alluvium. We did this as a precautionary resolution of the inconsistency in the final determination relating to community p45. The inconsistency is that SWSF is stated to occur 'On waterlogged or periodically inundated alluvial flats and drainage lines and river terraces...' but there is no explicit qualifier for community p45, for which several plots previously allocated to this community (and thus included by the final determination) do not occur on any of these landform features. We considered that plots which belonged to community p45 with membership <0.5 were potentially SWSF and we assessed these depending on their relationships to other communities. We followed a similar procedure to allocate plots to other TECs included in our broader study. These are described in separate reports (OEH, 2016a, 2016b).

3.5.5 Allocation of partial floristic plots

For each partial floristic plot, we identified the communities with the highest number of shared species and calculated the proportion of plots within each of those communities with that maximum number of shared species. We calculated binomial confidence limits for the proportions. If only a single plot within one community had the highest number of shared species, we also identified communities with fewer species and calculated proportions for those. We assigned each partial floristic plot to the community with the highest proportion of plots with the maximum number of shared species if the proportion was significantly greater than the next highest proportion. If confidence limits of proportions substantially overlapped, we regarded the plot as ambiguous and did not assign it to any community. Calculations were done using scripts in R.

3.6 Indicative Distribution Map

A niche modelling approach (also known as species or habitat distribution modelling) was used to create indicative potential distribution map of SWSF. This approach attempts to extrapolate the fundamental niche of the TEC in question outside the locations where it is known to be present (its realised niche), by relating known occurrence and absence to environmental predictors.

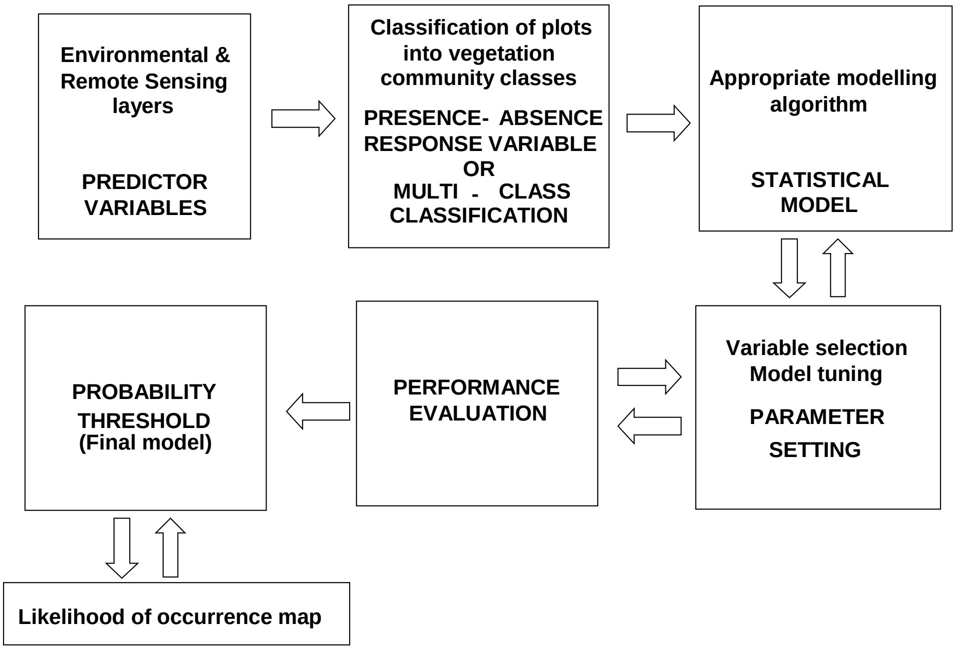
In order to model the distribution of SWSF, we need to characterize the environmental conditions that are suitable for the community to exist. The inclusion of the absence data from the plot allocation allows us to constrain the potential distribution model to a set of favourable environmental conditions that are not occupied by other existing vegetation communities. Nonetheless, without API and associated on-ground validation, it is difficult to determine the extent to which potentially suitable habitat is occupied by the TEC.

3.6.1 Modelling process

Ecological niche modelling involves the use of environmental data describing factors that are known to have either a direct (proximal) or indirect (distal) impact on a species or ecological community. Proximal variables directly affect the distribution of the biotic entity, while distal variables are correlated to varying degrees with the causal ones (Austin 2002).

To create an indicative map of the potential distribution of SWSF we used a Boosted Regression Tree (BRT) presence-absence modelling approach. BRT combines traditional regression tree techniques (Breiman et al. 1984) with 'boosting', a method for combining many simple regression trees to model relationships in multivariate data (Friedman 2001). Diagram 2 provides an overview of the step-by-step modelling process.

Diagram 2: Process for creating indicative TEC distribution maps.



3.6.2 Environmental and remote sensing predictor variables

A total of 144 environmental and 28 remote sensing variables were available for the South Coast study area. These included variables describing the climate, vegetation, topography and soils that were available across the entire modelling region at 30 metres resolution. The data consisted of raster grids, all with the same spatial extent and cell-size. The layers can be divided into 15 broad groups.

- **Location**: (5 variables - distance to coast and four distance to various stream orders)
- **Climate - Radiation and Energy** (8 variables)
- **Climate - Temperature** (17 variables)
- **Climate - Rainfall** (17 variables)
- **Geology** (2 variables)
- **Geophysics** (14 variables)
- **Landform and Terrain** (19 variables)
- **Landscape** (4 variables)
- Nine soil variables derived from the **Great Soil Group soil mapping**
- **Soil Minerals** (6 variables)
- **Soil Profile** (49 variables)
- **Soil NIR Spectra** (6 variables)

- **Soil Weather Index** (1 variable)
- **Single point in time imagery** (Remote Sensing) (3 variables)
- **Time-series analysis** (Remote Sensing) (3 variables)

3.6.3 Modelling algorithm

Boosted Regression Trees are an ensemble method for fitting statistical models (Elith et al. 2008) that differs fundamentally from more conventional techniques which aim to fit a single parsimonious model using as few uncorrelated variables as possible (e.g. GLM). A BRT model is a linear combination of many hundreds or thousands of regression trees, where a random subset of data is used to fit each new tree. Boosting works on the principal that it is easier to find and average many rough rules of thumb, than to find a single, highly accurate prediction rule. The final model is a linear regression model, where each term is a tree.

BRTs are capable of dealing with non-linear relationships and high-order interactions. This makes

them particularly well suited for ecological data (Elith et al. 2008). BRT was also chosen as the preferred method for modelling because it is relatively robust to the effects of outliers and irrelevant predictors, and can handle multiple variables that are correlated with one another (Leathwick et al. 2006). The method can handle NA values in the predictors, and no scaling or normalisation of the predictors is necessary (Leathwick et al. 2006). Further details on the application of BRT to ecological data can be found in Elith et al. (2008), Leathwick et al. (2006) and De'ath (2007). BRT models were fitted using the 'Dismo' (Hijmans et al. 2012) and 'gbm' (Ridgeway 2007) packages developed for R (v 3.2.2). Ten-fold cross-validation was used to train and test the model rather than splitting the data into a separate datasets. Models were evaluated on the basis of observed verse predicted (fitted) values, where the probability of occurrence (PO) values for all plots allocated to SWSF were plotted against the highest ranked PO values across all absence plots.

3.6.4 Variable selection TEC-habitat relationships

Many of the available predictor variables have little or no relevance to the SWSF, but this relevance is not known in advance. Elith and Leathwick (2016) provide a guide to BRT variable selection using the

R DISMO package (*https://cran.r-project.org/web/packages/dismo/vignettes/brt.pdf*). Following their procedures, we ran a gbm.step model using all available predictors, setting the learning rate (*lr*) to 0.001, the tree complexity set to 5 and bagging fraction set to 75%. All variables that returned relative influence values of > 1% (24 in this case) were then run through two alternative variable selection processes. First, the gbm.simplify algorithm was run to find those variables that give no evidence of improving predictive performance. Second, the VSURF in R package was also used identify a smaller subset of predictors relevant to the classification. VSURF performs a preliminary ranking of the explanatory variables using the random forests permutation-based score of importance, and proceeds using a stepwise ascending variable introduction procedure.

3.7 Operational TEC Map

3.7.1 Initial aerial photograph interpretation

The mapped extent of coastal floodplain by the Comprehensive Coastal Assessment and alluvial model derived from the 1 metre DEM were used as starting point for mapping the distribution of SWSF on State Forest. Aerial photograph interpretation (API) was used to assess both floristic and structural attributes found on modelled alluvial and related environments. In addition API was used to modify the boundaries of the modelled alluvial area using a prescribed list of eucalypt, casuarina and melaleuca species in combination with the interpretation of landform elements relevant to alluvial and floodplain environments.

API technicians, experienced in interpretation of NSW forest and vegetation types, used recent high resolution (50 centimetre GSD) stereo digital imagery, in a digital 3D GIS environment to delineate observable pattern in canopy species dominance, understorey characteristics and landform elements. Interpreters adopted a viewing scale between 1:1000 and 1:3000 to mark boundaries to infer changes in canopy and/or understorey composition. A mapping pathway (Diagram 3) and a set of attribute codes were established to ensure consistency in approach between interpreters. New classes were established where recurring image and field species patterns did not match predefined classes.

A minimum map polygon size of 0.25 hectares was used to inform the detection and delineation of image patterns. Interpreters were supplied with a range of environmental variables to accompany interpretation including existing vegetation community maps including forest management species typing, substrate maps, roads and trails and tenure boundaries. All relevant georeferenced floristic data held in OEH databases was extracted and supplied to aid interpretation. Floristic data was supplemented by interpreter field traverse using an iterative process to boost interpretation confidence by relating field observations to image patterns.

The initial API layer was cross-checked against the mapped outputs of the predictive modelling for the TEC. This process identified any areas of high likelihood of occurrence and checked that detailed API mapping was completed accurately against the detailed 3d image patterns.

Attribute codes applied to API mapping in the Eden region are presented in Appendix C1 and for the South Coast (Nowra to Bega) in Appendix C2.

2.7.2 Integration of spatial data

We used the API line work in combination with floristic plot data (both full and partial floristic plots) and field notes, to develop an operational map using the following procedure:

- For each polygon code (defined by unique combinations of canopy composition and understorey characteristics) we assessed the extent of plot sampling and the proportion of plots which we had assigned to SWSF. For codes which had been sampled but for which all plots had been assigned to communities other than SWSF, we excluded all polygons with that code from the SWSF map if the API description was consistent with the API type not being SWSF.
- For unsampled polygon codes, we considered the API description in relation to plot data and our interpretation of the final determination, sampling in other codes with similar canopy composition and location of individual polygons in relation to landscape features and composition of adjacent polygons, to make a subjective judgement whether polygons were likely to belong to SWSF. We did this assessment by individual polygons for those with matching canopy composition.

We believe that this procedure provides a precautionary operational map of SWSF. Polygons mapped as SWSF may include some which do not belong to this TEC using either our interpretation or an alternative interpretation.

2.8 Validation

We did not conduct any formal validation of our mapping of Swamp Sclerophyll Forest specifically, due to the expected limited extent in state forests. However, we collected an independent data set for validation of River-flat Eucalypt Forest TEC which we designed to sample environments in which SWSF occurs. This provides an indication of the extent to which we may have overlooked SWSF. For this sample, we applied a regular systematic grid over alluvial and floodplain environments in state forests which we had not otherwise mapped as any TEC, to provide 100 plots. We sampled 40 of the 100 plots using the OEH standard survey methods (Section 3.4.2), giving preference to those which were most accessible, but subject to ensuring a good geographical spread. We used the same fuzzy clustering methods that we used in our initial analyses (described in Section 3.5.1) to determine whether plots belonged to vegetation communities which we had included in SWSF or other TECs, or to other communities not included in any TEC.

4 Results

4.1 Survey Effort

Within our study area there were 6234 standard full-floristic plots in the OEH VIS database which we used for our initial analysis, 756 of which are in state forest. This includes 171 plots that were surveyed specifically for our project. We collected standard full-floristic data from a further 40 plots for validation, primarily designed for validation of mapping of River-flat Eucalypt Forest TEC. In addition, we collected partial floristic data and other observations for TEC assessment at a further 292 sample points in state forests.

4.2 Classification Analyses

4.2.1 Relationships to existing classifications

Of the 6234 plots analysed, 3590 (58%) could be allocated with a high degree of confidence to an existing community described either by Gellie (2005) or Tozer et al. 2010 ('SCIVI' community). A further 1257 (20%) were not closely related to any of the communities selected for inclusion in the analysis, but formed additional floristic groups. In some cases these were groups corresponding to communities that have been described elsewhere but which we chose to not include in analysis because they were not relevant to any TEC in our study area. In other cases they may represent previously undescribed communities. The remaining 1387 plots (22%) are not readily allocated to any single community and show a degree of relationship to two or more. Some of these may represent undescribed communities but many are likely to represent transitional vegetation or vegetation which belongs to communities not included in our analysis.

Table 5 summarises the distribution of plots among vegetation communities, based on allocations to SCIVI communities, for all plots with the cover-abundance score of any of the major overstorey species of SWSF of at least 2. In addition to p45, there are seven communities with a substantial proportion of their plots with at least one of these overstorey species. Of these, four are referrable to other EECs (p3 to Illawarra Lowlands Grassy Woodland, p210 and possibly xs13 to Littoral Rainforest, p64 to Bangalay Sand Forest). We have included newly-defined group xs6 in River-flat Eucalypt Forest TEC and discuss it in the report for that TEC. We consider community p86 (Murramarang-Bega Lowlands Forest) and new group xs19 further in the next Section 4.2.2.

Map 5: Distribution of new full-floristic and rapid surveys on state forest estate.

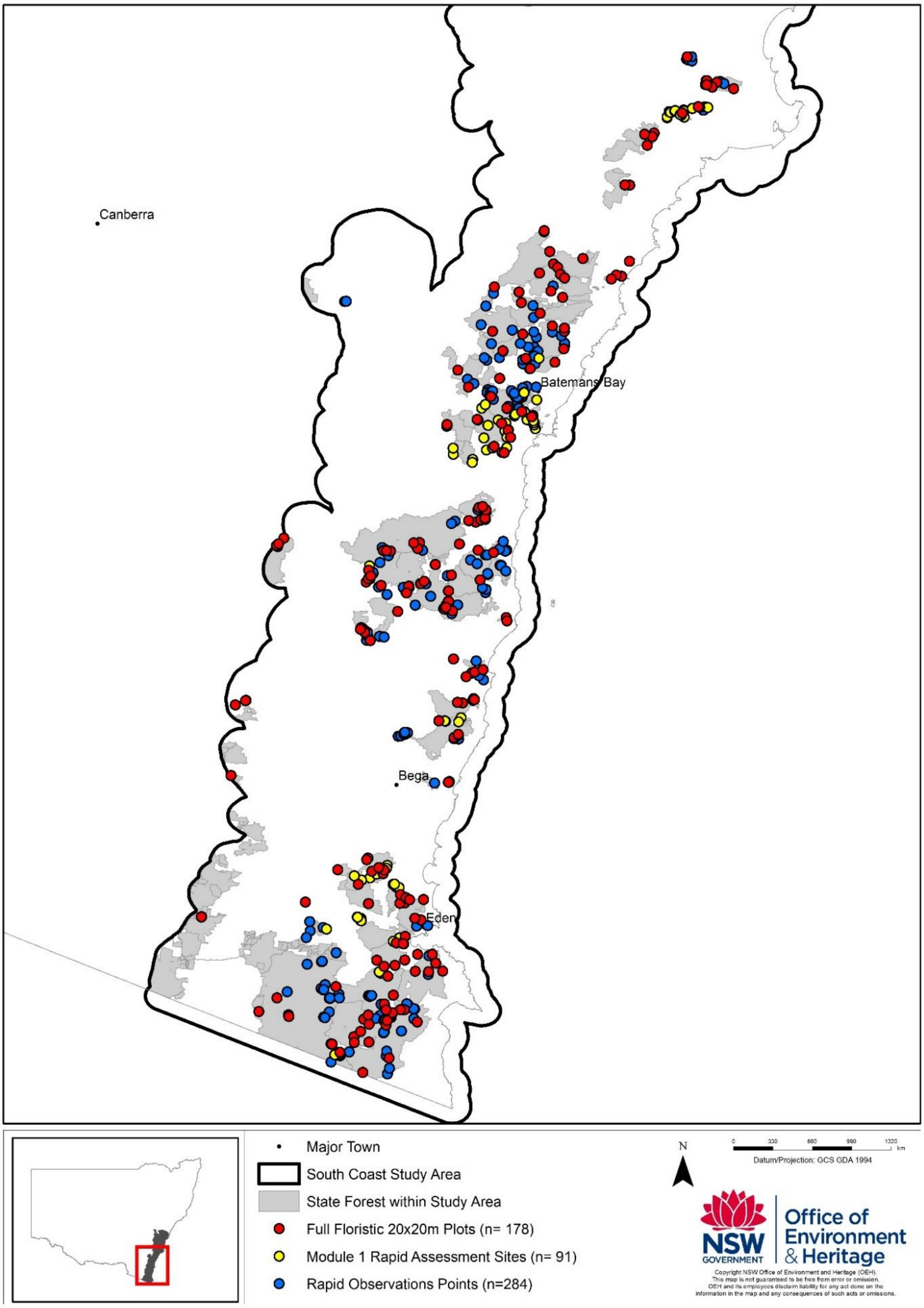


Table 5: Distribution among vegetation communities, using fuzzy clustering, of plots with SCIVI (Tozer et al. 2010) membership >=0.5 and column species cover score >=2. Numbers under species columns are numbers of plots in mapped alluvium, with total number of plots in parentheses. Only communities with at least 2 plots or at least one alluvial plot with these overstorey species are shown.

SCIVI community	*Eucalyptus robusta*	*Melaleuca quinquenervia*	*Eucalyptus longifolia*	*Eucalyptus botryoides*	Total plots not in mapped alluvium	Total plots in mapped alluvium	Total plots
e19				0 (8)	64	2	66
e20p229				1 (2)	85	4	89
e32a			0 (4)		37	0	37
e34			0 (6)	0 (1)	26	0	26
m15			1 (1)		2	9	11
n183			1 (1)	0 (3)	47	1	48
n184			0 (4)		21	1	22
p103				0 (2)	27	5	32
p105	2 (3)			1 (2)	12	23	35
p107	1 (1)			1 (1)	2	13	15
p109		0 (1)			12	4	16
p110				5	63	1	64
p111				1 (1)	65	2	67
p112				1	57	2	59
p113				4	81	0	81
p210	0 (1)			1 (8)	14	3	17
p3			3 (14)	1	15	4	19
p30			1	1 (1)	6	10	16
p33			1	2	53	0	53
p40			1 (2)	1 (3)	39	7	46
p434			1	1 (5)	10	3	13
p45	9 (11)				4	10	14
p63		0 (3)		1 (6)	34	1	35
p64	0 (2)	0 (1)		14 (28)	26	20	46
p86			8 (13)	1 (4)	11	10	21
p90			2		52	3	55
p99				2 (11)	43	3	46
xs10				1 (4)	11	1	12
xs13			4 (7)	14 (21)	51	46	97
xs14		0 (7)			21	2	23
xs19			23		31		31
xs4				3	91	4	95
xs6			4 (4)	7 (9)	20	49	69

4.2.2 Floristic relationships of communities to SWSF determination assemblage

The determination assemblage is one of the two legally prescribed descriptors of any TEC. No guidance is available on how it could be used for assessment. We chose to make comparisons between the assemblage list and related communities defined by plot data by using median and cumulative proportions of assemblage species in plots for each community, as described in Section 3.5.3. Appendix C shows the results for the communities relevant to our analyses. Of those included in our study, community p45 is clearly the community which is most similar to the determination assemblage, consistent with the determination. Community p86, often with *Eucalyptus longifolia* as a dominant species, is relatively more similar to the assemblage than most other communities in our analysis, but less so than communities referable to other EECs, such as p105 (Swamp Oak) and p64 (Bangalay Sand Forest). SWSF (p45) differs from p86 by the presence of *Eucalyptus robusta* and *Baumea juncea*, the more frequent occurrence of *Gahnia clarkei* and the absence of *Lepidosperma laterale*, *Gahnia radula*, *Leucopogon juniperinus* and *Acacia irrorata*.

Group xs19 is a non-alluvial, dry shrub/grass group with a high frequency and sometimes dominance of *Eucalyptus longifolia*, otherwise characterised by *Platysace lanceolata* and *Rytidosperma pallida* and is floristically very distinct from the assemblage list. Group xs14 is sometimes dominated by *Melaleuca quinquenervia* but is mainly non-alluvial. It is predominantly a wetland community in disturbed or highly disturbed areas in the Sydney urban area, characterised by *Typha orientalis* and *Isachne globosa*. It does not occur in state forests. It has a relatively high mean proportion of species per plot in the assemblage list, but a low cumulative proportion. This is because some plots have very low species richness and contribute little to a cumulative proportion.

Community m15 Eden shrubby swamp woodland has a relatively high proportion of assemblage species and occurs in regularly inundated alluvial environments, but had not been described at the time of the determination. It differs from SWSF by the abundance of *Melaleuca squarrosa*, frequent dominance of *Eucalyptus ovata* and absence of *Eucalyptus robusta*, *Leptospermum polygalifolium* and *Imperata cylindrica*.

4.2.3 Assessment of plots and communities as SWSF TEC

In total, we assessed 22 plots as SWSF TEC, 21 full floristic plots (Appendix D) and a single partial floristic plot. From our floristic analysis we regard, as a minimum expression of SWSF, all plots with a membership >=0.5 of p45 or which were allocated to p45 by Tozer et al. 2010, even though some of these are not alluvial. We have assessed 18 full floristic plots as SWSF based on this criterion.

An additional single partial floristic plot is also most strongly related to p45 and we have assessed this plot as SWSF. *Eucalyptus robusta* is rarely a community dominant in any community other than p45 and the other communities in which it occasionally occurs are all referable to EECs. Any community in which it is dominant may be referrable to Forest Ecosystem 175 described by Thomas et al.(2000), but this is uncertain because no plot data have been used to define FE 175. Because of the relationship of *E.robusta*-dominated vegetation to EECs and the uncertainty over which of these is covered by the SWSF final determination, we suggest that all vegetation in our study area in which *E.robusta* is dominant should be regarded as SWSF. Vegetation dominated by *E.robusta* occurs predominantly on alluvial flats or other periodically inundated flats, but occasionally extends upslope from those areas and also occurs on non-alluvial landforms. We include those parts of vegetation dominated by *E.robusta* which extend upslope or occur on non-alluvial landforms, because of the close floristic relationship between these areas and community p45 and the lack of any explicit qualifying condition in the final determination to limit SWSF to p45 only where it occurs on alluvial features (i.e. the final determination states that SWSF 'includes' p45). This is inconsistent with the statement in paragraph 1 of the final determination which states that SWSF occurs on alluvial flats and drainage lines. We have chosen to resolve this inconsistency in a precautionary manner.

We assigned a further three plots, with ambiguous floristic relationships, to SWSF. These plots were floristically more closely aligned to p107 (Swamp Oak), but were also related to p45 and had *Eucalyptus botryoides* as the dominant overstorey species and *Casuarina glauca* was either absent or in low abundance. Despite statements in the final determination, we did not find any evidence of forest dominated by *Eucalyptus longifolia* belonging to Swamp Sclerophyll Forest TEC.

Communities p86 and m15 could possibly be regarded as SWSF by virtue of their relative similarity to the assemblage list, though they are less similar than communities belonging to other EECs. Community p86 was described at the time of the final determination but was omitted, implying that it was not intended that the final determination include p86. Community m15 was not considered for the final determination, but is relatively very well conserved, is geographically disjunct and is likely to have a very different threat status. We suggest that neither p86 nor m15 be included in SWSF as currently determined.

4.2.4 Evidence of occurrence on state forest

Out of 22 plots, we identified two plots in state forest (one in Nowra State Forest and one in Termeil State Forest) which we assessed as Swamp Sclerophyll Forest TEC. SWSF is of very limited occurrence on state forest. Evidence from plot data, API and modelling results indicates that SWSF TEC occurs only in Nowra, Currambene and Termeil State Forests.

Photo 1: Nowra and Currambene State Forests together encompass the majority of the area of Swamp Sclerophyll TEC in the South Coast region. At this plot near the south east boundary of Nowra State Forest low lying alluvial flats support a forest dominated by *Eucalyptus robusta* in combination with *E. longifolia*. Paperbarks are prominent with both *Melaleuca ericifolia* and *M. linariifolia* present. A waist high cover of *Gahnia clarkei* marks the lower layer with the lower growing twig-rush *Baumea juncea* also present.

<u>Photo 2</u>: Just south of the Lake Tabourie village small drainage flats in Termeil State Forest have been assessed as Swamp Sclerophyll Forest TEC. The stands here are dominated by *Eucalyptus botryoides* and also feature dense swards of *Gahnia clarkei.* The area occupies very low elevations around 5 metres above sea level. We found this plot shared a stronger relationship with Swamp Oak on floodplains TEC owing to the diversity of sedges and rushes thriving on the wet soils. However because the stand is dominated by eucalypts we chose to allocate these stands to the Swamp Sclerophyll TEC.

4.2.5 Field key and/or defining floristic attributes

Table 6 lists the 30 species which are most strongly characteristic of South Coast SWSF (as defined by 21 plots allocated to SWSF) in the context of all 6234 plots used in our floristic analysis. Species which are listed as characteristic in the SWSF final determination are annotated with 'D'. Half of the species which characterise our interpretation of SWSF are also listed in the final determination. Though the seven species with the highest contribution are listed in the final determination assemblage, the overall proportion might be considered relatively low. This low proportion may be partly because the assemblage list is comprised of species which occur through the range of SWSF, including the much more extensive occurrences north from Sydney which are likely to differ floristically from our interpretation because of latitudinal differences in species occurrence. Appendix E is a field key for identifying SWSF in areas south of Nowra.

Table 6: The 30 most strongly characteristic species of South Coast SWSF in order of decreasing contribution to ΔsumAIC, plus all eucalypts recorded in SWSF, using 21 plots assigned to SWSF with a high degree of confidence compared to all other 6213 plots used in the analysis. Species annotated with '(D)' are listed in the final determination assemblage. Mean is mean cover score over all plots including zeros. Median is derived from non-zero scores only. Zeros may represent small values, due to rounding.

Species	SWSF freq	SWSF mean	SWSF median	other freq	other mean	other median	ΔsumAIC
Eucalyptus robusta (D)	0.71	2.48	4	0	0.01	3	-452
Gahnia clarkei (D)	0.81	2.24	3	0.03	0.07	2	-223
Baumea juncea (D)	0.43	1.57	4	0.01	0.03	2	-199
Melaleuca ericifolia (D)	0.62	1.48	2	0.02	0.05	2	-148
Villarsia exaltata (D)	0.33	0.57	2	0	0	1.5	-106
Baumea articulata (D)	0.38	0.71	1	0	0.01	2	-96
Melaleuca linariifolia (D)	0.48	1.05	3	0.02	0.05	2	-89
Baloskion tetraphyllum	0.19	0.62	3	0	0.01	2	-83
Leptospermum polygalifolium (D)	0.52	1.29	3	0.08	0.14	2	-68
Gonocarpus micranthus	0.24	0.57	2	0.01	0.02	1	-58
Selaginella uliginosa	0.33	0.62	2	0.02	0.03	2	-48
Leptocarpus tenax	0.19	0.62	3	0.01	0.03	2	-48
Schoenus brevifolius	0.19	0.57	2.5	0.01	0.04	3	-41
Hydrocotyle sibthorpioides	0.48	0.67	1	0.04	0.07	2	-35
Lobelia anceps	0.33	0.43	1	0.02	0.02	1	-33
Parsonsia straminea (D)	0.48	0.95	2	0.11	0.19	1	-30
Imperata cylindrica (D)	0.52	1.1	2	0.14	0.27	2	-28
Acacia longifolia (D)	0.62	1.05	2	0.15	0.25	2	-27
Gleichenia dicarpa	0.19	0.52	2.5	0.03	0.06	2	-27
Chorizandra cymbaria	0.1	0.24	2.5	0	0	2	-26
Cyperus polystachyos	0.1	0.24	2.5	0	0.01	1	-23
Centella asiatica (D)	0.38	0.57	1.5	0.06	0.1	2	-21
Melaleuca thymifolia	0.14	0.24	2	0	0.01	2	-21
Leptospermum continentale	0.24	0.43	1	0.03	0.05	1	-20
Hypolepis muelleri (D)	0.29	0.52	2	0.04	0.08	2	-20
Empodisma minus	0.19	0.38	2	0.02	0.04	2	-20
Hemarthria uncinata	0.14	0.24	2	0.01	0.01	1	-19
Entolasia marginata (D)	0.62	1	2	0.18	0.31	2	-18
Baumea tetragona	0.05	0.14	3	0	0	2.5	-17
Entolasia stricta (D)	0.76	1.48	2	0.35	0.64	2	-16
Eucalyptus botryoides	0.19	0.43	2	0.05	0.14	3	-6
Eucalyptus globoidea	0.1	0.1	1	0.15	0.32	2	-3
Angophora floribunda	0.05	0.05	1	0.11	0.22	2	-2
Corymbia gummifera	0.14	0.14	1	0.14	0.31	2	-1
Corymbia maculata	0.05	0.05	1	0.05	0.14	3	0
Eucalyptus piperita	0.14	0.14	1	0.1	0.25	3	1
Eucalyptus longifolia	0.1	0.1	1	0.04	0.1	3	2
Eucalyptus pilularis	0.1	0.19	2	0.08	0.22	3	2

4.3 Indicative TEC Mapping

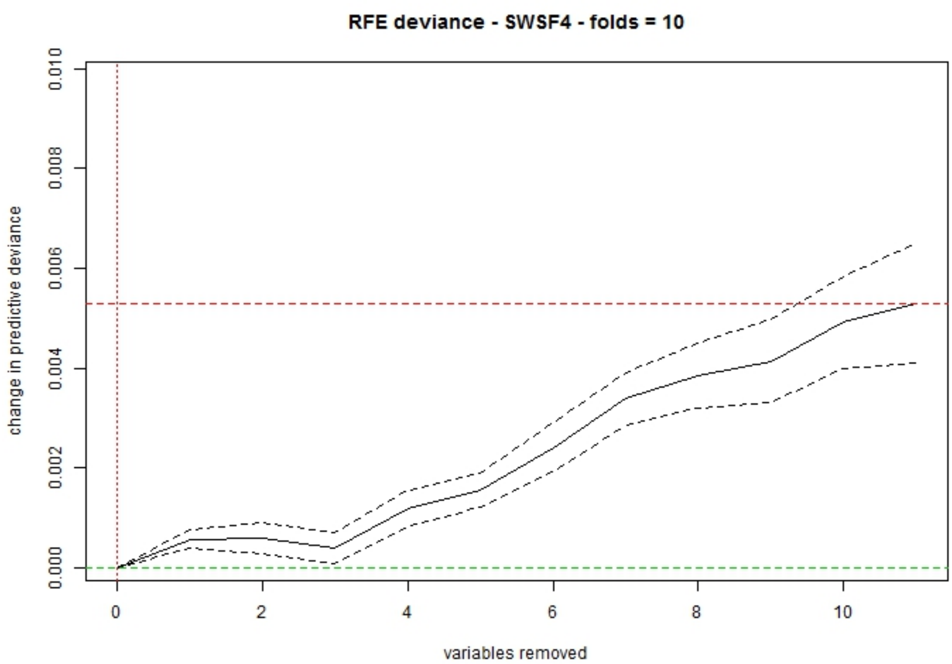
4.3.1 Presence/absence dataset

Initial Boosted Regression Tree (BRT) models were run using 22 plots allocated to SWSF as presence plots, and the remaining 6262 plots as absences. However, to model the potential distribution of SWSF in the broadest possible terms, we decided to increase the number or presences from 22 to 97 by adding in an extra 75 verified observation records of *Eucalyptus robusta* from the Atlas of NSW Wildlife (Map 6). This provided a much greater number of plots to characterise the environmental niche of the TEC, and in turn, a better fitting model than the 22 SWSF plots on their own. However, this was only possible in this study area because *E. robusta* is strongly characteristic of the TEC and is unlikely to be confused with alternate non-TEC assemblages.

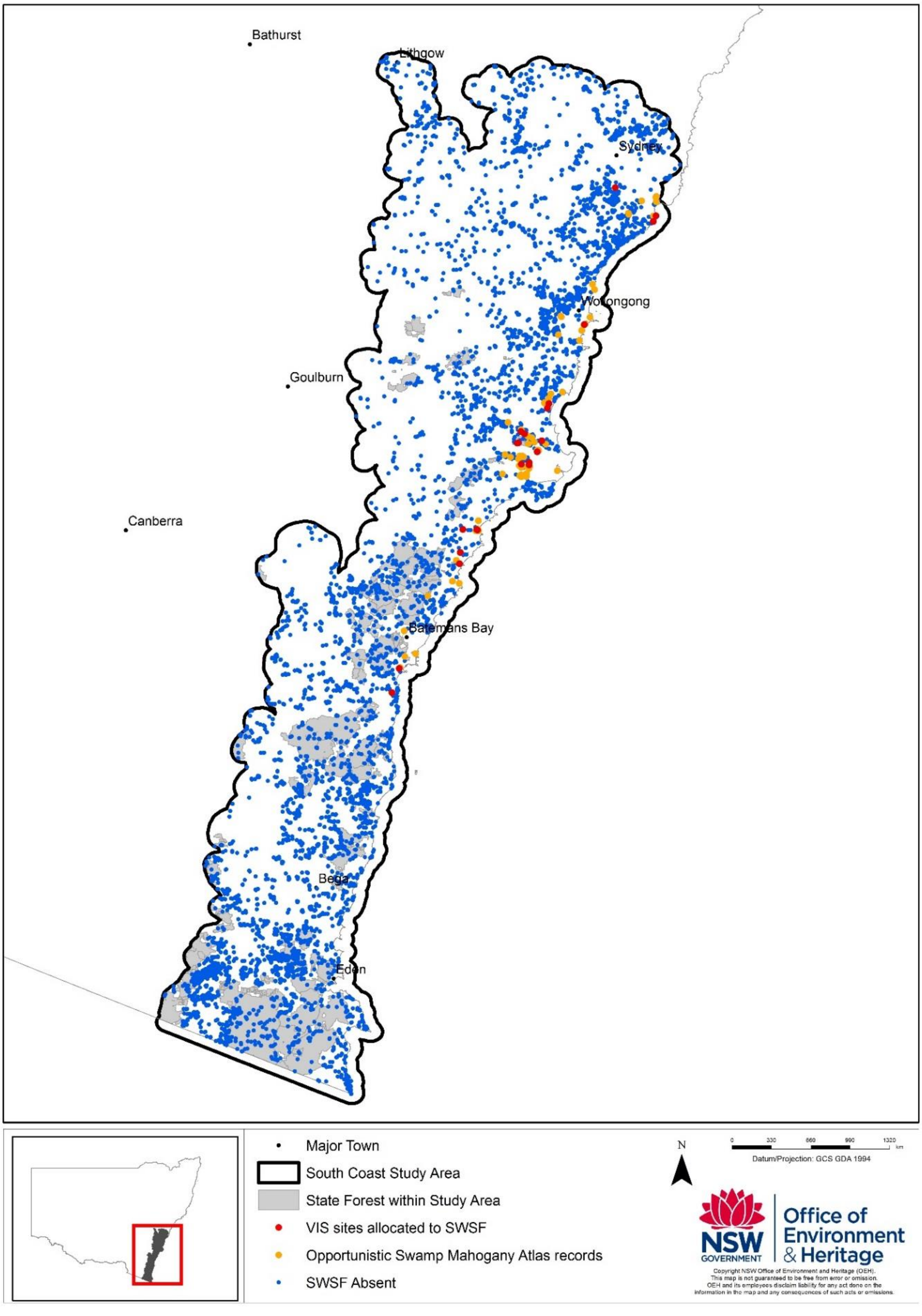
4.3.2 Variable selection

To identify a suitable subset of predictors for modelling, we followed the recommendations outlined in Elith and Leathwick (2016). First, a *gbm.step* algorithm was run using all available predictors, setting the learning rate (*lr*) to 0.001, the tree complexity set to 5 and bagging fraction set to 75%. All variables that returned relative influence values of > 1% (19 in this case) were then subjected to an additional two (alternative) variable selection processes. Second, a *gbm.simplify* algorithm was run to find those variables that give no evidence of improving predictive performance. This takes an initial cross-validated model produced by *gbm.step* and performs backwards elimination of variables. The function returns a list containing the mean change in deviance and its standard error as a function of the number of variables removed (Figure 2).

<u>Figure 2</u>: Output from *gbm.simplify* algorithm showing mean change in predictive deviance and its standard error as a function of the number of variables removed.



<u>Map 6</u>: Sample plots allocated to SWSF, additional Swamp Mahogany NSW Wildlife Atlas records and plots where SWSF is known to be absent.

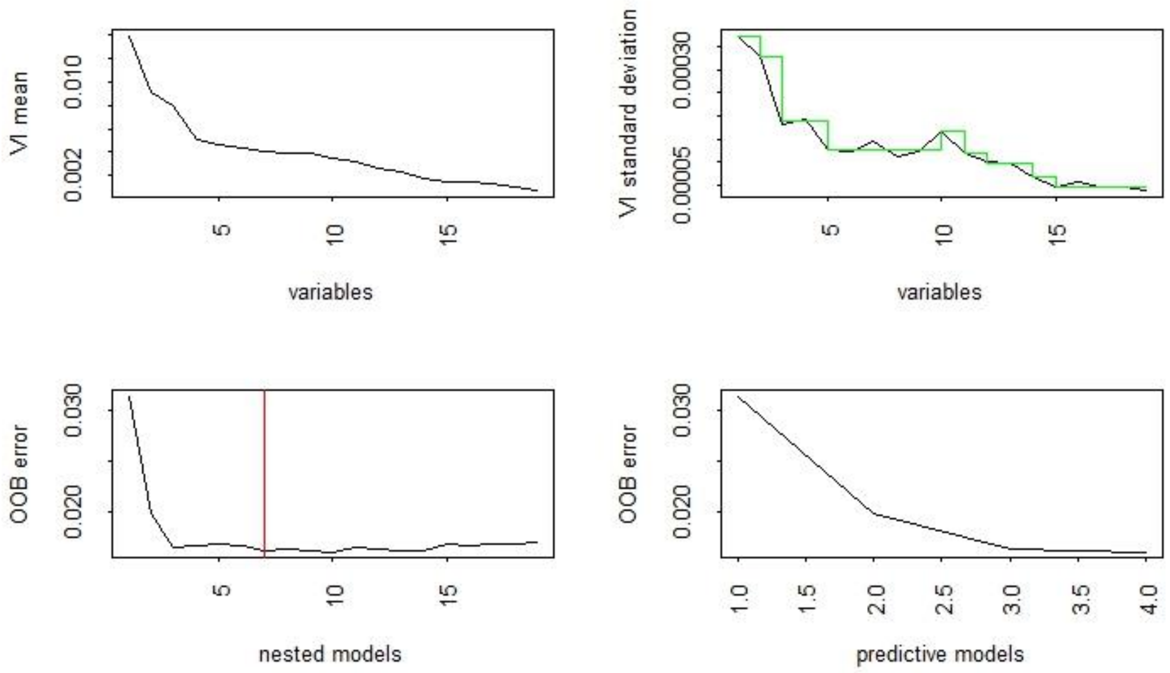


As an alternative approach to *gbm.simplify*, the VSURF in R package was used to try to identify a smaller subset of variables relevant to the classification. VSURF performs a preliminary ranking of the explanatory variables using the random forests permutation-based score of importance, and proceeds using a stepwise ascending variable introduction procedure.

Figure 3 shows the VSURF results. The two graphs of the top row correspond to the ‘thresholding step’ dedicated to eliminating irrelevant variables from the dataset. The top left graph plots the mean variable importance in decreasing order (black curve), while the top right graph plots the standard deviation of variable importance with variables ordered according to their mean variable importance in decreasing order (black curve). The green line represents the predictions given by a CART tree fitted to the black curve (the standard deviations).

The bottom left graph shows the mean OOB error rate of embedded random forests models (from the one with only one variable as predictor, to the one with all variables kept after the ‘thresholding step’). The vertical red line indicates that 7 predictors should be retained in the model. The bottom right graph plots the mean OOB error rate of embedded random forests ‘prediction step’, which is designed to find and eliminate any redundancy among the set of variables chosen in the thresholding step. In this case, 4 variables were selected, representing the minimum set of variables that could be retained in a model.

<u>Figure 3</u>: Outputs from VSURF algorithm showing mean change in predictive deviance and its standard error as a function of the number of variables removed.



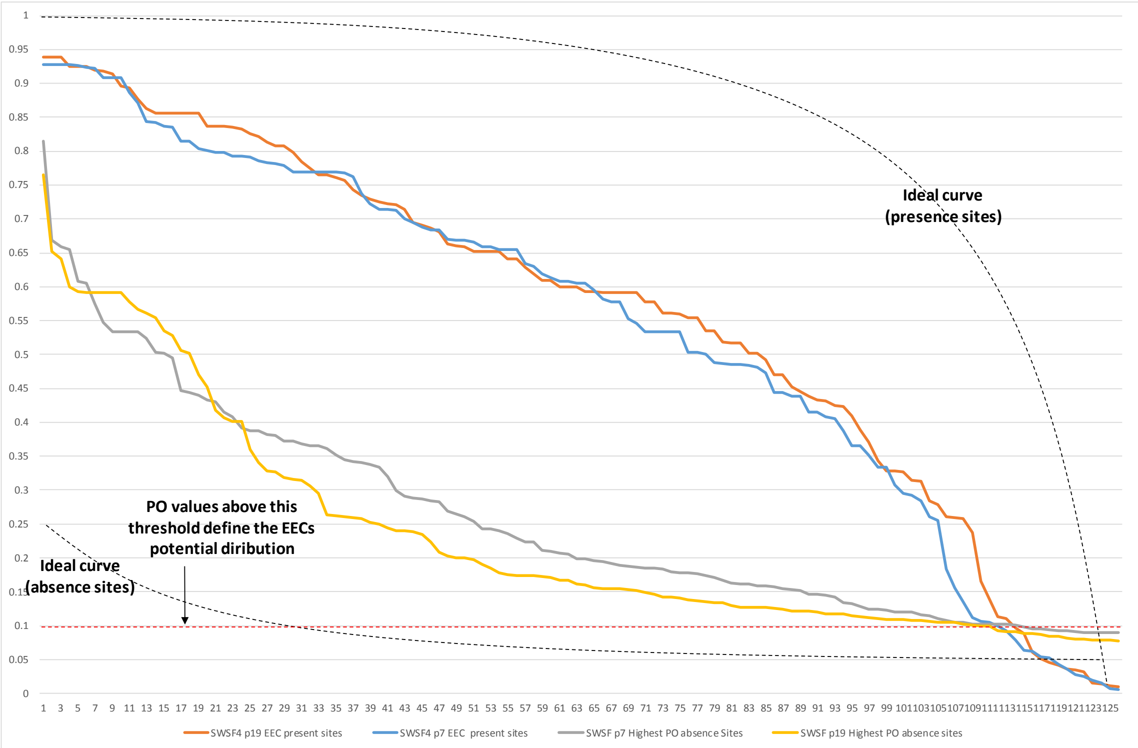
Separate *gbm.step* models were run for each of the two predictor sets (7 and 19 variables).

The performance of the models are compared in Figure 4. Modelled probability of occurrence (PO) values for all plots allocated to SWSF are shown in descending order along with PO values for the same number of highest ranked absence plots. A good model can be defined as having high PO values across the majority of SWSF reference plots, dropping sharply at the end for those plots that occupy marginal environmental space (these could potentially be misclassified false positives). Likewise, absence plots should ideally have a PO values as close to zero as possible, with the vast majority of plots below the 0.1 threshold.

Generally, the more predictors one has in a model, the better the fit. However, adding variables also adds to the risk of over-fitting the data, where a much more complex model can become non-seneschal from an ecological perspective. Given that the p7 and p19 models have similar performance curves, the p7 model was chosen as the final model as it is the more parsimonious of the two.

In terms of the likelihood that SWSF occurs in any given state forest, the 'potential' distribution of the TEC is defined as any 30x30m pixel that lies above a 0.1 (10%) PO threshold. At this threshold, using the model with 7 predictors, 92.85% of the 88 plots allocated to SWSF and 98.23% of the 6249 absence plots are correctly predicted.

<u>Figure 4</u>: Evaluation of the performance of three BRT models used to predict the distribution SWSF. The models have 7 and 19 predictors.



4.3.3 TEC-habitat relationships

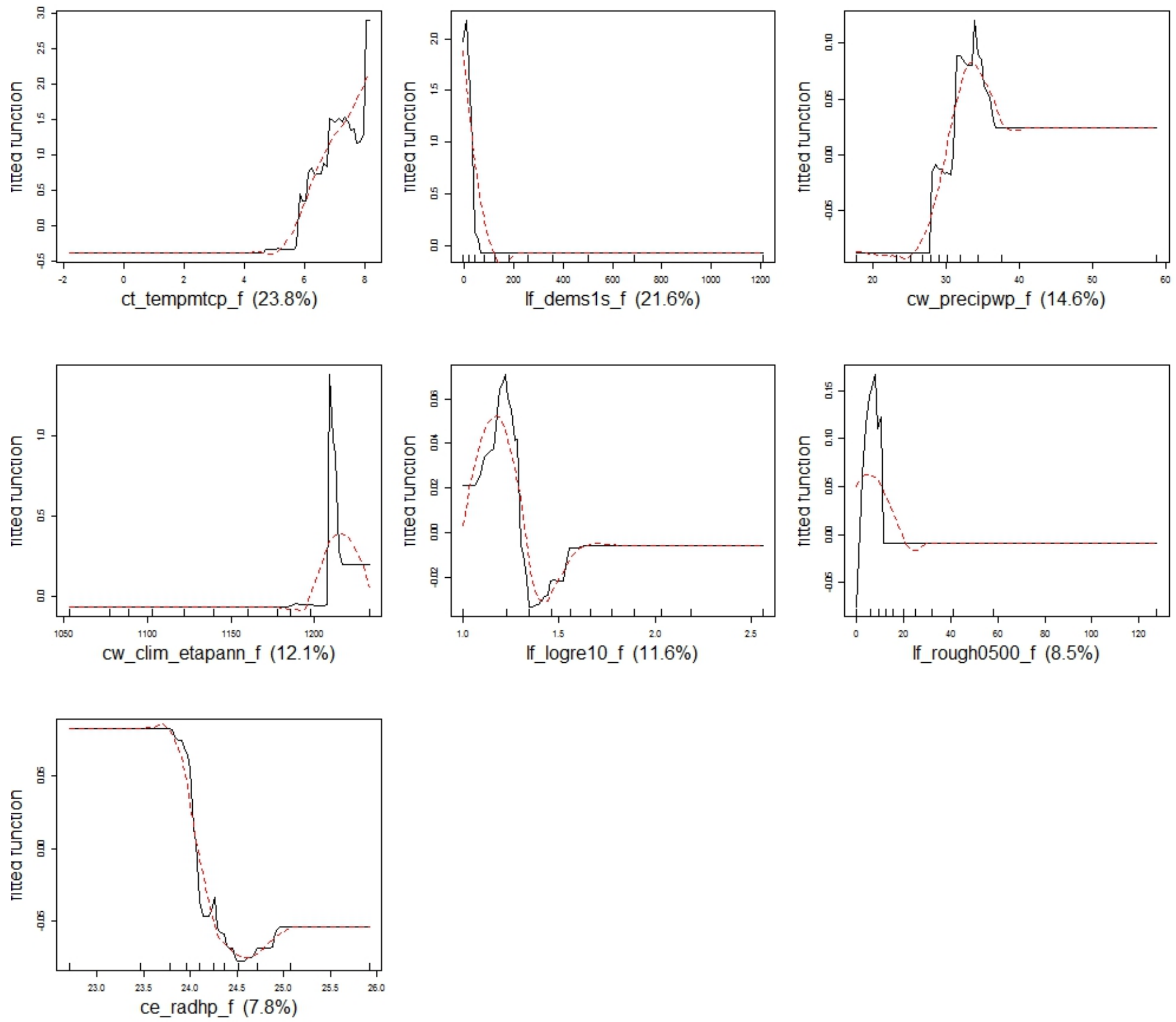
The fitted functions from models can be used to evaluate whether the modelled relationships make sense based on what we know about the current distribution of SWSF. For example, we know from the final determination that 'SWSF *generally* occurs below 20 m though sometimes up to 50 m, on waterlogged or periodically inundated alluvial flats and drainage lines and river terraces associated with coastal floodplains'.

Figure 5 shows the fitted functions for the 7 predictors used in the model (Table 7). Broadly speaking, the TEC occurs in relatively warm, wet areas where the minimum temperature of the coldest period is above 4ºC and precipitation of wettest period is greater than 25 millimetres. It also occurs in in relatively flat (low roughness), low lying topographic positions less than 100 metres in elevation. Highest period radiation, potential evapotranspiration, and cold air drainage also appear to have an influence on where the TEC can potentially occur.

Table 7: Description of predictors used in final BRT model.

Code	Description
ct_tempmtcp_f	Min Temperature of Coldest Period (bio6)
lf_dems1s_f	1 sec SRTM smoothed DEM (DEM-S)
cw_precipwp_f	Precipitation of Wettest Period (bio13)
cw_clim_etapann_f	Average areal potential evapotranspiration - Annual
lf_logre10_f	Cold air drainage
lf_rough0500_f	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 500 m neighbourhood.
ce_radhp_f	Highest Period Radiation (bio21)

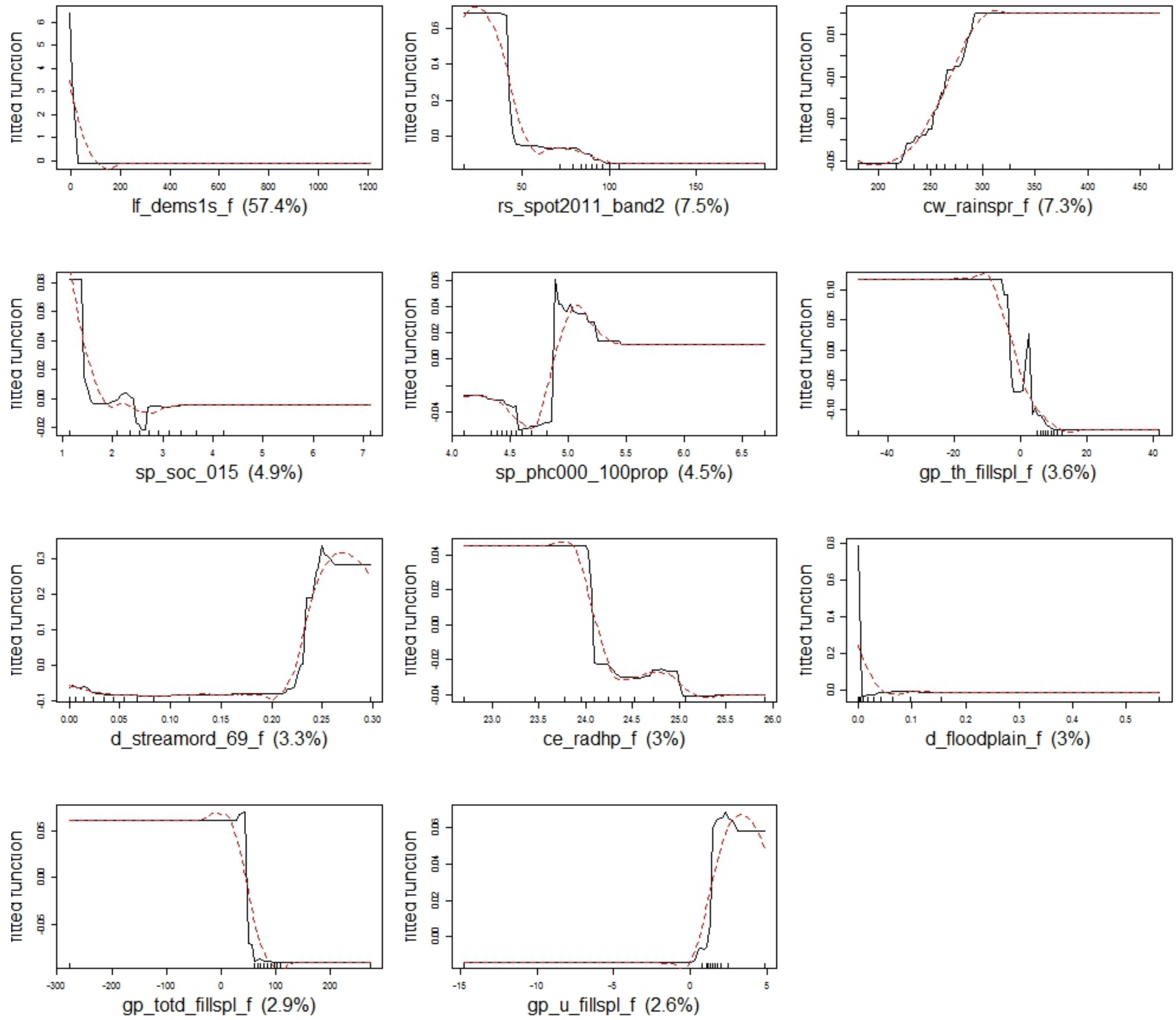
Figure 5: Fitted functions in the final BRT model.



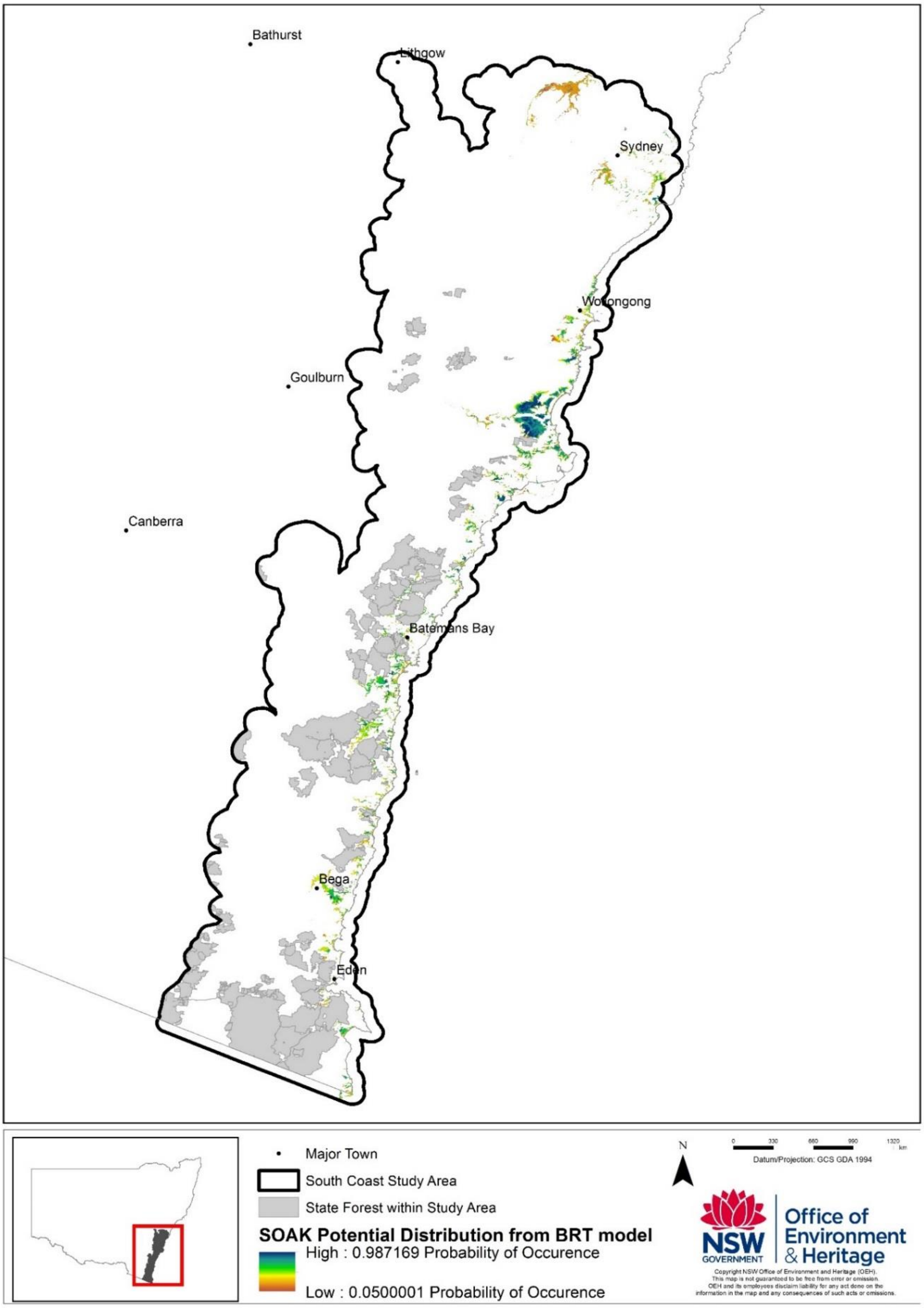
4.3.4 Predicted distribution map

A map of the potential distribution of SWSF as defined by the area with a probability of occurrence value of 0.05 and greater is shown in Map 9.

<u>Figure 5</u>: Fitted functions in the final BRT model.



Map 7: Predicted distribution of SWSF as defined by the area with a probability of occurrence value of 0.1 and greater.



4.4 Aerial Photograph Interpretation

A total of 5945.1 hectares of modelled alluvial and floodplain habitat was initially assessed using aerial photograph interpretation to identify structural and floristic attributes of the vegetation cover. This comprised 3538.6 hectares in state forests south of the Bega Valley and 1956.5 hectares to the north. Assessment also included the identification of additional candidate habitat outside the modelled areas and within the 250,000 hectares of state forest in the study area. This resulted in an additional 1030.9 hectares being identified in the area south of Bega Valley, whilst this same process north of Bega Valley resulted in an additional 2371.2 hectares being added. Overall, as a result of 3D API, almost 50% more habitat was identified than the model using the prescribed mapping pathway. This was to be expected as the fine scale DEM that supported the model was not available for all state forest areas. Fifty-one classes were used to describe patterns in canopy (mainly eucalypt) composition across alluvial areas in the study area. In total, 32 hectares (17 polygons), all north of Batemans Bay, was identified as meeting the landscape, canopy species and understorey characteristics criteria relevant to further assessment of SWSF.

4.5 Operational TEC Mapping

After integrating information from API results (including checking against predictive models), plot data and environmental features, using the method described in Section 3.7.2, we mapped 32.3 hectares of Swamp Sclerophyll Forest in state forests in our study area, comprising 13 polygons with a mean size of 2.5 hectares. The distribution of the SWSF in state forest across our study area is shown in Map 8. An example of the operational map in Currumbene SF is shown in Map 9.

Areas which we mapped as SWSF comprised all polygons in state forests which had *Eucalyptus robusta* as a canopy dominant, plus a single polygon which had *Eucalytpus botryoides* as a canopy dominant but which we assessed as floristically SWSF based on a single plot within the polygon. We delineated 54 other polygons with *E. botryoides* as a canopy dominant elsewhere in state forests. We mapped most of these as River-flat eucalypt forest and some as not TEC, using plot data and predicted probabilities from models for SWSF and other TECs. These occupied environments distinct from the polygon we mapped as SWSF and we have no evidence to indicate that any other polygons belong to SWSF.

4.6 Validation

We concluded that none of the 40 validation plots used to sample floodplain and alluvial environments on the South Coast were referable to SWSF.

<u>Map 8</u>: State forests with mapped occurrences of Swamp Sclerophyll Forest in the South Coast study area.

Map 8: Example of operational map of Swamp Sclerophyll Forest TEC in Currumbene State Forest.

5 Discussion

5.1 Summary

5.1.1 Cited vegetation communities and determination species assemblage list

The application of TEC reference panel principles to the floristic attributes of Swamp Sclerophyll Forest TEC in the south coast region was successful. Our analysis identified strong agreement between the characteristic species listed in the final determination and the cited vegetation communities identified as Swamp Sclerophyll Forest. This provided an unambiguous foundation to assess the relationships between new samples and these cited communities.

The project did rely on several assumptions to provide some certainty with the interpretation of the TEC. We found that some samples located on alluvial soils were related to vegetation communities in existing studies that are not cited in the final determination. The project assumed that where there was weak association with other existing vegetation communities and they were not included in either the list of communities relevant to the Swamp Sclerophyll Forest on the South Coast or in the threat assessment then these were definitively not the TEC. There are no statements in the final determination to explicitly identify how vegetation classification sources have been assessed and which communities have been examined and excluded, however, without the adoption of these rule sets, effectively any native vegetation found on alluvial or floodplain landscapes would be a candidate for the TEC. Such an outcome would conflict with the Panel interpretation principles that the threat assessment parameters used to underpin the TEC are not significantly exceeded. The final determination for Swamp Sclerophyll Forest TEC includes a general statement in Paragraph 7: 'the Determinations for these (floodplain) communities collectively encompass the full range of intermediate assemblages in transitional habitats'. However, the panel was unable to resolve the meaning of the statement as it conflicted with the stated species assemblage, the cited vegetation communities and the threat assessment parameters. Even if these conflicts are ignored, it would not be possible to apply this statement to define the TEC in any practical sense because of the vagueness of what limits a 'floodplain' and what the term 'transitional habitats' means.

5.1.2 Distribution and habitat descriptors

The final determination includes a set of environmental descriptors that assist in locating Swamp Sclerophyll Forest on the South Coast. However there is considerable uncertainty as to whether these criteria had to be satisfied in order to assign the TEC. The panel addressed this uncertainty by adopting those criteria which were accompanied by statements that suggested a definitive association; bioregion, alluvial flats and floodplains and elevation.

Notwithstanding these decisions, the inclusion of floodplain and alluviums as a prescribed condition of the Panel interpretation of the TEC required an interpretation of what comprised these landscapes on the South Coast. There is no reference in the final determination to mapped information defining floodplain and alluvial landscapes. The definition provided contains insufficient detail to apply a diagnostic rule to a plot. The project adopted a precautionary interpretation of the landscape criteria by using the best available published maps, models of water flow accumulation using fine scale digital models and aerial photographic interpretation. We believe that the layers that we generated offer the best available representation of candidate alluvial and floodplain landscapes on state forest. Less refined floodplain mapping remains on other tenures as API assessment has not been completed.

The difficulties in identifying suitable habitat characteristics was exacerbated in the final determination by the absence of any qualifying statements for vegetation community Coastal

Sand Swamp Forest (p45 Tindall et al. (2004); Tozer et al. 2010). This community is a primary source of the floristic and distribution data used in the Swamp Sclerophyll Forest for the South Coast. However, samples used to define the cited community are frequently located on marine sand deposits in dune swales and depressions. This appears to conflict with the habitat descriptions that underpin the final determination. The project overcame these conflicts by adopting all included locations irrespective of substrate as the TEC. As there are few areas of marine sand deposits found in state forests, we believe we avoided major definition and interpretation difficulties. However, on tenures other than state forests the interpretation difficulties for this TEC may be acute.

We found general agreement with the elevation thresholds described in the final determination. On the South Coast our indicative model suggested a very low likelihood of suitable Swamp Sclerophyll Forest habitat occurring above 70 metres above sea level. We believe that this threshold together with floristic data can be used as a useful field key to diagnose the Swamp Sclerophyll Forest TEC on state forest to reasonable levels of certainty.

5.2 TEC Panel Review and Assessment

5.2.1 Summary of discussions

A summary paper of issues was presented to the TEC Panel and discussed at the meeting held on 14 October 2015. The issues and comments from the Panel are shown in Table 8.

Table 8: Summary of issues and Panel review of SWSF, meeting held 14 October 2015.

Determination	TEC Panel Principles	Our Project	TEC Panel Review
Occurs in '….Sydney Basin, South East Corner Bioregions'	Accept Bioregional Qualifiers	Adopted	Accepted
Is 'associated with humic clay loams and sandy loams, on waterlogged or periodically inundated alluvial flats and drainage lines associated with coastal floodplains. Floodplains are level landform patterns on which there may be active erosion and aggradation by channelled and overbank stream flow with an average recurrence'	Assess habitat descriptors and whether these constrain or define the limits of the TEC which otherwise may have a broader distribution	Floodplain and alluvial landform elements represented by an alluvial model derived from 1m Lidar DEM, supplemented by stereoscopic digital aerial photograph interpretation Landscapes unambiguously defined by marine sand deposition were excluded from TEC candidacy	Accepted
Occurs on Coastal Floodplains generally occurs below 20 m (though sometimes up to 50 m) elevation, often on small floodplains or where the larger floodplains adjoin lithic substrates or coastal sand plains	Assess habitat descriptors and whether these constrain or define the limits of the TEC which otherwise may have a broader distribution	Sample plots that conform to the TEC generally meet the elevation qualifier, with one plot situated at 60m asl The model and API may predict suitable habitats are present at higher elevations	The Panel accepted that the 50m threshold not be applied strictly if plots with strong floristic relationships occurred at slightly higher elevations
In the Illawarra, this community includes 'Alluvial swamp mahogany forest' (map unit 35) of NPWS (2002). On the south coast, this community	Assess references to existing vegetation classification sources in the determination.	Analysed relationships between new samples collected on state forest and samples used to define source classifications	Inconsistencies noted. The exclusion of mapped marine deposits, but an otherwise

Determination	TEC Panel Principles	Our Project	TEC Panel Review
includes 'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175) of Thomas et al. (2000) and 'Coastal Sand Swamp Forest' (map unit 45) of Tindall et al. (2004)	The panel will note whether the existing classifications are 'included within' are 'part of' or 'component of' the determination Classifications developed using traceable quantitative data will be recognised as primary data upon which to assess floristic, habitat and distributional characteristics. Where data has been sourced and used in alternate regional or local classification studies the results will be considered by the panel to assist in the development of the TEC definitional attributes	Difficulty in obtaining consistency in the relationships of source communities to the TEC. Determination cites '*E. robusta* stands (map unit 35 Illawarra study) but excludes a related *E. robusta* forest (map unit 34) from the same study presumably on the basis of its occurrence on sand plain swales' Conversely Coastal Sand Swamp Forest (SCIVI p45) is wholly included with no qualifiers relating to substrate and includes samples located on sand plains. Gellie type 'Northern Coastal Lowlands Swamp Forest' (forest ecosystem 175) is not defined by quantitative data For mapping purposes we excluded samples that were unambiguously located on mapped marine sand deposits	precautionary approach taken by the study team to resolving inconsistencies, was endorsed
Characterised by the list of 86 plant species	Be guided by the species lists presented in the determination	Compared species assemblage data drawn from source classifications with that presented in the determination. We found that SCIVI p45 Coastal Sand Swamp Forest (*E. robusta/E. botryoides*) is most similar to the determination assemblage. Two other communities found on the South Coast floodplains SCIVI p105 (Coastal Floodplain Forest) and p107 (Estuarine Creek-flat Forest) are also similar, but have stronger relationships with another TEC, Swamp Oak Forest on floodplains Four plots, all dominated by eucalypts, supported an ambiguous relationship between SCIVI p107 and p45. For purposes of this project we assigned these to Swamp Sclerophyll TEC	Accepted
	<u>Other Issues</u>: New Included Vegetation Communities	Nil	

Determination	TEC Panel Principles	Our Project	TEC Panel Review
	Other issues: Excluded Vegetation Communities	There are a number of eucalypt dominated communities with elements of swamp sclerophyll flora that have been excluded based on a weaker similarity to the determination assemblage. These are in decreasing order of similarity SCIVI m15 (Eden Shrubby Swamp Woodland (*E. ovata/Gahnia clarkei*) found on inundated alluviums in the Eden region. Not described at the time of the determination SCIVI p86 (Murramarang-Bega Lowlands Forest) (*E. longifolia*/*C. maculata*) includes part of its distribution on alluvial flats. Implicitly excluded in the determination	Endorsed the approach taken by the study team, to exclude these from Swamp Sclerophyll Forest TEC, because of different distribution and conservation status (SCIVI m15) or implicit exclusion from the determination (SCIVI p86)

5.3 Final State Forest - TEC Occurrence Matrix

Table 9: Total area of SWSF mapped across all state forests in the study area.

State Forest	Area (Ha)	AREA SWSF (Ha)	State Forest	Area (Ha)	AREA SWSF (Ha)
Badja State Forest	4839		Moruya State Forest	4059	
Bateman State Forest	1		Mumbulla State Forest	6137	
Belanglo State Forest	3891		Murrah State Forest	4215	
Benandarah State Forest	2761		Nadgee State Forest	20537	
Bermagui State Forest	1861		Nalbaugh State Forest	4396	
Bodalla State Forest	24079		Newnes State Forest	281	
Bolaro State Forest	1779		North Brooman State Forest	3631	
Bombala State Forest	620		Nowra State Forest	521	15.0
Bondi State Forest	12742		Nullica State Forest	18298	
Boyne State Forest	6161		Nungatta State Forest	887	
Broadwater State Forest	167		Penrose State Forest	1986	
Bruces Creek State Forest	791		Shallow Crossing State Forest	3855	
Buckenbowra State Forest	5193		Shoalhaven State Forest	104	
Cathcart State Forest	1735		South Brooman State Forest	5587	
Clyde State Forest	3587		Tallaganda State Forest	1363	
Coolangubra State Forest	8489		Tanja State Forest	867	
Corunna State Forest	183		Tantawangalo State Forest	2466	
Cumberland State Forest	40		Termeil State Forest	698	1.3
Currambene State Forest	1695	16.0	Timbillica State Forest	9144	
Currowan State Forest	11977		Tomerong State Forest	212	
Dampier State Forest	33746		Towamba State Forest	5471	
East Boyd State Forest	21010		Wandella State Forest	5492	
Flat Rock State Forest	4896		Wandera State Forest	5198	
Glenbog State Forest	4641		Wingello State Forest	3975	
Gnupa State Forest	1318		Woodburn State Forest	10	
Jellore State Forest	1411		Yadboro State Forest	10750	
Jerrawangala State Forest	268		Yambulla State Forest	47108	
Kioloa State Forest	171		Yarrawa State Forest	179	
Mcdonald State Forest	3684		Yerriyong State Forest	6604	
Meryla State Forest	4554		Yurammie State Forest	4050	
Mogo State Forest	15498		**Total**	**352971**	32.3

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Appendix A

Communities for which all previously allocated plots were included in one or more analyses.

Table A1: Vegetation groups described by Gellie (2005).

Group number	Group name
VG 1	Southern Coastal Foothills Dry Shrub Forest
VG 2	Coastal Lowland Dry Shrub Forest
VG 3	Northern Hinterland Dry Shrub Forest
VG 5	Jervis Bay Lowlands Dry Shrub-Grass Forest
VG 6	Southern Coastal Lowlands Shrub/Tussock Grass Dry Forest
VG 7	Southern Coastal Hinterland Dry Shrub-Tussock Grass Forest
VG 8	Far Southern Coastal Dry Shrub Forest
VG 9	Coastal Lowlands Cycad Dry Shrub Dry Forest
VG 10	Southern Coastal Lowlands Shrub-Grass Dry Forest
VG 11	Coastal Shrub/Grass Dry Forest
VG 12	Coastal Hinterland (Buckenbowra) Dry Shrub-Cycad Forest
VG 13	Deua-Belowra Rainshadow Dry Shrub-Tussock Grass Forest
VG 18	Southern Coastal Hinterland Moist Shrub-Vine-Grass Forest
VG 19	Coastal Escarpment and Hinterland Dry Shrub-Fern Forest
VG 20	Coastal Hinterland Ecotonal Gully Rainforest
VG 21	South Coast Foothills Moist Shrub Forest
VG 24	Coastal Wet Heath Swamp Forest
VG 25	South Coast Swamp Forest Complex
VG 26	Coastal Dune Herb/Swamp Complex
VG 27	Ecotonal Coastal Swamp Forest
VG 28	Coastal Sands Shrub-Fern Forest
VG 29	Northern Coastal Sands Shrub-Fern Forest
VG 30	Jervis Bay Moist Shrub-Palm Forest
VG 33	South Coast Hinterland Gully Head Shrub Forest
VG 35	South Coast and Byadbo Acacia Scrubs
VG 47	Southern Escarpment Herb - Grass Moist Forest
VG 48	Coastal Lowlands Riparian Herb-Grass Forest
VG 49	South Coast Hinterland Shrub-Herb-Grass Riparian Forest
VG 50	South Coast Escarpment DryHerb-Grass Forest
VG 51	Araluen Acacia Dry Herb-Grass Forest
VG 52	Bega Valley Shrub/Grass Forest
VG 53	Riparian Acacia Shrub-Grass-Herb Forest
VG 54	Far Southern Dry Grass-Herb Forest-Woodland (171)
VG 56	Tableland and Escarpment Moist Herb-Fern Grass Forest

Group number	Group name
VG 57	Southern Escarpment Shrub-Fern-Herb Moist Forest
VG 58	Tableland and Escarpment Wet Layered Shrub Forest
VG 59	Eastern Tableland and Escarpment Shrub-Fern Dry Forest
VG 61	Southern Escarpment Edge Moist Shrub Forest
VG 62	Southern Escarpment Edge Moist Shrub-Fern Forest
VG 64	Southern East Tableland Edge Shrub-Grass Dry Forest
VG 136	08a Sandstone Plateau Heath Forests
VG 137	08a Sandstone Plateau Heath Forests
VG 138	08a Sandstone Plateau Heath Forests
VG 139	08a Sandstone Plateau Heath Forests
VG 143	08b South Coast/Hinterland Heathlands/Tall Shrublands
VG 165	Southern Escarpment Cool-Warm Temperate Rainforest
VG 166	Central Coastal Hinterland and Lowland Warm Temperate Rainforest
VG 167	Coastal Lowland Sub Tropical-Littoral Rainforest
VG 168	Araluen Ecotonal Granite Dry Rainforest
VG 169	Coastal Hinterland Sub Tropical Warm Temperate Rainforest
VG 170	Southern Coastal Hinterland Dry Gully Rainforest
VG 171	Coastal Shrub/Grass Forest
VG 179	Eastern Deua Dry Shrub Forest

Table A2: Communities described by Tozer et al. (2010).

Code	Community name
e1	Southeast Dry Rainforest
e13	Southeast Hinterland Wet Fern Forest
e14	Southeast Hinterland Wet Shrub Forest
e15	Southeast Mountain Wet Herb Forest
e17	Southeast Flats Swamp Forest
e18	Brogo Wet Vine Forest
e19	Bega Wet Shrub Forest
e20p229	Southeast Lowland Grassy Woodland
e25	Southeast Sandstone Dry Shrub Forest
e26	Southeast Tableland Dry Shrub Forest
e27	Waalimma Dry Grass Forest
e28	Wog Dry Grass Forest
e29	Nalbaugh Dry Grass Forest
e3	Rocky Tops Dry Scrub Forest
e30	Wallagaraugh Dry Grass Forest
e31	Southeast Hinterland Dry Grass Forest
e32a	Deua-Brogo Foothills Dry Shrub Forest

e32b	Far South Coastal Foothills Dry Shrub Forest
e33	Southeast Coastal Range Dry Shrub Forest
e34	Southeast Coastal Gully Shrub Forest
e35	Southeast Escarpment Dry Grass Forest
e37	Southeast Lowland Gully Shrub Forest
e38	Far Southeast Riparian Scrub
e39	Bega-Towamba Riparian Scrub
e4	Brogo Shrub Forest
e42	Southeast Inland Intermediate Shrub Forest
e43	Southeast Mountain Sandstone Shrub Forest
e44	Southeast Foothills Dry Shrub Forest
e46b	Southeast Lowland Dry Shrub Forest
e47	Eden Dry Shrub Forest
e48	Mumbulla Dry Shrub Forest
e49	Southeast Coastal Dry Shrub Forest
e50	Genoa Dry Shrub Forest
e52	Southeast Mountain Rock Scrub
e57	Southeast Lowland Swamp
e60	Southeast Floodplain Wetlands
e6e7	Southeast Warm Temperate Rainforest
m15	Eden Shrubby Swamp Woodland
n183	South Coast Hinterland Wet Forest
n184	Clyde-Tuross Hinterland Forest
n185	Wadbilliga Gorge Dry forest
p100	Escarpment Foothills Wet Forest
p103	Clyde Gully Wet Forest
p104	Southern Lowland Wet Forest
p105	Floodplain Swamp Forest
p106	Estuarine Fringe Forest
p107	Estuarine Creekflat Scrub
p110	Warm Temperate Layered Forest
p111	Subtropical Dry Rainforest
p112	Subtropical Complex Rainforest
p113	Coastal Warm Temperate Rainforest
p114	Sandstone Scarp Warm Temperate Rainforest
p116	Intermediate Temperate Rainforest
p148	Shoalhaven Sandstone Forest
p3	South Coast Lowland Swamp Woodland
p30	South Coast River Flat Forest
p31	Burragorang River Flat Forest
p32	Riverbank Forest

p33	Cumberland River Flat Forest
p34	South Coast Grassy Woodland
p38	Grey Myrtle Dry Rainforest
p40	Temperate Dry Rainforest
p44	Sydney Swamp Forest
p45	Coastal Sand Swamp Forest
p58	Sandstone Riparian Scrub
p63	Littoral Thicket
p64	Coastal Sand Forest
p85	Currambene-Batemans Lowlands Forest
p86	Murramarang-Bega Lowlands Forest
p89	Batemans Bay Foothills Forest
p90	Batemans Bay Cycad Forest
p91	Clyde-Deua Open Forest
p95	Southern Turpentine Forest
p99	Illawarra Gully Wet Forest

Appendix B

Aerial Photograph Interpretation Codes

Table B1: Eden Region Canopy Species API Codes (South of Bega Valley).

ALLUVIAL API CODE	Common Dominant / Co-dominants	Common associates (subsidiary and minor) and may occasionally be co-dominant
POTENTIAL TARGET TYPES, TO BE MAPPED WITHIN AND OUTSIDE ALLUVIAL MODEL		
108	*E. elata, Angophora floribunda*	*E. cypellocarpa, E. baueriana, E. tereticornis, E. ovata* *E. longifolia (Eviminalis riparian)*
109	*E.longifolia*	*E. cypellocarpa(often co dom) Angophora floribunda,* *E. angophoroides, E. viminalis (sometimes oc patches of E. ovata)*
110	*E. ovata*	*E. cypellocarpa E. elata E. muelleriana, E. radiata/croajingolensis, E. globoidea (M. squarrosa/Gahnia common components)*
153	Swamp shubland (T to VT)	*Typically M. squarrosa (fresh water, frequently with E. ovata) sometimes M. eric (sub saline to saline)*
156	Intermediate shrubland (T to VT)	*Tall shrubs dom in large canopy openings e.g. Pomaderis etc*
115	Viney Scrub	*Mesic shrubs / vines dom in large canopy openings*
150	Freshwater Wetlands	
154x	Riparian complex	*Complex comprising several riparian associated features such as water, gravel, rock, streambank shrubs/trees eg. Tristaniopsis etc.*
154	Riparian streamside shrub/low tree complex	*Vegetated riparian zones such as streamside embankments / stream beds that are frequently inundated by high energy flood water. Commonly dominated by Tristaniopsis and may include oc trees (commonly E. elata, E. cyp, E. vim) Callistemon Melaleuca various shrubs etc.*
155	Riparian streambed complex	*Streambed complex which essentially comprises water, gravel, rock and very sparsely scattered shrubs/trees etc.*
NON-TARGET TYPES, ONLY MAPPED WHERE THEY OCCUR WITHIN ALLUVIAL MODEL		
218	Rainforest (unidentified type)	*Unidentified*
202	*Acmena smithii*	
216	*Acacia*	Typically *Acacia mearnsii*
211	*E. sieberi*	*E. globoidea, E. muelleriana*
215	*E. globoidea +/- A. litto*	*E. consideniana, E. sieberi*

219	*E. globoidea +/- A. litto*	*E. cypellocarpa, E. longifolia, A. floribunda, E. obliqua E. sieberi E. consideniana*
214	Seepage zone woodland	*E. ignorabilis, E. consideniana, E. globoidea, A. floribunda Oc: E. ovata, E. croajigolensis*
217	*E. cypellocarpa +*	*E. obliqua, E. elata, E. croajigolensis, A. floribunda E. muelleriana (E. viminalis E. angophoroides riparian)*
220	*E. obliqua, E. radiata/ croajingolensis*	*E. cypellocarpa, E. viminalis, E. sieberi, E. fastigata, E. globoidea, (E. ovata)*

Table B2: Eden Region Understorey Attributes.

Understorey label	CODE	Additional Comments
Moist Alluvial Types		
General	M0	may include localised swampy patches
Ferny (+)	M1	Commonly presents as Gahnia directly associated with minor watercourse/s and grading to ferns / Lomandra etc from streambank to more (slightly) elevated flats. May include localised swampy or mesic patches.
Vine Scrub	M2	
Mesic shrubs and or palms	M3	
RF Sub-canopy	M4	
Acacia	M5	Typically A.mearnsii
Intermediate Grasses/Forbs/Sedges/Rushes	M6	Relatively high soil moisture, scattered Lomandra typically a feature, somewhat grassy (oc ferns)
Dry Types		
General	D0	
Grassy	D1	
Shrub/Grass	D2	
Allocas + dry shrub / grass	D3	
Intermediate to dry grass/shrub +/- ferns, Lomandra	D4	Drier than M6. Applied to stringybark +/- oc yertchuk silvertop ash monkey gum occurring in drainage depression. Typically at gully heads. Slightly more moist than surrounding type usually RN113, RN112, RN123.
Swampy		
General	S0	May include a mosaic swamp shrubs sometimes tending mesic. Gahnia, scattered melaleuca sedges rushes etc.
Paperbark		

Melaleuca	S1	
Swampy to dry shrubs sedges grasses	S2	Non-alluvial seepage zones. eg. *E. consideniana E. ignorabilis* woodland
Other		
Disturbed	X0	
Exotics Dominant	X1	
Riparian complex	X2	
Saline/subsaline	X3	
Not Applicable	9999	

Table B3: South Coast Canopy Species API Codes (Nowra to Bega).

ALLUVIAL API CODE	CANOPY1 Common Dominant / Co-dominants	CANOPY 2 Common associates (subsidiary and minor)
101	***Angophora floribunda***	*E. tereticornis*
102	***E. tereticornis, Angophora floribunda***	*E. globoidea*
103	***E. tereticornis***	*Angophora floribunda, E. globoidea*
104	***E. baueriana, E. angophoroides***	*E. angophoroides, E. elata, E. globoidea, Angophora floribunda*
105	***E. bosistoana***	*E. longifolia, E. botryoides*
106	***E. botryoides***	*E. longifolia, E. elata*
107	***E. elata***	*Angophora floribunda, E. baueriana, E. tereticornis, E. viminalis*
108	***E. elata, Angophora floribunda***	*E. baueriana, E. tereticornis, E. cypellocarpa*
109	***E. longifolia***	*Angophora floribunda, E. cypellocarpa, E. angophoroides, E. viminalis*
111	***E. robusta***	*E. longifolia, E. botryoides*
112	***C. glauca***	not present
113	***C. glauca***	*E. longifolia,* other euc spp.
114	***C. glauca, Melaleuca spp.***	
116	**Viney Scrub**	
150	**Freshwater Wetlands**	
151	**Saltmarsh**	
152	**Grasslands**	
153	**Freshwater Wetlands**	

154	**Riparian streamside shrub/low tree complex**	
154x	**Riparian complex**	
155	**Riparian streambed complex**	
156	**Intermediate Shrubland**	
157	**Freshwater Wetlands**	
NON-TARGET TYPES, ONLY MAPPED WHERE THEY OCCUR WITHIN ALLUVIAL MODEL		
200	**Unidentified**	Unidentified
201	***Backhousia myrtifolia***	*Acmena smithii*
202	***Acmena smithii***	
204	***C. maculata***	*S. glomulifera, E. longifolia*
205	***E. globoidea***	*E. pilularis*
206	***E. muelleriana, E. cypellocarpa***	*E. maidenii*
208	***E. pilularis***	
209	***E. piperita***	
210	***E. saligna or*** ***E. salignaxbotryoides***	*E. pilularis, E. piperita, S. glomulifera, E. elata,* *E. longifolia, Angophora floribunda*
212	***E. sclerophylla, C. gummifera***	
213	***E. scias (pellita) or E. resinifera***	
214	**Mangrove**	
215	***C. cunninghamiana***	
216	**Acacia scrub**	
217	***E. paniculata***	

Appendix C

Comparison of SCIVI floristic communities with the assemblage list in the SWSF TEC final determination. Additional communities which were derived from analyses for our project but do not closely match SCIVI communities have 'xs' prefix.

SCIVI Community Code	Original allocation			Fuzzy clustering allocation			
	Number of plots	Mean proportion	Cumulative number of species	Number of plots	Mean proportion	Cumulative number of species	Status in Study Area
p45	11	0.48	40.75	14	0.51	38.73	Included in SWSF
p44	3	0.44	na	5	0.42	na	Excluded from SWSF, not cited in the determination, not present in SF
p105	22	0.43	26.92	35	0.46	26.74	Considered under Swamp Oak TEC
p107	12	0.43	20.97	15	0.44	22.05	Considered under Swamp Oak TEC
m15	8	0.41	na	11	0.36	24.43	Excluded, not cited in determination
p64	51	0.36	27.09	46	0.37	25.88	Considered under Bangalay Sand Forest TEC
p434	9	0.32	na	13	0.30	24.4	Themeda grassland TEC, not present in SF
p86	21	0.32	26.41	21	0.34	28.13	Excluded, not cited in determination
p63	28	0.31	23.81	35	0.31	23.55	Considered under Bangalay Sand Forest TEC
p143	3	0.29	na	6	0.28	na	Excluded, not cited in determination
p30	37	0.28	33.03	16	0.30	30.27	Considered under River-flat eucalypt forest TEC
p31	9	0.26	na	7	0.28	na	RFEF Warragamba catchment, not present in SF
p99	71	0.26	29.97	46	0.26	29.4	Excluded, not cited in determination
p103	26	0.25	27.1	32	0.26	28.37	Excluded, not cited in determination

SCIVI Community Code	Original allocation			Fuzzy clustering allocation			
p104	75	0.24	28.61	51	0.24	26.75	Excluded, not cited in determination
p168	42	0.24	25.61	18	0.25	20.9	Excluded, not cited in determination
p106	19	0.24	8.37	58	0.21	9.86	Considered under Swamp Oak TEC
p102	7	0.24	na	14	0.24	23.25	Excluded, not cited in determination
e37	19	0.24	21.37	na	na	na	Excluded, not cited in determination
p210	11	0.23	24.18	17	0.24	20.69	Considered under Littoral Rainforest TEC
p3	18	0.23	20.76	19	0.23	21.42	Considered under Illawarra Lowlands Grassy Woodland TEC
p85	45	0.22	23.08	36	0.22	23.09	Excluded, not cited in determination
p87	33	0.21	25.53	38	0.21	23.94	Excluded, not cited in determination
e60	11	0.20	15.55	9	0.20	na	Considered under River-flat Eucalypt Forest TEC
p100	35	0.20	23.07	22	0.21	21.12	Excluded, not cited in determination
n183	70	0.19	24.16	48	0.18	21.2	Excluded, not cited in determination
p58	18	0.19	23.85	22	0.17	21.35	Excluded, not cited in determination
p33	73	0.19	22.06	53	0.18	20.92	RFEF on Cumberland Plain, not present in SF
p40	66	0.19	22.71	46	0.19	19.6	Excluded, not cited in determination
p34	37	0.19	23.55	31	0.18	21.68	Excluded, not cited in determination
e34	45	0.19	22.91	26	0.20	23.7	Excluded, not cited in determination

SCIVI Community Code	Original allocation			Fuzzy clustering allocation			
p110	81	0.18	23.56	64	0.18	21.5	Excluded, not cited in determination
p95	52	0.18	20.17	46	0.19	20.19	Excluded, not cited in determination
p90	90	0.18	22.17	55	0.18	21.51	Excluded, not cited in determination
p32	31	0.18	19.04	27	0.20	17.93	Excluded, not cited in determination
p98	42	0.18	14.28	36	0.17	12.58	Excluded, not cited in determination
e38	5	0.18	na	2	0.23	na	Excluded, not cited in determination
e13	53	0.17	18.49	20	0.17	15.95	Excluded, not cited in determination
e85	16	0.17	16.88	20	0.16	17.13	Excluded, not cited in determination
e42	64	0.17	12.38	42	0.17	13.19	Excluded, not cited in determination
e32a	76	0.17	17.68	37	0.17	16.5	Excluded, not cited in determination
xs14				23	0.37	15.48	Highly disturbed, Sydney area, not present in SF
xs10				12	0.36	29.44	Sydney area, not present in SF
xs5				47	0.28	27.61	Sydney area, not present in SF
xs6				69	0.26	29.33	Considered under River-flat Eucalypt Forest TEC
xs18				64	0.23	25.53	Related to p140, excluded, not cited in determination
xs19				31	0.16	12.73	Related to e32, excluded, not cited in determination

Appendix D

Plots assessed as Swamp Sclerophyll Forest TEC.
Reference plots are those which are strongly matched floristically to a community cited in the final determination and for which habitat features match environmental descriptors in the determination. We have a high degree of confidence that these belong to SWSF.
Other plots are those with a weaker floristic relationship to any community cited in the final determination, or habitat features which may not match environmental descriptors, or both. We are less confident that these belong to SWSF.

Plot	latitude	longitude	SCIVI	SCIVI memb	Gellie	Gellie memb
Reference plots						
ELAGAR10	-35.30615	150.465	p45	0.97	g24	0.26
ELAGAR11	-35.30743	150.4674	p45	0.93	g24	0.36
HUS016CS	-35.00255	150.7003	p45	0.98	g24	0.27
NOW31P7L	-34.96917	150.6221	p45	0.69	xg7	0.24
SZ22401F	-35.04494	150.6692	p45	0.98	xg7	0.31
SZ22402G	-34.96838	150.6264	p45	0.98	xg7	0.34
SZ23043	-34.81469	150.7456	p45	0.93	g29	0.24
Other plots assessed as Swamp Sclerophyll Forest						
ALP30Q7F	-34.50678	150.8841	p45	0.96	xg7	0.23
BRUN06	-34.93287	150.6502	p45	0.15	g27	0.34
BRY034CS	-34.8335	150.7393	p45	0.96	xg7	0.25
BTN17H3V	-33.97385	151.0044	p45	0.77	xg7	0.37
EURJM14P	-35.94096	150.1339	p107	0.48	g28	0.31
HUS11M4	-35.0511	150.638	p107	0.57	g24	0.75
LGFL105	-34.10564	151.1527	p45	0.84	xg7	0.38
LGFL106	-34.08325	151.1629	p45	0.55	xg7	0.34
NOW005A	-34.92372	150.6366	p45	0.52	xg7	0.25
NOW11C5	-34.95964	150.718	p45	0.31	xg7	0.23
SZ22400F	-35.05392	150.6678	p45	0.88	g29	0.47
SZ24065F	-35.8469	150.1627	p45	0.29	xg7	0.23
SZ24081G	-35.39462	150.4004	p45	0.43	g143	1.00
TAB05P0F	-35.43864	150.3973	p107	0.39	g24	0.46

Appendix E

Field key for identification of Swamp Sclerophyll Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions in the South Coast study area.

This key is for use only in the area between Nowra and Batemans Bay (Sydney Basin and South East Corner bioregions). There is currently no evidence that this TEC occurs south of Batemans Bay. The key is expected to detect more southerly occurrences if they exist, but south of Bega it is likely to incorrectly identify Swamp Oak Floodplain Forest as Swamp Sclerophyll Forest. Assessment should be done in 20 metre x 20 metre plots or areas of similar size. The more plots assessed, the more reliable the result. Likelihoods given below use a 95% confidence interval and are for a single plot. This key and the likelihoods provided are based on distinguishing Swamp Sclerophyll Forest from vegetation not currently listed as any TEC. Vegetation identified as Swamp Sclerophyll Forest (SWSF) by this key may also, or alternatively depending on degree of floristic overlap, belong to other TECs. In particular, the key is unlikely to distinguish Swamp Oak Forest from Swamp Sclerophyll Forest in many cases. The elevation threshold is based on evidence that the community may occur up to 60 metres, including an allowance for uncertainty. The use of a 50 metre elevation threshold is more strictly consistent with the final determination.

1. Is the area at or below 70 metres elevation?
   If yes, go to 2.
   If no, the area is not SWSF.

2. Are at least two of the species *Eucalyptus robusta*, *Melaleuca ericifolia*, *Gahnia clarkei*, *Villarsia exaltata*, *Baumea juncea*, *Baumea articulata* or *Lobelia anceps* present?
   If yes, the vegetation is SWSF, with a likelihood of 75% (range 55-89%). (Note: This criterion does not distinguish SWSF and Swamp Oak Forest TEC; the latter can be distinguished in most cases if *Casuarina glauca* is dominant).
   If no, the vegetation is NOT SWSF, with a likelihood of incorrect diagnosis of 0-16%.