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The creation and conservation effectiveness of State-wide wetlands and waterways and coastal refugia planning overlays for Tasmania, Australia

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ABSTRACT

Coastal wetlands and waterways are important for biodiversity conservation and ecosystem services. Many have been under threat from land clearing, infill development and, increasingly, to sea level rise. Such wetlands not only need to be conserved at their present locations, they must be also able to retreat landwards if ecological functionality and resilience are to be maintained. While land use planning processes and applications can provide a structured approach for both in situ conservation and preservation of retreat pathways, rarely have these outcomes been achieved. This paper documents the development of GIS-based State-wide wetlands and waterways and coastal refugia planning overlays in Tasmania, south-eastern Australia, for inclusion within the new State-wide planning system. The overlays were designed to conserve current wetland extent, their buffers and future retreat areas. Through this case study, we describe and discuss the important technical, procedural and socio-political requirements for effective wetlands protection overlay development, application, monitoring and revision. The overlays provide a useful planning tool for evaluating how best to accommodate wetland conservation. We recognise, though, that planning processes will always entail trading-off development benefits, social costs, and environmental impacts within a context of increasing socio-political awareness of the functions, benefits and ecosystem services of wetlands and waterways.

1. Introduction

Coastal wetlands and waterways provide a range of well recognised ecosystem services and are important for biodiversity conservation (Barbier et al., 2011; Millennium Ecosystem Assessment, 2005). These environments are subject to heavy use and anthropogenic change at various temporal and spatial scales (e.g. Hadley, 2009; Junk et al., 2013). Chief among the human-induced pressures on wetlands and waterways are cumulative and incremental habitat alteration caused by clearing and infilling (e.g. Boon et al., 2015; Finlayson and Rea, 1999; Lee et al., 2006; Prahalad, 2014; Threatened Species Scientific Committee (TSSC), 2013). Sea level rise caused by human-induced global warming further threatens coastal wetlands and their provision of ecosystem services (Kelleway et al., 2017; Saintilan et al., 2018). There is an important need to both conserve wetlands and waterways at their present locations and to secure the availability of upland areas to which these ecosystems can retreat as they respond to sea level rise (Bell et al., 2014; Burley et al., 2012; Ledoux et al., 2005; Rogers et al., 2014a).

Public reservation of particular geographic locations has been an important tool for protecting wetlands and waterways of conservation significance. However, there are a number of well-known limitations with this approach. Typically, public reserves are not comprehensive, adequate or representative of variation in wetlands, lack an adaptive approach to the migrating boundaries of wetlands and waterways, and have insufficient resources allocated to monitoring and on-ground management (Fitzsimons and Robertson, 2005; Mendel and Kirkpatrick, 2002; Prahalad and Kriwoken, 2010; Rogers et al., 2016). There is a need for additional policy options and tools that can enable governments to better conserve wetlands in the long term (Shoo et al., 2014).

Covenants and management agreements have become an important mechanism for both governments and private agents to use as a ‘low cost option’ to fill in gaps in the public reserve system (Adams and Moon, 2013; Fitzsimons and Carr, 2014). However, private and public conservation reserves combined do not cover all wetlands and waterways of conservation significance, or all of the land that will be necessary for wetland retreat (e.g. Prahalad, 2014). Private reserves also have limitations, being subject to opportunity costs pressures, funding availability, uncertainties in permanence and security, and lacking

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adequate longer-term monitoring data on their conservation effectiveness (e.g. Boon and Prahalad, 2017; Fitzsimons, 2006; Hardy et al., 2017). These inadequacies of reserves highlight the need for alternative policy and regulatory mechanisms that are articulated though state policies, land use and environmental planning apparatus – specifically environmental and planning laws and regulations (Abel et al., 2011; Lindsay, 2016).

Land use planning development assessment and permitting processes are an important mechanism that governments use to deliver public good outcomes in land and property development (Garrard and Bekessy, 2014; Randolph, 2004). The planning tool-box available to planners and land managers includes planning codes and overlays that both define and map wetlands and waterways across land use zones. The overlay maps function as a 'spatial filter', flagging any potential conflicts between infrastructure development and protection of wetlands and waterways (Harty, 2001, 2004). Overlays can also signal their conservation importance to development proponents. Once a flag is thus raised, planning authorities can then determine if a development application is consistent with local planning codes and regulatory processes.

Increasingly, opportunities are being identified to employ such land use planning measures in wetland conservation whilst also recognising that realising these opportunities can be challenging for both technical and socio-political reasons (Brody and Highfield, 2005; Harty, 2001; Hurlimann et al., 2014; Ledoux et al., 2005; McDonald et al., 2013). In the context of coastal adaptation to sea level rise, there have been numerous calls for the use of a general overlay to recognise wetland retreat areas at early stages of planning (e.g. Abel et al., 2011; Bell et al., 2014; Ledoux et al., 2005; Harty, 2004, 2009; Shoo et al., 2014). Yet, and despite increasing institutional awareness of sea level rise effects on coastal wetlands (e.g. Threatened Species Scientific Committee (TSSC), 2013), we are not aware of any published accounts of an overlay developed to specifically address this need. Furthermore, while overlays have generally been used in planning schemes to achieve a range of environmental outcomes (e.g. Garrard and Bekessy, 2014), there are few published accounts of their development and potential effectiveness, the development of the Wildfire Management Overlay for Victoria, Australia (Hughes and Mercer, 2009) being one example.

The present paper documents the process followed in the development of State-wide wetlands and waterways and coastal refugia overlays for Tasmania, south-east Australia, as part of the new single State-wide Tasmanian Planning Scheme effective from 2017. We also gauge the potential effectiveness of the overlays in the context of the provisions and processes in the State-wide planning scheme. To illustrate our arguments, we use the example of coastal saltmarsh wetlands that are: a) widespread in Tasmania (Prahalad and Kirkpatrick, in review); b) subject to clearing and reclamation (Prahalad, 2009, 2014); and, c) affected by the effects of climate change and sea level rise (Prahalad et al., 2012, 2015). These coastal saltmarshes are listed under the Australian national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as a threatened ecological community (Threatened Species Scientific Committee (TSSC), 2013). As part of the listing, the Australian Government has explicitly identified the need to liaise with planning authorities to include development controls on current wetland extent, their buffers and future retreat areas (Threatened Species Scientific Committee (TSSC), 2013). The present paper addresses this conservation need and provides a case study for the design context, components, constraints, opportunities and likely conservation effectiveness of overlays.

We describe the overlays and associated Tasmanian land use decision-making processes in detail. We derived these data from the State Planning Provisions (Department of Justice, 2017) and our experience in applying the business rules developed in consultation with the Tasmanian Department of Justice. Our analysis of the potential effects of the layer was based on a thorough literature review and a deep understanding, through experience, of the Tasmanian planning process and the biophysical characteristics of the Tasmanian wetlands.

2. An overview of land-use planning in Tasmania

Land-use planning in Tasmania is governed by the State's *Land Use Planning and Approvals Act 1993* (the Act), part of the Tasmanian Resource Management and Planning System (Castles and Stratford, 2014; Stratford, 2008). Major planning reform in Tasmania has been underway since 2014, when the then newly elected Liberal Government (conservative) followed through on an election commitment to create a "fairer, faster, cheaper, simpler planning system" as part of a plan "to make Tasmania attractive for investment, to create jobs" (Tasmanian Liberals, 2018). Amendments made to the Act since 2015 have seen the introduction of the promised single State-wide Tasmanian Planning Scheme (STPS) which will replace the 30 local schemes specific to individual municipal areas under the pre-existing Interim Planning Schemes (see Castles and Stratford, 2014). The stated aim of the STPS is to streamline approvals, with one set of documents providing more consistency and shorter assessment timeframes which will "cut red and Green tape by 20 per cent" (Tasmanian Liberals, 2018).

The two-part Scheme has set out State Planning Provisions to provide the generic planning rules per the objectives of STPS, while allowing local councils to prepare their Local Provision Schedules to tailor and apply State Planning Provisions within their municipalities (Department of Justice, 2017). State Planning Provisions also set out administrative processes and list exemptions for the 23 land use zones and 16 codes (along with their respective overlay maps). Local Provision Schedules include maps of the zones, overlays and other considerations specific to selected areas of local significance. State Planning Provisions provide guidance for local councils in interpreting and revising overlay base maps supplied State-wide. The Tasmanian Planning Commission, an independent body previously established under the *Tasmanian Planning Commission Act 1997*, is tasked with the role of guiding local councils in this process (Tasmanian Planning Commission, 2017).

The Natural Assets Code is one of the 16 codes under the STPS and has a specific role to provide consistent advice regarding the conservation of important natural values across the State. The Code covers Waterway and Coastal Protection Areas, Future Coastal Refugia Areas and Priority Vegetation Areas (Fig. 1). Priority Vegetation Areas have a broad function in biodiversity conservation under STPS by affording protection for threatened native vegetation communities and flora species, including significant habitat for threatened fauna species and other locally important native vegetation (Tasmanian Planning Commission, 2017). The threatened communities and species are identified with reference to State legislation including the *Nature Conservation Act 2002*, *Threatened Species Protection Act 1995* and the *Forest Practices Act 1995*. The Priority Vegetation Areas overlay map is derived from Tasmania-wide vegetation (TASVEG) mapping and from the Natural Values Atlas, both public databases managed by the Tasmanian State Government Department of Primary Industries, Parks, Water and Environment (DPIPWE).

The Waterway and Coastal Protection Areas protect wetlands, waterways and the land that buffers existing wetlands and waterways, including the coastal zone. The Future Coastal Refugia Areas protect the land that facilitates natural processes through the retreat of coastal habitats in response to sea level rise. The two related overlays address some of the aims of the Tasmanian *State Coastal Policy 1996*, *State Policy on Water Quality Management 1997*, while also incorporating aspects of the *Tasmanian Wetlands Strategy 2001*. Climate change and sea level rise are not, however, addressed well within the *State Coastal Policy 1996* (the Policy). An amendment drafted in 2013 was rejected by the Tasmanian Planning Commission after public consultation, in large part due to inadequacies in dealing with climate risks (Gurran et al., 2013). However, the Policy does state that the natural values, ecosystems and processes in the coastal zone need to be sustainably managed as we

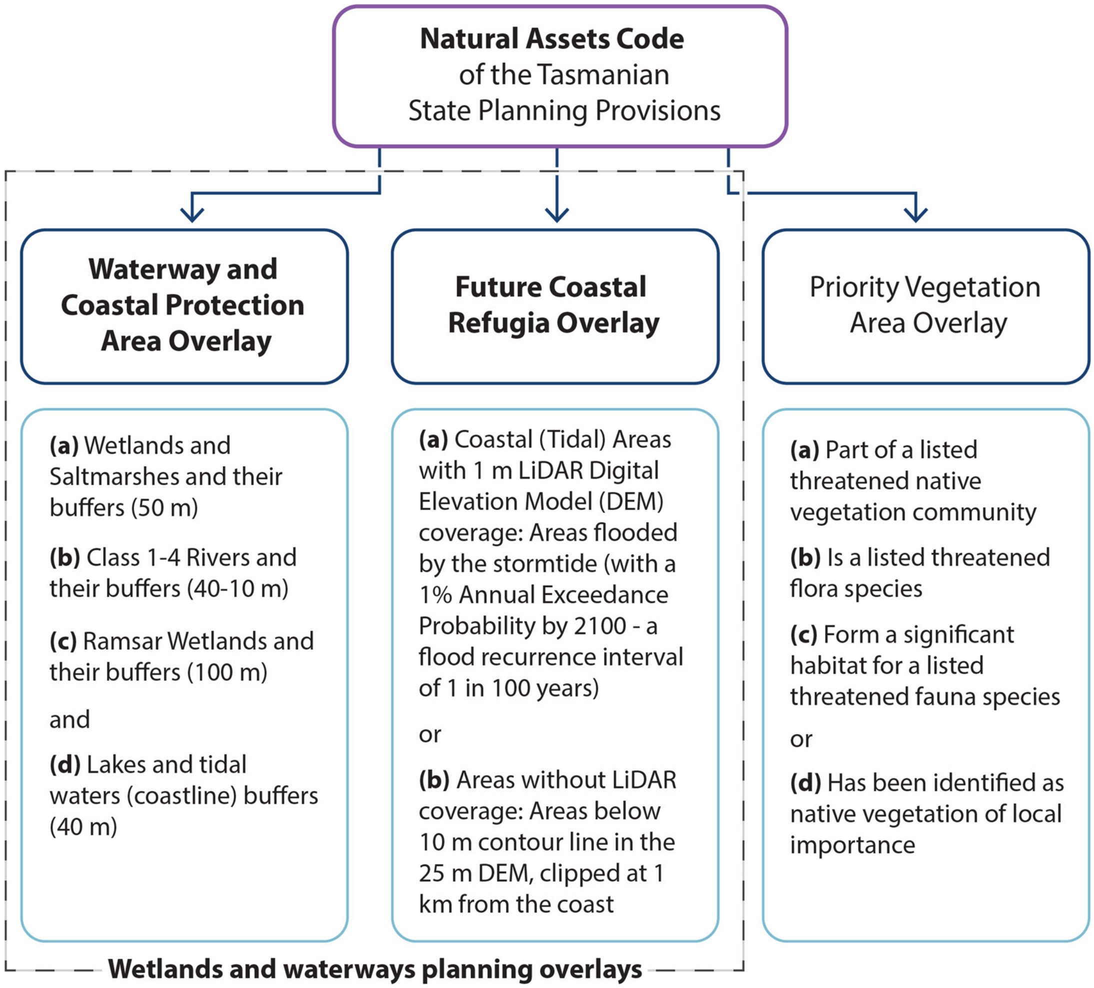

Fig. 1. Natural Assets Code, its three overlays and the natural values covered under each of the overlays, as set out by the State Planning Provisions under the new State-wide Tasmanian Planning Scheme. See text for further details.

respond to climate change and sea-level rise effects. In support of this aim, later regional land use strategy development and regional policies enabling coastal refugia were endorsed by prior Tasmanian Governments and, as such, viewed to be consistent with the existing Policy.

3. Creation of the overlay maps

3.1. Development of the business rules

The overlay maps were developed as per business rules that were formulated as part of the STPS. The business rules evolved in a series of incremental steps spanning a decade. This period was marked by an increasing socio-political awareness of the functions, benefits and ecosystem services of wetlands and waterways (e.g. Threatened Species Scientific Committee (TSSC), 2013). New data, tools and applications were developed (e.g. Department of Premier and Cabinet (DPAC), 2016; Department of Primary Industries, Parks, Water and Environment (DPIPWE), 2015; Lacey et al., 2015; Prahalad, 2009). A leadership role in expanding data, skills and the structural and cultural capacities of institutions (Measham et al., 2011) was taken by many government staff and a few elected representatives. Many complementary efforts were made to link land use planning with strategic plans, operational plans and other natural resource management activities undertaken by local councils (e.g. water sensitive urban design). The relevant key steps are briefly summarised as follows:

1) Data collation, creation and analysis (e.g. Prahalad, 2009; Prahalad et al., 2009), and communication with Tasmanian State government and local councils as part of the inclusion of provisions for wetland refugia in regional land use strategy development. This was done in accordance with the *State Coastal Policy 1996* guidelines (as also noted in previous section).
2) Integration of regional land use strategy guidelines into the development of the Interim Planning Scheme (Castles and Stratford, 2014).
3) The adoption of the Interim Planning Scheme provisions within the draft STPS, and subsequent consultation with the three Natural Resource Management (NRM) regions in Tasmania (Prahalad and Kriwoken, 2010), State government and local councils, and other stakeholders.
4) The final formulation of the business rules were made after the consultation process and then used to create the overlays as described in the present paper.

The Department of Justice oversaw the creation of the overlays by three of the authors (VP, JW and AL), through the financial support of the Derwent Estuary Program, a regional partnership between local councils, the Tasmanian State government, commercial and industrial enterprises, scientists and the community.

3.2. Waterway and coastal protection area overlay

The Waterway and Coastal Protection Area overlay covers wetlands, waterways and their landward buffer areas. The buffers acknowledge

Table 1
Spatial data sources used in the creation of the single State-wide wetlands and waterways overlay for Tasmania ('Waterway and Coastal Protection Overlay' under the new Tasmanian Planning Scheme). Data currency is indicated by the most recent year(s) of updates of the respective data layers. * indicates the spatial features included in the creation of the overlay. # Buffers for the larger rivers were derived from the Tasmanian Information and Land Services polygons.

Natural Assets Code Class	CFEV Ecosystem Themes [2010]	TASVEG 3.0 Vegetation Communities [2013]	Prahalad and Kirkpatrick [2013-18] Coastal Saltmarshes	Ramsar Wetlands [1982]
Wetlands	Wetlands*	AHF Freshwater aquatic herbland* AHL Lacustrine herbland* AHS Saline aquatic herbland* ASF Freshwater aquatic sedgeland and rushland* AWU Wetland (undifferentiated)*	–	Applicable*
	Saltmarshes*	ARS Saline sedgeland/rushland* ASS Succulent saline herbland* AUS Saltmarsh (undifferentiated)*	Saltmarshes (Coastal/Tidal)*	Applicable*
Waterways	Rivers*,#	–	–	Applicable*
	Waterbodies	–	–	Applicable*
	Estuaries	–	–	Applicable*
Not included	Karst Systems	–	–	Applicable*
	Groundwater Dependant Ecosystems	–	–	Applicable*

the need for fringing areas landward of aquatic ecosystems to be protected and managed in order to "minimise the impacts on water quality, natural assets including native riparian vegetation, river condition and the natural ecological function of watercourses, wetlands and lakes" (Tasmanian Planning Commission, 2017, p. 34). Landward buffers also extend along the coastline to "minimise impacts on coastal and foreshore assets, native littoral vegetation, natural coastal processes of surrounding land use activities and the natural ecological function of the coast" (Tasmanian Planning Commission, 2017, p. 34–35).

We derived wetland and waterway features from existing mapping (Table 1). The Tasmanian Government Conservation of Freshwater Ecosystem Values (CFEV) Project generated a comprehensive State-wide database of spatial features across seven ecosystem themes – wetlands, saltmarshes, rivers, waterbodies, estuaries, karst systems and groundwater-dependent ecosystems (Department of Primary Industries and Water (DPIW), 2008; also see Prahalad and Kriwoken, 2010). Each feature has been assigned a conservation priority for water management and planning processes (Department of Primary Industries and Water (DPIW), 2008). All CFEV features attributed as wetlands, saltmarshes and rivers were selected for inclusion in the overlay. Under the State Planning Provisions, rivers are referred to as watercourses and they differed from wetlands (and saltmarshes) in that they have "a defined channel with a natural or modified bed and banks that carries surface water flows" as opposed to being "a depression in the land, or an area of poor drainage, that holds water derived from ground water and surface water runoff and supports plants adapted to partial or full inundation and includes an artificial wetland" (Department of Justice, 2017, p. 3.0 Interpretation: 14). CFEV represents all river systems as lines, while some of the wider river systems are more accurately represented as polygons. These features were sourced from the Tasmanian Information and Land Services, part of DPIPWE.

The TASVEG map covers more than 150 plant communities (Kitchener and Harris, 2013). Several of these communities are associated with wetland types and were included within the CFEV database (TASVEG Version 0.1 May 2004). Of these, updated mapping for the eight non-forest type wetland and saltmarsh communities in Version 3.0 (released November 2013) of the TASVEG map were extracted and included in the overlay (Table 1). A more recent project undertaken since 2012 by the three NRM regions in Tasmania focussed on updating and improving the mapping of saltmarshes (Prahalad and Kirkpatrick, in review). The project was confined to tidally-influenced coastal saltmarshes on the basis of their recognition under the EPBC Act as a threatened ecological community (Threatened Species Scientific Committee (TSSC), 2013). All saltmarshes mapped under this project were included in the overlay.

The overlay also included all wetlands listed under the Convention on Wetlands (Ramsar, Iran, 1971), as sourced from Information and Land Services. Ramsar wetlands, whilst they overlap with existing wetlands and saltmarshes mapped under CFEV, TASVEG and by the NRM regions, also contain other areas included either as rivers, waterbodies or estuaries (Table 1). Five of the 10 Tasmanian Rasmar wetlands are either entirely or partly within private land (Prahalad and Kriwoken, 2010). All Ramsar wetlands are afforded the highest level of legislative protection, being considered as matters of national environmental significance under the EPBC Act.

In addition to the mapped footprint of wetlands, saltmarshes, rivers and Ramsar wetlands, associated landward buffers were also included. While the width of the buffer zone depends on the specific context (e.g. nature and size of the catchment in relation to the wetland and waterway: Houlahan and Findlay, 2004), a minimum of 30–60 m of terrestrial zone has been recommended for buffering aquatic habitats and their water resources (Semlitsch and Bodie, 2003). Although variable-width buffers would allow adjustments based on site-specific considerations (Department of Environment and Resource Management (DERM), 2011), they are deemed to require greater expenditure and offer less predictability for land use planning (Castelle et al., 1994). Hence a fixed-width buffer is often preferred as a statutory starting point in planning and was used for the overlay. Wetlands and saltmarshes were allocated a 50 m buffer, while Ramsar wetlands had a 100 m buffer. The buffer distances for waterways varied between classes (40 m for Class 1; 30 m for Class 2; 20 m for Class 3; and 10 m for Class 4 rivers), following the Tasmanian *Forest Practices Code 2015*. A landward buffer of 40 m extended from inland lakes and tidal waters, including estuaries and the coastline across Tasmania, considered in the overlay as Class 1 watercourses. Spatial layers for these features were provided by Information and Land Services.

3.3. Future coastal refugia area overlay

The Future Coastal Refugia Area overlay covered the retreat paths of coastal wetlands in order to "protect vulnerable coastal areas to enable natural processes to continue to occur, including the landward transgression of sand dunes, wetlands, saltmarshes and other sensitive coastal habitats due to sea-level rise" (Tasmanian Planning Commission, 2017, p. 35). There are dynamic, inter-related and often site-specific driving factors (e.g. topography, vegetation types, primary productivity, temperature, rainfall, catchment runoff, grazing pressure and other drivers of competitive exclusion) that determine the habitat

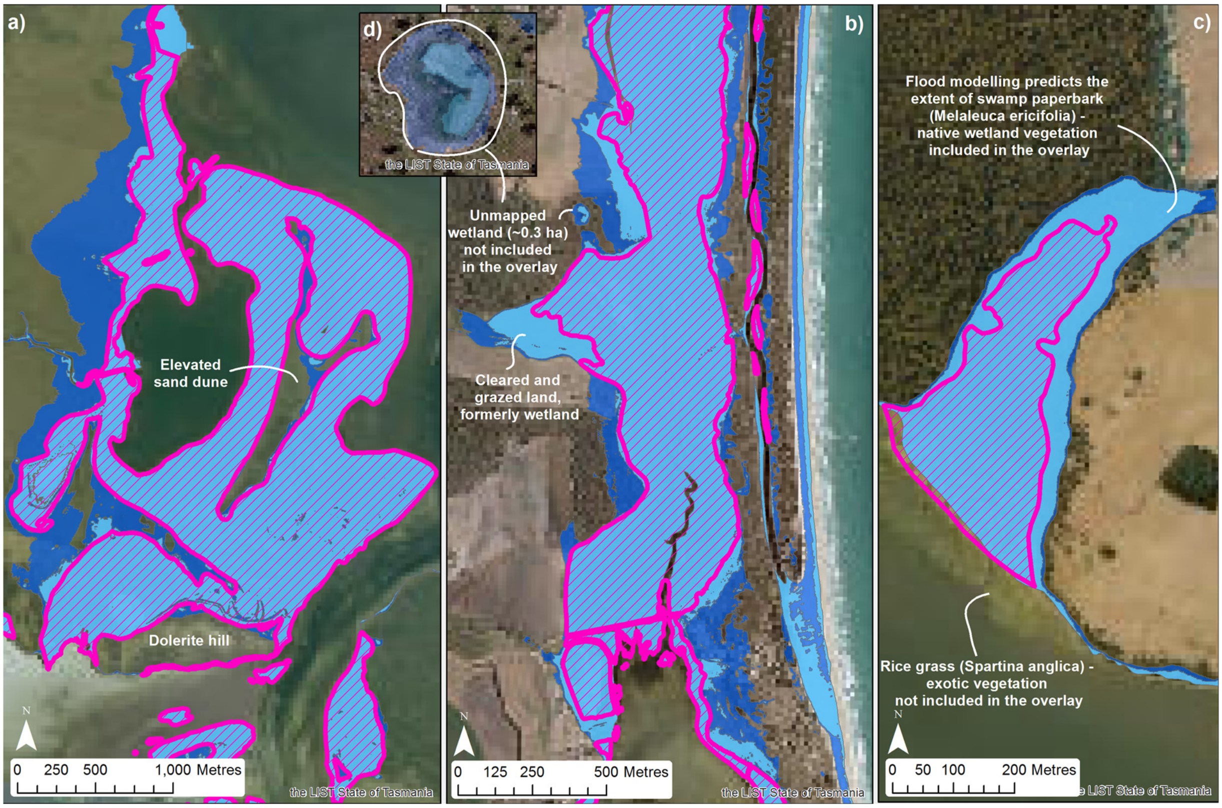

Fig. 2. Three examples at different spatial scales and geomorphic contexts depicting the relationship between current saltmarsh extent (in hatched polygons), the modelled current (2010) storm tide extent (inner, light blue polygons) and the modelled future (2100) storm tide extent (outer, dark blue polygons) – (a) Long Point saltmarsh in Moulting Lagoon on the east coast is the single largest saltmarsh in Tasmania (359 ha) and has retreat areas on nearby agricultural land, (b) Marion Bay (Marchweil) saltmarsh in south-east Tasmania also has retreat areas on nearby agricultural land where there has been some historic clearing and grazing that has restricted wetland extent, (c) saltmarsh with a landward fringing zone of *Melaleuca ericifolia* paperbark swamp, as part of the Tamar drowned river valley estuary in northern Tasmania, has steeply rising upland areas unlikely to provide room for retreat, (d) an example of an unmapped freshwater wetland area in Marion Bay that has not been included in the overlay (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

suitability of retreat areas. In addition to the uncertainties inherent in global climate models (Hunter et al., 2013), these variables combine to make detailed predictive modelling highly probabilistic and contingent on prevailing conditions and assumptions (Boon et al., 2010; Mogensen and Rogers, 2018). The Tasmanian context adds further difficulties given both the high environmental variability (e.g. annual rainfall differential of 490–2140 mm on the coast) and a paucity of information required for more detailed and context-specific modelling.

While relevant modelling techniques and data continue to expand (e.g. Prahalad et al., 2015; Prahalad and Kirkpatrick, in review), in the interim, a simple yet robust proxy can be applied through flood modelling. This technique indicates the availability and extent of retreat areas that are accessible for wetlands to establish (e.g. Boon et al., 2010). The ecological basis that underpins this proxy is from the observed realised niche of wetlands in the Tasmanian coastal landscape which largely coincides with the extent of the modelled present day (2010) storm tide (Fig. 2; Mount et al., 2010; Prahalad et al., 2009). Hence, flood modelling with projected sea level rise can act in most cases as a reliable proxy to predict potential wetland retreat pathways at early stages of planning. On-ground evidence of wetland retreat in some of these areas already exists and vegetation changes can provide visual cues for ground-truthing the model at individual sites (e.g. Prahalad et al., 2012).

For the overlay, we adopted the flood modelling for the coastal zone undertaken by the Tasmanian Department of Premier and Cabinet (DPAC) as part of the Tasmanian Coastal Inundation Mapping Project (Lacey et al., 2015). Mapped areas include parts of coastal Tasmania where LiDAR Digital Elevation Model (DEM) of 1 m resolution has been used to identify an inundation extent based on the predicted sea level rise allowance of 0.8 m and 1% Annual Exceedance Probability (AEP) storm surge height mapping for 2100 (relative to 2010). The parameters were determined by DPAC and based on the broadly applied IPCC A1FI emission scenario (Hunter et al., 2013). This mapping covers most urban and semi-urban areas along the coast. For the remaining areas which lacked LiDAR coverage, the 25 m DEM available from Information and Land Services was used as “the best available alternative to the LiDAR DEM … at least [to] provide an indication of areas potentially subject to inundation due to sea level rise” (Lacey et al., 2015, p. 8).

Once the extent of the overlay was determined though the adoption of DPAC flood modelling, the Tasmanian Planning Commission (2017) provided policy advice based on compatibility with current land use zoning. The policy advice classed the 24 Interim Regional Planning Schemes zones into four policy zones under STPS (Table 2). The advice identified that 12 planning zones are not compatible with the overlay and that local councils may consider their removal in areas covered by the overlay as part of their Local Planning Provisions. An additional 6 zones were recommended for case by case consideration and 2 other zones were subject to special consideration. This allows 4 zones within which the Natural Assets Code regulations are fully compatible.

3.4. Geoprocessing steps

We performed the entire process of the overlay creation on an online Geographical Information System (GIS) platform using ArcGIS™ 10.3 for Desktop. Once the objectives and rules were determined for the overlays (as discussed above), they were sorted into distinct tasks, their component geoprocessing steps and ordered into a workflow as follows.

Table 2
Land use planning zones (10–33, n = 24) under the pre-existing Interim Planning Scheme (Tasmania wide, except for Flinders Municipality covering Furneaux Group of islands which fall under the Flinders Planning Scheme 2000) and their respective policy considerations (i.e. Policy Zones) as integrated in to the Future Coastal Refugia Area overlay (Tasmanian Planning Commission, 2017). The 19 Interim Planning Scheme zones highlighted by underlining have been transferred over to the new State-wide Tasmanian Planning Scheme, three others renamed (as Rural, Agriculture and Landscape Conservation Zones) and the remaining two fused into a single Future Urban Zone.

Policy Zone	Planning Zone (Interim Planning Scheme)	Planning Zone (Flinders Planning Scheme 2000)
1.0 Special Consideration	13. Rural Living Zone	Rural Residential Zone
	14. Environmental Living Zone	
2.0 Case by Case Consideration	17. Community Purpose Zone	Public Purpose Zone
	18. Recreation Zone	
	28. Utilities Zone	
	30. Major Tourism Zone	
	32. Particular Purpose Zone 1 – Urban Growth Zone	
	33. Particular Purpose Zone 2 – Future Road Corridor	
3.0 Retain (Compatible)	19. Open Space Zone	Rural Zone
	26. Rural Resource Zone	Environmental Management Recreation Zone
	27. Significant Agricultural Zone	
	29. Environmental Management Zone	
4.0 Remove (Incompatible)	10. General Residential Zone	Residential Zone
	11. Inner Residential Zone	Low Density Residential Zone
	12. Low Density Residential Zone	Commercial Zone
	15. Urban Mixed Use Zone	Village Zone
	16. Village Zone	
	20. Local Business Zone	
	21. General Business Zone	
	22. Central Business Zone	
	23. Commercial Zone	
	24. Light Industrial Zone	
	25. General Industrial Zone	
	31. Port and Marine Zone	

The first task involved combining existing wetland and waterways mapping layers into a single shapefile layer. Given the different source layers and their attributes, the final master layer preserved all of the original attributes in order to trace the genesis of the spatial features. This has been done to allow overlay users to interpret map accuracy and attribute quality (Chrisman, 1987). The second task involved applying defined buffers to the wetlands and waterways master layer. For coastal wetlands, the buffers were clipped by the coastline and only included the area to the landward side. The outputs from these two tasks produced the Waterway and Coastal Protection Area overlay.

For the Future Coastal Refugia overlay, the first task involved adapting existing coastal flood modelling by Lacey et al. (2015) and reclassifying the areas to depict those with and without LiDAR DEM coverage. The second task involved attributing policy zones to the overlay to create four classes (see Table 2), with separate symbology for areas with and without LiDAR coverage. Both overlay maps are available through LISTmap (https://maps.thelist.tas.gov.au/listmap/app/list/map), an open source online map application maintained by Land Information System Tasmania (LIST). LISTmap allows users to view the overlay maps alongside zoning, cadastre and a range of other publicly available layers (Fig. 3).

4. Potential effectiveness of the overlay

4.1. Asset and context specific mapping and buffering

Overlay maps are generally an aggregation of different source layers with variable spatial and attribute accuracies. Therefore, as Chrisman (1987, p. 436) notes, "[t]he use of the overlay must be sensitive to the scale [and accuracy] intended in the original products." The original mapping products adopted for the Waterway and Coastal Protection Areas overlay include CFEV and TASVEG mapping at a nominal scale of 1:25,000, with mapping of some wetlands done at a larger scale, as for saltmarshes included in the overlay mapped at a scale of 1:500 to 1:3000 (Prahalad and Kirkpatrick, in review). Mapping of saltmarshes in urban and other built environments was done specifically at a scale suitable for use in planning applications where assessments of development proposals are often made at a 'backyard' resolution. The intent was to capture even smaller patches of saltmarsh as they can provide ecosystem services (e.g. bird habitat, fish nursery, climate and flood regulation) often disproportionate to their size (Lundquist et al., 2017).

The other wetland types derived from CFEV and TASVEG mapping have a lower spatial accuracy or coverage, with many wetland areas likely to not have been mapped (Dunn, 2002; Prahalad and Kriwoken, 2010). The saltmarsh mapping project, for instance, identified several saltmarsh areas previously unmapped or incorrectly attributed as agricultural, urban and exotic vegetation. It is likely that other wetland types, especially smaller patches (e.g. see Fig. 2), lack detailed inventories. An ongoing mapping process at the appropriate scale for the natural asset type is desirable, as is a monitoring program to determine changes in boundaries given the 'perambulatory' nature of wetlands and waterways (Rogers et al., 2016). This need is more imminent for coastal wetlands which are exposed to the effects of climate change and sea level rise (Ledoux et al., 2005; Saintilan et al., 2018).

The dynamic nature of wetlands and waterways also has implications for the suitability of buffer zones that can be effective in minimising impacts (Department of Environment and Resource Management (DERM), 2011). The Natural Assets Code currently states that the width of the buffer be "measured from the top of bank or high water mark of tidal waters, watercourses or freshwater lakes" (Department of Justice, 2017, p. C7.0 Natural Assets Code: 4). In the case of an inconsistency arising between the overlay map and on-ground measurement, due likely to natural variation in wetlands and waterways, the Natural Assets Code allows for the greater distance to prevail. This has potential to both remedy pre-existing inaccuracies in the overlay map and also address mapping obsolescence in dynamic landscapes (Saintilan et al., 2018). The efficacy of this provision can be improved through regular revisions of mapping, whereby the buffer zones can be updated to reflect temporal changes in wetlands and waterways.

Furthermore, the fixed-width buffer presupposes a contiguous zone of native vegetation without consideration of the actual composition of

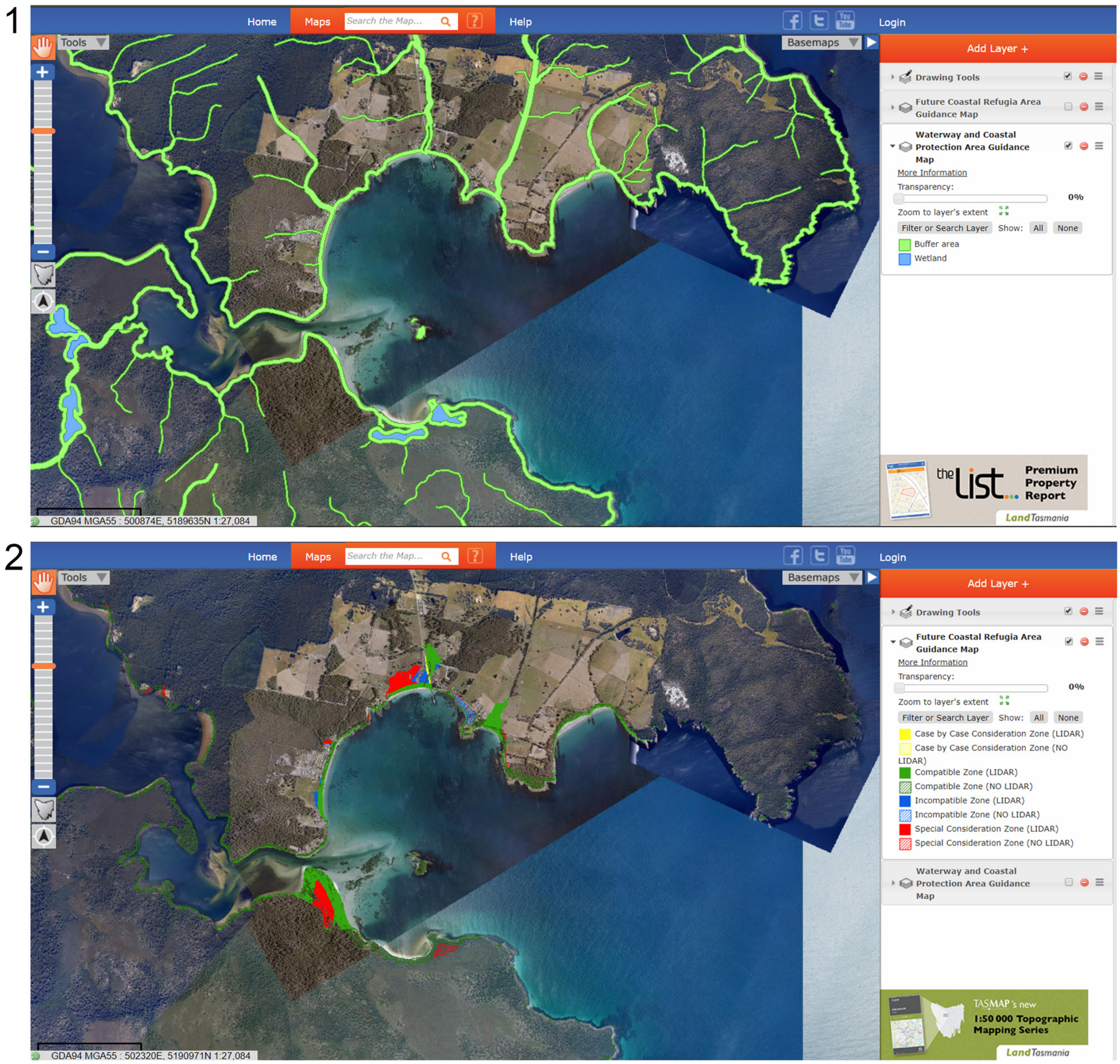

Fig. 3. Screenshots of LISTmap, an open source online map application maintained by Land Information System Tasmania (LIST), where the planning overlay and zone maps can be viewed along a range of other publicly available layers. The example shown here is from Southport, in south-east Tasmania, where there are areas both with and without LiDAR DEM coverage (see screenshot 2).

the buffer zone or of the nearby land use type and intensity. In many cases, native vegetation has been replaced with agricultural, urban and exotic vegetation or impervious structures. For example, over 65% of the saltmarshes of north-west Tasmania (~25% of State-wide extent) do not have a contiguous native vegetation buffer of 50 m, and are mostly fringed by cattle grazing pastures (Prahalad, 2014). In such cases, the Natural Assets Code allows current land uses to continue, and stipulates that any building and works should "… not have an unnecessary or unacceptable impact on natural assets" (Department of Justice, 2017, p. C7.0 Natural Assets Code: 6). A context-specific, variable-width buffer might be more suitable to minimise nearby land use effects, such as nutrient run off (Department of Environment and Resource Management (DERM), 2011; Houlahan and Findlay, 2004). Improved State-wide vegetation and land use mapping, along with studies on catchment hydrology (e.g. Holz, 2009), will assist in moving towards a variable-width buffer on a fit-for-purpose basis. An aspirational outcome when highly accurate spatial information is available would be for the overlay map to override the worded code.

4.2. Certainties and uncertainties in retreat scenarios

The Future Coastal Refugia Area overlay occupies an area of about 200 km^2 (~0.3% of Tasmania's landmass). The overlay includes highly developed coastal areas with existing land uses that preclude wetland retreat though infill development, ditching (e.g. 'hump and hollow' drainage: Holz, 2009), tidal barriers and active grazing (e.g. Prahalad, 2014). This creates potentially high opportunity costs in altering land use practises to allow room for coastal wetlands to retreat (Hadley, 2009; Ledoux et al., 2005). There is thus an important need for improved 'site-specific' mapping to prioritise resource allocation for reserving priority areas for wetland retreat (Bell et al., 2014; Shoo et al., 2014). An immediate step in this regard would be to expand LiDAR DEM coverage to all parts of the State to better predict wetland retreat areas at sub-metre resolution (Chmura, 2013).

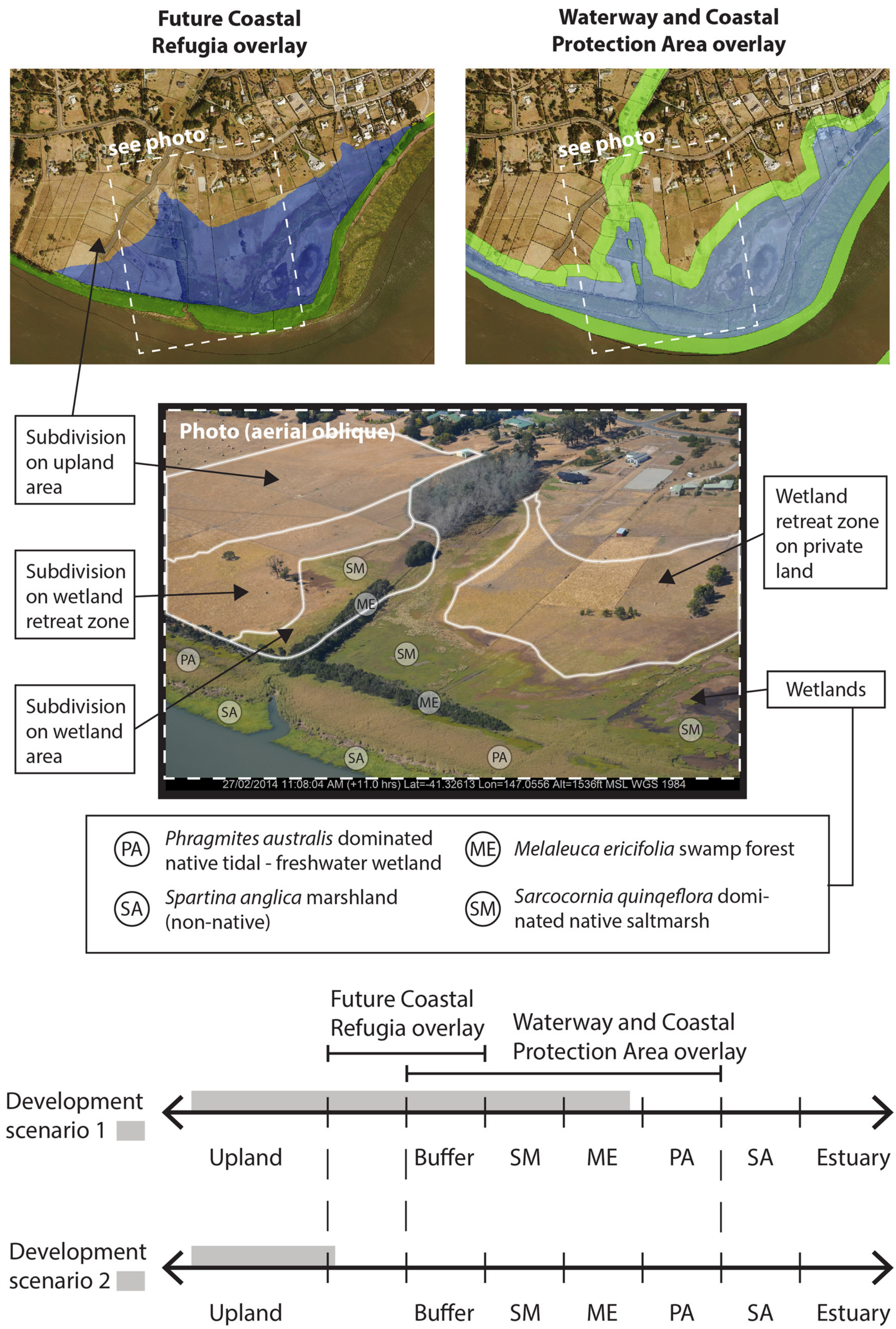

Fig. 4. Example of a wetland retreat area in the Tamar River estuary, northern Tasmania, which falls under the Incompatible - Rural Residential Zone (see Table 2), and hence exempt from the application of Natural Assets Code, except where there are present wetlands and their 50 m buffers. Under development scenario 1, the overlays and the code are not applied and development is approved to impinge on current wetland, its buffer and future refugia areas. Under development scenario 2, the overlays and the code are applied and current wetland, its buffer and future refugia areas are conserved (while also mitigating risk both in the vicinity and reduce flood water displacement on other low lying human assets within the estuary).

Where LiDAR coverage exists, further improvements in flood modelling have already been undertaken with the recent availability of finer-scale sea level rise estimates for individual local council areas in Tasmania (McInnes et al., 2016). These estimates are set across four greenhouse gas emissions scenarios and show variability between council areas, with higher rates along the east coast (Lacey, 2016). The Local Planning Provisions can be adjusted to account for this regional variability between council areas. The 'bath-tub' flood modelling used, however, does not consider other locally important factors, such as river flooding, wave setup and run-up that could amplify floods (Hunter et al., 2013; Lacey, 2016). Better understanding and integration of these site-specific factors in flood modelling will provide greater confidence in managing for coastal hazards (Bell et al., 2014). Even though stochastic extreme events may increase in the future, they are unlikely to change the persistent patterns of wetland occurrence (mainly, the formation of hydric soils), so can be discounted for the purposes of wetland retreat.

Surface elevation change (i.e. vertical accretion) and above and below-ground organic processes have been considered most important in modelling wetland retreat with sea level rise (Rogers et al., 2014a; Saintilan et al., 2009, 2018). In the Tasmanian context, the lack of mangroves means a lower ability for coastal wetlands to accrete sediment and buffer against losses from erosion events (e.g. Rogers et al., 2014b). Furthermore, several Tasmanian coastal environments have a negative sediment budget, with little capacity for sediment accumulation (Mount et al., 2010). The dominant factor affecting saltmarsh resilience in such environments is the relative exposure to wind-generated waves (Prahalad, 2009; Prahalad et al., 2015). With an increase in higher energy wind waves and storm frequency, saltmarshes can retreat even under modest sea level rise due to wave erosion (e.g. Marani et al., 2011).

Increased mean and maximum wind speeds have been observed already in Tasmania coastal wind records (Kirkpatrick et al., 2017; Prahalad et al., 2012). The effect of increased wind speeds are observable in Tasmanian marshes as visible erosion scarps with no evidence of intermittent accretion (e.g. secondary marsh development after a phase of erosion: Adam, 1990), and are in a trajectory of long term drowning (Prahalad et al., 2015). The preponderance of the 'coastal squeeze' scenario has also been documented in temperature latitudes of the Northern Hemisphere, where sea level rise is causing saltmarshes to drown due to a 'negative accretion balance' (e.g. Crosby et al., 2016). The only sustainable alternative for many marshes is to retreat inland onto low lying areas, a process that has already occurred in Tasmania (Mount et al., 2010; Prahalad et al., 2012). It is obviously desirable to have a process to update the overlay boundaries as sea levels and land use change. With the present rate of sea level rise and coastal development, we suggest that the effectiveness of the planning provisions be monitored and the overlay be updated as new information becomes available (Bell et al., 2014). The process of ongoing revision is consistent with a long term adaptive approach to land use planning (e.g. Burley et al., 2012).

4.3. Exemptions and opportunities in achieving code purpose

The potential effectiveness of the wetlands and waterways planning overlay in achieving the purpose of the Natural Assets Code (noted in above sections) will depend on how they are revised as part of the Local Provision Schedules before an 'enforceable' map is generated. The Tasmanian Planning Commission, in their guidelines to local councils, have identified that the overlay maps can be modified to address any anomalies or inaccuracies in the mapping. There is provision in the case of Future Coastal Refugia Area overlay for both adding "a larger area if demonstrated as necessary to protect identified future coastal refugia areas, such as mobile and other sensitive coastal habitats and existing saltmarshes and tidal wetlands" and removing areas that "will constrain the future use and development of existing habitable buildings, major infrastructure, key community facilities and services and the like" (Tasmanian Planning Commission, 2017, p. 38). This flexibility allows local councils with sufficient resources to tailor the overlay to suit their particular environmental needs. The design specification of the overlay to be bare minimum fit-for-purpose also makes it suitable for local municipalities with limited resources (Warnken and Mosadeghi, 2018).

The overlay has several exemptions based on the application of policy zones (see Table 2). Close to 6% of the modelled retreat area is free from Natural Assets Code regulations and another 12% has either special or case by case consideration. These exemptions remove or restrict the potential of wetland refugia in these zones (Fig. 4), and have several public policy implications worth considering (e.g. Hurlimann et al., 2014). A number of coastal areas in Tasmania that have been zoned as residential, urban or business are subject to flooding risk, due in part to previous policy failure in "locating developments in harm's way" and exacerbating flooding risk (Randolph, 2004, p. 4). By exempting these zones from the overlay, a range of potential adaptation options are being overlooked. Flood-prone areas can be subject to buyouts, rolling easements or land swap programs coupled with wetland rehabilitation to meet multiple objectives (e.g. Calil et al., 2015).

Coastal flooding events are increasingly being considered by insurers as "predictable acts of humankind, and not acts of god" and properties are being exposed to loss of compensation benefits (Ledoux et al., 2005, p. 139). Indeed, climate change and sea level rise are increasingly reducing the opportunity costs for rehabilitation of developed land back to wetlands, an option that has been pursued as part of public policy in many parts of the world (e.g. Calil et al., 2015; Turner and Daily, 2008). An aspirational outcome would be for the Local Provision Schedules to integrate wetland and waterway areas lost due to clearing and infill development. Historic wetlands mapping is available for some parts of Tasmania (e.g. Prahalad, 2009, 2014). Extending the mapping State-wide can provide, in the first instance, as a valuable tool in addressing the 'shifting baseline' effect (Miller, 2005), in which pre-existing land uses (e.g. agriculture in coastal areas) are perceived as 'normal' baselines without reference to antecedent landforms such as coastal wetlands (Bromberg and Bertness, 2005). Historical wetlands mapping will also help overcome path-dependence in imagining options that could rehabilitate functioning wetland habitats (Abel et al., 2011).

Other exemptions that more broadly apply to the Natural Assets Code include all development assessed as large industry related Level 2 activities and a range of on-ground works by or on behalf of the Crown, State authority, or local council (Department of Justice, 2017). In addition, the performance criteria for buildings and works within the overlay areas allow a range of concessions, for example, by allowing "necessary" dredging and reclamation "to continue an existing use or development on adjacent land" or "for a use which relies upon a coastal location to fulfil its purpose" such as access to marine farming, infrastructure and recreation (Department of Justice, 2017, p. C7.0 Natural Assets Code: 9). These concessions do provide a degree of flexibility in blending the stated purpose and objective of the Natural Assets Code with new scientific developments such as in mapping and modelling (Bell et al., 2014). It remains to be seen how these exemptions and concessions will be interpreted and enforced to balance private benefits with social costs. The sustained use and effectiveness of the overlay will be contingent on increasing socio-political awareness among decision-makers and the general public of the costs and benefits of the ecosystem services of wetlands and waterways (Picketts, 2018).

5. Conclusions

While technical and procedural improvements are possible, opportunities and constraints to coastal wetland and waterway conservation, and the mitigation of the effects on them of sea level rise will stem from socio-political processes. Revisiting the underlying objectives of the STPS, to attract investment and cut 'Green tape' indicates a strong commitment to economic development (Tasmanian Liberals, n.d.). Judging from a Tasmanian historical context, a myopic commitment to economic growth and ensuing short-term political gains have compromised wetland conservation in many instances (Prahalad and Kriwoken, 2010; Stratford, 2008). Judging from similar ‘planning reforms’ that have been witnessed in other parts of Australia, such as in Queensland, Warnken and Mosadeghi (2018, p. 80) consider that the main focus of the State Planning Policies is to provide “flexible approaches to planning” to serve an economic growth agenda. Abel et al. (2011) also emphasise the preponderance of growth led polices in coastal land use planning in Queensland as a generalizable feature of coastal planning issues facing other high-income countries. This ‘neoliberal approach’ to land use planning that allows private investments to shape the coast with little public intervention is likely to continue to have poor outcomes for wetland conservation and ecosystem services (Boon and Prahalad, 2017). The conservation and public good deficit created by a lax planning regime is unlikely to be compensated by reservation, covenants and management agreements alone.

The good news we bring is that it is possible to develop overlays for planning schemes that could enable present and future conservation of wetlands and waterways. We believe, to the best of our knowledge, the current overlay is the first of its kind in the world to explicitly accommodate coastal wetland migration in a planning scheme. The integration of wetlands and waterways within the STPS provides a legitimate basis for their conservation under the Natural Assets Code guidelines (e.g. EDO Tasmania, 2016). The availability of an overlay now has the potential as a publicly accountable planning tool that provides a basis for grass root action to help balance private benefits with social costs. Its sustained and effective use is contingent on increasing socio-political awareness of the costs and benefits of the ecosystem services of wetlands and waterways.

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