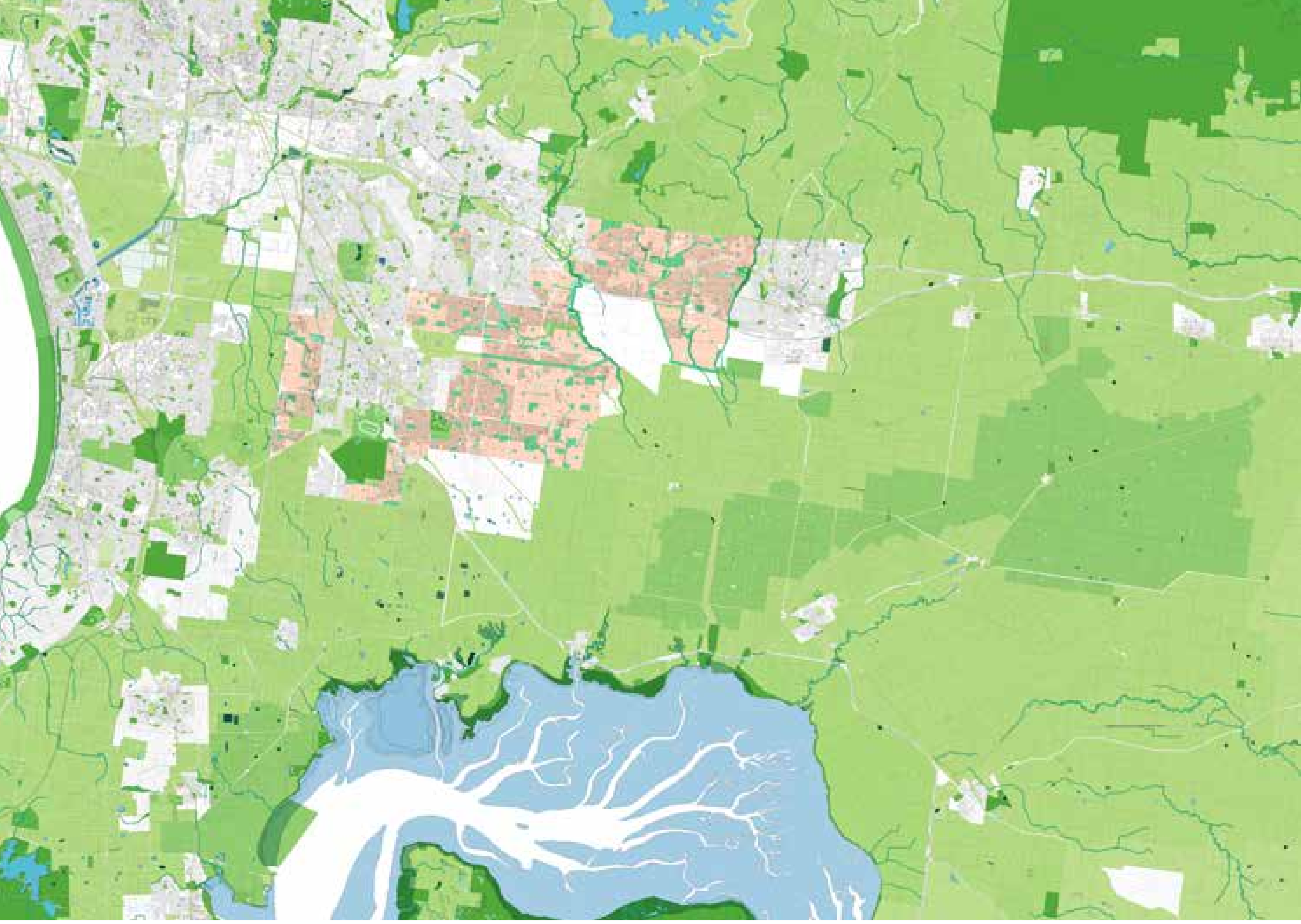

WATERFRONT:
PAST AND PRESENT WATERSCAPES OF TOORADIN AND KOO WEE RUP SWAMPLAND

PRIMER:

A selection of readings about the landscape of the old swamplands of Koo Wee Rup and the coastal shores of Tooradin and Westernport.

Compiled by Monash Urban Lab

Waterfront is proudly presented by Centre for Architecture Victoria | Open House Melbourne, in partnership with DELWP and East Gippsland Shire Council. Waterfront is part of Melbourne Design Week 2021, an initiative of the Victorian Government in collaboration with the NGV.


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Online Only

Map for a vanished landscape

by Liam Davison (1957–2014) (https://www.griffithreview.com/contributors/liam-davison/)

BRITISH ART HISTORIAN and veteran wheelman Tim Hilton once wrote that most cyclists are topographers by nature. It's true; there's an intimacy of engagement with a place that comes from cycling through it that is not afforded by driving past it in a car, which is what you do. Landscape is scenery from a car. You look at it. Riding through it, you feel its contours in your muscles and your lungs. You smell it like the living thing it is: the subtle shifts associated with vegetation and land-use or with water sitting or coursing through it. The smell of cut earth. And you become attuned to the passage of air moving across it as you alternately flow with and work against its prevailing winds.

You could argue that the same applies to walking but you'd be wrong. Walking takes you into a landscape in a particularly grounded, earthbound way. The difference is to do with pace and contemplation. On a bike, you are in the landscape but separate from it. It's why the advent of the bicycle had such a devastating effect on the rural towns and villages of Europe, offering as it did a means of escape not just in terms of distance, but also in separation or removal from the place that you travel through. Even in a bunch ride, the rhythm and pace of cycling offers a splendid isolation that provides access to a fugitive space that is entirely one's own. Cycling a landscape, like writing it, is essentially a contemplative act.

My first memory of the landscape that holds me to this day is from the window of my father's car. I am nine or ten years old and we are travelling east along the South Gippsland highway (the same road I'm travelling today) towards the tidal fishing town of Port Franklin. A few kilometres out of Tooradin the road gradually drops and cuts through a particularly low and flat stretch of land. To the right are mangrove flats stretching to the top end of Westernport Bay. The blind side of French Island floats on a horizon that curiously seems to sit above us. To the left is a wall of melaleuca scrub.

We cross a series of wooden bridges, and each affords a glimpse into a beguiling, vestigial landscape that vanishes as quickly as it appears, as though, even then, it is something remembered, not seen. Beneath each bridge, a steep-banked channel runs in a straight line away from us into a world that seems strangely remote and inaccessible to anyone travelling by road. The channels are overhung by tangled mangrove roots and I glimpse in some the unlikely stilt frames of jetties and boat-houses hunkered below us, as though there's a layered underworld hidden beneath the level of the road. It's a world to which I've been trying to gain entry ever since.

I know now that what I saw was the remnant landscape of the former Koo-Wee-Rup Swamp. At close to forty thousand hectares, it was once the largest swamp in Victoria and a virtually impenetrable barrier between Port Philip and Gippsland. The swamp was drained between the 1870s and 1900, although major flooding persisted well into the next century and, even now, the area is prone to flash-flooding and inundation. It's a reclaimed landscape, famous for its rich, black soil and the dairy, potato and asparagus farming communities it sustains. But reclamation implies a return to what it once was. A constructed landscape is closer to the truth – something fashioned out of what went before.

Today's race starts and finishes in Cora Lynn where the Main Drain crosses the Nine Mile Road. It was once the heart of the swamp. Driving in from the highway through the farming townships of Koo-Wee-Rup and Bayles, you are immediately aware of having entered a different world, one shaped by resourcefulness and a particularly European sensibility. While not completely self-contained, it owes much to the closed polder landscapes of Holland and Belgium, places it's easy to imagine you are riding through on a cold, winter's morning when a block headwind smatters you with rain.

Polders are low-lying tracts of land, often having subsided below water level, that are completely enclosed by embankments. They answer to their own hydrology. Water flow is regulated through a series of pumps and sluices and the landscape is reticulated with channels. Driving in now, the roads follow the channels then branch at right angles from them. Five Mile, Seven Mile, Nine Mile Road. Regular, imperial measurements. It's difficult to lose your way, but difficult also to see beyond what the place has become to what it once was.

Hedgerows shield cattle from the relentless wind that sweeps across damp, low-lying paddocks. Trees are pollarded to stop short against a vast, expansive sky. The original swamp paperbark (*Melaleuca ericifolia*) and Prickly Tea tree *(Leptospermum continentale)*, once so thick as to be impenetrable by foot, are all but gone, replaced by open pasture and shelter plantings of cypress, hawthorn and poplar. Fragmented remnant communities persist along creek lines or in isolated patches on the periphery of cleared land, but they are like ghost images from a vanished landscape, simultaneously promising and withholding entry to a place that belongs less to nature than to memory and imagination.

The race signs are out along the Tynong-Bayles Road and riders are warming up, bent low in the lee of the

embankment along the Main Drain Road. At Cora Lynn, I sign on and take my number. The wind is freshening from the east. It rattles through the reeds along the edge of the drain and brings the smell of rain from across the bay. Water stands in ditches beside the road from earlier showers. It seeps from the irrigation channels and trickles through culverts and spoon drains away from the raised surface of the road.

Cardinia Creek and the Bunyip and Tarago Rivers feed the catchment area from the north. The Bass and Lang Lang Rivers feed it from the east. Even with the strict regulation of the rivers, groundwater still flows from the alluvial plains that fringe the old swamp into aquifers that swell beneath impermeable layers of clay and peat. The land leaks water. Flow paths pattern the paddocks. The smallest depressions turn to pondage. Nothing seems fixed or solid. It's as though the land is something other than what it seems: something fluid and elusive that shifts like water the moment I think I know it.

Today's race is a handicap and I'm off twenty-one minutes. There are twelve of us and the pace is on early, rolling turns into a crosswind up the Nine Mile Road towards Tynong. The aim is to work together, to find a rhythm that will see us gain on the bunch ahead and stay clear of the faster groups behind. It's an abjuration of sorts, a disavowal of the self to be part of something better.

By the time we pass Daly Road, we are working without thinking. The pace-line moves up the inside, away from the wind. There's some shelter from a cypress windbreak where the Eleven Mile Road joins at an angle and I'm aware of a small drainage channel passing beneath the road. Beyond that, there is nothing but the rhythm of the pedals and the roll of the wheel in front of me. I am a still point. Everything moves, yet I am stationary, removed from the very place I'm passing through. The further we ride from the centre of the swamp, the closer I feel to gaining access to it.

THERE MUST BE a point where topography intersects with what Gaston Bachelard refers to as the place that has been transformed by memory and imagination into something sacred (*The Poetics of Space*, Gallimard, 1958). Every venture for me now is an exploration, whether by bike or language, into a place that can't be mapped. In *Soundings* (UQP, 1993), a work of fiction I wrote two decades ago, a photographer called Jack Cameron traversed the same landscape I'm riding now, photographing the land from every possible angle in an attempt to capture on film something of the elusive otherworld that was consistently withheld from him. He photographed the passage of time through a single point, producing strips of film that threw up strange, unsettling images of an inaccessible shadow place: isolated moments divorced from time that persisted behind the featureless land he saw.

Geography alone provides only partial entry. Landscape should not be mistaken for place. At Tynong, we swing left into the Nar Nar Goon-Longwarry Road towards Nar Nar Goon. We've dropped two and are down to ten. In unison, we rattle through the gears and resume the rhythm. The wind is behind us. There is no sound bar our own breathing as we float effortlessly above the barely perceptible undulations in the road beneath us.

We are now in what was once referred to as the outer swamp. Both sides of the road are planted with asparagus and I can smell the rich scent of turned earth in the air. The soil here is alluvial with occasional instances of organic peat and black clay. It was once dominated by Swamp Paperbark and the generically named Swamp Scrub. While most of it is long gone, creeks still harbour thickets of Blackwood (*Acacia melanoxylon*), and drainage lines support instances of Spike-sedge (*Eleocharis acuta*), Knotweed (*Persicaria decipiens*) and Water Ribbons (*Triglochin procera*) that were once integral to the region's unique ecosystem.

Clearing the scrub was a major undertaking. As early as the 1870s, individual settlers took to it with shovels and saws, cutting their own cross drains and channels that often flooded their neighbours' land. Burning and dragging opened larger tracts, but stump-grubbing and trenching required hard, manual labour. In 1876, the Koo-Wee-Rup Swamp Drainage Committee began excavation of a main channel to direct water from Cardinia Creek to Westernport Bay at Moody's Inlet. But it was the 1880s and '90s that saw genuinely co-ordinated efforts. By 1889, more than five hundred men were working on the Bunyip and Main Drains and living with their families in a village settlement on the partly reclaimed land.

In his photographic investigation of the swamp, Jack Cameron glimpsed disturbing images of families living half-amphibious lives in huts thrown up from the very mud they dredged, navigating their way to work in small boats, and supplementing their wages with what they could coax from dank, flood-prone

allotments. While the drainage scheme was officially complete in 1897, Italian engineer Carlo Catani continued to oversee the project until his retirement in 1917. He introduced the monstrous Lubecker from Germany, a steam-driven bucket dredge that propelled itself on its own tracks and shifted 60 cubic metres per day. As the soil dried, it shrank and compacted, subsiding into a vast depression. In dry years, it burned. Peat layers smouldered beneath the surface for months.

At Nar Nar Goon we swing left again, back into a cross-headwind that fans us into an echelon across the road, rolling turns up the outside. The sign says Main Street but it reverts to its true name once we reach the town perimeter. The Seven Mile Road runs in a straight line south, back to the Main Drain with a slight downhill gradient that keeps the pace up. Just south of Bald Hill Road, the Northern Boundary Drain passes beneath us then runs parallel to the road for half a kilometre or so, flanked by acacia and tea-tree. There's a shift in the quality of the air, a slight smell of dampness, before it swings away towards the Five Mile and McDonald's Drain and we continue on.

DESPITE NEW SUB-DIVISIONS and re-named streets, the original network of roads and drains persists, shaping our perception of the landscape in much the same way that an enclosure defines a place while denying access to it. I co-ordinated a mapping project in the region in the early 1990s. Conventional cartography provides entry of sorts to topography, but my ideas at the time coincided with Paul Carter's notion of mapping 'the qualitative world of shadows and footprints': the less tangible experiences carried by landscape that give personal and social meaning to it, as he put it in *The Road to Botany Bay* (Faber and Faber, 1987).

A group of people, already connected to the region, each chose a specific point in the landscape that had significance for them: a particular stand of trees; the junction of two channels, the corner of a paddock where the land rose slightly towards the sun. Over a period of three months, they visited their chosen site multiple times. Their field notes recorded observations of the natural world (the weather, plant and animal life, moisture in the soil), but also reflections on the particular meaning and associations the places had for them.

For some, it was memory tied to that location: events that had stayed with them for whatever reason and had helped shape both the person they had become and the land they saw. For others, it was shared or borrowed memory passed down as part of family lore. In some instances, it was an imaginative association with another place, a projection of France or Holland triggered by the fall of light on a tract of open land or the scent of cut grass on the wind. Each location, then, became a contour point in a layered map of a vast emotional landscape that extended beyond the mere spatial confines of the swamp.

My place, of course, is not the same as your place, even if the GPS co-ordinates are identical. Constructing place requires both a willing blindness and rejection of what you see before you, and a projection of your own desires to claim it.

We're strung out now, heading toward the southern perimeter of the swamp. Two properties are pumping water from their front paddocks. They sit below the level of the road and the water flows across the bitumen to the channel on its opposite side.

In 1859, William Lyall, a Scotsman from Aberdeenshire, took over Yallock Station on the damp southern fringes of the swamp and began work on his grand, gabled homestead, Harewood. He also took out a twenty-one-year improvement lease on Tobin Yallock swamp. Harewood became something of a social centre for the region. Its dining room commanded views across Westernport Bay. Its stately columns doubled as drainage pipes for an underground cistern.

Improving a landscape implies an idyll to work towards, obviously something different to what one sees. As a successful stockbreeder and founding member of Victoria's Acclimatisation Society, Lyall's improvements included the introduction of exotic species to the swamp. He released pheasants and partridges for hunting parties visiting from Melbourne. Hares and deer claimed the drier grasslands. Yellow gorse (*Ulex europeaus L.)* spread from his hedges to infest the waterways.

While it's easy to assume the biodiversity of the swamp has shrunk considerably since white settlement, many of the original wetland species of flora and fauna still persist, although confined to the drains and creek lines. Blackberry (*Rubus spp.*), Broom (*Genista spp.)* and Gorse obviously coexist and require constant control. But the Water Ribbons, Spike-sedge and reed beds (*Phragmites australis*) that were integral to

the aquatic mosaic of the inner swamp that supplied fish, bird and animal life to the Bunerong people are still there.

Likewise, there are still instances of Common Tussock Grass (*Poa labillardierei*) and Coast Tussock Grass (*Poa poiformis*) that once populated the wet grassland adjacent to the swamp, despite the predominance now of Paspalum, Kikuyu and Canary Grass introduced for grazing. It should be remembered that much of the scrub and timber clearing that accompanied the draining of the swamp restored the landscape to a closer approximation of the thinly timbered, open grassland that existed before the demise of the Aboriginal fire regime. In 1827, explorer Samuel Wright reported extensive grassland that 'appeared like beautiful Meadows in England, very thin of Timber, grass excellent'.

Introduced and remnant vegetation both continue to support significant regional bird species like the Yellow-tailed Black Cockatoo, Nankeen Night Heron, Long-billed Corella and Brown Goshawk. The Masked Lapwing, which I still know as a Plover, is also prevalent. But they also support more visible local species, like the Magpie and Magpie Lark and exotic introductions such as the Goldfinch and Common Mynah. Like the European Rabbit, these have flourished with agricultural development. The ring-tailed possum has adapted successfully (some would say too successfully) to introduced tree habitats, while remnant swamp scrub supports the endangered Southern Brown Bandicoot (*Isoodon obesulus obesulus*).

The nocturnal bandicoot is only one of the rarely observed but significant species to haunt this deceptively elusive landscape. The drains and channels are also home to the vulnerable Growling Grass Frog (*Litoria raniformis*), a ground-dwelling tree frog that favours sluggish streams and slow moving backwaters. The Dwarf Galaxias (*Galaxiella pusilla)*, a tiny, transparent fish with clear fins and black stripes floats like a spectral presence through the same waters and goes to ground in summer, lying dormant in disused yabbie holes. Lewin's Rail (*Rallus pectoralis*) is a secretive, flightless bird that conceals a cup-shaped nest of grass close to the edge of the channels. It is cousin to the ghost species Lewin's Water Rail (*Rallus pectoralis clelandi)* once reported as extinct.

WE ARE IN a place removed, pedaling relentlessly into the wind with the landscape closing indifferently behind us as we pass.

The capacity for cyclists to disappear into the landscape is well known. A bike draws little attention to itself. Eighty per cent of the space it occupies, after all, is comprised of emptiness. In wartime, French bike couriers were known to cross enemy lines time and again without challenge, almost as though they could not be seen. There comes a point also, in a long ride, where the rhythm and movement and the pleasant muscularity of the endeavour results in a dissociative shift that removes you from time and place, even as you travel through them. Jean-Paul Sartre, an avid cyclist, wrote of the particular pleasure in his 1943 essay, *Being and Nothingness* (Gallimard, 1943). 'Each trip,' he wrote, 'disintegrated into a thousand appropriative behaviour patterns, each one of which refers to others.'

It's tempting to think of the old swamp as flat. It's not. By the time we pass the Old Drouin Road, we've climbed close to fifty metres since crossing the Main Drain. The gradient averages 1 to 2 per cent to create what cyclists know as a faux plat, or false flat. Your legs reveal what your eyes conceal. Water might find its level, but even before the drainage and reclamation projects, the contours of the swamp were anything but consistent.

To the north and east, the land rises gradually to the foothills of the Dandenongs and the Bass Hills. To the south, it slides away to the tidal mudflats of Westernport. But I know that at the fifty kilometre mark of the race, after we've swung left through Longwarry with the wind behind us and are heading back through Garfield toward Tynong, there are two rises that stronger riders will use to their advantage. They're not hills as such, but ridges that kick the road up to a pinch.

Early surveyors reported the presence of sandy rises elevated above the level of the peat beds. Pastoralists used them for stock access to the centre of the swamp. It's likely that the Bunerong people also used them to source fish and waterbirds from the abundant but otherwise inaccessible inner swamp. The rises are Aeolian dunes, wind-formed lunettes formed before the last ice age when the region was a dry, semi-arid landscape. Other rises are alluvial: remnant levees and bed deposits from the broad alluvial fan of the Bunyip River.

Flatness in a landscape is not so much an illusion as a willing disregard for what lies before you. The swamp maintained an average surface slope of 1.3 metres per kilometre. Even in the early days, it could never have

held a single body of standing water. Rather, it was a series of lake-like cells or contiguous bogs, each draining through reed mass and channels like a natural filtration system.

The road continues to rise all the way to Longwarry. The gap to the lead car closes painfully and slowly, and by the time we get the tail wind, my legs are burning. There's still work to be done before the rises. We pass by the edge of Bunyip and can see the group of five front-markers ahead. We take them on the first rise and don't look back. The second pinch, on the far side of Garfield, is longer and steeper. There's still twelve kilometres of racing on the other side of it.

There are five of us, working together to joint advantage. But it's only a matter of time before things change. I hold close to the wheel in front of me. Each of us tries to gauge how the other feels: what's left in the legs; how badly they want it. There's a rattle of gears before the rise and the move is on. A gap opens in front of me and I strain to close it. The road slants upward and it's all I can do to hold the same distance, hoping nobody comes around me. At the top of the rise, I'm still in touch and there are three of us now, heads down, flying toward the homeward stretch.

Low cloud has moved in from the east and a smattering of rain quickly turns to showers. The road throws it back at us from the wheels and we breathe it in. It's like an elemental shift. Water streams from my nose and chin. As we make the last turn toward the finish line, back to the heart of the swamp, we're still clear of the scratch group, but we know they're coming. The lead car is a blurred presence before us, like the shade ofDante's Virgil, guiding us in.

THE CORE OF the inner swamp was a different world. Geologically, the soil beneath us is not soil at all but organic peat deposited over thousands of years. Beyond the reach even of the alluvial rises, few trees would have grown here. Permanently inundated reeds and rushes laid down a deep fibrous mat that resisted erosion and rose to as much as three metres before subsiding after the swamp was drained. Once a hidden but abundant source of fish and waterfowl, it is now amongst the richest agricultural land in the country.

With three kilometres to go, we are still together, but riding alone. For all our collaborative endeavour, we each know that we are riding for ourselves now. I can feel the weight of the road in my legs: each hill, each turn into the wind, each effort to close a gap. It will still be there tomorrow, like a residual memory of the place we've travelled through.

The finish line is two hundred metres past the place we started. It's an arbitrary point in the landscape that closes the circle and brings us home. Before it, the road is still charged with possibility. Beyond it is scenery. I remember once standing at dusk in a lowish dune watching rafts of Short-tailed Shearwaters circling in to roost. The Shearwater is a seagoing bird that negotiates a thirty thousand kilometre journey from the Arctic Region to go to ground in the same burrow amongst the tussock grass it left the year before. Once concealed below ground, the bird calls for its mate who circles silently in the darkening sky listening for its point of entry to a familiar but foreign shore.

To watch a single Shearwater move silently above you is to remove oneself from the surrounding clamour and enter the still point of individual disintegration that Sartre wrote of. You are neither present nor absent, but a small part of something beyond your comprehension. As I approach the line, there is a point where movement approximates stillness and for a moment, I am not so much passing through the landscape as riding into it.

But the moment cannot last. The scratch riders have gathered all before them and there is a terrible beauty about the sound of their approach, at speed across the rain-soaked road. They are upon us in an instant, a writhing, sinuous line shrouded in water, driving toward the line with a momentum that catches us up, draws us out of our saddles to join it. Timing and pace are everything. I click through the gears and hold my line between the riders and the soft edge of the road until a gap eventually opens, and I slot in, holding tight to the wheel in front of me.

There are no half measures. I am part of it now, moving relentlessly forward at a pace determined by others. I am aware of jostling ahead of me, and a late attack splintering from the far side. The bank of the Main Drain is a blur beside me, and then it's over. We cross the line and the group disintegrates. We are individual riders pedalling slowly through soft rain. The paddocks are wet beside me. The ditches are full. Everywhere about me is the sound of water.

NO TWO RACES are ever the same. No two ventures into the swamp deliver the same result. The rain falls in sheets across the windscreen as I turn back onto the South Gippsland Highway, out of the closed landscape that still withholds its secrets. Toward the bridges, the sky is a grey expanse above a sodden stretch of land that again touches something in me. Seen through the filter of the tinted, rain-washed windscreen, it might be the salt marsh landscape of East Anglia claimed by the German poet WG Sebald in *The Rings of Saturn* (Harville, 1995).

For Sebald, the marshland was a landscape of exile, offering erasure rather than comfort. It was a land that belonged to post-memory. And I realise now that what attracts me here might well be absence. The place I seek is already lost. Yet, it is still potentially there, in its creek beds and remnant stands of vegetation and in those fleeting vistas where it seems still to linger at the very edge of the tangible world. Crossing the first of the bridges, I glance right and wait only half expectantly for the gap, knowing it will close like a shutter as quickly as it opens.

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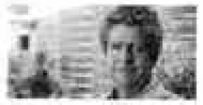

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Source: *Monash Urban Lab*

The Swampy Lowlands of Melbourne

Catherine Murphy and Nigel Bertram

Along the Victorian coastline and into southern New South Wales there is a recurring formation: terminal lagoons at different scales truncate rivers, which flow south towards the sea. As rivers hit the coast they bank up against the wind-blown sand dunes and shift sideways, opening up a broad waterbody over the sand, often stained tea-coloured due to melaleuca tannins leached into the water as it passes through coastal scrub. This type of lagoon is classified as 'intermittently open and closed' – in that it moves through alternate states of being open, with water draining freely to the sea, and closed, when sand builds up through the action of waves and wind, blocking the passage of fresh water, forming a terminal brackish pool behind the dune.

This basic typology recurs at a range of scales, from small individual creeks to large conglomerates of truncated rivers. The natural seasonal dynamism of the sand, which alternately silts up and then overflows or breaks through in times of high water, is in many cases too unpredictable for modern human needs; in response, permanent channels connecting lagoons to the ocean have been cut, such as at Gippsland's Lakes Entrance in 1929 to allow shipping movements. Such permanent connections dramatically altered saline levels and resultant plant and marine ecologies of the intermittent lagoon system, and require continual dredging of sand to remain open.

The transformation of a natural, dynamic water scenario to a more fixed or predictable altered condition is emblematic of the process of Melbourne's urban transformation.

Sunkland

> *At settlement by Europeans the land was full of swamps and lakes – it was a soft land where 'the untrodden sward...was literally comparable to a bed of sponge; our horses sank to their fetlock with every step...'*[1]

Large parts of Melbourne lie within a physiographic zone known as the Victorian Southern Lowlands, which collects sediment and run-off from the Great Dividing Range. Its natural pre-colonial state contained large areas of spongy waterlogged land – most of which has now been drained over time for agriculture and urban settlements. Within this broad lowland region is a localised 'sunkland' – the Port Phillip and Westernport Sunkland – that stretches from Rowsley Fault near Bacchus Marsh in the west to Heath Hill Fault near Drouin in the east. Melbourne's Central Business District (CBD) is located at the geological junction point within this terrain, a hinge between four different types of ground – leading to asymmetrical conditions, land uses, vegetation, climate and development patterns around the core over time.[2]

The flatness of this sunkland means that small fluctuations in sea level and rainfall flood level can have a large territorial effect.[3] The edge between land and water once contained numerous variants of saltwater and freshwater ponds, marshes and intermittently open and closed lagoons. These previous wetlands, marshes and grasslands have been the subject of radical and comprehensive modifications over the nineteenth and twentieth centuries including large-scale drainage, land filling, river diversions, undergrounding of creeks, dredging and reclamation works. While these are all completely typical actions for low-lying coastal cities worldwide, they are perhaps all the more pertinent here due to the central significance of wetlands and swamps to Indigenous culture, for social gatherings and food supply – and the absolute contrast of this sense of abundance with the way such lands were viewed by Western colonisers.[4]

The submerged or sunken coastline of the two bays results from rising sea levels that truncated rivers and creeks over many thousands of years. The overall sunkland structure is broader than the current metropolitan extent, also extending beyond the coastal edge of what is currently accepted as the limits of land, to include the shallow basins of the bays. These currently underwater spaces form an integral part of the overall system and structure of the lowlands.[5]

In the process of European settlement, many small and large brackish marshes and intermittent water bodies in and around Melbourne have been drained, channelled, and/or permanently connected to the bay. Others have been artificially kept full of water for recreational and aesthetic purposes. The intermittent nature of water in Victoria was an ongoing challenge for colonial settlers and urban dwellers – from the central goldfields' creeks and chains of ponds north-west of Melbourne that ceased flowing or dried up in summer months, to the low-lying wetlands and marshes around the city's southern fringes that were sometimes full with water, and other times dry basins of untraversable mud. These environments all have their own natural water patterns and associated rich ecologies of plant, animal and bird life, but their intermittent wetness proved an aesthetic, practical and moral obstacle as the city grew and formalised over the nineteenth and early twentieth centuries.[6]

The draining of different types of swamps fundamentally changed the prior conditions of Melbourne's lowlands. The accounts and maps of early settlers reveal the locations of large lagoons, ponds and marshes within the current urban footprint.[7] For the colonial settlers these watery landscapes were generally viewed as impediments, as 'eyesores', as sources of disease and as threats to public health and sanitation. The soft, spongy land was an impediment to explorers and their horses, to commerce and trade, non-productive, threatening and unoccupiably 'other'. Vegetation within and around these unvalued lagoons was easily erased through burning, and they were gradually filled, drained and built over.[8]

The natural system of the lagoons was a fluctuating one, with dry and wet ephemeral conditions: water sometimes present, sometimes not. In Gippsland, these natural fluctuations are still apparent in the relatively unmodified environments of coastal national parks, where the water systems either open or close every two to five years, depending on the climatic conditions from droughts or floods from heavy rain. The silt and sand that builds up in between these events alters the flow of water and changes the surrounding natural environment.[9]

In the nineteenth century, numerous public demands and engineering schemes for draining swamps were lobbied for, with various Acts of Parliament, including the Land Act of 1884 which included specific provisions for the draining of swamps, forming the legislative framework for these actions. Many grandiose schemes for canalising and draining wetlands of different types occurred throughout Victoria, all in the name of progress: for agriculture, for subdivisions, for infrastructure. There was an obligation to get rid of these undesirable water bodies, to create efficient drainage, that would enable trade routes, transportation and create space for the needs of the modern city.[10]

Two examples of regional swamps that were drained include Buckley Swamp in south-west Victoria,[11] which was drained for its rich soil for cultivation and grazing, and the Moe Swamp (Mouay meaning 'swampy country' in Gunaikurnai language)[12] in Gippsland that was drained in the 1890s for farming land and housing. But without the swamp acting as a filter to control the volume of the inward flowing rivers and creeks, these greatly changed landscapes suffered from increased flooding conditions, which, along with their deep peat ground unsuited to cattle grazing, produced poor farming land.[13]

In Melbourne and its hinterland, a significant remodelling of the natural landscape occurred from the 1880s until the 1960s. Led by skilled engineers such as William Thwaites and Carlo Catani, transformative visions were achieved and entrepreneurs poured money in to realise dreams of taming the mud.[14]

Swamps were cleared to create suburbs built on remnant sand dunes, with flat areas of rich sedimentary deposits being used for market gardens, and sandy conditions resulting in a disproportionate number of golf courses, as well as sand mining industries.[15]

27

27
Buckley Swamp drainage channel near Hamilton in south-west Victoria, 2016.

28

28
Drainage channel with mangroves migrating inland, Koo-Wee-Rup, 2016.

One area of focus for the engineers was Elwood, a bayside suburb that was originally part of a larger system of lagoons that sat behind inner and outer sand dunes along the foreshore of Port Phillip Bay. The terminal lagoon of Elwood Swamp was dug and drained around 1880 to make room for a market garden and later a subdivision. The old swamp was diverted into the constructed Elwood Canal, which continued the alignment of Elster Creek that had formerly flowed into the swamp. With the canal now connecting the lower reaches of Elster Creek with Port Phillip Bay, the water system became permanently connected to the bay. Since its establishment as a residential suburb flooding has been a ongoing problem for Elwood, where the previously wet ground is never truly stable, where the high tides wash in and out of the Elwood Canal dramatically changing water levels, and where floodwaters from upstream rush down, all to meet in this vulnerable low-lying bayside suburb.

Further east along the sandbelt, Carrum Carrum Swamp was a massive lagoon about 15 kilometres long, covering a region extending from Mordialloc to Frankston, with excess water flowing into Port Phillip Bay through Mordialloc and Kananook creeks. As it was a major impediment to development, a large channel was cut through the swamp, known as Patterson's Cut, which became the Patterson River, connecting the old swamp to Port Phillip Bay. In response to ongoing flooding, drainage took place over a century, gradually releasing land for housing and industry.[16] Two remnants of the former swamp, Edithvale and Seaford wetlands, have been preserved.

Around the same time, the vast, brackish saltwater lagoon known as the West Melbourne Swamp (or Batman's Swamp) was drained to release land for use by industry and rail. This lagoon, which was described by earlier explorers as beautiful and blue, had various waterways and creeks running into it, including the Moonee Moonee Chain of Ponds.[17] Located at the centre of the activities of the new colony, the swamp soon became a filthy dump, filled with the refuse of the settlers, and in 1883 the Victorian Government's Royal Commission on Low Lying Lands recommended doing away with the 'repulsive aspect' of this area, including the extensive lagoon, through a program of drainage, reclamation and improvement.[18] Sir John Coode drew up plans for the Melbourne Harbour Trust to divert the difficult-to-navigate course of the lower Yarra into the Coode Canal, a wide, deep canal along a direct course from the city to the river's mouth at the sea. A second canal was dredged to the north for the delivery of coal to the rail yards and this became the outlet for the channelised Moonee Moonee Ponds (now Moonee Ponds Creek), the rail yards and some of Melbourne's docks. It was not until the 1960s that the last parts of this ancient lagoon were finally erased, with industrial developments and city infrastructure assembled on its previously wet ground.[19]

Historian Gary Presland has re-evaluated Indigenous understandings of these places in relation to the current sites of Melbourne. He describes swamps as great Indigenous meeting places, sources of food and centres of cultural life – the 'supermarkets', 'chemists' and 'hardware stores' of Indigenous culture. The swamps were the only places able to sustain large gatherings over extended periods, such as during clan meetings. West Melbourne Swamp was the meeting place for groups travelling from east and west. The complete destruction of the swamps by Europeans is in stark contrast to the prior productive and sustained use by the Kulin Nation.[20]

The largest swamp reclamation project in terms of its scale and complexity, was the drainage of the Koo-Wee-Rup Swamp on the eastern edge of Melbourne that made way for numerous towns and opened up transport connections. This 'Great Swamp' provided a natural barrier between Melbourne and West Gippsland and extended over a vast area, densely covered with vegetation such as swamp paperbark, reeds and bulrushes in deep peat soil. Its complex ecosystem was formed by multicellular inner and outer swamps that were permanently inundated; a complex mosaic of intertidal, salt and freshwater marshes and lagoons of differing levels spilled into each other with multiple outlets into Westernport Bay around Tooradin and Lang Lang. The Land Act of 1884 authorised the process of draining this extensive complex, with scores of linear channels built into the former great wetland, opening it up for land speculation, agriculture, the building of towns and the Great Southern Railway.[21]

The formalisation of swamps as permanent lakes was another recurring technique that occurred at the same time as draining and channelisation. With the purposes of both water supply and recreation, dams were made and pipelines installed to create lakes for recreational activities and water supply. This pattern of previously intermittent swamps becoming permanent lakes occurred across Victoria. To keep these places functioning as deep-enough water bodies, water has had to be diverted from other water sources and sub-catchments, which over time has had serious detrimental consequences on the larger systems of water and their environments.[22]

In Melbourne, the most important example of this is Albert Park Lake, which is part of the former South Melbourne Swamp, a shallow, salt lagoon that formed part of the Yarra Delta. In the 1880s, silt in the lagoon was excavated and used as fill to create a permanent shallow lake for the yacht club, which required water diverted from the Yarra River to fill it. Its high levels of evaporation and shallowness means that it continues to periodically suffer from low water levels, requiring an elaborate piping system to divert water from other creeks and rivers to keep it deep enough for boating activities, and its reedy base requires ongoing care and management. With its concreted edge and surrounding parklands, Albert Park Lake is an important recreational place for Melburnians; however, its ongoing thirsty state will always need to quenched and managed.[23]

At the same time as these drainage, damming and diversion works, another type of formalisation was occurring north of the Great Divide, where large-scale irrigation schemes that control water through open channels were created, partially in response to drought and partially to drive agricultural production of pasture and crops. Like the lakes, these channels divert water from creeks and rivers, including the great Murray River. A typology of 'dig and mound' channels was deployed for both supplying and removing water, involving digging a trench and piling up the spoil on banks to form a levee. These ambitious irrigation schemes have had a devastating impact on the natural environment, particularly in the vast Murray Darling Basin system, which is under significant threat from the diversion of waters to benefit agricultural production. The management of this scheme and its water is an ongoing political and economic complexity.[24]

Urban Water

Port Phillip Bay is a saucer-like structure that could be thought of as an enormous lagoon. The bay is nearly landlocked and is not really a sea; rather it is a shallow basin with deep channels that converge towards its narrow entrance to Bass Strait.[25] The total evaporation of its surface has been calculated as greater than the total current freshwater input from rivers and rainfall combined. If the bay was blocked without access to the sea, it could possibly revert to its previous grassland state with a shallow terminal lagoon. It has recently been hypothesised that this might have happened naturally between one to two thousand years ago, when the congested mouth of the bay may have silted up with a natural sand bar[26] – perhaps this more recent dry spell has contributed to Aboriginal oral history of a once drier bay and its re-flooding. To this day, Port Phillip Bay continues to naturally silt up and is kept open by continual dredging operations.[27]

When thinking of Port Phillip Bay over this type of long-time scale, it can be thought of as an upscaled version of other lagoon environments across the state, such as the Gippsland Lakes, with rivers and creeks flowing into shallow coastal water bodies, with complex layers of inner and outer dunes backed with spreading swamps that once filtered the flowing waters. Like these examples,

Port Phillip Bay has accumulated sediment so layered and complex that there is a lack of clarity as to what kind of waterbody it truly is: lake, lagoon or sea.

Melbourne's water supply comes from the clean-forested catchments of the foothills of the Great Dividing Range to the east and north of the city. A gravity fed system of pipes and aqueducts is part of an expanded method of collecting water and supplying it from these catchments in protected national parks, which are pristine and pure environments. Dams receive high quality water from this trickling source that requires little treatment. Melbourne's Yan Yean Reservoir was the first large-scaled engineered water supply system in Victoria that consisted of catchment weirs and reservoirs connected by aqueducts and pipe track.[28] This system has been expanded a number of times with additional storage capacity, most notably by the large Thomson Reservoir, first proposed in 1968 and completed in 1984, which was designed to build up Melbourne's water supply in wet years for use during dry years and has a capacity four times that of Melbourne's next largest storage body.[29] This reservoir takes water from the adjacent catchment of the Thomson River (water which would naturally flow into the Gippsland Lakes) and feeds it through pipelines into the Silvan Reservoir via Upper Yarra Reservoir. The combination of this reservoir capturing natural flows and further diversion through irrigation in the lower floodplains of the Thomson River has dramatically reduced the freshwater input into the Gippsland Lakes (Lake Wellington), substantially altering water salinity levels, causing algal blooms and affecting aquatic plant and animal systems.[30]

Waterfront Economy

Cut to 2018 and Melbourne is booming. It is undergoing a population explosion of around 125,000 new residents per year, and over the past 20 years the knowledge economy has gradually shifted focus from the suburbs back onto the centre of the city with select 'employment clusters' of research and education.[31] These factors, among others, have made land in the centre of the city much more valuable resulting in governmental and market pressures to develop any unused parcels of land within proximity of the CBD. And it happens that all of the available, largely industrial, land is located within the lowlands zone, which is sedimentary, alluvial and flood-prone by nature.

Most of this land had previously been occupied for industrial use and is highly modified, including large areas of fill and reclamation. The phasing out of old industries has left behind sparsely populated but well-located land close to the city centre, which because of its position on the water's edge is now highly desirable for views and its potential lifestyle. But these areas are also vulnerable and fragile; susceptible to predicted impacts of climate change such as sea level rise and flash flooding. With intensified urbanisation, both within the boundaries of these areas and in linked upper catchment areas, these places face major water issues that will play out at catchment scale. People may have been able to ignore the previous flooding of industrial or working-class areas; however, as development pressures build, this is an increasingly important topic for these newly desirable and proximate locations. Urban renewal in these areas provides the opportunity to leverage new approaches to water, and to reframe place through new understandings of old water and Melbourne's lowland swamp/wetland systems.

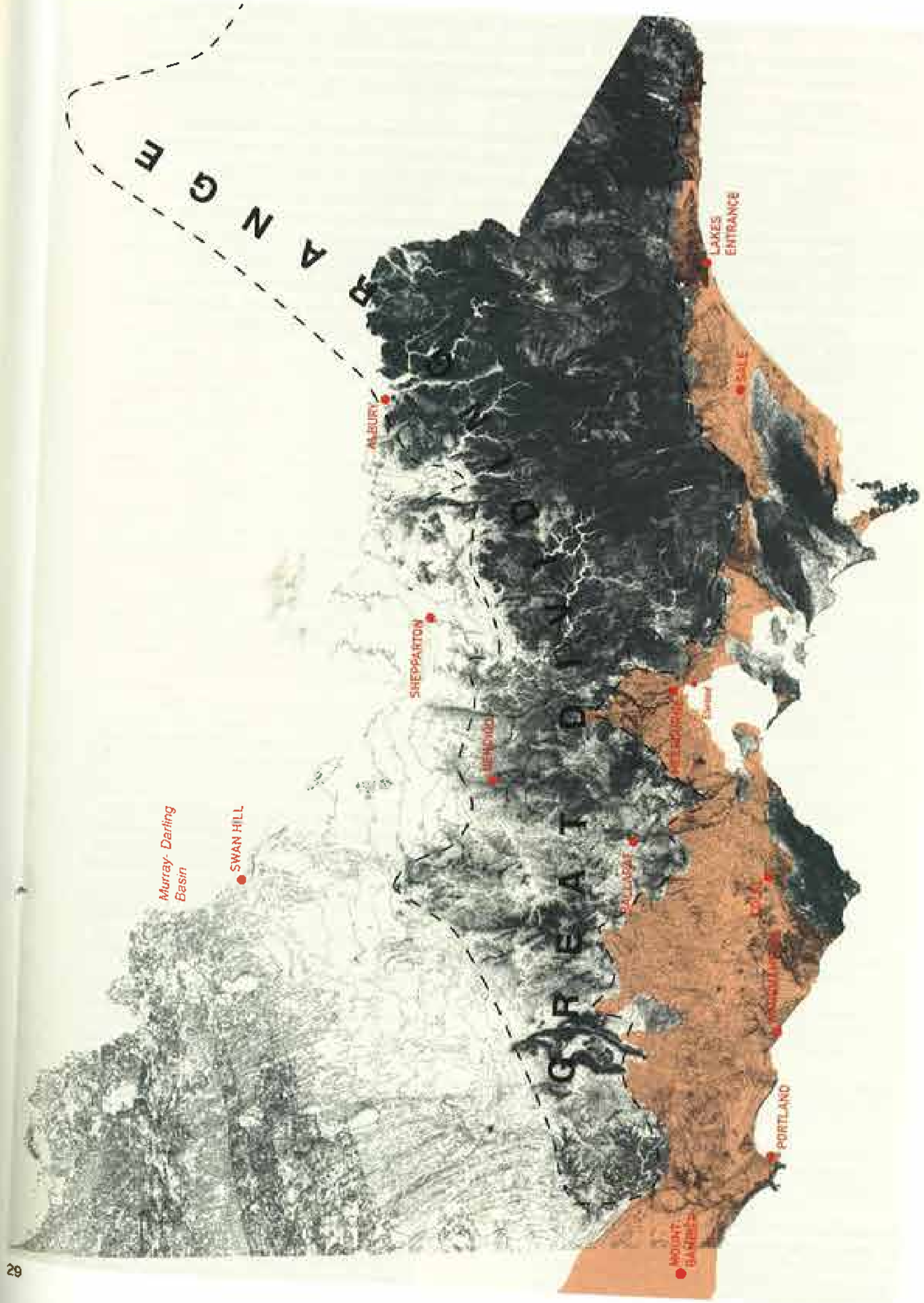
The low-lying areas of coastal cities all over the world are facing similar issues of developing on key sites in dockland-type conditions, at the interface of where the economy meets the port and the waterfront. Urban waterfronts have almost without exception been substantially transformed and modified: 'dredged, drained and reclaimed',[32] in similar ways all over the world, through a combination of necessity and opportunism, and because their relatively flat and alluvial geography makes such modifications achievable. The prior industrial use of many of these urban lowlands is also a common factor, with cities located close to rivers used for industrial waste and transport, recurring sites of industry and infrastructure such as airports, water treatment plants and oil and gas storage located on the flat floodplains of river deltas or coastal plains, and rail and road transport connecting these areas to the surrounding city and suburbs, utilising the natural topography of continuous creek and river corridors.

Melbourne has a number of sites that fit this condition, and most major sites of current urban renewal development are located in low-lying areas of previous swampland or marshy territory.[33] Arden Macaulay (discussed in the 'Testing Grounds' section of this chapter) is typical of this. This site was previously a hub of industry, and is being renewed for new 'smart' industries and high-density housing with significant investment of infrastructure to generate the economic uplift.[34]

All ports and harbour environments undergo constant siltation that requires regular dredging to maintain suitable condition for navigation. This perpetual process has been described by North American landscape urbanists[35] as a productive phenomenon, a continuing process of moving soil and sand, a maintenance process that allows for vital logistical operations in port cities. Ports are created through a hybrid system that combines human-made interventions and natural systems. In Port Phillip Bay, ships enter the city's port through a naturally deep channel but one that has been dredged in selected sections and therefore still requires constant dredging to keep the levels by removing the natural build-up of silt and sand. Without constant dredging, its bathymetry would naturally change according to the wind, to the rain and to the movement of sand, gradually silting up and then opening up gradually, as it did in the pre-colonised past.

The lowlands are inherently modifiable and modified by constant manipulation of their topography and bathymetry, swapping of land and water, and flow of materials; dredging and depositing under water, and reclaiming land above ground. Dredging together with a series of other actions forms a continuous urban process, a hybrid of artificial interventions and natural processes in modifying lowlands. The actions can be thought of in relation to the topographical gradients on which they operate, from the shallow waters extending out to the sea, to liminal areas between land and sea, to urbanised sections of the low-lying areas, in an extended zone between deep waters and high-lying areas. Of these new development areas, the ongoing urban process involves filling, dumping, dredging, excavating, cutting and levelling, all of which will undoubtedly continue with urban growth and perhaps will be exacerbated by existential threat of climate change and rising sea levels. Rising sea levels will change the contours of the lowlands, mould and remould their topographies, causing destruction on one hand and reshaping new landscape on the other hand. By understanding this as a vital and a continuous urban process in low-lying areas of coastal cities, these actions should be undertaken in ways that are more aligned to understanding them as a hybrid of both natural processes and artificial interventions that can potentially produce a new kind of hybrid infrastructure at territorial scale.

The cleanliness of the water from the catchment entering Port Phillip Bay is key to the health of the bay. Sitting at the bottom of the lowlands system and located adjacent to but on opposite sides of Port Phillip Bay, sewerage is pumped and gravity fed to the shallow lagoons of Melbourne's Eastern and Western Treatment Plants where is it treated in open ponds; these ponds have also become world-recognised for their significant habitat for birds.[36] The topography of the lowlands enables these treatments to occur next to the bay. However, with changing climate dynamics, all metropolitan facilities, such as these sewerage treatments, located in lowlands, are vulnerable. In coastal cities worldwide, the future of the location of critical infrastructures is being questioned: for instance, it is predicted that half of the runways at San Francisco airport could be underwater by 2100.[37]



Stormwater also makes its way into the bay; some of it is filtered through wetlands that provide a natural way to treat pollutants before the water enters creeks, rivers and oceans. However, much stormwater remains untreated before reaching the bay and is an ongoing management issue for the flora and fauna in our rivers and creeks that flow into the bay.

This section has shown that Melbourne's lowlands and bayside areas have a complex and rich water story of lost wetlands and ephemeral swamps. However, all need not be lost. Rather, this way of viewing our lowlands as an integral part of the story of our city offers a replicable methodology, an environmental framework for thinking about contemporary urban conditions that is relevant to urban planners and designers. By connecting the past and the present and understanding water movements and the city's underlying condition, a pathway is created towards the repair and rejuvenation through intelligent development of post-industrial sites (e.g. Arden Macaulay), as well as the infill and adaptation of existing sites (e.g. Elwood) undertaken with a long-term view.

29 (p. 89)
Contour map of Victoria highlighting, in orange, the extent of the Southern Lowlands in between the Highlands of the Great Dividing Range and the Southern Uplands (Otway Ranges, Mornington Peninsula, Strzelecki Ranges and Wilsons Promontory).

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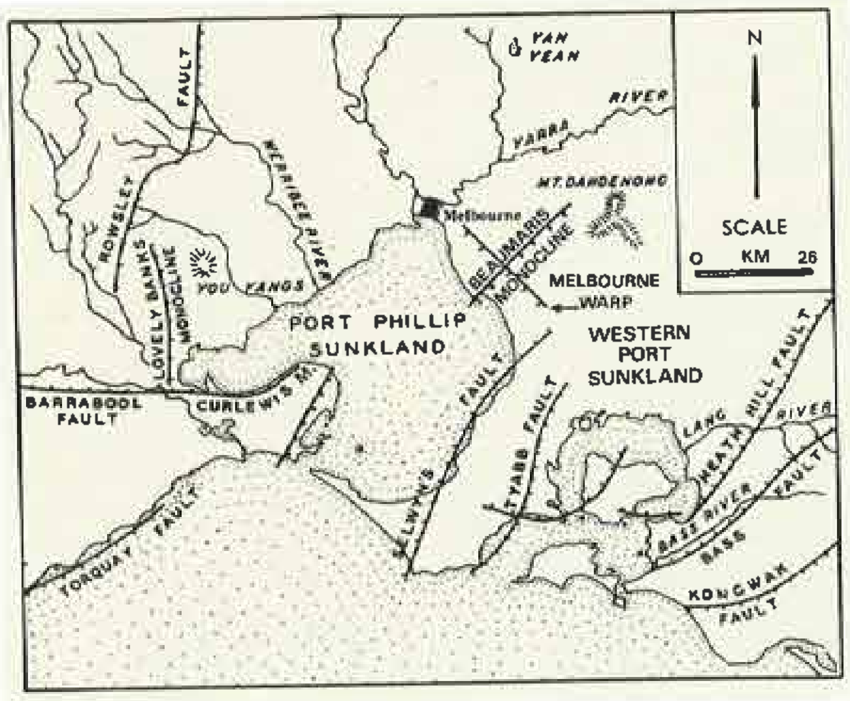

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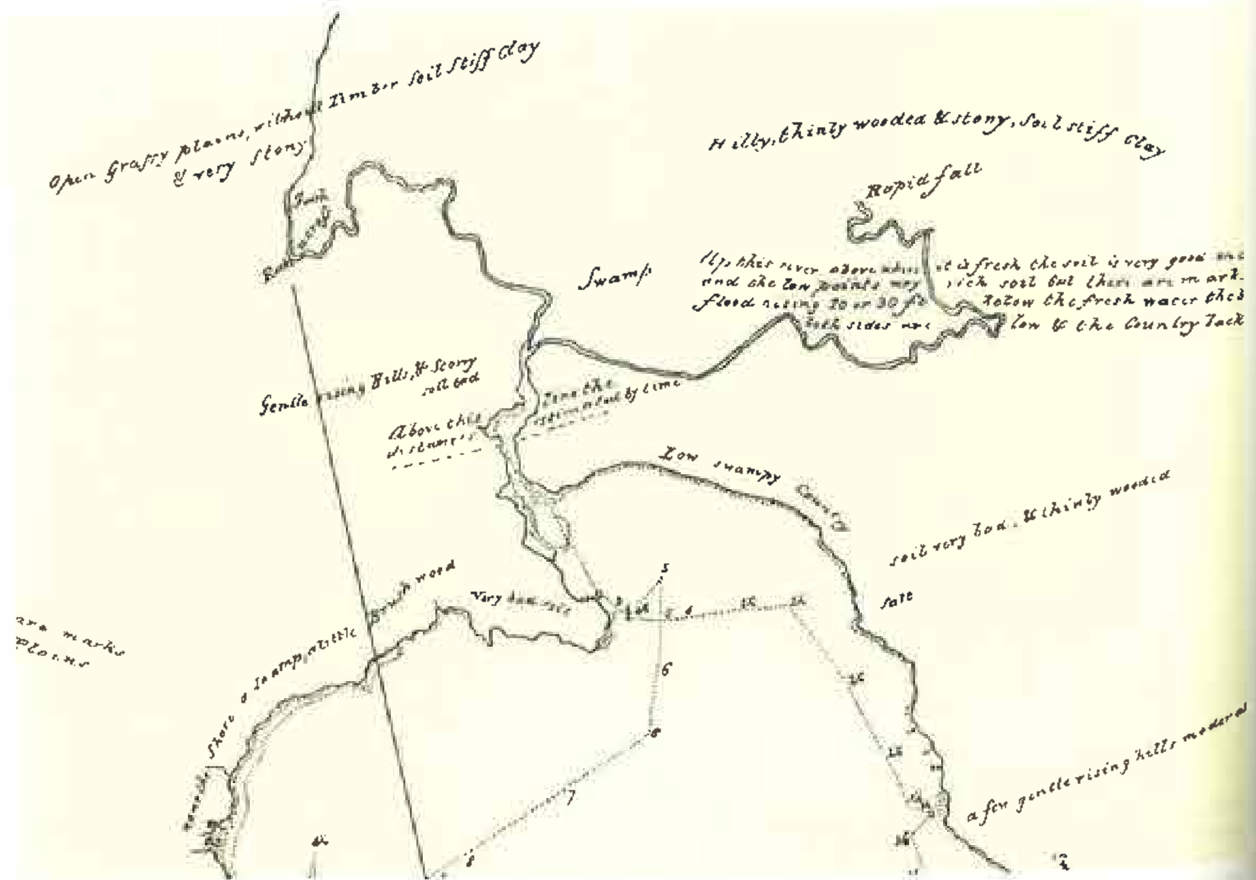
33
Map by E. Sherbon Hills of Port Phillip and Western Port 'Sunklands', with major watercourses and faultline structures. The combined sunkland extends from Rowsley Fault in the west near Bacchus Marsh to Heath Hill Fault in the east, near Drouin.

34
Fragment from Grimes' 1803 Port Phillip Survey Map with notes recording the physical features around the bay. The current suburbs along Port Phillip Bay (roughly Middle Park to Elwood) are noted as 'low swampy country'.

35
Permanent opening to Bass Strait at Lakes Entrance, 1929. The Gippsland Lakes, a complex system of rivers, coastal lagoons and wetlands, were dramatically altered in 1889, when an artificial channel was cut to Bass Strait for shipping access. The creation of this entrance shifted the Gippsland Lakes from an intermittently open-and-closed coastal lagoon system to one permanently linked to the ocean, and resulted in a change in water levels and chronic salinisation of a formerly fresh and brackish-waterbody.



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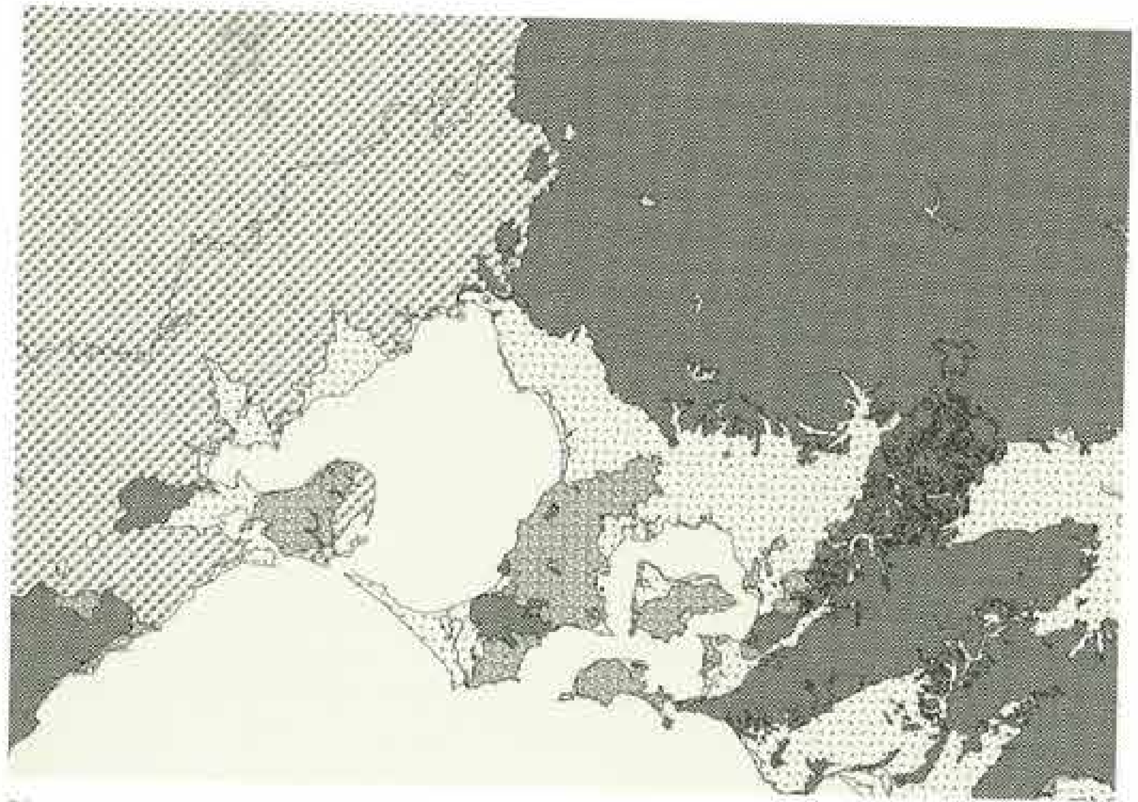

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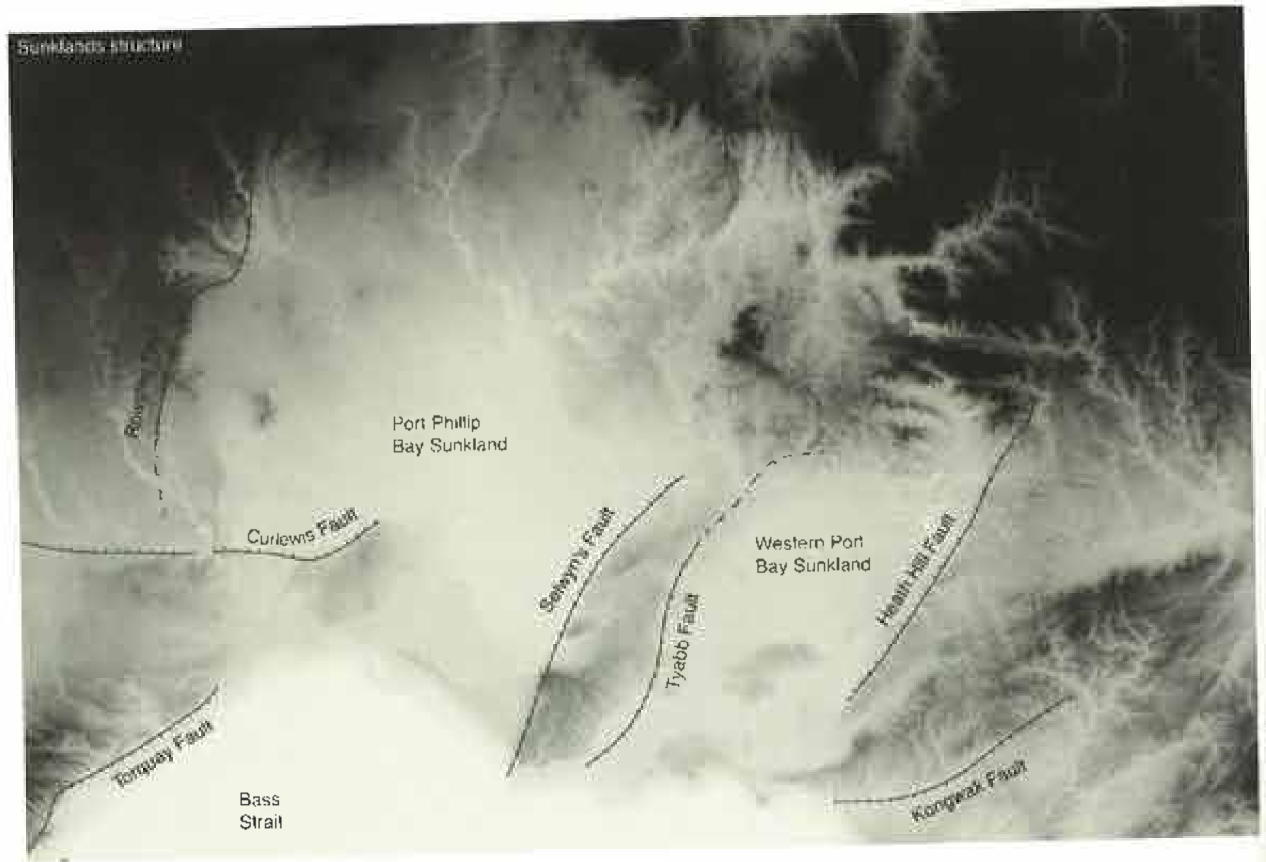
Diagram of four key geological types around Port Phillip and Westernport bays: silurian rock to the east, volcanic plains to the west, sandstone towards the south, and alluvial sandy deposits around coastlines and low-lying areas. Melbourne's CBD is at a hinge-point between three different geological conditions.



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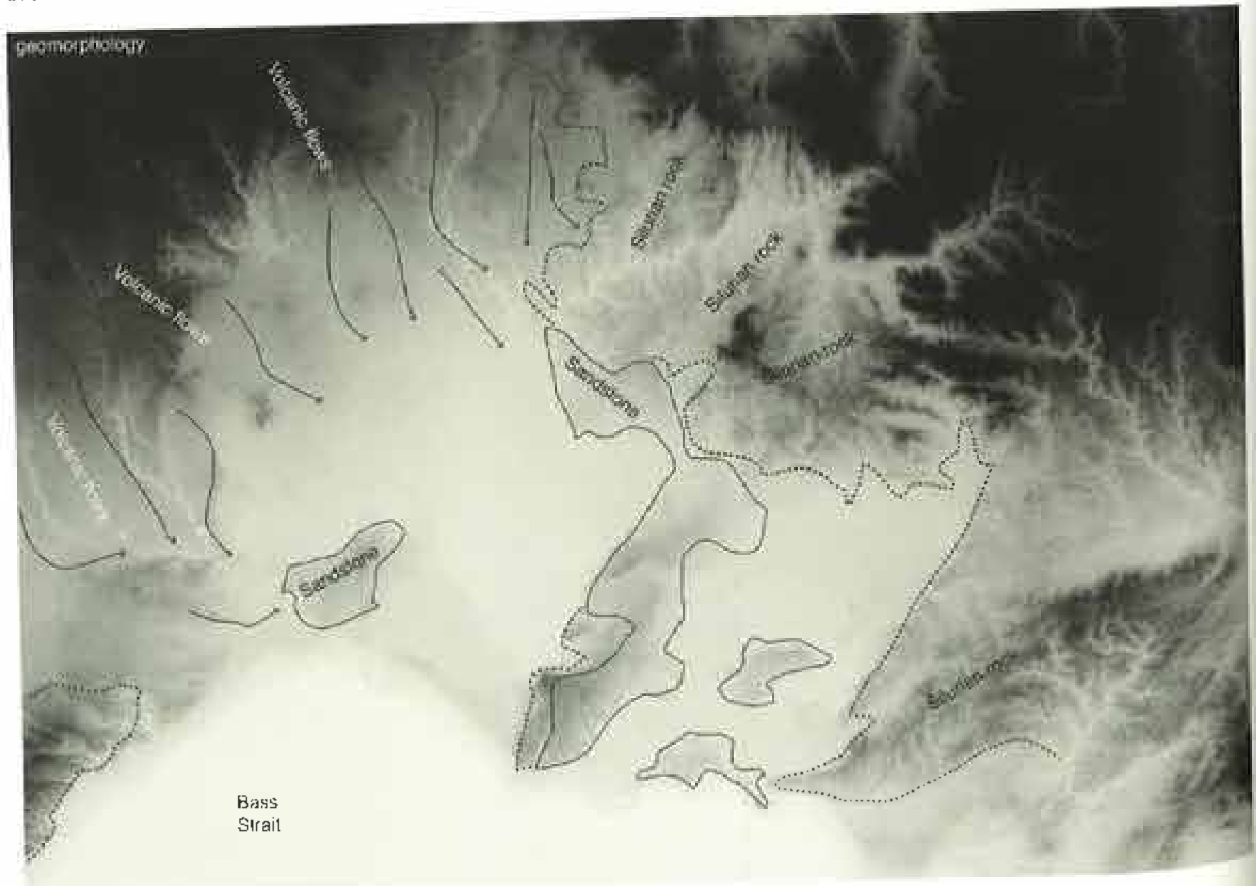

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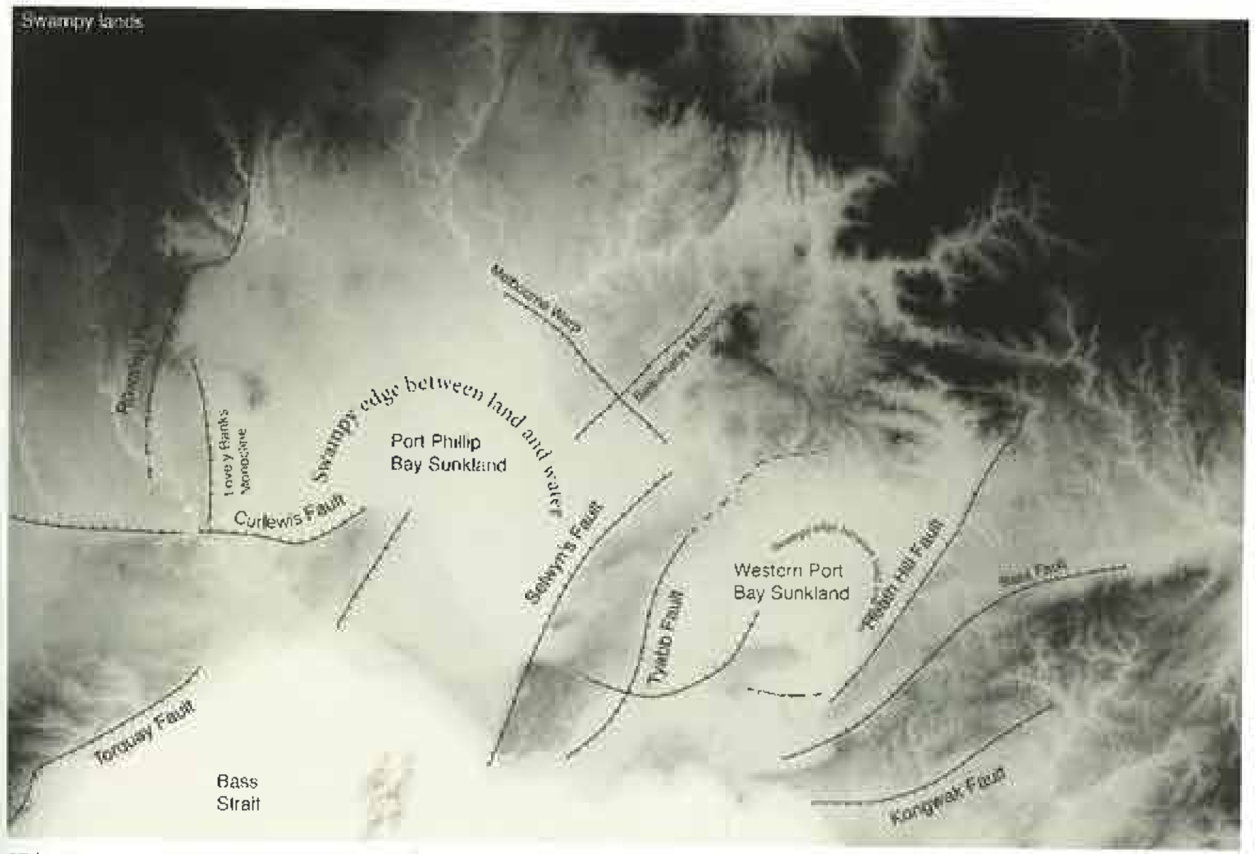

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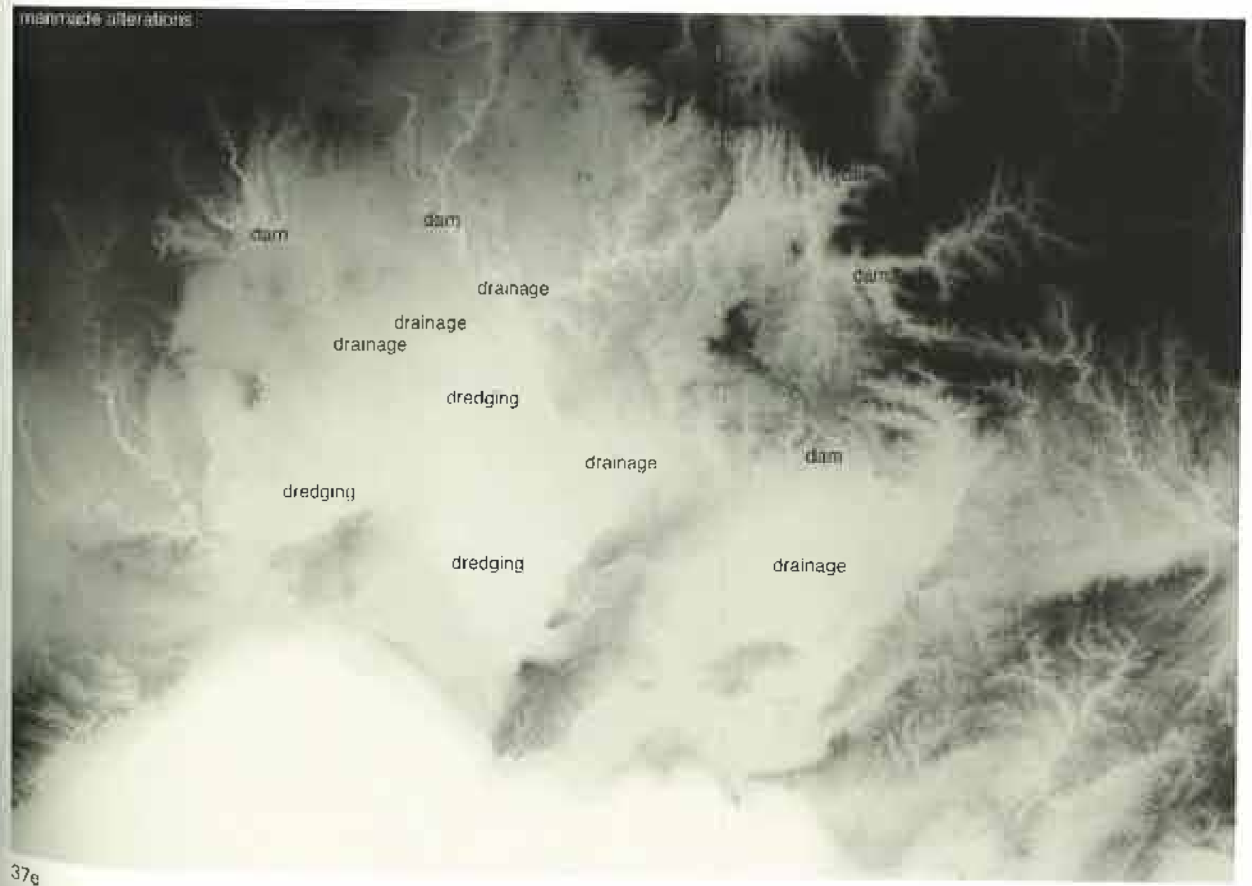

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Source: *Monash Urban Lab*

ECOLOGY OF THE KOOWEERUP SWAMP AND ASSOCIATED GRASSLANDS

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YUGOVIC, J.V., 2011. Ecology of the Kooweerup Swamp and associated grasslands. *Proceedings of the Royal Society of Victoria* 123(2): 172-188. ISSN 0035-9211.

An understanding of the ecology of the Kooweerup Swamp is obtained from historical maps and survey plans and modern soil mapping. The probable boundary of the former largest swamp in Victoria is determined. The immense swamp had distinct zones formed by inner and outer swamps: the inner swamp was a permanently inundated reedswamp with emergent sand ridges and a descending series of lake-like cells, while the fringing outer swamp was largely paperbark scrub subject to frequent flooding. Grassland and *Acacia* woodland were locally extensive adjacent to the swamp in areas of periodic flooding. The inner swamp boundary was probably flood controlled while the outer boundary was probably fire controlled on the plains and topographically controlled by hills to the east. Small areas of swamp scrub and grassland remain, with significant examples at The Inlets in Koo Wee Rup.

Key words: Kooweerup, Koo Wee Rup, Koo-Wee-Rup, swamp, grassland

THE KOOWEERUP SWAMP, also known as The Great Swamp, The Great Marsh and Kuwirap, was the largest swamp in Victoria (Fig. 1). Draining and clearing the immense swamp for agriculture was a major undertaking commencing in 1876 and continuing in stages to 1962, imposing hardship on early settlers and drainage workers. The major drain is the Bunyip Main Drain which was constructed in 1889–1893 and later enlarged. There have been several attempts to drain the swamp during which time there have been at least 14 floods. The Cora Lynn spillway, constructed in 1962, was the last major drainage project (Roberts 1985) but the swamp is not entirely tamed as there have been significant floods since then. The natural swamp was destroyed without any detailed account of its original condition (Hills 1942) so what is known of its ecology is based on fragmentary and often indirect evidence.

The Aboriginal name Kuwirap is said to mean 'blackfish swimming', from kowe = water and wirap or werup = blackfish (Database of Aboriginal Placenames of Victoria 2002). Surveyor William Urquhart (1847) recorded the name of the swamp. His field book states that the swamp was called 'Cowirrip' by the 'Natives'. The name of the swamp is spelt in several ways. Kooweerup and Koo-Wee-Rup are official historical place names. The spelling Kooweerup is more in keeping with the Aboriginal name and is applied here. Koo Wee Rup is now the official place name of the town on the former edge of the swamp.

The Kooweerup Swamp was effectively impassable and formed part of the boundary between the inland Woi wurrung and the coastal Bun wurrung people. The northern edge was inhabited by the Bulug willam clan, meaning 'swamp dwellers' from buluk = swamp and willam = dwelling place. The southern edge was inhabited by the Yallock balug clan of the Bun wurrung, meaning 'river people' from yallock = river and bulluk = people (Clark 1990).

In order to understand this unique ecosystem and locate remnant vegetation, historical sources are used here to map the outer boundary of the swamp. Soil mapping allows a glimpse of the inner swamp. Further analysis is in Yugovic and Mitchell (2004, 2005). This paper updates and expands upon Yugovic and Mitchell (2006) and includes a clear map of the reconstructed swamp boundary.

METHODS

Copies of historical and maps survey plans were obtained from Land Victoria and the State Library of Victoria. Mapping was undertaken using GIS software. Plans were scanned and registered as accurately as possible, using reference points such as creek alignments, land boundaries and, in the

Fig. 1. The Great Swamp, map of Australia Felix (Ham 1849).

case of Urquhart (1847), Mount Ararat and Cannibal Hill. Swamp and grassland boundaries were digitally traced and combined on one composite map.

Map data and information sources were:

Survey map of Urquhart (1847)
Map of the western and northern edge of the swamp and adjacent open plains from Tooradin to Garfield, remarkable detail with chainage points shown, with annotations on vegetation.

Survey map of Foot (1855)
Map of the southern swamp edge from The Inlets to Yallock, shows crown allotments allowing better resolution and registration with the base map, with annotations.

Survey map of Callanan (1859)
Map of the northern swamp edge from Cardinia to Pakenham, shows allotments, with annotations.

Plan K118 (1866)
Map of the southern swamp edge in the Yallock area, shows allotments, with annotations.

Plan L3335 (1866)
Map of the near-coastal swamp edge and The Inlets, shows allotments, with annotations.

Plan Rail 84C2 (1873)
Railway survey map of the eastern swamp edge from Garfield to Yannathan, uniquely covers a large area but relatively small scale.

Map of Torbonarach and Red Bluff (Moore and Martin's Yallock stations)(no date)
Sketch map of the Yallock area in Gunson (1968), not to scale but informative.

Map of land subsidence of Hills (1942)
Remarkable map of early land subsidence, overlaying early contours with 1914 contours. Subsidence was due to shrinkage and loss of up to about eight feet of peat from drainage, fires, wind erosion, compaction and oxidation. The distribution of the former peat deposit is assumed to indicate the extent of the inner swamp. Points where contour lines from the two surveys converge indicate no subsidence and the edge of the deposit. Coverage is not complete so the entire deposit is not indicated. Map also appears in Hills (1975).

Soil map of Sargeant et al. (1996)
Primary source on the extent of the former peat deposit and thus the inner swamp. Map units Koo-

Wee-Rup peaty clay (Ko) and Koo-Wee-Rup peaty clay with sandy ridges (Ko/sr) indicate the former extent of peat (I. Sargeant pers. comm.). These soils are developed on alluvial deposits that pre-date the swamp. Apart from some of the higher sandy ridges, these deposits were below the original peat layer and now incorporate ploughed-in residue from the peat, hence the description 'peaty' (Hills 1942; Goudie 1942).

Hills (1942) indicates a larger area of peat deposit but Sargeant et al. (1996) is adopted for the inner swamp boundary due to its complete coverage; however, soil map units Ko and Ko/sr may represent a minimum estimate. The present organic or peaty content of soil is expected to be lower towards the edge of the former peat deposit where the overlying peat would have been shallow. Marginal areas of Monomeith clay loam and Narre clay loam, which have normal amounts of organic matter, may have had shallow peat although it was 'no more than a few inches', and the transition from peaty clay to clay loam is very gradual (Goudie 1942: 103).

Swampy riparian woodland is indicated in the mapping along the Bunyip River before it enters the inner swamp and along Yallock Creek after it leaves the inner swamp. The woodland is modelled in order to complete the map, all other data being sourced from existing maps. The notional width of woodland is approximately 100 m on each side of the stream based on the example at Bayles, while the old course of the Bunyip River is unclear.

RESULTS AND DISCUSSION

Historical maps and survey plans and modern soil mapping are combined to delineate the original inner and outer boundaries of the Kooweerup Swamp in Fig. 2. The outer boundary is taken to be the mapped edge of Swamp Paperbark *Melaleuca ericifolia* scrub. Where there are discrepancies between sources, the best source in terms of resolution is given priority. Where no data is included, along small sections of the outer boundary, no line is indicated.

The scale and accuracy of the reconstructed swamp boundary varies with the source data. Source maps such as Foot (1855) are remarkably detailed and probably accurate to within tens of metres, while other maps are at smaller scales and one is not to scale. The outer swamp boundary is a compilation of historical maps and survey plans, while the inner boundary is inferred from soil mapping and is indicative only.

The Koo Wee Rup Plain included a number of swamp complexes (Rosengren 1984):

- Kooweerup Swamp
- Dalmore Swamp, contiguous with above, to the west
- Tobin Yallock Swamp, effectively separate from both of the above, to the south

Grasslands and woodlands were locally extensive on the margins of these swamps.

Kooweerup Swamp

The Kooweerup Swamp was joined with the Dalmore Swamp to form a major wetland complex with an east-west orientation. With maximum dimensions of 32 km and 14 km and 30 000 ha in area, this was by far the largest swamp in Victoria.

The swamp was situated on the Koo Wee Rup Plain, the northern and terrestrial part of the Western Port Sunkland which is a product of block faulting (Spencer-Jones et al. 1975). The swamp formed after the last Ice Age in what had been an arid or semi-arid landscape. A previously dry climate is indicated by wind-formed curved ridges (lunettes) on the east side of former intermittent lakes (Sargeant et al. 1996). With climate warming there was more rainfall and permanent flow in the Bunyip River. Permanent inundation of the inner swamp initiated peat deposition which was continuous up to the time of drainage (Hills 1942).

Sea level rise following the Ice Age truncated the swamp, greatly reducing its size. Freshwater swamp deposits outcrop along the coast as low cliffs between The Inlets and Lang Lang beach (Gell 1974; Rosengren 1984). Peat deposits also have been traced below the mudflats of Western Port Bay where they are exposed in tidal channels. Peat 0.5 m above the base of the freshwater swamp deposit on the floor of the bay was dated 12 280 to 13 480 years BP. Given the age of the peat sample and its location relative to the base of the deposit, it is likely that initial deposition began around 14–15 000 years BP. Prior to the marine incursion, the Kooweerup and Tobin Yallock Swamps extended well onto the present floor of the bay where they merged to form a large swamp for several thousand years (Miles 1976).

The fall of the swamp decreased towards the coast, as the fall of the main drain ranges from 1.9

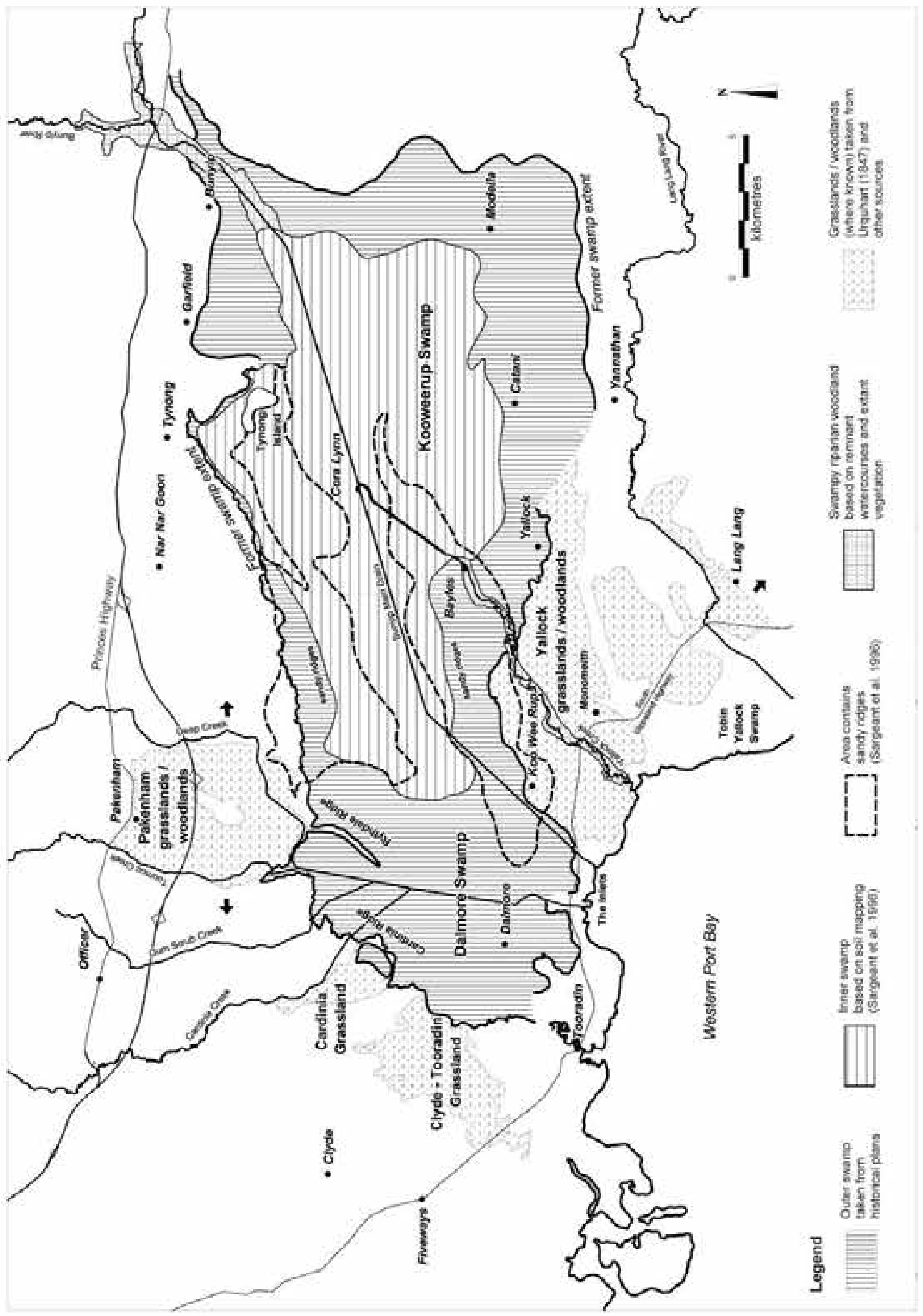

Fig. 2. Kooweerup Swamp, reconstructed from historical sources and soil mapping.

m/km near Bunyip to 0.6 m/km in the lower reaches (Hills 1942). This is due to the shape and size of the old alluvial fan of the Bunyip River that lay under the swamp (Goudie 1942).

The outer swamp consisted primarily of closed scrub 4–6 m in height and dominated by the shrub or small tree Swamp Paperbark *Melaleuca ericifolia* (Urquhart 1847 field book). The dense scrub grew on essentially mineral clay soil rather than the deeper organic peat of the inner swamp, as *Melaleuca* requires drainage and generally does not tolerate permanent inundation. *Melaleuca* substrates may develop a shallow peaty surface layer where frequently waterlogged, and the species may colonise peat during dry phases when water levels are low.

Some areas within the outer swamp, probably mostly localised sand ridges, supported swampy woodland of Swamp Gum *Eucalyptus ovata* with *Melaleuca* understorey, the 'Gum Scrub' of Urquhart (1847). These sites had more soil aeration and possibly a higher fire frequency. Sand ridges also impeded drainage, resulting in local reedbeds and waterholes in the outer swamp (1866 Yallock plan) and there were 'water channels in places' (Hills 1942: 79). The presence of natural levees supporting swampy riparian woodland including Manna Gum *Eucalyptus viminalis* as evidenced by the remnant at Bayles along outflowing Yallock Creek within the outer swamp indicates that the entire swamp would flood at times.

The core of the swamp was a very different environment, being relatively open and dominated by reeds and rushes. 'Two transects of the swamp made in 1868 show mainly reeds, rushes, and water where peat has now been mapped, with a small area of stunted tea-tree noted on the eastern edge' (Goudie 1942: 95). Hills (1942) thought the reeds and rushes were probably Common Reed *Phragmites australis* and a species of *Scirpus* (this genus was subsequently split into several genera, the species of deep water is River Club-sedge *Schoenoplectus tabernaemontani* which would certainly have occurred in the swamp). The early 1868 survey, which could not be located during this study, also indicates the presence of open water.

The 13 000 ha inner swamp was essentially a massive peat bog. With an average surface slope of 1.3 m/km (Hills 1975), it could not have held one continuous standing body of water. Hills (1942) suggested it consisted of relatively small lake-like cells separated by dense growths of reeds and rushes that acted as slowly permeable barriers to the flow of surface water, while Goudie (1942) referred to 'many lagoons'. A particularly large cell or 'sheet of water' with deep peat probably existed between Cora Lynn and Catani (Goudie 1942). Groundwater moved more slowly through the peat and, in effect, the swamp was a gigantic sponge with large volumes of water slowly moving through, with increased surface flows during floods.

Permanent inundation in the centre of the swamp resulted in the deposition of 'fibrous peat, six to ten feet deep, waterlogged for the most part' (East 1935: 80), consisting of *Phragmites* and other vegetation not fully decomposed due to anaerobic conditions. Remains of *Phragmites*, *Typha* and *Melaleuca* were found in remnant peat by Goudie (1942). The peat also included a small amount of gravel from the catchment transported into the swamp by water currents. Up to 3 m of peat had accumulated over thousands of years, and since peat is resistant to erosion the massive peat deposit acted as a local base level for streams (Hills 1942, 1975).

Vegetation patterns, particularly within the inner swamp, were probably intricate. The lake-like cells postulated by Hills (1942) are likely to have supported a mosaic of reedswamp (*Phragmites* and *Typha*), aquatic sedgeland (including *Baumea*, *Eleocharis* and *Schoenoplectus*), aquatic herbland (including *Azolla* and *Triglochin*) and open water. Emergent sand ridges would have supported paperbark scrub within the inner swamp and eucalypt woodland within the outer swamp, adding to the complexity of the vegetation.

The Kooweerup Swamp was fed by about 10 creeks and rivers but mainly by the Bunyip River with headwaters in the cool temperate rainforests and Mountain Ash forests of the Central Highlands 25 km north. Before it was channelled, the Bunyip River was 'about 10 feet wide and 5 feet deep' (Catani 1901). It is not clear whether levees lined the river before it entered the inner swamp as levees are not apparent at sites 28 and 29 of Rosengren (1984). All contributing streams dissipated within the swamp, the outlets being separate streams.

Paperbark scrub extended back along the rivers and creeks entering the Kooweerup Swamp, making the boundary of the swamp somewhat arbitrary in places. For example, swampy vegetation east of Bunyip along the Bunyip River and its tributaries may be considered part of the larger swamp complex but is not included in this analysis. Further historical research and map compilation are required east of Bunyip in particular.

Six creeks drained the swamp: Sawtell Creek, The Inlets (four creeks) and Yallock Creek. The main outlet was Yallock Creek which issued from the southern edge of the inner swamp at Bayles and was essentially the lower course of the Bunyip River which entered the inner swamp in the north-east (Rosengren 1984). Natural levees lining the creek supported riparian eucalypt woodland; a priceless example is the isolated woodland at Bayles. Yallock Creek and its levee woodland meandered through 3 km of scrub before leaving the outer swamp and passing through woodland and grassland to the coast. According to Foot (1855: annotation on plan), Yallock Creek 'runs the greater part of the year, but towards the end of summer becomes only a chain of ponds'. Hovell, in January 1827, found the water 'exceedingly good'.

Sand ridges were reportedly used to access the swamp for stock grazing (Hills 1942). Narrow meandering sandy ridges slightly above the present surface occur in parts of the swamp area, both inside and outside the area of the former peat deposit. There are two 'sandy complexes', in the north and south of the swamp, where sand ridges occupy more than 20% of the area, and occasional ridges occur outside these areas (Goudie 1942, Sargeant et al. 1996, Fig. 2). Many ridges are now modified by gravel extraction (I. Sargeant pers. comm.) but they were 0.3 to 1.5 m high and from a few metres to 20 to 40 m wide (Goudie 1942). A site with one metre ridges occurs at Pakenham South (Rosengren 1984). The ridges are probably abandoned levees and bed deposits of distributary channels of a large alluvial fan made by the Bunyip River under more arid conditions prior to formation of the swamp (Hills 1942).

Judging by the map of early land subsidence (Hills 1942), the original surface of the sandy complex areas was 0.6 to 2.1 m higher. Given that the ridges were up to 1.5 m high, it follows that some but not all of the ridges were buried under the peat, which is consistent with some ridges having a peaty loam soil indicating past coverage by peat while others do not (Goudie 1942, Sargeant et al. 1996). It is also likely that ridges in the outer swamp (which were exposed as there was no peat) extended into the inner swamp before disappearing below peat.

The sandy complexes impeded drainage and influenced the distribution and size of lagoons within the inner swamp. The southern sandy complex at Bayles may have been responsible for a 'large area of standing water' between Cora Lynn and Catani. Similarly, the northern complex blocked Ararat Creek forming a northern arm of the inner swamp (Hills 1942).

An island in the swamp occurred at Tynong where a low granite hill had become surrounded by swamp (Fig. 2). The description on Urquhart's map is 'island heavily timbered with gum and dense scrubs' suggesting lack of fire. At Tynong there was an abrupt sequence from grassy eucalypt woodland on granite hills to reedswamp on the plain with a fringe of *Melaleuca* and swampy woodland. The extensive view from the hills over 'impenetrable scrubs of Tea Tree, Gum Scrubs and Reeds' (Urquhart 1847) included the northern arm reedswamp and the vast inner reedswamp stretching south-west to the horizon.

Two curved ridges of similar orientation on the north-west edge of the swamp appear on Urquhart's map: the 3 km Rythdale ridge and the 2 km Cardinia ridge (Fig. 2). Five to eight metres above the swamp surface, these features are lunettes that formed on the downwind side of intermittent lakes that were the terminations of creeks (Toomuc and Cardinia Creeks respectively) under dry Ice Age conditions before the swamp existed (Sargeant et al. 1996). They are different in origin from the lower alluvial sand ridges and have state geomorphic significance due to their unusual landform (Rosengren 1984). Both ridges were high ground in the swamp but they did not reach the inner swamp (the other high ground was the Tynong island). From remnant vegetation, the crest of Rythdale ridge supported grassy woodland of Manna Gum. The southern tip of the ridge was annotated 'point of timber' by Urquhart (1847).

A specimen of Leadbeater's Possum *Gymnobelideus leadbeateri* at Museum Victoria was collected from the hollow branch of a tree being felled at 'the edge of the Koo-Wee-Rup Swamp long before the swamp was drained, about three miles due south from Tynong railway station' (Mason in Brazenor 1932: 108). This location is within the original swamp but peripheral clearing may have occurred by that time. The hollow-bearing tree may have been a Swamp Gum on a sand ridge outcropping above the peat to the south-west of the Tynong island. A sand ridge mapped by Rosengren (1984) may have been the collection site.

Magpie Goose *Anseranas semipalmata* is recorded from Koo Wee Rup and the swamp would presumably have supported large numbers of this bird which was locally abundant in south-east Australia. The habitat preferences and behaviour of the species in northern Australia (Nye 2004) indicate that the inner swamp would have provided nesting habitat, the outer swamp roosting habitat in trees and shrubs, and the adjacent floodplain grasslands foraging habitat. The swamp area thus provided all necessary habitats for the species as well as drought refuge.

The close proximity of the inner and outer swamp boundaries for about 8 km between Nar Nar Goon and Garfield is of considerable interest. This area is likely to have been highly productive for the Bulug willam clan ('swamp dwellers'), providing easy access to the inner swamp where fish and waterbirds would have been abundant. Tynong is said to mean 'plenty of fish' (O'Callaghan 1918). River Blackfish *Gadopsis marmoratus*, after which the swamp is named, is a valuable eating fish that presumably occurred in the swamp. Black Swan *Cygnus atratus* eggs may have been obtained in spring when most breeding occurs. Plant resources included food plants such as Water-ribbons *Triglochin procera* with edible tubers, and Cumbungi *Typha* spp. with edible rhizomes, as well as Common Reed used for spear shafts, bags, baskets and necklace beads (Gott 1993). On the south side of the swamp, the Yallock balug clan ('river people') could reach the inner swamp at Bayles via the Yallock Creek levees.

An early sketch map of Western Port drawn by Assistant Aboriginal Protector William Thomas in 1840 depicts an area well inland of his coastal route with the label 'Pan-der-buit or Great Impassable Swamp' (Thomas in Cannon 1983). This may have been a name of the inner swamp, from buth/butj = 'grass in general' also referring to reeds and sedges (N. Scarlett, pers. comm.).

As with many swamps in Australia, Kuwirap was said to be inhabited by a large black monstrous amphibious creature with a harsh call known as the bunyip. The Woi wurring called the creature Banib, hence the place name Bunyip, while the Bun wurrung called it Tooroodun, hence the name Tooradin (Database of Aboriginal Placenames of Victoria 2002).

'On the Western Port plains, there is a basin of water—never dry, even in the hottest summers—which is called Toor-roo-dun, because the Bun-yip lives in that water' (Smyth 1878, Vol.1: 436), which suggests Toor-roo-dun was also a name of the inner swamp. Reputed to devour human beings, Toor-roo-dun was said to inhabit the deep waters and the thick mud beneath the waters of the swamp, and to have a head and neck like an emu's (Smyth 1878).

No bunyip story in Australia is recorded in detail. The story may relate to seals, which occasionally visit freshwater rivers and swamps, as bunyips reported by early Europeans were apparently vagrant seals, or even to extinct megafauna such as *Diprotodon* (Flett 1999) although the swamp formed well after the megafauna extinction. It is implausible that the coastal Bun wurrung would not have recognised seals even outside their usual habitat, but they may have regarded vagrant seals within the swamp to be inhabited by Tooroodun.

Draining and clearing the Kooweerup and Tobin Yallock Swamps rapidly led to deep incision and channel erosion of the feeder streams upstream due to lowering of the local base level. By 1916 the Bunyip Main Drain had deposited a layer of sediment two feet thick 1½ miles out to sea (East 1935). Bunyip Main Drain and Lang Lang River (Drain) remain by far the largest contributors of suspended sediment to Western Port Bay (Wallbrink et al. 2003). The slow recovery of seagrass cover since the decline of the 1970s (Ball and Blake 2001) and declining fisheries in the bay (DPI 2004) may be affected by the resulting high turbidity.

Dalmore Swamp

Before it was drained and cleared, Dalmore Swamp was known for its dense, almost impassable scrub (Goudie 1942). It occurred on mineral clay soil rather than the deep peat of the inner Kooweerup Swamp. A continuous line of 'impenetrable scrubs' was mapped by Urquhart (1847) along the west and north edges of 'The Great Swamp' then consisting of both swamps in combination. Dalmore Swamp was joined with the Kooweerup Swamp, forming a western extension of the outer swamp. The swamp was drained by five tidal creeks: Sawtell Creek at Tooradin and four creeks at The Inlets.

The central area has a layer of decomposed peat, up to 60 cm in thickness, approximately 75–85 cm below the surface (Goudie 1942). The peat seam is valuable in market gardening due to the internal soil drainage it provides (Sargeant et al. 1996), the overlying black clay preventing it from being lost. Remains of club-sedge *Bolboschoenus* have been found in the peat (S. Seymour pers. comm.), consistent with Goudie (1942) who identified seeds of '*Scirpus* and *Lepidosperma*' in the peat (*Bolboschoenus* was previously *Scirpus*).

The centre of the Dalmore Swamp may have once been an arm of the inner swamp until local geological uplift reduced the catchment size and stream flow of the western feeder streams, ending peat formation and leading to deposition of the overlying Dalmore clay (Hills 1942). However, soil maps indicate the Dalmore peat was not connected with the in-

Fig. 3. Moodys Inlet, former Kooweerup Swamp in background, Koo Wee Rup.

ner swamp peat (Goudie 1942, Sargeant et al. 1996), suggesting the past existence of two inner swamps.

The Inlets

The Inlets are a series of meandering tidal creeks opening onto the mangrove-fringed shore of northern Western Port Bay. They were major outlets of the Kooweerup Swamp, previously draining the western outer swamp (the Dalmore Swamp). Old growth remnants of the swamp and its boundary with estuary vegetation occur at The Inlets (Yugovic 2008, Figs 3–6).

The number of creeks comprising The Inlets is between two and four depending on definition. There are two central inlets: the eastern Moodys Inlet and the western unnamed (and largely unreserved) inlet. Bird & Barson (1975) consider the Bunyip Drain (east of the waterway reserve), known as Reeces Inlet before modification, to be one of the inlets. Hills (1942) considers Lyalls Inlet (west of the waterway reserve) to be another inlet.

The central Inlets area including Moodys Inlet is protected within the 83.7 ha The Inlets Waterway Reserve located in Koo Wee Rup and Dalmore and managed by Melbourne Water. Swamp remnants extend onto the drainage reserve to the north as far as the disused South Gippsland rail line, and also occur on adjacent private land. The waterway reserve is also contiguous with the North Western Port Nature Conservation Reserve on the coast.

The Inlets formed within the Kooweerup Swamp and are not the lower reaches of streams that entered the swamp, as all feeder streams dissipated in the swamp.

> In plan the Inlets show a dendritic pattern of branching channels, each representing a self-contained drainage unit which is long compared with its breadth, and they present a remarkable similarity in form to the rill-marks that develop on sloping surfaces of water-saturated sand or mud, such as may be seen on beaches at low tide. (Hills 1942: 81).

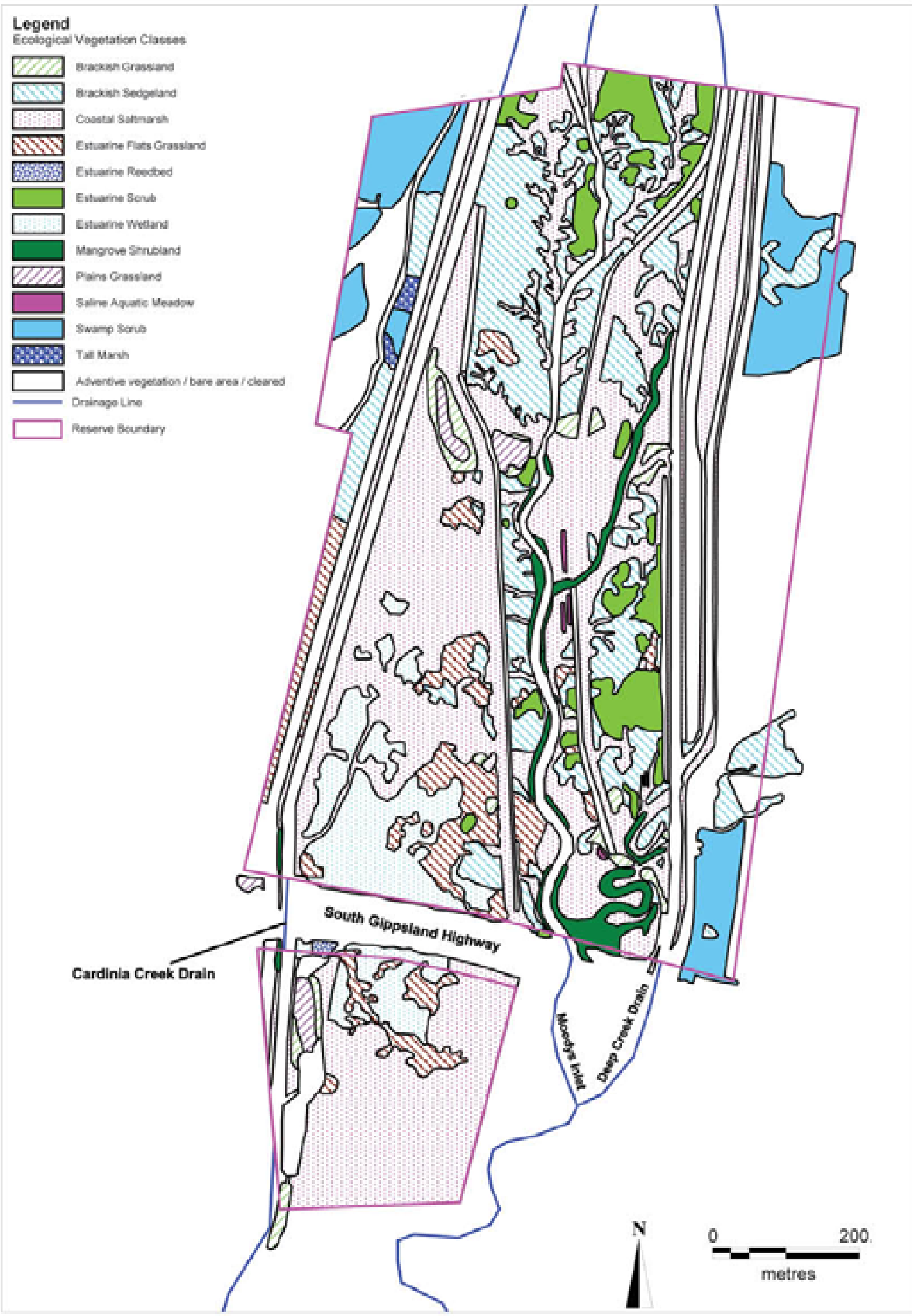

Fig. 4. Vegetation, The Inlets Waterway Reserve, Koo Wee Rup.

Fig. 5. Edge of Kooweerup Swamp, Cardinia Creek drain in foreground, The Inlets.

The central creeks form a compound estuary as they share the same floodplain but enter the sea separately.

The meanders in the creeks are apparently stable as they have not changed significantly since The Inlets were first surveyed in 1866. This may be due to the tidal nature of the channels—in a freshwater stream meanders migrate downstream over time due to unidirectional current flow, whereas in a tidal stream the flow reverses regularly so that meanders are more likely to be stable. However, mangrove shrubland tends to occur on the sheltered downstream sides of meanders in Moodys Inlet (Fig. 4), possibly due to strong currents during freshwater floods inhibiting the establishment of mangroves on the relatively exposed sides of meanders.

The waterway reserve supports diverse, high quality native vegetation almost throughout. Old growth Kooweerup Swamp scrub occurs on inland sites and forms a sharp boundary with saline, treeless estuary and saltmarsh vegetation. Estuary vegetation at the boundary is dense sedgeland dominated by Coast Saw-sedge *Gahnia trifida*. Large tussocks of Prickly Spear-grass *Austrostipa stipoides* line the winding channel of Moodys Inlet above the mangroves. Six native grassland communities occur on a range of saline to freshwater soils, making The Inlets outstanding in a state context. The area is also a stronghold for the significant Swamp Skink *Egernia coventryi* and Southern Brown Bandicoot *Isoodon obesulus*. Constructed levee banks support variable native and introduced vegetation (Yugovic 2008).

The vegetation of The Inlets is highly complex due to variable water, salinity and disturbance regimes. Important factors determining vegetation patterns are (a) topography in relation to inundation, the variation being created by natural features (islands, meandering channels and the dendritic drainage pattern) overlaid by artificial features (drains, levee banks and borrow pits) and (b) the salinity gradient, which varies in time and space and generally exhibits a decrease in salinity with distance inland. Due to the scale of mapping, the vegetation map (Fig. 4) is necessarily a simplification of the intricate vegetation pattern on the ground.

Low 'islands' of terrestrial grassy vegetation, set within the estuary vegetation, support distinctive plant communities (Fig. 4). Some islands form a line 1500 m in from the mangrove shoreline and may represent the coastline during the mid Holocene marine maximum. The highest site, which is split in two by a minor drain, has a fringe of brackish grassland dominated by Common Tussock-grass *Poa labillardierei* with a halophytic component including Rounded Noon-flower *Disphyma crassifolium* (subject to occasional flooding by brackish water). The higher central area supports plains grassland with entirely glycophytic (freshwater) vegetation including Kangaroo Grass *Themeda triandra*, Grass Triggerplant *Stylidium graminifolium*, Branching Bluebell *Wahlenbergia multicaulis*, Pale-fruit Ballart *Exocarpos strictus* and six *Acacia* species (never flooded). The fauna of the islands includes Swamp Skink, Southern Brown Bandicoot, Metallic Skink *Niveoscincus metallicus*, Blotched Blue-tongue Lizard *Tiliqua nigrolutea* and Lowland Copperhead *Austrelaps superbus*.

Aboriginal names for The Inlets are given on the sketch map of the Western Port District by Assistant Protector William Thomas (1841) who named each of the '4 Muddy Rivers' suggesting that The Inlets consists of four streams. The western of the central pair of inlets (unnamed today) is Lalln, while the eastern of the central pair (Moodys Inlet) is Koonham (probably pronounced Goonum with short 'oo'). According to Bun wurrung legend, The Inlets were formed by the wriggling of an immense snake (Gunson 1968).

In the 1840s, The Inlets was the greatest natural hazard on the route between Melbourne and Port Albert due to the channels which were tidal and prone to freshwater flooding. 'The noise of the overflow of the Swamp rushing through the tea tree at the inlets was enough to frighten a faint heart.' (Gunson 1968: 2). The first bridges were washed away but permanent bridges were eventually built across The Inlets (Gunson 1968; Roberts 1985).

Settler and swamp drainer William Lyall was a member of the Acclimatization Society and introduced several fauna species to the area including Sambar Deer which occur there today. In 1873–4, he planted 40 000 Sydney rock oysters within the channels of The Inlets but the enterprise was a disaster as the oysters were killed by freshwater floods (Gunson 1968).

The Inlets contain the first drains constructed within the Kooweerup Swamp. Construction of the first drain, Cardinia Creek, which was 8 m wide at the surface, began in 1876 (Roberts 1985). The location of the original Cardinia Creek and Toomuc Creek drains indicated in Roberts (1985) is unclear but they are likely to be the pair of minor drains with parallel low levees within the central area, one on each side of Moodys Inlet (the western drain bisects the highest island). These drains and levees strongly influence vegetation patterns (Fig. 4).

Today three large drains and their parallel levee banks pass north to south through the reserve: Cardinia Creek drain on the west which crosses the highway under a bridge, and Deep Creek drain and a closely parallel drain on the east. The latter two drains converge north of the highway (within the reserve) to become Deep Creek drain which also crosses the highway under a bridge. Cardinia Creek drain is approximately 20 m wide and is assumed to be the new drain referred to by Roberts as constructed in the summer of 1938–39, along with the Deep Creek drain, following the 'super flood' of 1934. These drains have high levee banks to confine overflows to the large area of natural vegetation between them. Toomuc Creek drain empties into the natural channel of Moodys Inlet at the northern edge of the waterway reserve.

Ironically, the large Cardinia Creek and Deep Creek drains have helped to protect the central area of The Inlets from destruction by agricultural development; however, there were unsuccessful attempts to develop the area for agriculture, as evidenced by abandoned fences, a fallen windmill, and a derelict stock pen on one of the islands.

The Inlets is no longer an obstacle to travel due to constructed road bridges over drains that channel most of the fresh water through the area and out to the Bay. Since tides still penetrate the natural channels of the estuary, and fresh water is diverted into drains except for Toomuc Creek which flows into Moodys Inlet (via a drain), it is possible that the area is now generally more saline than originally; however, the boundary of the Kooweerup Swamp (defined by *Melaleuca*) with the estuary at The Inlets has not changed significantly since the 1866 survey.

Tobin Yallock Swamp

The former extensive Tobin Yallock Swamp was south of the Yallock grasslands and was fed mainly by the Lang Lang River. It consisted largely of *Melaleuca* scrub fanning out to form a 6 km length of the north-east coast of Western Port Bay. With no mangrove or salt marsh fringe and no beach, this shoreline *Melaleuca* scrub was highly unusual in Victoria. The shore was probably cliffed and receding when

mapped by Smythe, the low two metre cliff consisting of exposed freshwater swamp peat and clay. There was no single outlet, water issuing from the swamp via 'numerous rills of fresh water continually running' (Smythe 1843). 'It is possible that floodwaters spilling out in this way produced the crenulate shoreline, with waterfalls scouring out each cove' (Bird & Barson 1975: 23).

Gum Scrub Creek drained the outer Kooweerup Swamp at Caldermeade and was vegetated by 'Tea Tree Swamp'; it then entered Tobin Yallock Swamp and dissipated. The scrub from the two swamps almost connected via a tenuous link where the first European 'road' was situated (Smythe 1843), almost certainly following the Aboriginal trail between the swamps.

A valuable 1887 Lands Department plan of Tobin Yallock Swamp, showing scrub along the coast and a mosaic of scrub and grassland further inland, is in Key (1967: map 5). The grassland is described as 'course pasture land very wet in winter' and 'very good pasture land'.

The original boundary of the Tobin Yallock Swamp is not delineated by this study. Further research and mapping is required to better define the edges of the Tobin Yallock and Kooweerup Swamps and the largely open area between them.

Associated grasslands

While being very familiar to the Yallock balug clan, explorer Samuel Wright was the first European to see the extensive grassland or open woodland on the floodplain of Yallock Creek between the Kooweerup and Tobin Yallock Swamps, describing it in 1826 as follows:

> in point of quality. . . equal to any he ever saw in the Colony, it appeared like beautiful meadows in England, very thin of timber, grass excellent (Wright in Gunson 1968: 18)

Soon after, explorer William Hovell described the same area:

> one mile from the tent [mouth of Yallock Creek], I came to a fine open level country, very thinly covered with trees, soil of a good quality, and the grass long and fresh. . . the only objection to it is that I think it lies too flat to be perfectly dry in rainy seasons (Hovell 1827: 87-88)

This grassy plain south of Yallock Creek seen by Hovell is in Monomeith which is an Aboriginal word meaning 'pleasant, good, pure' (Massola 1968), 'good and beautiful' (Gunson 1968) or 'pleasant, agreeable' (Blake 1977). The name is likely to be a reference to the open and productive grassy terrain compared to dense swamp scrub. It is noted that 'monomeeth poath' means 'a grassy plain, a lawn' (Bunce in Smyth 1878, Vol. 2: 142).

With an extensive view to the ranges of the Great Divide to the north, the open expanse would have indeed been beautiful, being composed mainly of blue-green Common Tussock-grass. As with the Clyde-Tooradin grassland (Cook and Yugovic 2003), in spring this plain would have been studded with bright yellow Buttercup *Ranunculus lappaceus*, shimmering purple and pink patches of Chocolate Lily *Arthropodium strictum* and Pale Vanilla-lily *Arthropodium milleflorum*, and clusters of pure white Smooth Rice-flower *Pimelea glauca*.

'It was this natural grassland which made the Yallock area, just south of the swamp, so attractive to the early squatters' (Key 1967: 17). Smythe (1843) mapped swamp scrub and *Acacia* woodland forming a mosaic in the local area. The description of the relatively open country between belts of 'Tea Tree Swamp' is 'Rich black soil wooded with Lightwood' and 'good grass'. The map of the open areas includes many clusters of dots that may represent trees, thus depicting a mosaic of grassland and *Acacia* woodland.

On its western side, The Great Swamp had an adjacent 'open grassy plain' at Cardinia where Cardinia Creek entered the swamp (Urquhart 1847). Another 'open grassy plain' north of Tooradin about 5 by 2–3 km in size (Cook and Yugovic 2003) was described by Hovell:

> I came to another open space, quite clear of trees for several miles square, but so perfectly flat that the water appears to have no possibility of draining off, consequently after rain the ground must be some time before it can absorb the whole, but at this time we could not get a drop to moisten our lips, which would have been very acceptable from it being so very hot, and which we so much required, having come upon a native path, which led in the direction I wanted to go, I kept upon it in hopes that it would lead to water (Hovell 1827: 90)

Explorer William Blandowski crossed the grassy plains of Western Port in 1855.

> Between Lisle's station [Tooradin] and the inlets, the land is swampy, and luxuriantly covered with excellent grass, well adapted for fattening cattle. . . Between Lisle's and Cuthbert's station [The Gurdies] the country consists of magnificent pas-

> ture grounds, the horse having to walk through thick kangaroo grass, reaching up to the girths. (Blandowski 1855: 50-51).

The grassland strip between the inland paperbark scrub (Kooweerup Swamp) and the coastal saltmarsh and mangrove scrub was less than 300 m wide in the vicinity of The Inlets, and would have been a vital corridor in the middle of the Bun wurrung range. The grassland is described as 'good grass pasture land' on the 1866 survey plan. Remnant vegetation includes grasslands associated with various salinity regimes. Relatively saline sites are dominated by Coast Tussock-grass *Poa poiformis*, brackish sites by Common Tussock-grass (Fig. 6) and non-saline sites by Common Tussock-grass or Kangaroo Grass. Native grassland on the 'islands' at The Inlets has been previously discussed.

Grassland and *Acacia* woodland, essentially the same plant community, were locally extensive on alluvial plains outside the wall of *Melaleuca* scrub that defined the edges of The Great Swamp and Tobin Yallock Swamp. The major grass was moisture-demanding Common Tussock-grass. Also present, usually on slightly drier sites, was Kangaroo Grass *Themeda triandra*, the dominant grass of dry basalt grasslands in western Victoria. The grassland was rich in flora and fauna (Cook and Yugovic 2003) including the Aboriginal staple Murnong (Yam Daisy) *Microseris* sp. which was probably common.

Blackwood *Acacia melanoxylon* (then called Lightwood) and to a lesser extent Swamp Gum were the major trees in this grassy environment due to their resilience to flood, drought and fire. Blackwood's suckering habit enables it to survive fire. Some individuals would reach tree size and avoid grass fires, forming a woodland. The area is just beyond the range of River Red-gum *Eucalyptus camaldulensis* probably due to high rainfall. *Acacia* woodland on flood plains, previously a distinctive part of the landscape, is now very rare or extinct as an ecosystem. However, Blackwood remains widespread, mainly on road and rail reserves.

The outer swamp boundary has no clear relationship with soil type (Sargeant et al. 1996) as the same

Fig. 6. Native grassland on an 'island' within the estuary, The Inlets.

soils occur on both sides of the surveyed boundary. Since *Melaleuca* tends to occupy former grassland sites today, it is likely that Koories were burning back the edge of the swamp for access and hunter gathering. All the early European explorers of Western Port noted that large areas of land were burnt (Gaughwin 1981). Urquhart's field book refers to frequent burning reducing the *Melaleuca* on open plains 'producing good grass'. William Thomas noted that since the neighbouring Yowengarra clan was defunct their country had become scrubby because it was not being periodically burned (Clark 1990). 'Many layers of burnt tea tree branches were found when the swamp was drained' (Roberts 1985: 6). As dry peat is flammable, accumulation of the massive peat deposit in the presence of the Aboriginal fire regime was presumably due to water in the inner swamp preventing major peat fires.

Melaleuca ericifolia reproduces by root-suckering and seedlings, enabling rapid spread under suitable conditions. The Koories were probably advantaged by a natural weakness or tolerance limit of *Melaleuca*: while it was flood tolerant it was not tolerant of the high fire frequency on the swamp margin associated with drier soils and more flammable vegetation. *Melaleuca* can regenerate after fire but may be greatly reduced in cover, so the position of the swamp boundary is likely to have been a long-term response to repeated burning.

Drainage patterns indicate the floodplain grasslands and woodlands occurred on slightly higher and therefore less flooded land than the swamp. It follows that the soils were more prone to dry out and crack in summer but it is unlikely that soil factors alone would have controlled *Melaleuca*. A combination of soil and fire factors may have operated to confine the scrub. Both the inner and outer swamp boundaries may have been relatively stable over time, or dynamic and responsive to change in factors such as rainfall, evaporation, flooding and fire.

Fire may have been particularly important to the Bun wurrung for access purposes. Aboriginal burning is likely to have maintained the 18 km open space corridor between Tooradin and Lang Lang and the effective separation of the Kooweerup and Tobin Yallock Swamps. The Yallock balug clan were most likely managing their grassy open landscape by regular burning, without which the land would have become dense and effectively uninhabitable scrub. In doing so they maximised both food production and biodiversity.

Fig. 7. Native grassland on the floodplain of Yallock Creek, Monomeith Road, Monomeith.

Despite the once locally extensive occurrence of floodplain grasslands in the region, recognition of this distinctive ecosystem only occurred in the 1990s with the listing of 'Plains Grassland (South Gippsland)' under the *Flora and Fauna Guarantee Act* (SAC 1994), reflecting early modification and loss of the grasslands before recording. These grasslands are more depleted than the familiar but also endangered basalt grasslands of western Victoria.

The extremely rare plains grassland may be predicted to occur on alluvial 'black soil' outside the margins of former swamps on the Gippsland plain. The eastern side of The Great Swamp may have had little or no grassland, as in the north-east area where foothills of the ranges formed an edge with the swamp (Garfield to Bunyip). Here *Melaleuca* evidently extended to the break of slope. However, the rail survey map with this evidence was compiled after cessation of the Aboriginal fire regime, so *Melaleuca* may have spread onto grassland.

By enabling targeted survey, this detailed knowledge of the swamp boundary has been useful in locating and recognising several significant remnants of grassland such as the Clyde-Tooradin grassland along the South Gippsland rail line (Cook and Yugovic 2003) and the Yallock grassland seen by Samuel Wright 185 years ago (Fig. 7). Similarly, extremely rare remnants of outer swamp scrub have been found, including significant examples at The Inlets.

Native grassland at The Inlets discovered by this study is now being managed by Melbourne Water. The main objectives for vegetation management are to limit *Melaleuca*, which is overabundant due to lack of fire, and to control introduced plants. Foxes are also being controlled to assist the population of Southern Brown Bandicoot.

ECOLOGICAL VEGETATION CLASSES

Native vegetation in Victoria is classified into ecological vegetation classes (EVCs) by the Department of Sustainability and Environment (DSE). Numerous EVCs occurred within the Kooweerup Swamp area. The mapping of the original (1750) vegetation on the DSE Biodiversity Interactive Map shows only one extensive EVC, Swamp Scrub, throughout almost the entire area of the swamp deposit including areas now known to have been extensive reedswamp (inner swamp) and grassy open plains (surrounding areas). Depicted occurrences of Swampy Riparian Woodland running through the entire swamp are also incorrect as all feeder streams dissipated within the swamp.

The following EVCs are likely to have been present:

Inner swamp:	
Tall Marsh	widespread, extensive (reed swamp)
Aquatic Herbland	lakes within reedswamp
Aquatic Sedgeland	lakes within reedswamp
Outer swamp:	
Swamp Scrub	widespread, extensive
Swampy Woodland	sandy ridges
Swampy Riparian Woodland	levees lining creeks
Estuarine Scrub	estuaries draining the swamp
High ground within swamp:	
Grassy Woodland	Rythdale Ridge, Cardinia Ridge, Tynong Island
Surrounding plains:	
Grassy Woodland	locally extensive on plains
Plains Grassland	locally extensive on open plains, and The Inlets
Plains Grassy Wetland	drainage lines and depressions on open plains
Estuarine Reedbed	estuaries draining the swamp
Estuarine Wetland	estuaries draining the swamp
Brackish Sedgeland	estuaries draining the swamp
Brackish Grassland	estuaries draining the swamp
Estuarine Flats Grassland	estuaries draining the swamp
Coastal Saltmarsh	estuaries draining the swamp
Mangrove Shrubland	estuaries draining the swamp

CONCLUSION

The Kooweerup Swamp was a unique ecosystem with distinct zonation formed by inner and outer swamps. The inner swamp was a permanently inundated reed and rush swamp on deep peat with localised emergent sand ridges. It consisted of a descending series of lake-like cells or lagoons separated by dense belts of vegetation, resulting in multiple internal water levels rather than the single water level of most swamps. The fringing outer swamp was subject to frequent flooding and supported dense *Melaleuca* giving an impression that the scrub occurred throughout. Adjacent grasslands and grassy woodlands were occasionally flooded and were locally extensive beyond the generally sharp swamp boundary.

It appears that the inner swamp boundary was primarily flood controlled while the outer swamp boundary was primarily fire controlled on the plain, and topographically controlled by hills to the east. Aboriginal burning maintained the adjacent grasslands and woodlands but had little or no influence on the core of the swamp where permanent water prevented major peat fires.

Despite the major environmental change, some of the wetland flora and fauna of the original swamp live in, visit or pass through the area today, the many drains and pastures providing modified habitat. Swamp Paperbark and Common Reed are conspicuous along many drains. In addition, some flora and fauna from the forest catchment of the Bunyip River, such as Silver Wattle *Acacia dealbata*, have colonised the banks of the Bunyip Main Drain.

This study shows how careful interpretation of small remnants, in combination with examination of archival records, can further our knowledge of highly fragmented vegetation types such as native grasslands. It also demonstrates that existing vegetation on roadsides and in drains may be misleading as to pre-European vegetation patterns.

Further historical research and field investigation would resolve these wetland and grassland ecosystems more clearly, this analysis forming a basis for further study. An understanding of historical and existing ecosystems and landscapes provides the basis for informed land management. Small areas of scrub and grassland remain, with significant examples at The Inlets Waterway Reserve currently being managed by Melbourne Water.

All remnants of the Kooweerup Swamp and its associated grasslands require detailed mapping and scientifically based management for biodiversity conservation.

ACKNOWLEDGEMENTS

Thanks to Sally Mitchell, Katherine Crowder, Bretan Clifford, Robert Fitzgerald and Paul Young (Biosis Research) for mapping, Tim Allen for Fig. 3, and Damien Cook, Doug Frood, Ian Sargeant, Neville Scarlett, Jill Anderson, Gary Vines, Ian Smales, Chris Bloink, Peter Menkhorst, Ian Miles, Rob Gell, Scott Seymour and Cathy Dowling for comments.

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Source: *Monash Urban Lab*

The Coast of Victoria

The Shaping of Scenery

Eric C. F. Bird

Melbourne University Press
1993

First published 1993

Designed by Lauren Statham
Typeset by Syarikat Seng Teik Sdn. Bhd., Malaysia, in 11/13 point Goudy
Printed in Australia by
Brown Prior Anderson Pty Ltd, Burwood, Victoria, for
Melbourne University Press, Carlton, Victoria 3053
U.S.A. and Canada: International Specialized Book Services, Inc.,
5804 N.E. Hassalo Street, Portland, Oregon 97213-3644
United Kingdom and Europe: University College London Press,
Gower Street, London WC1E 6BT

National Library of Australia Cataloguing-in-Publication entry

Bird, E. C. F. (Eric Charles Frederick), 1930– .
The coast of Victoria.

Bibliography.
Includes index.
ISBN 0 522 84544 4.

1. Coasts—Victoria. 2. Geology—Victoria. 3. Geomorphology—
Victoria. I. Title.

551.45709945

Grateful acknowledgement is made to the Publications Sub-Committee, on behalf of the Committee on Research and Graduate Studies of the University of Melbourne, for a grant towards costs of production.

Contents

CHAPTER

6

Westernport Bay, French Island and Phillip Island

Westernport Bay

Westernport Bay occupies part of a tectonic depression, described as the Western Port sunkland by Keble (1950), between the Mornington Peninsula to the west and the South Gippsland Highlands to the east (Figure 131). On the western side the depression is bounded by the Tyabb Fault, and to the east by the Heath Hill and Bass Faults. It is more complex than the Port Phillip Bay sunkland, for it includes French Island and Phillip Island as relatively high areas and extends northward beneath the Koo-wee-rup plains as an area of swamp now largely reclaimed.

In Eocene times the Older Volcanics were laid down across the southern part of what is now Westernport Bay, and when the volcanic activity came to an end in the Oligocene a wide basalt plateau extended from the Mornington Peninsula across to Phillip Island and the southern parts of French Island. Broad valleys were then cut down into this plateau by rivers draining from north to south, and tectonic movements created the lowland within which—as in the Port Phillip area—there are Miocene and Pliocene marine deposits indicating successive incursions of the sea. In the Pleistocene there were further tectonic movements as well as sea level oscillations, so that Westernport Bay existed as a marine inlet during high sea level phases and as a coastal lowland when sea level fell. It attained its present outlines during the Late Quaternary marine transgression, about 6000 years ago, after the sea invaded the lowlands around French Island and Phillip Island. The geology of Westernport Bay was described and illustrated by Jenkin (1962, 1976), and discussed by Spencer-Jones et al. (1975).

Although tectonic movements played an important part in the evolution of Westernport Bay there is no simple relationship between the fault pattern and the present coastline. The outlines produced by tectonic deformation have been modified by subaerial processes, including erosion and deposition by runoff and rivers, as well as the effects of marine submergence and the shaping of coastal

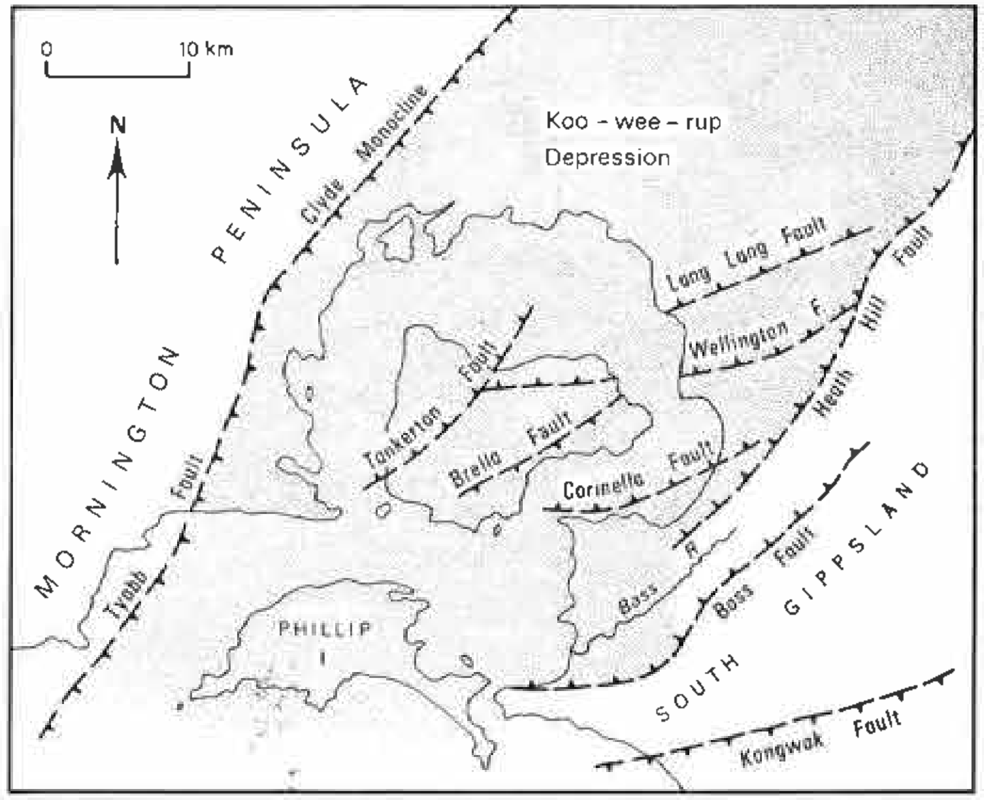


Figure 131 The Westernport sunkland (after Jenkin 1962)

and sea floor morphology by waves and currents. There was, for example, an episode in Pleistocene times when quartzose sand dunes formed in a zone that runs south-east from Melbourne through Cranbourne to Lang Lang and on to the northern parts of French Island (Whincup 1944). The climate was evidently then more arid, vegetation was sparse, and wind-blown sand was derived from weathered exposures of Tertiary sandstones, notably the Red Bluff Sand and the Baxter Sandstone. This sand was built into elongated ridges and parabolic dunes trending south-eastward across what is now the northern part of Westernport Bay to French Island: they formed during the Late Pleistocene low sea level phase when the bay floor was dry land. When the rising sea returned to Westernport Bay some of these dunes were were overwashed and rearranged into shoals.

Rivers draining into Westernport Bay include small streams such as Merricks Creek, flowing from the eastern slopes of the Mornington Peninsula, those that descend from the hill country north and east of the Koo-wee-rup plains, notably the Bunyip and the Lang Lang (which formerly discharged into extensive freshwater swamps and are now conveyed to Westernport Bay by artificial channels), and the Bass River entering the south-eastern corner. These streams deliver only small quantities of fresh water and sediment to Westernport Bay, which is (like Port Phillip Bay) essentially a marine rather than estuarine inlet.

Yet there are vast quantities of muddy sediment in and around Westernport Bay, forming intertidal shoals and marshlands and underlying the swampy Koo-wee-rup plains. With a more intricate configuration than Port Phillip Bay, where the intertidal zone is generally sandy or rocky, Westernport Bay has been an environment in which muddy sediment could accumulate during Pleistocene and Holocene times. The mud (consisting of silt, clay and organic matter) was derived partly from inwashed river sediment, and partly from the re-working by waves and tidal currents of fine-grained material derived from outcrops around and beneath the bay. A notable source was the clayey mantle on the weathered surface of the Older Volcanics, which are now exposed in cliffs, shore platforms and reefs around the southern parts of the bay. Onshore the basalt carries a capping of weathered clay, and a similar capping must have existed on outcrops that were submerged during the Late Quaternary marine transgression. Clay washed in from this weathered mantle was carried into the upper reaches of the bay by waves and incoming tides.

Shelly organisms live in these mud deposits. The shells have been sorted by waves and currents and banked alongside tidal creeks, or washed onshore to form shelly beaches, as on the north-east coast between Yallock Creek and the mouth of Lang Lang River.

During the Late Pleistocene low sea level phase Westernport Bay became a lowland bordered by hill country, with French Island a central and Phillip Island a southern upland. Bass River incised its channel across this lowland to flow out of what is now the eastern entrance at San Remo, and the small streams from the Mornington Peninsula extended their courses across the emerged sea floor to meet those draining the western parts of French Island and Phillip Island in a valley that ran out beneath the wider western entrance, and across the exposed plains that floor Bass Strait (Figure 3).

It seems that the area north of Westernport Bay escaped fluvial dissection during the Late Pleistocene low sea level phase, and retained a very low gradient, possibly back-tilted by tectonic movements: it persisted as Koo-wee-rup Swamp, an area of peat accumulation and occasional inflow of sediment from such streams as the Cardinia, Toomuc, Ararat, Bunyip and Lang Lang (Hills 1942). Tobin Yallock Swamp, south of Lang Lang, was another area of peat accumulation (Gunson 1968). It is probable that in Late Pleistocene times these swamps extended southward across to the north coast of French Island, where there are freshwater peat and black clay deposits similar to those of Tobin Yallock.

As the Late Quaternary marine transgression brought the sea back into the Westernport sunkland, waves swept sand in from the sea floor through the Western Entrance to nourish beaches along the Mornington Peninsula and Phillip Island coasts (Figure 132). To the north and east there was quieter submergence of alluvial lowlands and bordering freshwater swamps. A strait formed north of Phillip Island, and marine inlets developed and widened on either side of French

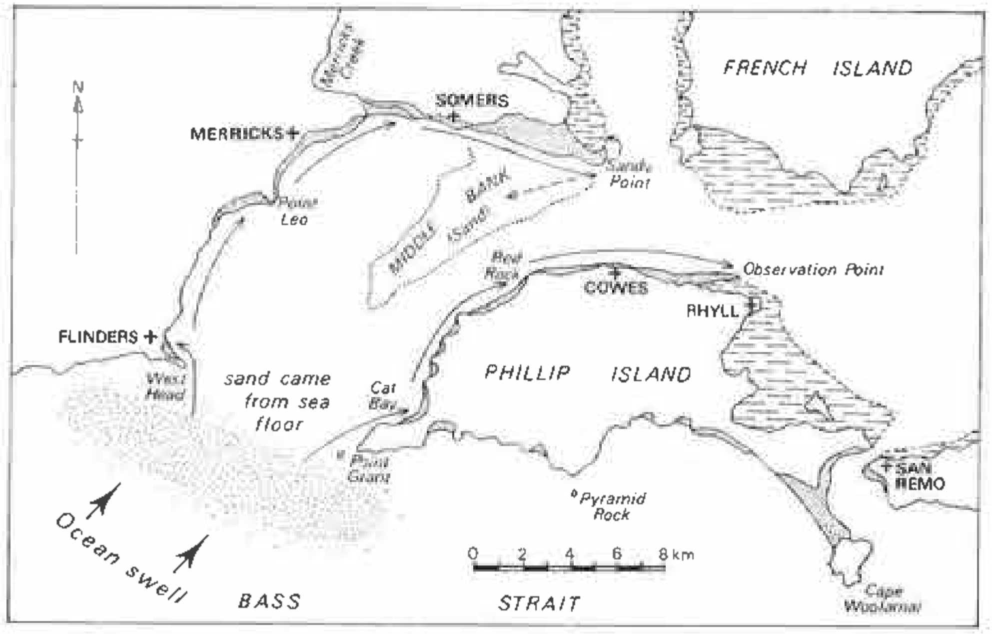


FIGURE 132 Sand movement into the south-west of Westernport Bay during Holocene times. Sand washed in from the sea floor has drifted along the coast from Flinders to Point Leo, Somers and Sandy Point, and some has been swept back on to Middle Bank by ebb tides. Sand has also drifted in to Cat Bay and along the north coast of Phillip Island, past Red Rock and Cowes to Observation Point.

Island until the two invading arms of the sea met in the north-east. The margins of Tobin Yallock Swamp were then trimmed back to form the low cliffs of black peaty clay seen north of Lang Lang.

Apart from a few cliffed sectors the present coast of Westernport Bay consists mainly of sandy beaches, spits and salt marshes with a seaward fringe of mangroves, fronted by extensive intertidal mudflats (Figure 133). The mangroves are submerged at high tide, but at low tide the sea retreats to expose a broad zone of mudflats with a patchy seagrass cover (Fetterplace 1974). At low tide the sea subsides into two dendritic channel systems, diverging from a tidal watershed north-east of French Island (Figure 134). The floor of Westernport Bay thus has a largely tide-dominated morphology, shaped and maintained by the ebb and flow of the tides, the spring tide range increasing from 1.5 metres at Flinders to over 3.3 metres along the northern shore at Tooradin.

In the northern parts of the bay the salt marsh and mangrove fringe has built a terrace upward and outward in front of an early Holocene coastline that was generally sandy, with some cliffed sectors. This former coastline developed about 6000 years ago, as the Late Quaternary marine transgression came to an end. A sandy beach can be traced at the inner edge of the salt marshes along the north-western shores of the bay, around Quail Island and Chinaman Island, and on the northern shores of French Island. Near Yaringa it becomes a recurved spit,

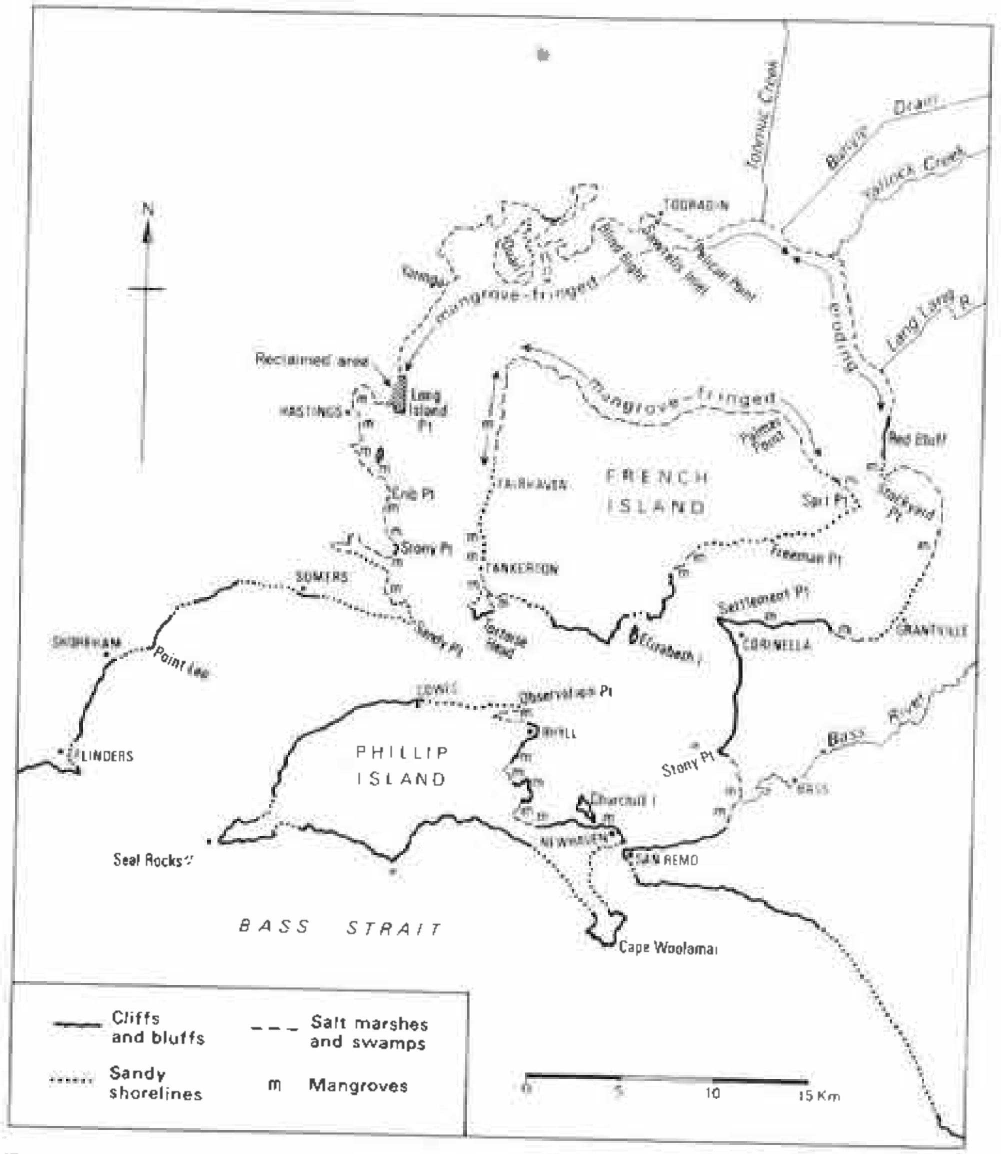


FIGURE 133 The coastal landforms of Westernport Bay, including French Island and Phillip Island

now completely enclosed by marshland (Scott 1977). Elsewhere the early Holocene coastline consisted of cliffs that are now bluffs behind the salt marsh, or low-lying swampy or alluvial land. The building of a mangrove-fringed salt marsh terrace around the northern shores of Westernport Bay during the past 6000 years was the outcome of vegetation colonising and stabilising foreshore areas as muddy sediment accreted (Figure 135). Although mangroves occur in other inlets and estuaries along the Victorian coast, it is in Westernport Bay that they are most extensive, and have been most studied.

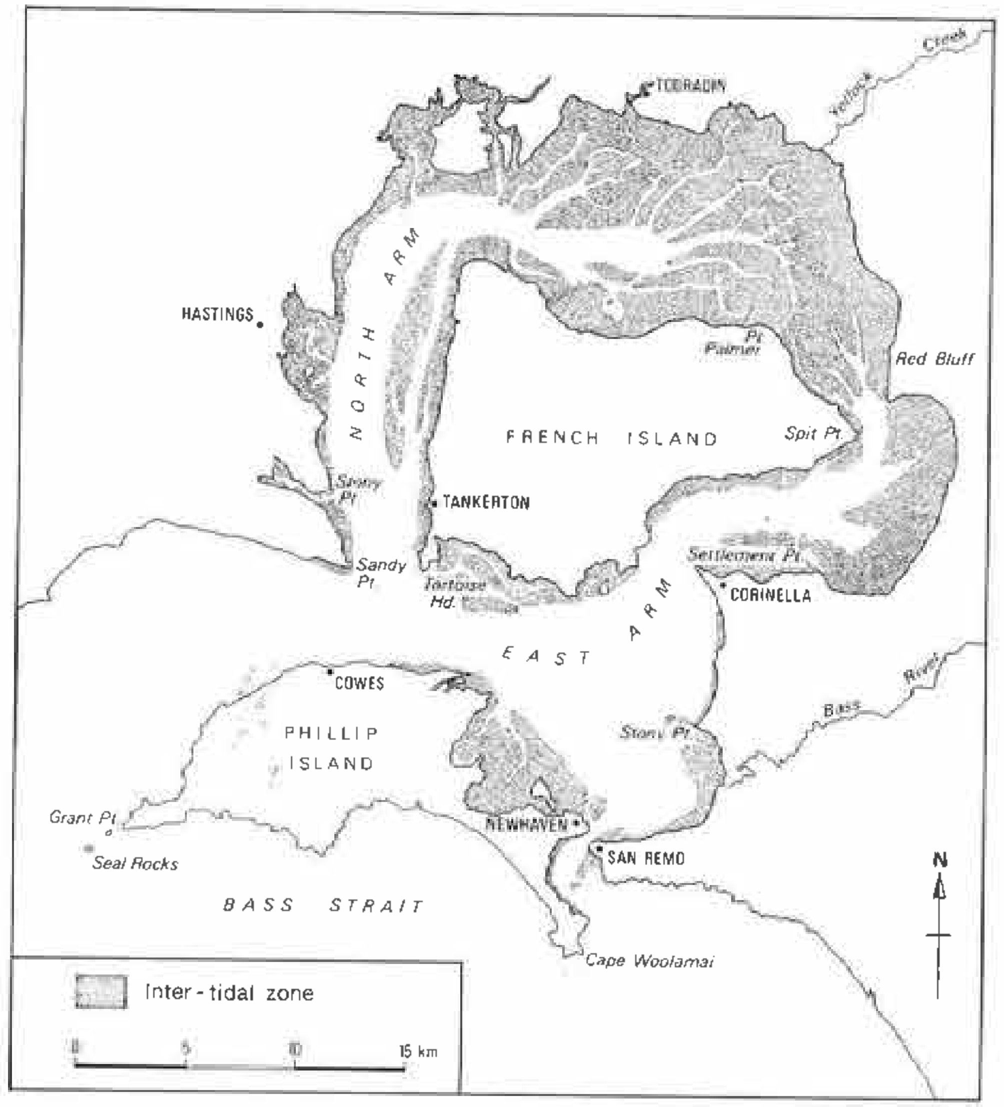


FIGURE 134 Extensive mudflats and sandy shoals are exposed at low tide in Westernport Bay, when creeks diverge from a tidal watershed that runs north-east from Palmer Point and flow into the deeper North Arm and East Arm channels.

The shores of Westernport Bay have been modified since George Smythe first surveyed them in 1842, as can be seen when his maps are compared with modern air photographs (Bird & Barson 1975). The bordering mangrove fringe has been much reduced by the cutting of channels to provide boat access, and by the arrival of drifting sand, which has killed the mangroves by covering and waterlogging their projecting pneumatophores. For a short time in the mid-nineteenth century mangroves were harvested and burnt to make barilla ash for soap manufacture (J. F. Bird 1975). They have also been damaged by occasional

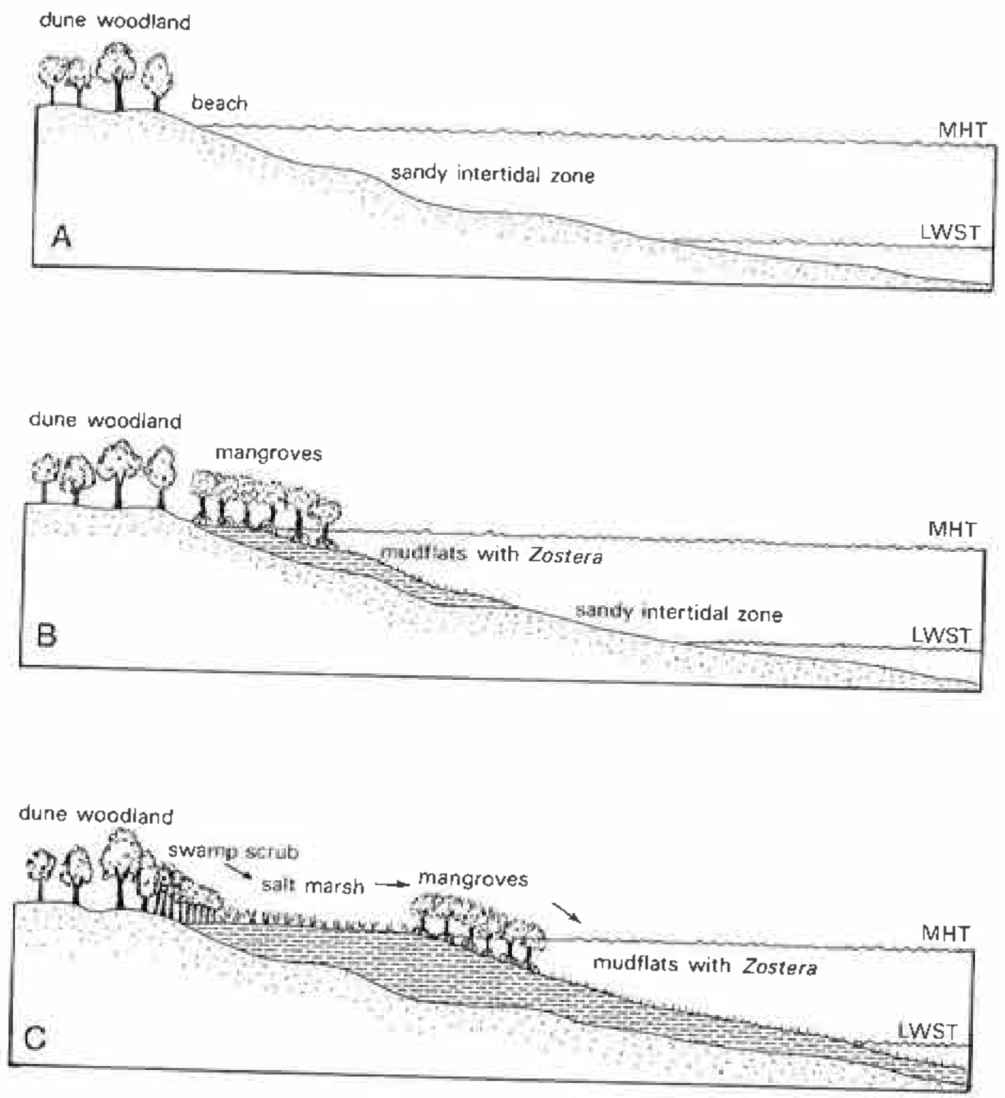


FIGURE 135 Evolution of the mangrove-salt marsh terrace on the shores of Westernport Bay: A, the sandy coast at the end of the Late Quaternary marine transgression; B, with Holocene mud accretion, a mangrove fringe developed and began to spread seaward; C, as the muddy terrace built up to mean high tide level (MHT), mangroves were displaced by salt marsh, backed by swamp scrub vegetation.

frosts, and defoliated by the accumulation of blankets of seagrass hay (mainly *Zostera*). Where the mangrove fringe has disappeared, the salt marsh terrace has been exposed to wave erosion, and a small cliff has formed (Figure 135; Enright 1969). There are only a few places where the mangroves have spread seaward during the past century and a half, such as the sheltered shores of Watson Inlet and east of Tortoise Head (Bird & Barson 1975).

The coasts of Westernport Bay and its islands can be divided into several segments. These will be discussed in sequence, starting from Flinders.

Flinders to Somers

The coast between Flinders and Somers consists of grassy and scrubby bluffs, with cliffed headlands fronted by shore platforms, all cut into Older Volcanics, mainly lava, with some tuff and agglomerate (Jutson 1948). The basalt has generally been strongly weathered to a friable brown rock or clayey material, but locally there are cliffs with ledges and rocky outcrops of darker unweathered lava, as on West Head at Flinders. Sandy beaches, backed by low grassy dunes, occupy intervening embayments, narrowing as they extend past rocky headlands. The beaches are 50 to 70 metres wide at low tide, and consist of fine to medium quartzose sand with some pebbles of basalt derived from the shore platform and dune calcarenite washed in from the sea floor. Low grassy terraces, consisting of sandy material over sand and gravel beach deposits can be seen in Kennon Cove, at Shoreham Beach, and between Point Leo and Merricks Beach. Overlooked by vegetated bluffs, these terraces originally formed during a mid-Holocene episode of higher sea level, but there have been subsequent phases of erosion and rebuilding along their outer fringes and detailed surveys are necessary to separate the mid-Holocene terrace (marked by an incipient soil profile) from the younger unweathered sand deposits.

The north-eastern shore of West Head is much less exposed than the oceanic south-western coast, and has scrubby slopes in weathered basalt, with some slump scars, and only minor basal cliffing behind a wide shore platform. The bluff runs behind Kennon Cove and northwards past Flinders Jetty. A broad shore platform then develops, and there are successive cliffed headlands, with some outlying stacks, and intervening bays with sand and basalt shingle beaches, low dunes and backing bluffs of varying steepness. Locally the bluffs are slumping.

At Shoreham Stony Creek flows out of an incised valley, and the beach is interrupted by scrub-coverted bluffs at Honeysuckle Point. A south-facing sandy beach resumes beneath The Pines, and runs in a gentle curve, shaped by slightly refracted ocean swell, to Point Leo. In recent decades the beach near Honeysuckle Point has prograded, and is backed by a low grassy dune. To the east this divides into a series of distinct parallel ridges, which eventually give place to higher grassy dunes, somewhat disrupted by blowouts, especially along the main access track to the beach. An interruption in the shore platform, occupied by gently-shelving nearshore sands, provides good waves for surf-riding off Point Leo beach.

The bluffs re-emerge as rocky cliffs on the headland at Point Leo, where there is a wide shore platform, and the beaches to the north have been shaped by waves that at high tide move in obliquely across the shore platform and drift sand northward (Figure 136). The mouth of East Creek has been deflected by this beach drifting, and the beach continues in front of scrubby bluffs with occasional cliffed promontories behind a wide shore platform diversified by ledges,

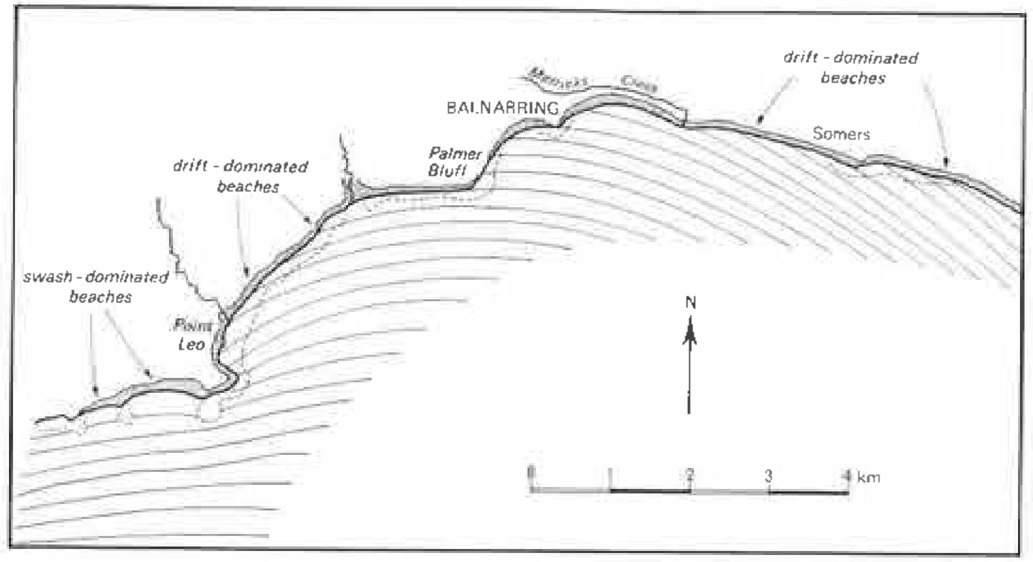


FIGURE 136 Typical wave patterns in south-western Westernport Bay, producing swash-dominated beaches west of Point Leo and drift-dominated beaches along which sand is carried to Balnarring, and on past Somers.

bouldery segments, and transverse clefts. There are several sectors with low grassy dunes that were built up by sand accretion after a phase of erosion in the 1950s, when several storms accompanied high spring tides. At Balnarring Beach this erosion threatened buildings, and a protective timber wall was built, with a boulder rampart and several groynes. When erosion gave place to accretion these became buried in a rebuilt sandy terrace, although in 1990 the outer edge of the grassy dunes was again cliffed and receding. Thus there have been alternations of erosion and accretion over periods of several decades in the southern part of Westernport Bay, related to the recurrence of unusual weather and tide associations, and perhaps to cycles of sand movement on the sea floor in the Western Entrance (see below, p. 202).

East from Balnarring Point the beach becomes a dune-capped spit that has deflected the mouth of Merricks Creek eastwards (Figure 137). The position of the outlet has varied considerably. Air photographs taken in the 1920s show the mouth of Merricks Creek well to the east of its present position, opening through the beach in front of the Somers Post Office. In the 1960s the present outlet was stabilised by wooden training walls, after which the beach prograded to form a slight foreland, with an intertidal sand delta.

Somers to Sandy Point

The beach at Somers is sandy, with some pebbles of dune calcarenite and basalt, and runs behind a wide shore platform, backed by steep scrub-covered bluffs, cut in Older Volcanics which pass inland as the shore platform comes to an end. The

FIGURE 137 Balnarring Beach, which has prograded in the past few years, with a grassy backshore and a convex beach profile with a wave-built berm (b)

beach continues, backed by dunes, for another five kilometres to Sandy Point, off which sand bars and shoals, partly exposed at low tide, run out south-west to Middle Bank (Bird 1985b). High tide in Westernport Bay reaches Somers 10 to 15 minutes after Flinders, and Sandy Point a few minutes later. The rising tide generates an eastward current of up to 80 cm/sec. along the coast between Somers and Sandy Point, and as the tide ebbs a strong outflow develops off Sandy Point, sweeping sand out to Middle Bank (Figure 132).

Ocean swell (wave periods typically 8 to 14 seconds) is much weakened as it passes northward through the shallow water towards Somers. East of Balnarring swell waves diminish because of the sheltering effect of Middle Bank, but they can sometimes be detected between Somers and Sandy Point at high tide, particularly when they are reinforced by a strong southerly wind. At low tide they do not penetrate the shallow nearshore waters. Wave action is also generated by local winds, which produce short (3 to 6 second) waves, arriving mainly from the south-west, but occasionally from the south-east. Waves from the south-west arrive obliquely, and produce eastward beach drifting, as well as a longshore current towards Sandy Point as the tide rises. At low tide wave action is diminished because the nearshore waters are shallow and dense seagrass beds absorb much of the wave energy. The prevailing westerly winds also carry dry beach sand along the shore, but occasional south-easterly winds temporarily reverse this aeolian drifting.

Whereas Point Leo beach is swash-dominated, with waves arriving to fit the curving beach, the beaches north to Balnarring and east past Somers are drift-dominated, with waves arriving obliquely to the shore and edging sand along the coast (Figure 136). The eastward drifting from Somers to Sandy Point takes the form of migration of a series of sandy lobes on a sinuous shore. The lobes may have originated from the intermittent passage of drifting sand past the mouth of Merricks Creek when it was sealed off by sand accretion, with interruptions when the creek mouth was open. Migration of sand lobes along the shore has resulted in phases of accretion as they arrived and erosion as they moved on. When Somers Yacht Club was built on one of these lobes it was not realised that this was a transitory feature: the severe erosion that has since developed here is the outcome of its onward migration. Building a wooden groyne has failed to trap drifting sand, probably because the armouring of the coast with large boulders has led to lowering of the foreshore by reflection scour, sand being swept offshore. The natural formation and migration of sand lobes has thus been interrupted, and erosion has become severe on Somers Beach as sand moves away along the coast.

This drifting sand eventually reaches Sandy Point, where there has been substantial progradation in recent years. Sectors of receding coastline (beach backed by cliffed dunes) alternate with sectors of advancing coastline (beach backed by incipient foredunes), the most obvious of which are at Cormorant Point and Sandy Point. On eroded sectors the dune cliff is almost vertical, and the beach profile smooth and evenly sloping or concave down to the low spring tide line (Figure 138). On prograded sectors the upper beach, fronting foredunes, has an undulating topography with layers of seagrass litter incorporated in the sand, which is loose and soft in texture, while the beach profile is convex. In the intertidal and nearshore zones there are low mounds of fine sand held in place by seagrasses (*Zostera* and *Cymodocea*), some of which have been eroded into steep-edged, flat-topped mesas capped by vegetation.

Changes along the beach between Somers and Sandy Point were monitored during the decade 1975–85 by means of repeated surveys along a series of 24 transects from fixed points in the dunes out to the low spring tide line. At the end of this decade the net change in cross-sectional area on each pair of adjacent transects was multiplied by the intervening distance to calculate the volume of sand gained or lost. The resulting sediment budget is presented in Figure 139. It was evident that substantial quantities of sand moved eastward along the beach.

Sand is swept out from Sandy Point by ebb currents to form a broad intertidal and subtidal shoal, Middle Bank, running out south-west, and shaped by the interaction of these currents and incoming ocean swell. It is possible that a cycle is completed during episodes of south-easterly wave action, when sand from these shoals moves across the bay floor to be deposited on the beaches between Shoreham and Somers. Some sand may also have moved across to Phillip Island, but the dredging of the Western Channel to maintain a navigable approach 750 metres wide with a minimum depth of about 14 metres for ships to reach port facilities at Crib Point and Long Island Point has probably halted this.

FIGURE 138 Erosion of the beach east of Somers has resulted in the cliffing of backshore dunes and a low, gently concave beach profile.

The Sandy Point dune foreland

The beach between Somers and Sandy Point is backed by numerous sub-parallel dune ridges bearing scrub and woodland (Figure 140). The area was first described by the French explorer Dumont D'Urville (1833), who landed near Sandy Point during his visit to Westernport Bay in the *Astrolabe* in November 1826, and walked inland across parallel ridges and swales so regular that he had difficulty in understanding how they had been formed without the work of man. The ridges have an amplitude of up to 3 metres, and soil profiles beneath the ridge crests increase in depth landwards, indicating that they formed successively on a prograding sandy coast (see Figure 184). The innermost carry *Eucalyptus* woodland with an understorey of bracken and heath plants. This gives place seaward to *Banksia integrifolia* woodland, then *Leptospermum laevigatum* (coast tea-tree) woodland, declining to scrub and grassy vegetation on the youngest dunes, immediately behind sectors of the beach that have recently prograded. The soil profiles and vegetation associations are of Holocene age, but there is an area of more deeply leached sandy terrain farther inland which may be older (Pleistocene) dunes of very low amplitude. Robin and Parsons (1976) found contrasts between the vegetation on the older, deeply leached sands and the younger parallel dunes, but the plant communities have been much modified by clearing and burning during recent decades.

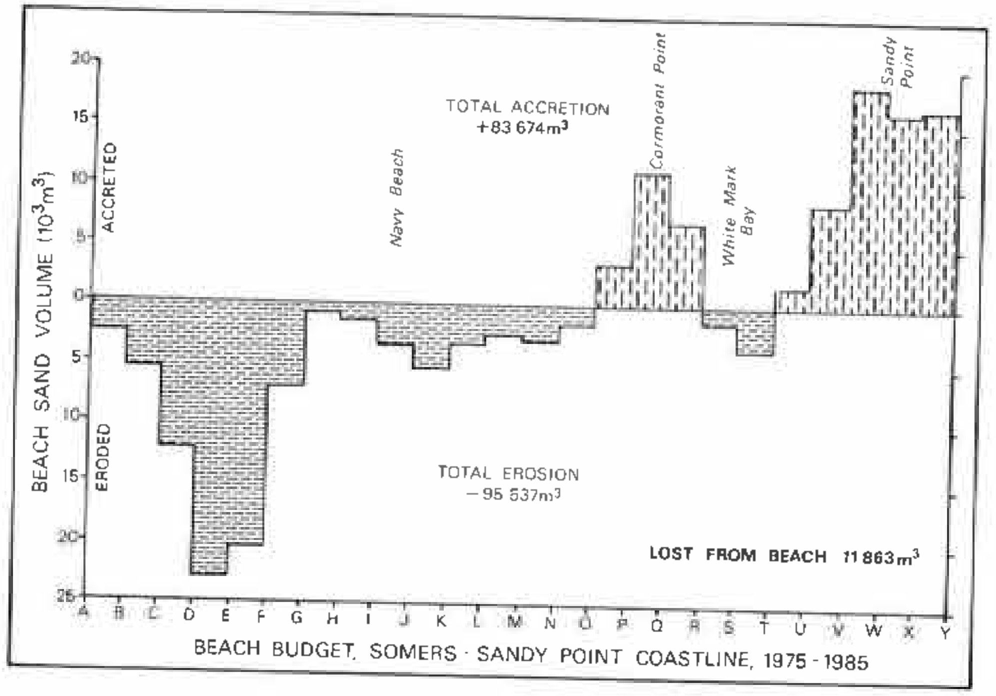


FIGURE 139 Gains and losses of sand volume measured in surveyed compartments along the beach between Somers and Sandy Point between 1975 and 1985 (Bird 1985). Over this period the coastline receded by up to 21.4 m on eroding sectors, and advanced by up to 55.3 m on accreting sectors. An area of 2.7 ha of sandy terrain was lost by erosion and almost 3.4 ha gained by deposition: the newly deposited land was generally lower in elevation than the receding sectors of dune cliff. The volumes of sand removed from the eroded sectors and added to the prograded sectors are indicated, with a net loss of about 11 800 m^3 from the beach system, which included sand blown to backshore dunes, swept round Sandy Point to be deposited on the spit to the north, and swept offshore, especially by the ebb current at Sandy Point. Similar changes have continued since 1985.

The parallel Holocene dunes on this large sandy foreland have been deposited since the Late Quaternary marine transgression brought the sea up to approximately its present level, about 6000 years ago (Marsden & Mallett 1975). The coastline east of Somers then consisted of cliffs behind shore platforms cut in Older Volcanics, but soon the drifting sand began to accumulate. As the marine transgression came to an end, sand was carried shoreward by wave action to be deposited as beaches along this coast. Bird and Jones (1988) documented the evolution of foredunes on Sandy Point, where intervening swales remained unvegetated and were deflated by wind eddies.

Stages in the growth of this sandy foreland may be deciphered from the dune ridge pattern, as shown in Figure 141. The later stages can be confirmed from early maps and charts and air photographs taken in 1939 and subsequently (Figure 142). In 1939 the coastline for a kilometre west from Sandy Point had been cut back to form a prominent dune cliff, which is still traceable behind the more

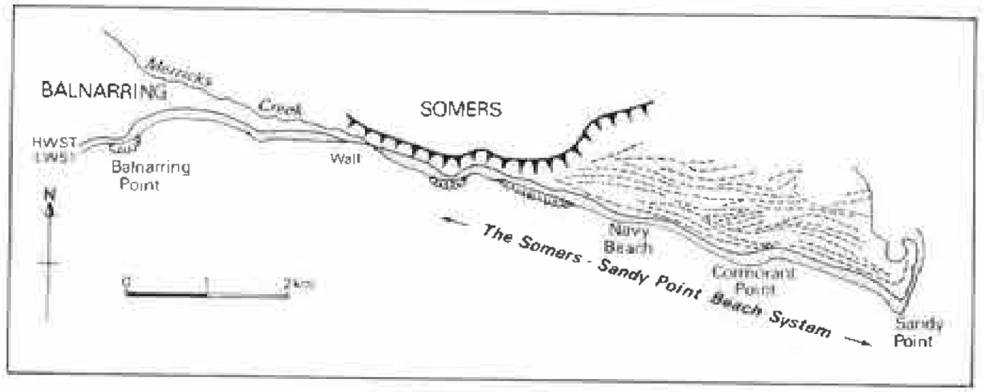


FIGURE 140 Coastal landforms near Somers, showing the beach system extending eastward to Sandy Point, backed by a wide foreland with multiple dune ridges, with the coastal bluffs passing inland

recent dunes east of Cormorant Point. Subsequent air photographs show that Cormorant Point has developed as a migrating lobate foreland, with erosion truncating foredunes on its western flank and successive dune ridges added along the prograding eastern shore (Figure 143).

The western shores of Westernport Bay

North of Sandy Point undulating low sand cliffs mark the truncated eastern shore of the beach ridge foreland, fronted by salt marsh with a seaward fringe of mangroves that curves round into Hanns Inlet. The Royal Australian Navy base HMAS *Cerberus* has been built at the head of this Inlet, and parts of the shore have been reclaimed for port structures. To the north the mangrove-fringed salt marshes resume in front of bluffs of Baxter Sandstone, but towards Stony Point the mangroves were interrupted when they were cleared in the mid-nineteenth century to give access for boats that landed and took off cattle. This exposed the sandstone bluffs to cliff erosion, releasing sand that drifted southward into the mangroves blanketing their pneumatophores and so killing them. Behind the dead mangroves a shelly sand beach formed and grew southward along the outer edge of the eroded salt marsh (Enright 1973). Subsequently the erosion of the sandstone cliff was halted by a sea wall, the supply of sand diminished, and the mangrove fringe has been reviving.

North of Stony Point the coast consists of a succession of bays with mangrove-fringed salt marsh in front of wooded bluffs and low headlands, such as Crib Point, where Baxter Sandstone and ferruginous gravels are exposed. At Jacks Beach there is a shore outcrop of strongly folded Silurian sandstones and mudstones partly obscured by mangroves. Offshore is Sandstone (Koolamadoo) Island, which consists of an anticlinal ridge in Silurian rocks, exposed in planed-off strata around the island shores (Keble 1950), and backed by grassy bluffs that

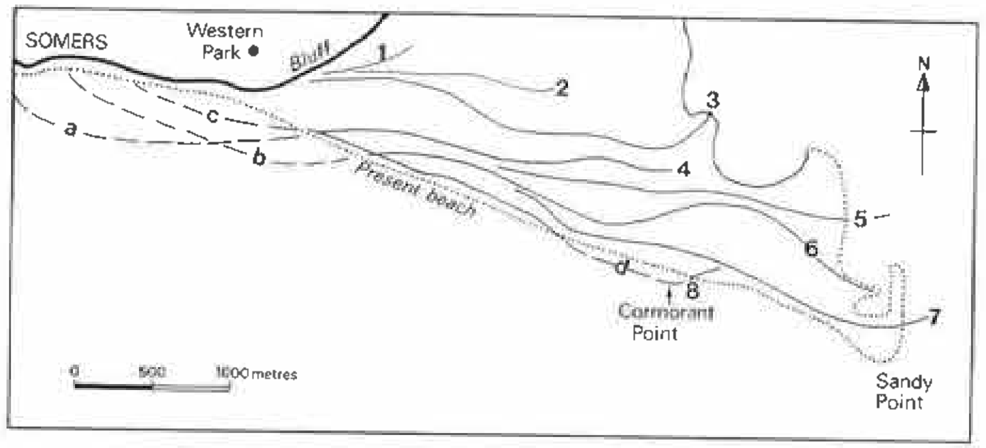


FIGURE 141 Stages in the evolution of the Sandy Point foreland. At stage 1 a beach formed in front of the bluff at Western Park, and at stage 2 a ridge developed in front of it, extending further eastwards. With further sand accretion, stage 2 was outflanked and extended as a recurved spit (stage 3). By stage 4 there had been progradation south of Somers, forming a lobe (a). By stage 5 the spit had grown eastward, but this has been truncated by erosion on the eastern shore. By stage 6 the coastline had become sinuous, with a lobe south of Western Park (b), which was then cut back (c). Stage 7 saw a further outgrowth, bringing the coastline to the configuration found by the European explorers who came here at the end of the 18th century.

The outline of Sandy Point was first shown on a sketch map drawn by George Bass when he discovered Western Port in 1798. Slightly different versions appear on charts compiled by Flinders in 1799, Barrallier in 1801, Faure in 1802, D'Urville in 1826 and Weatherall in 1827, but it is doubtful if the discrepancies indicate actual changes of the coastline, for none of these charts was based on detailed surveys. The first map based on triangulation, by George Smythe in 1842, showed an almost straight, slightly sinuous coastline like that of stage 7, and similar outlines appeared on charts produced by Stokes in 1843 and Cox in 1865.

Stage 8, attained early in the present century, included a small lobe (d), which can be seen on aerial photographs taken in 1939 (see Figure 142).

were cliffs when sea level was slightly higher. There is an outcrop of ferruginous Tertiary sandstones on the southern coast, where wave action from the south-east at high tides has built a sandy beach; on the more sheltered north-west shore there is a stand of mangroves.

At Hastings the mangroves and salt marshes have been replaced by a marina and parkland, and there has been land reclamation for port development on Long Island Point. At Denham Road the mangroves were cleared to provide boat access, and the backing salt marsh terrace was cut back by waves, producing a cliff a few centimetres high behind a wave-cut platform in marsh clays declining seaward. To the north there is evidence from air photographs that the mangrove fringe was much reduced in the 1930s, and has since partly recovered: the deduced sequence is shown in Figure 144. At Yaringa (Figure 145) a boat harbour was

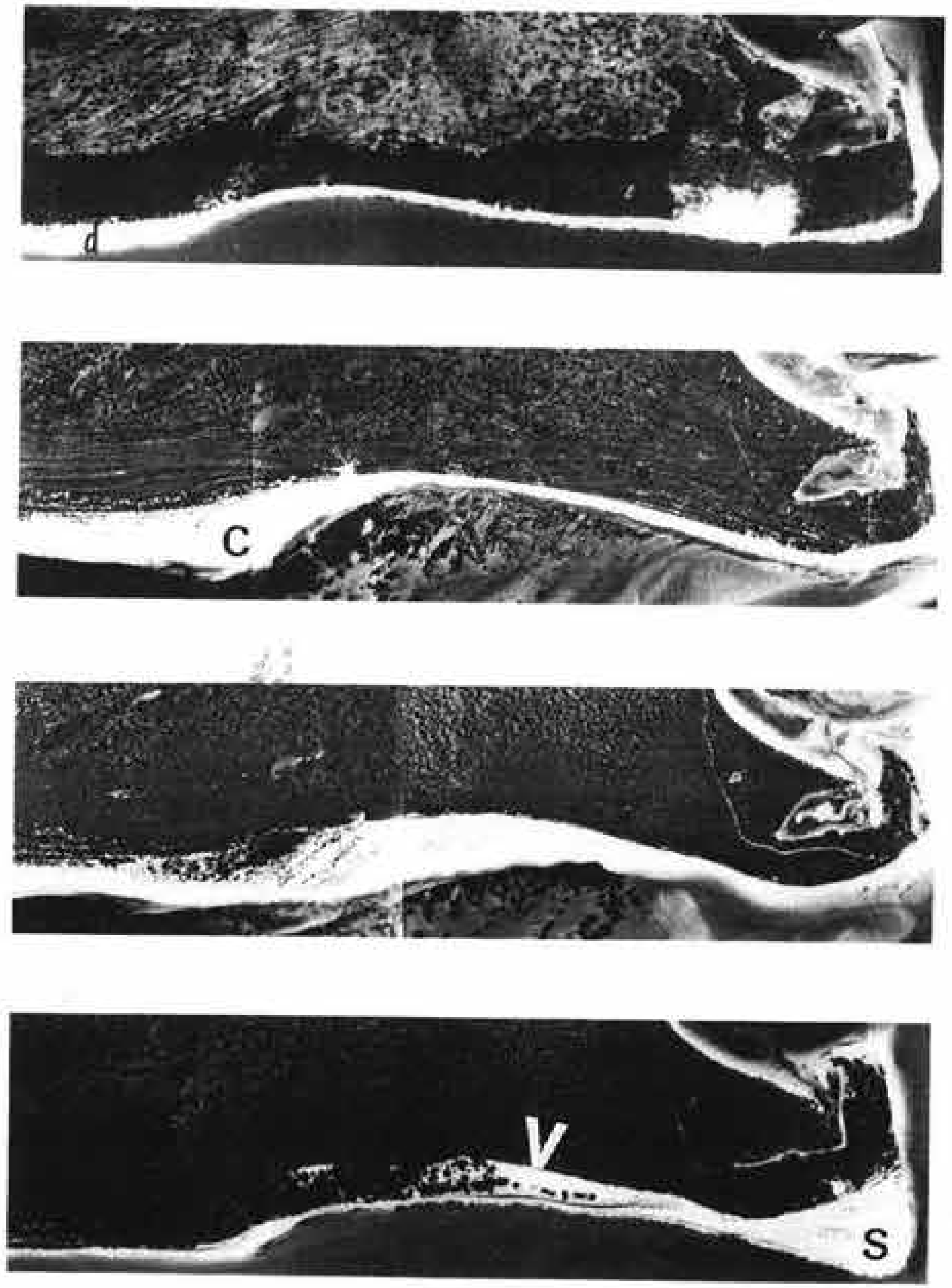


FIGURE 142 Aerial photographs showing stages in the eastward growth of Cormorant Point (C) and progradation on Sandy Point (S) between 1939 and 1984. V points to the cliffed dune marking the 1939 coastline. Crown Copyright Reserved.

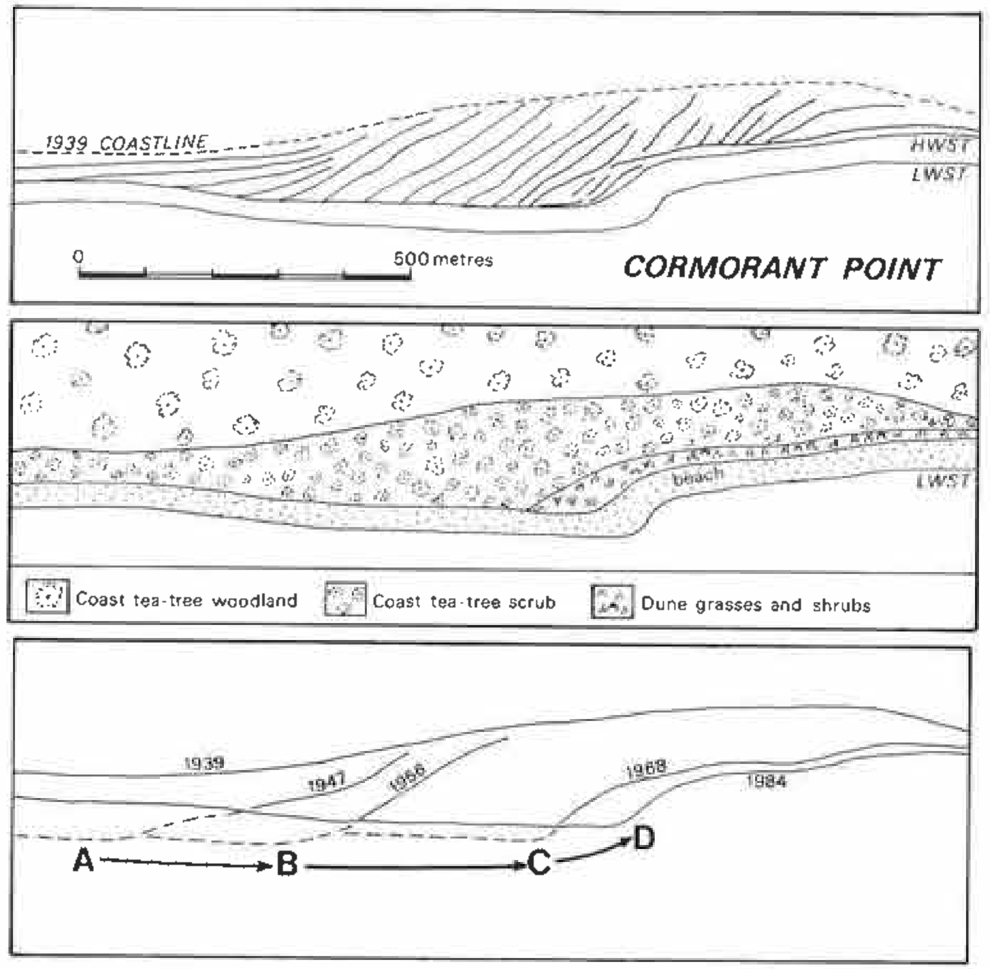


FIGURE 143 The pattern of dune ridges fronting the 1939 coastline at Cormorant Point (see Figure 142), and the vegetation cover in 1984. The lower diagram shows stages (A → D) in the evolution of this sandy coastline.

dredged through the salt marsh and mangroves, and out across tidal mudflats in 1967, and subsequently enlarged.

Successive surveys at Yaringa have shown sedimentation proceeding more rapidly in the mangrove fringe than on the salt marshes to the rear, while the level of the mudflats oscillated (Bird 1971). The mangroves are therefore acting as a land-building agent. As they spread forward on to the mudflats they create a more sheltered environment in which muddy sediment, carried in by waves and rising tides, is retained in such a way as to build up the depositional terrace to mean high tide level, where the mangroves are replaced by salt marsh plants (Bird 1980b). There have been phases when the mangrove fringe was reduced, and the salt marsh edge cliffed (Figure 144), and in places sandy material has

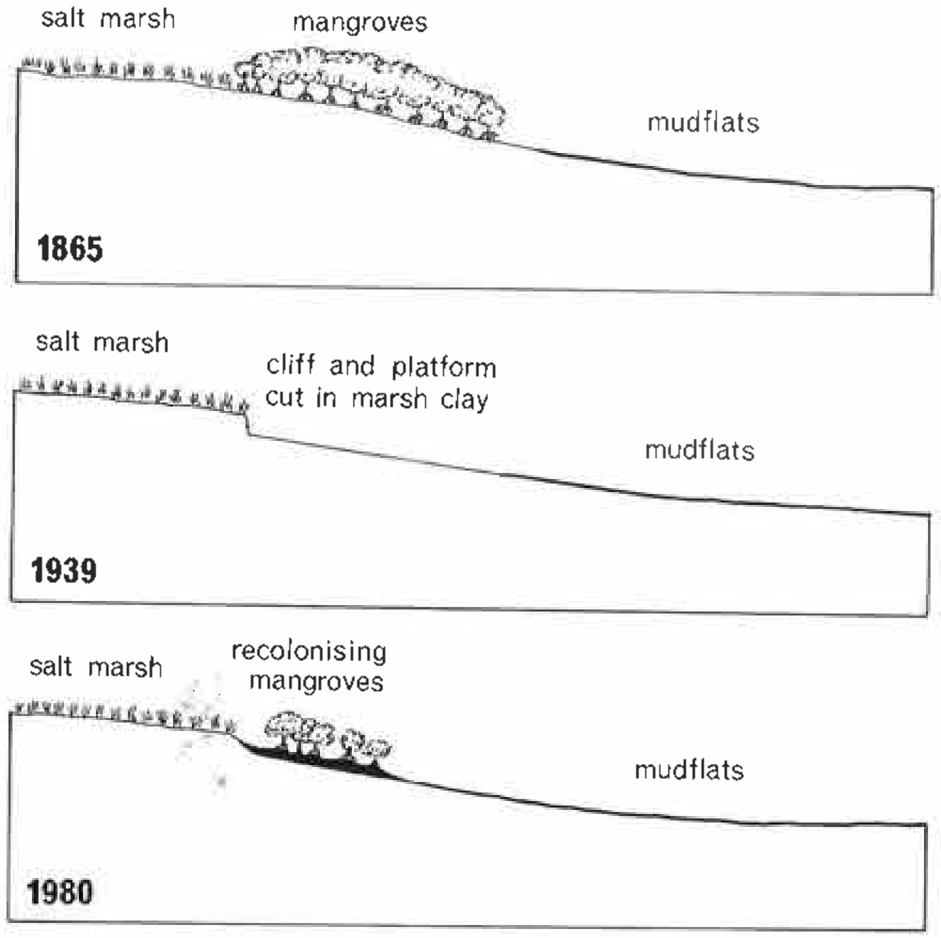


FIGURE 144 Changes at the outer edge of the salt marsh on the western shores of Westernport Bay. Cox's 1865 chart shows salt marsh bordered by mangroves, but on the 1939 air photographs the mangrove fringe is much depleted, and in places absent: the salt marsh margin has been cliffed behind a wave-cut platform in marsh clay. Subsequently much of the mangrove fringe has revived, but it is still possible to find the salt marsh cliff at the back of the mangroves.

been washed up on to the marshland, forming a perched ridge of sand, termed a chenier (Figure 146).

The northern shores of Westernport Bay

Similar mangrove-fringed salt marshes are advancing into Watson Bay, and they extend round Quail Island and Chinaman Island, where they enclose low undulating areas of quartzose dune sand (Jenkin 1962). Cannons Creek arrives between river cliffs cut in Baxter Sandstone, capped by Pleistocene quartzose dunes. Warneet stands on these low dunes beside Rutherford Creek, and the

FIGURE 145 An aerial view of the boat harbour at Yaringa (Y), formed by dredging a channel across the salt marsh, mangrove fringe and intertidal mudflats. The mid-Holocene sandy coastline can be seen as a pale line behind the salt marsh at Yaringa and on Quail Island (top right), and the mangrove fringe is spreading seaward on to mudflats on the shores of Watson Bay (top left).

dunes continue eastward past Tooradin until they disappear beneath the drained swamp land.

The mangroves and salt marshes extend behind Blind Bight to Sawtell Inlet, a mangrove-fringed tidal estuary at Tooradin. The hinterland here was the extensive Koo-wee-rup Swamp, which was an area of reeds, rushes, paperbark scrub and shallow meres when it was explored by William Hovell in 1826. It was drained during the later decades of the 19th century, when several channels were cut to carry water into the northern part of Westernport Bay (Key 1968). The drained land has subsided variably (up to 3 metres) as the result of shrinkage, compaction, oxidation and combustion of the peaty deposits (Hills 1942). Layers of sandy material washed out from the drains are interbedded with marine clays, as can be seen at low tide in the deposits exposed on the sides of tidal channels off The Inlets, Main Drain, and Yallock Creek. East of The Inlets the mangrove fringe fades out, and the low-lying coast has salt marshes and occasional cheniers of shelly sand driven on to the marshland by waves during exceptionally high tides. In the 1860s a ditch was cut to form an outlet for Lang Lang River, which had previously faded into Tobin Yallock Swamp, so that the swamp could be drained (Gunson 1968); it failed to confine the floodwaters, and was enlarged to a channel 3 metres wide and a metre deep in the 1870s and has since been widened further (J. F. Bird 1980). The river now opens to a wide intertidal delta

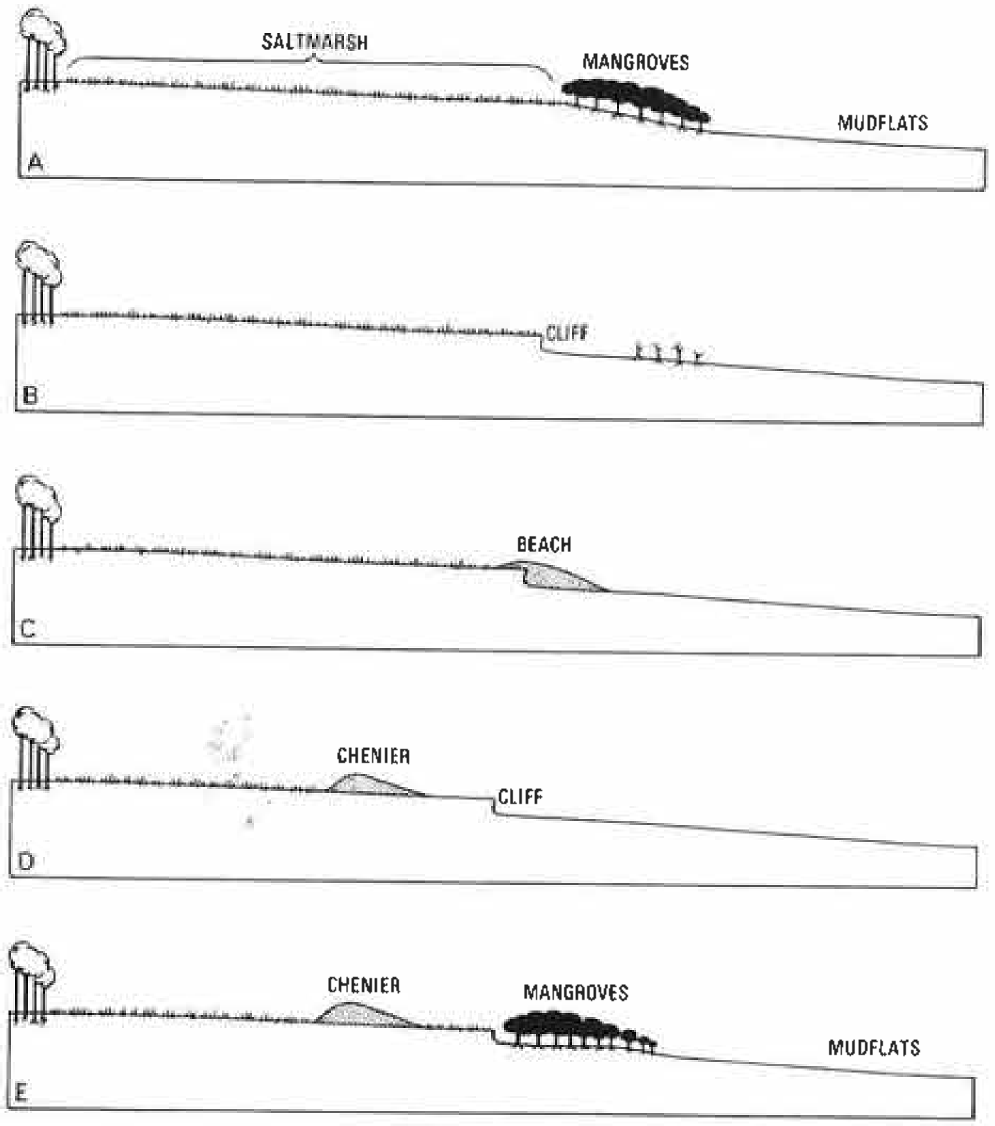


FIGURE 146 Evolution of cheniers on the salt marshes of Westernport Bay

consisting of silt washed out from the artificial cut as a result of flood control measures, but there has not been sufficient sediment to build a true delta above high tide level.

South-east of the mouth of Lang Lang River the coastline consists of embayed cliffs up to 2 metres high, cut in black swamp clays, generally steep or vertical, and fronted by a wave-cut ramp in firm black clay which passes seaward beneath soft mud (Gell 1974). When these clays dry they shrink and crack, and the polygonal fragments litter the shore as clay pebbles (Figure 147). The scalloped outlines of the Lang Lang clay cliffs may have originated before the artificial

FIGURE 147 Receding clay cliffs on the coast at Lang Lang, fronted by a sloping intertidal wave-cut platform which is littered with rounded cobbles and boulders of black clay

channel was cut, when floodwaters used to drain through the swamp scrub on Tobin Yallock and pour out as waterfalls along the shore.

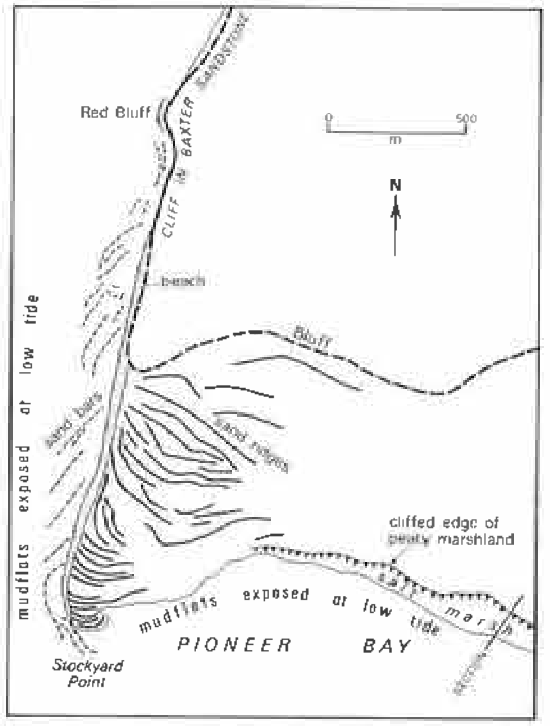
Offshore the dark grey mudflats, with patches of seagrass, widen on either side of a tidal watershed, exposed at low spring tide, with channels diverging to the west and south-east (Figure 134). It is a difficult area to work in because the mud is very soft, but it can be traversed by walking on platcher-boards or in kayaks propelled by hand across the mudflats (Bird 1974b). Miles (1974, 1976a) overcame these difficulties to make a study of the tidal watershed, which consists of 10 to 50 cm of soft mud over a shelly horizon capping freshwater peat similar to that beneath Koo-wee-rup Swamp. A sample from the top of the peat gave a radiocarbon date of 12 505 ± 300 years B.P, indicating that it formed during a Late Pleistocene stage before the rising sea reached this part of Westernport Bay, when freshwater swamps still extended across this area. The soft mud is stabilised by seagrass vegetation, and as the tide falls the sea subsides into saucer-shaped depressions, within which are channels, initially about 20 cm deep and 30 cm wide but growing in size and converging downstream. At low tide the outflow is confined to these channels, which it enters over receding waterfalls (Figure 148). At high spring tides the whole area is submerged by up to 2 metres. In recent years the heads of channels on the western side have been enlarging and extending, while those to the south-east have been shrinking and shortening, so that

FIGURE 148 Ian Miles at work during a low spring tide in 1974 on the tidal watershed in Westernport Bay, standing beside a waterfall that descends into a channel incised in the soft mud

the tidal watershed has been shifting south-eastward. The geomorphology and stratigraphy of this area requires much closer study.

Red Bluff at Lang Lang is a cliff cut in Baxter Sandstone, which here consists of stratified sandstone, sandy clays and gravels. Erosion of the softer layers has led to undercutting and collapse of sandstone blocks as the cliff retreats. Waves have carried sand derived from the cliff both northward to Lang Lang jetty and beyond, and southward to nourish the growth of the recurved spit at Stockyard Point (Nicholson 1974). This is because waves reaching this west-facing shore at high tide arrive either from the south-west, causing northward drifting, or from the north-west, carrying shore sand southward: the same pattern of alternating drift seen on the east coast of Port Phillip Bay (p. 148). Southward drifting has produced a succession of transverse migrating sand bars on the shore down to Stockyard Point. This is one of the sites where mangroves were cut in the 1840s to be burned for barilla ash, from which soap was manufactured (J. F. Bird 1975): a few scattered elderly mangrove trees survive on the shore south of Red Bluff.

Stockyard Point has grown southward by the successive addition of sandy beach and dune ridges, colonised by grasses and scrub. On the salt marsh terrace bordering Pioneer Bay Miles (1976b) found marine clay over freshwater clay with *Phragmites* relics, indicating that the terrace had been built up during the Holocene (Figure 149). The salt marsh has been much eroded following clearance of the



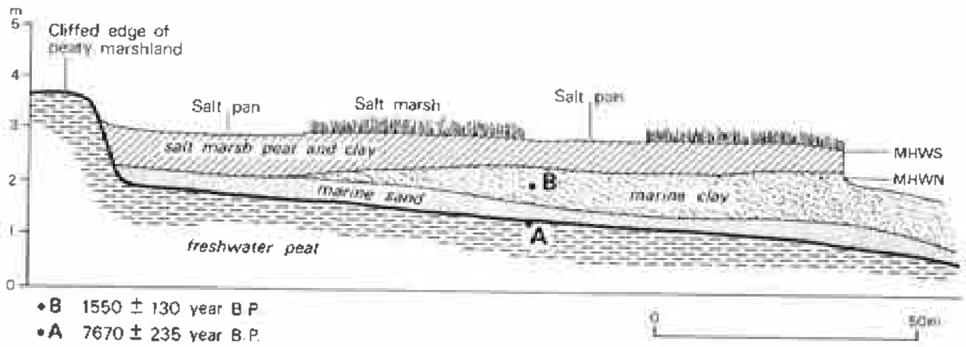


FIGURE 149 The recurved spit at Stockyard Point, Westernport Bay (above). The cliff at Red Bluff is receding, and sand is drifting southwards along the beach and in migrating nearshore bars to prolong Stockyard Point. The ridge pattern indicates that the western shore has been truncated as successive recurves were added to the south. As the spit grew the northern shore of Pioneer Bay became more sheltered, and salt marshes have developed in front of the formerly cliffed peaty marshland. A cross-section through the salt marsh (below) shows that it is backed and underlain by freshwater peat. Radiocarbon dates from a sample taken at A show that this peat was forming in mid-Holocene times. It was submerged and eroded by the rising sea about 6000 years ago, then overlain by Holocene marine sand and clay about 1500 years ago (sample B), since when the salt marsh has formed. Smythe's survey in 1842 showed the salt marsh with a seaward fringe of mangroves which has since disappeared: the seaward margin is now cliffed (based on diagrams by Miles 1976).

mangrove fringe, as off the old settlement of Queensferry, where there are wide intertidal sandy mudflats. To the south, a peninsula of Baxter Sandstone, underlain by Older Volcanics, runs out to Corinella, and is crossed by a low alluvial corridor which Rosengren (1988b) identified as an abandoned Holocene delta which Bass River had built when it flowed northward to this shore.

At Settlement Point, Corinella, the cliffed headland exposes the Older Volcanics, lava and tuff weathered to a friable red and yellow rock. These have been cut back to form a cliff, fronted by a shore platform on less weathered, or perhaps re-indurated, volcanic rock (Figure 150). On the headland an emerged shell bed is one of several indications of a higher Holocene sea level in Westernport Bay, overlain by an aboriginal kitchen midden. Pelican Island is a heap of basalt blocks and cobbles exposed during the ensuing emergence, and now covered with blackwood scrub.

Bays backed by low cliffs and bluffs cut in weathered basalt continue southward past Cobb Bluff, which has another wide shore platform, to Stony Point, where a dissected lava flow runs out as a swatchway to basaltic Reef Island, with a small outlier of Miocene sandstone. The bluffs then swing inland on the northern side of the Bass valley, behind a shallow embayment. Bass River flows out from a terraced valley through a wide triangular area of salt marsh interspersed with sandy beach ridges behind a shore fringed by intermittent mangroves

FIGURE 150 Cliff and shore platform cut in weathered basalt at Corinella on the eastern shore of Westernport Bay. The weathered basalt is soft and friable in the receding cliffs, but has been superficially indurated on the shore platform.

(Marsden & Mallett 1975). Within the salt marsh a cut-off meander is occupied by *Spartina* grass, introduced here from England in the early 1930s. *Spartina* was introduced to several Victorian estuaries: it failed in Lake Connewarre and Corio Bay, but has persisted at sites bordering Westernport Bay, Andersons Inlet and Corner Inlet (Boston 1981a). Off the mouth of the river a large fan of river silt and sand exposed at low tide (Figure 151) is the foundation for a future delta.

Along the southern side of the Bass valley a fault-line scarp marks the edge of the uplifted Cretaceous rocks of the South Gippsland Highlands, where bluffs and low cliffs of mudstone and Older Volcanics run out along the San Remo Peninsula, beside the eastern entrance to Westernport Bay.

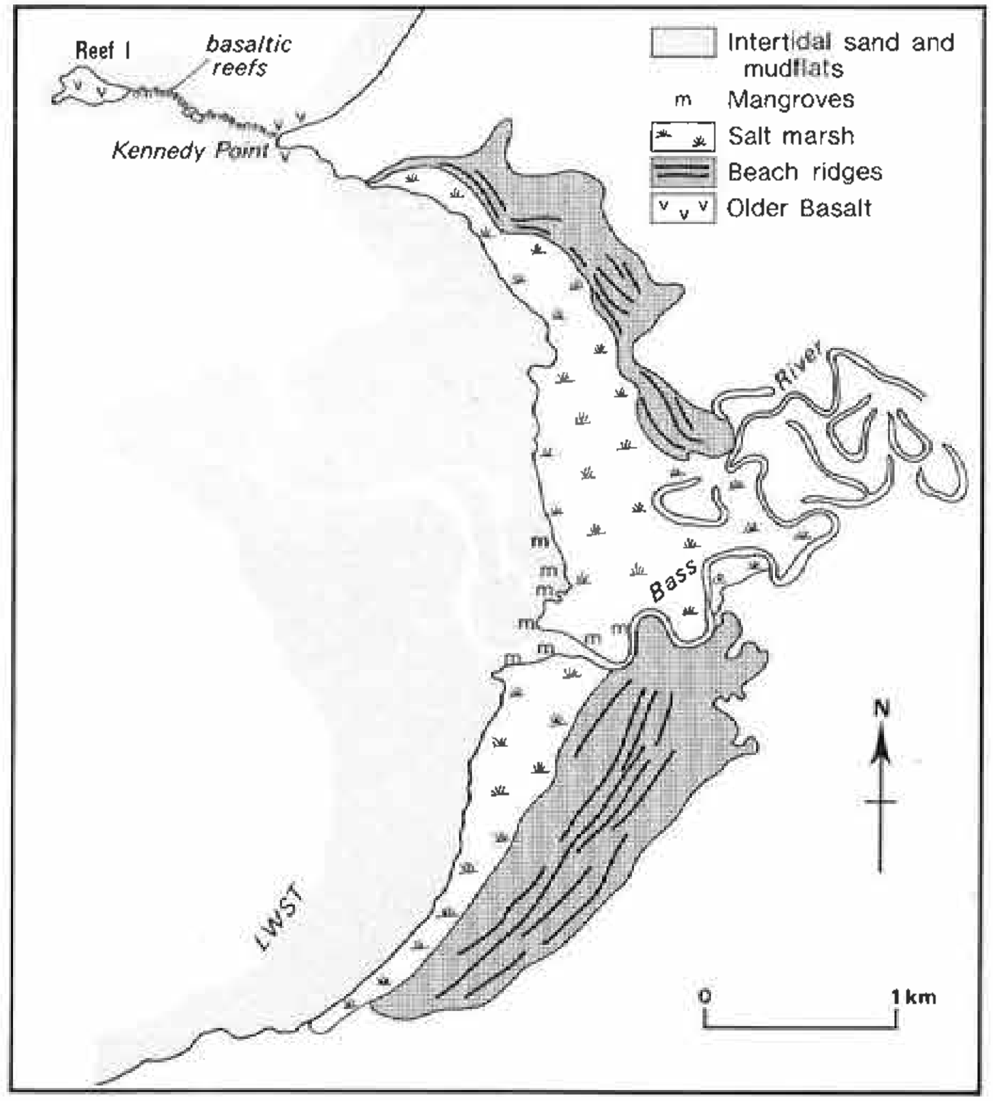


Figure 151 Coastal landforms in the vicinity of the Bass River delta (after Jenkin 1962)

French Island

French Island, with an area of about 167 square kilometres, consists of a broad ridge of Cretaceous rock running from south-west to north-east, bordered and overlain by Tertiary sands and clays, with a southern fringe of Older Volcanics, and extensive areas of Pleistocene quartzose dunes (Jenkin 1962). Almost all of the coastal fringe lies within the French Island State Park.

Tortoise Head (Figure 152), at the south-western corner, is a former island of Older Volcanic rocks, mainly basalt, attached by a beach of sand and gravel, bordered on the eastern side by salt marshes with a mangrove fringe. The headland is cliffed on the western and southern shores, exposed to attenuated ocean swell as well as south-westerly storm waves, but these pass into grassy bluffs on the more sheltered eastern and northern flanks. A landslide in weathered basaltic clays on the western side has pushed out a festoon of rocky boulders across the shore.

To the north there are bluffs and a shore platform cut in weathered Older Volcanics at Tankerton, but beyond the pier the bluff recedes behind a low coastal plain bearing sandy beach ridges, fringed by remnants of an eroded salt marsh, a line of old mangroves marking their former seaward limit. This mangrove fringe was intact when the coast was surveyed by George Smythe in 1842; now it begins farther north, and extends to Scrub Point, where it has also been interrupted. It is possible that these were sites where mangroves were harvested for barilla ash in the nineteenth century.

Transverse channels such as Redbill Creek are narrow and deep where they cross the salt marsh and mangrove fringe, but wider and shallower where this vegetation has been lost. Comparisons of vegetated and unvegetated shore sectors

Figure 152 Tortoise Head, French Island, showing the landslide (V) on the western slopes

at Scrub Point have shown that salt marsh and mangroves promoted sedimentation and built up depositional terraces that were soon lowered and cut back by erosion in sectors where the mangroves have disappeared (Figure 153; Bird 1986). The outlying mudflats surround outcrops of weathered basalt and spreads of ferruginous gravel and sand, which at Barrallier Island have been piled up by wave action into ridges, bordered by scrub-covered sand and mangroves.

The mangroves and salt marshes resume along the north shore of French Island to Palmer Point, where they are up to a kilometre wide. There are depressions within the salt marsh, one of which persists as a tidal lagoon, The Duck Splash, with inflowing creeks: it is uncertain how or when these depressions formed. At Palmer Point the salt marshes still show relics of rectangular enclosures built in the nineteenth century as evaporation ponds for salt production, but soon abandoned (Kraemers 1975).

East of Palmer Point low beach-fringed cliffs and bluffs pass behind a cuspate sandy foreland at Spit Point (also known as Sandy Point), where the northern shore has been truncated by wave action. The south-eastern coast of French Island has cliffed sectors at Blue Gum Point and Stockyard Point, and a sandy beach with occasional mangroves behind soft mudflats. On the embayed south coast there are cliffs and platforms cut in Cretaceous mudstone from Stockyard Point past Red Bluff almost to Long Point, and on the northern point of Elizabeth Island. Long Point and Peck Point are headlands with cliffs and reefs of Older Volcanics, which also dominate outlying Elizabeth Island, and form the causeway

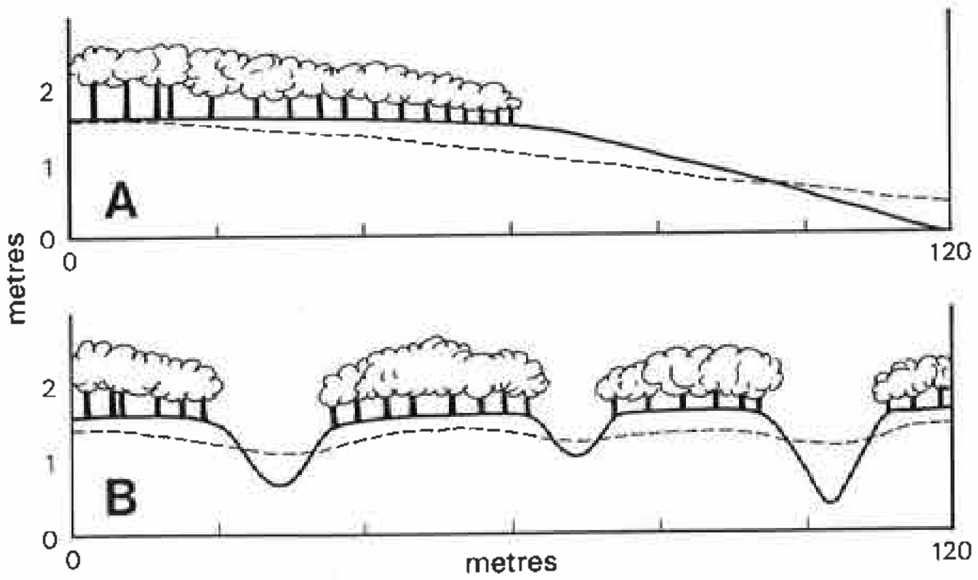


FIGURE 153 Sections showing changes in profile on the intertidal terrace bordering Westernport Bay where the mangrove cover has disappeared (pecked line). The lowering of the terrace and the shallowing of tidal creeks are reversed where mangroves have recolonised. The implication is that the mangroves trap sediment in patterns that would not otherwise develop, and thus play a geomorphological role (Bird 1986).

that runs out to Rams Island. Between the headlands are wide curving sandy bays, but the shore is too exposed for salt marshes or mangroves, except in the lee of Tortoise Head.

Phillip Island

Phillip Island lies across the southern part of Westernport Bay, between the wide Western Passage and the narrower Eastern Entrance. Its coast consists largely of cliffs and bluffs bordering a gently undulating plateau that rises southward to elevations of 40 to 50 metres along the bold Bass Strait coast. Small valleys have been incised by a few short streams, such as Saltwater Creek and Native Dog Creek.

The island is dominated by Older Volcanic rocks deposited in middle to late Eocene times, as indicated by a date of 47.1 million years obtained by potassium–argon analysis of a sample of basalt taken from Point Grant (Wellman 1974). They are a continuation of the Older Volcanics seen between Cape Schanck, Flinders and Somers, and show similar geomorphological features. On Phillip Island basalt was extruded from a number of cylindrical vents, now occupied by volcanic plugs, exposed on the south coast, as at Watt Point and Helen Head, and through fissures, seen as narrow dykes running across shore platforms, as at Kennon Head and Wild Dog Bluff (Figure 154). Successive lava flows spread across the landscape, and in cliff sections, especially along the south coast, they are seen as horizontal or gently dipping (rarely more than 5°) layers of solid or cindery grey to black rock, with intervening faintly stratified horizons of red, brown or grey tuff and agglomerate formed by the deposition of volcanic ash and gravel. On the south coast of the island cliffs and steep bluffs have been cut into basaltic lava, while the tuffs form intervening gentler slopes, as on Redcliff Point. The cliffed promontories are on harder basalt outcrops, and the bays have been excavated in the softer tuffs: Sunderland Bay, for example, has been cut in a red-brown tuff outcrop between headlands of basalt. In places the lavas show columnar structures with vertical polygonal jointing, as in the low cliffs at The Colonnades, and in Pyramid Rock, a conical stack of basalt rising from a foundation of pink and brown granite, which forms a rugged reef off the southernmost point of the island.

There are up to 60 metres of volcanic deposits on Phillip Island, burying older rock formations which outcrop only locally. Underlying Cambrian rocks have been found on the shore at Watt Point (Henry & Birch 1992). Cretaceous sandstones and mudstones, equivalent to the rocks seen on the south coast of French Island and the San Remo peninsula, are exposed in a quarry north-west of Rhyll, and a small area of Silurian rock outcrops on the shore of Reid Bight to the south. The basement of Devonian granite emerges to the south-east as Cape Woolamai, rising 109 metres above sea level, and to the south in the reef beneath Pyramid Rock.

FIGURE 154 A basaltic dyke on the shore platform at Wild Dog Bluff, Phillip Island, looking towards Redcliff Head. Generally the dykes are harder than the bordering volcanic rock, and stand up as walls across the shore platform, but in some places they are softer, and are etched out as ditches.

According to Edwards (1945) the general outline of Phillip Island consists of three former islands linked by sand deposition: Summerland Peninsula by an isthmus of dunes between Cat Bay and Summerland Bay, and Cape Woolamai by a similar isthmus. Sand deposition has enclosed lagoons and swamps, such as Green Lake and Swan Lake, in former embayments.

The coastline shows contrasts related to the degree of exposure to wave action. The southern coast receives the full force of south-westerly swell from the Southern Ocean and storm waves generated in Bass Strait, which break heavily across the shore platforms and attack the base of the cliffs. Between Point Grant and Pyramid Rock they have cut high cliffs in the steep coastal slopes, and shaped curving sandy surf beaches, but from Pyramid Rock to Sunderland Bluff the cliffs and surf beaches give place to grassy bluffs and rocky shores on a coast that faces south-east and receives diminished wave energy. On the west coast exposure to strong wave and wind action declines from Cat Bay to Red Rocks, and as it does so the cliffs become less bold and the beaches wider and more irregular in outline. These continue along the more sheltered north coast, while on the east coast, where wave energy is very low, there are embayments containing salt marshes, mangroves, and tidal mudflats.

Several parts of the coast of Phillip Island were formerly cliffed, but are now steep grassy or scrubby bluffs, with a somewhat rounded profile, convex-above-concave. These can be seen on the less exposed parts of the southern coast between Pyramid Rock and Sunderland Bluff, on the western shores of the Summerland Peninsula, where they are protected by a high shore platform of hard basalt, and on the more sheltered western and northern coasts. They are also found on the eastern coast, passing behind the mangrove-fringed salt marshes in Reid Bight and along the southern shores of Rhyll Inlet. Reduction of vertical sea cliffs to rounded, vegetated bluffs is probably the outcome of a slight fall in sea level about 4000 years ago, the active, receding cliffs persisting only on the most exposed parts of the coast. Emergence has also assisted the development of tidal mudflats, mangroves and salt marshes in the eastern bays, and around Rhyll Inlet, in the shelter of the spit at Observation Point.

The beaches of Phillip Island consist mainly of sand washed in from the sea floor. They contain a high proportion of quartz and carbonate, and only small amounts of material derived from erosion of the Older Volcanics. The few small streams that drain to the coast carry silt and clay, rather than sand. There are also varying proportions of shelly material, washed in from nearshore reef habitats, as at Shelly Beach and Cowrie Beach on the Summerland Peninsula, where there are whole shells as well as shelly material broken down to calcareous grit and sand, sometimes arranged into beach cusps. After stormy periods sand is washed away to expose underlying basaltic gravels eroded from the cliffs and shore platforms.

Sand blown inland by onshore winds has formed dunes, as at Summerland Bay, and there is Pleistocene dune calcarenite behind Cat Bay. In Summerland Bay the beach is backed by dunes in which the Fairy Penguin (*Eudyptula minor*), the only penguin species that breeds on the Australian coast, has a major colony. The penguin parade at Summerland Beach each dusk has become a world-famous tourist attraction.

Features of the south coast of Phillip Island, from Point Grant to Cape Woolamai and Cleeland Bight will be described first, and then those of the western, northern and eastern coastline.

The south coast of Phillip Island

At Point Grant solid lava flows can be seen in the cliffs and in The Nobbies, a chain of steep-sided islets that rise above the wide bouldery intertidal shore platform. Pink and grey tuffs and agglomerates underlie a dissected lava flow; their colours are due to varying degrees of oxidation of iron compounds contained in the volcanic rocks. Offshore, remnants of basaltic lava flows form Seal Rocks, seaward of Point Grant, a State Faunal Reserve for the protection of the seal colony. Seals used to be common along the Victorian coast, but they were hunted intensively during the early decades of European occupation, and are now found only on a few rocky islands.

East from Point Grant, on the southern coast of the Summerland peninsula, several gorges have been cut out by the sea, working back along joint planes. There are pebble, cobble and boulder beaches in the coves, consisting of rock fragments eroded from adjacent basalt cliffs. They are separated by narrow steep-sided promontories, which follow a SSW–NNE trend. Marine erosion along planes of jointing has formed gulches across the shore platforms and caves in the cliffs. The Blowhole, near Point Grant, is a cave that has been excavated in the basalt cliffs behind such a gulch by storm waves: at low tide it is about 6 metres wide, 12 metres long and 4.5 metres high. Large waves swirl into it and trap air against the rear wall, and as each wave subsides the compressed air escapes violently, blowing out showers of spray. It is a marine cave rather than a true blowhole, which is an opening in the ceiling of a cave through which spray is ejected, as in The Blowhole near Lochard Gorge (page 74).

The shore platforms on the coast between Point Grant and Pyramid Rock are strongly influenced by geological structure, many segments coinciding with the upper surface of a lava flow. Some are storm wave platforms, shaped by strong wave attack which has dislodged and removed overlying weathered rock material and cut out cliff-face ledges along the flat or gently dipping lava surfaces, as on Helen Head. There are horizontal platforms cut in lavas and tuffs at about mid-tide level as the result of weathering by repeated wetting and drying, similar to those seen on the basalts of the Portland-Port Fairy and Flinders coasts. In places potholes have been scoured out where stones have been swirled by wave swash, and on Helen Head some of these have been enlarged by abrasion to pools which may eventually become connected to form gulches or gutters along joints. Low residual stacks of harder basalt rise above the shore platform.

On parts of the southern coast, as at Phelan Bluff, there are platforms 3 to 5 metres above high tide level, some of which are prominent ledges of basalt, exposed by storm wave erosion of overlying tuffs. Others may be remnants of shore platforms cut when the sea stood at a higher level, but storm waves still occasionally break over them, and may have helped to shape them. They are backed by sloping bluffs. Storm-piled cobble beaches now form grassy terraces 1 to 2 metres above the present limits of active beaches, as at Point Grant and on the western side of Helen Head, and are probably a legacy of a higher Holocene sea level phase, when the sea stood 1 to 2 metres above its present level and the bluffs which now back them were receding cliffs. A subsequent fall in sea level has resulted in the degradation of the cliffs to sloping bluffs, and the dissection of the shore platform into irregular, bouldery areas with relics of the higher platform and patches of flat, wet shore platform at present mid-tide level.

Between Pyramid Rock and Sunderland Bluff the coast curves round to face south-east and the grassy bluffs show only minor cliffing behind shore platforms (Figure 155), which include segments of the slightly emerged mid-Holocene platform which stand at a level now awash only at the highest tides, and are now undergoing dissection and lowering. Abrasion ramps are found where waves have moved sand or gravel to and fro, scouring a smooth rock slope at the base of the cliffs. Outcrops of softer light brown tuff and agglomerate have been excavated

FIGURE 155 Bluffs on the south-east coast of Phillip Island were cliffs during a mid-Holocene higher sea level phase, behind segments of slightly emerged shore platform still visible at high tide.

to form lower platforms and gulches through which sand has been washed up from the sea floor to form occasional beaches. At Smith Bluff spheroidal weathering around central residual corestones is displayed in the basalt, the corestones having weathered out to form an accumulation of rounded boulders at the cliff base. The basalt hereabouts is vesicular, with cavities occupied by calcite, and iron oxides have also been deposited along joints. At the eastern end of Smith Beach there is an unusual outcrop of coarse quartzose sandstone that was deposited between successive lava flows, and has been silicified to a cream-coloured quartzite. The adjacent beach, derived from this quartzite, is much coarser than the other sandy beaches on Phillip Island.

Beyond Sunderland Bluff the rocky shores give place to lengthening surf beaches of calcareous sand, with only intermittent cliffs and shore platforms. Forrest Caves have been cut into a high segment of shore platform, the surface of which has been indurated by ferruginisation. They are submerged at high tide, and their roofs have partially collapsed, leaving heaps of large boulders. Exposure to strong wave action increases again towards Woolamai Surf Beach, on which dark heavy minerals, including olivine derived from basalt and zircon, augite, rutile, tourmaline and garnet from granite (which outcrops offshore between Cape Woolamai and Pyramid Rock) are abundant (Beasley 1957).

Woolamai Surf Beach is backed by Pleistocene dune calcarenites and capping Holocene dunes of the Woolamai isthmus, up to 100 metres high, which attaches the granitic upland of Cape Woolamai to the mainland. The dune calcarenites are underlain by quartzose dune sands, which emerge to form parabolic dunes on the higher slopes of the Cape. Jenkin (1962) suggested that sand dunes on Cape Woolamai were aligned along joints in the granite, but there is little evidence to support this idea, and Teh Tiong Sa (1973) concluded that the dune ridge alignments had developed along parallel strips where marram grass was planted in the 1920s. The parabolic dunes have orientations related to onshore wind resultants.

Cape Woolamai

In contrast with the extrusive volcanic rocks, the pink granite of Cape Woolamai was intruded into Palaeozoic rock formations, probably during the Devonian period, about 390 million years ago. The granite is a coarse crystalline rock, with veins of fine-grained aplite, and some cavities lined with ingrown quartz and felspar crystals. There are numerous vertical and horizontal joints which intersect the crystalline rock at various angles, and have been etched out by weathering to produce cracks and crevices between blocks, columns and pinnacles of granite. This castellated profile contrasts with other granites on the Victorian coast, which show domal structures.

South-east of Woolamai Beach the proportion of granite pebbles to basalt pebbles increases along the shore as the basalt outcrop gives place to well-jointed granite. The initially angular granite fragments have become rounded as waves

rolled them along the shore. At the base of the cliffs there is an abrasion ramp cut where waves have moved pebbles to and fro on the shore, and percussion marks and flaking indicate the erosion that occurs when they are hurled at the cliff during storms. Towards the top of the cliff the granite has been decomposed by weathering, and is overlain by derived pale quartz and felspar grits, capped by dunes.

On top of the cliffs the weathered material and dune capping are riddled with mutton-bird burrows, partly unvegetated, partly obscured by *Tetragonia* growth. These Bass Strait mutton-birds (short-tailed shearwater, *Puffinus tenuirostris*) come to the coastal rookeries at dusk in the summer months. They are away over the Pacific from April to September, but return to their burrows here and along the southern coast near Forrest Bluff and the south-west coast behind Woolshed Bight, prior to the breeding season in November (Teh Tiong Sa 1974).

The granite cliffs of Cape Woolamai are higher (about 75 metres) and more rugged on the south-west side, which faces the strongest waves, than on the less exposed south-eastern and eastern shores. Marine erosion has penetrated along joint planes, forming alternating gorges and buttresses. Storm-tossed boulders are found along the cliff tops, proof of the fury of wave attack during storms. Rock stacks formed of pillars and columns of granite occur along the east coast of Cape Woolamai, separated from the cliff by marine erosion along joint planes.

The Cape Woolamai granite ends northward on the shores of Cleeland Bight, where there was formerly a granite quarry. Squared blocks of cut and chiselled granite have been piled up to form a quay, and there are the remains of a loading jetty. The quarry was opened in 1891 to win stone used in the Colonial Mutual Life Assurance Building in Collins Street, Melbourne, but it fell into disuse the following year after the ship that carried the stone disappeared offshore.

Cleeland Bight

Dunes have spilled across the Woolamai isthmus to the shore of Cleeland Bight (Figure 156), supplying sand to form wide beaches backed by grassy low foredunes (Bird 1980a). Longshore drifting carried sand northward as far as the road bridge at Newhaven (Figure 157). The sand dunes on Cape Woolamai were probably fairly stable and well vegetated until the introduction of rabbits in the late nineteenth century led to depletion of the vegetation cover and the mobilisation of drifting sand. In 1979 marram grass was planted to stabilise these dunes, thereby reducing the sand supply to Cleeland Bight, and beach erosion has ensued, spreading northward along the shore, where the beach is backed by cliffs of crumbling sand (Figure 158). Sand eroded from this beach has drifted northwards to accumulate along the shore beyond Homestead Point, which has advanced by at least 100 metres since air photographs were taken in 1941. Low grassy dunes have built up on successive ridges on this prograded sandy shore.

FIGURE 156 Cape Woolamai in 1957, showing sand drifting across the isthmus from Woolamai Surf Beach (right) to Cleeland Bight (left). Photograph by Airspy Limited.

The west and north coasts of Phillip Island

On the west coast of Phillip Island Flynn Reef is an example of a shore platform developing through the disintegration of an intricately jointed lava flow. It includes sharp escarpments, clefts eroded along joints, and residual mesas of hard basalt. Faceted blocks of lava, bounded by intersecting joints, have been dislodged from the reef and rolled up on to the shore, where they have become rounded into boulders, diminishing by attrition to cobbles and pebbles on the beach. To the north, Grossard Point is a rocky promontory formed where hard, dark, little-weathered basalt outcrops at the cliff base and on the adjacent platform, but the cliff face is receding in soft, weathered tuff which has decomposed to form cracking clays. Beaches are backed by a low grassy foredune, then by older, scrubby dunes, the seaward margin of which was cliffed during storms in the 1950s. Outcrops of red tuff also form small cliffs and shore platforms between Penguin Rocks and Cowes, where three small headlands interrupt the sandy beach. Interspersed with the shore platforms are segments of steep-edged seagrass terrace, similar to those at Somers (p. 202), built by the accretion of fine sand and silt in patches of *Zostera* growing below mid-tide level.

Sandy beaches are almost continuous, interrupted only by minor rocky promontories, from Cat Bay to Ventnor, and on past Cowes and Erehwon Point to form the northern shore of a compound recurved spit which culminates in Observation Point (Barnes 1976). These beaches are similar to those that extend from Point Leo past Balnarring to Somers and Sandy Point on the Mornington Peninsula to the north-west. Both have been produced by the inwashing of sand from the sea floor in the western approaches to Westernport Bay, and along the bordering coastlines (Figure 132) during and since the Late Quaternary marine

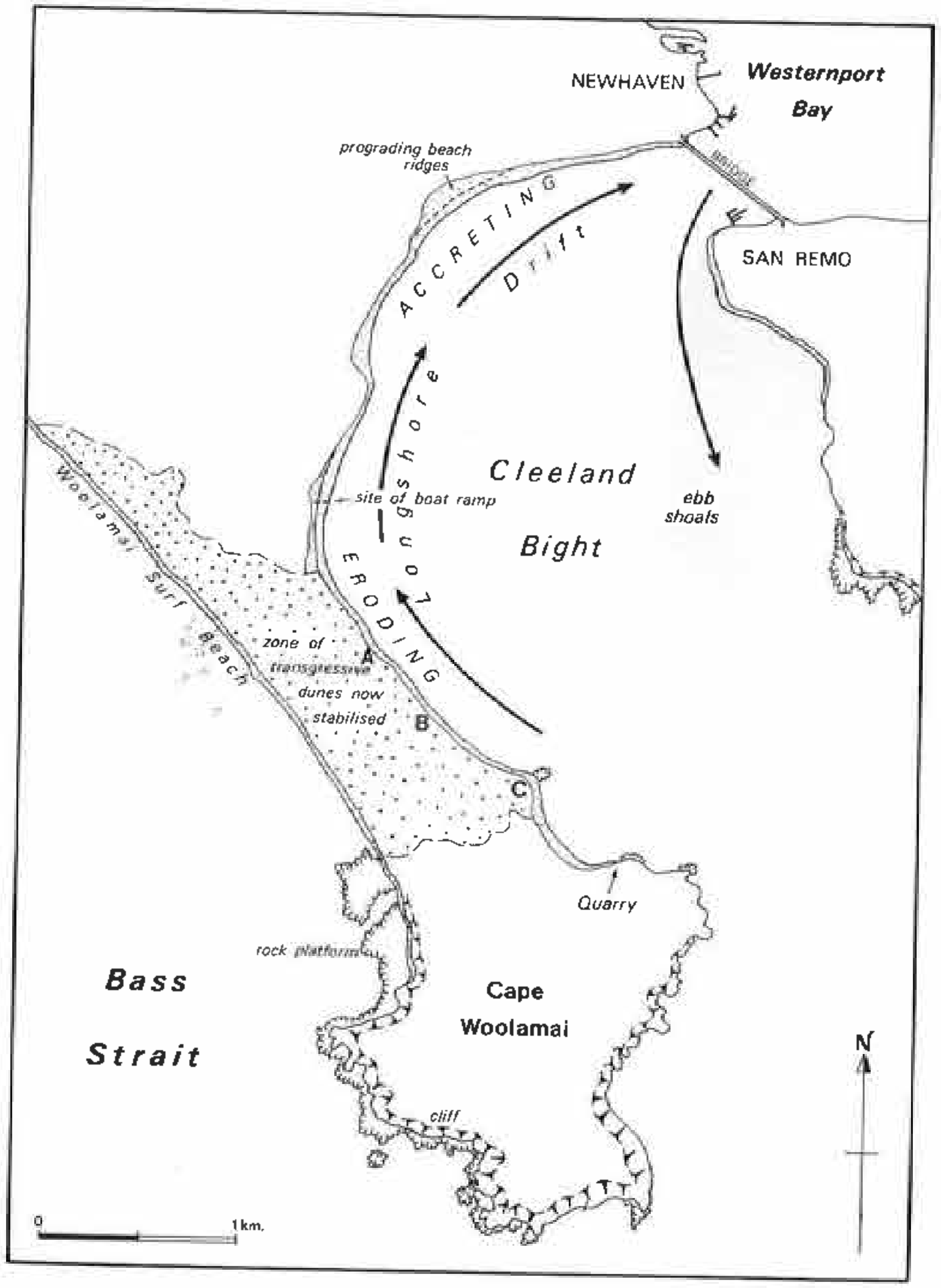


FIGURE 157 Cleeland Bight, showing the northward drifting of sand towards Newhaven. When dunes were spilling on to the shore the beach was built upward and outward, but after the dunes were stabilised in the 1980s by planting marram grass this supply was reduced, and beach erosion ensued (see Figure 158).

FIGURE 158 The southern shore of Cleeland Bight in 1977 (above) when dune sand was still being delivered to the adjacent shore, and in 1984 (below) after dune stabilisation had halted this supply

transgression. Ocean swell, refracted as it enters the western approaches to Westernport Bay, arrives obliquely to the north coast of Phillip Island, where it generates eastward drifting, assisted by waves and currents generated by westerly and north-westerly winds. The beaches are backed by low foredunes. In recent decades beach erosion has become a problem on the north coast of Phillip Island. Successive air photographs show that, as on the Somers coast to the north, lobes of sand have formed and moved eastward along the shore, past Erehwon Point, and eventually to Observation Point. Surveys organised by the Phillip Island Conservation Society in 1986–87 showed alternations of erosion and accretion along these beaches, with gains during relatively calm weather and losses in episodes of storm wave activity and an eastward prevalence of longshore drifting (Bird 1987b). Erosion has predominated, and various structures have been built in attempts to control it. Groynes have failed to intercept much eastward drifting sand, while sea walls, boulder ramparts and timber fences have resulted in adjacent beaches being lowered and flattened by wave reflection, and consequent undermining of these structures. Beach renourishment has been suggested, but no action has yet (1993) been taken.

Cowes Bank and Observation Point

East of Cowes the nearshore waters become very shallow, the intertidal zone broadening into Cowes Bank (Figure 159), a sandy area about five kilometres long and up to 450 metres wide (Marsden & Mallett 1975). When it is submerged at high tide, waves move across to break upon the sandy beach; at low tide a gently undulating topography is exposed, the surface consisting of up to a metre of soft fine sand with varying proportions of silt and clay, much churned by burrowing soldier crabs. At the northern margin a sandy slope falls away steeply to depths of 10 to 15 metres. The internal structure of Cowes Bank is not known, but may consist of a mudbank similar to those bordering French Island to the

FIGURE 159 Cowes Bank, showing intersecting sand bars, and the coastline between Cowes (left) and the recurved sandy spit at Observation Point (right), backed by mangrove-fringed salt marshes in Rhyll Inlet. Crown Copyright Reserved.

north, overlain by a veneer of sand deposits that have drifted in from the west, past Cowes.

Cowes Bank is dominated by large, asymmetrical sand bars and intervening troughs, some of which contain muddy sediment up to 5 centimetres thick. In the western part the bars trend west to east, then south-west to north-east, often with a steeper southeastern flank, and in the eastern part they trend south-east to north-west, often with a steeper flank to the north-east. The two sets of bars mingle in the central and eastern parts of Cowes Bank, forming a set of rhomboidal structures. Comparisons of successive air photographs taken between 1939 and 1985 shows that the basic pattern of sand bars and troughs on Cowes Bank changed little, although there were minor variations: at some times the bars that trend south-west to north-east have been more prominent, at others those trending north-west to south-east have predominated, but at all stages both trends have been present in an intersecting pattern. The bars and troughs have been shaped by wave action, with frequent north-westerly waves producing the south-west to north-east series and the less frequent north-easterly waves the south-east to north-west series, but some of the latter may also have been influenced by the reflection of incident north-westerly waves by the upper beach, or from sea walls and boulder ramparts.

The sandy beach behind Cowes Bank continues eastward to the recurved spit at Observatory Point. On the inner side of the spit sandy ridges fading into salt marshes mark earlier stages in the eastward growth of Observation Point, but the distal end has been cut back since 1826, when a sketch by Sainson, drawn during the visit of Dumont D'Urville to Westernport Bay, showed boats drawn up on a sand spit that extended some distance east of the present termination. Successive maps, charts and air photographs show variations in outline. Two small islands mapped by George Smythe in 1842 were washed away before 1929, and although eastward growth has resumed in recent years it has not yet restored the spit to its nineteenth-century length.

The east coast of Phillip Island

On the shores of Rhyll Inlet, in the lee of the Observation Point spit, mangroves and salt marshes are drained by tidal creeks which converge eastwards into mudflats exposed at low tide. Nit Island is a mangrove island, and the mudflats are underlain by gravels and rocky areas, with protrusions of basalt and tuff forming rocky intertidal islands. The inlet was used as a sheltered anchorage by explorers, notably Dumont D'Urville, who called it 'le crique des mangliers' (mangroves creek). On its southern side are steep bluffs and basal cliffs cut in deeply-weathered granite, fronted by cobble-strewn abrasion ramps, eastward to Lady Nelson Point.

Between Rhyll and Newhaven the east coast of Phillip Island is sheltered from strong wave action, and has mangrove-fringed salt marshes behind wide intertidal sand and mud flats in Swan Bay, Denne Bight and Reid Bight, backed by bluffs which sweep out to successive partly cliffed promontories of weathered

basalt and tuff at Chambers Point, Pleasant Point, and Long Point. At low tide extensive mudflats and sandflats are exposed, with creeks draining to the deeper channels. Seagrasses (*Zostera*) are extensive, and there are shelly splays. The bluffs continue round to Churchill Island, an embayed hilly island of weathered basalt and tuff, separated from Phillip Island by a shallow strait where the basalt is overlain by mudflats. When James Grant visited Westernport Bay in March 1801 he landed on Churchill Island and cleared a small area of bushland to plant various crops and fruit trees and build a log hut. The island is thus of historical importance, and is a reserve managed by the Department of Conservation and Natural Resources. To the south is a bay with mangroves and salt marsh, backed by low bluffs which run out to form the coast round past Newhaven to the Phillip Island bridge.

Exposure to south-easterly wind and wave action increases south of the bridge, where the mangroves and salt marshes give place to sandy beaches backed by dunes and minor cliffed promontories down to Cleeland Bight. Sand drifting into the eastern entrance is swept by rising tides under the San Remo bridge towards Newhaven, where it forms a tidal delta. Much of it is carried back out by strong ebb currents, with velocities of up to 4 m/sec., to form shoals and beaches on the eastern side, south of San Remo. This marks the beginning of the South Gippsland coast.

Source: *Monash Urban Lab*