Appendix 6. Regionalisation Results 4. The Upper Macquarie and Apsley domain mosaics and the system controls on river development and behaviour.

This appendix contains maps that demonstrate the relationship between the domain mosaics of the upper Macquarie and Apsley case study area and the system controls on river development and behaviour that were the basis of the Environmental Domain Analysis. See Chapter 4 for a discussion on each of these system controls and how they influence the development and behaviour of rivers.

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Introduction

This report considers the geomorphic nature, condition and value of the stream systems on King Island. This includes not just the stream channels, but also the surrounding swamps and riparian areas. By geomorphology, we are referring to the physical form of the river. This means the shape of the stream, how it relates to its floodplains and catchment, and how it transports its water and sediment. Understanding the geomorphology of a stream will help you understand how the stream formed, and how it might respond to disturbance. This report attempts to identify the different geomorphic types of stream that can be found on King Island, and to understand them, in order that they can be better managed.

The natural drainage system on King Island has a range of values. They may be useful both for drainage and water supply at different times of year. Streams may also be used to dispose of wastes. However, as well as being valuable in this utilitarian sense, King Island’s streams also have important environmental values. These relate to the riparian forests, and their associated fauna, and to the aquatic ecology in the streams and associated wetlands. Another valued aspect of the streams is their geomorphology – that is, the stream as a part of the landscape. To a large extent, these values are inter-woven. Good water quality will be important for the aquatic ecology, but also for water supply. Both the terrestrial and aquatic ecology rely, to an extent, on the physical condition of the stream. Likewise, the riparian vegetation is often an important control on the geomorphology. This report will make some recommendations about conservation priorities and stream management activities on King Island, based on the fluvial geomorphology. It is up to the manager of the stream to assess the ecological and utilitarian values of the stream, before decisions are made that might effect all aspects of the streams.

Working out where to spend limited resources to get the best possible result for conservation can be a difficult task. However, there are some guiding principles that can help with this task. These were recently published in ‘A Rehabilitation Manual for Australian Streams’, by (Rutherfurrd et al., 1999a). It is worth noting here that there are two reasons to protect a reach of stream. One reason is the conservation value of the stream. A second reason is hazard prevention. In sensitive areas, damage to a given reach may start a degradation process with consequences for other uses of the river, up and down stream. So, you might decide to protect one reach because it is in excellent condition and represents a rare geomorphic or ecological feature, and a second reach because clearing riparian vegetation would increase the risk of erosion that would damage assets such as areas with high conservation value, farmland, bridges or water supplies up or down stream.

Stream management is made easier if you are able to classify streams into groups that have a similar form, and ideally, similar behaviour. If this is possible, then attention can be drawn to the management practises that are most suitable for each class of stream, and efforts can be made to avoid those types of disturbance that the stream is particularly sensitive too. Although there are some doubts as to whether predicting stream behaviour in this way is actually possible (Miller and Ritter, 1996), even small advances could be of great assistance to stream managers.

How do you go about dividing the streams in an area into groups? Even if you try to classify streams according to their appearance, it can be difficult to decide on group boundaries. This job becomes even harder when you try to group streams according to how they will respond to different disturbances. This future behaviour can’t be seen, and so must be predicted – a difficult task for one stream, let alone for all the streams on King Island. One approach is to take a step back from the streams, and look instead at those aspects of the landscape that have influenced the development of the streams. These include geology, climate, topography, landscape history and time. Kiernan (1995) referred to these as the system controls. If we
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can identify regions where these system controls are the same, we can then make the prediction that the streams of that region should behave in a similar way. Of course, this prediction must be carefully tested, but it is a useful start to the problem of stream classification.

This information will eventually form part of a report on a state wide geomorphic assessment of river systems. However, the preparation of this report was prompted by the King Island Resource Management Group receiving a NHT devolved grant to be spent on fencing remnant vegetation, although it will also form a part of a state wide geomorphic assessment of river systems. Accordingly, we will include a brief discussion on how riparian vegetation can influence fluvial geomorphology. We will then discuss the system controls on the rivers of King Island, and describe the geomorphic history that has formed the distinctive landscape. Having described the different regions that occur in the landscape, we will describe the stream types that have formed in each region, and comment on identifying sections that are a high priority for conservation. Finally, we will discuss how these regions interact, and how some of the management techniques presently used might affect the different stream types. This will include some comments on when streams should be protected as hazard prevention.

Unfortunately, as is usually the case, field time for this project was limited. The reader should be aware that the comments on general stream condition and conservation value are based on a brief field reconnaissance, and much interpretation of maps and aerial photography.

**How can riparian vegetation influence the geomorphology of streams?**

Riparian vegetation is a very important part of the stream environment. It is integral to both the terrestrial and aquatic ecology that is associated with streams. However, as well as this biological role, vegetation also has a major physical influence on the geomorphology of streams. Because of this influence, maintaining healthy riparian vegetation is usually essential to maintaining a geomorphically ‘healthy’ stream. Also, vegetation can be a powerful tool for rehabilitating degraded streams. So, how does riparian vegetation influence stream geomorphology? Most of this section has been summarised from the Riparian Land Management Technical Guidelines and A Rehabilitation Manual for Australian Streams (Lovett and Price, 1999b; Lovett and Price, 1999a; Rutherfurd et al., 1999b).

Vegetation has an effect on the formation and maintenance of both floodplains and river channels. This effect comes about in two ways. Firstly, vegetation can reduce the flow velocity near the bank. This means the water is less able to erode and transport sediment. Secondly, vegetation can increase the resistance to erosion of both channel and floodplain sediments.

Vegetation can affect the ability of the stream to erode and transport sediment. There are two important thresholds of water velocity to be considered in the erosion and transport of sediment. Firstly, in order to scour sediment from the channel or floodplain, the water must be moving fast enough to overcome the forces such as gravity and cohesion that would otherwise hold that sediment in place. Secondly, the water must keep moving fast enough to keep that sediment moving either suspended in the water or bouncing along the bed. Without vegetation, during floods water can flow smoothly and rapidly over the banks and floodplain. However, with riparian and floodplain vegetation, the banks and floodplain are much rougher, and this will slow the water down. At this slower velocity, the floodwater may be unable to erode sediments, and will also be more likely to deposit sediments. Vegetation on the floodplain may play an important role in encouraging the deposition of the fine sediments that make fertile soils.
Vegetation can also make bank material stronger and more resistant to erosion. It achieves this in several ways. Firstly, vegetation will reduce the impact of many sub-aerial (i.e. not in the water) erosion processes such as rain splash and rill erosion that occur out of the water, high on the banks or during periods of low flow. One of the only sub-aerial erosion processes that will continue regardless of vegetation is trampling by stock. Secondly, vegetation can protect surfaces from scour. This occurs by covering the surface in a root mat or ground cover that has been flattened by the force of the water, and by the effect of fine roots binding the soil particles together. Thirdly, vegetation can greatly strengthen banks against mass failure. Mass failure collapse is when sections of the stream bank fall or slide down into the channel. Roots can bind the soil together, in effect binding potential slump blocks into place. The large, dense root balls of mature trees are particularly effective at preventing mass failure. Obviously, different aspects of vegetation will effect different erosion processes. If you have an erosion problem, it is important to work out which of these processes is causing that problem, so that you can develop an appropriate response.

Which type of bank erosion process dominates at a site depends on the size of the stream. Sub-aerial processes will only take place out of the water. The potential for scour to occur is related to the depth of flow and the channel slope. For mass failure to occur, the banks must be high and steep enough that they are unable to support their own weight when saturated with water. This means that sub-aerial processes are dominant on very small streams, where the channel is small and the flow is often not enough to generate much scour. They will also be important in streams that are seasonally dry. On King Island, this would include most of the drains, and also many of the natural channels, as these are often seasonally dry. The upper Seal River is one example. Scour is more important in medium sized streams, because the larger flows have more power to erode sediment. The Ettrick River below the spring is an example of a stream where erosion processes are dominated by scour. Mass failure is common only on larger streams. There are few rivers on King Island that are large enough for this process to dominate. Some sections of bank on the lower Fraser River, near Naracoopa could potentially undergo mass failure. There may also be some sites on the lower and middle Sea Elephant where this process could occur. Even in big rivers where mass failure is frequent, scour can still be the process that determines the overall rate of erosion. This is because scour at the toe of the bank is needed to make the bank steep enough to collapse under its own weight. Note that all these erosion processes are natural, and are important for maintaining the stream channel, so long as they occur at natural rates. Only when rates accelerate, as may happen after disturbances such as clearing of riparian vegetation, does erosion become a problem.

As we have said, vegetation can be very effective at preventing erosion of stream banks and floodplains. This means it can be an extremely valuable tool for rehabilitating eroding streams. The key is to identify the process that is causing the erosion problem, and plant accordingly. For example, some rules of thumb are that if you are worried about sub-aerial erosion, you will need to exclude stock and plant ground cover species. If scour dominates the erosion processes, you should plant species that will slow down the water near the banks. If you need to reduce the risk of mass failure, then you should plant trees such as paperbark of tea-tree on the top of the bank where you think the slump blocks will break away. Bear in mind that vegetation will not be effective in the following situations (Rutherford et al., 1999b).

- If the banks are eroding too fast, any young plants will get washed away before they have a chance to reduce erosion rates.
- If the bed of the stream is eroding and the channel is getting deeper, eventually the banks will reach an unstable height regardless of vegetation. In this case, you need some other strategy to try to stop the bed erosion.
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- If the banks are too tall, then the roots of plants on the top of the banks will not grow deep enough to have any effect on scour at the toe of the bank.
- In some situations, vegetation may not be able grow on the bank. This might be because the stream is too saline, the water flows too fast, the bank is too steep, because the bank sediments are not a suitable substrate for plants (e.g. coarse gravel) or because the stream is regulated and has prolonged periods of high flow.

If one of these situations occurs, some instream works may be required in combination with revegetation in order to stabilise the stream. However, on King Island, all the natural rivers are very small and generally quite stable. In most foreseeable circumstances, revegetation will be the only tool required for rehabilitation.

**Controls on the development of King Island’s stream systems**

The character of any stream system in SE Australia is fundamentally controlled by the interaction of geology and broad scale landform systems, modified by changing climate and its effects on the erosion and deposition of sediments (water and wind borne, physical and chemical) throughout the last few tens of millions of years.

King Island’s streams have developed through the interaction of rainfall, surface water and groundwater systems with a wide range of bedrock types and structures, and surficial deposits such as sand dunes and sheets of at least two ages. Additionally, there is good evidence to suggest that the broad physical structure of the island has developed through successive uplift events interspersed by long, relatively stable periods during which the landscape was ‘planed off’ horizontally, through the action of the sea or, to a lesser extent through lateral widening and coalescence of river valleys on coastal plains (Jennings, 1959). This has led to a ‘stepped’ profile where differences in the hardness of the bedrock have played a relatively minor role in conditioning landscape features. A large proportion of the island’s freshwater discharge appears to be through groundwater systems, with many of the upland reaches of streams being intermittent, apart from where they traverse escarpment reaches.

In all landscapes, water will tend to take the shortest, straightest course to the sea. It may, however be diverted from this course by differences in rock hardness, caused either by changes in rock type or structure. For example, hard layers of quartzite will tend to be preserved from erosion, whilst relatively soft beds of siltstone will tend to be eroded, and stream directions will often trend along the strike of the rock in sedimentary or metamorphic sequences. Similarly, joints or fault zones will tend to be preferentially eroded before the solid bedrock that they have disrupted, the parallel drainage systems on igneous rocks such as granite being a good example. This happens both in surface streams and groundwater systems. If the slope is steep enough, or the power of streams is high enough these structural and bedrock constraints will be progressively ignored by surface streams because their energy is great enough to maintain a reasonably straight course, even though it may cross structural boundaries.

The roles of rock type, structure and landform history have therefore been intricately linked over time to provide the landscape upon which King Island’s drainage system has developed. The relative importance of

- stream power, as controlled by the ‘steps’ and ‘flats’ in the land surface and catchment size, as compared with
- bedrock type and structure

as controls on the character of streams depends on each reach’s location in relation to breaks in slope in land surfaces, and relative differences in rock hardness.
Present climate

As noted above, King Island has been subject to widely fluctuating climatic conditions throughout the last few million years, which has influenced sea level change, mobility of sand dunes, and development of river terraces. These aspects are discussed further below. Whilst an understanding of these fluctuations is important in understanding how rivers have developed over time, and their likely development into the future, present day variations in climate are important in making decisions about local scale, short duration issues.

At present a rainfall gradient exists, decreasing from south to north, and from east to west, with the south eastern plateau receiving approximately 1000 mm per year. A narrow band stretching north from Stokes Point to the Yellow Rock river receives between 900 and 1000mm, with the country to the north of Yellow Rock receiving between 750 mm and 1000 mm (Figure 1). Rainfall south of Yellow Rock could therefore be considered to be reasonably uniform. Rain is winter dominant, with July receiving on average 125 mm. January receives 35 mm. The monthly distribution is similar for all centres. Rainfall reliability is very high, with percentage variability around 14 – 16% for the majority of the island.

Figure 1: Average annual rainfall for King Island. From Richley (1984).

Given this amount of rainfall, one would expect at least the large streams on the island to be perennial. However, many reaches of even the larger streams regularly dry out in summer. This is thought to be a result of the island’s physiography, the interaction of surface sand deposits with streamflow, and the seasonality of rainfall. These controls have important repercussions for stream management, as they vary somewhat from what might be considered normal in a cool-humid west coast environment. The issues are discussed further in ‘Interactions between landscape regions’, below.

Geological controls

The bedrock geology of the island is shown in Figure 2. The majority of rocks are Precambrian in age, the oldest rocks being steeply dipping, north-south striking, fine grained sediments which have been progressively metamorphosed towards the west. These are bounded to the west by granites which intruded them, partially melting and recrystallising them. Contact relationships are well exposed in the bed of the Yellow Rock River at AMG 335997 where narrow granite dykes have intruded north-south trending bedding planes leaving well defined, alternating layers of granite and metamorphosed sediments. These metamorphics are composed of interbedded quartzite, schist and phyllite, grading to relatively unaltered banded or laminated siltstone and mudstone in the east. In the absence of other controls, the metamorphic rocks would tend to produce north-south trending stream systems with a branching network of tributaries. Particularly hard and resistant beds could divert east-
west flowing streams if their gradient was low. The granites are strongly jointed and tend to produce rectangular drainage systems with straight, joint controlled reaches when streams erode bedrock.

In the southeast around Grassy, a faulted sequence of interbedded volcanic rocks (basalts) and sediments conformably overlies the Precambrian strata. The sedimentary units include chert, shale and marine dolomite. These rocks have been intruded by Devonian age granodiorite (much younger than the west coast granites) which have partially metamorphosed the Cambrian sequence in the vicinity of Grassy. The scheelite formed through metasomatism\(^1\) of marbles, which were originally produced through metamorphism\(^2\) of dolomite units (Brown, 1989). These rocks again tend to produce dendritic\(^3\) drainage networks. The dolomite units are particularly prone to weathering and may act as preferred paths for stream channels in the absence of other controls.

Devonian granite also crops out in the valley of the Sea Elephant River, at Mt Counsel, presumably within Precambrian sediments, and also in a northwest-southeast trending band of low hills inland from the northwest coast. Similarly to the Precambrian granites, these granites tend to produce rectangular drainage systems.

A long gap in the stratigraphic sequence is broken by Tertiary (most likely Miocene) marine limestones, found widely scattered over the lower levels of the island. The most extensive of these is found around the Blowhole on the east coast, extending underwater as far north as Cowper Point, and inland for at distance of at least four to five kilometres, where overlying Quaternary sand sheets obscure outcrop. This limestone also crops out in the banks of the middle reaches of the Sea Elephant River, allowing the possibility that they may be continuous from here to the Blowhole. Tertiary limestone is also found in a tributary of the Seal River, and also in Mt Stanley Ck, both within 4 km of Big Lake. The Tertiary limestones appear to have had little direct effect on stream patterns, however in common with other karst forming rocks, they may promote underground piracy of surface drainage. It would be worth checking whether streams lose surface flow when crossing from impermeable rocks to this limestone.

Extensive deposits of dune sand and sand sheets, as well as coastal deposits of Pleistocene age, are found across the island. These deposits are semi-permeable; in some cases effectively damming surface flows to produce extensive lagoon systems, in others streams and precipitation are dispersed underground to reappear as springs and soaks further towards the coast. The diversity of dune-related streams are described in sections describing the eastern and western dune regions. As these deposits are an important source of evidence for the sequence of development of the broad landscape features of the island, they are further discussed, along with an interpretation of the landscape history of the island, below.

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1. Metasomatism: replacement of one mineral with another through solution and precipitation in hot fluids.
2. Metamorphism: changes to rocks in the Earth’s crust brought about by heat and pressure
3. Dendritic: Branching as a tree.
Figure 2. Bedrock geology of King Island
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Topographic controls

Rivers may be characterised according to how they fit in with present-day topography, however a better prediction of how streams are likely to behave in the future may be made through an understanding of how they have developed, along with the surrounding landscape, in the past. The best source of information about these clues is J.N. Jennings paper on the coastal geomorphology of King Island, and how this relates to changes in the relative level of the land and sea over the past few million years (Jennings, 1959). Although he extrapolated this study to inland parts of the island only in restricted areas, it should be possible to make better correlations between the coastal evidence and evidence from rivers and inland surfaces and related sediment deposits. Our reconnaissance of these relationships has produced some possible correlations, however these should be checked, and could be greatly expanded on in future work.

The origins of King Island’s river systems may be traced back to the late Cretaceous - early Tertiary (60 – 80 million years ago) when Bass Strait was beginning to open up, separating Tasmania from mainland Australia; a part of the major Gondwanan split up at that time. Although more evidence needs to be gathered, it is likely that the pre-rifting topography was quite flat, the result of many millions of years of erosion. If King Island was similar to other parts of Australia at this time, the major ancestral stream systems were orientated broadly north-south, following this major structural trend in the strike of the bedrock of the Tasman Fold Belt. The uplift of King Island in relation to the sea has caused steep landscape gradients to cross the grain of the country at right angles, diverting marginal streams to the east and west.

The tectonic (uplift and subsidence) history of King Island appears to have comprised a series of relatively short uplift events, separated by long periods of stillstand in absolute land level. These uplifts are thought to have been the result of upwelling magma along mid-ocean ridges forcing the trailing edges of the major continental plates (in this case Tasmania and the Australian mainland) upwards and apart as Gondwana broke up. The parallel, east-west trending escarpments of Victoria’s Great Dividing Range, and the Western Tiers in Tasmania are the major structural landforms resulting from the Bass Strait rifting. (The north-south trending Great Escarpment of eastern mainland Australia, and the north-south trending Midlands Graben and Eastern Tiers in Tasmania are thought to be a result of rifting of the Tasman Sea). King Island was left stranded in the middle of the Bass Strait rift, possibly as an uplifted block, or horst, although no structural information relating to the Bass Strait geology exists to confirm this.

Overlain on these tectonic events are fluctuations in sea level due to climatic change; the locking up of large volumes of sea water in polar ice caps has led to absolute drops of up to 120 m in sea level during cold climate phases of the last two million years, whereas corresponding warm periods have increased the oceans’ volumes to a level only slightly greater than that of today. It is widely accepted that at the height of the last interglacial, absolute sea levels worldwide were no more than six metres or so above present. Beyond about two million years ago, the sea level record becomes very sketchy, as erosion has removed most of the sources of evidence, however it is likely that similar sea level adjustments occurred throughout the Tertiary, albeit of a lesser magnitude.

The relationships between absolute land and sea levels throughout the Cainozoic (Tertiary and Quaternary) have controlled base levels of erosion on the island. When the relative levels of land and sea remained constant for long periods (in times of uniform climate and stable tectonics) relatively flat land surfaces developed at sea level. Because rivers could not erode deeper than the sea surface, they tended to erode laterally, developing wide coastal plains. Low lying parts of the plains were then covered with sediments of both marine and terrestrial origin; the rivers aggrading through overbank deposition in fans and lowland meandering
reaches, and the sea depositing parallel beach ridges composed of gravels and sands. These coastal plains developed horizontally over all rock types, although some relatively restricted outcrops of the harder granites or metamorphics remain as small hills above the surrounding plains.

With abrupt changes in either sea or land level these base level relationships were disrupted. If, in relative terms, these coastal-plains became elevated above the sea (through a tectonic rise or sea-level drop during glacials), powerful marine erosion would eventually develop a cliffline, or at least a relatively steep escarpment corresponding to the new relative sea level. This would elevate rivers above the coast, and create knickpoints in their long profiles. The knickpoints retreated upstream, whilst the edges of the surrounding raised land surfaces retreated much more slowly – erosion being spread out over the whole escarpment edge rather than being concentrated along stream channels.

On the other hand, if the sea level rose in relation to the land (through sea level rise in interglacials, or through tectonic subsidence), pre-existing valleys would be drowned at the coastline, coastal barrier systems and beaches initiated and river valleys would be backfilled by sediment generated in upstream reaches. A further drop in relative sea level, if reasonably abrupt, would incise the fluvial sediments to leave terrace systems along rivers, or leave ‘fossil’ raised beaches or beach ridge systems stranded above the new coastline. In general terms, uplift events have outstripped subsidence (or drowning through sea-level rise). Constructional landforms, which are related to these minor periods of relative high sea-levels are generally less extensive than erosional forms, however they are very important as markers of base levels to which rivers were graded during depositional phases.

As well as this (oh no, why is life so complicated?) climatic changes also altered the ways in which sediments were supplied to rivers, and the amount and seasonality of water the rivers had to erode and transport them and weathered bedrock with. On King Island there is evidence that at least some river terraces (particularly those set into otherwise steep-valleyed escarpment streams) are the result of deposition of excess sediment rather than incision following a drop in relative sea-level. Some of these terraces also contain beds of coarse cobbles amongst predominantly sandy depositional units, indicating significantly more powerful streams than today, in combination with a much greater sediment supply. Large sources of sediment for streams exist in the form of easily erodible sand sheets over much of the island. These would have been active throughout at least the last two glacial advances, and the early stages of the last interglacial and the present Holocene interglacial, when a massive sand source existed on the then-exposed Bassian Plain (the floor of Bass Strait exposed during glacial sea level minima).

Evidence for these potential combinations of land and sea level change is widespread on King Island, in fact the abundance of well preserved ‘fossil’ coastal and fluvial features across the island means it is probably one of the best places in Australia to observe them. They also help us to re-create the likely sequence of development of the island’s stream system which (after all) is what we’re here for (finally, good grief!).

As with most of the earth sciences, historical geomorphology, - landscape history - usually becomes more difficult to trace the further back in time you go. This is because older landforms tend to be obliterated by younger features, particularly where processes repeatedly act in certain key areas, and also because older landforms and surficial deposits associated with them, gradually weather or erode away over geological time. Hence, as you attempt to look back in time, landforms or deposits crucial to reconstructing landscape history tend to be

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4 Knickpoint: These are the points of abrupt steepening in stream gradient, at which fluvial erosion is focussed, as an abrupt change in stream energy occurs just as stream gradients steepen.
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more widely spaced or less well preserved. This means that when attempting to trace the history of older landforms, you are restricted to making far wider generalisations than when studying younger features.

Jennings’ (1959) paper illustrates this well. The evidence for periods of relative stillstand in land and sea levels is best summarised in this paper, although more recent research suggests that Jennings’ age estimates may need revision. The following paragraphs summarise Jennings’ inventory, and suggest how the features he has mapped (see Jennings 1959, p5, 9, 15) may be used as evidence to deduce history of development of the island’s stream systems. This is based on the crucial control that sea level plays in determining the base level of erosion of the rivers at each major stillstand in the relative levels of land and sea.

- **The New Shorelines and Dunes and the lowest land surfaces**

In looking at the coastal landforms of the island in relation to the relative level of land and sea, Jennings cites a large amount of detail on the younger ‘fossil’ beach and shoreline deposits, many believed to be related to a slightly higher relative sea level stand in the mid-Holocene, around 6000 years ago. Many features scattered around the island, including low, vegetated clifflets, small sea caves no longer affected by wave action, inactive shore platforms and shingle banks, and others are thought by Jennings to represent the effects of a drop in relative sea level of around 2 – 3 m since the mid Holocene. These features are related to what he terms the ‘New Shorelines’. The ‘New Dunes’ – those comparatively active dunefields termed ‘coast country’ by local graziers were largely emplaced in the period before the development of the New Shorelines, although they are still active today.

The New Shorelines are most likely related to low terraces found in the coastal plains reaches of streams such as the Fraser, Sea Elephant and Seal. They were formed as the rivers rapidly cut down into sediments graded to the New Shoreline levels.

- **The Old Shorelines and Dunes and associated land surfaces**

A second set of features, now well and truly inactive, are termed the ‘Old Shorelines’. These features, found between 20 m above sea level and present sea level, provide striking evidence of the uplift of the island throughout the Quaternary. Emerged shell beds, estuarine-marine sediments, beach ridges, marine terraces, ‘fossil’ cobble beaches, inactive sea caves and sea cliffs all attest to periods of stability and change in the relationship between levels of land and sea. Whilst spread right across this altitude range, Jennings has identified a sequence of constructional and erosional coastal landforms related to halts at 20 m, 13 – 15 m and 7 – 10 m above present mean sea level. Massive rounded boulders preserved at 15 m above sea level within Blister Cave on the cliffed SW coast are some of the most graphic indicators of relative sea levels at this time (Goede, *et al*., 1979) (Figure 3).

The ‘Old Dunes’, locally known as the ‘semi-coast’ country, are now largely inactive and cemented into aeolianite. They were thought by Jennings to be genetically related to the older shorelines, and given a probable age of Last Interglacial. More recent research, including some tentative absolute dating by Murray-Wallace and Goede (1995) suggest that some of these features are more likely to be older than the last interglacial, with histories stretching back to the mid Pleistocene. Present work underway by John Grindrod at Monash University is directed at absolute dating of the ‘Old Dunes’ using thermoluminescence techniques. These results will be useful in determining the ages of both the dunes, and the shoreline features with which they may be associated.
Figure 3: A) The entrance to Blister Cave on the south west coast of King Island. B) A boulder beach preserved 15 m above present sea level within Blister Cave
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Both the New and Old dunes were deposited during times of cooler, drier, windier conditions associated with the later stages of the last and penultimate glaciations. The massive sandsheets and inland dunefields found on the southern plateau country were most likely also deposited at this time, although their mode of deposition was different. Whilst some of the sand for these sheets may have come from the distal ends of the major dune systems, the pattern of sand sheets between the major dune ‘lobes’ suggests that coastal sand was funnelled through the main river valleys such as the Ettrick, Badger Box Ck, Porky Ck etc, then spread as low relief coatings on hillsides with a westerly aspect. East facing hillslopes in the catchment of the Seal River, for example, have far thinner sand deposits over in-situ soils, or the sand is absent entirely. These inland sand deposits appear to be the major sediment sources for river terraces and fans in the lower incised reaches of the major rivers, such as the Seal, Ettrick and Sea Elephant.

In the north and east of the island Egg Lagoon and Southeast Lagoon have developed on what Jennings believes to be uplifted coastal lagoons related to the Old Shorelines. Cores taken from Egg Lagoon contained marine shell fossils, now at a height of 12 – 15 m asl, tentatively dated to the mid Pleistocene by Murray-Wallace & Goede (1995). These are now covered by 5 m or so of freshwater swamp deposits and peats from which Pleistocene megafauna fossils have been obtained. Further dating by Grindrod will test these dates and more accurately determine the timing of uplift. To the east of Southeast Lagoon a series of uplifted parallel beach ridges and dunes, trending north south, decrease in altitude until the east coast is reached. These deposits obscure underlying land surfaces, however they have had a significant effect on the direction of low-energy streams which feed the Sea Elephant River from the north. Emerging from these plains and ridge systems are the granite residuals of Counsel Hill and the low granite hills inland from the Three Sisters. The ages of these hills and their relationship with emerged coastal surfaces and associated fluvial systems is difficult to determine at this stage, as very little evidence of planation is found on their flanks. To the west of Southeast Lagoon, a major NS trending ridge is thought by Jennings to be an emerged offshore bar, now protruding through freshwater deposits.

Jennings (1959, p. 9) maps the large terrace at the mouth of the Fraser River, approximately 15 m asl, as part of this sequence of Old Shoreline related features. Some of the higher and more extensive terrace systems in the coastal reaches of rivers such as the Sea Elephant, Seal and Ettrick may be correlated with the Old Shorelines, however they may also be the result of deposition by streams with high sediment loads generated by glacial climatic conditions. Further analysis of terrace materials is necessary; the presence of imbricated\(^5\) cobble beds in terraces along the Ettrick River and Badger Box Creek suggest far more powerful stream flows than occur now. Knickpoints in the lower reaches of streams such as the Seal, Ettrick, Eel Ck and possibly others are possibly related to bedrock benches at these levels in the landscape.

- **The 40 – 45m Sea Level Stand – middle land surfaces**
  Jennings reports excellent evidence of a sea level stand at a relative level approximately 40-45 m above present sea level, consisting of a series of fossil beach deposits in the Grassy Mine (Figure 4). These deposits are quite spectacular and, although their age is merely speculative at present, the highly weathered nature of some of the volcanic clasts suggests a Pleistocene age. At this location the raised beaches are overlain by sands of the Old Dunes, suggesting a considerable age for these dunes also. Jennings also reports flattened spurs at this level in the vicinity of City of Melbourne Bay.

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\(^5\) Imbricated: Where a bed of cobbles all ‘lean’ in the direction of current flow.
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Figure 4: A fossil beach deposit in the Grassy Mine

At the time of Jennings survey the island had not yet been topographically mapped. He suggested that a close morphological analysis of the plateau would be valuable once mapping was undertaken. On the most recent mapping distinct, large scale ‘embayments’ in the higher plateaus of the island occur at about this level, most markedly in the hinterland of Big Lake, and to the SW of the Grassy Mine. A larger bench around Loorana, another at Reekara and again in the mid reaches of the Sea Elephant River and Fraser River also approximate the 40 – 45 m level.

In the Sea Elephant basin, extensive deposits of rounded gravels are found as a series of small mounds capping a flat surface along Ridges Road. Further examination is necessary to determine if these are marine or fluvial in origin. Extensive quartz gravels at this elevation are found along the Fraser Road, the highest occurrence noted at approximately 50 m asl. (AMG 448803), where rounded cobbles at least 2 m in depth are exposed in a dam excavation. These gravels may be marine in origin, however it is also possible that they may be the remnants of a high level terrace related to a former course of the Sea Elephant River. At AMG 430790 is a possible stream capture site. Field evidence, including both the valley morphology and the gravel deposits cited above, suggests that the headwaters of the Sea Elephant River may have once flowed down to the Fraser through a broad, shallow valley, now occupied by a small, intermittent stream. Downstream from the possible capture site the Sea Elephant now flows through what appears to be a complex fan, composed of terraces up to 10 m above the present channel. These terraces may be the result of a complex response to a stream capture, however many other factors may be involved. Further research is necessary.

The major inland Tertiary limestone deposits on the island are found at approximately this elevation, in the Sea Elephant Basin inland of the Blowhole, at approx AMG 432832, at approx AMG 383593 in the Seal River, and AMG 418592. It is possible that these limestones record the relative level of the sea in these areas, at approximately the 40 – 45 m elevation, which formed the base level of erosion for streams at this time. Jennings assigns these limestones to the Miocene, or late Tertiary, making this scenario a possibility, although the
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The presence of old dunes overlying raised beaches at this level at the Grassy mine contradict this, suggesting the age of the surface as early – mid Pleistocene.

- **The 70 – 75 m Sea Level stand – the main plateau surface**
  Jennings (1959) cites the existence of quartz pebble gravels on Fraser Bluff, and concordant notches in spurs at a slightly higher elevation in the City of Melbourne Bay area, as evidence of a sea level stand at approximately this altitude. The main plateau surface of the island, located south of Currie, is a broadly flat bench, varying between approximately 75 m in elevation at its rim on the east and west coasts, and sloping gently to an undulating surface at around 100 m centred on Pegarah. This broadly domed shape may be explained through degradation of the plateau escarpment at a faster rate than the more remote central area. It is possible that the major phase of planation affecting this southern area is related to this sea level stand. The plateau also appears to slope gently downwards to the north although the northern limits of the plateau to the north of Tin Mine Road still maintain an altitude of 75 m. Jennings suggests that this northward slope is most likely due to a slight tilting during uplift.

A feature of this surface, not generally found on the lower surfaces, is the widespread occurrence of ferricrete, either at the land surface or buried within the soil profile. Ferricretes in south eastern Australia are usually associated with warm, wet environments, driving the translocation and accumulation of iron oxides as the top of the B horizon in the soil (Taylor and Ruxton, 1987). Some evidence for the deposition of ferricretes under cool, wet conditions in south eastern New South Wales also exists (Taylor and Ruxton, 1987). However, most writers attribute the majority of ferricrete deposition in south eastern Australia to the early – mid Tertiary. The apparent lack of ferricrete on the lower surfaces of King Island suggests that environmental conditions following the exposure of lower surfaces were more like present conditions, cooler and drier, relating to what we know of late Tertiary – Quaternary environments. The ferricretes on the main King Island surface have influenced the rate at which rivers and sheetwash have eroded the surface margins. It is a particularly hard, dense layer in the soil profile which has ‘held up’ the retreat of knickpoints and the general plateau rim. Some of the best exposures of this material are found at AMG 493770, on the plateau margin at 93 m asl in the Pegarah State Forest.

- **The 120 – 130 m surface – the highest surface**
  Although not described by Jennings (because it does not occur near the coast!) a further high level surface may be distinguished at around 120 m in the Mt Stanley – Lymwood area. This surface, which also bears ferricrete outcrops, is quite restricted in extent. However, it forms a significant part of the upper catchment of the Seal and Ettrick Rivers. The highest peaks on the Island, Gentle Annie and the related peaks to the north and south, are most likely residual hills, remaining when this surface was planated at sea level.

**Discussion**

The coastal evidence, presented by Jennings (1959) and Murray-Wallace & Goede (1995) suggests that the island’s major landscape units have developed through planation during periods of relative stillstand in both land and sea levels, interspersed by relatively quick uplift events. This has produced a series of rolling land surfaces at approximately 120 m, 75 – 100 m and 40 – 45 m in the south and centre of the island, each surface separated by relatively steep escarpments. In the north of the island the plains around the Yellow Rock River, South East Lagoon and Egg Lagoon all approximate the main level of the Old Shorelines at approximately 20 – 25 m asl. These major landscape units are shown in Figure 5.

On both the west and east coasts the bedrock relief is obscured by the thick Old and New Dune deposits and beach ridge deposits. The types of deposits are quite different though, with the west coast systems dominated by massive parabolic dune systems, and the east coast by a combination of striking north-south trending beach ridges flanked to the west by smaller
parabolic dune fields. Where streams such as the Ettrick River, Porky Creek, Yellow Rock River and Eel Creek have maintained their courses over bedrock, some idea of the nature of the underlying bedrock surface may be determined for the west coast systems. These streams all suggest a distinct escarpment exists in the bedrock below the western dunes. Also, high rocky bluffs such as that at Whistler Point, suggest that a distinct coastal escarpment exists buried below the lithified sands. No bedrock is exposed in the beds of streams traversing the eastern dunes/ridges.

These topographical, geological and climatic controls comprise the main constraints within which the Island’s stream system has developed. The following sections describe how individual streams have developed according to the broad landscape and climatic history of the island. This has allowed classification of streams according to their position in the landscape and relationships with fluvial, aeolian and coastal deposits, and how a knowledge of that position and relationships may be used to better determine priorities for stream management.
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Figure 5. The landscape regions of King Island.
Stream types on King Island

On King Island, there are five obvious types of landscape where streams of distinctly different character have developed (see Figure 5). These regions are generally defined by the dominant landscape surfaces described above. The landscape types are:

1. the relatively flat landscape surfaces, in the south of the island (at 40-45 m, 70-75 m, and the 120 m surfaces);
2. the steep escarpments where one surface steps down to sea level or a lower surface;
3. the area covered by the dunes along the western coast;
4. the area influenced by the dunes along the eastern coast, and
5. the low surface in the north of the island, including the drained lagoons.

A single stream can run through one or many of these landscape regions, sometimes in repeating sequence. However, each region has a distinctive effect on the stream reaches that run through it.

1. Surface Reaches

The distinctive character of streams on the surfaces that form the southern surfaces is controlled by the gentle gradient of the landscape. This means that streams have relatively little energy with which to shape their environment. As a result, much of the sediment carried into surface reaches will be deposited, contributing to the development of the large floodplains that are characteristic of these systems. There are two important sediment sources for these systems. The more conventional source is any steeper reaches upstream, which are more competent to erode and transport sediment. When the river reaches the flatter landscape of the surface, this sediment is deposited, initially as a gently sloping alluvial fan, then as overbank deposits on floodplains or swamps. On King Island, aeolian sand is a second important sediment source. It has probably been directly incorporated into floodplains, briefly reworked by the stream and deposited as a fluvial sediment.

Further evidence of the lack of stream power is the development of valleys. Surface streams may have almost no notable valley, or have a very wide (hundreds of metres) and shallow (only a few metres) valley (Figure 6). It is possible that some of these streams have in fact cut much deeper valleys in the past, but these have become filled with sediment. As discussed below, the valley dimensions on the surface streams are related to migration of erosion heads from the downstream escarpment reaches, and to sediment supply from upstream reaches.

Stream channels on the surfaces are often surprisingly inefficient. Where the catchment size is small, the stream may be a swampy drainage line, rather than a distinct channel. It is important to recognise that these swampy areas are also a part of the fluvial system. They represent important sediment stores, and will also have an influence on the hydrology of the entire stream network (see the section ‘Effects of draining on hydrology’). Where the stream has a larger catchment, a small channel is usually present. It is not known what the minimum catchment area is for channel formation. Although the surface reaches typically run through swamps, they are frequently dry in summer.

Because of the depositional environment, these channels are generally free to meander across soft sediments. They are often very sinuous and hydraulically rough. As such, they are probably quite inefficient at transporting water, and the surrounding landscape would be swampy and wet for much of the year. Neil Burgess said that the Seal River in the state forest...
Figure 6: A cross section of the Seal River valley near 80 m asl, showing a wide and shallow valley.

West of Mount Stanley Road, can remain flooded for up to seven months of the year. This contrasts with the summer months, when these streams may well stop flowing altogether. This curious flow regime means that the stream may flow fast enough to maintain its channel only during the short period when the channel fills at the start of winter until the water spills overbank, and again when the flood water is draining off the floodplain. In between, when the water is deep on the floodplain, it is likely that the velocity in the channel is slowed down by the interaction with the still water on the floodplain.

Floodplain vegetation and the woody debris it produces seem to have an important effect on the stream channels on the surface. Most of the following observations come from the Seal River in the State Forest near Neil Burgess’ property. The vegetation at this site is a dense young forest dominated by paperbarks, with a sparse understorey of cutting grass and ferns. Such a density of trees would contribute greatly to the hydraulic roughness of the floodplain, which could have the effect of reducing the velocity of floodplain flows, as well as binding the floodplain and bank sediments with roots. This vegetation is potentially an important influence on floodplain and channel development through its effect on the rates of sediment deposition and channel formation and migration. Note that vegetation is not the only control on the velocity of overbank flow. Water can also be slowed down above a constriction caused by the topography of the floodplain. If this occurs, water will always flow slowly regardless of the vegetation.

Where vegetation remains on the floodplain, there is often lots of large woody debris present. This woody debris is of two types, reflecting two very different forest types. The debris delivered by the present forests is a large quantity of relatively thin logs around 10-20 cm diameter. These fallen trees have formed a network of logs that cover the floodplain, and often lie across, or angled into the channel (see Figure 7). Aside from contributing to the roughness of the floodplain and channel, it is possible that this debris has little direct effect on the morphology of the channel. The second type of debris suggests a forest of far larger trees, which were presumably present in the forests prior to the clearing and burning associated with European exploration and settlement. These are very big logs, some over a metre in diameter (see Figure 8 for an example). They are usually partly buried in the bed, banks or floodplain. These logs sometimes appear to have a direct influence on channel morphology, acting as bed or bank armour and controlling the radius of some bends, and the position of bars and pools in the bed.
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Figure 7: The Seal River in the state forest. Note the quantity of thin woody debris. Person in the centre of the photo is standing in the channel.

Figure 8: A massive log crossing the Seal River in the state forest. The channel flows from the other side of the log, straight towards bottom of photograph.
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How do you recognise a typical surface stream?

- **Valley character**: These streams either have no noticeable valley, or a very wide and shallow valley, depending on the size of the catchment and the proximity to the escarpment. Valley floors would probably have been swamp forests, prior to clearing and draining.

- **Floodplain**: Floodplains typically support swampy vegetation on organic rich loamy sediments with varying amounts of wind blown or reworked sand. It seems probable that considerable quantities of large woody debris are incorporated into the floodplain. There is very little evidence for channel change such as the development of meander neck cut-offs, or noticeable old channels. In the Seal River swamp near Neil Burgess’ property, the distal part of the floodplain was constricted by low dunes.

- **Channel character**: Where there is a channel, it is usually quite small, and very sinuous. Often there is large quantities of woody debris in the channel. These channels are hydraulically very rough (Mannings $n^6$ probably higher than 0.07, maybe as high as 0.2).

- The channel bed consisted of a loamy organic clay, showing very few signs of recent fluvial transport. In the upstream part of the swamp, sand could be found in the bed at varying depths below the surface. Considerable quantities of wood are incorporated into the bed.

- **Variation in surface streams**: The limited fieldwork time for this project prevented a full assessment of variation within this stream type. Where the catchment is very small there is probably no defined channel, but it is not known what the threshold is for channel formation. These swampy drainages are also a part of the stream system, and are a legitimate target for conservation. At sites with a channel, the sinuous nature of the channel, the role of woody debris, and the apparent stability of the planform remained similar.

**Condition and conservation significance**

These streams have been widely degraded by clearing, grazing and draining. This is particularly the case with the drainage lines above the limit for channel formation. These sections of the drainage network have been widely altered by the construction of drains, and also by cattle pugging.

Where any sections of stream in good condition occur on the surfaces, they will have high conservation value, and should be a high priority for fencing. The Seal River where it runs through the state forest west of Mount Stanley Road is an example of this type of river in good condition. Reaches to be fenced should not be directly effected by drain construction or channelisation. Intact reaches can be recognised by either the lack of a channel where the catchment is small, or by a highly sinuous channel. Healthy riparian vegetation is also a requirement for a healthy river. Longer sections of stream should have higher priority than short sections, unless the latter can be shown to have exceptional value, or is included in a larger reach with great recovery potential.

It is also important to consider the width of the riparian vegetation. From an ecological point of view, larger areas of vegetation will be better value than smaller areas. However, from a geomorphic point of view, there are two reasons to consider the width of protected vegetation.

$^6$ Mannings $n$: A measure of the resistance to flow in a channel. It is difficult to estimate accurately. Higher values mean rougher channels, and slower flowing water. A clean, straight lowland channel usually has Mannings $n$ around 0.03, a very weedy channel with timbered floodways might get to 0.15 (Gordon et al., 1992).
Firstly, as we said above, riparian vegetation can be very effective at slowing flood waters down and removing some of their erosive power. If thick riparian vegetation is left in a narrow strip along the stream channel, surrounded by grazing land, then during floods the easiest path for the water is not down the channel, but around the outside of the vegetation. This increases the risk of erosion on the floodplain, and also for avulsion to occur (when the stream abandons part of its channel and erodes a new path). Secondly, over long time periods, meandering streams will naturally move around their floodplains. Individual meander bends will move as the outside bend gradually erodes and sediment is deposited on the inside bank. So that this natural process does not damage farm assets such as fences or grazing land, you should leave room for the river to move. Rather than fencing a thin riparian strip that closely follows the course of the stream, consider fencing out the whole meander belt plus a buffer zone of at least 10 metres (see Figure 9). On King Island, the Sea Elephant River 2 km upstream of Fraser Road is one site that shows some evidence of relatively recent channel migration.

Figure 9: An example of how a meandering channel might migrate across a floodplain, and possible fence lines. The fence close to the river will be damaged by the new channel, while the fence outside the meander belt is unscathed.
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2. Escarpment reaches

The steepness of the landscape has given the streams far more energy to shape their environment in the escarpment regions. As a result, escarpment reaches are characterised by deep valleys and gorges that have cut back into the edge of the flat surfaces above. The planform and long profile are frequently controlled by bedrock. This contrasts to the surface streams that generally meander freely on unconsolidated sediment. Even though the development of these valleys does partly smooth out the steep gradient of the escarpment, these rivers are still generally much steeper that the surface reaches up and downstream. This means these reaches are still considerably more powerful, and capable of transporting gravel sized sediments, whereas surface reaches seem to move only sand and mud.

Despite this greater stream power, the streams at the bottom of these valleys have often formed small discontinuous floodplains. In the valleys of the lower Seal, Ettrick and Sea Elephant Rivers, there is a large terrace. This shows that despite being relatively high energy systems, these confined valleys can form depositional environments in their lower reaches. This sediment could have come from the erosion that formed the valley itself, or be dominated by aeolian sand that was blown into the catchment and subsequently transported by the river into the valley. It appears likely that this second source has dominated, from the type and texture of the sediment in the terraces. There are two complementary explanations for these depositional features. One is that in the past, the sediment supply to the valley was great enough to have outstripped the stream’s competence to transport it. In this case, the terraces could be the head of an old alluvial fan (see ‘Interactions between landscape regions’ for more information on the formation of fans). Also, it is possible that the vegetation in the valleys has been an important part of this floodplain development by slowing flow and encouraging deposition, and by protecting existing floodplains from erosion.

Examples of escarpment reaches can be found on all the major streams in the southern part of King Island. The Grassy River is a good example, cutting into the 75-100m surface above Grahams Road, and forming a deep valley that runs almost all the way to the coast. Note that some streams, like the Seal River and Mount Stanley Creek, include two sets of escarpment reaches, one cut into the 120-130 m surface around Mount Stanley, and another cutting into the 75 – 100 m surface.

How do you recognise a typical escarpment stream?

- **Valley character**: These reaches have cut deep valleys into the edge of the surface. The Grassy River, for example, has formed a valley 70 m deep near the town of Grassy. More commonly, valleys are 30 to 50 m deep. The depth of the valley depends on the size of the stream, and the height and steepness of the escarpment.

- **Floodplain and terraces**: A small, often discontinuous floodplain is commonly present in escarpment valleys. In the major escarpment reach on the Seal River, this floodplain was around 10 m wide. Terraces were found on the lower Seal River, the Sea Elephant River, and on Yarra Creek. Terraces are also present on the lower Ettrick River, which has many features in common with escarpment streams despite running through the western dunes.

- **Channel**: Channels in these reaches frequently have a pool riffle sequence. This was observed in the escarpment reaches of the upper and lower Seal River, Yarra Creek, and the Sea Elephant River. The bed material was sandy and muddy, with angular gravel in the riffles. The channel in these reaches is relatively wide and shallow.

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7 A long profile is a graph of the elevation of the river.
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- **Variations in escarpment streams**: There are two influences on the form of escarpment streams. Firstly, catchment area on the surface above the escarpment influences the development of the valleys. Secondly, whether or not the shape of the escarpment is influenced by marine erosion, as well as fluvial processes, will influence the stream character.

**Streams with no catchment on the upper surface.** This type of escarpment reach has its headwaters on the steep escarpment itself. These streams do not cut such deep valleys into the surface, because the headwater sections carry little water and have insufficient stream power to cut far into the surface above. Examples of this stream type are the tributaries of the lower Fraser River such as Rafferty Creek, and Parer Creek (between Grassy and Little Grassy Rivers). Figure 10 shows the relationship between the long profile of Parer Creek and the surrounding escarpment.

**Streams with a catchment on the upper surface.** This type is the more common and obvious escarpment stream with a large catchment on the surface above the escarpment. These reaches tend to have formed much deeper, longer valleys, because the stream carries considerably more water, and therefore has more power at the top of the escarpment. Examples of this type of stream are the escarpment reaches of the Grassy River and the Sea Elephant River. Figure 11 shows the relationship between the long profile of Grassy River and the surrounding escarpment.

**Streams on an escarpment not influenced by marine erosion.** Escarpments to the north and south of the surfaces generally have relatively gentle slopes, and accordingly, the streams that have developed on these slopes have relatively shallow valleys. The long profiles of these valleys have been developed entirely by fluvial processes. As a result, the reaches on these escarpments have long profiles that are concave upwards, as is typical of most rivers. The chief streams that flow over these gentle escarpments are the Seal River and Mount Stanley Creek in the south, and the Sea Elephant and Fraser Rivers in the north. Figure 12 shows the long profile of the Seal River.

**Streams on an escarpment influenced by marine erosion.** Scarps on the southern east and west coasts of King Island are influence by marine processes. On the west, this has chiefly been the formation of the dune fields which have covered the escarpments (see section ‘3. Western Dune Reaches’ below). However, in some places there are escarpments that continue almost to sea level. This occurs at the cliffs near Seal Rocks on the west coast, and from Grassy to Fraser Bluff on the east coast. At these sites, powerful marine erosion at the toe of the cliffs has maintained the steep slope of the escarpment. The streams that run over this escarpment have uncharacteristically convex long profiles. The steep slope of the escarpment also leads to the development of deep valleys. The Grassy River, for example, has a strikingly convex profile and a valley some 70 m deep (see Figure 11).

**Condition and conservation significance**

Because of the steepness of the valleys, these reaches have commonly remained uncleared. However, this does not mean ungrazed, and many of these reaches have been degraded by cattle trampling. Because these streams are relatively high energy, there is probably a greater risk of erosion (mainly by fluvial scour) following degradation of the vegetation than in most sections on the flat surface parts of the landscape. Areas where the riparian vegetation is still intact and cattle have not had access to the stream have high conservation value, and should be a priority for fencing. Areas where cattle access has caused minor damage to the vegetation will have a good chance for recovery if stock are excluded. Such areas may also be a priority for fencing.
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Figure 10: The long profile of Parer Creek, and the elevation of the surrounding landscape. This stream has almost its entire catchment on the escarpment, and as a result has been unable to erode a deep valley.

Figure 11: The long profile of Grassy River, and the elevation of the surrounding landscape. This stream has a considerable catchment on the surface above the escarpment, and has eroded a deep valley. Note also that the long profile is convex upward.

Figure 12: The long profile of the Seal River, and the elevation of the surrounding landscape. This stream runs south from the 75 – 100 m surface, across a relatively gently sloping escarpment. Accordingly, the river has a relatively shallow valley, as compared to Grassy River.
3. Western Dune Reaches

The stream reaches that flow to the west and south west coasts have had to contend with the development of the coastal dunes. In the absence of the dunes, these streams would probably have reached the sea in a sequence of surface and escarpment reaches, as is the case on the eastern coast. However, the dune systems have had several impacts. Firstly, they have raised the surface of the landscape, creating a ridge that is higher than the areas immediately inland (Jennings, 1957). Secondly, the sand of the new dune systems is relatively permeable. Thus the sand dunes have raised a topographic barrier, and at the same time stolen water through the permeable sand, in a double attack on the west draining surface streams. The stream types that have developed in response to these conditions vary, depending on the catchment size, and the elevation of the surface inland of the dunes.

The distinctive features of this landscape region are the wetlands and lagoons along the inland edge of the dunes, the valleys of varying depth cut through the dune system, and the springs that occur near sea level on most of these streams.

To understand how these features have developed, it helps to imagine the landscape underneath the dunes. Typically, immediately inland of the dunes is one of the relatively flat surface surfaces. In the south of the island, this surface is as high as 100 m, while in the north it is as little as 20 m asl. In the relatively short distance covered by the dunes, the underlying landscape must be reduced to sea level. This suggests an escarpment, or possibly a series of escarpments and surfaces, as can be found in areas not covered by dunes. Rock outcrops in the beds of streams that have incised into the dunes support this theory. Let us now consider the river systems in this pre-dune landscape. It seems reasonable to expect that, prior to the development of dunes in response to the present sea level, that the streams made their way across the escarpments to the sea. As with today’s escarpment streams, they had probably carved valleys of varying depth. It is, of course, impossible to guess the exact shape of this landscape, and the steepness of the escarpment, without considerable further field investigation. However, even this general model of valleys in an escarpment is useful for explaining some of the features found today on the west coast.

Wetlands of widely varying size and depth can be found along the western, southern and northern coasts of King Island. There are a variety of types of lakes and wetlands on the island (Jennings, 1957). However, on the western coast, most are outcrops of the watertable that has been raised because of the dune field, or are either surface drainages dammed by the formation of the dunes.

Another striking feature of the west draining streams is that they have all been found to be spring fed in their lowest reaches. On some streams, such as the Pass River, the spring is within a couple of hundred metres of the coast, while in the Ettrick, the spring is several kilometres upstream. These springs are probably fed by the same ground water that feeds the wetlands inland of the dunes. This water would then flow down the valleys that are buried by the dunes, and reappears in the stream channels near the coast.

It is notable that all the larger streams on King Island have managed to maintain their courses through the western dune field without being dammed or diverted around the inland edge of the dunefield. In order to maintain this flow direction, some streams have deep valleys through the dunes. The Ettrick is the most dramatic example of this, with a valley that is some 30 or 40 m deep. This raises the question of how these streams managed to maintain straight courses despite the deposition of such large volumes of sand. It has been suggested that the ‘steady regime’ of the rivers allowed them to maintain their courses (Jennings, 1957 p 61). However, there are other possibilities. As discussed above in the section ‘Controls on the development of King Island’s stream system’, it is likely that sand was whisked through
the main pre-existing valleys and deposited as sand sheets inland. It is also possible that sand did cover the valleys during the most active phases of dune construction, and that this sand has since been eroded. It is unlikely that this erosion was driven by surface drainages, because the chaotic topography of the dune field would have prevented such straight water courses from forming. However, even when covered by sand, the original stream valleys could still have concentrated groundwater flow along the old path of the stream. This may have been enough to recreate these valleys, either by sapping from the spring head where the flow emerges, or by dissolution of the sand where underground flow was concentrated. It is difficult to be certain which of these processes may have been operating. Probably, the influence of each varied depending on the original topography.

It is worth considering the management implications of how streams maintain a channel in an environment where there is so much mobile sand. The streams exist because of a balance between the amount of sand blown into the stream, and the amount that the stream can transport in order to maintain its channel. If the flow in that stream is changed because of the construction of drains in the catchment, then this balance could be destroyed. Depending on the change, the stream might erode or become swamped by sand. This issue is discussed in more detail below, in ‘Effects of draining on hydrology’.

Several very different styles of stream have developed in this landscape region. However, they can be viewed as a continuum of increasing influence of the dunes, from those that have maintained a long profile controlled by bedrock rather than sand (eg the Ettrick), through some that run through the dunes, such as Badger Box Creek, to those that have been almost entirely overwhelmed by sand, and have little obvious surface drainage (eg Boggy Creek). These three points on this continuum are described below.

Of all the west draining rivers, the Ettrick River is possibly the one that has most managed to hold its own against the dunes, possibly because it has a relatively large catchment (about 40 km²)on the highest two surfaces of the island. As with other streams in this region, flow in the lower section is spring fed. However, the spring on the Ettrick River is considerably further upstream than on other streams, giving the lower 2 or 3 kilometres more or less perennial flow. The Ettrick has cut a valley through the sand dunes to the underlying material (see the elevation of the river relative to the surrounding landscape in Figure 14). In steep sections the river has a gravel or cobble bed, with a pool riffle sequence in places. There are also some bedrock bars, and some bedrock visible in the lower sections of the valley walls (Figure 13). The river has maintained a long profile that is controlled by the underlying topography and rock, rather than dunes. Where the stream bed is sandy, the sand has the appearance of having been moved by the river. A discontinuous sandy floodplain is present, as are occasional terraces. At these sites, the Ettrick River has more in common with an escarpment stream such as the incised reaches of the Seal River than many of the other streams in the dune landscape region.

Badger Box Creek is the next stream to the north of the Ettrick. However, it has a considerably smaller catchment, in the order of 10km². Badger Box Creek has a far shallower valley than the Ettrick (Figure 16), and on the whole the stream bed is sandy or organic, rather than dominated by gravel or rock. The spring on this creek is fairly close to the coast. Above this spring, the creek was dry, and had the appearance of being regularly dry. The stream bed consists of an almost peaty sand (Figure 15). It seems likely that the long profile of this creek is controlled by the dunes, rather than the underlying rock. However, vegetation is also an important control. Because the channel is so small, the riparian vegetation can have a profound impact on the river. In several places, we observed steps in the river bed of up to one metre that were held in place by tree roots or large woody debris. So, the sand dunes are able to form the long profile of the creek because of the small portion of the year when the stream actually flows, combined with the effect of the vegetation in binding the bed material.
Figure 13: The lower Ettrick River where it flows over a bedrock control

Figure 14: The long profile of the Ettrick River and the elevation of the surrounding landscape.
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Figure 15: Badger Box Creek, above the spring. At this site, the stream is so small it looks more like a foot track than a channel.

Figure 16: The long profile of Badger Box Creek, and the elevation of the surrounding landscape.
It is interesting to contrast this creek with Bungaree Creek, which would naturally have had a catchment only a little larger than Badger Box, and would possibly have looked quite similar. However, Bungaree Creek has been impacted by grazing in the riparian zone through the sand dune region, and acid sulphate drainage, possibly from a gravel pit and a very large drain. It is also possible that the catchment area of Bungaree Creek has been dramatically increased by the construction of drainage networks that link it to Eel Creek and Yellow Rock River to the north. It is hard to separate the effects of each of these impacts, but there is little doubt that the stream is in very poor condition. Erosion of the bed and floodplain stripping have occurred in some places. This is discussed further in the section ‘Effects of draining on hydrology’.

Boggy Creek is on the far end of the continuum of stream types in this landscape region. The character of this stream is dominated by the presence of the dunes, although an underlying valley may well be important in drawing together underground flows. The catchment is quite small (approximately 3.5 km$^2$), and there is very little development of a channel. Flow is dominantly underground, and emerges in a series of soaks and springs along the coast. Considerable deposition of calcium carbonate occurs here to form the tufa terraces that are listed in the Tasmanian Geoconservation Database as a site of national geoconservation significance.

The Yellow Rock River does not really fit the pattern of the Western Dune reaches. It is different to other west coast streams because the dunes do not extend far inland at this point, and direction of the beach at its mouth is orientated virtually ninety degrees from that of other rivers. The mouth has been barred and diverted by a parabolic dune system advancing parallel to the coast. This section of the river that is influenced by these dunes actually has more in common with the Eastern Dune streams, than those typical of the west coast.

**How do you recognise a typical western dune stream?**

As described above, there is a considerable range of ‘typical western dune streams’ to be found on King Island. This variation depends on the extent to which fluvial processes have prevailed against the dunes. This is largely related to catchment size.

**Streams only slightly influence by dunes (for example the Ettrick River).**

- **Valley character:** These rivers have valleys deep enough to expose the rocks underlying the dunes for a considerable length of stream. Valleys may be up to 50 m deep, with steep sandy sides, and possibly with rock visible near stream level.

- **Floodplain and terraces:** Small discontinuous floodplains are mostly present, but may be absent in places. Floodplains are usually quite sandy, and incorporate organic material. Probably thickly wooded with tea tree or paperbark. Terraces containing infrequent cobble beds are occasionally present.

- **Channel character:** Channel dimensions are variable, depending on slope. Steeper sections may have bedrock outcropping in bed, otherwise some gravel or cobbles. A pool riffle sequence may be present. Channel relatively wide and shallow. In sections with more gentle gradient, the channel is narrower and deeper with sandy bed and banks. In these sections, a root mat may be binding the bed or lower banks.
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Figure 17: A surface stream at the coast in the proximity of Boggy Creek.

Figure 18: The long profile of Boggy Creek, and the elevation of the surrounding landscape.
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**Streams moderately influenced by dunes (for example Badger Box Creek)**

- **Valley character:** Valleys not as deep as above. Some bedrock outcrops may occur, but most of the stream bed is sandy.
- **Floodplain and terraces:** Irregular and small floodplains may be present. Mostly valley slopes directly and gently into channel. Thick vegetation grows right to channel banks.
- **Channel character:** Channel above the spring is often variable in size and shape, from very small and dish shaped (approximately 1 by 0.3 m) to more trench like (approximately 2 by 0.9 m). Generally has sandy or organic sandy bed, with relatively little sign of fluvial transport.

**Streams dominated by dunes (for example Boggy Creek).**

These streams have very poorly developed surface flow features such as valleys, floodplains and channels.

- **Valley character:** Very shallow valley, may be indistinguishable from dune surface.
- **Floodplain:** The channel frequently runs through swampy areas. Some floodplain development may have occurred.
- **Channel character:** Majority of flow may be underground. Where channel is present, it is very small (under 1 m). In flat swampy areas channel is sinuous. Multiple channels may be present. In steeper areas, channel may be much straighter. The sandy bed is often covered by aquatic plants.

Condition and conservation significance

The lower Ettrick River has a considerable conservation significance, because it is possibly the only stream of this type on the island. To add to its significance, it remains in relatively good condition, although it is currently threatened by a dam proposal for the mid reaches. The effect of such a dam could be to reduce the size of the winter floods. This could have a dramatic effect on the river downstream, as it is could be these winter floods that prevent the sand from influencing the river channel.

Boggy Creek is at the other extreme of western dune stream types. This stream has national conservation significance because of the tufa terraces formed at the coast. The terraces themselves should be protected from stock damage. These delicate formations depend on the maintenance of the delicate chemical balance that dissolves calcium carbonate from the dune sands and re-deposits it on the surface where the springs emerge. Any changes to the water chemistry in the catchment, such as draining acid water from the swamps into Boggy Creek, could have a devastating effect of the terraces. It is also interesting to note that part of Boggy Creeks catchment may have been diverted into the Seal River by the construction of drains. It is unclear what effect this would have for the formation and maintenance of the tufa terraces, but it is possible that the rate of tufa formation has decreased.

In between these two extremes, there are a variety of streams. Many of these are in quite good condition in the lowest sections, and should be a priority for fencing where stock access is likely. Vegetation is very important in maintaining bed, bank and floodplain strength in these very sandy streams. Where this vegetation remains intact, fencing should be a priority. Bungaree Creek is an exception to this general rule. This stream has been badly degraded by acid sulfate drainage and possibly interbasin transfer of water. Unfortunately, simply excluding stock and revegetating will not improve this situation. It is far more efficient use of
scarce resources to look after streams that are still in good condition, rather than spend our effort attempting to fix streams such as Bungaree Creek that are already degraded.

4. Eastern Dune Systems

On the north-east and, to a lesser extent the south-east coast of the island, parabolic dunefields have been built up by sand driven predominantly by easterly winds. Parallel beach ridges have developed through deposition at the backs of beaches following longshore drift and landward motion of sea-bed sand. The beach ridges form the sediment source for the dunefields. The main difference between these and the west coast systems is the presence of the long, parallel ridges of sand and sometimes pebbles, forming striking linear features when viewed from above. They have been deposited on a very flat substrate and hence any surface drainage here has very little capacity to erode or, in many cases to even maintain a channel in the face of masses of mobile sand. Hence, many cutoff channels and lagoons are visible on air photos.

This process has occurred during the deposition of both the Old Dunes and Shorelines and the New Dunes and Shorelines. The New features are presently active, and adjacent to the sea. The Old systems are located up to a few kilometres inland, generally at a higher altitude.

The direction and planform of the main stream systems associated with these deposits is almost entirely controlled by the orientation of beach ridge systems. The main rivers affected are the lower Sea Elephant, Saltwater Creek in the vicinity of the Nook Swamps and the Seal River in the vicinity of Big Lake and Colliers Swamp. Although not specifically related to easterly systems, the mouth of the Yellow Rock River shows some similarities with these streams, as it has been barred and diverted by a parabolic dune system advancing parallel to the coast.

The best example of this type of stream is the Saltwater Creek – Lower Sea Elephant system. This consists of a series of east-west flowing tributaries including the Sea Elephant River itself, the drain from Egg Lagoon, an unnamed stream draining the southern half of Lavinia Nature Reserve, and small streams draining the hills in the Counsel Hill area. In some cases these streams have breached the Old Shorelines and Dunes, flowing through to the Nook. In others, ridges have dammed the drainage, forming small lagoons.

A long, low, relatively flat valley is found between the New and Old Dune systems, possibly a section of raised seabed, uplifted since the close of the last interglacial. It is unlikely that the valley is the result of widening by a meandering stream, as Saltwater Creek is unlikely to ever have had sufficient stream power to laterally erode and redistribute the sediment. In contrast, downstream of where the Sea Elephant enters the valley, large partially inactive meander scrolls cut across the floodplain and would have aided in the formation of this surface. Saltwater Creek itself does meander, although with a much smaller amplitude. In its upper reaches it is often reduced to a series of lagoons.

To the north of Saltwater Creek this flat swale disappears, and the New and Old Dune systems converge. Between the two systems Pennys Lagoon and Lake Martha Lavinia are found. These lakes are partially dammed by New Dunes, but their shape is almost completely controlled by the stable ridge crests of the Old Dunes within which they nestle.

Big Lake and Colliers Swamp on the Seal River and Mt Stanley Ck have developed through a similar process, although on a smaller scale. The lake and swamp have developed at the junction of Old and New Dunes, however the lower Seal River has managed to continue to maintain a course through the New Dunes and a single raised beach ridge paralleling the present coast. Sand blows on Seal Point suggest the dominant wind direction here is east-
west, and the deflection of the river mouth to the west suggests a similar direction for longshore drift.

**How do you recognise a typical eastern dunes stream?**

- **Valley character**: These reaches have a very low gradient and, where not closely constrained by dunes or beach ridges, meander quite strongly. The lower Sea Elephant River is an example of a stream with sufficient power to alter its course quite dramatically through lateral migration. However, streams such as Saltwater Creek do not have sufficient flow to erode the dunes and change its course.

- **Floodplain and terraces**: These systems are very low energy types, any terrace systems have generally been swamped (or were never able to develop) through migration of dune sand and development of beach ridges. Where larger rivers are involved (such as the Sea Elephant) floodplains are maintained by lateral migration of meanders.

- **Channel**: In headwaters channels are indistinct of form a series of lagoons. In lower reaches channels are continuous, shallow and sandy, apart from in estuarine reaches where tidal movements maintain channel scour (eg Seal River mouth).

- **Variations with catchment size**: As with the western dune streams, these streams follow a similar pattern in their broad relationships with dunes and beach ridge development. However, differences in stream power have produced a continuum of responses. The trends of all streams are strongly controlled by beach ridge formation, however dune systems have more effect on smaller streams, diverting and partially damming them at times to form lagoons. Dune systems have an almost negligible effect on the lower Sea Elephant River because of its high stream power, whereas the Seal and the Yellow Rock are moderately influenced by parabolic dune systems as well as beach ridges. Dune systems have significantly constrained the planform and channel/lagoon system of the Nook Swamps/Saltwater Creek area.

**Condition and conservation significance**

In general these reaches are in good condition. For many of these reaches, the natural condition is a continual state of flux relative to dune and beach ridge systems anyway. If any of these streams were artificially stabilised they would be regarded as being in poor condition, as whole ecosystems would be disrupted. Some of the best examples are found in the Lavinia Nature Reserve, and they are well protected. The mouth of the Seal River is also in good condition, although the channel connecting Colliers Swamp with Big Lake has some artificial erosion occurring, particularly near Big Lake. Whilst actually located on the west coast, the mouth of the Yellow Rock River has physically more in common with eastern dune systems. At present the mouth is in good condition, however it is probably the river mouth most at risk if the dune systems controlling its course were destabilised.
5. Northern Plains Reaches

The streams that flow across the northern plains are possibly the youngest on King Island. For the most part, the surface on which they flow is formed of shallow marine and estuarine deposits, covered in places by freshwater deposits, that were uplifted during the late Pleistocene. The plain is scattered with Old and New dunes, and even an old off shore ridge relating to sea levels when the marine sediments were originally deposited. As a result, this landscape region is intermingled with the Eastern and Western Dunes regions. The streams of this region are the lower Sea Elephant River and tributaries, most of the Yellow Rock River catchment, the lower Fraser River, Egg Lagoon Creek and Saltwater Creek, and other small streams and artificial drains.

There are extensive drainage works through this landscape region. These drains have both extended the existing streams, and created entirely new drainage systems, such as Egg Lagoon Creek. The Yellow Rock River is a good example of this. Almost every tributary and part of the main stream are marked as drains on the 1:25,000 maps. These drainage works have made a large area of swamp and lagoon available for agriculture. However, because of the marine origin of the plain, the soil in this region is quite salty. This is probably responsible for the relatively high conductivity of the Yellow Rock River and Egg Lagoon Creek reported in Bobbi et al. (1999).

The southern most section of the northern plains is somewhat different in origin. This area, north of the lower Fraser River, is underlain by Tertiary marine limestone. It is possible that this soft, easily eroded rock that promoted the formation of this section of the northern plain as an embayment into higher surfaces.

There are three distinctive influences on the natural drainage systems in this region.

1. The northern plains are very flat. As a result, the natural streams may have features in common with streams of the landscape surfaces, such as meandering channels with sandy beds, running through frequent swampy wetlands. The lower Sea Elephant and Fraser Rivers are good examples of the meandering planform that can be developed in such low relief landscapes.

2. At only 20 m asl, the northern plains are very close to sea level. This means that where the streams reach the coast, they have very little energy with which to maintain a path through the dune systems that are built in such places. This has lead to the formation of the characteristic Eastern Dunes landscape where the dunes and streams interact to form features such as the Nook Swamps. This interaction is also evident on the Yellow Rock River. There are two coastal lagoons present on this stream. At the river mouth there is the active lagoon, formed by the damming of the mouth by the New Dunes that are associated with the present sea levels. Further inland is Muddy Lagoon, which is associated with the higher sea levels that formed the Old Shorelines and Dunes (see ‘Controls on the development of King Island’s stream system’).

3. The bulk of the northern plains are surrounded by a series of features of greater elevation (Figure 5). These are the Western Dunes, a fossil off-shore ridge in the south west, the granite residuals to the north, the Eastern Dunes, and a part of the 40-45 m surface to the south. While the Yellow Rock River and the Sea Elephant River have both managed to breach these barriers, the overall effect is of a shallow enclosed basin. As a result, much of this region was naturally shallow lagoons. These lagoons were Lake Flannigan, Reedy Lake (a shallow extension of Lake Flannigan); Egg Lagoon; and the South East Lagoon. Extensive drainage works have now drained the lakes and made much of this area available for agriculture. It is interesting to note that although Egg Lagoon Creek (actually a drain!) runs to the east, the old lagoon area is wettest at the western end, and
probably originally drained under and through the western dunes to the coast (Jennings, 1957).

How do you recognise a typical northern surface stream?

The few natural streams of this region have a great deal in common with the streams of the surface regions, largely because of the very low gradient of the landscape. Unfortunately, limited field time in this region restricts what we can say about these rivers.

- **Valley character**: Valleys are usually open and shallow. In the lowest reaches, the stream may be confined by terraces.

- **Floodplain and terraces**: The floodplains of streams in this region would naturally be thickly vegetated. As with other regions on King Island, there was little evidence of lateral movement of the channel on the floodplain of the Fraser River, suggesting that under natural conditions the stream is quite stable, and rates of channel migration are low. Terraces were present on the lower Yellow Rock and Fraser Rivers. These probably are New Shoreline features, related to slightly higher sea levels around 6000 years ago.

- **Channel character**: Channels are typically continuous, with sandy bed and banks. Some outcrops of bedrock do occur, for example on the lower Yellow Rock River. However, for the bulk of their length, the streams are alluvial and have a tightly meandering planform. For the Sea Elephant River, this planform is visible on the 1:25,000 scale map. However, a similar sinuous pattern was observed on the lower Fraser River, where dense vegetation has prevented detailed mapping.

- **Variation with catchment size**: The limited fieldwork time for this project prevented a full assessment of variation within this stream type.

Condition and conservation significance

Generally, the fluvial systems in this landscape region have been degraded by draining and clearing. Of the lakes and wetlands that once occupied much of the region, Lake Flannigan is the only significant remnant. As such, this lake has high conservation value. Of the streams themselves, the Sea Elephant and Fraser Rivers receive much of their flow from the surfaces to the south of the plain. This contrasts to the Yellow Rock River, which has the bulk of its catchment on the lower plain.

Both the Fraser and Sea Elephant Rivers in this region retain considerable riparian vegetation. In these areas, the rivers and their tributaries are probably in good condition. The most significant disturbance is the working of alluvial tin deposits on Tin Creek, a tributary of the Sea Elephant, in the early part of last century. Without checking in the field, it is difficult to assess the impact of this mining. Tin mining has had dramatic impacts on other streams in Tasmania (eg Knighton, 1991). However, in this case the mine was relatively small (Hooper, 1973), but it would be worth checking the extent of its impact on both Tin Creek and the Sea Elephant River.

The Yellow Rock River has an extensive drain network throughout the catchment, and is also largely cleared. It seems likely that little of this system remains in good condition, partly because of the effects of clearing and grazing in the riparian zone, and also because of the hydrological impacts of the drains. These impacts are discussed in more detail in the section ‘Effects of draining on hydrology’, below. The mouth of the Yellow Rock River is still in good condition. This situation depends on the continuing stability of the dunes at this point of the coast.
Interactions between landscape regions

The previous section described the typical rivers within each landscape region. However, almost every stream on King Island runs through more than one region. A lot of the most interesting and active change in stream systems happens in the areas where one region influences the reaches of the next region. Here we present some simple theories as to what processes create the patterns of interaction seen in the field. This should be regarded as a working hypothesis that may change as more information becomes available.

The boundary between landscape regions is where things happen. Here, the stream changes from the predictable form and behaviour it has had for kilometres, and tries to find a new look to suit its new environment. In the transition, a series of feature form that are indicative of the changes taking place. These transition zones show up in two ways. The ability to transport sediment changes, creating depositional and erosional features that indicate this. On King Island, a second obvious change in the balance between surface and groundwater flow.

In most places on King Island where landscape regions interact, there is a change in stream slope. Let us consider the common surface to escarpment to surface sequence. The main difference between these regions is the slope of the river and the size of the valley. Figure 19 shows the long profile of the Seal River, and compares it to the height of the surrounding landscape. The escarpment reaches show up as an increase in slope and valley depth. Figure 20 shows how the valley cross section varies between the landscape regions.

Let us consider a simplified version of this change from a surface reach through an escarpment to a lower surface. The features described here can be seen below in Figure 21. First, consider the flat areas of the surface regions. In this landscape, fluvial processes have relatively little energy to spend on erosion. Fluvial sediments are likely to build up in alluvial fans and floodplains, and bedrock is likely to be buried deeply by these sediments, and by in situ regolith (weathered bedrock). This contrasts with the escarpment regions, where the streams are steep, making it unlikely that large volumes of sediment will be deposited and giving them enough energy to erode bedrock as it weathers. This process has driven the formation of the escarpment valleys.

What happens where a stream crosses the boundary between two landscape regions? In the transition zones from one region to another, distinctive features are created by erosion or deposition of sediments as the stream adjusts to the new conditions. These features have the effect of smoothing out abrupt changes in slope.

In escarpment reaches, the stream runs through a steep, confined valley, where considerable sediment can be transported. Where the escarpment reaches a lower plain, the valley opens out, floodwaters can spread out and slow down, and the ability of the stream to transport sediment decreases. At this point a fan of alluvial sediments is deposited on the toe of the escarpment reach and the start of the plain, where it grades into the floodplain.

Where there is a transition from a gentle slope to a steep reach, the ability of the stream to erode and transport sediment increases. At the top of the scarp, the stream will incise rapidly until it is slowed by the presence of something hard, like rock. However, above this hard point, a knickpoint will continue to erode its way upstream in the softer regolith (Figure 22). This steeper section of stream is the transition zone between the two reaches. On King Island there is an added complication. Within the erodable regolith on the surface related to the 70-75 m sea level, there is ferricrete (see section on ‘Controls on the development of King Island’s stream system’). This forms a very hard layer in the soil that will be resistant to erosion, and may form another knick in the long profile of the stream near the edge of surface reaches.
Figure 19: The long profile of the Seal River, and the elevation of the surrounding landscape
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Figure 20: Cross sections of the Seal river valley, showing the sequence of surface and escarpment reaches. See Figure 19 for locations of cross sections.

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Figure 21: How the stream reaches of surface and escarpment landscape regions might interact. The transition zone above the escarpment shows a slight increase in stream slope and valley depth. Below the escarpment, the transition zone is an alluvial fan. Here the stream slope and valley depth decrease.
Figure 22: A detailed view of the long profile of a stream at the transition from a surface to an escarpment reach. (A) shows the most simple situation, where the stream can erode uniform soils and regolith. (B) shows how the long profile might look if ferricrete is present. Note that there is considerable vertical exaggeration.
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Figure 23: Barrier Creek at Milwood Rd, at the edge of the 75 – 100 m surface. (A) looks upstream to the surface, and the knickpoint at the top of the transition zone. (B) looks downstream into the developing escarpment valley.
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The general position of the transition zones is broadly determined by the shape of the landscape. However, the exact position and some of the characteristics of the transition zone are influenced by the hydrology of the stream, the sediment supply, and the vegetation growing on the site. Changes in any of these variables will influence the balance between the capacity of the reach to transport sediment, and the amount of sediment supplied to the reach from upstream.

If the stream is capable of transporting more sediment than is supplied from upstream, then it is likely to erode the bed or banks. This will move the transition zone upstream of the escarpment further upstream, as the knickpoint retreats. The alluvial fan downstream of the transition zone will be incised, creating terraces like those seen on the lower reaches of many streams on King Island. The transition zone, in the form of a new fan. These effects are shown in Figure 24. Note that incision can also be caused by the upstream retreat of knickpoints caused by changes in base level downstream.

If the stream is unable to transport all the sediment that is supplied from upstream, then deposition becomes more likely. Sediment will be deposited at the start of the transition zones, particularly alluvial fans. This will have the effect of moving the fan further upstream (see Figure 24). It could also move the transition zone upstream of the escarpment downstream, although this is more difficult to predict.

Changes in hydrology might be caused by long term climate change or to short term, land management related changes to the drainage network such as construction of artificial drains, and removing water from the stream to fill dams (see section ‘Effects of draining on hydrology’). Changes can include changes to the flood frequency or the size of the annual flood.

Changes in sediment supply occur when the rate of erosion occurring upstream changes, or with changes in the efficiency of sediment transport. On King Island, aeolian sand could also have been a significant sediment source to the stream systems. Variations in dune building activity over time could have caused variations in sediment supply to the streams. The construction of drain networks, clearing of vegetation in the riparian zone and catchment, and grazing in the riparian zone, all have the potential to increase sediment loads in the streams of King Island. Dams constructed in the stream will decrease the delivery of sediment to downstream reaches.

Vegetation tends to increase stability of fluvial features, and to encourage deposition. This means steeper slopes of stream might be maintained as stable. For example, an alluvial fan might start further upstream in the escarpment reach if there is thick vegetation to encourage and stabilise the deposits. Also, the transition reach at the top of an escarpment could be steeper with vegetation than without. That is, the knickpoint in the regolith would be closer to the edge of the escarpment (Figure 24).

Unfortunately, changes in the three variables of hydrology, sediment supply and condition of vegetation will often interact. Vegetation clearance and drain construction can lead to increased sediment supply, creating the potential for deposition, but could also increase flood peaks, creating the potential for erosion. It is also difficult to tell how close to instability a given section of stream actually is. Given the general principles described above, each site will need to be assessed according to its individual history and trajectory.
Figure 24: How changing the relationship between the capacity of the stream to transport sediment and the amount of sediment supplied can influence the position of the transition zones.
Any description of the streams of King Island must attempt to explain the idiosyncratic character of the island’s hydrology. Despite the high rainfall (almost a metre per year in the south) the streams are remarkably small, and for the most part intermittent. The swampy areas of the streams on the landscape surface regions are particularly prone to drying in the summer, while the steep escarpment reaches often continue to trickle. The streams contrast with the farm dams, which occur in remarkable density and appear to hold water for a considerably larger portion of the year. Another feature worthy of interest is the relationship between the west draining catchments and the Western Dunes. Where these regions interact lagoons and wetlands appear, and small streams may disappear. Here we propose a conceptual model that goes some way to explaining these patterns. Note that this theory has not yet been tested in the field!

The basis of this model is the relationship between groundwater, surface water, and the influence of topography and the varying depth of regolith and wind blown sand. It seems likely that groundwater is a significant component of the hydrology of the King Island. This is possible because of the deep regolith and sandy soils that are common across the island. In winter, streams are fed by surface runoff across the saturated soils, and from the seasonally high watertable. However, in summer, the deep regolith of the flat surfaces can accommodate all the available water. The water table sinks below the stream channels and the streams cease to flow. However, dams that are dug down to this water table will still contain water. Dams perched above the water table need to be clay lined in order to hold water. In contrast, the escarpments lack this deep cover of regolith. In these steep regions, groundwater is forced to the surface by bedrock, and the streams may continue to flow for a considerably larger portion of the year. If there is another surface below the escarpment, the depth of regolith will again increase, and the water will again flow underground.

A different situation exists on the inland border of the western dunes. Here, the dunes have partially or completely dammed much of the surface drainage of the adjoining areas, creating a ridge of groundwater that forms the wetlands and lakes that are so common along the west coast. However, the dune material is relatively permeable, and some of the water escapes underground, to reappear near the coast in springs and soaks. There are three different types of west coast spring (Figure 26).

1. There are springs where the groundwater is forced to the surface by salt water at the coast. The Springs, west of Lake Flannigan, is an example of this. In this case, the string has eroded upstream by sapping at the spring head.

2. Where there is bedrock underlying the dune, this can force groundwater to the surface. As with escarpment reaches, shallow bedrock forces groundwater to the surface. Eel Creek has an example of this type of spring where granite outcrops in the bed. Badger Box Creek is another example, although in this case, the ‘bedrock’ is actually the lithified Old Dune. Once past the bedrock outcrop, the water may again disappear underground, to re-emerge in a type 1 spring near the coast.

3. On Boggy Creek, there is a variation on a type 1 spring, with the water emerging at the coast. However, on this stream considerable calcium carbonate is deposited in the spring, to form the tufa terraces that are present at the site. It is these terraces that determine the height at which the water emerges.
Figure 25: A model of the interaction between groundwater and surface water flow on an escarpment and the upper and lower surface. Under winter conditions (A) streams flow along their whole length. Under summer conditions (B), flat reaches of stream often cease to flow.
Figure 26: A model of the interaction between groundwater and surface water flow where the western dune region meets the coast
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Effects of draining on hydrology

Extensive drainage systems have been constructed on King Island in order to increase the area of land suitable for agriculture. The immediate goal has varied from simply improving the drainage on the flats and slopes in the south of the island, to converting lagoons and wetlands such as South East Lagoon and Egg Lagoon to agriculture. However, as well as reducing waterlogging of farmland, by influencing the route that water takes through the landscape it is likely that these artificial drainage networks effect both groundwater flow and the surface streams.

Drainage schemes can effect the level of the water table. Draining swamps that are outcrops of groundwater is in effect directly lowering the water table. Also, by reducing the amount of time that rainwater spends in recharge zones, inputs to the groundwater could be reduced. Such reductions would have implications for the amount of the year that dams recharged by groundwater remain full. It is also possible that the base flow in the streams could be reduced. Note that there are also other pressures on the groundwater hydrology on King Island, such as direct pumping and evaporation from dams recharged by groundwater. It is beyond the scope of this report to comment more fully on this.

More directly relevant to this report are the effects of artificial drainage on the natural waterways downstream that receive the water. There are two possible ways that natural streams may be affected, both of which result in changes to the frequency and size of flows. Firstly, without drains, runoff is delayed in wetlands and small depressions in the paddocks and the soil itself before it reaches the streams. However, drains are designed to move water faster and more efficiently off the paddock and into the stream. This means that during and after a storm, runoff from the drained areas reaches the streams faster. The stream must transport the same amount of flood water in a shorter time, which means that the floods come faster and are deeper. Increasing flood size can cause erosion in the stream.

The second way that drainage schemes can effect the hydrology of natural streams is by changing the catchment boundaries. Because King Island is so flat, it is quite possible for a drain to be dug across the drainage divide. This can been seen on the 1:25,000 maps. The clearest example is the drains that link the Yellow Rock River, the headwaters of Eel Creek, and Bungaree Creek. It is probable that there are other cases. In this situation, which way the water runs will depend on the profile of the drain, rather than the topography of the natural landscape. Possibly, it will also be affected by the intensity of rainfall. To identify the new catchment boundaries would be a matter of surveying the drains, or simply watching which way the water flows. If the constructed drains do effect the catchment areas, both the stream that gains area, and the stream that loses area will respond. The stream that receives runoff from a increased catchment area will receive larger floods, and possibly larger base flows. This could cause considerable erosion of the channel and floodplain, as the stream adapts its morphology to take the changed flows. In contrast, the stream that has lost part of its catchment will suffer a decrease in flow. It may be unable to maintain its channel, which could become choked by vegetation and sediment. It is possible that this has happened in the case of Eel Creek and Bungaree Creek, although this would require conformation in the field. However, the two catchments are connected by drains. Eel Creek appears to have lost some flow. In the lower section, the channel is presently being covered by sand. In contrast, lower Bungaree Creek appears to have undergone considerable erosion of the channel and floodplain.
Figure 27: The lower section of Eel Creek, which appears to be in the process of being overwhelmed by sand.

Figure 28: Erosion on the lower floodplain of Bungaree Creek. Note the pedestals of soil around the base of the trees, indicating that the floodplain was once at that height.
It is worth noting that it is not just the stream channels that might have difficulty accommodating flows delivered by the drains. The drains themselves must be an appropriate size for the flows they receive. If changes to the drain network increase the flow in a drain that has not been designed to take that much water, there is a chance that the drain will erode. Figure 29 shows an erosion head on a drain that, according to the landowner, has recently had considerable flow diverted into it.

Figure 29: An erosion head in a drain that was not designed to receive the flows delivered by its catchment.
Riparian fencing for hazard control

In the introduction of this report, we mentioned that there are two motivations for fencing riparian vegetation. One is to protect the conservation value of the area, and this is largely what we have been discussing so far. The other motivation is to prevent erosion from damaging assets such as conservation areas, farmland, fences and roads. This section will discuss where it is important to protect riparian vegetation in order to minimise the risk of erosion.

Vegetation is most important for stream stability in areas where the stream is close to instability. The most obvious place where this occurs is where the stream changes from a deposition dominated surface reach, to an erosion dominated escarpment reach, or the other way round. As discussed above (in the section on ‘Interactions between landscape regions’), the exact position of this transition will have been influenced by the presence of riparian vegetation. Clearing that vegetation could destabilise the stream, allowing that transition zones between reaches to migrate up or downstream. We will briefly discuss the implications of this for the transition zones up and downstream of an escarpment reach.

According to the model presented above (Figure 22), the transition zone upstream of an escarpment reach consists of a knickpoint in the regolith, below which the slope of the stream might increase slightly, until it reaches the first bedrock outcrop that marks the beginning of the escarpment reach. In a worst case scenario, removal of the vegetation at this point could trigger movement of the knickpoint further upstream, causing considerable erosion of the stream bed and destabilising the stream banks. It would be difficult to predict how far upstream the knickpoint would travel under these circumstances. Such gully erosion can be seen on the lower section of Little Porky Creek, although at this site the cause of the erosion has not been clearly identified.

Figure 30: Erosion in the lower section of Little Porky Creek has undercut this small weir.
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At the downstream end of the escarpment reach the stream deposits an alluvial fan. At this point, the valley may widen, and the slope of the river decreases. Again, the exact position of this feature has probably been influenced by the presence of vegetation. The worst case scenario response to vegetation clearance at this point could be channel enlargement and stripping of the floodplain. It is possible that such an event has occurred in the Sea Elephant River, just downstream of the site of the possible stream capture discussed in the section ‘Controls on the development of King Island’s stream system’. This site is worthy of further investigation to determine if such a response has occurred.

Another area that may be susceptible to erosion after vegetation clearance is the confined floodplains of the escarpment reaches. The slope of these reaches is relatively steep, and flood waters are confined to what is often a very narrow valley. In these circumstances, flood waters can have considerable erosive power. Removal of the vegetation on the riparian zones and floodplains of these reaches could result in stripping of the floodplain. It is possible that even stock trampling in these areas could be enough to significantly increase the risk of erosion. Sites such as the Sea Elephant River in the escarpment and Grassy River at Grahams Road have the potential to suffer this type of erosion.

This talk of major stream erosion may seem out of place on King Island, which gives the impression of being a very stable place. In many areas of mainland south eastern Australia, major episodes of gully erosion began after agricultural expansion in the late 1800’s, and had almost stabilised by the 1940’s (Prosser and Winchester, 1996). King Island, unlike mainland Australia, has suffered the bulk of land clearing relatively recently. Fires in the 30’s and 40’s and the development of soldier settlement farms following the first and second world wars achieved considerable deforestation, but even in the early 60’s, only 30% of the island was under improved pasture (Hooper, 1973). It is possible that clearing on King Island has increased the potential for erosion, but because of the short time since clearing occurred there has simply not been a big enough flood to start the instability. It could be difficult to judge how stable the streams of King Island would remain during and after a large flood event.
Conclusions

This report set out to define regions within which the streams of King Island have similar form, and hopefully behaviour. To this end, we have described five regions where the controls on river behaviour differ. These regions are the relatively flat landscape surfaces, the escarpments at the edges of these surfaces, the dune fields of the west and east coasts, and the young northern plains. The streams of each of these regions do appear to have a characteristic form.

It is interesting to note that geology and climate had little direct influence on the definitions of these regions. Generally, climate and geology are important controls on the development of streams. The lack of climatic influence is explained by the relatively uniform climate across the island. The geology on the island has been subordinate to the history of the aeolian processes that formed the dune fields, and the geomorphic history that lead to the development of the surfaces and escarpments. This is not to say that geology has no influence on individual rivers, rather that it has not played a role in developing the character of an entire stream type. In this sense, King Island is remarkably different to much of western Tasmania, which is characterised by the dominant influence of geology.

Within the context of the landscape regions, riparian vegetation plays an important role in maintaining the stability of stream channels and floodplains. Vegetation has probably played an important part in the development of stable long profiles on the sand bedded rivers of the western dunes, has encouraged floodplain development in escarpment reaches, and influenced the stable slope in the transition zones at the top and bottom of escarpment reaches. In these cases, the continuing presence of healthy riparian vegetation could be essential to the stability of the stream. However, even in more robust sites, riparian vegetation is an essential part of a geomorphically healthy stream.

We hope that this classification of the streams of King Island will help with their management. The descriptions of the form of these rivers will probably become refined with use, and the predictions of their behaviour better developed. Time will tell if the regions themselves are correct!
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References


