2.6 Wetland forms

For palustrine and estuarine wetlands this category is a set of descriptors of landforms that wetlands occupy, and forms they create or contain. Other wetland forms are associated with standing open water, and flowing open water and channels.

The main broad-scale landforms associated with wetlands are shown diagramatically in Figs 21 and 22. There is considerable scope for applying more detailed geomorphological concepts and terms in order to understand and classify New Zealand wetlands. Our diversity of basement geology, substrate materials, and processes, provide many landform settings and patterns of water movement for distinctive types of wetlands. These details are beyond the scope of this book; field workers should become aware, from general texts on geomorphology, and from geological and soil maps, of the regional landforms that occur in their particular study areas. The following outline is intended as a summary guide to readily observable landform features.

2.6.1 Landforms which wetlands occupy

Five basic landforms that act as the containers or hosts to wetlands are: flats (Fig. 23), channels, basins (Fig.24), slopes, and hills or highlands (Semeniuk & Semeniuk 1995). This simple classification can be used as an aid to the grouping of similar wetlands or to provide an additional descriptor in documenting a particular wetland site.

The general nature of the land surface is an informative feature to record. The movement of groundwater and surface water can often be inferred by observing whether the ground surface is concave, convex, or planar, in two dimensions: along the contour (across the slope) and in profile (up-and-down the slope). These can help in understanding how and where groundwater enters a wetland, and its likely contribution of nutrients.

Fluvial processes – the action of streams and rivers – create many landforms. A currently active river will have reaches of different gradient, places of erosion, and sites of deposition such as floodplains, levees, and deltas. The earlier courses of a river are evidenced by forms of similar sculpture, as abandoned channels or terrace remnants of former floodplains.

Key to wetland forms

1 Not influenced by tidal water 2
Influenced, at least for some time, by tidal water 13

2 Inland peatland, with surface raised above surrounding terrain 3
Inland peatland or mineral wetland, with surface not raised above surrounding terrain . . 5

3 Surface flat to irregular with sloping margins . . . . . **plateau mire**
Surface convex 4

4 Convex surface small . . . . . **cushion mire**
Convex surface often extensive (>100 m) . . . . . **domed mire**

5 Adjacent to lakes and slow-flowing waters, with marked water fluctuations and periodic flooding 6
Not adjacent to lakes and slow-flowing waters 10

6 Floating . . . . . **floating**
Not floating 7

7 Located along shores of lakes . . . . . **shore**
Located near continuously flowing waters 8

8 Immediately alongside streams or rivers . . . . . **riparian**
Not immediately adjacent to flowing water 9

9 In or along cut-off channels . . . . . **channel**
Behind levees, on alluvial plains or terraces along valleys . . . . . **floodplain**
In interfluvial basins, channels or levees on active deltas . . . . . **delta**

10 Surface flat, topographically confined, with distinct slopes to the side 11
Surface flat to undulating, often appreciably sloping, peaty 12

11 Basin deposit, with greater depth in centre . . . . . **basin**
Orientated in linear patterns, the hollows between beach ridges or interdunal depressions . . . . . **swale**
Flat deposit, depth generally uniform, with water sometimes flowing into the middle . . . . . **flat**

12 Surface pattern of ridges and pools distinct . . . . . **string mire**
Surface pattern of pools generally absent . . . . . **blanket mire**

13 Semi-enclosed body of water having a free connection with the open sea with channel complexes that drain during low tide . . . . . **estuary**
An inland body of water, separated from the ocean by a barrier and situated in basins or embayments that do not drain during low tide . . . . . 14 **(lagoon)**

14 Generally coast-parallel bodies of predominantly fresh water impounded by a long narrow spit formed by longshore drift offsetting at a river mouth . . . **river mouth lagoon (hapua)**
Exceedingly 'choked' with respect to exchanges of water with the ocean via an inlet or inlets, with openings to the sea rare and short-lived unless created by human action . . . . . **coastal lake / lagoon**

(Note: many additional forms are associated with riverine, geothermal, and plutonic hydrosystems, but these are not within the scope of this book.)

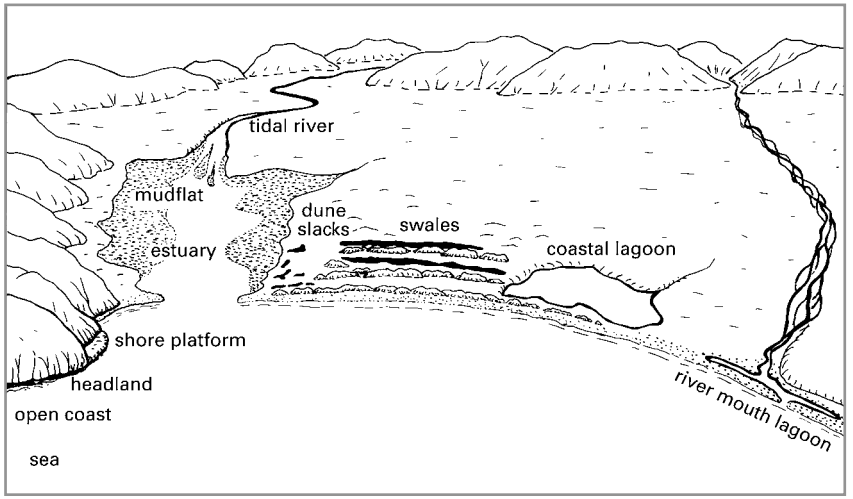

Fig. 21 Landforms of the estuarine hydrosystem.

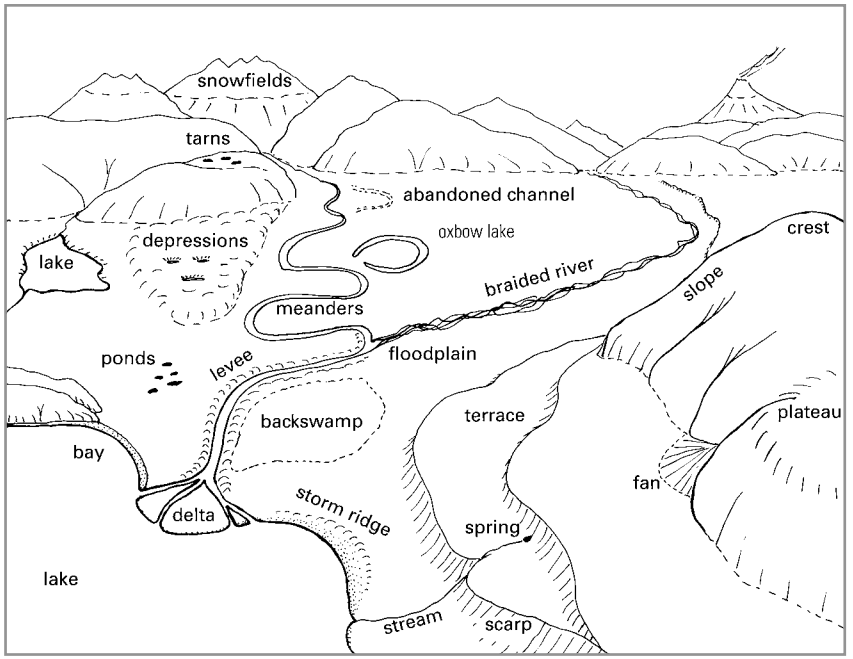

Fig. 22 Landforms of the palustrine and lacustrine hydrosystems.

Fig. 23 On a coastal plain near Haast, south Westland, wetlands occupy the elongated hollows, or swales, between old beach ridges, now forested, and formed in sequence as the land has risen relative to sea level and as the coast has built seaward. The youngest ridges and wetlands are those closest to the coast. These peaty wetlands receive some water flow and nutrients from the adjacent land and are therefore mainly fens, though the least fertile parts are bogs, including forest bog on the small 'islands' of slightly higher ground within the swales.

Many palustrine wetlands occur upon landforms that owe their origin to riverine systems yet are no longer actively affected by river or stream processes. Poorly drained parts of old river systems become marshes, swamps, and bogs. Many marshes occur along the inner margin of river terraces, where they are fed by seepages or springs from the foot of the scarp which lies below the next highest terrace. When in flood, sediment-carrying rivers tend to deposit some of their sandy and silty material close to the river margins, gradually building an elevated ridge, or levee; and whereas levees themselves are relatively well drained, the lower-lying land behind becomes progressively less so. A wetland that develops on a river terrace behind a levee is termed a backswamp. The development stages of

Fig. 24 Teviot Swamp occupies an upland basin on the Lammerlaw Range, Otago. Best classified as fen, the main peatland has developed upon a poorly drained fan that slopes gently to the right. The fen grades to seepages where water flow is more pronounced, both on the downslope margins and in the gullies upslope. The whole system is nourished by water that percolates from the deep soils of the adjacent tussock-grassland hills: a reminder that many wetlands are a surface expression of a whole catchment of groundwater.

river deposits and the relative ages of their wetlands can be gauged from aerial photos.

Coastal dune systems provide habitats for wetlands in the form of dune hollows which may hold seasonal or permanent water, more extensive damp sand plains, dune slacks (e.g. Sykes & Wilson 1987) which lie close to the sea and become ponded by rainfall or by incursions of the highest tides, and swales which are elongated depressions between beach ridges (Fig. 23).

Shore landforms are relevant for lakes, estuaries, and open coasts. A simple distinction can be drawn between headlands and bays; one an eroding environment exposed to wind, waves, and currents, and the other

a more sheltered place where sediment is deposited. New Zealand has diverse examples of strongly indented coastlines – large estuarine harbours, sounds occupying drowned valleys, inlets, and fiords – which provide many sorts of sites for wetlands. Shore features demonstrate something that is important in relating all landforms to wetland types: that of scale. For example, wave erosion on a macro-scale can produce a cliffed headland on an open coast; on a meso-scale a steep bank on a tidal river; and on a micro-scale a winnowed scarp a few centimetres tall in a lake-edge marsh. Storms at times of high lake level produce raised storm ridges of gravel or sand – the lake equivalent of river levees – and these are responsible for the impeded drainage that can encourage some palustrine wetlands to develop closely adjacent to lakes.

Different zones of freshwater and tidal water bodies have a specialist terminology, the following being of most relevance in the context of wetland studies. In lakes and ponds the littoral zone is the zone which extends from uppermost water level to the depth limit of rooted plants. The eulittoral is the portion between highest and lowest water levels, while the infralittoral is the zone segment just below the water's edge where emergent or floating vegetation is prominent. Pelagic describes the open waters of a lake; benthic the bottom habitats. On tidal shores the main terms applied to zones are intertidal for the zone that spans the distance between highest and lowest tides, subtidal for the permanently submerged zone below this, and supratidal for the zone above the highest tide level where there is an influence of wave splash and salt spray.

2.6.2 Forms which wetlands create

The most creative of wetlands are bogs, fens, and swamps, in the sense that they can create features at a small scale and distinctive landforms at a large scale because of the ways in which they accumulate an ever-increasing depth of peat.

Undulations of hummock-and-hollow topography on a mire surface become accentuated over time because peat growth is slower in the water-holding hollows than upon the hummocks. A bog surface often has mini-hummocks (Fig. 25) or surface channels (Fig. 26), while the hummocks in a swamp can grow to be thickly vegetated pedestals that teeter a metre or more above the intervening dark runnels (Fig. 27).

Fig. 25 Many wetlands create a hummock-and-hollow surface, because plant growth and peat accumulation are favoured on any ground elevated above the water table. This bog in the Mararoa Valley, northern Southland, has developed cushion forms. On a larger scale, note the islands formed by the elevated trunks of *Carex secta* within the pool.

Fig. 26 Surface channels are common in peatlands, though often hidden by vegetation. In this Westland fen, fire has removed the former cover of plants and litter (these resprouting ferns and sedges are just 3 months old). A channel 10 cm deep is illustrated by the cutaway section of peat, revealing also that the water table, after a period without rain, lies somewhat below the channel base.

Fig. 27 A swamp pool in south Westland beneath trees and *Carex secta* tussocks, and covered with floating leaves of *Potamogeton suboblongus*: an example of how one wetland class (shallow water) can occur within another (swamp).

Fig. 28 Two flarks in an upland gully seepage, Lammermoor Range, Otago. Flarks are temporary ponds in peatland and they can become deeper, permanent pools as peat growth continues only on the vegetated margins.

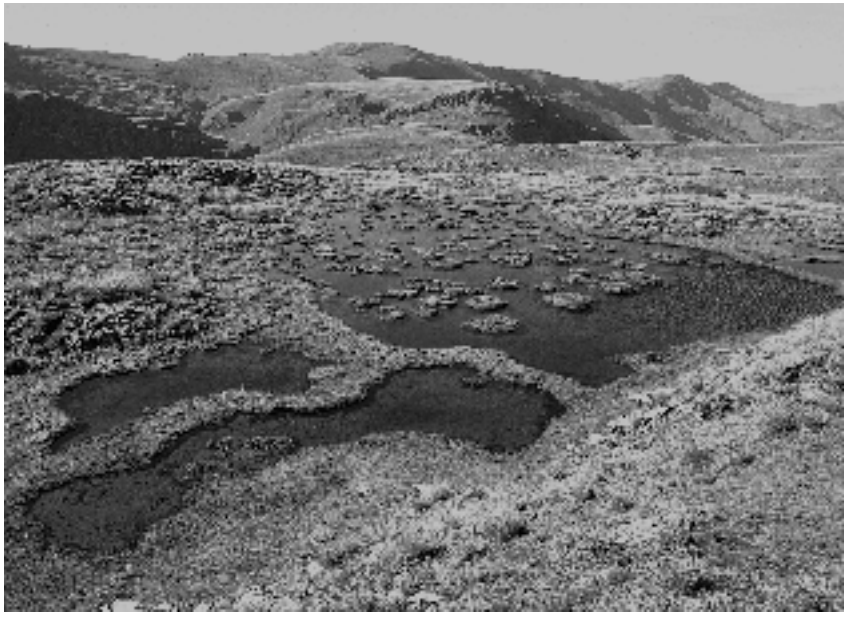

Fig. 29 A string mire is a superb example of a form created by wetland processes. The 'strings' are the elongated ridges of peat that act as dams on slight slopes, creating a sequence of pools in terrace fashion. Peat growth is most active where the bog mosses and sedges are constantly moist yet not inundated, so that the surface level of both the pool rims and the small pedestal islands continue to elevate, Garvie Mountains, northern Southland.

On a sloping peatland, depressions that are temporarily ponded (called flarks; Fig. 28) develop into permanent pools as peat growth adds to the relative height of their impounding rims (or strings), to produce a large-scale pattern of numerous pools, their long axes aligned across the slope: a string mire (Fig. 29), which is an excellent example of a patterned wetland. Little attempt has yet been made to classify New Zealand wetlands in terms of their patterning of surface form, relief, and arrangement of water features.

One of the classic forms created by natural wetland processes is the domed bog (Figs 30 and 135), where peat has grown deepest in the most poorly drained centre, resulting in a convex surface that rises above the local topography and becomes progressively more isolated from inputs of nutrients from either the underlying mineral substrate or the surrounding

Fig. 30 A domed (or raised) bog is one having a convex surface, resulting from greatest peat growth in the most poorly drained central part. Lake Kini Pakihi in Westland is an example, though its dome, typically, is difficult to discern by eye.

land. It is also commonly called a raised bog, and in earlier terminology 'high-moor', as distinct from 'low-moor', the latter describing a relatively young wetland having a level or concave surface. A plateau bog is a form of raised bog having sloping margins but a plateau surface rather than a fully convex dome; the term does not refer to a bog upon an underlying plateau landform.

Fig. 31 A lagg stream: one which drains the perimeter of an extensive domed bog (see Fig. 30), Lake Kini Pakihi, Westland.

The convex nature of a domed bog is not always obvious to the eye, and may be confirmed only by accurate survey of the ground profile. The margins of a domed bog, more sloping, are where outward seepage can sometimes be discerned; these marginal slopes are referred to as the rand, and they typically drain down to a peripheral stream or swamp called a lagg (Fig. 31).

A blanket mire (or blanket bog if wholly rain-fed) is a peatland which extensively covers the crests, slopes, and hollows of an undulating landform, generally one of low relief (Fig. 32).

When several wetland classes or even more than one hydrosystem occur together, as indeed happens regularly, they form what is termed a wetland complex.

Fig. 32 Blanket peatland can cover large extents of gently sloping land, irrespective of topography, in districts with a cool, windy climate. Here on the West Cape table-lands in Fiordland, tussock bog covers the most poorly drained peat, and grades to shrub bog and tree bog where drainage and fertility are marginally better. (Photo by Kelvin Lloyd.)

There are many situations where the growth habit of wetland plants influences the small-scale forms in wetlands. Cushion (or bolster) plants can be common in upland mires, forming hard convex cushions which may fuse into gently undulating mosaics, forming what is called a cushion bog, though some cushion communities are on fens, or can occur on mineral and sometimes scarcely wet substrates. Many mosses, including some *Sphagnum* species, form soft cushions (see Fig. 53), eventually rising to a level that provides a drier surface that other plants colonise, the whole process resulting in a long-lasting hummocky topography. Large hummocks are formed by many sedges and grasses of tussock habit as they raise themselves upon a pedestal or short trunk of persistent rhizomes and roots.

By trapping inorganic sediment, marsh plants build pedestals or platforms that influence the arrangement of water channels, most notably in large expanses of saltmarsh rushland where distinctive patterns of vegetated and bare ground are largely caused by the plants themselves (Fig. 33).

Rafted (or floating) wetlands are produced by vegetation that starts as a water-surface mat, then becomes a buoyant platform of roots, rhizomes, and

Fig. 33 Distinctive forms created by oioi restiad rushland, New River Estuary, Southland. These 'pikelets' are elevating themselves above the level of mudflats and tidal channels as the rushes trap sediment. They are 50–80 m across, but still actively expanding at their margins.

emergent foliage (see Fig. 94). Organic matter settles into the thick soup of underlying water, but may also accumulate as sedentary peat on the surface, eventually leading to a domed bog, yet still with a body of water beneath.

2.6.3 Forms of standing open water

Depending on their size and setting, bodies of standing (i.e. non-flowing) open water can be wetland hydrosystems or classes in their own right, or they can be inclusions within other wetland classes (Fig. 34). Lakes are the largest and they can be arbitrarily defined by having a major dimension of 0.5 km or more, the criterion used by Irwin (1975a) in his checklist of New Zealand lakes. Nevertheless, many smaller bodies of water, including some dune lakes, kettle lakes, and oxbow lakes, could be validly referred to as lakes on the basis of depth, permanence, or the operation of typical lake processes such as stratification and wave-action. Thermal stratification

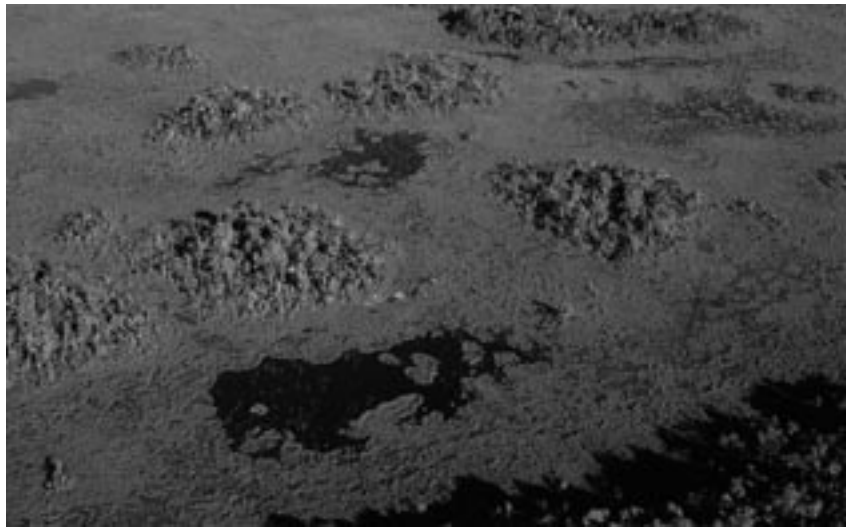

Fig. 34 Pools of shallow water are common in many palustrine wetlands, their shape, size, and distribution often being characteristic of particular wetland systems. These pools form part of a mosaic pattern with sedgeland, clumps and islands of reedland, and forested knolls in a Westland swamp system.

is the process whereby annual temperature cycles result in lake waters having horizontal layers of different densities. Monomictic lakes have a single period of stratification each year, generally in summer, alternating with a destratified period when mixing of the water layers, along with their nutrients and oxygen, is able to take place. Polymictic lakes have several periods of stratification and mixing each year. Amictic lakes are those which do not stratify.

A tarn is a small mountain lake (Fig. 35). A pond is an enclosed body of water, smaller than a lake, and often artificial, like the typical ponds of farmland. The term pool is applicable to an even smaller body of still water, often relatively stable in level, though it applies also, of course, to the deep and slow-flowing reaches of streams and rivers. The term peat pool is a useful one for pools within bogs and fens, these often having a characteristic rounded or oval shape, a relatively level base, and steep or overhanging peat margins.

A lagoon is a shallow lake, especially one that is permanently or periodically linked to a river, lake, or the sea. In New Zealand the term

Fig. 35 An alpine tarn – or small lake – on the flanks of Mt Tongariro, Volcanic Plateau. This tarn has relatively little fluctuation, and is bordered by zones of cushion plants, tussockland, then shrubland.

lagoon is most often used for coastal lagoons (Fig. 36) but it is also used for inland examples. Coastal lagoons are separated from the sea by barriers of sand and gravel. They are usually shallow, often elongated parallel to the coast, with varying degrees of tidal prism and tidal mixing, and water that varies from fresh to brackish, and even to hypersaline where evaporation leads to salt concentrations (40‰ or more) exceeding than of oceanic water (c. 35‰). In the South Island, Kirk & Lauder (2000) recognise two distinct types of coastal lagoon: a 'hapua' type associated with the mouths of large braided rivers, having mainly freshwater but receiving some salt from spray and wash-over; and a 'Waituna' type (after Waituna Lagoon, Southland), more usually closed from the sea than open to it, having small inputs of river inflow, and with wind waves, currents, set-up, surge, and seiches as important mixing agents.

An estuary is a coastal body of water, partly enclosed by land but open to the sea, where seawater is diluted by land drainage, and where tidal effects

Fig. 36 Part of a coastal lagoon (Te Whanga Lagoon, Chatham Island) that is periodically open to the sea. In the background, beyond fernland and scrubland on blanket peat, are two coastal lakes, separated from the sea by dunes.

are evident. Many estuaries are located at the widened funnel-shaped mouth of a river, while others receive their freshwater only from streams (Fig. 37) and inflowing groundwater. Tidal rivers are those lowermost reaches of rivers affected by tidal flow or backwater, though these effects may have an influence further up-river than the inland boundary of the estuarine hydrosystem, defined by the place where marine salt concentration is 5‰. Harbours, inlets, and bays that are open to the sea have oceanic water and belong to the marine hydrosystem, but the deep and elongated fiords of high-rainfall Fiordland are distinctive as they receive considerable inputs of freshwater which persists as a permanent surface layer of low-salinity water buoyant above deeper seawater.

Man-made bodies of standing open water come in many forms, including hydro-electric lakes, reservoirs for irrigation or domestic water supply,

Fig. 37 A tidal creek in a bush setting, Stewart Island: an estuarine wetland with shallow water and a saltmarsh of *Puccinellia* grassland, influenced by gentle tidal ebb and flood flow, and by the mixture of freshwater and seawater.

farm ponds, ponds used for aquaculture, ornamental ponds, borrow pits, and ponds for the settling, treatment, or oxidation of discharges from stormwater, quarrying, mining, industry, and sewage.

2.6.4 Forms of flowing open waters and channels

Many wetlands either contain, are fed by, or are almost wholly composed of areas of moving water. Flowing waters within relatively permanent and well-defined channels will usually be classified within the riverine hydrosystem. Different portions of streams and rivers can be described by terms such as fall, cascade, rapid, riffle, run, glide, pool, backwater, bed, braid, and delta. Riparian habitats are those that occur along the margins of streams and rivers. Channels range in gradient from steep to gentle, and they may at one extreme be confined within a gorge (Fig. 38), or at the other extreme, free to spread laterally across a floodplain.

A braided river is one which carries a high sediment load, the ever-deepening shingle causing the river to follow numerous channels which

Fig. 38 A gorge (appropriately, Gorge River, south Westland) where extremes of flood discourage tall plants but encourage a broad zone of seepages.

repeatedly branch and rejoin, with an intervening pattern of low islands and shallow bars (Fig. 39). A meandering river or stream occupies a valley of low gradient, where the main channel is able to swing across the full width of its floodplain in sinuous turns called meanders (Fig. 40). As the channel shifts course the abandoned meanders (or oxbows when the cut-off river bend returns almost upon itself) can develop to marshes, ephemeral wetlands, swamps, or oxbow lakes.

Water channels that occur within palustrine wetlands are often too small or too slow to be called streams, but they can nevertheless display on a small scale many of the same sorts of adjacent features that can be seen on their larger counterparts. Much of the flowing water in palustrine wetlands is not channelled, but percolates as groundwater, or as a sheet of surface water (see Fig. 82).

As described earlier, the term seepage is here adopted for one of the wetland classes. A seepage (Fig. 41) is an area where groundwater percolates

Fig. 39 A braided river: one having numerous channels and carrying a heavy load of sediment, Waimakariri River, Canterbury.

to the land surface, the flow being less than that which would be considered a spring. A flush is a type of seepage that carries a periodic flush of water across the ground surface (Fig. 42). A spring is a stream emerging to the surface from underground at a point source (Figs 43 and 44). Both springs and seepages can emerge either upslope of, within, or at the toe of sloping wetlands. Their occurrence within a fen, for example, can be caused by an upwelling of groundwater through hydrostatic pressure, producing localised areas, sometimes as raised pustules, of enhanced aeration and nutrient status (Fig. 45).

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Fig. 40 Stream meanders and oxbows of former channels are typical of a valley having a gentle gradient and a wide floodplain. This upland valley in the Garvie Mountains, northern Southland, holds a mixture of bogs and fens on the valley floor, and of seepages and pools on the opposite hillside.

Fig. 41 A seepage complex on the Lammermoor Range, Otago, nourished both from the adjacent tussock grasslands and the peat-retained pool on right, showing how degrees of water movement and flushing have produced a fine-scale pattern of different vegetation types, distinguishable by their colours.