5. DESCRIPTION OF THE ENVIRONMENT

5.1 Geology and Geomorphology

The Shire of Broadford contains a number of different geology types which have influenced landform development since the Paleozoic era over 400 million years ago. There are extensive folded and deeply dissected sedimentary hills, granite intrusions forming plateaus resistant to weathering, volcanics forming extensive basalt flows and cones, long periods of erosion creating colluvial fans, and recent alluvial deposition forming broad creek floodplains and terraces (Table 5.1).

The highest point of elevation in the Shire is 800 m at Mt Tallarook in the Tallarook State Forest, and the lowest point is 190 m in the north of the Shire along the Sunday Creek terrace. The majority of the Shire lies within the Goulburn River catchment area. A number of large creeks, including King Parrot Creek and Sunday Creek, dissect the Shire and are important tributaries of the Goulburn River. In the south of the Shire, the small Wallaby Creek catchment drains towards Melbourne.

Landforms discussed in section 5.1 have been classified according to McDonald *et al.* (1984), (Table 5.2).

Table 5.1 Geological history

GEOLOGICAL HISTORY	TIME SCALE (million years)	MAJOR EVENTS	MAP UNIT
Quaternary	1.8-present	Formation of creek floodplains and terraces e.g. King Parrot Creek, Sunday Creek. Formation of hill wash, fan deposits after long periods of erosion. Volcanic activity at the end of the Tertiary and the beginning of the Quaternary periods created basalt plains and cones close to Broadford township.	Qa Qf Qb
Tertiary	65-1.8	Formation of hill wash, fan deposits	
Carboniferous - Cretaceous	376-65	Major erosional period, exposure of granitic intrusions forming plateaus at Mt Tallarook and Mt Disappointment.	
Devonian	416-367	Substantial intrusion of granite and granodiorite at Mt Tallarook and Mt Disappointment. Continuous uplift, folding and faulting of Silurian/Devonian sediments creating highland areas in the east of the Shire and lower hills in the west. Deposition of marine sediments	Dg Ds
Silurian	436-416	Extensive deposition of marine sediments	

5.1.1 Sedimentary Undulating Low Hills/Undulating Hills

The undulating low sedimentary hills are common in the Shire of Broadford (Figure 5.1). They occur mostly to the south and north of Broadford township, and are bordered by undulating basalt plains in the west and steep granitic and sedimentary hills in the east. Minor occurrences are also adjacent to King Parrot Creek in the west of the Shire. Side slopes of these hills are generally between 3% and 10%, however there are occurrences of slopes greater than 10%. Creeks such as Dry, Sunday, Mia Mia and Dabyminga creeks dissect these hills. Saline discharge areas have been recorded in these landforms, as has gully and sheet erosion.

Table 5.2 Simple types of erosion landform patterns characterised by relief and modal slope

	MODAL TERRAIN SLOPE						
RELIEF	**LE Level >1% (about 1:300)**	**VG Very gently inclined 1-3% (about 2%)**	**GE Gently inclined 3-10% (about 6%)**	**MO Moderately inclined 10-32% (about 20%)**	**ST Steeply inclined 32-56% (about 40%)**	**VS Very steeply inclined 56-100% (about 70%)**	**PR Precipitous >100% (about 150%)**
Very High >300 m		-	-	RM Rolling Mountains	SM Steep Mountains	VM Very Steep Mountains	PM Precipitous Mountains
High 90-300 m	-	-	UH Undulating Hills	RH Rolling Hills	SH Steep Hills	VH Very Steep Hills	PH Precipitous Hills
Low 30-90 m	-	-	UL Undulating Low Hills	RL Rolling Low Hills	SL Steep Low Hills	VL Very Steep Low Hills	B Badlands
Very Low 9-30 m	-	GR Gently Undulating Rises	UR Undulating Rises	RR Rolling Rises	SR Steep Rises	B Badlands	B Badlands
Extremely Low <9 m	LP Level Plain	GP Gently Undulating Plain	UP Undulating Plain	RP Rolling Plain	B Badlands	B Badlands	B Badlands

source: McDonald *et al.* (1984)

Figure 5.1 Sedimentary low hills

5.1.2 Sedimentary Steep Hills/Rolling Hills

Steep and rolling sedimentary hills cover much of the centre and western half of the Shire (Figure 5.2). These hills are characterised by high relief and narrow, rocky crests with steep side slopes generally ranging between 33-60%. Ridges generally run north-south and are separated by streams. Steep escarpments surround both the Mt Tallarook and Mt Disappointment plateaux. Metamorphic ridges, such as the Three Sisters, which were produced as a result of contact between existing sedimentary rock and upwelling granite, are included in these landforms. The potential for sheet, rill and gully erosion in this unit are high.

5.1.3 Granite/Granodiorite Steep Hills/Rolling Hills

The granitic batholiths in the Shire have been exposed by weathering and are now in the form of dissected plateaux surrounded by deeply dissected terrain classified as rolling and steep hills (Figure 5.3). Generally it is the later landform that is found in the private land study area. These granitic hills occur in the Toolangi and Mt Disappointment State Forests with convex slopes generally between 20%-56%. Outcropping granite boulders are common in these landforms. A small area of granite is also located near Flowerdale although most of this area has been eroded away to form a mix of colluvium with sedimentary material. Only a couple of small rock outcrop areas still exist there.

Figure 5.2 Sedimentary steep hills

5.1.4 Basalt Gently Undulating Rises/Undulating Low Hills/Rolling Low Hills/Rolling Hills

There are five volcanic eruption points in the Shire (Figure 5.4). The major points are close to the township of Broadford at Round Hill and Prospect Hill. The lava flows associated with these cones were fast and shallow creating undulating rises and low hills with average side slopes between 0% and 10% (Figure 5.5). The cones themselves are classed as rolling low hills with slopes up to 32%. The other volcanic eruption points at Bald Hills, Clonbinane and just east of Broadford township were more viscous flows and therefore more confined. They are all rolling low hill landforms with average side slopes between 10% and 32% and relief between 30 and 90m. Rock outcrops are common on crests and cones of each of the flows.

Figure 5.3 Granite steep hills

Figure 5.4 Basalt cone at Round Hill

Figure 5.5 Basalt gently undulating rises

Figure 5.6 Colluvial fans of the Three Sisters metamorphic aureole

5.1.5 Quaternary Fans Undulating Low Hills/Rolling Low Hills/Rolling Hills

A complex colluvial fan area, that is a mixture of both sedimentary and granitic material, has formed on the eastern slopes of the Three Sisters Range as a result of extensive erosion and hillwash (Figure 5.6). These fans are classed as rolling low hills with slopes between 10%-32%. A small sedimentary fan is also in this area. It is steeper and part of the rolling hills landform. Undulating fans, with slopes between 3%-10%, have formed on sedimentary hill footslopes.

5.1.6 Alluvial Floodplains and Terraces

Alluvial floodplains or terraces occur along the major creeks in the Shire as a result of overbank flooding. The most substantial accumulations are the floodplains along Sunday Creek and King Parrot Creek (Figure 5.7). The morphology along these floodplains, particularly the later, are very complex because of abandoned meander loops and channel bars. The alluvial terraces are only a small component of the study area, but are significant due to their fertile soils, their proximity to streams and their unique characteristics.

Figure 5.7 Alluvial floodplain at King Parrot Creek

5.2 Soils

Soil development is dependent upon a number of interrelating factors which include parent material, topography, vegetation, climate and time. The many soil types in the Shire of Broadford reflect the variations in these factors. This report identifies the range and location of the soil types present and describes their physical and chemical properties in detail.

In this chapter the soils are discussed in general terms and have been grouped into the geomorphic units already described in the preceding chapter. More detailed descriptions of the soils and their corresponding land units are provided in Section 4.2.

The soil types have been described and categorised, into three major groups, according to Northcote (1979).

Uniform soils: Soil profiles with very little, if any, textural change with depth.

Gradational soils: Soil profiles that become increasingly finer textured (greater clay content) with depth.

Duplex soils: Soil profiles that have a clearly pronounced texture contrast between the A and B horizons.

5.2.1 Sedimentary undulating hills/low hills/steep hills/rolling hills

Three major soil types occur throughout the sedimentary landforms: yellow duplex, light grey gradational and uniform fine sandy loams.

Yellow duplex soils
Factual Key: Dy3.41
Map units: Dsc, Dsd, Dsf, Dsg
Plate: 1

These common yellow duplex soils have hardsetting silty loam, fine sandy topsoils, bleached gravelly A2 horizons and mottled medium to heavy clay subsoils that are well structured. They generally occur on gentle to moderate slopes with deeper profiles on the former. They tend to be low in nutrients and have low permeability rates.

Factual Key: Dy3.42
Map unit: Dsh

The yellow duplex soils in the sedimentary drainage lines are similar to those on the slopes. The main differences being a deeper profile, a lower gravel content, a neutral pH trend and the presence of iron and manganese nodules. Nutrient status is again low in the topsoil and permeability is low. Salt content can be moderate or even high in the subsoil indicating probable rising saline water tables.

Light grey gradational soils
Factual Key: Gn2.94
Map unit: Dse
Plate: 2

Shallow gradational soils occur on the gentle sedimentary crests. Hardsetting apedal loams overlie bleached apedal clay loams and silty clay A2 horizons. The subsoils are mottled light clays which are also apedal. Gravel is very common throughout the profile. These soils are strongly acidic, low in nutrients and have low water holding capacities, therefore exotic plant growth will be restricted.

Uniform fine sandy loams
Factual Key: Uc2.21
Map units: Dsa, Dsb
Plate: 3

Shallow loams and fine sandy loams are located on the narrow sedimentary ridge lines and steep slopes. One of the most characterisitc features of these soils is the very large amount of gravel throughout the profile. Other features include high acidity, low nutrients and rapid permeability. These features make these soils unsuitable for most uses other than native vegetation growth.

5.2.2 Granite/Granodiorite rolling/steep hills

Two main soil types occur on the granitic hills: yellow duplex and uniform coarse sands.

Yellow duplex
Factual key: Dy3.42
Map units: Dgc, Dgd
Plate: 4

Yellow duplex soils exist on the moderate granitic slopes. These soils have dark grey light sandy clay loam topsoils, deep bleached clayey sand A2 horizons and highly mottled clay loam subsoils. Nutrient status is low throughout the profile. These soils are generally only used for native forests and pine plantations.

Uniform coarse sands
Factual Key: Uc2.21
Map units: Dga, Dgb
Plate: 5

Shallow coarse sands occur on the crests and steep slopes of the granite terrain amongst outcropping boulders. Profile development is minimal and limited to organic matter accumulation and structure in the topsoil. These soils are generally only used to support native vegetation because of their low water holding capacity for plant growth and low nutrient status.

5.2.3 Basalt Gently Undulating Rises/ Undulating Low Hills/Rolling Low Hills/Rolling Hills

Three major soil types occur on the basalt; red gradational, dark uniform and yellow duplex soils.

Red gradational
Factual Key: Gn3.12
Map units: Qba, Qbc, Qbd, Qbf
Plate: 6

Moderately shallow gradational soils that are usually red in colour but sometimes brown, are the most common soil type on the basalt cones, hills and rises. The topsoils are well-structured heavy clay loams and the subsoils medium clays also with a strong structure. Nutrient status is moderate to high throughout the profile and permeability is moderate. It is these properties which make these soils relatively favourable to grazing and so they mostly have been cleared of native vegetation.

Factual Key: Ug6.1
Map unit: Qbg
Dark uniform
Plate: 7

Black cracking clays are common on the very gentle basalt slopes, particularly around Round Hill. Dark grey structured heavy clay topsoils overlie dark greyish brown clay subsoils. The properties of these clays cause them to shrink and crack upon drying, hence their name 'black cracking'. When moist, these cracks close and their permeability is then very low. These soils have a very high nutrient status throughout the profile and have been cleared substantially for grazing.

Yellow duplex
Factual Key: Dy3.13
Map unit: Qbh
Plate: 8

Alluvial soils in the basaltic drainage depressions are variable in nature but are predominantly yellow duplex. Black light clay topsoils overlie greyish brown clay loams and then greyish brown heavy clays. The subsoils are mottled, indicating impeded drainage and low permeability.

5.2.4 Colluvial Fans Undulating Low Hills/Rolling Low Hills/Rolling Hills

Three soil types are associated with the colluvial fans in the Shire. Yellow duplex, dark duplex and uniform gravelly loams.

Yellow duplex
Factual Key: Dy3.42
Map units: Qf1d
Plates: 9

The soils on these units near Flowerdale have been developed from a mix of hillwash from the above sedimentary hill and remnant granite/granodiorite and are therefore variable in nature. The soil profiles are generally deep with loam topsoils, bleached clay loam A2 horizons and mottled clay subsoils. Coarse sand content will vary. Being a recently deposited material, these soils are very susceptible to erosion.

Factual Key: Dy3.41
Map units: Qf2f, Qf2g
Plate 10

The colluvial soils on the sedimentary hill footslopes have weakly structured grey loam topsoils, bleached apedal clay loam A2 horizons and mottled light medium clay subsoils. The profiles are moderately deep and permeable and have randomly distributed gravel throughout. Nutrient status is low and the profile is strongly acidic.

Dark Duplex
Factual Key: Dd2.42
Map unit: Qf1f
Plate: 11

This colluvial fan land unit is in sequence with the other Flowerdale fan units discussed above. It is a similar soil in that it has a loam topsoil with fine sand, a bleached A2 horizon and mottled clay subsoils. The distinguishing feature of this profile is that the clays are a dark grey. The topsoils of this soil are low in nutrients and strongly acidic. Profile permeability is very low.

Uniform gravelly loams
Factual Key: Um
Map unit: Qf3c
Plate: 12

This colluvial soil is associated with a small fan near the Three Sisters near Flowerdale. The profile has a uniform texture throughout; silty loams and loams with abundant sedimentary fragments. The colour of the profile grades from dark brown to yellowish red and brown and is highly permeable and low in nutrients.

5.2.5 Alluvial Floodplains and Terraces

Three major soil types occur on the alluvial floodplains and terraces in the Shire; uniform silty loams, yellowish brown gradational soils and uniform fine sandy loams.

Uniform silty loams
Factual Key: Um
Map unit: Qa1
Plate:13

The soils found along the Sunday Creek floodplain are uniform brown to greyish brown silty loams with fine sand. They are the result of overbank flow from the creek, and because they are relatively young, profile development is minimal. Soil structure is weak platy throughout and nutrient status is low. The profile is moderately permeable and capacity for water storage for plant growth is high.

Yellowish brown gradational soils
Factual Key: Gn4.66
Map unit: Qa2
Plate: 14

Compared to the soils described above, the soils along King Parrot Creek show greater profile development. Dark greyish brown fine sandy loam topsoils overlie bleached fine sandy loam A2 horizons. The subsoils are yellowish brown fine sandy clay loams with abundant mottling. Structure is moderate to weak and nutrient status is low. The topsoils are strongly acidic and as a consequence aluminium contents are high. The permeability of these soils is very low.

Factual Key: Gn4.64
Map unit: Qa3
Plate: 15

These terrace soils found along creeks such as Mia Mia are very similar to those above. Dark greyish brown loams with fine sand overlie a bleached loam A2 horizon and a yellowish brown clay loam subsoil with mottling. The major differences between the two profiles is that this one has gravel fragments in most horizons and is acidic throughout the profile.

Uniform fine sandy loams
Factual Key: Uc2.21
Map unit: Qa4
Plate: 16

These alluvial soils consist of a mix of fine sandy loams and rounded gravel layers that have originated from stream beds. The sands are weakly structured or apedal and low in nutrients. Colour ranges from dark brown in the topsoil to bleached then brown in the subsoil. The soil's capacity to store water is low and it is moderately permeable.

Plate 1 Yellow duplex soil (Dy3.41)

Plate 2 Light grey gradational soil (Gn2.94)

Plate 3 Uniform fine sandy loam (Uc2.21)

Plate 4 Yellow duplex soil (Dy3.42)

Plate 5 Uniform coarse sands (Uc2.21)

Plate 6 Red gradational soil (Gn3.12)

Plate 7 Uniform dark clay soil (Ug6.1)

Plate 8 Yellow duplex soil (Dy3.13)

Plate 9 Yellow duplex soil (Dy 3.42)

Plate 10 Yellow duplex soil (Dy3.41)

Plate 11 Dark duplex soil (Dd2.42)

Plate 12 Uniform gravelly loam (Um)

Plate 13 Uniform silty loam (Um)

Plate 14 Yellowish brown gradational soil (Gn4.66)

Plate 15 Yellowish brown gradational soil (Gn4.64)

Plate 16 Uniform fine sandy loam (Uc2.21)

5.3 Land systems

A land system is an area of land, distinct from the surrounding terrain, that has a specific climatic range, parent material and landform pattern. These features are expressed as a recurring sequence of land components. Land system mapping is generally at a scale of 1:100 000 or 1:250 000 and is appropriate for large scale planning exercises, such as regional planning.

Land units or components are distinguished by recurring slope, soil, aspect and vegetation patterns. Land units are therefore subject to similar forms of land degradation. A map unit may be the same as a land unit, however a larger mapping scale allow land components to be divided into further distinct areas based on more specific soil and topographical characteristics.

The hierarchy of the Land System concept has been maintained in this study. At the broadest level, Rowan (1990) identified seven land systems in the Shire of Broadford at a scale of 1:250 000. In the Reconnaissance Survey of the Middle Reaches of the Goulburn River Catchment, White (1990) identified 18 land units at a scale of 1:100 000.

In this study, at a scale of 1:25 000, 27 map units have been identified. In Table 5.3, the close relationship between the soils of the two more-detailed studies can be seen. Where clear relationships do not occur, the 1:25 000 land capability study has invariably been able to identify more accurately the dominant soil.

Table 5.3 Comparisons of scale and detail in land inventory studies

(i) Land Systems of Victoria 1:250 000	**(ii) Land Units in the Mid Goulburn Catchment 1:100 000**		**(iii) Map Units in the Shire of Broadford 1:25 000**		
land system	**land system**	**soil**	**map units**	**soil** major	minor
1.1 Gg8-1	PHu4	Gn/Dy	Dgd	Dy3.42	Uc2.21
	PLHr-u4	Gn/Dy	Qf1d	Dy3.42	
	P/Dsm4	Gn/Dy	Qf1f	Dd2.42	
	Sg4	Gn4.5			
1.1 Gs7-4	Hr2	Gn3/4	Dsd	Dy3.41	Gn3.04
1.1 Gs8-1	LHu2		Dse	Gn2.94	Dy3.41
	Sg2		Dsf	Dy3.41	Gn3
	Svg2		Dsg	Dy3.41	Gn3
			Dsh	Dy3.41	Gn3
			Qf2f	Dy3.41	Gn3.84
			Qf2g	Dy3.41	Gn3.84
	DC2/7		Qa1	Um4	
			Qa2	Gn4.66	
			Qa3	Gn4.64	
			Qa4	Uc2.21	
1.1 Sg8-1	Hs4	Gn/Dy	Dga	Uc2.21	
	Es4	Gn/Dy	Dgb	Uc2.21	
			Dgc	Dy3.42	Uc2.21
1.1 Ss7-2	Es2	Gn3/4	Dsa	Uc2.12	Gn4.64
1.1 Ss7-3	Hs2		Dsb	Uc2.12	Gn4.64
			Dsc	Dy3.41	Gn4.64
			Qf3c	Um	
7.1 Pvf7-8	Hu7	Uf6.2/3	Qba	Gn3.12	Gn4.42
	LHu7	Ug5	Qbc	Gn3.12	Gn4.42
	DC7		Qbd	Gn3.12	Gn4.42
	R7		Qbf	Gn3.13	Gn4.42
	Hr7		Qbg	Ug6.1	Gn3.12
			Qbh	Dy3.13	Ug6.2

5.4 Existing land uses

Past and present land use will provide some indication of the nature of the land. Historically the Shire of Broadford has hosted many uses including agriculture, mining, timber harvesting, industrial and residential development.

5.4.1 Public land

Public land accounts for approximately one third of all land in the Shire of Broadford. Major parcels include part of the Tallarook State Forest (49 km^2) and part of Mt Disappointment State Forest (232 km^2). Smaller parcels include the Mt Piper Education Reserve, Waste Treatment Ponds and various recreation reserves.

5.4.2 Forestry

Timber production occurs on both private and public land in the Shire. Production of the softwood timber *Pinus radiata* occurs on private land in the east of the Shire at Flowerdale and Strath Creek. Production of mixed hardwood timbers occurs on public land in the Tallarook and Mt Disappointment State Forests.

5.4.3 Mining

Old goldmines and gold workings in the Tallarook and Mt Disappointment State Forests are evidence of past mining activities in the goldmining era. Gold prospecting still continues within the Shire. There are numerous sites of gravel extraction within the Shire. The gravel is primarily used for the construction of roads.

5.4.4 Grazing

Sheep grazing for wool and meat production, and cattle grazing for the production of veal and beef are the most important agricultural industries in the Shire. Other grazing enterprises include deer farms and horse studs. Because of the pressure of rural residential development, the number of large holdings and full-time farmers has decreased dramatically.

5.4.5 Recreation

There are a wide range of recreational pursuits undertaken in the Shire of Broadford, most of which occur on public land. Community sporting facilities provide opportunities to play golf, tennis, football, basketball and netball, while State Forest and Conservation Reserves provide opportunities for bushwalking, orienteering, four wheel driving, hunting, and sightseeing. The major creeks are popular fishing spots.

5.4.6 Residential Development

The population of the Shire of Broadford is expanding due to its close proximity to the suburbs of Melbourne and the Hume Highway. Small lot development is occurring in the south and east of the township of Broadford. Smaller, isolated development is also occurring at Reedy Creek and Waterford Park. Large areas of private land have also been subdivided for rural residential development across the Shire. These rural residential blocks range in size from 1 ha to 40 ha. Hobby farming is popular on properties of this size.

Residential development can result in soil erosion and pollution of waterways when not correctly managed. As development continues, the provision of community services to population centres in the Shire will assume greater importance.

The need to provide for residential development and community services may often conflict with agricultural, recreation and conservation needs.

5.5 Land degradation: incidence and susceptibility

The fragile nature of our soils and landscapes, coupled with intensive land use, can result in deterioration of the land resource. Some land deterioration processes are natural (e.g. soil creep) but their rate has been accelerated since European settlement and associated changes in land use. The Shire of Broadford hosts many different uses, as outlined in Section 5.4, and contains a wide variety of landscapes and soils with varying resistance to land degradation. More detailed information on the susceptibility of a particular land unit to forms of degradation is outlined in Section 4.2.

5.5.1 Dryland salinity

Dryland salinity is the result of saline groundwater reaching the soil surface or plant root zone and affecting plant growth and soil structure. It is caused by excess water infiltrating through the soil profile into the groundwater system. This results in mobilisation of salts in the subsoil and rising groundwater transports this salt into the root zone. This process is aggravated in areas where native vegetation has been removed and replaced with shallow-rooted species causing rain water, in excess of plant requirements, to run off as surface flow or percolate through the profile to the groundwater table. The groundwater level then rises until it reaches the surface at lower points in the landscape.

The areas within the landscape that contribute to the groundwater are known as recharge areas. The areas showing signs of salinity and high watertables are discharge areas. High recharge areas generally have shallow soils which contain a large percentage of coarse material, such as gravel or sand. They usually occur on the higher parts of the landscape such as ridges and crests. Potential recharge refers to the ability of an area to contribute to the groundwater system. Land management has a major influence on recharge to groundwater, for example, an area has a high potential recharge but because of existing dense tree cover, accession to the groundwater is low. However, accession would be high if the trees were replaced with shallow-rooted pastures.

Contributions to the groundwater system can be either on a regional basis; carried through to adjacent subcatchments, or local; within the subcatchment boundary. The Shire of Broadford, with its range of geomorphological types, possesses a number of potentially high recharge areas. Those land units with potentially high or very high groundwater recharge potential include the crests of the basalt cones (unit Qba), the narrow crests and steep slopes in the sedimentary hills (Dsa, Dsb), parts of the lower more gentle crests in the sedimentary undulating hills (Dsd) and the high rocky crests and steep slopes in the granite or granodiorite (Dga, Dgb).

5.5.2 Sheet Erosion

Sheet erosion arises when the forces due to rainfall, flowing water and gravity overcome the cohesion and weight of the soil particles. This usually occurs when rainfall exceeds the infiltration capacity of the soil and run-off results.

The soils most susceptible to sheet erosion have low infiltration capacities, occur on steep slopes, have heavy textures, poor structure and are dispersive, and have minimal vegetation cover.

Landscapes that are highly susceptible to sheet or rill erosion in the Shire usually are those on the steeper slopes and include the moderately and steeply sloping fans near Flowerdale (Qf1d, Qf3c), gentle and moderate basalt slopes (Qbc, Qbd, Qbf), the moderate and steep sedimentary slopes (Dsb, Dsc, Dsd) and all granite slopes (Dgb, Dgc, Dgd).

5.5.3 Gully Erosion

Gully erosion is the removal of soil resulting in the forming of channels deeper than 300 mm that will disrupt normal farming operations (Charman and Murphy 1991). Gullies generally evolve in drainage lines where runoff and seepage accumulates. The lower drainage lines in the catchment are particularly prone to as they receive a greater volume of water. Gullies are most common in catchments with moderate to steep slopes and where native vegetation removal is extensive.

Gully erosion is quite common in the Shire on the gentle slopes and drainage lines of the sediments and colluvial fans. These gullies are most likely the result of changing land use; clearing of native vegetation for agriculture or residential purposes, and the disturbance of drainage systems, usually through road construction.

5.5.4 Mass movement

Mass movement occurs when gravitational stresses on soils exceed resistance and the soil moves down slope. Usually a combination of factors will contribute to mass movement. Rock and soil weathering, increases in soil water content, vegetation removal, slope and man made interferences, such as road building, are all important causes. There is a significant occurrence of mass movement on the western slopes of Bald Hills Range. Other land units that may be susceptible include other moderate and steep basalt slopes (Qbc, Qbd), the moderately sloping fans near Flowerdale (Qf1d) and the steep sedimentary and granite slopes.

5.5.5 Wind erosion

Wind erosion is the movement of soil particles by wind. It occurs on soils of light texture under conditions of low rainfall and strong winds, and is most extensive on the inland farming areas where annual rainfall is below 375 mm (Charman and Murphy 1991). It will not often occur in the Broadford Shire except in times of drought when the soils dry off, but significant damage could occur at these times. Soils that will be most susceptible will be the light textured King Parrot Creek floodplain soils, some of the colluvial fans, the sedimentary drainage depressions and light textured sandy soils on the steep slopes.

5.5.6 Soil structure decline

Soil structure decline is a result of cropping practices. Lost productivity due to soil structure decline is difficult to detect and often goes unrecognised. Traditional cultivation techniques, not suited to Australia's weakly structured topsoils, break down soil aggregates into finer particles. These finer particles can slump together forming a seal on the soil surface which impedes the flow of water and air. This reduction in permeability and aeration decreases plant germination and growth, and increases run-off and consequently soil erosion. Excessive cultivation can also produce a hard pan at the bottom of the cultivation layer. As cultivation is not common in the Shire, this degradation form is not likely to be a problem.

5.5.7 Soil acidification

granite crests and

Soil acidification is a land degradation problem that has only been recognised in recent years. It involves declining pH values to levels low enough to retard plant growth through associated nutritional and microbiological changes (Maheswaran and Crawford 1992). This decline is caused by a number of processes associated with agricultural systems; application of ammonium based fertilisers, large amounts of product removal and nitrate leaching from subclover based pastures.

Soil types most susceptible to soil acidity include those with light textures, low organic matter contents and moderate acidity, and those used for agriculture (Maheswaran and Crawford 1992). Those soils that are naturally strongly acidic are not susceptible to further acidity.

Figure 5.8 Gully erosion in sedimentary undulating hills

5.6 Climate

The climate in the Shire of Broadford is influenced to a major extent, by the Tallarook and Mt Disappointment Ranges. In general, areas of lower altitude have warmer, drier climates while those of higher altitude have cooler, wetter climates. The direction of prevailing winds is variable across the Shire due to the changing topography associated with the highland areas.

There is insufficient climatic data for the entire Shire of Broadford. Where necessary, the nearby recording station of Seymour has been utilised as a guide to climate patterns. The Seymour recording station is located outside the northern boundary of the Shire.

5.6.1 Rainfall

The average annual rainfall in the Shire of Broadford is approximately 730 mm. The northern lowlands have an annual average rainfall of 656 mm and are drier than the southern lowlands which have an annual average rainfall of 805 mm. The highlands annual average rainfall frequently exceeds 800 mm. It is not uncommon for light snowfalls to occur at higher elevations in the Mt Disappointment and Tallarook state forests. Rainfall is highest in the winter months of July and August and driest in the summer months of January and February. The mean monthly rainfall, and the number of rain days are shown in Table 5.3.

Table 5.4 Mean monthly and yearly rainfall (mm) and number of rain days

STATION	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Broadford													
Rainfall	37	42	44	47	62	67	68	69	65	63	47	45	656
Rain Days	5	4	6	8	11	13	15	14	12	11	8	7	114
Flowerdale													
Rainfall	40	51	48	63	81	76	89	85	79	74	63	56	805
Rain Days	5	6	7	9	14	14	18	17	14	13	10	8	135
Seymour													
Rainfall	33	37	42	45	57	68	59	63	56	54	45	37	596
Rain Days	4	4	5	7	9	11	12	12	10	9	6	5	94

Source: Commonwealth Bureau of Meteorology

5.6.2 Temperature

There is no data for the mean maximum, minimum and average temperatures for the Shire. The nearby recording station of Seymour has again been utilized as a guide (Table 5.4). The summer months of January and February are the warmest with mean maximum temperatures greater than 29^{o}C . The winter months of June and July are the coldest with average temperatures below 10^{o}C .

5.6.3 Frost

Frosts mainly occur during the winter months. Individual factors such as position in the landscape and vegetation cover can influence the susceptibility of an area to frost. Frost can have a considerable impact upon plant growth, especially when the plant is immature or flowering, and severe frost may result in plant death. There is no frost data available for the Shire. The nearby recording station of Seymour has been utilized as a guide for the number of frost days (Table 5.5).

Table 5.5 The mean maximum, minimum and average monthly temperatures (^{o}C) for Seymour

STATION	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Maximum	29.5	29.9	26.1	21.5	16.5	13.6	12.2	14.3	16.3	21.0	23.8	26.2
Minimum	12.9	14.1	11.0	7.4	5.3	2.7	2.8	3.7	5.2	7.2	9.2	11.5
Average	21.2	22	18.6	14.5	10.9	8.2	7.5	9.0	10.8	41.1	16.5	18.9

Source: Commonwealth Bureau of Meteorology

Table 5.6Average number of frost days (<2.2^{o}C) per month in Seymour

STATION	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Seymour	0	0	0	1	3	7	9	6	2	1	0	0

Source: Commonwealth Bureau of Meteorology

5.6.4 Wind

Wind direction is very variable due to local and regional topography. The prevailing winds travel from the north-west to south-west. North and south winds become more common during spring and summer months while east winds are rare.

Strong winds are capable of causing soil erosion. Wind erosion is likely to occur with light textured, dry and exposed soils during the drier months of the year. Wind direction will have an effect upon which slopes are most susceptible to wind erosion. For example, a slope with a northerly aspect will be most susceptible to winds from a northerly direction. Erosive winds are those winds which exceed 30 km/h (Lorimer 1985). In the Broadford Shire these winds will likely occur during the months of November through to March.

5.6.5 Length of growing season

The length of growing season is determined by combining temperature, rainfall and evapotranspiration information. Each of the above factors has an impact upon plant growth.

When temperatures drop below 10 ^{o}C plant growth is restricted (Trumble 1939) and when below 6 ^{o}C it ceases (Martin and Leonard, 1967). During the months from May to August, plant growth in the Shire will slow as mean average temperatures drop below 10 ^{o}C and at times cease with mean minimum temperatures less than 6 ^{o}C.

Potential evapotranspiration is an estimate of the amount of moisture that a fully vegetated area can lose by evaporation and transpiration when soil moisture is not limiting. There is no evapotranspiration data for the Shire so an approximation has been calculated using Leeper's modification to Thornwaite's formula (Leeper, 1950). During the warmer months from October to April evapotranspiration exceeds rainfall, while in the winter months from May to September rainfall exceeds evapotranspiration.

The period when rainfall exceeds evapotranspiration is used to determine the length of the growing season as this is the time when moisture is not limiting for plant growth. This rainfall is known as 'effective rainfall' as it is necessary to start germination and maintain growth after the requirements of evapotranspiration and soil storage have been satisfied. Figure 5.9 indicates the average monthly rainfall and evapotranspiration for Seymour.

Plant growth within the Shire is limited by inadequate soil moisture during summer months and cool temperatures below 10^{o}C during winter months. The length of the growing season has been calculated using the formula below.

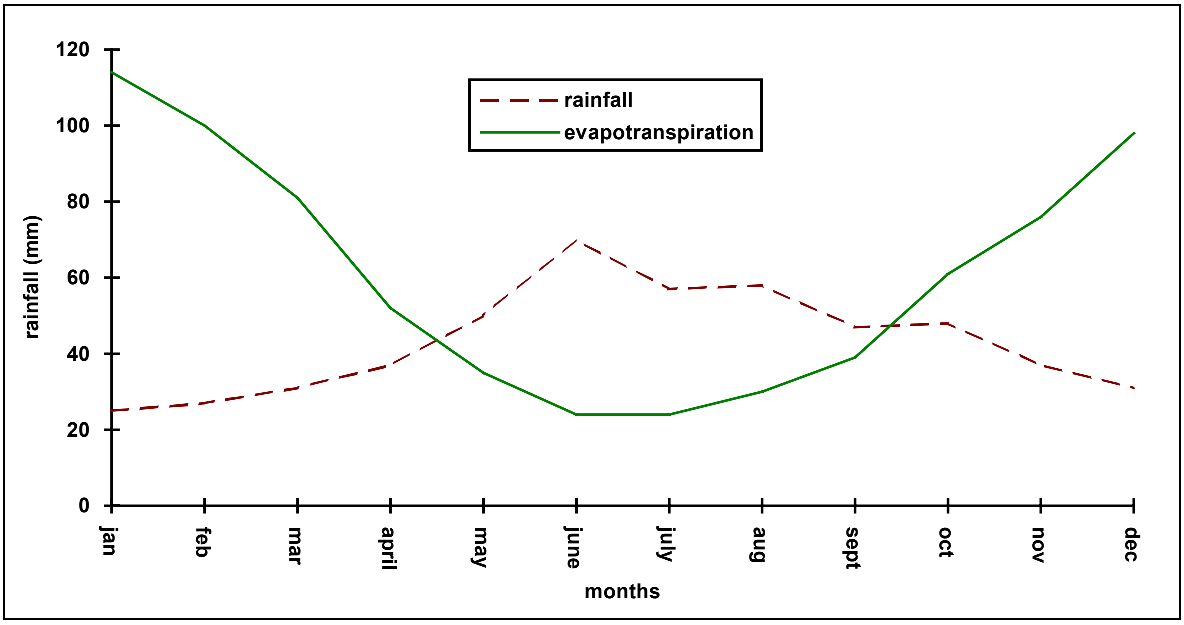

Figure 5.9 Average monthly rainfall and evapotranspiration for Seymour

Length of Growing Season = 12 months - (P + T)

Where :

P = No. of months where evapotranspiration > average monthly rainfall

T = No of months where mean average monthly temperature <6 ^{o}C

Length of Growing Season = 12 - (7+ 0) = 5 months

The average length of the growing season in the Shire of Broadford is approximately five months. This figure is based upon data obtained from the Seymour recording station (142m AHD). Due to the wide variations in elevation, temperature and rainfall within in the Shire, the growing season is expected to vary.

5.7 Native vegetation

There are substantial areas of native vegetation remaining in large parcels of public land in the Shire of Broadford. The vegetation communities within these large parcels of public land have been well protected from the extensive clearing of private land for agricultural purposes. Logging, fire and weed invasion have altered the public land forests to some degree, however they remain essentially unchanged. Remnant vegetation on private land is frequently isolated with little or no understorey remaining. In many cases isolated clumps of mature trees are affected by dieback.

5.7.1 Sedimentary Gently Undulating Rises/ Undulating Rises / Rolling Low Hills

The sedimentary undulating rises and low hills have an open forest of Narrow-leaved Peppermint *(Eucalyptus radiata),* Broad-leaved Peppermint *(E. dives)* and Red Stringybark *(E. macrorhyncha)*. Red Box *(E. polyanthemos)* often occurs as pure stands on drier, crests and rises. The understorey is usually sparse containing tussock grasses and low shrubs. This vegetation community generally occurs at elevations below 350 metres. Remnants of this forest can be found as isolated patches on private land.

5.7.2 Sedimentary Steep Hills

An open forest containing Messmate *(E. obliqua)*, Narrow-leaved Peppermint, Red Stringybark and occasionally Broad-leaved Peppermint is present upon the sedimentary steep hills. The understory is similar to the above open forest. Much of this vegetation community has been cleared for agriculture despite the steep slopes. Large remnants are still present on private land adjoining State Forests. This vegetation community generally occurs at elevations below 600 metres.

5.7.3 Granite/Granodiorite Steep Hills / Rolling Hills

The granitic steep and rolling hills contains two major vegetation communities, a mixed species forest and Mountain Ash *(E. regnans)* forest. These vegetation communities occur at elevations above 600 metres.

The Tallarook State Forest, Mt Disappointment State Forest, Sunday Creek Water Supply Catchment and Wallaby Creek Water Supply Catchment support a mixed species forest. This forest contains a number of eucalypt species in the overstorey, these include Messmate, Narrow-leaved Peppermint, Mountain Grey Gum *(E. cypellocarpa)* and Blue Gum *(E. globulus ssp. bicostata)*. The understory varies considerably, but common species include Silver Wattle *(Acacia dealbata)*, Hazel Pomaderis *(Pomaderis aspera)*, Musk Daisy-bush *(Oleria argophylla)* and Bracken *(Pteridium esculentum)*.

Mountain Ash forest is also present in the Mt Disappointment and Wallaby Creek Water Supply Catchment areas. Mountain Ash is usually found in dense stands of uniform age with an understorey containing Blackwood *(A. melanoxylon)*, Silver Wattle, Hazel Pomaderis, Musk Daisy-bush, Blanket-leaf *(Bedfordia arborescens)*, Common Cassinia *(Cassinia arculeata)*, Soft Tree-fern *(Dicksonia antarctica)* and Rough Tree-ferns *(Cyathea australis)*.

5.7.4 Basalt Gently undulating Rises / Undulating Low Hills

Most of the original vegetation present upon the basalt undulating rises and low hills has been removed, leaving only isolated trees remaining. Historically the overstorey of these areas contained scattered River Red Gum *(E. camaldulensis)* and wattles such as Blackwood.

5.7.5 Colluvial Fans Undulating Low Hills/ Rolling Low Hills / Rolling Hills

The colluvial fan slopes contain open forest similar to those present upon the sedimentary undulating rises and low hills mentioned above. These vegetation communities have been extensively cleared and only small remnants remain on private land.

5.7.6 Alluvial Terraces

The wider alluvial terraces along King Parrot, Sunday and Dry Creeks contain an overstorey of River Red Gum with occassional Yellow Box *(E. melliodora)* and an understorey of native grasses including Wallaby Grass *(Danthonia spp.)* and Kangaroo Grass *(Themeda spp.)*.

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7. REFERENCES

Australian Standard 1289 (1977) *Methods of Testing Soils for Engineering Purposes.* Standards Association of Australia. Standards House, Sydney.

Charman, P.E.V. and Murphy, B.W. (1991) *Soils - their properties and management.* Sydney University Press; Soil Conservation Service, NSW

Craze, B. and Hamilton, G.J. (1991) Soil physical properties. Ch. 10. Charman, P.E.V. and Murphy, B.W. (eds) In: *Soils, Their Properties and Management* . University Press, Sydney.

Elliot, G.L. and Leys, J.F. (1991) Soil erodibility. In *Soils - their properties and management.* Eds. P.E.V Charman and B.W. Murphy. Sydney University Press; Soil Conservation Service, NSW

Emerson, W.W. (1977) Physical properties and structure. In *Soil factors in crop production in the semi-arid environment.* Eds. Russell, J.S. and Greacen, J.S. Univeristy of Queensland Press.

Emerson, W.W. 1967. A classification of soil aggregates based on their coherence in water. *Aust. J. Soil Res*. 5, 47 - 57.

Environment Protection Authority, Department of Water Resources and Health Department. (1990) Septic tanks code of practice.

Hicks, R.W. (1991) Soil engineering properties. Ch. 11. Charman, P.E.V. and Murphy, B.W. Eds In: *Soils, Their Properties and Management*. University Press, Sydney.

Hutton (1956) *A method of particle size analysis of soils*. Divisional Report No. 11/55., CSIRO, Division of Soils.

Isbell, R.F. (1992) *A Classification System for Australian Soils. Second approximation*. Technical Report 1/1992, CSIRO Division of Soils.

Leeper, G.W. (1950) Thornwaite's climatic factor. J. *Aust. Inst. Ag. Sci.* 16: 2-6.

Lorimer, M.S. (1985) Estimating the susceptibility of soil to wind erosion in Victoria. *J. Aust. Inst. Ag. Sci.* 51: 122-126.

Lorimer, M.S and Schoknecht, N.R. (1987) *A study of the land in the Campaspe River Catchment* Department of Conservation, Forests and Lands, Victoria.

Loveday, J. and Pyle, J. (1973). *The Emerson Dispersion Test and its Relationship to Hydraulic Conductivity.* Tech. Pap. 15, CSIRO Divn. Soils. CSIRO, Melbourne.

Maheswaran, J. and Crawford, D.M. (1992) Soil acidity and acidification in Victoria: a state-wide perspective. In: *Acid Soils: Research and Extension Seminar Paper*. State Chemistry Laboratory.

Martin, J.H. and Leonard, W.J. (1967) *Principles of field crop production.* McMillan and Co., New York.

Matters, J. and Bozon, J. (1989) *Spotting Soil Salting.* Land Protection Division, Department of Conservation, Forests and Lands, Victoria.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1984) *Australian soil and land survey - field handbook.* Inkata Press.

Northcote, N. (1979) *A factual key for the recognition of Australian soils*. Rellim Technical Publications Pty. Ltd., South Australia.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Cir. US. Dept. Agric. No. 939.

Peech, M., Cowan, R.L. and Baker, J.H. (1962) A critical study of the barium chloride - triethanolamine and ammonium acetate methods for determining exchangeable hydrogen of soils. *Proc. Soil Sc. Am 26*, 37 - 40.

Rayment, G.E. and Higginson, F.R. (1992) *Australian Laboratory Handbook of Soil and Water Chemical Methods*. First edition. Inkata Press, Melbourne.

Rowan, J. (1990) Land systems of Victoria. Land Protection Division, Department of Conservation and Environment.

Rowe, R.K., Howe, D.F., and Alley, N.F. (1980) Manual of Guidelines for Land Capability Assessment in Victoria. moisture characteristics of soil. *J. Soil Sci.* 20: 126-31.

Skene, J.K.M. (1956) Soil analysis as an aid to diagnosing deficiencies of phosphorus and potassium. *Proc. Aust. Plant Nutrition Conf. Melb.* Vol.1, 146 - 153.

Salter, Williams (1969) *The influence of texture on the soil for plant growth.*

State Chemistry Laboratory (1991) *Soils analysis - methods manual*. Department of Agriculture, Victoria.

Trumble, M.C. (1939) Climatic factors in relation to the region of Southern Australia. *Transactions of the Royal Society of South Australia* 63(1): 36-43.

USDA (1954) *Diagnosis and improvement of saline and alkali soils.* U.S. Salinity Laboratory Staff, Washington, D.C. Agriculture Handbook 60.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 37, 29 - 38.

White, L.A. (1990) *Reconnaisance survey of the middle reaches of the Goulburn River Catchement.* Department of Conservation and Environment, Victoria & Department of Primary Industries and Energy, Canberra.