Arrowsmith and Hakatere Ecological Districts, Canterbury, New Zealand

Annotated bibliography for conservation

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A B S T R A C T

This bibliography contains material of particular interest to the Department of Conservation in the Arrowsmith and Hakatere Districts of the Heron Ecological Region. These areas are extraordinarily rich in natural values, which are important regionally, and in some cases at national and international levels, but some are threatened by proposed developments. The bibliography is followed by summaries of: the outstanding features of the Arrowsmith and Hakatere Ecological Districts; gaps in information which need to be closed. Some suggestions are made for conservation action required for priority natural area recognition and reservation.

Keywords: bibliography, natural values, protected natural areas, Arrowsmith and Hakatere Ecological Districts, Canterbury, New Zealand.

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1. Introduction

This bibliography contains material of particular interest to the Department of Conservation in the Arrowsmith and Hakatere Ecological Districts (EDs) of the Heron Ecological Region, within the mountains of western Mid-Canterbury (Fig. 1). The Heron Ecological Region and its subunits, the Arrowsmith and Hakatere EDs are extraordinarily rich in natural values, important not only regionally, but in some cases at national and international levels. Some of these values are threatened by proposed developments such as the irrigation dam in the lower South Ashburton gorge, or the activities of some of the recreationists at Lake Clearwater. Others could be threatened in other ways. It is desirable that information on them should be clearly available so that the values can be recognised and necessary steps taken to protect them from harm.

The boundaries of the Arrowsmith and Hakatere EDs in relation to the main landscape features and important placenames are shown in Fig. 1. The boundary limits are primarily from the survey report for the New Zealand Protected Natural Areas Programme (Harrington et al. 1986, p. 8: ref. 53 in this bibliography). Areas not strictly within these bounds that are covered here also, because of their contiguity, or ecological affinity, are: the Harper Range and adjacent Rangitata River margin; the lower Lake Stream and Prospect Hill; valleys of the Palmer Range and Mt Taylor Range that face the Lake Heron Basin. Ecologically the mountainous parts of these blocks have much in common with the eastern Arrowsmith Range.

Topographic map coverage of the Arrowsmith and Hakatere EDs is in:

Department of Lands and Survey. 1990: New Zealand Topographical Map 1:50 000. NZMS 260, Sheets J35 Arrowsmith, and J36 Clearwater. 1st edn.

The Arrowsmith ED is predominantly mountainous, with many rugged peaks rising above 1800 m (the highest, Mt Arrowsmith, to 2795 m). The area is cut by deep river valleys. On the north-west are the Lawrence flowing into the Clyde and part of the main Rangitata. Towards the north-east there are the Potts, upper South Ashburton (each of these two with substantial gorges in their lower reaches within the ED), and the Cameron and Lake Stream Valleys. Both South Ashburton and Cameron Valleys have small glaciers at their heads.

Except for the isolated Harper Range and the valleys of the Palmer and Taylor Ranges, each with rugged, high ridges (and which for the purposes of this account are regarded as part of the Hakatere ED), the latter ED is generally lower-lying. Other high ridges in it include the Clent Hills and Moorehouse Range blocks, with rounded summits as high as 1300 m or more. Otherwise the intermontane basins and low hills, downs and valley floors of the Hakatere ED lie at 500–800 m a.s.l.

The rivers traversing the Hakatere ED include the middle reaches of the Rangitata on the south-west, the South Ashburton, which flows through a lower gorge near Sandy's Knob, the Lake Stream in the north, a short stretch of the lower Cameron, and the valley of the Stour in the east. The lower portions of the ED also take in Butler's Downs near Mesopotamia, the Lake Clearwater–Lake Emma–Pudding Valley depression, the Lake Heron–Maori Lakes depression and

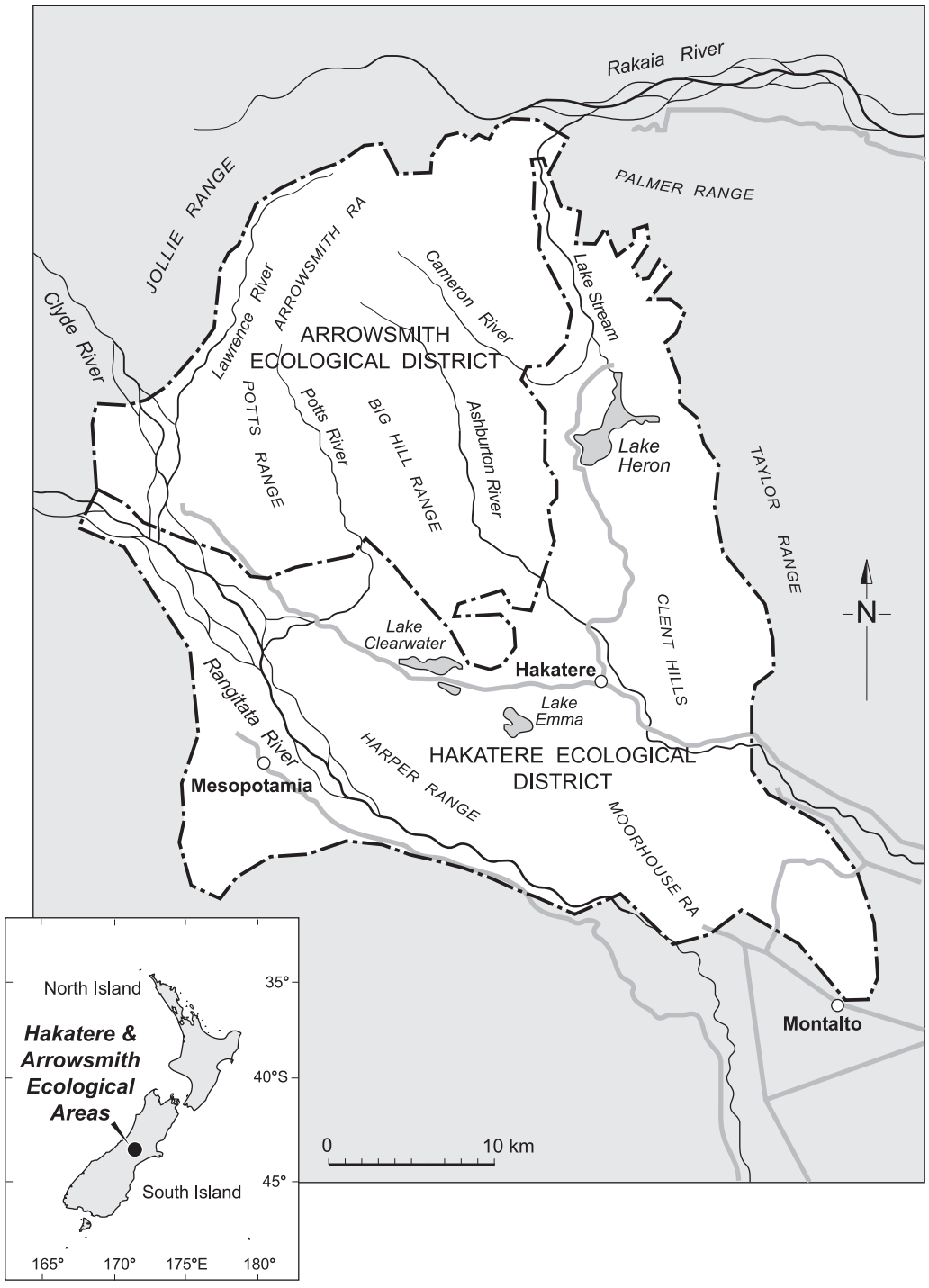

Figure 1. Map showing the boundaries of the Arrowsmith and Hakatere Ecological Districts and some of their prominent landscape features.

the block east of the Moorehouse Range that includes the upper Hinds River. Within the intermontane basins which constitute the lowland areas of the Hakatere ED are numbers of lakes, many tarns and some extensive vegetated wetlands.

The Arrowsmith and Hakatere EDs have been farmed since about 1856 (Acland 1975: ref.44 in this bibliography), mainly with extensive grazing of sheep for wool, and store cattle in the lower areas, on unimproved pasture. Relatively few properties are involved. In the last 40 years considerable fencing subdivision has taken place, together with some wind-break conifer planting, cultivation for fodder and sown pasture, oversowing and fertilisation of rough pasture and

diversification into deer-farming and tourism (with one ski-field development, now not in use). Settlement is still sparse, with buildings confined to areas near the station homesteads, a group of about 180 holiday cottages at Lake Clearwater and some musterers', hunters' and mountaineers' huts in the remote valleys.

As the farming industry in the local region developed, with acculteration of various sorts, the Arrowsmith and Hakatere districts received many plants and animals foreign to the New Zealand flora and fauna. Introduced organisms, plant and animal, are pervasive in the lowlands, often outnumbering native organisms. They are much less evident in the high-altitude areas above about 1200 m. Nevertheless some foreign plant species, especially grasses and weedy herbs such as *Hieracium* species occur in the remote valleys, and some foreign vertebrate animals occur sparsely but widely at high altitude (hares, Himalayan thar, chamois).

2. Land status

A map shows the present status of land in the Arrowsmith and Hakatere EDs:

Department of Conservation. 2001: Disposition of land in the Hakatere Basin 1:70 000. Department of Conservation, Christchurch.

Four categories are involved: Public Conservation Land, surrendered land, riverbed unoccupied Crown Land, Crown Grazing Leases.

Public Conservation Land

Public Conservation Land, held under various pieces of legislation, is under the direct jurisdiction of DOC. The areas are the Wildman's Brother Range, and Arrowsmith Range in the upper Cameron, South Ashburton and Lawrence Rivers; Lake Heron and adjacent wetlands (hereafter +a.w.); three smaller lakes in the Lake Heron Basin +a.w.; Lower Swin River floodplain; Maori Lakes +a.w.; Lakes Clearwater, Camp, Emma +a.w., and Lake Denny +a.w.; a portion of the Rangitata River floodplain between the Potts River (E side) and Black Birch Stm (W side); courses of streams on Mesopotamia Station; Dr Sinclair's Grave.

Surrendered land

The areas classed as surrendered land have been retired from grazing within the last few decades. A large block, Big Hill Range and Dogs Range, between the Potts and South Ashburton Rivers, lies in the Arrowsmith Range massif, while the other is the south-eastern end of the Harper Range block (including, on its southern side the lowlands facing the Rangitata River). Although the ultimate status of these areas is not yet determined, de facto they have virtually the same status as the Public Conservation Land areas.

Riverbed unoccupied Crown Land

The areas classed as riverbed unoccupied Crown Land are: the floodplain of most of the Rangitata River lying within the Hakatere ED; the floodplains of lower Bush Stm, lower Potts River, South Ashburton and lower Cameron Rivers,

lower Lake Stm, lower Nell and Ribbonwood Stms. Although these areas are not included in the grazing leases, de facto they are treated as parts of the leases and stock usually graze them; often they are not fenced off from the adjoining leasehold.

Crown Grazing Leases

The remaining areas, constituting well over half of the total area of Arrowsmith and Hakatere EDs combined, are held as Crown Grazing Leases. There are, however, some considerable areas of freehold, mainly around each homestead. At Mt Possession there is a more extensive freehold area than at the other stations in the region, recently purchased former University of Canterbury Endowment. Although lessees of the grazing areas have a free hand in management of their leases (subject to constraints on stocking rates, burning of the vegetation and animal and plant pest control which may be specified by local statute) indigenous organisms on these Crown Grazing Lease areas are under the care of DOC. However, it is usually more difficult to exercise such care than in areas under the direct jurisdiction of the Department.

3. Organisation of the bibliography

The titles listed relate to **Earth science** (Section 3.1); **Biology** (Section 3.2); and **Human interest** (Section 3.3), with appropriate subcategories. A category **General** (Section 3.4) deals with substantial and diverse references covering a range of topics. The references are all numbered consecutively, and listed alphabetically within each major or minor category according to the surname initial of the first author or editor. Where more than one subject area is covered by a reference, cross-referencing of the varied subjects is done by referring to the title number, in the appropriate category. Square brackets enclose some interpolations bringing information up to date.

Effort has been made to identify and list salient references, including a few unpublished accounts or reports, and to précis the main messages that they contain about conservation interests. Not every known article on any topic is listed because often articles are repetitive, or derivative, or well referred to in other listed accounts. Some older references are also not listed because the information in them has been superseded by more recent work.

The bibliography is followed in Section 4 by summaries of: the outstanding features of the Arrowsmith and Hakatere EDs; gaps in information which need to be closed; and some suggestions for conservation action required, including additions to, and implementation of, proposals in Harrington et al. (1986: ref. 53 in this bibliography) for priority natural area recognition and reservation.

Appendix 1 is a list of references which could contain relevant information. There was not time to examine them during the present search. Some student research theses are included in the list.

3.1 EARTH SCIENCES

3.1.1 Older rocks and fossils

References 1–13; cross-reference 14

1. Campbell, J.D.; Force, E.R. 1972: Stratigraphy of the Mount Potts Group at Rocky Gully, Rangitata Valley, Canterbury. *New Zealand Journal of Geology and Geophysics 15*: 158–167.

(Rocky Gully = Lizard Gully). Non-marine plant beds underlie a thick marine sequence with molluscs, brachiopods and ichthyosaur bone, then a thinner zone with bivalve and gastropod molluscs, crinoids, cidaroids and brachiopods. All are of Triassic age. As fossils are very scarce in the Torlesse rocks of the Southern Alps this is a very important location.

2. Campbell, H.; Oliver, P. 1994: Balmacaan Stream. Field Trip Guide for Joint Annual Conference of New Zealand Geophysical Society and Geology Society of New Zealand. *Geological Society of New Zealand Miscellaneous Publication 63B*: 196–203.

Describes the setting and lists the fossils from middle Triassic rocks of the Balmacaan Formation, Balmacaan Stream, Harper Range. Among the fossils are undetermined plants, brachiopods, gastropods, bivalve molluscs, nautiloids, ammonoids, scaphopods, echinoderms, crustacea, fish and ichthyosaurs.

3. Edwards, W.N. 1934: Jurassic plants from New Zealand. *Annual Magazine for Natural History 10*: 18–209.

Plants from Haast Stream in the Clent Hills are identified as ferns, cycadophytes, equisitaleans and others. [The rich flora from this site and a different one from nearby Potato Stream are being investigated (John Lovis, Plant Science, University of Canterbury).]

4. Fleming, C.A.; Gregg, D.R.; Welles, S.P. 1971: New Zealand ichthyosaurs – a summary, including new records for the Cretaceous. *New Zealand Journal of Geology and Geophysics 14*: 735–741.

Ichthyosaur remains (the classification not yet resolved) occur in Triassic rocks in the Mt Potts Range, exposed in gullies overlooking the Clyde River between Erewhon Station and the Lawrence River. Large bones collected in the 19th Century have been lost. This location is very important, as these are the oldest fossil tetrapods known from New Zealand.

5. Gair, H.S. 1967: Sheet 20 Mount Cook. Geological Map of New Zealand 1:250 000. DSIR, Wellington (1st edn).

Covers the southern half of Arrowsmith and Hakatere EDs. Basement rocks (sandstones, siltstones, conglomerate) of the Torlesse Supergroup form the main upstanding mountain blocks of the area. Ages are Triassic and Jurassic; Permian rocks may be present. [Chlorite II Zone Schist is ***not*** now recognised in the area. Fossil localities are noted in other references.] Near the eastern lower basement blocks in Hakatere ED are extensive Cretaceous volcanics and small low-lying outcrops of softer Tertiary rocks, including limestone, sands, siltstones, coal measures. Most of these are rich in fossils. They range in age from Paleocene to Pliocene (representing each epoch of the Tertiary). The mainly low-lying cover beds are glacial, slope, and alluvial gravels, with a loess veneer. They are of late Pleistocene and Holocene age.

6. Kenny, J.A.; Hayward, B.W. (eds) 1998: Inventory and maps of important geological sites and landforms in the Canterbury Region, including the Chatham Islands. *Geological Society of New Zealand Miscellaneous Publication 98.*

Each site is considered under headings: Significance, Locality, Exposure type, Classification of importance, Vulnerability, Hazards, Informants, References. Listed sites are:

Arrowsmith ED

- Cameron Valley moraine loop(s). Good example of moraine complex NZMS 260 J35/501576.
- Ashburton River rock avalanche: well defined. J35/501520.

Hakatere ED

- Smite River Oligocene shark teeth. Abundant shark teeth in greensand (originally found by J. Haast). J35/695562.
- Swin River alluvial fan. Fan on drainage divide between Lake Heron (Rakaia catchment) and South Ashburton. Streams on fan may go either way. J35/686438.
- Rocky Gully (= Lizard Gully), Mt. Potts, Triassic beds. Rich Triassic macroflora and macrofauna. J35/379461.
- Lake Heron reverse fault (3 locations): (a) alluvial terrace offset 15 m J36/592343; (b) terrace offset J36/598357; (c) moraine-draped scarp J36/570313.
- Hakatere kettle lakes. Excellent example of kettle lakes—Spider Lakes, Lake Donne. J36/580318.
- Clent Hills Jurassic macroflora. Haast stream. J36/644349.
- Rangitata ice-margin features. Sequence from valley floor to uppermost ice level during Otira Glaciation (and signs of deglaciation). J36/366195–446257.
- Bland's Bluff paleokarst. Surface on Otekaike Limestone, beneath Curiosity Shop Sandstone. Cavendish Limestone Quarry. K36/727245.

7. Mason, B. 1948: Middle Tertiary strata at Smite River, Lake Heron, New Zealand. *New Zealand Journal of Science and Technology B 30*: 55–58.

Beds of sands with coal and shallow water molluscs, brachiopods and shark teeth occur in a slumped deposit.

8. Oliver, P.J.; Campbell, J.D.; Speden, I.G. 1982: The stratigraphy of the Torlesse rocks of the Mt Somers, area (S81), mid-Canterbury. *Journal of the Royal Society of New Zealand 12* : 243–271.

Triassic and Jurassic siltstones, sandstones and conglomerates occur widely in the Hakatere ED Among plant fossils in non-marine beds at Haast Creek (Clent Hills) are fern-like species and *Maitaia podocarpoides,* a conifer placed in the Podocarpaceae. Plant fossils are also present in Harper Range and Low Hills. Marine beds with animal fossils are also present in several locations in the area.

9. Oliver, P.J.; Keene, H.W. 1989: Sheet K36A,C and part Sheet K35, Mount Somers. Geological Map of New Zealand 1:50 000 and text (36 p.) DSIR, Wellington.

Covers a segment of the eastern part of the Hakatere ED. Some Triassic sandstone, siltstone, conglomerate lie at the eastern end of the Moorehouse Range. Extensive mainly light-coloured Cretaceous volcanics (dacite and associated tuff at Surrey Hills–Gawler Downs; rhyolite and some andesite at

eastern Clent Hills). Limited areas of Tertiary rocks include sandstone, mudstone, greensand, silica sand, limestone and basaltic intrusions and tuff. These mainly shallow water marine sediments range in age from Eocene to Miocene and are fossil rich. A small area of Paleocene coal measures occurs near Woolmer Hill. The Quaternary deposits are sheets of gravel deposited by rivers issuing from large glaciers during the Waimaunga, Waimea and Otira Glaciations and stream gravel, fans and other landforms of Holocene age [see ref. 10, Oliver & Keene 1990 for more detail]. Faults delineate the margins of the Surrey Hills–Gawler Downs area and the Moorehouse Range block. A notable landscape feature is downland developed on a plateau-like area (430–670 m) between Gawler Downs trig and Woolmer Hill.

10. Oliver, P.J.; Keene, H.W. 1990: Sheet J36 B.D. and Part Sheet J35, Clearwater. Geological Map of New Zealand 1:50 000 and text (48 p.) DSIR, Wellington.

Basement rocks of Triassic age occur in the Arrowsmith Range, Mt Guy, Isolated Hill, and Ricki Spur. A distinct lithological group, also of Triassic age, occurs in the Moorehouse Range, Trinity Hill, western Clent Hills, and lower slopes of Harper Range. In this group is the Balmacaan Formation, with grey and red siltstone, sandstone and some conglomerate. Other basement rocks at the east end of Harper Range and western side of Clent Hills are of Jurassic age.

Cretaceous andesite and some rhyolite occur in the Clent Hills. Tertiary rocks are confined to an area in the upper Hinds River, near Edendale and small pockets on the west side of Clent Hills, Smite River, and Cameron and Potts Rivers (sandstone, mudstone, greensand, silica sand, volcanic ash, coal measures and some clay). They range from Paleocene to Pliocene.

Quaternary deposits on the valley floors and walls take the form of glacial moraine and ouwash, with distinctive hilly landforms, some lakes and many tarns. The oldest till sheets lie at high levels, up to about 1600 m. They are mapped as Waimaungan and Waimean. The most abundant and prominent glacial deposits are from the Otira Glaciation, including some large lateral and terminal moraines. Among extensive Holocene deposits are hillslope screes, young stream fans, river terraces and floodplains, and some large wetlands. Well-defined Quaternary fault traces and some large rockfalls and landslides are also present.

11. Retallack, G.J. 1979: Middle Triassic coastal outwash plain deposits in Tank Gully, Canterbury, N.Z. *Journal of the Royal Society of New Zealand 9*: 397–414.

Fossil wood and roots occur in conglomerate and sandstone overlain by coal measures (coal and carbonaceous shale) with plant leaves, etc. The Triassic environment is reconstructed. Fragments of ichthyosaur bone were found.

12. Retallack, G.J. 1980: Middle Triassic megafossil plants and trace fossils from Tank Gully, Canterbury, N.Z. *Journal of the Royal Society of New Zealand 10*: 31– .

The flora (leaves, some seeds) includes a probable fern, sphenopsids, seedferns, ginkgophytes, a probable glossopterid. This is the type locality for several taxa.

13. Warren, G. 1967: Sheet 17 Hokitika. Geological Map of New Zealand 1:250 000. DSIR, Wellington (1st edn).

Covers the northern half of Arrowsmith and Hakatere EDs. Basement rocks of the Torlesse Group form the main Arrowsmith Range block. Near Lake Heron and the Lake Stm are low-lying cover beds of Late Pleistocene and Holocene ages.

3.1.2 Quaternary rocks, Landforms

References 14–21; cross-references 6, 9, 10

14. Burrows, C.J. 1975: Late Pleistocene and Holocene moraines of the Cameron Valley, Arrowsmith Range, Canterbury, New Zealand. *Arctic and Alpine Research 7*: 125–140.

The Aranui-age moraines in the upper Cameron and South Ashburton Valley heads are the main focus, but the older, Otira-age glacial features are noted, and more ancient, red-weathered ones, high on the summit of Mt Pyramid.

15. Burrows, C.J. 1996: Radiocarbon dates for Holocene fires and associated events, Canterbury, New Zealand. *New Zealand Journal of Botany 34*: 111–121.

Ancient fires in two locations in the Hakatere ED are dated: At Bush Creek in the Lake Stream fires occurred 8880 ± 60 years B.P. and 5910 ± 60 years B.P. These ages provide time limits for stages in development of an alluvial fan. At the Jumped-up Downs (Erewhon Station) a fire occurred 940 ± 100 years B.P. About 75 cm of loess accumulated after this time.

16. Burrows, C.J.; Duncan, K.W.; Spence, J.R. 1990: Aranuian vegetation history of the Arrowsmith Range Canterbury. 2. Revised chronology for moraines of the Cameron Glacier. *New Zealand Journal of Botany 28*: 455–466.

Ages of the post-Otira Glaciation moraines range from more than 10 000 years old to modern. The sequence of soil development and associated vegetation on these moraines is as follows. The youngest moraines (up to about 1000 years) have sparse vegetation, with increasing cover of low shrubs and herbs, and very little soil development. Moraines from about 1500–6500 years have almost complete cover of shrubs (especially *Dracophyllum spp, Podocarpus nivalis, Phyllocladus alpinus*), tall tussocks (*Chionochloa rigida, C. macra*), and herbs (*Celmisia* spp.) and podsolic soils with grey-brown to dull yellowish-brown B horizons. The oldest moraines, 10 000 years or more in age, have tall tussock grasses and some areas of scrub. The original cover, probably of tall scrub, was burnt about 600 years ago. The soils have grey-brown A horizons and bright yellowish-brown B horizons.

17. Burrows, C.J.; Randall, P.; Moar, N.T.; Butterfield, B.G. 1993: Aranuian vegetation history of the Arrowsmith Range, Canterbury. 3. Vegetation changes in the Cameron, upper South Ashburton and Paddle Hill Creek catchments. *New Zealand Journal of Botany 31*: 147–74.

The article is mainly about changes in the vegetation of the Arrowsmith ED over the last 10 000 years. Soil development on dated surfaces is noted. Most relevant to the present day are the transformation of the vegetation in the last 2000 years from predominantly woody (with very extensive mountain toa toa *Phyllocladus alpinus* and a variety of trees, including mountain totara, *Podocarpus hallii*) (represented in the Cameron by rare logs) to the predominant present cover of snow tussock (*Chionochloa rigida*) and mountain daisy (*Celmisia spectabilis* var. *magnifica*) with extensive shrub patches, especially matagouri (*Discaria toumatou*) and scattered mountain ribbonwood trees, (*Hoheria lyallii*). Modern pollen rain was studied from several sites. Exposures, with radiocarbon-dated horizons are described. Eilness in the Cameron and Invarness in the Ashburton are the most important.

18. Burrows, C.J.; Russell, J.B. 1975: Moraines of the upper Rakaia Valley. *Journal of the Royal Society of New Zealand 5*: 463–477.

Glacial features of Prospect Hill and the Lake Stream are mapped and described. A glacial readvance about 12 000 years ago formed a prominent moraine. The glacier dammed the Lake Stream and the lake stretched up-valley to the site of modern Lake Heron. Lake beaches around Lake Heron and in several places in the Lake Stream Valley were formed at the time. Wetlands occupy a large section of the old lake bed—the lake drained as the glacier melted, probably after 10 000 years ago.

19. Burrows, C.J.; Russell, J.B. 1990: Aranuian vegetation history of the Arrowsmith Range, Canterbury.1. Pollen diagrams, plant macrofossils and buried soils from Prospect Hill. *New Zealand Journal of Botany 28*: 323–345.

Pollen analyses from two tarns are described and adjacent landforms and vegetation noted. Loessic soil accumulation (still continuing) is recorded. The tarns, Windy and Quagmire, are recommended for reservation.

20. Mabin, M.C.G. 1980: Late Pleistocene glacial sequences in the Rangitata and Ashburton Valleys, South Island, New Zealand. PhD Thesis, University of Canterbury.

Detailed descriptions, with large-scale maps, are presented for the very extensive glacial deposits and landforms. The most abundant and predominant deposits are those of the Otira Glaciation, but two prior glaciations are also represented, especially in the Lake Heron Basin and Ashburton River–Clent Hills area.

The glacial episodes, recognised from prominent moraines and related outwash sheets, are identified, classified and named. The glaciers which gave rise to the deposits (which cover a great deal of the Hakatere ED) originated in the Rangitata, Ashburton, Cameron, and Rakaia catchments. During the largest earlier glaciations ice streams from the Rakaia and Rangitata merged in the southern part of the Lake Heron Basin. Well-defined advance and recessional moraines are present in the area. Some proglacial lake silt deposits occur in the Rangitata Gorge.

21. Mabin, M.C.G. 1984: Late Pleistocene glacial sequence in the Lake Heron basin, mid Canterbury. *New Zealand Journal of Geology and Geophysics 27*: 191–202.

Glacial deposits are mapped for the area between Upper Lake Heron Station and the Maori Lakes. The excellent preservation of glacial landforms is noted, particularly for the last (Otira) Glaciation.

3.1.3 Soils

References 22–23; cross-references 16, 53

22. Harvey, M.D. 1974: Soil studies in a high-country catchment, Paddle Creek, South Canterbury. MAgrSci Thesis, Lincoln College, University of Canterbury.

Soils in Paddle Hill Creek and on the Dogs Range were investigated and mapped. On the elevated plateau of the Dogs Range the Puketeraki soil set is developed on old glacial till with a loess veneer. Kaikoura soils occur on colluvium on high slopes of the valley wall beneath the plateau. Cass Hill soils are on hummocky terrain underlain by thick colluvium on the lower slopes, where loess also covers much of the landscape. Present vegetation is mainly *Chionochloa rigida* and *C. macra* tall tussock. Each of these major soil groups (all high-country

yellow-brown earths) has many variants according to degrees of substrate difference, stoniness, degrees of waterlogging, and of erosion. In the valley floor are some young soils on small alluvial fans, and gley soils in a marshy area.

Landforms on the Dogs Range show signs of strong periglacial processes with stone polygons, stone drains and solifluction lobes. Present day frost-lift due to needle ice formation, run-off and wind-blow contribute to the evident strong erosion. Some old slips and debris flows occur on the slopes. Buried soils with charcoal are found commonly and radiocarbon dates showed that fires must have contributed to soil instability about 1800 and 5000 years ago.

Some chemical and physical analyses were done. The soils are infertile. Loess content affects the hydraulic properties of the soils.

23. Soil Bureau. 1968: General Survey of the Soils of South Island, New Zealand. *Soil Bureau Bulletin 27.* DSIR, Wellington. Also Soil Bureau. 1969: Regional soil maps accompanying General Survey of the Soils of South Island, New Zealand. DSIR, Wellington.

The soil sets of the Arrowsmith and Hakatere EDs are covered by Sheets 5 and 8. Soils are classified according to the older Soil Bureau system (as below), with basic differentiation according to profile characteristics. Subdivisions within the major categories are according to site (including landform, climatic/soil moisture features and substrates). The descriptive text with Soil Bureau (1968) lists typical soil profiles, and features of soil chemistry, land use capability and erosion potential of each soil type. In the Arrowsmith ED the main soil type is Alpine, with areas of Kaikoura on the vegetated valley walls (and Tekoa on the western flanks of the Palmer-Taylor Ranges) and some Kirkliston and Puketeraki

MAJOR CATEGORY	SUBSTRATES AND OTHER SITE FEATURES	SOIL NO. AND NAME
Relatively mature soils		
Yellow-Grey Earth	Thick loess	10a Omarama
Yellow-Grey to	Same	29c Kakahu
Yellow-Brown Earth Intergrade		
Yellow-Brown Earth	Loess and weathered sandstone, siltstone, low but steep hills	41a Hurunui
	Sandstone alluvial gravel with loess	48 Pukaki
	Same	49a Acheron
	Sandstone, glacial till with loess	50 Tekapo
	Same	50c Ohau
	Same	52b Mesopotamia
	Till and alluvium with loess	53 Cass
	Old till, outwash	53a Avoca
	Weathered sandstone and some loess	55a Kirkliston
	Same	55b Puketeraki
	Same	57 Kaikoura
	Same	57a Tekoa
	Rhyolite, some loess	57b Koikoi
Brown Granular Loam	Andesite–basalt	77e Middlehurst
Immature soils		
Recent	Water-logged alluvium	90d Dobson
	Well-drained alluvium	99 Tasman
Alpine steepland	Little-weathered sandstone detritus, little or no vegetation	100 Alpine

on Dogs Hill and Dogs Range. Much greater variety of soil types occurs in the Hakatere ED: Kaikoura on the higher sandstone ranges; Omarama on the flanks of the Harper Ra. and Clent Hills; Hurunui on the flanks of the Moorehouse Ra. and Harper Range; Tasman on the river floodplains and margins and stabilised alluvium on valley floors; Dobson in wetland areas; Tekapo, Mesopotamia, Cass and related soils on the old glacial moraines; Kakahu on the eastern low hills and downlands; and Koikoi and Middlehurst on the volcanics of the Clent Hills.

3.1.4 Hydrology, Climate

References 24–26; cross-references 22, 35, 49, 52

24. Griffiths, G.A.; McSaveney, M.J. 1983: Distribution of mean annual precipitation across some steepland regions of New Zealand. *New Zealand Journal of Science 26*: 197–207.

Short-term gauge measurements were used to estimate, using a proportionate allocation formula, the mean annual precipitation from locations from Westland, in a series across the Main Divide of the Southern Alps, and down the Rakaia Catchment to the top of the Canterbury Plains. Gauges close to the Arrowsmith and Hakatere EDs registered amounts (mm/annum): Lyell Lake 4826; Jellicoe Creek 2291; Upper Lake Heron 1108; Glenfalloch 1699; Smite Peak 1815.

25. Irwin, J. 1985: Lakes Camp, Clearwater. Bathymetry 1:5000. N.Z. Oceanographic Institute Chart, Lake series; Irwin, J. 1985: Lakes Emma, Roundabout, Maori Lakes. Bathymetry 1:5000. N.Z. Oceanographic Institute Chart, Lake series. DSIR, Wellington.

Underwater contours of the lake floors are shown.

26. Ryan, A.P. 1987: The climate and weather of Canterbury (including Aorangi). *New Zealand Meteorological Service Miscellaneous Publication 115.*

A few stations in the Arrowsmith and Hakatere EDs measure rainfall (Erewhon, Mt Potts, Upper Lake Heron, and two stations on the southern margin of the Hakatere ED). Only generalised information can be drawn from the extensive tabulated records and some maps in this reference.

Much of the time strong westerly winds affect the area and much of the precipitation is from this quarter. Arrowsmith, Mesopotamia and the northern part of Hakatere are in a zone with 1000–1500 mm of precipitation. The south-western part of Hakatere receives between 800 and 1000 mm (closer to the latter). Flooding of the Rangitata River occurs during north-west storms. However, the areas near the Canterbury Plains receive southerly and sometimes easterly storms, and flooding can occur during the heaviest of these. Precipitation levels increase with rise in altitude.

Snowfalls are mainly brought by southerly storms. Snow occurs in most winters but only lies on the valley floors for a few days a year. Occasional exceptional snowstorms are experienced. Thunderstorms occur from time to time in summer, associated with westerly storms or sometimes with convective heating.

There are no long-term temperature records from the area. Mean daily radiation is between 14.5 and 15.5 megajoules/m^2. First frosts occur in the basins in March and last frosts in late November. Temperature maxima in the basins can reach 30°C during anticyclonic weather in summer and minima –10°to –15°C in

similar conditions in winter. Inversion frosts occur. Mean annual evaporation is between 800 and 900 mm.

3.2 BIOLOGY

3.2.1 Plants, Vegetation

References 27–37; cross-references 16, 17, 50, 51, 53, 54

27. Burrows, C.J. 1977: Forest and scrub flora of the upper Rangitata, Rakaia and Wilberforce Valleys. *Canterbury Botanical Society Journal 10*: 1–8.

The main woody vegetation of the Lawrence Valley and the Lake Stream tributaries is briefly described, with notes on boundaries between beech and mountain totara forest types, and a list of the flora. The silver beech (*Nothofagus menziesii*) occurrences in Lower Washbourne, Downs Hut, Bush and Charlies Stream catchments are noted. The large stand of mountain beech (*N. solandri* var *cliffortioides*) on Butlers Downs, Mesopotamia, is mentioned; hybrids of mountain beech with red beech (*N. fusca*) were found there. No other unexpected finds were made except *Olearia moschata* on the upper Cameron Valley moraines where it appears to be at its northern limit.

28. Burrows, C. 1995: Some localities for pygmy mistletoes in Canterbury. *Canterbury Botanical Society Journal 29*: 76–78.

Two locations are noted for the uncommon tiny mistletoe *Korthalsella clavata*, in the upper valley of the South Ashburton River, on *Coprosma propinqua*; and in the Potts River valley, on *Discaria toumatou.*

29. Burrows, C. 1996: Records of the forest and scrub flora of eastern-southern Arrowsmith Range valleys. *Canterbury Botanical Society Journal 31*: 71–76.

In the Arrowsmith ED the peripheral north-western (Lawrence), northern (Lower Washbourne, Lake Stream) and western (Potts) valleys have patches of beech or totara-mixed broadleaf forest. Only scattered trees are present in the upper South Ashburton, Cameron, and Paddle Hill Stream valleys. The commonest tree in these last three valleys is deciduous mountain ribbonwood *Hoheria lyallii*. A few other tree species occur in the Potts Valley and upper South Ashburton. Bush Stream (a tributary of the Lake Stream) has more tree species, including mountain and silver beech (*Nothofagus solandri* var. *cliffortioides* and *N. menziesii*) and an area of mountain totara (*Podocarpus hallii*) forest. It also has the richest shrub flora; some additional shrub species occur in the Potts valley. Both the Potts and Paddle Hill Stream have small populations of mountain beech and mountain totara trees and kanuka patches (*Kunzea ericoides*).

30. Burrows, C.J.; Comrie, J. 1996: Some interesting plant distributions in the eastern Arrowsmith Range, Central Canterbury. *New Zealand Botanical Society Newsletter 44*: 9–11.

Cushion bogs on plateaux covered with ancient glacial till, at relatively high altitude (1000–1600 m) on the interfluve between the Cameron and South Ashburton watersheds, and the Lake Heron Basin, are of two kinds. In extensive areas where red tussock, *Chionochloa rubra* dominates the main plants are *Oreobolus pectinatus* and *Abrotanella caespitosa,* with a variety of other common wetland species. A single small bog contains some of the same species,

but also some others that are very rare in Canterbury: *Centrolepis pallida, Dracophyllum prostratum, Euphrasia dyeri, Kelleria (Drapetes) laxa, Rostkovia magellanica*. This is outstanding, from a biogeographic viewpoint. It suggests that these species could have inhabited the area during the last glaciation.

Also in the same neighbourhood are occurrences, in tussock grassland or on rock outcrops, of *Lobelia linnaeoides, Raoulia hectori,* and *R. petriensis*. This appears to be the northern limit for these three species.

31. Connor, H.E.; Macrae, A.H. 1969: Montane and subalpine tussock grasslands in Canterbury. Pp. 167–204 *in*: Knox, G.A. (ed.) The Natural History of Canterbury. Reed, Wellington.

As part of a wider Canterbury study, detailed species composition lists were gathered for six stands of tall tussock grassland in Hakatere ED and five in Arrowsmith ED. *Chionochloa rigida* vegetation at altitudes 716–1325 m, with *Aciphylla aurea, Celmisia spectabilis,* and *Poa colensoi,* had about 30 other associated species. *Chionochloa* 'Q' (= *C. macra*) stands at altitudes 1143–1370 m had *Celmisia spectabilis, Poa colensoi,* and about 30 other associated species. *Chionochloa rubra* stands at 865–1048 m had *Schoenus pauciflorus, Bulbinella angustifolia,* and about 20 other associated species.

32. Johnson, P.; Macmillan, B.; Molloy, B.P.J.; Williams, P.A. 1979: Sets of unpublished notes (under the names of separate authors) on wetlands and lakes of the South Ashburton–Lake Heron areas (Hakatere ED) held in files at Botany Division, DSIR (now Landcare Research, Lincoln).

Species composition of vegetation is summarised for each lake and the surrounding wetland vegetation. The reports contain comprehensive species lists.

33. Molloy, B.P.J.; Given, D.R. 1977: The flora and vegetation of the Lawrence Catchment. Botany Division, DSIR, Lincoln, unpublished report.

Contains a description of the vegetation in the valley, noting presence of mountain totara *Podocarpus hallii,* mountain toa toa, *Phyllocladus alpinus* and mountain beech, *Nothofagus solandri* var. *cliffortioides.* Scrub, grassland and other herbaceous vegetation are covered also.

34. Tanner, C.C.; Clayton, J.S.; Coffey, B.T. 1985: Notes on the submerged vegetation of Lakes Heron, Clearwater and Camp, Canterbury, South Island, New Zealand. *New Zealand Journal of Botany 23*: 213–218.

From samples in a limited number of sites at each lake the distributions of vascular and characean species were determined. A common pattern was evident, with short turf species (including *Lilaeopsis, Isoetes* and 10 or more others) present to from 1–2 m below the surface; a middle zone with some charophytes and long-stemmed native angiosperms (*Potamogeton* spp., *Myriophyllum* spp.) and the introduced weedy species *Elodea canadensis* present 1.5–4 m down; and a deeper zone dominated by charophytes > 4 m down. At 9–10 m depth the macrophytes phase out. The data presented include altitude, area and maximum depths of each lake and a species list. A rich charophyte flora (8 species) is present.

35. Williams, P.A. 1977: Growth, biomass and net productivity of tall-tussock (*Chionochloa*) grasslands, Canterbury, New Zealand. *New Zealand Journal of Botany 15*: 399–442.

Stands dominated by *Chionochloa rigida* and *C. macra* were studied in 1971–1974 at 884 and 1257 m, respectively, in Paddle Hill Creek and on Dogs Range. The high-country Yellow-brown Earth soils are infertile. Climate parameters measured were solar radiation, wind, precipitation, and temperature in the air and at three soil depths. Conditions at the higher site were more severe than at the lower site. Total above-ground biomass during summer was 3800 g/m^2 for *C. rigida* and 1600 g/m^2 for *C. macra,* while live above-ground biomass was 700 g/m^2 and 360 g/m^2, respectively, and root mass (live and dead) was 3100 g/m^2 and 2200 g/m^2, respectively.

During a 7.5 month growing season net production of leaf material was 518 g/m^2 for *C. rigida* and 330 g/m^2 for *C. macra.* Roots are concentrated near the soil surface, and a high amount of leaf litter is produced annually. At the *C. rigida* site (mean annual temperature 7°C, mean annual precipitation 95 cm), annual above-ground net production amounts to 5400 kg/ha and annual litter production to 5200 kg/ha.

36. Williams, P.A.; Nes, P.; O'Connor, K.F. 1977: Macro-element pools and fluxes in tall tussock (*Chionochloa*) grasslands, Canterbury, New Zealand. *New Zealand Journal of Botany 15*: 443–71.

In *Chionochloa rigida* and *C. macra* stands at Paddle Hill Creek the above-ground element pools of P, S, N, K, Na, Mg, Ca were considerably higher for the larger *C. rigida* than for *C. macra* (usually at least twice as high). The nutrient pools in underground systems were correspondingly larger for *C. rigida.* This means that returns of nutrients to the soil as litter decays are greater for stands of *C. rigida*.

37. Wilson, C.M.; Given, D.R. 1989: Threatened Plants of New Zealand. DSIR Publishing, Wellington.

Among threatened plants listed, marsh arrow grass *Triglochin palustre* occurs in the Hakatere ED. This plant is widespread in the Northern Hemisphere, but scarce in the Southern Hemisphere, and very rare in New Zealand (known from a site near Lake Coleridge, one near Lake Clearwater, and one in Central Otago). It lives in marshy areas adjacent to lakes and is vulnerable to grazing, trampling and fire. [In the mid 1960s it was seen at the west side of Lake Heron. It has not been seen in the ED recently.]

3.2.2 Animals

References 38,39; cross-references 49, 50, 51, 52, 53, 54

38. Bigelow, R.S. 1967: The Grasshoppers (Acrididae) of New Zealand: Their taxonomy and distribution. University of Canterbury, Christchurch.

Alpine species of grasshopper present in the Arrowsmith and Hakatere EDs include: *Paprides nitidus; Brachaspis nivalis; Sigaus australis, S. campestris,* and *S. villosus.* They each occupy distinct habitats.

39. Johns, P.M. 1969: The mountain invertebrate fauna. Pp. 391–399 *in*: Knox, G.A. (ed.) The Natural History of Canterbury. Reed, Wellington.

Distribution maps provide records in the Arrowsmith and Hakatere EDs for: *Icosidesmus* sp. A. (millipede); *Celatoblatta montana* and *C. pallidicauda* (cockroaches). The long-legged black weta *Pharmacus montanus* occurs on high mountains [including Mt Arrowsmith].

3.2.3 Habitats, Ecology, Conservation

Reference 40; cross-references 6, 19, 49, 50, 51, 52, 53, 54, 55

40. Stout, V.M. 1969. Lakes in the mountain region of Canterbury, New Zealand. *Verhandlungen, Internationale Vereinigung für Theoretische und Angewandte Limnologie 17*: 404–413.

Four of the Ashburton lakes (Clearwater, Camp, Emma, and Roundabout) were studied. Their areas and depth are listed. Emma and Roundabout freeze over in most years, the others may freeze during severe winters. None of the lakes is thermally stratified because they are subject to strong wind and are shallow. Values for the range of water temperatures measured, pH, conductivity and water chemistry indicate that the lakes are relatively infertile (oligotrophic to slightly eutrophic). However, algal growth is abundant in Clearwater and Emma and their pH may rise on the alkaline side in summer. Algal blooms sometimes occur in small, very shallow Roundabout.

The genera present in phytoplankton vary from lake to lake. They include diatoms, desmids, single-celled or colonial green algae and Chrysophyceae. The zooplankton include rotifers, Cladocera and water mites.

3.2.4 Pests

References 41, 42; cross-references 49, 50, 51, 53, 54

41. Fraser, K.W.; Cone, J.M.; Whitford, E.J. 2000: A revision of the established ranges and new populations of 11 introduced ungulate species in New Zealand. *Journal of the Royal Society of New Zealand 30*: 419–437.

The established ranges of the mammals were mapped from a survey in 1993–96. For the Arrowsmith-Hakatere EDs the data are relevant to red deer (fig. 1), feral goats (fig. 9), Himalayan thar (fig. 10), chamois (fig. 11). Goats have been recorded in small numbers in the east of the region. Thar occur in the west, and red deer and chamois in suitable habitat throughout.

42. King, C.M. (ed.) 1990: The Handbook of New Zealand Mammals. Oxford University Press, Melbourne.

Distribution maps show that brushtail possum, hedgehog, rabbit, hare, Norway rat, ship rat, mouse, stoat, weasel, ferret, cat, chamois, thar, and red deer occur in the Arrowsmith and Hakatere EDs.

3.3 HUMAN INTEREST

3.3.1 Archaeology, Tangata whenua

Reference 43

43. Tau, Te Maire; Goodall, Anake; Palmer, David; Tau, Rakiihia. 1990: Te Whakatau Kaupapa: Ngai Tahu Resource Management Strategy for the Canterbury Region. Aoraki Press, Wellington.

Maps 5 and 6 show two registered archaeological sites (at south side of Maori Lakes and at Blondin Stream). Wahi tapu sites are not differentiated and the Blondin Stream site is apparently a lime quarry from the European era. No specific mention is made of the fishery in lakes and streams, or collection of waterfowl, mussels, etc.

3.3.2 European history

References 44–48

44. Acland, L.G.D. 1930: The Early Canterbury Runs. (4th revised edn, ed. Scotter, W.H., 1975) Whitcoulls, Christchurch.

The text provides brief histories of the runs (taken up in the late 1850s to early 1860s): Stronechrubie (later Erewhon), Hakatere, Clent Hills, Lower Lake Heron (later Mt. Arrowsmith), Upper Lake Heron, Double Hill[1], Mt Somers[2], Mt Possession[3], Anama[2], Shepherd's Bush[2], Mesopotamia[3].

45. Butler, S. 1863: A First Year in the Canterbury Settlement. (1964 edn, eds Brassington, A.C.; Maling, P.B.) Blackwood & Paul, Auckland.

Butler's account of his time in Canterbury, including exploration of the Rangitata and Rakaia Valleys and occupation of Mesopotamia.

46. Haast, J. 1861: Mr Potts Station [Hakatere] Two Thumb Range (Mts Sinclair, Sugarloaf, Alma, Forbes). Watercolour and pencil – present Hakatere homestead site. Alexander Turnbull Library Pictorial Art Collection C97/5; and Haast, J. 1864: Lake Heron from Messrs Walker's Station. Watercolour and pencil – present Lower Lake Heron (Mt Arrowsmith) homestead site. Alexander Turnbull Library Pictorial Art Collection C97/36.

47. Haast, J. 1879: Geology of the Provinces of Canterbury and Westland. Lyttelton Times, Christchurch.

Haast, a geologist with interest in other natural science subjects including botany and zoology, was the first scientist to examine the Arrowsmith and Hakatere ED area (during trips in 1861, 1864, 1871/72, and 1875). He prepared a topographical map of central South Island which included the area, made sketches of the landscape in it, and wrote accounts of the geology and of the older glaciations near Mesopotamia, Hakatere and Lake Heron. He also described the scenery and the existing glaciers in the Lawrence, Ashburton and Cameron Valleys. He mapped the rocks including the Tertiary deposits (especially coal seams). He found many of the important fossil locations. This volume summarises his work and includes maps, diagrams.

48. Maling, P.B. 1960: Samuel Butler at Mesopotamia (together with Butler's 'Forest Creek' manuscript and his letters to Tripp and Acland). Government Printer, Wellington.

The documentary and pictorial information about Butler's occupation of the Mesopotamia Runs 1860–64, first at Forest Creek, then at the present Mesopotamia homestead site, is assembled.

3.3.3 Recreation

Cross-references 49, 50, 51, 52

No separate references on this subject were seen. However, a short section in reference 49 and a chapter in reference 52 discuss the topic. Also refer to Appendix 1.

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[1]Homestead in Rakaia Valley, run later subdivided. [2]Homestead on Canterbury Plains, subdivided into farms; [3]later subdivided into smaller runs. Otherwise the runs had (and still have) their homesteads in Hakatere ED

3.4 GENERAL

References 49–55

49. Bowden, M.J. (principal compiler) 1983: The Rakaia River Catchment: A Resource Survey. (4 vols) North Canterbury Catchment Board and Regional Water Board, Christchurch.

Only the Lake Stream and tributaries, Cameron River Catchment, Lake Heron and the streams that flow into it are relevant to this bibliography.

Volume 1. Discusses climate, with generalised rainfall map, temperature values, wind conditions, etc. Includes other generalised maps of soils, erosion, vegetation, and land use capability. Almost all of the area falls into classes VII, VIII. Some class VI occurs in valley floors and a little class V is coincident with the Lake Stream red tussock and the Lower Cameron Fan marsh. The top of the Cameron Valley is in the Whitcombe–Browning Crown Land Management Area.

Volume 2. Considers water resources. Flow data (1978–81 inclusive) for the Lake Stream. Annual mean monthly discharge is 10.96 cumec (range 9.07 in 1981 to 12.19 in 1979).

Volume 3. Has a section on Lake Heron. Water quality sampling has been done at 20 sites in the Lake Stream, Lake Heron, Cameron River. The pH, conductivity and ionic analyses, as well as faecal coliform counts, show that the water is of good quality and low in ions and faecal contamination. High amounts of oxygen saturation are evident. A comprehensive account of stream aquatic invertebrate animal groups is given, but it is not specific to the Lake Stream. Fish listed for Lake Heron include brown and rainbow trout and salmon. Native fish listed are long-finned eel *Anguilla dieffenbachii*; koaro *Galaxias brevipinnis*; common bully *Gobiomorphus cotidianus;* and upland bully *G. breviceps.* Among the native fish recorded in surrounding areas of the Arrowsmith and Hakatere EDs are *Galaxias vulgaris, G. prognathus,* and *G. paucispondylus*. Good data are presented on birds of river floodplains, some relevant to the Lake Stream–Cameron.

Volume 4. Recreational resources and wild and scenic values of the area are described. A map shows the mountain huts in the Lake Stream–Lake Heron–Cameron areas (used by fishermen, hunters, trampers, climbers). Comparative information on values of Canterbury rivers for recreation is tabulated. These include, with assigned relative values: Lake Stream, exciting jet boating, access problems, but popular canoeing, high. Ashburton upper gorge, canoeing, low. Upper Ashburton, canoeing, rafting, intermediate. Upper Rangitata, jetboating difficult, intermediate. Middle Rangitata, experienced jetboating, rafting, canoeing, exceptional. Wild and scenic values are assessed as generally high for Arrowsmith ED. Much general literature on recreation is referenced. Some additional recreational opportunities mentioned are off-road driving, trail biking.

50. Burrows, C.J.; Comrie, J. 1996: Conservation Resource and Values of Arrowsmith Station Pastoral Lease, Mid-Canterbury. Unpublished pastoral lease tenure report to Knight Frank Ltd. Department of Conservation, Canterbury Conservancy, Christchurch.

Mt Arrowsmith Station Pastoral Lease (10 239 ha) lies on the south-west side of the Cameron Valley, the east side of the upper South Ashburton Valley, and the

elevated slopes and ridge between the two rivers, as well as the adjacent slopes facing the Lake Heron basin and the gentler terrain below these, including the environs of the lake. The predominant vegetation cover (apart from worked paddocks near the homestead) is snow tussock grassland on slopes and morainic downlands and drier short tussock on the Cameron Fan. Some dense scrub occupies parts of the valley floors and slopes, and gullies. Wetlands are extensive on the margins of Lake Heron and on the high plateau area between the Cameron and Ashburton Valleys. Barrenlands are extensive on high ridges and on the river floodplains. Stocking is with merino sheep and store cattle. Some of the higher country on the west of the block was destocked within about the previous decade.

Recreational uses in the area are chiefly fishing in Lake Heron (fly-fishing and no powered boats, no shooting), some duck shooting on tarns, tramping and mountaineering in the heads of the Ashburton and Cameron Valleys, some canoeing in the upper gorge of the Ashburton. A small camping ground is present beside Lake Heron.

A survey was done to identify places of value for conservation. The starting points for the survey were priority natural areas (p.n.a.s) recognised during the Protected Natural Areas Survey (Harrington et al. 1986; ref. 53 in this bibliography). The relevant sites on the Run were re-examined and some quick survey sampling of the vegetation was done. Other locations were also traversed. Floristic lists were compiled for each significant area examined. Animals (especially birds, mammals) were noted whenever they were evident, but no attempt was made to sample for animal composition. Dragonflies (especially *Uropetula carovei*), grasshoppers, moths, butterflies (*Argyrophenga antipodum*), beetles, flies, scale insects, and spiders were noticed.

1. The most important site for conservation is Lake Heron. In the sedge marsh on the lower Cameron Fan some detailed observations were made. The dominant plant cover is red sedge *Schoenus pauciflorus* but there is also much *Chionochloa rubra* and *Carex diandra. Carex secta* is important at the south-west end. In the marsh important ecological features are: cushion vegetation with *Oreobolus pectinatus* and mounds of *Sphagnum cristatum*. Left undisturbed, parts of this area could develop into raised bog. The flora is varied and the small clear spring streams that traverse the area are important havens for invertebrates and small native fish. Threats to the integrity of the area are stock trampling, human trampling, invasion by *Lotus* and grey and crack willows, and a drain established (illegally) in the area. Potential dangers are nutrients in runoff from the paddocks to the west, fire, interference with lake level. A strong recommendation was made for fencing to prevent stock access to the area, removal of willows, and a board walk on the lake margin, for fishermen.
2. Dryland on the Cameron Fan. East of the Mt Arrowsmith–upper Lake Heron Road the fan has been converted into paddocks. West of the road the short dry grassland with dominant *Racomitrium* moss cover should be protected. It has a distinctive flora containing *Carmichaelia corrugata, Gentiana serotina, Hebe pimeleoides, Raoulia parkii, Stackhousia minima,* etc. The area is threatened by indiscriminate off-track running with wheeled vehicles. Top-dressing with fertiliser would be adverse.

3. Cameron River. The p.n.a. recommendation was for the whole catchment to be reserved. This is not necessary—the appropriate boundary of a reservation would be the present Mt Arrowsmith Station boundary. However, Big Gully (with *Hoheria* and *Myrsine divaricata* etc) and the terrace slopes along the river from Big Gully to the top of the Cameron Fan should be protected. Some plants that are rare in the area—kowhai, kanuka and manuka—occur here.
4. Summit of Mt Pyramid including rocky moraines, grassy and wind-eroded areas. Here *Lobelia linnaeoides, Raoulia hectori,* and *R. petriensis* are at their northernmost known limit. *Ranunculus crithmifolius* is present. Adventives are rare. The moraines (from Waimaunga, or an earlier glaciation) are among the highest in Canterbury. This area is of great scientific value. The area should be extended south-eastward to take in a bog with a remarkable assemblage of plants very rare in Canterbury (noted in Burrows & Comrie 1996; ref. 30 in this bibliography) and also to incorporate the good snow tussock area in the head of Olliver Stream. Fencing is needed.
5. Upper Harding Stream bog and red tussock area—apparently unique in Canterbury—cushion bog slowly replacing red tussock. Also noted in Burrows & Comrie (1996: ref. 30 in this bibliography).

   Several other reservations were recommended: old lake beaches around Lake Heron; tarns near Dunbar Stream; Invarness gravel cliff with plant fossils about 7000 years old in the Ashburton Valley; lower Harding Stream area of *Hoheria, Kunzea, Rubus,* and shrubs; slopes below Trig A with *Coprosma intertexta, C. ciliata, Hebe* cf. *glaucophylla, Corokia cotoneaster, Olearia virgata.*

51. Burrows, C.J.; Stout, V.M.; Eunson, F.; Ridgen, R. 1997: A Biological Survey of the Lakes and Other Wetlands of the University Endowment Land at Mt Possession–Hakatere, 1989–1994. Report to the Council of the University of Canterbury, Christchurch.

The survey involved extensive field observations and sampling of plant and animal life. The data gathered were used to provide profiles of the vegetation and animal assemblages of the lakes, tarns and vegetated wetlands. This work was done mainly in the summers of 1989/90 and 1993/94. Its aim was to examine each significant lake, many tarns, and all extensive areas of wetland vegetation on, or closely adjacent to the University property. These included Lakes Emma and Roundabout (both Crown reserves), Denny and Trinity, the extensive marshy and swampy areas adjoining them, and a few tarns and stream sides. It also involved some large wetlands on the Rangitata River side of the Harper Range. Extensive wet habitats also occur close to the University property, as public reserves (Lakes Camp and Clearwater) and in the form of marsh, swamp or streamside, flush or tarn, on Crown Leasehold land north of the Hakatere–Mt Potts road. Most of the tarns examined are in this area.

Flora and vegetation. About 150 native macrophyte plants that live only in wet sites were recorded (including some charophytes, mosses, liverworts). About 40 other native plants often occur in the wet sites as well as some drier sites. More than 60 adventive wetland plants were also recorded. The main physiognomic vegetation types are: *Schoenus pauciflorus* sedgeland; *Chionochloa rubra* tall grassland; *Carex secta* tussock sedgeland; *Typha orientalis* tall reed vegetation; *Carex diandra* short sedgeland; *Salix fragilis* and *Salix* sp. aff. *cinerea* willow thicket (both introduced species); emerged

short turf of tarns and lake margins; shallow water tarns and lakes; deep water lakes; seepages, streamsides, streams. Samples from these are tabulated.

Fauna and faunal assemblages. Wide collection sampling of invertebrates was done in lakes; marshy wetlands; swampy wetlands, tarns, and inflow and outflow streams of the lakes. Observations and records of birds and other vertebrates were made as they were encountered. About 120 invertebrate species (or groups in which identification to genus or species was not possible) were found. The occurrences were very diverse, but some patterns were evident in the various habitats. The numbers of aquatic species in major invertebrate groups were: coelenterates 2, flatworms 4; oligochaete worms 3; leeches 2; gastropod molluscs 7; bivalve molluscs 3; crustaceans (Notostraca 1; Cladocera 10; Ostracoda 13; Copepoda 7); mites 5; insects (dragonflies 4; mayflies 2; stoneflies 2; caddises 16; bugs 3; beetles 8; dobson flies 1; craneflies 1; mosquitos 1; dixid flies 1; sandflies 1; midges 8; some other fly groups including soldier flies, muscids; moths 1). Fish collected included *Galaxias fasciatus* (and an unidentified species of *Galaxias*), *Gobiomorphus breviceps*, young trout.

The most widespread species were among the snails, crustacea, bugs and beetles. About a quarter of the species were in restricted habitats. Proportions of different species varied widely between locations. The occurrences are tabulated. A substantial database is available for comparisons of the composition of lake margins, different kinds of vegetated wetland and tarns.

Limited sampling of the phytoplankton and zooplankton of open water in the four largest lakes was done from a boat and by diving, and this applies also to the fauna of the more deeply submerged macrophyte zones and the lake floor mud. The phytoplankton consist mainly of green algae, diatoms and one cynobacterium, *Anabaena* (which can bloom in the shallow lakes Emma and Roundabout). The zooplankton are mainly cladoceran crustaceans. Macrophytes in the deeper water included *Chara corallina, C. fibrosa* and *Nitella hyalina,* and some angiosperms, especially *Lilaeopsis, Myriophyllum* and *Elodea.*

The fauna on submerged macrophytes was of low diversity consisting of snails, one bivalve mollusc, midge larvae and tubificid worms. Some galaxiads, bullies and eels were seen, also freshwater mussels *Hyridella menziesi.* A table of bird counts provides data augmenting those of Stokes & Grant (1992: ref.52, vol. 2 in this bibliography). A great deal of new information was gathered. Complex and diverse wetland vegetation patterns are present. Some areas are severely degraded (especially through farming activities around the lake or wetland, including stock trampling). Other areas are in excellent condition.

Among outstanding features of the wetland–lake vegetation complex are: the richness and diversity of the flora; the occurrence of one very rare plant species, *Triglochin palustris*; and, in the regional context, the presence of species uncommon in Canterbury (*Acaena buchananii, Callitriche petriei, Centrolepis minima, Elatine gratioloides, Eleocharis pusilla, Iphigenia novae-zelandiae).* Also, several species occur in the area which are not usually present so far inland, though they occur commonly in coastal lagoons: *Potamogeton ochreatus, Ruppia polycarpa, Selliera radicans, Triglochin striata.*

Among the more important invertebrate animal finds were: uncommon Cladocera, *Pseudomoina lemnae, Leydigia macrodonta, Neothrix armata;* New Zealand's only aquatic moth *Hygraula nitens*, restricted to lake margins in a few localities; shield shrimp *Lepidurus apus,* a threatened species of temporary ponds; a snail *Gyraulus kahuica*, uncommon anywhere and not previously known from south of Kaikoura; an uncommon flatworm, *Mesostoma ehrenbergi.* The importance of the indigenous waterbird fauna of the region has been emphasised by Stokes & Grant (1992; ref. 52, vol. 2 in this bibliography). Its richness is evident also from the data tabulated here. The presence of very large numbers of swans and Canada geese, especially in Lakes Emma and Roundabout, is probably adverse to the indigenous bird fauna. Faecal enrichment must be high in these lakes.

When the lakes and wetlands examined were classified using a range of criteria (scenery, recreation value; geomorphic and other 'landform' values; lack of disturbance; wetland vegetation variety; bird habitat; rare plants; rare birds; rare invertebrates), the five with the highest ratings were Clearwater > Denny > Spider and Donne > Emma > Roundabout. This is notwithstanding the adverse influences (including presence of feral cats and, at times, too many people) at Clearwater.

Suggestions are made about better protection of the public land which includes the lakes and wetlands. Categories of protection proposed include: ***Formal***: *Scientific* for Spider Lakes complex and Denny; *Scenic* and *Wildlife* for Emma and wetlands west of it and Roundabout, Clearwater and wetlands west of it and east of it. ***Informal*** protection: recognition of the importance of the areas and, where possible, protective covenants are suggested for several other wetlands, including the extensive ones on Potts Downs and around the old Mt Harper Skating Rink. Secure fencing and other good practices are proposed. [Note. Some of the suggested reservations have been accomplished during negotiations on the sale of the land by the University to the owners of Mt Possession Station. Follow-up is needed to ensure that transfer of land to administration by the Department of Conservation has been accompanied by fencing and other appropriate management].

52. Dons, T.; Stringer, D. (collators) 1992: Natural Resources of the Ashburton River and Catchment. (3 vols) Canterbury Regional Council, Christchurch and Timaru.

Volume 1.

- Young, J.R. Rainfall and river flows of the Ashburton catchment, p. 12–94.

  Few gauges are present in the upper South Ashburton area. A map of isohyets shows annual average precipitation to be 2000 mm at Mt Arrowsmith, 1000 mm in the southern Lake Heron basin, 900 mm at Lake Clearwater. High-intensity rainfalls occur from time to time during north-westerly, or easterly–southerly storms. The hydrologic records (with hydrometric sites at lake outlets and on major streams) show highs November–February and lows March–May, but the lowest levels in June–September. Flood frequencies are noted. Extensive meteorological and hydrologic statistics are provided.
- Sevicke-Jones, G.T. River, lake and groundwater quality of the Ashburton catchment, p.137–180.

  Overall water quality is thought to be good in the upper catchment. Nine water quality monitoring sites are present in the area above Blowing Point. The

lakes are oligotrophic to mildly eutrophic with inherently low cation and anion content. However, no coliform data are available and summer algal blooms occur in Lakes Clearwater, Camp, Emma and Roundabout. [It is evident that faecal contamination from high bird numbers occurs in Lakes Emma and Roundabout at least].

- Cuff, J.R. Land resources of the Ashburton river catchment, p.235–54.

  The assessment covers not only the upper South Ashburton, but also the Plains and North Ashburton. Values are given (and there are maps) for the areas of rock types, slope classes, soil types, the main kinds of vegetation, erosion severity and type. The maps show that the upper South Ashburton has predominantly tall and short tussock vegetation, and generally moderate to severe erosion, and that the main land use capability classes are VI, VII, VIII.

Volume 2.

- Sagar, P.M. Flow requirements for wetland birds, p. 276–288.

  Flow requirements are most circumscribed for the two threatened indigenous species wrybill (which occur in the mountain part of the catchment August–January) and black-fronted terns. Wrybills feed in shallow water on aquatic insects, mainly mayflies. Terns feed by skimming insects and fish while in flight and need good flows of deeper water. The threatened black-billed gull and non-threatened pied oystercatcher and pied stilt have less stringent requirements (but need water flow of braided streams).

- O'Donnell, C.F.J. Birdlife of the Ashburton River Canterbury, New Zealand, p. 289–351.

  The entire river catchment was surveyed once in each spring (between end of October and first weekend in December) 1981–90. The uppermost section in the South Ashburton catchment extended from Maori Lakes, over 8.9 km to Sandys Knob in the lower gorge. The first 2 km has a wide extent of open shingle, with braided streams and low vegetation of mat plants, lichens, mosses, short tussocks and some *Discaria*. The remaining section is more confined, with the river in a single channel, with encroaching taller plants including willows, broom, gorse. For the 18 bird species seen, this section is the most important part of the river, or otherwise very important as territory for: paradise shelduck, pied oystercatcher, banded dotterel, wrybill (endangered), black-backed gull, black-billed gull (endangered), black-fronted tern (endangered). Sparse (but important) sightings of bittern (endangered), black-fronted dotterel were made. Appendices list the distribution of birds on each section of the river, each year 1981–90.

- Stokes, S.J.; Grant, A. Birdlife of the lakes of the upper Ashburton catchment and their habitat requirements, p. 352–403.

  Objectives of the study were to estimate use made of the Ashburton Lake complex by birds, particularly endangered species, to determine their habitat requirements, identify potential dangers and to formulate management recommendations to safeguard the habitats. Data are given for the area, altitude, and depth of the lakes.

  The information on which the study was based is a database accumulated by monthly census of nine lakes, April 1986–January 1989, conducted by Dept of Conservation staff (and another database from surveys in winter by N.Z. Ornithological Society). The data sets were incomplete (some months missed in

each year). An index of lake use was derived from total numbers of observations for each species for each year, investigating 10 species (introduced game birds: black swan, Canada goose, mallard; indigenous species: crested grebe (endangered), paradise shelduck, shoveler, and grey duck (game birds), and scaup, grey teal, and coot). Lakes were listed in descending order of use; the first five lakes were considered in rank order for each species for single years and the total period. Detailed tables for the data are presented. Diversity of species was greatest in Lake Heron, followed closely by Clearwater, Emma and Maori. A total of 54 bird species is recorded for Lake Heron and 38 species use the adjacent wetland for feeding, breeding, moulting, resting.

In 1986–88, by species the overall order of lakes according to rank sums were: for crested grebe Clearwater(C)/Emma(E) > Heron(H) > Emily(Em) > Maori(M) > Trinity (T); paradise shelduck T > H/M > Roundabout(R) > Denny(D) > Em; grey teal H > C > E > Em > M > R; scaup H > E > R > C > T/M; shoveler R > E > H/C > M > D; coot H > E > Em > C > T. Estimates of populations in the area each year for two species for the 1986–88 period were: scaup 578–1973 (lowest in summer); crested grebe 4–76 (lowest in summer). For all species there were intricate seasonal patterns of movement and use of particular lakes presumably connected with feeding, breeding, weather conditions, presence of hunters and other factors. Some birds congregate in some lakes to moult (e.g. paradise shelducks in Trinity, Denny, Roundabout in summer).

All of the lakes except Camp are of considerable importance for the birds. Some lakes have special importance for certain rare bird species because of the good cover/nesting habitat (e.g. Maori Lakes for bittern, marsh crake). The lakes classed as of ***outstanding*** value because of the combinations of qualities are: Emily, Denny, Maori, Emma, Clearwater, Heron. Heron, in terms of diversity of birds and their abundance, is the most important lake in the area—the largest and most valuable wildlife habitat of its type (sizeable lake surrounded by good wetland). It is also nationally important because in winter it supports large populations of grebe, scaup and coot.

Overall the Ashburton Lakes have a very large resource of waterfowl, very important for conservation on the one hand, and game production on the other. About a quarter (or more) of New Zealand's endangered crested grebe population lives in the Hakatere ED.

Some threats to the wildlife are perceived: habitat modification, unrestricted access by stock to some lakes; mustelids, feral cats; recreational disturbance (especially at lakes Emma and Clearwater). Some more subtle threats exist, e.g. eutrophication of water from fertilised pasture, or faecal contamination. No motorised craft are allowed on Heron, Clearwater, and Maori, while Emily has a speed limit restriction for motorised craft. Suggestions are made for improving conditions by good management (e.g. through publicity, predator control, stricter protection of breeding areas).

- Mansell, R.; Quiding, J.; Harper, R. Ashburton Catchment recreational user survey, p. 404–493.

  Over 600 households in the catchment area were surveyed, with 50% response rate. There was slight bias in favour of men, elderly, urban dwellers. The respondents listed their main recreational activities in the following descending order of importance: driving for pleasure, walking, trips and picnics, cycling, running, swimming, fishing, camping, boating, skiing (this applied to

the whole catchment—maps of relevant locations are given for the various activities). In the upper catchment recreation opportunities are perceived to be: walks, fishing (for brown and rainbow trout), sailing, windsurfing, canoeing, powerboating/water skiing (presumably only in Lake Camp), swimming, and, in the Arrowsmith Range, alpine climbing. 'Passive' activities include picnicking, birdwatching, scenery viewing, photography, painting. The respondents suggested improvements in conditions for recreation in: water quantity and quality, lake settings, physical access, information, noxious plant and animals, picnic spots and camping, walking tracks, fish stocks.

Volume 3.

- Strange, B. Status of the fisheries of the Ashburton Lakes, p. 559–607.

  Almost all of this report is about introduced fish in the rivers, streams and lakes (brown and rainbow trout, brook char and perch). Brief mention only is made of indigenous bullies, galaxiids, and eels.

53. Harrington, W.M.; Cooper, P.J.; Davis, C.M.; Higham, T.D.; Mason, C.R. 1986: Heron Ecological Region: Arrowsmith, Hakatere and Two Thumb Ecological Districts. Survey Report for the Protected Natural Areas Programme. *New Zealand Protected Natural Areas Programme 4*. Lands and Survey Dept, Wellington.

[Note. Some points brought up-to-date are enclosed by square brackets.]

A land systems approach was used to identify landform–vegetation patterns which also have components related to climatic and soil conditions and sometimes rock types. Ecological surveys of plants as well as habitat conditions on sample sites were used (through presence–absence clustering), to arrive at a vegetation classification. Conspicuous animals were also recorded. A very extensive database on the survey information is held on file.

Using experience from this field survey, representative ***priority natural areas*** (p.n.a.s) were identified. These were chosen as good representative examples of the landform–vegetation patterns in each ED, or to protect important natural values. These p.n.a.s were delineated on maps using topographic features for boundaries where possible.

The summary of results of the survey (214 pages long) begins with an outline of the background to p.n.a. surveys and statements on the objectives and scope of the project (Chapter 1); the methods and concepts used, and format of the report (Chapter 2). In Chapters 3 & 4 the Arrowsmith and Hakatere EDs are each described according to the criteria for the study under headings: description, boundaries, topography, climate, geology, soils, land systems, vegetation and flora, vegetation classes, fauna, existing protection, checklist of communities, a systematic list of priority natural areas (each with a map). An extensive bibliography is followed by appendices: ecological units, a species list with common plant names, a glossary of terms.

Hereafter is outlined a brief summary of important characteristics of each ED and a list of the recommended p.n.a.s

Arrowsmith ED (54 330 ha)

Climate. Strong westerly winds; precipitation 300–350 cm per annum in the far west, 100 cm in southern Lake Heron basin. Snow and severe frost in winter, warm in summer.

Vegetation. Extensive grasslands with prominent areas of *Chionocholoa rigida, C. macra,* and some *C. rubra, Festuca novae-zelandiae, Celmisia spectabilis.* Some areas in valley floors with dominant introduced *Agrostis capillaris* and *Anthoxanthum odoratum.* Tall- and short-tussock grasslands on slopes, in gullies and valley floors form mosaics with shrubby vegetation. Shrubs may be scattered individuals or in small or large discrete patches. Many species are present, with *Discaria toumatou, Coprosma* spp., *Aristotelia fruticosa, Dracophyllum uniflorum* being relatively very common. Individuals or small groves of the small tree *Hoheria lyallii* are widespread but never very abundant. Other trees, particularly mountain beech *Nothofagus solandri* var. *cliffortioides* and mountain totara *Podocarpus hallii* (with *Phyllocladus alpinus* and a few other tree species) form small, discrete patches around the periphery of the ED.

Birds known from the ED are mostly associated with the forest patches: rifleman, bellbird, tomtit, grey warbler, fantail, silvereye, brown creeper plus introduced species. On river and stream floodplains occur black-billed gull, black shag, banded dotterel, pipit, black-fronted tern, pied oyster catcher, paradise shelduck. Blue duck have been recorded from the Cameron Valley. NZ falcon and kea are present in the main valleys.

Fish recorded from the area include three species of *Galaxias.* Skinks (*Leiolopisma* sp.) are often seen. Few invertebrate animals are recorded: species of grasshopper, butterfly, peripatus. Nothing is recorded about aquatic invertebrates.

Animal pests include red deer, thar, chamois, possums, hares and, at lower altitudes, mustelids, hedgehogs, rabbits.

Recommended Priority Natural Areas

(Soils: A Alpine, B Bealey, C Cass, K Kaikoura, Ki Kirkliston, M Mesopotamia, P Puketeraki, T Tasman)

1. Lawrence. Slopes and valley floor shrub, tussock, mountain totara forest; soils A, B, C, K, T.
2. Hermitage. Boulderfield Old stable rockfall with trees, shrubs, herbs.
3. Lizard Gully. *Myrsine divaricata, Brachyglottis cassinioides, Phyllocladus alpinus,* some mountain beech; mid-upper Triassic fossil location. A, K.
4. Erewhon mountain beech remnants. K.
5. Dogs Range and Mystery Lake. *Chionochloa rigida, C. macra, C. rubra,* bog species; high-level lake [also ancient glacier-margin gorges with kanuka, mountain totara]. C, K, P.
6. Upper Harding Stream. On ancient moraines. *Chionochloa rubra* and bog *Oreobolus, Abrotanella, Schoenus.* C, Ki.
7. Cameron Valley. Varied vegetation, tussocklands, scrub, screes, small extant glaciers, moraines, high alpine peaks. A, C, K, T.
8. Lower Lake Stream (and lower Washbourne Stream). Forest remnants. Areas of mountain and silver beech [and mountain totara] and scrub and tussocklands. K, T.

9. Rocky Gorge Stream. Mountain beech, shrub and tussocklands, rock outcrops, screes. A, C, K, T.
10. Lawsley Faces. Moraines, hillslopes with tussocklands, scrub. C, K.
11. Lawsley Red Tussock. Red tussock and drier grasslands and *Schoenus* wetlands. C.
12. Cloudy Peaks. Astride the glacially-sculptured spur at the end of Cloudy Pk Range. Scrub and tussocklands, rock outcrops, scree. A, K, M.

Hakatere ED (75 260 ha)

Climate. Strong westerly winds (channelled down Ashburton and Rangitata Gorges). South-west weather, with rain, snow in winter affects south-eastern part. Precipitation 90–100 cm generally, c.160 cm in north, 80 cm in south-east. Frosty in winter, snow to low levels, warm in summer.

Vegetation. Extensive grasslands with *Chionochloa rigida, C. macra, Celmisia spectabilis* at higher levels; *C. rubra, Festuca novae-zelandiae* in valleys and basins. Some intensive farming with clearance of native vegetation and replacement with sown pasture and fodder and other crops. Drier short tussock grasslands are extensively invaded by *Agrostis capillaris, Anthoxanthum odoratum, Hieracium* spp. Wetland vegetation covers some large areas especially near lakes. Sedge marshes including *Schoenus pauciflorus, Carex* spp.; also *Bulbinella. Typha, Carex secta* on some lake margins. Many tarns occur in morainic downlands. Shrublands with *Discaria toumatou* and various other divaricate species cover areas of valley floor, hillside and in gullies. *Hoberia lyallii* is scattered on hillsides and there are a few small patches of mountain beech.

Birds. In lakes, crested grebe (Lake Heron the most important New Zealand breeding area for this endangered species and an overwintering area) [but see Stokes & Grant (1992: ref. 52, vol.2 in this bibliography)]. Bittern, marsh crake, and grey teal (all endangered), scaup, coot, pukeko, shoveler, grey duck, paradise shelduck, and stilt are the other indigenous birds on this and other lakes of the district. Introduced birds are mallard, Canada goose, black swan. The last two are in pest proportions. On river floodplain are wrybill plover, black-fronted tern, black-billed gull, and black stilt (all endangered), banded dotterel, black-backed gull, and pied oystercatcher. In the sparse forest areas are rifleman, tomtit, grey warbler, silvereye. Falcons (valleys), pipits and harriers (open basins) are present.

Skinks are found widely. Ten species of native fish (galaxiads and bullies) occur in lakes and streams. Canterbury mudfish*Neochanna burrowsius* (endangered) has been found in the eastern part of the area. A considerable variety of aquatic invertebrate animals is present. Pest animals include hare, rabbit, hedgehog, mustelids, cats, rats, mice and some red deer.

Reserves. Lake Heron and Maori Lakes (Nature Reserves – lakebeds only – and Wildlife Refuges – lake surface and 40.23 m strip around them [also, for Lake Heron, Lake Stream, and Cameron River – National Water Conservation Order, as part of the Rakaia Catchment]). The beds of Lakes Clearwater, Camp, Emma, Emily, and Manuka are Crown Land, and each is surrounded by a protected (section 58) strip reserve (i.e. protected from sale).

Recommended Priority Natural Areas

(Soils: Ac Acheron, C Cass, D Dobson, H Hurunui, K Kaikoura, Ka Kakahu, Ko Koikoi, Mi Middlehurst, O Omarama, Pu Pukaki, T Tasman, Te Tekapo, Tg Tengawai)

1. Bush Creek Fan. Red and fescue tussock, matagouri and stream floodplain. C, T.
2. Lake Stream / Cameron Fan / Lake Heron. Complex area. Lake Stream valley floor wetland [on ancient lake bed sediments]; dry lower part of Cameron Fan grading into wetland where groundwater emerges; floodplain of lower Cameron River; dry moraine at southern end of Lake Heron, with some tarns; wetland around Lake Heron margin and the water body and lake bed. The great value of the lake for birdlife is the main feature but the other areas are important as buffer and supplementary habitat. The Lake Stream wetland has good red tussock with ponds. The lower Cameron fan wetland has sedge marsh with *Schoenus*, *Carex* spp. [The very rare plant *Triglochin palustris* has been found in this area.] Exotic willow extensive on south side Lake Heron.
3. Swin Fan. Floodplain *Raoulia*, *Epilobium, Festuca, Poa colensoi, P. cita, Discaria*. T, D.
4. Longman Range (and adjacent flats). Short and tall tussockland, shrublands and bracken, rock outcrops. Te.
5. Lake Emily (and Emily Hill). Extensive moraines and wetlands *Carex secta, C. diandra, Schoenus,* red tussock, *Bulbinella*. High wildlife value. Te, D.
6. Maori Lakes. Large wetland. *Carex secta, Typha, Carex* spp., *Schoenus.* High bird habitat values. Exotic willow area. D.
7. Potato. Old moraine at high level, with tussockland *Chionochloa rigida, C. rubra, C. macra, Schoenus, Festuca.* [Important Mesozoic plant fossil area also]. Te, O, K.
8. Clent Hill Boulderfield. Large boulder scree and adjacent tall tussockland. Marginal *Hoberia lyallii, Coprosma ciliata, Hebe rakaiensis.* O, K, Mi.
9. Paddle Hill Creek. Old outwash and glacial till. Extensive short and tall tussocklands. A few mountain totara, kanuka. Stable stream catchment. Te, Pu.
10. Ashburton Fans. Extensive stretch of Ashburton River floodplain with active and stabilized gravel areas. Sequence of vegetation development from open gravel to short tussock and *Discaria.* Important for floodplain bird life wrybill, black-fronted tern, and black-billed gull (all endangered), banded dotterel, pied oyster catcher, and pied stilt. T, Ac.
11. Spider Lakes. Tarns in prominent moraine from Otira Glaciation. Fescue tussock, *Discaria* on dryland, and patches of wetland with red tussock, *Schoenus.* Tarns have very diverse turf flora. Important for waterbirds. Te, D.
12. Lake Emma and Lake Roundabout. Two lakes with modified north to east margins and good large wetland on west to south. Moraine south-east of L. Emma with modified short tussock. Wetlands contain *Carex* spp.,

Schoenus, Bulbinella, Typha. On far west the proposed protected area takes in modified grassland, *Discaria* scrub and gravel of Balmacaan Fan. [Very important waterbird habitat and recreation area (fishing, bird-watching).]

13. Lake Clearwater and adjacent moraines. Proposed protected area extends over the lake and its margins, the wetland at its western end and an extensive area of ablation moraine rising uphill to the foot of Dogs Range near Mystery Lake. Includes dry short- and tall-tussockland and areas of red tussock and *Schoenus* wetland. Occasional small tarns. Some marginal willow around lake. The lake is a very important waterbird and recreation area (crested grebe (endangered), scaup, fishing, board sailing, bird-watching). C, D.

14. Stour shrub remnants. East side, at base of Clent Hills, on volcanics (outcrops, screes). Kanuka, *Corokia cotoneaster, Discaria, Griselinia littoralis, Hoberia lyallii,* small area of mountain beech, some *Chionochloa rigida, Celmisia spectabilis, Festuca.* Ko.

15. Moorehouse Range. Strip across range from Pudding Valley to North Branch of Hinds River. *Chionochloa rigida, Celmisia spectabilis, Festuca, Dracophyllum* sp. H, K.

16. North Branch of Hinds River. Gorge of river (in Torlesse sandstone and Cretaceous andesite) with scrub: *Coprosma* spp. *Aristotelia fruticosa, Hoberia lyallii* and threatened *Notospartium torulosum.* H, K.

17. Butler Downs. High lateral moraine with large patch of mountain beech forest. C, K.

18. Deep Stream. Stable stream with marginal *Schoenus, Carex coriacea,* modified fescue tussock. T, D.

19. Mount Sugarloaf. Hillside sequence on 'roche moutonnée' with short-tussock grassland and mixed scrub, some *Hoberia lyallii*, kowhai near base, to *Chionochloa rigida* and *C. macra* near summit. Rock outcrops. Tg.

20. Potts Gorge. Dense mixed scrub in narrow steep-sided valley. *Discaria, Hebe* sp, *Coprosma propinqua, Aristotelia fruticosa, Chionochloa rigida, Phormium cookianum.* A small mountain beech patch. K.

21. Rangitata River. Includes area from Havelock R. – Clyde R. confluence, and Potts R fan to eastern end of Rangitata Gorge. Mostly gravel floodplain with grassy areas (Fescue tussock, *Agrostis capillaris, Anthoxanthum odoratum, Discaria toumatou,* and open gravel with *Raoulia, Epilobium.* [*Myosotis uniflora* (endangered)is present rarely.] Very important bird habitat: wrybill, black-fronted tern, black stilt are present, and blue duck (all endangered) have been seen in the Rangitata Gorge. Outstanding area for birdlife because of large numbers of wrybill but also for pied oystercatcher, black-fronted tern, banded dotterel, black-billed gull (endangered). T.

22. Lake Denny. Small lake with good surrounding wetland. *Typha, Carex secta,* other *Carex* spp. Also dry hillside (moraine at crest) with scrub. Very

good bird habitat: grey teal, grebe (both endangered), shoveler, scaup, and many commoner species. Some willow at margin. Pu, D.

54. Kelly, G.C. 1972: Scenic Reserves of Canterbury. Biological Survey of Reserves. Report 2. Department of Lands and Survey, Wellington.

The two reserves noted for Hakatere ED are Lake Heron (685.5 ha) and Maori Lakes (28.5 ha). There are brief descriptions of the marginal vegetation and lists of flora and fauna (but not invertebrates). Habitat descriptions include details of site characteristics and animal life. Weeds and grazing by domestic stock are noted. There are recommendations for more stringent reservation and better management and increase in size of the Maori Lakes reserves.

55. National Water and Soil Conservation Authority. 1994: Grant of an Application for a Water Conservation Order for parts of the Rakaia River. (National Water Conservation (Rakaia River) Order, 1984).

In response to an application by a consortium of Acclimatisation Societies for establishment of a water conservation order the National Authority resolved to adopt the report of its appointed committee which had heard submissions for and against the application.

The order covers the river from the sea to its confluence with the Wilberforce River, as well as the Rakaia River and its tributaries upstream of the Wilberforce confluence, including Lake Heron and the streams flowing into it. Wetlands were not included within the order—in the Authority's opinion they are not covered by the terms of the relevant Act (Water and Soil Conservation Act 1967), which mentions only rivers, streams and lakes. [This is a moot point which needs to be resolved by legislation.]

Referring to Lake Heron, the statement says this lake… 'at the head of the Lake Stream is an outstanding example of a high country wetland bird habitat and has large numbers of the endangered crested grebe nesting on it.' The Conservation Order… 'by covering the Cameron River and Lake Heron, and the streams flowing into it, will contribute to the maintenance of the Cameron Fan wetland. This wetland is the most valuable swamp in the catchment and forms an integral part of the outstanding wildlife habitat of Lake Heron.'

The intent of the Order is, thus, to retain Lake Heron and the streams flowing into it in their natural state. No water rights may be granted to dam any river or stream forming part of the protected waters above the Rakaia/Wilberforce confluence. The only exception to this general point, under section 21, 23 or 24 of the Water and Soil Conservation Act 1967, is that rights may be granted for research into and enhancement of fisheries and wildlife habitats.

4. Summary of outstanding natural and scientifically important values

4.1 GEOLOGY AND LANDSCAPE

4.1.1 Older rocks

This is the most important area in the Southern Alps for Triassic and Jurassic fossil localities. Most of the Torlesse rocks which constitute the bulk of the Southern Alps have very sparse fossil occurrences. Here, however, five locations have very rich arrays of animal and/or plant fossils. This is of great significance for stratigraphy of the Torlesse rocks and the palaeobiogeography of New Zealand. The locations are both nationally and internationally important. The occurrence of the marine saurians, ichthyosaurs, the earliest tetrapod reptiles known in this country, is of major consequence.

The variety of rock types within the relatively small area of the two EDs is another important feature (especially for the Hakatere ED). Among them are volcanics of Cretaceous and Tertiary age and a scattering of mostly small deposits of Tertiary sedimentary rocks, with ages spread throughout the Paleogene and Neogene (i.e. there are representatives of Paleocene, Eocene, Oligocene, Miocene and Pliocene epochs). Most of these are shallow-water marine beds: sands, mudstones, limestones with abundant fossils, and coals are prominent.

Gaps in information. A full evaluation of the ichthyosaur fossils is required; marble in the upper Cameron and South Ashburton is not studied; modern analysis of the plant fossils in Haast, Potato and Balmacaan Streams needs to be completed. A booklet on the Mesozoic fossils would be useful. Study of some of the Tertiary rocks needs to be done, e.g. in the lower Cameron and Potts gorge. The Cretaceous and Tertiary coals require pollen analysis and study.

4.1.2 Younger rocks and landforms

The area contains one of the best-displayed examples of late Quaternary age glacial deposits and landforms in the Southern Alps. Moraine sets extend back in time to the Waimaunga Glaciation (about 300 000–250 000 years ago, possibly earlier), as well as the Waimea Glaciation (190 000–120 000 years ago) and the last, Otira, Glaciation (80 000–14 000 years ago). From a vantage point on the Clent Hills can be seen the evidence of the times during the Waimaunga and Waimea Glaciations when great ice-streams from the Rakaia and Rangitata valleys met, forming a mighty ice-sheet, which rode over the Clent Hills and sent glacier tongues out to the Canterbury Plains. The most prominent moraines, however, are those from the Otira Glaciation, which left fine terminal, lateral and recessional moraines on the valley walls or in valley floors near Mesopotamia, Hakatere Station and Lake Heron, and thick sheets of outwash gravels on the lower country.

Some spectacular ice-moulded bedrock landforms originated during the ice age. Among these are the large roche moutonnée Craig Phillips; the 'sugarloaf form', ice-overridden hill, Sugarloaf; and the ice-overridden spur end, Jumped-up Downs at Erewhon. Some of the best examples of ice-marginal gorges in the Southern Alps are the Labyrinth and Secret Gorges, between the Dogs Range and Mt Guy. On the ice-benched terrain between Mt Potts and Lake Clearwater a spectacular feature has been created by downcutting of the Potts River Gorge. The basins of hundreds of tarns and most of the larger lakes in the area have been formed as a result of glacial processes.

Gaps in information. Dating of the ice-age moraines could be done using the beryllium-10 technique. Little is known of the periglacial landforms present on the Dogs Range and some higher mountain-top plateaux. A booklet about the ice-age features of the area would be very useful.

Younger and smaller-scale landforms also contribute to the scientific value of the area, as well as to the variety of its scenery. Among them are: Moraine series c.12 000 years old up to modern in the valley heads of the Cameron and South Ashburton, as well as the extant small glaciers; the Prospect Hill 12 000-year-old moraines; lake beaches around Lake Heron and in parts of the Lake Stream valley, and the old lake bed in the same valley, formed at the same time; rock glaciers in high valleys in the Arrowsmith Range. Landforms associated with fault movement include the important fault traces between Lake Heron and the South Ashburton; large rockfalls or landslides in the Lawrence, Ashburton and Cameron Valleys.

Many factors including the glacial landforms contribute to the splendid mountain landscape of the region. The bare hilltops and extensive mobile screes of the region are not very beautiful but they, and the general lack of native forest (but abundance of tall tussock on slopes and downlands) are part of the essential character of the landscape. They form dramatic contrasts with the open tussock basins with their sparkling lakes and green wetlands. Behind them rise the snowy, jagged summits of the high Arrowsmith Range peaks. Another contrasting feature is the great, wide expanse of the Rangitata floodplain with its network of braided streams. The scenery is some of the finest to be found in Canterbury, remarkable for its variety.

4.2 BIOGEOGRAPHY AND ECOLOGY

4.2.1 Vegetation and plants

The region is notable for its limited forest cover; the predominant indigenous vegetation is tall *Chionochloa* tussock grassland. The two main forms are the dull green *C. rigida,* often associated with *Celmisia spectabilis* mats, and the reddish-brown *C. rubra.* The region is one of the best places in Canterbury in which to see large expanses of vegetation where these plants dominate.

Wetlands with raupo (*Typha*) or sedges such as reddish *Schoenus pauciflorus* are also plentiful, especially near the lakes. Abundant yellow-flowered Maori onion *Bulbinella* is evident in these in early summer. A common wetland vegetation type in the area is the turfy cover found on some lake margins and in

tarns. This is a diminishing biological resource throughout the South Island. The small plants (some literally tiny) in it (about 30 species) are adapted for coping with water fluctuations (ranging from cover by half a metre or more of water to periods of several months with no water at all). The *Abrotanella–Oreobolus–* red tussock bogs of upper Harding Stream are very unusual in Canterbury.

Other notable native types of plants in the region, which help to define its character, are: scattered mountain ribbonwood trees; grey scrub with variable composition of up to 8 or 10 species of shrub and vine; the tiny mistletoe *Korthalsella clavata*; high-altitude cushion plant communities and scattered grey, fleshy scree plants such as *Ranunculus haastii*; the sparse plant cover of river floodplains; scattered patches of silver beech *Nothofagus menziesii,* an uncommon species in mid-Canterbury, apparently a relic of ice-age forest distribution.

Some of the really special plants of the region include *Triglochin palustre*, a very rare species of wetlands. Some other wetland species are uncommon in our region (see Burrows & Comrie 1996: ref. 50 in this bibliography). Another set of wetland plants, of outstanding importance biogeographically, includes those from the small bog near the head of Olliver Stream (Burrows & Comrie 1996: ref. 30 in this bibliography): *Centrolepis pallida, Dracophyllum prostratum* (northern limit)*, Euphrasia dyeri, Kelleria laxa, Rostkovia magellanica.*

About 10 other species, mostly from well-drained alpine sites, have their northern limit in the area (*Acaena buchananii, Hebe buchananii, Lobelia linnaeoides, Olearia moschata, Parahebe birleyi, Pimelea pulvinaris, Raoulia hectori, R. petriensis, R. youngii.)* A smaller number of species have southern limits in the area: *Coprosma microcarpa, Epilobium brevipes, E. forbesii.*

Endangered plants of the area include the shrub *Notospartium torulosum* of shrubby gorge communities, the little cushion plant of river floodplains *Myosotis uniflora,* and a small rosette *Luzula celata,* for which the Potts River is the type locality.

Gaps in information. Is *Triglochin palustris* still present? What is the status of *Notospartium, Myosotis uniflora, Luzula celata?*

4.2.2 Animals

Among the indigenous animals only the birds of Arrowsmith and Hakatere EDs are well known. The main point to be made about them is the extraordinary importance of the region for birds of lake and wetland habitats. About a quarter of the endangered crested grebe population of New Zealand winters in the area and all of the larger lakes and some smaller ones are very important as feeding and breeding habitat for it. Lake Heron and its adjacent wetland is of surpassing importance for grebe, coot, scaup (and various other species). Small numbers of endangered bittern, marsh crake, black stilt, white heron have been observed in the region. Significant numbers of other native waterbirds are present, including grey duck, shoveler, grey teal, paradise shelduck.

The scarcer river floodplain birds wrybill, black-fronted tern, black-billed gull are well-represented in the area. Other scarce birds in the area are blue duck and falcon.

On the whole, although the aquatic invertebrates have received quite a lot of study (and common and rare species have been identified), there is very little information about the terrestrial invertebrates. The same applies to native fish and reptiles. The endangered galaxiid, Canterbury mud fish *Neochanna burrowsius,* has been recorded from the east side of Hakatere ED. Uncommon aquatic invertebrates are: the aquatic moth *Hygraula nitens;* shield shrimp *Lepidurus apus;* small crustaceans (Cladocera) *Leydigia macrodonta, Neothrix armata, Pseudomoina lemnae;* snail *Gyraulus kahuica*; flatworm *Mesostoma ehrenbergi.*

A species of peripatus was found in the upper Lawrence Valley and a black weta *Pharmacus montanus* on the summit rocks of Mr Arrowsmith.

Gaps in information. The status of blue duck and Canterbury mudfish need to be investigated. Are there rock wrens in the area? What is the position of the kea in this region? A full survey of lizard occurrence and native fish is required. The invertebrate terrestrial, river and stream fauna needs thorough investigation. (It is possible that some information is dispersed through the literature.)

Assessment is needed of the impacts of mammalian pests (rabbit, hare, possum, red deer, thar, mustelids, rats) on indigenous organisms. The same applies to the influences of prolific introduced waterbirds, such as black swans and Canada geese, on habitat and indigenous species.

A weed survey to gauge the present and potential influences of introduced plants on indigenous organisms would be useful. How are the pest plants *Hieracium* spp., *Hypericum perforatum* affecting indigenous vegetation?

4.3 HUMAN INTEREST

Gaps in information. There is next to no information on prehistoric sites in this area (C. Jacomb, Historic Places Trust, Christchurch). Clearly a site survey is needed. Are the Tangata whenua interested in harvest of eels, etc. in the region? Some sites of interest to European history are known but not explored. Work is required here.

I am not aware of a proactive role in recreation in the area by the Department of Conservation. The values of the area for recreation in the Public Conservation Land are manifest, so it is advisable that some efforts be made in this direction. This could be coupled with work on better protection of good sites for native organisms (Lakes Heron, Clearwater, Emma, Denny, Maori Lakes) by fencing and other appropriate management (including safeguards against human overuse). Substantial efforts are made to sort out conflicts of human use and aquatic bird requirements at Lakes Clearwater and Emma.

Information on the tremendous natural resources of the area should be made available to the public. Not least of the requirements is the need for very clear messages to be articulated about not interfering with Lake Heron, the water from the Cameron River, the Maori Lakes, and the floodplain of the South Ashburton River between its Upper Gorge and Blowing Point.

4.4 OTHER RECOMMENDATIONS

The priority natural areas survey provided some very useful suggestions about desirable reservations to protect areas with good natural or scientific values.

I recommend that efforts be made to achieve protection of the following sites recognised as priority natural areas in Harrington et al. (1986: ref. 53 in this bibliography, and given the same numbers as in that volume). Extensions and additional areas are also recommended.

Arrowsmith ED

3. Lizard Gully. Extend, also, to take in Tank Gully; protect the fossil locations and adjacent outcrops and indigenous plants and animals.
5. Dogs Range and Mystery Lake, including the glacier-margin gorges, Labyrinth and Secret. This will safeguard good plant and animal habitats also. Good alpine bogs and periglacial landscape features and a high-level lake.
6. Upper Harding stream wetland. Bogs with very unusual composition developed on till of Waimea Glaciation age. Rich flora and good series of bog evolution stages—a classic site for this.
7. Upper Cameron Valley from Highland Home hut westward, excellent moraines and other alpine landforms. Glaciers, alpine vegetation of great variety. Sequence of soil and vegetation development on moraines—another classic site in the Southern Alps. High mountains popular with climbers. Preferably also protect Big Gully and terrace on S side from it to Cameron Mouth. Ribbonwood forest, kowhai.
8. Forest areas in the Lower Lake Stream. Bush Stream is especially important: extensive silver beech (and mountain beech). Mountain totara–mountain toatoa in upper basin. Rich flora. All forest patches important for local birdlife (includes bellbirds). If possible include Charlies and Nell Streams which also have silver beech.
10. South Ashburton River floodplain (Upper Gorge to Blowing Point). Important for wrybill, black-fronted tern. Good example of floodplain revegetation series.
11. Lawsley Red Tussock. Good example of wetland; dryland on lower moraine. Also protects a section of old lake beach (c.12 000–10 000 years old).

Additions

- Summit areas Mt Pyramid. Ancient moraine of Waimaunga Glaciation age (possibly older). Plant species at their northern limits. Extend reserve to take in cushion bog and good alpine grassland. Remarkable plant assemblage including *Rostkovia magellanica.*
- Quaternary fossil locations in low cliff exposures. Eilness in Cameron, Invarness in South Ashburton. Exposed wood, leaves, etc.

Hakatere ED

2(a). Lake Stream Red Tussock: preferably reserve a section adjoining Lawsley Red Tussock. Good red tussock with tarns. Old lake bed.

2(b). Cameron Fan dryland. Sparse cover of specialist plants.

2(c). Cameron Fan wetland adjoining Lake Heron. All of this area ***must*** be fenced and stock kept out. Very important for waterbird habitat. Lake Heron the most important wetland site in the area.

5. Lake Emily–Emily Hill wetland. Good, undisturbed site. Remote. Important for waterbirds including grebe.

6. Maori Lakes. Extend into surrounding wetland. Buffer needed against farmed paddocks and fencing to keep stock out. Very important waterbird habit. Marsh crake, bittern, grebe.

7&8. Potato. Enlarge to include Potato Stream fossil location, Haast Stream fossil location and Clent Hills boulder field (block scree with ribbonwood, etc.). Good snow tussock and includes location on plateau of ancient glacial erratic boulders.

11. Spider Lakes and adjoining tarns, small wetlands and dryland on Otira Glaciation moraines. Among the best and least disturbed tarns in the area.

13. Clearwater moraine sequence. Include extensive wetlands at west and east ends in hope of protecting *Triglochin palustre.*

16. North Branch of Hinds Gorge: protect *Notospartium*.

17. Butler Downs mountain beech forest. Large patch of forest on Otira Glaciation moraines. Hybrid red beech present. Also preserve portion of moraines.

20. Potts Gorge. Extend to take in mountain totara patch, *Discaria* with *Korthalsella clavata* and Tertiary rock exposure overlain by Quaternary till.

Note. Lakes Emma/Roundabout and Denny are now protected. Consider protection of Lake Trinity.

Additions

- Balmacaan Stream fossil locations. A classic site.
- Potts River floodplain from 500 m above road bridge to edge of reserve on lower fan. Protect type locality for *Luzula celata.*
- Protect a sizeable portion of the sequence from Lake Heron to the top of the Ribbonwood Range to include the good Otira Glaciation age terminal and lateral moraines, and the successively older Waimea and Waimaunga age lateral moraines. No exotic tree planting should be allowed on this area.
- Prospect Hill moraines and tarns. Excellent expression of early Aranui-age glacial advance episode which dammed Lake Stream. Good tarns with small bogs (pollen analysis, carbon dates, beryllium-10 date for moraine 12 000+ years). Good snow tussock. ***No burning should be allowed.***
- Lake Heron fault traces near South Ashburton River. Clear expression of fault offsets on terraces. ***No burning.***
- Craig Phillips (= Mt Sunday) roche moutonnée and tarns. Excellent tarns, bog with deep post-glacial sediment.
- Jumped-up Downs: simply recognise this as an outstanding landform.

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Appendix 1

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