WATER & SOIL

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NO. 53

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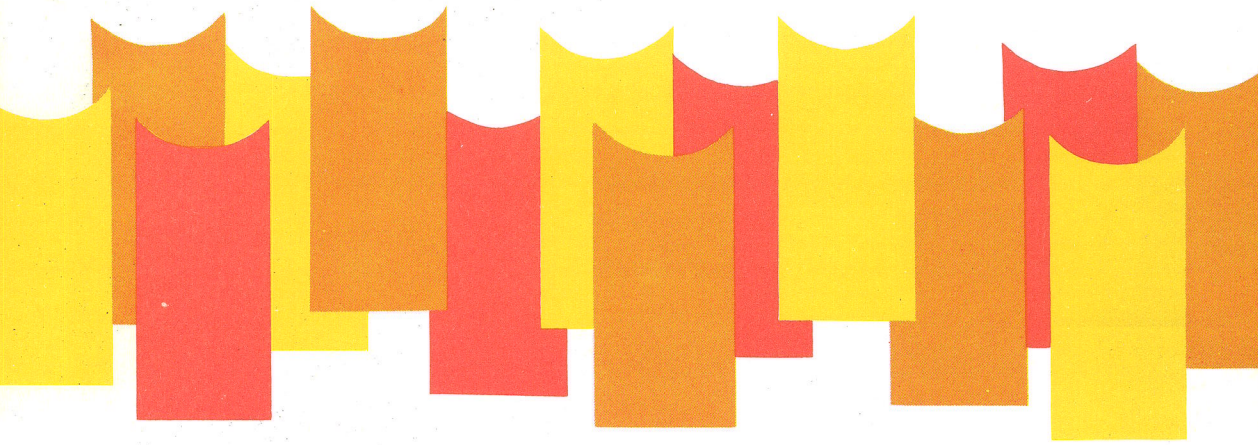

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Much of the research and survey work which is required to answer water and soil problems of concern to the National Water and Soil Conservation Organisation is carried out by staff of the Water and Soil Division, Ministry of Works and Development. This review presents an account of the progress made, up to the end of 1981, on the major projects of the individual research groups at the Division's 3 Water and Soil Science Centres at Hamilton, Aokautere (near Palmerston North) and Christchurch, and a list of staff publications for the period 1979–81. There is also a summary of progress for each of the research contracts with universities and other organisations which were under way at 31 March 1981 or which had been completed in the preceding 12 months.

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CONTENTS

INTRODUCTION

The National Water and Soil Conservation Authority has the responsibility to co-ordinate water and soil conservation research and survey. To assist it in this regard it receives from the Research and Survey Committee (through either the Soil Conservation and Rivers Control Council or the Water Resources Council) recommendations on what water and soil research and survey is required and how ongoing programmes may be modified or what new projects should be initiated.

Much of the research and survey work directed at answering problems of concern to the National Water and Soil Conservation Organisation is carried out by staff of the Water and Soil Division at the Ministry of Works and Development's 3 Water and Soil Science Centres located at Hamilton, Aokautere (near Palmerston North) and Christchurch. The Centre at Hamilton is the functional centre for studies of water quality, that at Aokautere for land resources, land instability and plants for soil conservation, and that at Christchurch for physical water resources (surface and underground). The science centres' work, particularly in the physical water resources sphere, is supplemented by that of groups in each of the 7 Ministry of Works and Development districts. Many of the projects involve collaboration with other research agencies and/or catchment authorities. Complementing these are specific studies undertaken (predominantly by universities) through the National Authority's research contract scheme. The scheme provides a means for drawing on specialist skills and resources that are not available or readily redeployable within the government or local body sector.

This review presents an account of the progress made, as at the end of 1981, on major projects of the individual research groups at the 3 Water and Soil Science Centres. There is also a summary of progress for each of the research contract studies under way at 31 March 1981 or which had been completed during the preceding 12 months.

AOKAUTERE

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The Centre is located on a 32 ha campus 10 km east of Palmerston North. It is the national centre for research and survey work relating to soil conservation issues. The principal areas of work are land resource surveys, land instability studies, the application of remote sensing techniques to soil conservation (and some water resource) issues, and the development of improved plant materials for land stabilisation, river control, windbreaks and shelter.

Thirty scientists and 15 technical staff are based at the Centre with a further 9 scientists and 6 technical staff elsewhere. In addition, there is a Water Resources Group at the Centre (but with functional responsibility to the Centre at Christchurch) which in association with field parties at New Plymouth, Wanganui and Turangi, undertakes water resources research and survey work in the Wanganui Ministry of Works and Development District.

The activities at the Centre and at its outstations in Whangarei, Gisborne, Napier, Christchurch and Alexandra can most informatively be summarised in response to 3 basic questions concerning erosion and soil conservation:

(i) What erosion has occurred, or is now occurring, and where?
(ii) Does it matter, and if so how much does it matter, in each of the many different geological and land use settings?
(iii) How can control be improved?

What is Occurring, Where?

The completion of national coverage in 1979 of the New Zealand Land Resource Inventory Survey provided a comprehensive record of what erosion is occurring where (both type and degree) at a scale of 1 mile to 1 inch. During 1981 the computer programmes needed for sorting and retrieving information from this survey became operational. These included programmes which enable scans of the data to be limited to superimposed boundaries such as county boundaries, catchment boundaries, Pest Destruction Board boundaries, etc.

The addition of stock carrying capacities and exotic forestry site indices (in consultation with Ministry of Agriculture and Fisheries and New Zealand Forest Service officers respectively) will be completed in 1982/83. This information is relevant to debates on "wise land use" which is one of the "control" measures considered under question 3 below.

The value of the Survey to a wide range of scientists, planners and others is confirmed by the growing demand for the services of the Liaison Unit set up at Head Office to assist users to make best use of the Inventory.

For pastoral hill country, methods have been further developed for making quantitative assessments of both storm damage and total erosion to date. These rely heavily on aerial photography which has the very real advantage of providing a permanent record of the situation against which the assessments may be checked — or the relative significance of damage in later years gauged.

Does It Matter?

Staff of the Remote Sensing Group discovered that they could delineate old erosion scars on pastoral hill country very accurately using the infrared end of the spectrum. These scars could then be dated by referring to old small-scale black-and-white aerial photographs. The grass growth rates (and by inference the recovery rates) on the different aged erosion scars have been measured under a joint project with Grasslands Division, DSIR. These rates, when integrated with measurements of the percentage area in each family (age) of erosion scars, yield measurements of reduction in potential dry matter production due to the erosion. These measurements are then convertible into stock units and from there into dollars by standard methods.

The results after 2 years of measurement show that the effects of the soil slip erosion are not only measurable but serious.

In the history of soil conservation this is almost certainly the most precise answer which has yet been given to the question "How much does soil slip erosion matter on pastoral hill country?". It is hoped that this work will allow reasonable estimates to be made of what is worth spending on control measures, in order to reduce the erosion rate and thereby preserve the pastoral productivity of the hill country.

How can Control be Improved?

The principal methods of control involve the use of appropriate plant materials. Poplars and willows are likely to remain the principal species used because of their relatively fast growth rates and ease of propagation.

Because poplars and willows cannot be grown successfully on seasonally dry hill country, a programme was initiated in 1978 to identify trees suitable for soil conservation planting in such areas. Much of the east coast hill country from Wairoa to the Wairarapa and in several areas of the eastern South Island must be regarded as "seasonally dry" in this context. Trials with eucalypts, acacias and other species, which were begun in 1978, are now yielding results and the "good bets" resulting from these trials are already being incorporated in "farm plans".

Whereas trees inhibit mass movement erosion (such as soil slip), surface erosion may be controlled both by trees (as shelter belts) and by improved ground cover. It is of interest to note that much of New Zealand's success with horticulture (particularly kiwifruit) in recent years has been made possible only as a result of the availability of fast growing disease resistant shelter trees (such as *Salix matsudana*) introduced into the country via Aokautere.

Improving ground cover on pastoral land (particularly the extensively grazed land) involves a search for grazeable grasses and legumes which will survive in semi-arid environments and compete successfully against unpalatable weeds, such as *Hieracium.* The Plant Materials Group has established large trials of the grazeable herb *Sanguisorba* (sheeps burnet) for the semi-arid lands, such as the Mackenzie basin, and the grazeable legume *Hedysarum coronarium* (sulla) which is more suited to somewhat less arid areas, such as East Cape.

Other methods of control include surface contouring (to shed surface water more rapidly and more safely during storms), underdrainage, and improved management (grazing patterns, etc.).

Because the ways in which these measures reduce instability are not at all well understood, the Land Stability Group has embarked on a programme designed to improve understandings of the basic mechanisms of instability. This includes a project in which methods are being developed for recording the passage of the seasons (the "weather") as seen from below the ground surface, i.e., near the potential failure zones. It is hoped that this will allow differences to be observed in rates of development of failure conditions between treated and untreated hillslopes, or between the 'before'- and 'after-treatment' situations on a single hillslope. The results should allow control measures to be designed for particular geological settings, both as regards type and degree of treatment, e.g., spacing of trees or underdrains.

LAND RESOURCES

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The Land Resources Group researches methods of land resource assessment and carries out studies specific to the needs of NWASCO. Since 1973 the main project has been to complete a survey of the physical capability of the New Zealand rural area for sustained primary production. This has produced the New Zealand Land Resources Inventory which provides the only detailed national assessment of our physical land resources, as well as standards for assessment of erosion and land use capability that catchment authorities use in their planning for the most effective land management. The completion of the mapping has allowed interpretative studies to be undertaken, specialised mapping techniques to be investigated and has provided data for a wide variety of departmental and private users.

1. The New Zealand Land Resource Inventory (NZLRI)

A basic requirement for the efficient development of rural New Zealand is an inventory of its physical resources and an understanding of the potentials and limitations for sustained use of each parcel of land. The NZLRI provides pertinent information through its resource inventory and land use capability classifications. With over 26 000 worksheets distributed since 1974 (national worksheet cover was only completed in 1979) and a Land Resource Liaison Unit of 3 Water and Soil Division staff members being established to service enquiries from the computerised data base, a new era in rural planning has been initiated. The computerised system allows selective extraction and display of all NZLRI data in tables or plots as single or multifactor summaries.

One of the first priorities of the Soil Conservation and Rivers Control Council, when established in 1941, was to request a survey of the extent of the national erosion problem. A number of attempts were made to provide these data but the NZLRI is the first survey to provide such a national assessment. Although analyses of erosion aspects of the survey are in the initial stages, the data provide an assessment of the extent and severity of present erosion and allow areas of potential severity to be identified. By relating extent and severity of erosion to the physical factors of rock type, soil, slope and vegetation, together with climate information, the causal factors of erosion can be investigated.

Table 1 indicates the areal extent of the main erosion types in New Zealand. The most significant factor is the assessed extent of surface erosion as compared with mass movement or fluvial erosion. Because surface erosion results in the loss of productive topsoil, priority needs to be given to management of affected lands to minimise soil loss. Management needs to be more concerned with protecting the long-term production potential of the soil rather than with short-term increases in carrying capacity or yield per hectare.

Analysis of individual erosion type data is providing a greater understanding of the national significance of these erosion types and the factors controlling their development.

Table 1: Area of New Zealand affected by erosion

	NORTH ISLAND		SOUTH ISLAND		NEW ZEALAND	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
SURFACE EROSION FORMS						
Sheet	2 117 300	18.6	8 316 900	55.2	10 434 200	39.4
Wind	526 600	4.6	2 865 800	19.0	3 392 400	12.8
Scree	416 900	3.7	3 259 700	21.6	3 676 500	13.9
MASS MOVEMENT EROSION FORMS						
Soil slip	3 396 800	29.8	3 615 700	24.0	7 012 500	26.5
Earth slip	280 300	2.5	58 500	0.4	338 900	1.3
Debris avalanche	1 219 000	10.7	1 602 900	10.6	2 821 900	10.7
Earthflow	1 011 500	8.9	33 300	0.2	1 044 800	3.9
Slump	65 700	0.6	44 000	0.3	109 800	0.4
FLUVIAL EROSION FORMS						
Rill	13 800	0.1	56 400	0.4	70 200	0.3
Tunnel gully	327 600	2.9	98 700	0.7	426 200	1.6
Gully	1 157 400	10.1	802 800	5.0	1 960 200	7.4
Streambank	240 400	2.1	491 000	3.3	731 500	2.7

NOTES: (1) Data obtained from the New Zealand Land Resource Inventory Survey (NWASCO 1975–79).
(2) The figures cannot be used to obtain totals for the area of each island affected by erosion, as due to the mapping technique, up to 3 erosion types can be recorded in each of the 89 000 mapping units identified.

For instance, tunnel gully erosion was traditionally considered to be most widespread on loess deposits in semi-arid areas. Analysis now indicates the most widely affected environment is the weathered sandstone hill country in Northland and the colluvial footslopes of Tertiary hill country (see Table 2). The use of computer plots provides visual presentation of analysis of the 90 000 map units in the survey. Figure 1 indicates the wide distribution of tunnel gully erosion in New Zealand, and its more frequent occurrence in Northland and in the Wairarapa.

Detailed analysis of the erosion data and their relationship to other physical factors provides a base for:

(a) rationalising erosion control policies;
(b) assessing the need for research into process and control measures;
(c) extending the results of research on specific erosion processes in a specific area to other areas with similar physical characteristics.

Emphasis is now being given to the preparation of bulletins describing the rock type, vegetation and erosion inventory classifications, and each regional land use capability classification, which were used in the survey. Correlation of the 706 North Island land use capability units at present in 10 separate regional classifications is almost complete. The collection of site index data (for *Pinus radiata*), stock carrying capacities and fertiliser requirements for each of the South Island LUC units is in the final stages of collation; the collection of North Island data was completed in 1980.

Table 2: Major rock types in which tunnel gully erosion has been recorded

NORTH ISLAND		SOUTH ISLAND	
Major Rock Types	Area (ha)	Major Rock Types	Area (ha)
Massive and banded sandstone, and coarse siltstone	173 800	Loess associated with various rock types	72 700
Jointed, massive and banded mudstone, and fine siltstone	97 800	Loess	6 900
Various minor rock types	18 300	Discontinuous loess cover over various rock types	14 400
Loess associated with various rock types	27 900	Other rock types	5 000
Ashes associated with various rock types	16 200		
Unconsolidated sediments	8 200		

2. Storm Damage Assessments

The Science Centre provides a service to catchment authorities by developing techniques aimed at assisting them in assessing the effects of major erosion events. In April 1981, a high intensity rainstorm passed over the Thames-Te Aroha area causing severe landsliding (Fig. 2) and widespread flooding. At the request of the Hauraki Catchment Board, staff of the Centre assisted in a storm damage assessment of the 81 000 hectares affected.

A combination of aerial photograph analysis and field mapping was used in the study. The Remote Sensing Group co-ordinated the taking of the 1:25 000 scale panchromatic vertical photos used for photo analysis. Large scale colour positive and colour infrared photos of selected areas were also taken for evaluation. Using the aerial photographs an assessment of the damage was carried out by staff of the Land Resources Group. Emphasis was on identifying all landslides and evaluating their causal factors. The information provided the basis for assessing not only areas eroded but also areas of significant erosion susceptibility so that remedial and preventive works could be carried out on areas most likely to benefit. Field checking of airphoto interpretation data and ground mapping was undertaken in collaboration with staff from the Hauraki Catchment Board and Hamilton District of Ministry of Works and Development.

Over 7000 landslides were identified. The most severely affected catchments were those to the west of the Coromandel Range divide. Landslide densities ranged from a high of 42/km² to a low of 1/km²; the worst affected catchments ranked with the more severe erosion events recorded in New Zealand in recent years.

The most frequent landslide type was small, shallow soil slips occurring mainly under pasture. However, where forest was present debris avalanches as well as soil slips were common. Only a few large, deep, earthslips were identified.

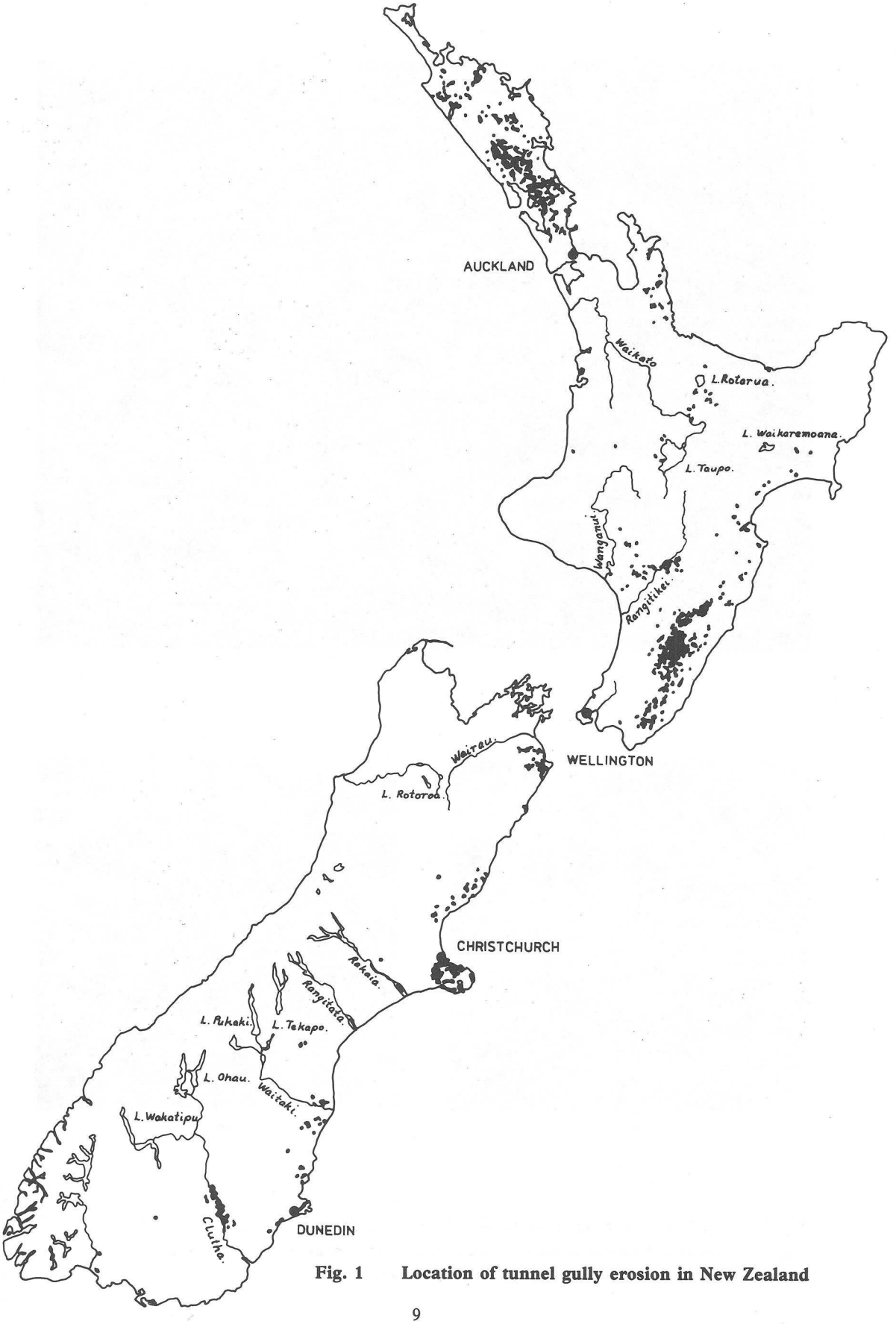

Fig. 1 Location of tunnel gully erosion in New Zealand

Fig. 2

Fig. 3

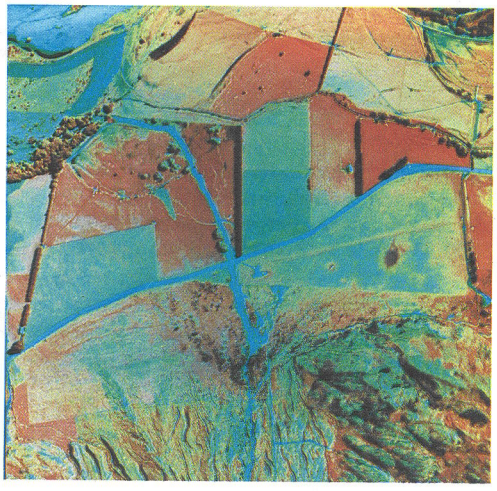

Fig. 4

Fig. 2 Landsliding in Thames-Te Aroha area, April 1981.
Fig. 3 Standard colour infrared aerial photograph, Makarora, April 1981.
Fig. 4 Enhanced colour infrared aerial photograph.

Field mapping indicated that much of the landsliding occurred on slopes which had a patchy tephra cover over various weathered and hydrothermally altered materials. The slip shear-plane often consisted of a surface of massive, pale, impervious clay derived from the underlying parent rock, and occurred at the base of distinct soil structure development. Colluvial slopes formed from previous landslide events were particularly susceptible to slipping, with the colluvium 'rafting' over underlying impervious layers.

In a number of catchments, especially those with low relief (up to 25°), zones of tension cracks covering areas of up to 40 ha were identified. The stability of these areas is uncertain; many such slopes could be preferential sites for future landsliding.

Analysis of the data showed the following:

(a) Few landslides occurred on slopes less than 20°, slopes in the 21–25° range had the highest landsliding density, and few occurred on slopes over 35°. These steeper slopes were considered to be less erosion prone because the tephra cover was shallow, or non-existent, and they had a more extensive indigenous forest cover.

(b) Aspect appears to have a marked effect on landslide location because 48 percent of all landslides occurred on slopes of northern aspect (see Table 3). This is attributed to the increased exposure of this aspect. Occurrence on east, south and west aspects was 25, 10 and 17 percent respectively.

(c) Under pasture and scrub a higher landsliding frequency was observed than under forest cover. There were 3729 on pasture, 2103 on scrub and 1199 on forest covered areas.

The board has used the data from the storm damage study to assist it in the preparation of regional land use and management plans. The plans will also identify areas where soil conservation works need to be concentrated in the future to minimise the effects of similar events.

3. Erosion Map of New Zealand

This comprises a series of 25 sheets at a scale of 1:250 000. Based upon NZLRI information and the assumption that a grassland cover with no conservation measures apply, it depicts potential erosion using a 6-part ranking of severity for 21 erosion associations which have been identified. A 3-part assessment for potential erosion is also made for arable areas, and areas of indigenous forest and major catchment boundaries are recorded. During the year 4 sheets were compiled leaving 3 to complete. However, only 12 sheets were printed by the end of 1981; 5 are expected to be printed in 1982 and the remainder in 1983.

4. Development of Techniques for Urban Resource Surveys

Techniques are being developed as part of a multi-disciplinary water and soil planning and management study of the Upper Waitemata Harbour Catchment. This has involved mapping at 1:25 000, the salient physical characteristics of rock type, soils, present erosion type and degree, potential erosion, drainage (including flooding potential, and vegetation). This inventory provides an overall assessment of the physical capability of the land prior to urban development. Assistance has been given to the Otago Catchment Board in preparing a similar study in the Green Island Borough.

5. Investigation of the Relationships Between Landform and Erosion Processes

During the year approximately 50 000 ha in North Canterbury have been mapped at the 1:15 000 scale to identify areas of present instability and to map the near-surface geology. From these data a 1 mile to 1 inch (1:63 360) scale derivative map is being prepared to identify areas of erosion hazard.

6. Vegetation Cover Map of New Zealand

This project, based on an interpretation of the vegetation factor in the NZLRI, will provide for the first time, a comprehensive picture of the total vegetation cover of New Zealand. Computer generated plots, at 1:250 000 scale, identify 48 nationally significant vegetation cover associations. Data on these plots are further grouped to a level of detail suitable for reduction to the 1:1 000 000 scale. These data are then closely field checked before reduction and compilation at the final scale of 1:1 000 000. Approximately 25 percent of New Zealand has been compiled.

REMOTE SENSING

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The Remote Sensing Group evaluates the application of remote sensing for determining conditions and trends of the nation's land and water resources. As well as conducting its own research programme, the Group provides specialised technical services to others, particularly other research and survey groups and catchment authorities. These services include advice on aerial photographic specifications, photo-interpretation and mapping methods, and arranging aerial photography.

1. Aerial Photography

The types of photography being evaluated include black-and-white, natural colour, colour infrared (or false colour infrared), and multispectral. Multispectral is a type of photography involving the use of 2 or more cameras with black-and-white films. Each camera lens is fitted with a special filter. These filters have been constructed to transmit light of specific wavelengths, e.g., blue, green, red or near infrared.

Of the above types of photography, colour infrared is the most difficult to undertake because of the stringent exposure and processing conditions of this relatively unstable film type. The Group has introduced to New Zealand a technique of testing film prior to exposure, so that exposure and processing methods can be standardised.

The Group has also developed a technique of enhancing colour and colour infrared aerial photographs by making dye layer separations (these film types are composed of 3 dye layers), modifying these layers then recombining them again. These developments have greatly increased the Group's aerial photographic capability.

Examples of colour enhancement techniques are shown in Figs. 3 and 4.

2. Soil Erosion's Impact on Hill Country Pasture Production

When the Group found that it could detect old revegetated slip scars on multispectral aerial photographs, and date these from historical aerial photographs, it saw a possibility of getting an objective answer to the question "Does erosion affect production, and if so, to what extent?". This led to a joint trial being set up with Grasslands Division, DSIR, to measure the pasture productivity (dry matter/ha/annum) on different aged soil slip scars and uneroded ground in the 'seasonally dry' Wairarapa hill country, south-east of Masterton.

Two year's data are now available from 40 pasture measurement sites and the long-term occurrence of soil slip erosion has been measured in great detail from sequential aerial photographs of the hillsides of, and adjacent to, the trial area. Interim results indicate that after c. 20 years, pasture growth on revegetating scars recovers to c. 80 percent of the pre-erosion level; and then levels off, remaining depressed at approximately the 80 percent level, on scars as old as 50 years. Fresh slips generally occur on uneroded ground, but with the passage of time, uneroded ground decreases and an increasing proportion of slips occur on previously disturbed ground so that the area subject to depressed pasture growth is increasing in the long term. A technique has been developed to determine the long-term impact of slip erosion on hill country pastoral productivity. This involves integrating the proportionate areas of eroded ground of each age class with the measured reductions in pasture production to give a quantitative measure of the reduction in potential productivity due to slip erosion. Preliminary results indicate that the overall cumulative reduction in potential productivity of the hillslopes is presently 14 percent, although on some hill slopes, it is as high as 25 percent.

A model is being developed to predict the future reduction in potential productivity by integrating the soil slip erosion rates with the rates of pasture recovery. When a longer record of results has been obtained, this physical model will allow agricultural economists to estimate the impact of erosion in terms of losses in stock carrying capacity and reductions in gross farm income.

3. Soil Erosion on Cropland

Mr Stephens (who had been seconded to the Canada Centre for Remote Sensing) has found that aerial photographs taken of croplands in Canada over a 40-year period can be used to identify land management changes which affect soil erosion. The most significant changes were an increase in downslope paddock length and a change in cropping rotations.

He also used colour infrared aerial photographs, in conjunction with soil, slope and climate data, to estimate long-term cropland soil erosion rates, and associated these with field measurements of reduced crop yield.

He also demonstrated that satellite images can be used to monitor crop rotations at the farm scale.

4. Aerial Photographic Services

In 1981, the Group co-ordinated 27 aerial surveys on behalf of catchment authorities, Water and Soil Division's (Ministry of Works and Development) planning and technical services staff, and other Science Centre research and survey groups. As well as co-ordinating aerial surveys, members of the Group also give the following assistance to clients:

Determination of photographic scale, film type to be used and the best times of the year to conduct photography to record the desired information.

Conducting research photography designed to suit specific management problems, and to evaluate untested applications of aerial photography.

Determining technical specifications for photogrammetric photography and ground survey for control points. Once determined, these jobs are routed through the Photogrammetric Branch, Department of Lands and Survey.

Advice to those who wish to take their own aerial photographs.

Photo-interpretation, field mapping and data analysis are conducted by the clients and other research groups because of the Group's limited number of staff, although staff can advise on these issues.

5. Satellite Imagery

Close links are maintained with the Remote Sensing Section, Physics and Engineering Laboratory, DSIR, to keep abreast with technical developments in image analysis. Satellite images have some value for repetitive reconnaissance surveys over wide areas of countryside, in particular to detect changes in land management which may warrant more detailed field inspection. In December 1980, DSIR hired an American airborne scanner (which records digital information on computer tape) to demonstrate scanner coverage of a resolution equivalent to what may be expected from the next generation of satellite-borne scanners (due for launch from 1982 onwards). The Group commissioned covereage of 3 areas—the eroded hill country in the Wairarapa, the South Island high country, and Lake Rotorua. This imagery is presently being evaluated.

PLANT MATERIALS

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The Plant Materials Group has as its aim the evaluation, development and release of improved plant materials for land stabilisation, erosion control, river control, and windbreaks and shelter.

To achieve this aim, a wide range of plants is being studied; tissue culture has been developed as a practical means of rapid propagation; and establishment techniques are being evaluated. Research work is concentrated at two centres, Aokautere and Alexandra (previously Earnscleugh Research Orchard of the DSIR). Field

trials and demonstrations continue to be most effective in testing and publicising plants, and their establishment and management in critical areas throughout New Zealand.

Integration of the Group's research with that of other groups at the Aokautere Science Centre involves basic studies to define the manner in which trees, shrubs and other plant materials stabilise the land. Such studies should result in better species selection and improved planting patterns for soil conservation.

The principal areas of study are:

Breeding and selection of improved poplar and willow clones.

Evaluation of alternative tree species to poplars and willows for specific problem areas; includes *Acacia, Eucalyptus, Platanus, Alnus, Robinia, Gleditsia, Ulmus, Betula* and *Erythrina* spp.

Evaluation of grasses, legumes and herbs for erosion control.

Propagation and establishment of soil conservation plants including micropropagation, methods of container growing, weed control, cool storage, fertiliser requirements, protection from sheep and cattle browsing, mycorrhizal studies, and resistance to drought and frost.

Monitoring incidence of diseases in soil conservation plants, pathogenicity studies and development of control measures.

Selection, establishment and management of tree and shrub species for farm and horticulture windbreaks and shelter.

Special projects to determine plants suitable for revegetation and stabilisation planting in the Shotover Catchment, Ruahine Ranges, semi-arid and drought prone areas, and for roadsides and industrially disturbed sites.

Root systems and water relations of land stabilisation trees.

1. Tree Species for Soil Conservation Planting on Seasonally Dry Hill Country

The establishment of trees for stabilising dry exposed north-west slopes, which occur throughout much of the east coast hill country of both North and South Islands, has been a major concern of catchment authorities in these districts for many years. Particularly severe erosion of the north-west slopes in the Wairarapa district during winter-spring 1977 emphasised the need for tree species adapted to these sites where traditionally used poplars and willows could not be established. More drought and wind tolerant species were necessary, and the eucalypts and acacias were considered to offer the most potential. In order to determine the most suitable species and establishment techniques, a series of trial plantings were made; major trials in the Wairarapa district in 1978–79, and smaller ones at other sites in Hawke's Bay, Nelson and Canterbury in 1979–81.

The major trials, which included some 70 species (137 provenances), are now in their third and fourth growing seasons, and major differences in species performance are apparent. Species from the ash and peppermint groups of eucalypts, together with *Acacia melanoxylon,* are the most promising.

Table 3: Early growth of most promising species in trials at Kahuiti and Pakaraka, Wairarapa (3 years after planting)

Species	Provenance	Mean Survival (%)	KAHUITI Height (m)	KAHUITI DBH (mm)	PAKARAKA Height (m)	PAKARAKA DBH (mm)
Eucalyptus brookerana	Fingal, Tas.	100	3.68	475	2.67	392
E. fastigata	Oakura, NZ	90	2.67	335	3.56	486
E. fraxinoides	Badja Mtn, NSW	78	1.97	200	3.69	471
E. nitida	Maydena, Tas.	91	3.86	380	2.77	340
E. obliqua	Nietla, Tas.	86	2.83	341	3.62	433
E. pulchella	Mt Judbury, Tas.	67	2.46	287	2.90	344
E. regnans	Moogara, Tas.	88	2.81	286	4.69	493
Acacia melanoxylon	Tasmania	98	2.31	296	2.80	488

The tentative selections listed in Table 3 are made on the basis of only 3 years growth (Fig. 5) A considerably greater period is required to determine the long-term suitability of these species for wide-spaced planting on pastoral hill country, particularly with regard to the ultimate size of the trees and their contribution to slope stability. An additional factor is the differential preference of the Eucalypt tortoise beetle (*Paropsis charybdis*) for juvenile or adult foliage of the species under test, and it may be some years before the true susceptibility of species such as *E. brookerana* and *E. nitida,* which have not been planted extensively in New Zealand, is determined.

Techniques for establishing these species on difficult sites are also being investigated. Greatest success has been obtained by planting small container-grown (peat pots) stock, with strict weed control for the first year.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 5 *Eucalyptus regnans* **3 years after planting, Wairarapa.**

Fig. 6 *Sanguisorba minor,* **Earnscleugh Nursery, Alexandra.**

Fig. 7 *Hedysarum coronarium* **in mudstone gully, Puketiti, East Cape.**

Fig. 8 **Weed control effected 12 weeks after spraying by terbacil (foreground) and diuron (rear) at 4.8 kg a/ha.**

2. Release of Improved Willows for Soil Conservation and Windbreaks

The Group has recently released a new range of improved clones and clonal mixes of both tree and shrub willows specifically bred and selected for slope stabilisation, riverbank protection and windbreak planting. The range includes 2 clones introduced from Europe in 1967, and 13 clones and clonal mixes resulting from the Group's willow breeding programme. This programme, which began in 1969, is directed at providing *Salix* clones with more desirable characteristics than those available in the past, such as faster growth rate, better stem form, less palatable to possums (*Trichosorus vulpecula*) and domestic stock, less brittle branches, and male sex to prevent seedling establishment in river channels.

Important characteristics considered in the selection of willows for windbreaks, particularly for horticulture, are length of leafing period, and low-branch retention.

The released clones have been selected from a large range of clones tested at several sites throughout New Zealand. Their use will considerably extend the degree of genetic variation in the material planted for soil conservation and shelter in New Zealand, and so lessen the disease risk associated with the extensive planting of only a few clones. Already more than 80 000 cuttings of the new clones have been supplied to catchment authorities and commercial nurseries.

Tree willows

The new *Salix matsudana* x *alba* clones which have been selected are all faster growing than the parent clones and, although somewhat similar in appearance, each has its own characteristic features. Two of the clones ('Tangoio', 'Makara') have been selected specifically for use in farm and horticultural shelterbelts; 2 clones ('Adair', 'Moutere') can be used both for general soil conservation planting as well as for shelter; and 2 clones ('Hiwinui', 'Wairakei') are suitable only for general soil conservation planting. All the clones have a common female parent, a single clone of *S. matsudana* which was the only clone of this species available outside of eastern Asia at the time these hybrids were produced. Since that time, other clones of *S. matsudana* have been introduced from China, but they are still being evaluated.

Shrub and osier willows

Nine clones and clonal mixes of specially bred shrub and osier willows have now been released; all are male (non-seeding) and have bitter foliage unpalatable to possums. They are suitable for gully planting, streambank stabilisation, roadside planting, and mountainland revegetation. Included are 3 clones of *S. purpurea* ('Holland', 'Irette', and 'Pohangina'), 2 hybrid clones (*S. incana* × *daphnoides* 'Tiritea', *S. repens* × *purpurea* 'Kumeti') and 4 clonal mixes ('Wither Hills', 'Tara Hills', 'Mid Dome' and 'Glenmark'). The clonal mixes have been released in order to provide a wider genetic range of improved shrub and osier willows without unduly complicating nursery management and planting operations. Each clonal mix or multi-clonal variety includes up to 9 clones of morphologically similar but genetically distinct clones.

3. Sheeps Burnet (*Sanguisorba minor*) for Revegetation of Semi-Arid Land

In Central Otago, the Mackenzie Basin, and parts of Marlborough, severe depletion of tussock grasslands is common. Revegetation is difficult because of low rainfall, very low winter temperatures, late spring frosts and desiccating summer winds.

Promising shrub, herb, legume and grass species for revegetation in these areas are being evaluated for soil conservation purposes at Earnscleugh Nursery (near Alexandra), and in field trials carried out on stations in the area: Bendigo, Olrig, Cluden, Black Forest, Otematata, Tara Hills, Haldon and Grays Hills. Of those species under investigation, *Sanguisorba minor* (Fig. 6) in particular is very impressive, and has good potential for use on droughty or semi-arid hillsides where the natural vegetation has become severely depleted.

The species is a small perennial herb, usually 10–20 cm tall, but with a woody flower stem, which can reach to 90 cm, and pinnate leaves which often form a rosette. The roots will extend down to at least 40 cm. Its natural range extends from Spain and Portugal, around the Mediterranean Basin into southern U.S.S.R. and south-western and central Asia. It is adapted to growing on droughty grassland or rocky ground, with rainfall as low as 300 mm, and temperature extremes ranging from below −20 °C to over 40 °C.

Early trials conducted by Macpherson in 1910 and Cockayne in 1922 showed promise, and plants from these trials have become naturalised and still persist today, despite heavy uncontrolled grazing. Because of the promise shown by these early trials, the National Plant Materials Centre (now the Plant Materials Group) began a provenance testing programme with *Sanguisorba* in 1973 by importing 47 accessions of all sub-species of *S. minor* to assess establishment and persistence on depleted sites where soil erosion is a major problem. The accessions included material from the Mediterranean Basin, Iran, Afganistan, U.S.S.R. and commercial lines from Italy, France and western U.S.A. Seed was collected from material that had naturalised in Central Otago and the Mackenzie Basin.

Initial screening, which was carried out at sites in the Mackenzie Basin and on the Wither Hills near Blenheim, have now been completed. At all sites accessions of *S. minor* spp. *muricata* were superior. At the Mackenzie Basin sites, accessions from Iran and the Western U.S.A. were generally the best, while

at the Wither Hills Spanish, Italian, or Oregon accessions were superior. Several lines have performed well at all sites, including commercially available lines from Oregon, Idaho, and Utah.

Although no lines selected by the Group have yet been released, seed from Oregon has been imported for larger scale oversowing, and some seed production areas (total 35 ha) have been sown.

Current investigations are aimed at determining the establishment, persistence and vigour of plants on depleted sites and under grazing pressure, selecting accessions with good dry matter yield, selecting plants with a shorter summer dormant period, and determining the tolerance of, or resistance to, competition from *Hieracium pilosella.* Management is extremely important, especially during the establishment period when the young seedlings compete poorly with existing vegetation; this aspect also requires further study.

The potential of *Sanguisorba,* if production rates comparable to those obtained overseas can be achieved, appears very promising. The ability to produce a significant amount of foliage to protect not only depleted areas from soil loss by sheet or wind erosion but also to provide nutritious spring forage could make this plant extremely valuable for soil conservation in the tussock grasslands of New Zealand.

4. *Hedysarum coronarium* : A New Legume With Potential For Soil Conservation

Hedysarum coronarium (sulla) is proving to be a very promising legume for revegetating eroded sites in many areas of New Zealand. Although introduced as long ago as 1949 by the Botany Division, DSIR, for evaluation as a forage legume, it was not until 1971 that work was begun in earnest by the Group to evaluate sulla for use in soil conservation.

Sulla is a short-lived perennial herbaceous legume which rapidly grows to a height of 30–150 cm, and has a strong and branched tap-root. It flowers from early summer to autumn with an attractive deep red inflorescence. The seeds are borne in flattened slightly spiny pods which break into segments ideally suited to lodging in depressions and cracks on eroding sites.

Sulla originates in the Mediterranean region, and is adapted to climates with warm summers and mild winters. It can, however, withstand summer drought; in New Zealand it has been successfully established on sites with annual rainfalls as low as 360 mm. Ecotypes differ in the degree of drought tolerance and winter hardiness, with those from southern Italy and Sicily being more drought resistant but less cold tolerant than ecotypes from northern Italy and North Africa. Amongst the accessions evaluated by the Group several have withstood frosts of −11.5 °C in Central Otago.

Preferred soils are neutral to alkaline, and well drained; they could be considered to be similar to those required by lucerne. In the Group's trials sulla has persisted on mudstone soils in Northland, Poverty Bay and King Country, limestone rock near Hastings, siltstone soils near Taihape, loessial soils near Blenheim and Dunedin, and soils derived from schist at Bendigo and from greywacke at Otematata.

The major use of sulla for soil conservation is expected to be in the rapid establishment of a vegetative cover on gully, sheet, and wind eroded sites retired from grazing. In trials at Puketiti and Tawai Stations, East Cape, 80–90 percent cover was achieved on bare steep mudstone gully sites within 6 months of late spring oversowing of unhulled seed (Fig. 7). By this time individual plants measured up to 70 cm in height and 135 cm in diameter, and many had already flowered and set seed. Previous attempts to revegetate these sites with conventional pasture species had failed. It is anticipated that the beneficial effect of this initial cover on stability and microclimate will enable longer lived grasses and legumes to become established, and for woody plants to be planted if desired.

Sulla also appears promising for the revegetation of road batters and other disturbed industrial sites, either by conventional oversowing, or by hydroseeding. Several hydroseeding trials have incorporated sulla in conjunction with other grasses and legumes, such as phalaris, perennial ryegrass, cocksfoot, lucerne, white and red clover, sweetclover, and "Maku" lotus, with considerable success.

Sulla produces non-bloating forage, and in the Meditteranean region is widely used for hay, silage, and greenfeed. It may be possible to graze sulla directly, but very careful stock management would be required to ensure the survival of the stand.

Currently, extensive trials are being laid down on a semi-operational basis in the Wairarapa and Northland districts to determine the adaptability of sulla to more difficult acidic and argillitic sites. Investigations are also continuing at Aokautere to determine the most suitable weed control and harvesting techniques for seed production areas. Some 1.2 ha of seed increase area has been established, and during the last 2 years 1500 kg of seed harvested.

5. Nursery Weed Control

Nurseries operated by catchment authorities for the production of poplar and willow planting material have expanded rapidly in recent years, with an area of more than 225 ha now planted. Weed control in these nurseries is often less than adequate, resulting in poor growth, and necessitating longer rotations to produce material suitable for planting. Most weed control in the past has been carried out by cultivation, which is very expensive in labour costs. The use of herbicides provides a more economic alternative which

has not been widely taken up because of the bewildering array of chemicals available and few data on their compatibility with these hardwoods under New Zealand conditions.

Most investigations carried out by the Group have been directed at determining suitable herbicides for use in cutting beds. Early trials indicated that simazine could be tolerated by poplar and willow cuttings at rates of up to 1.5 kg a.i./ha, and now is commonly used in several nurseries.

During the last 5 years a much wider range of both contact and residual herbicides has been tested, primarily at Aokautere, but also in East Cape Catchment Board's nurseries. Residual, or soil acting, herbicides applied to soil in the presence of newly planted cuttings were the most promising. In general, simazine has proved to be a good all round herbicide where a number of poplar and/or willow species are planted in the area to be treated. For individual poplar and willow species, some other herbicides were better. Terbacil is very promising for black poplars (e.g., *P* × *euramericana* 'Flevo') at rates of up to 4.8 kg a.i./ha, giving excellent weed control and growth rates similar to those achieved with weed control by cultivation (Fig. 8). However, the white poplars (e.g., *P. alba, P. alba* × *glandulosa*) and willows have shown considerable sensitivity to terbacil in trials carried out to date and therefore it should not be used on these species until further investigations are made. Diuron at 4.5 kg/ha has often resulted in superior growth than has simazine for both poplars and willows; it could be used more widely but, unlike simazine, it cannot be sprayed over the top of cuttings once they have begun to leaf. Terbumeton + terbuthylazine ('Caragard') has proved satisfactory on *P. alba* and *S. matsudana* × *alba* but, because only relatively low rates are tolerated, weed control and growth is often less than that achieved with diuron. It should not be used at rates greater than 3 kg or 1/ha (i.e. terbumeton + terbuthylazine at 0.75 kg a.i./ha each).

LAND STABILITY

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The objectives of the Land Stability Group's research are to improve understandings both of the processes which lead to mass movement on hillslopes and of how slope stabilisation techniques operate (so that these can be planned more effectively and promoted more confidently) and to develop more objective measures of erosion potential and severity. The Group's programme includes the following major projects:

Investigation of hillslope hydrology and its relationship to slope instability.

Characterisation of the mechanical/physical nature of regoliths on earthflow and soil slip susceptible hill country in the North Island.

Factors governing the stability of earthflows in the Gisborne area including quantitative measures of change in stability attributable to enhancement of internal friction by stabilisation treatments.

Impact of trees used for slope stabilisation on soil moisture in time and space in different soils.

Numerical modelling of hillslope soil water systems as an approach to developing methods for the design and evaluation of mass movement stabilisation techniques.

1. Hillslope Hydrology

Pressure exerted by water in the voids between soil or rock particles has long been recognised as the most important single factor determining the stability of slopes. Slopes fail as slips, slumps or flows when these pore pressures exceed certain levels and cause frictional resistance to drop below that required to ensure stability. The principal cause of fluctuations in these pressures is the weather; the response of the soil itself to the pressures may also modify them. Because the pore pressures vary in the soil-rock (or 'regolith' as the potentially mobile layer of soil and rock is termed) with the nature of the vegetation cover, it is widely considered that the introduction of pastoral land use practices in hill country has altered the water regime in hillslopes beneath pasture sufficiently to promote more frequent and more severe slope instability problems. This is believed to be particularly important because the restraining root systems of indigenous forests have also rotted away. Improvement of slope stability must be achieved under the present potential land use by modification of the slope water regime or by the introduction of some form of artificial restraint.

Despite the primary importance of the system of pore water pressures which develops in slopes in response to changing weather patterns, virtually nothing is known of the relationships which exist between weather patterns and soil water systems. Until recently, the reason for this has been the impracticability and expense of collecting the necessary field data; as weather varies rapidly, meteorological and groundwater parameters commonly need to be monitored hourly or even more frequently. This clearly requires an automated system. With microprocessor technology, data collection systems can now be designed and built to handle thousands of measurements per day and store them in a way that they can easily be presented to a computer for analysis.

To fill the gap in our knowledge of slope systems, the Group designed, built and field tested a new automated data collection system. Using this system, it is now possible to monitor rainfall infiltration as it occurs and the subsequent redistribution of water throughout the slope profile by internal drainage. Because the system measures quantities which are intimately connected with runoff generation, the data should also be of considerable use to hydrologists concerned more specifically with problems of water supply.

The system is capable of monitoring pore water pressures (see Fig. 9) in the range −100 to +100 kPa depending on the depth of the sensor. It is relocatable, with only relatively inexpensive components having to remain in the ground. At present, the system can monitor 30 pressure sensors and meteorological instruments every hour and be left unattended for over a month before the data storage device becomes full. The sensors are installed at various depths beneath the surface at points of particular interest.

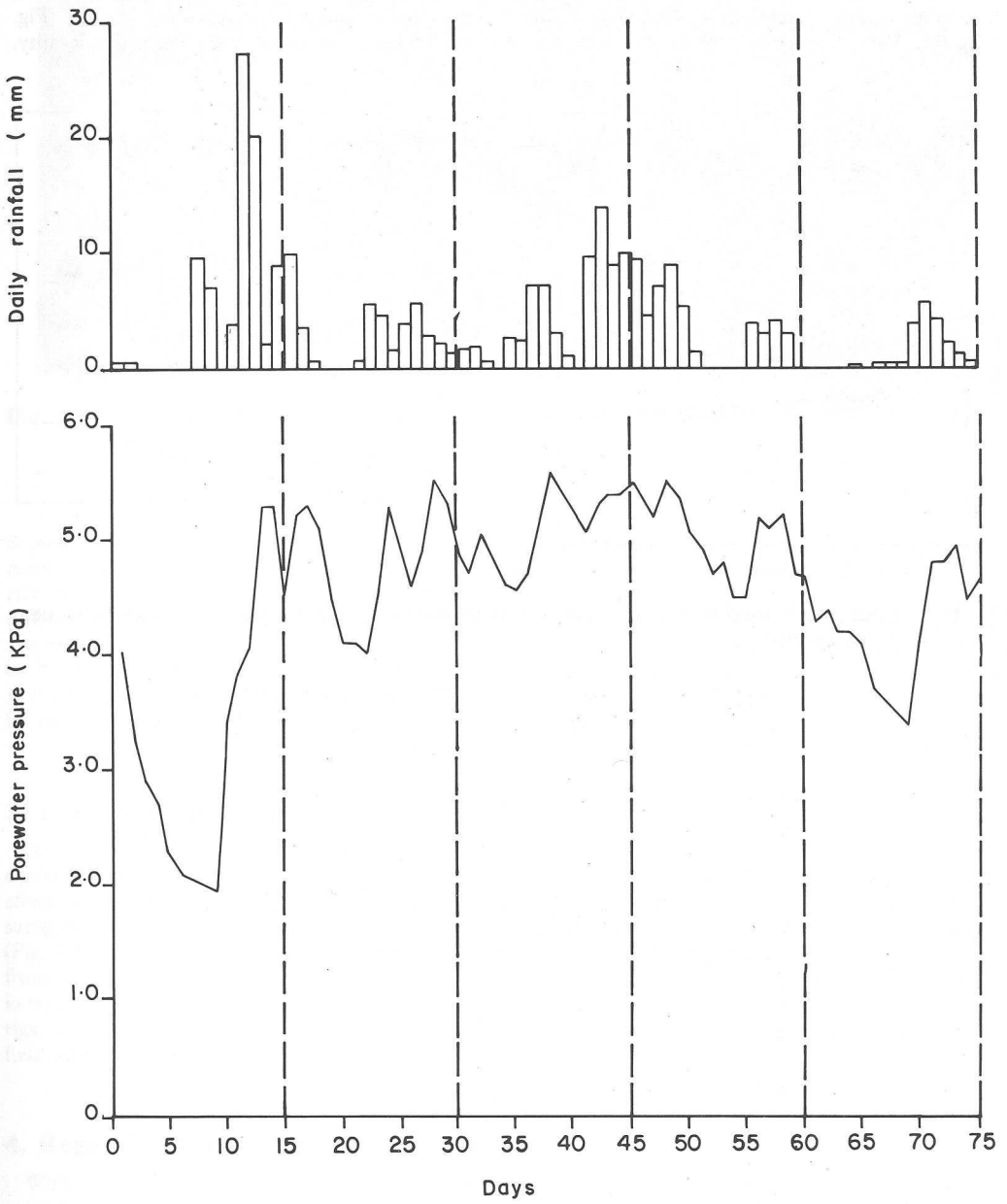

Fig. 9 **Rainfall and daily porewater pressure record obtained from hourly measurements made using the automated field data acquisition system developed by the Land Stability Group.**

The first site being monitored is east of Waipukurau in mudstone on a slope prone to slow earthflow movement. It is also intended to instrument a steeper slope prone to soil slip erosion — shallow, rapid earth movement, probably in the Wairarapa.

2. Processes in Deepseated Creeping Earthflows

Movement of deepseated creeping 'earthflows' in Mahoenui mudstone near Taumarunui has been monitored for 3 years using inclinometers and ground surveys. Although the primary purpose of this monitoring has been to characterise movement patterns prior to land stabilisation works taking effect (in order to subsequently determine the effectiveness of the works), it has been possible to combine soil mechanics tests with the movement record to infer the nature of the processes which develop, sustain and cause acceleration of movement. The movements are truly creeping, averaging 29 cm/year for the sites monitored. There is no sign of overall deceleration and in some cases the movement appears markedly seasonal (Fig. 10 (a), (b)). Very deepseated movement is less seasonal and appears considerably slower at this locality.

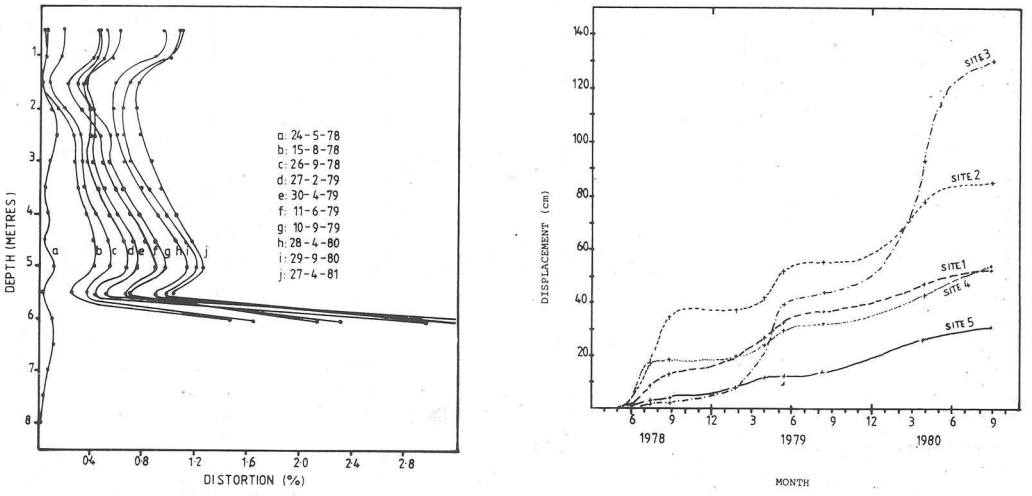

Fig. 10 Internal distortion (a) and surface movement (b) of deepseated earthflows near Taumarunui.

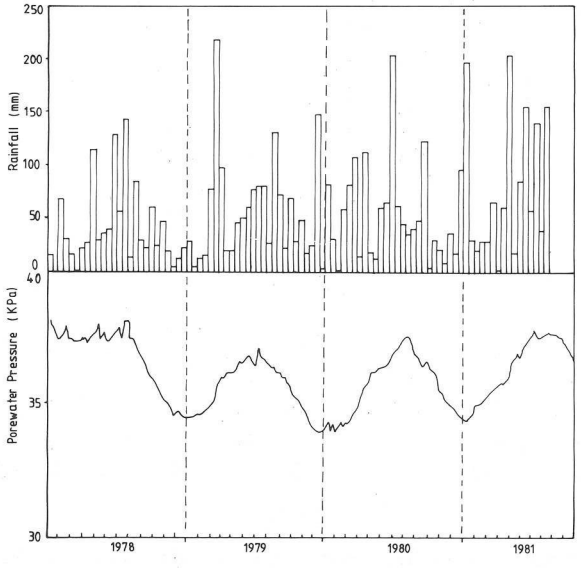

Fig. 11 Characterisation of 'pre-treatment' porewater pressures prior to application of stabilisation techniques.

Fig. 12 Deep soil sampling using motorised equipment designed by the Land Stability Group.

Seasonal porewater pressure variations (Fig. 11) are probably significant at depths as great as 7–8 metres. A zone of plastic flow 1.5–2 metres thick occurs at the base of the earthflows. Above this is a slowly distorting, relatively intact regolith, which triaxial tests suggest is nevertheless weakening and getting wetter by "strain softening". Overconsolidation ratios of the material in the zone of primary basal shear are low suggesting this material is in what is known as its 'critical state', offering purely frictional resistance to shear. Shear in this zone can continue at constant water content while weakening and increase in water content occurs in the material above. The earthflows have probably developed as a result of progressive failure initiated by removal of support, either by stream erosion or by adjacent mass movement.

3. Deep Sampling Operations in Rough Terrain

One reason why research into rural slope stability has lagged in the past has been the inadequacy of equipment available for obtaining 'undisturbed' samples of regolith at depth. While most stability problems affecting farmland are relatively shallow (less than 3 metres) a number of mass movements have failure surfaces considerably deeper. In 1981 the Group completed the testing of a new portable motorised sampler (Fig. 12) designed by staff. It is now possible to obtain high quality samples up to 100 mm in diameter from depths exceeding 10 metres, and on slopes up to 30°. Additions to the equipment enable sampling in very wet ground using a piston sampler similar to those used on heavy civil engineering site investigation rigs. The fact that such equipment can be used with a portable system has opened new possibilities for field investigations.

4. Regolith Characterisation Programme

While mass movement problems affecting hill country pasture have been well characterised in terms of gross features such as lithology and slope, negligible data are available characterising the regoliths in terms of the physical and mechanical properties which are critical in determining stability or their suitability for various stabilisation techniques. In an effort to provide at least some data upon which to base assessments of slope stabilisation works and further research, a regolith characterisation programme was commenced.

To date this has involved taking continuous undisturbed 100 mm diameter sample profiles from 18 regoliths susceptible to mass movement (at this stage mainly earthflow activity). We are now in a position to more clearly identify normal and exceptional problems, besides having a base of data upon which to plan further work. Tests have included permeability, bulk density, water retention characteristics, engineering indices, consolidation, moisture content and particle size distribution determinations.

5. Experimental Evaluation of Slope Stabilisation Techniques

A field experiment in progress at Gisborne has the objective of evaluating the effect of a number of slope stabilisation techniques such as conservation planting, underdrainage and graded banks on the slope soil water system. A group of 8 similar earthflows in bentonitic mudstone has been instrumented over the last 4 years. The principal quantity being investigated is porewater pressure which controls the amount of frictional strength the slope can mobilise to resist movement. Computer analysis to check the consistency and validity of the pretreatment 'calibration period' data is in progress prior to implementation of the treatments. Encouragingly consistent seasonal patterns have emerged and surprisingly fast pore water pressure response times to rainfall have been observed suggesting that these slopes at least may lend themselves well to stabilisation by subsurface drainage in particular.

CHRISTCHURCH

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The Centre, which is located in the centre of the city, is the national focal point for research and survey work concerned with physical hydrology.

The work of the Centre is carried out by 20 scientists and 16 technical staff in 6 groups which cover the fields of environmental hydrology, groundwater, hydrology network and equipment development, hydrosystems, alpine processes, and instrument servicing.

In addition there are hydrology groups in each of the 7 Ministry of Works and Development districts which have functional responsibility to the Centre. The district groups, which have a total staffing of 9 scientists and 65 technicians, conduct a specified programme of field measurements, process the data collected to specified standards of validation and archive their data.

Also located at the Centre are staff who are carrying out research and survey programmes that are the functional responsibility of another science centre; water quality for Hamilton, and land resource surveys and plant materials for Palmerston North.

HYDROSYSTEMS

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The Group develops analytic techniques for the interpretation of hydrological information for use in management decisions. While the analysis work is largely statistical, interpretation of the results requires a knowledge of how the processes of hydrological systems behave. From such knowledge simulation models are built which are tested against measured data, and if they are found to fit the measured data they are then used to study changes to the systems. The Group is also involved in providing mathematical expertise and computer software to assist other groups in their studies of the physical water resource.

1. Area Rainfall

This project has involved the examination of 2 aspects of severe rainstorms.

When high intensity rainfall data are used for design purposes they are commonly in the form of estimates of the various durations and return periods at measurement sites. For areas large enough for the average rainfall to depart appreciably from that at any measurement point, area reduction factors (ARF) are used to reduce the point values to area estimates. Clearly, if a 50-year return period value at the measurement site of a 6-hour rainfall is 70 mm, then the corresponding value for, say a 100 km² area (enclosing the point), will be less, by a factor which is called the ARF.

In New Zealand the conversion of point estimates to areal values is currently done using computations based on very limited overseas results and is known to involve a large degree of uncertainty. The area rainfall project aims to reduce this uncertainty and quantify it. An experimental area in the greater Wellington region was chosen for study because it had the required density of rainfall stations and was one with topography and rainfall patterns not dissimilar to many of the regions in New Zealand. Table 4 gives the computed ARF values for the region, and which have been calculated to be within plus or minus 4 percent of the real values.

Table 4: Computed area reduction factors for 1-, 6- and 24-hour rainfalls of 2- and 50-year return periods.

kilometres²	Rainfall duration					
	1-hour		6-hour		24-hour	
	2-year	50-year	2-year	50-year	2-year	50-year
1000	0.81	0.68	0.84	0.64	0.84	0.84
500	0.81	0.68	0.84	0.68	0.84	0.84
250	0.81	0.68	0.92	0.75	0.84	0.84
125	0.81	0.68	0.96	0.82	0.84	0.84
62.5	0.81	0.68	0.96	0.96	0.93	0.93

The second aspect of the study was to examine the time sequence of rainfalls in storms. This was done by computing storm profiles and producing these in graphical form to show the accumulation of rainfall with time during storms. From overseas and New Zealand studies it has not been possible to produce classifications of storm profiles that distinguish different 'types' or features of storms. In this study a principal component analysis was used to sort the annual maximum storm rainfall patterns into independent groups. Three main groups were used: frontal zone in major trough of low pressure moving eastwards over the area; centre of low pressure in northern Cook Strait with light southerly wind at Wellington; strong southerly flow. These categories failed to produce distinct rainfall profiles and accordingly it was concluded, as in earlier studies, that apart from the tails of the storms (the starts and ends) the rainfall is on average uniform throughout the storms.

2. Flood Forecasting

Studies for the forecasting of river flow several hours ahead from telemetered water-level and rainfall data have been undertaken for the Grey River basin. For retrospective analyses, the flow record for the Grey at Waipuna has been used with a rainfall record derived to represent mean rainfalls at 2-hourly intervals over the basin. This work has illustrated the difference between simulating a flow record given a rainfall sequence, and adaptively forecasting flows by using the most recently observed flows and rainfalls to forecast what the flows will be for several hours ahead. A very simple model has been applied to the basin to provide a benchmark against which more sophisticated basin models can be compared.

Floods for the Grey River at the Waipuna gauging station for the decade 1971–1980 were studied. A daily-read raingauge is located centrally in this basin at the confluence of the Grey and Robinson Rivers (Fig. 13). The nearest automatic raingauge, which is adjacent to the basin boundary (Fig. 13), was used to indicate the hourly patterns of rainfall over the basin by multiplying the Grey-Robinson daily total by the ratio (automatic gauge hourly total/automatic gauge daily total). The hourly rainfall series thus obtained was denoted by P_i where "i" denotes hour "i". The series were aggregated to 2-hour totals and were smoothed to obtain what was considered to be a more representative mean rainfall over the basin. The smoothing used:

$$\bar{P}_j = 0.6\ P_j + 0.3\ P_{j-1} + 0.1\ P_{j-2}$$

where j denotes time at steps of 2 hours and $\bar{P}_j$ is the smoothed rainfall.

The basin model applied to the Grey River data was that which had been used successfully in forecasting studies for small basins in North Wales. In the model the basin is considered as a single storage, S, which is augmented by rainfall, p, and depleted by runoff, q. Study of recessions during periods without rain suggests that S is a linear function of logarithms of flow. This relationship, and application of the continuity equation, leads to a single parameter basin model in which flow at time t + u is estimated explicitly from flow at time t and intervening rainfall. A second parameter, lag, is introduced by shifting the rainfall in time so that computed flow matches the observed flow at time t.

In trial runs the model was fitted to recessions from several storms and was then implemented for both simulation and corrective modes for other storms. In fitting data to the model it was found necessary to use separate linear functions depending upon whether the flow was above or below 260 m³/s to represent the storage-outflow function. Furthermore, although a lag of at least 2 hours was anticipated, best fit for the model was achieved with zero lag. This suggests that for the events studied, rain fell at the automatic gauge a few hours after it fell over the Grey basin. Therefore, flow forecasts of the Grey River flows at Waipuna from the rainfall record are not possible unless forecasts are made for rainfalls.

To examine the potential for improving a flow forecast by using an accurate rainfall forecast a series of storms over a 6-day period in May 1975 were used. Two-hour ahead forecasts of flows, assuming perfect

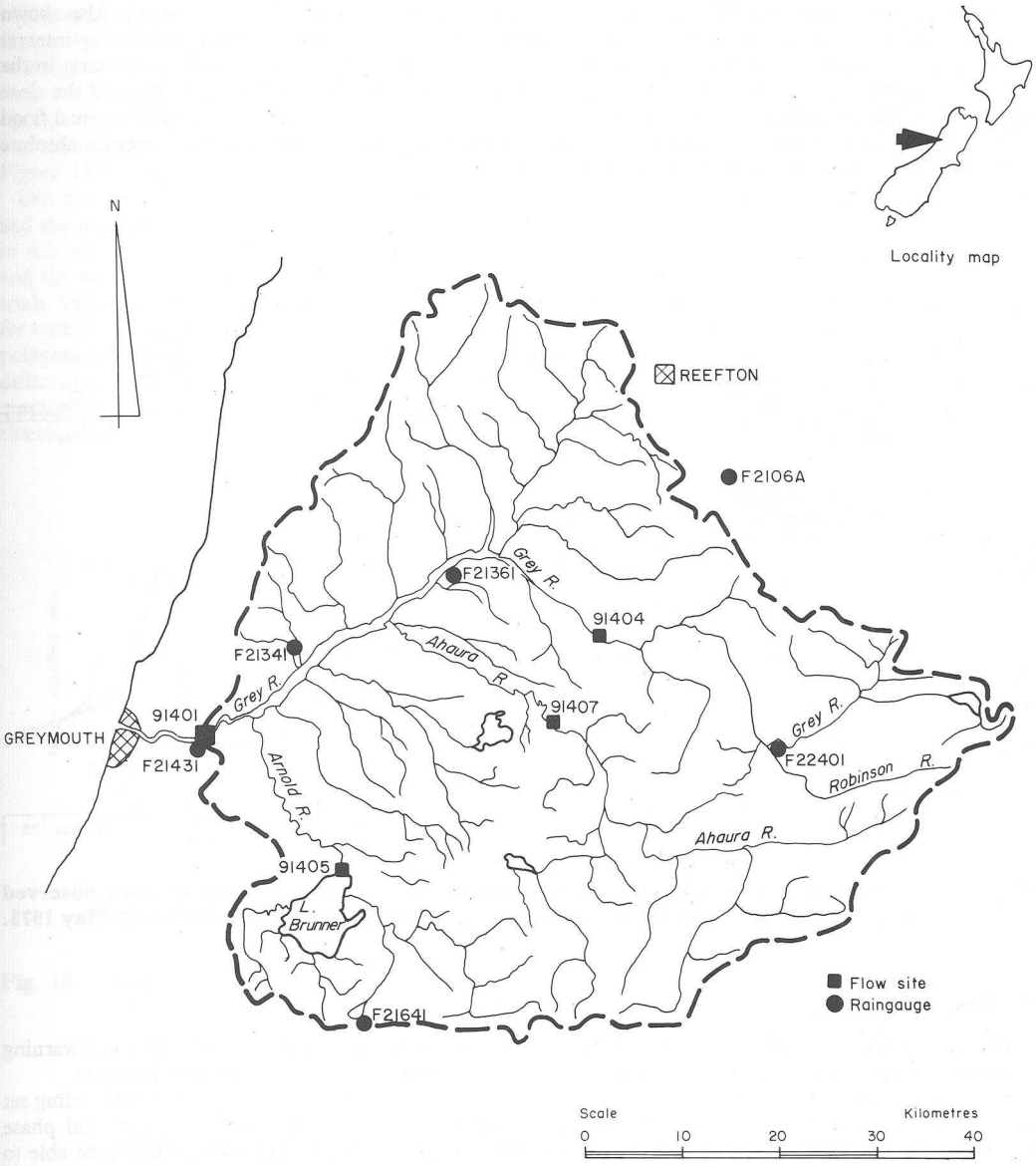

Fig. 13 **Location of flow and rainfall measurement sites for the Grey River basin flood forecasting study.**

forecasts of 2-hour ahead rainfalls, are shown and compared with observed flows in Fig. 14. Also shown is the rainfall, and the simulated flows estimated using the observed flow at the start of the 6-day interval and the rainfall sequence. Points to note from Fig. 14 are the large overestimates in forecasts early in the period, presumably through taking insufficient account of the state of wetness of the basin, and the close estimation of the peak flood of 750 m^3/s on 19 May. This peak is comparable with the mean annual flood of 830 m^3/s. The forecasts account for 87 percent of the variance of the flows and the average absolute difference between observed and forecasted is 34 m^3/s.

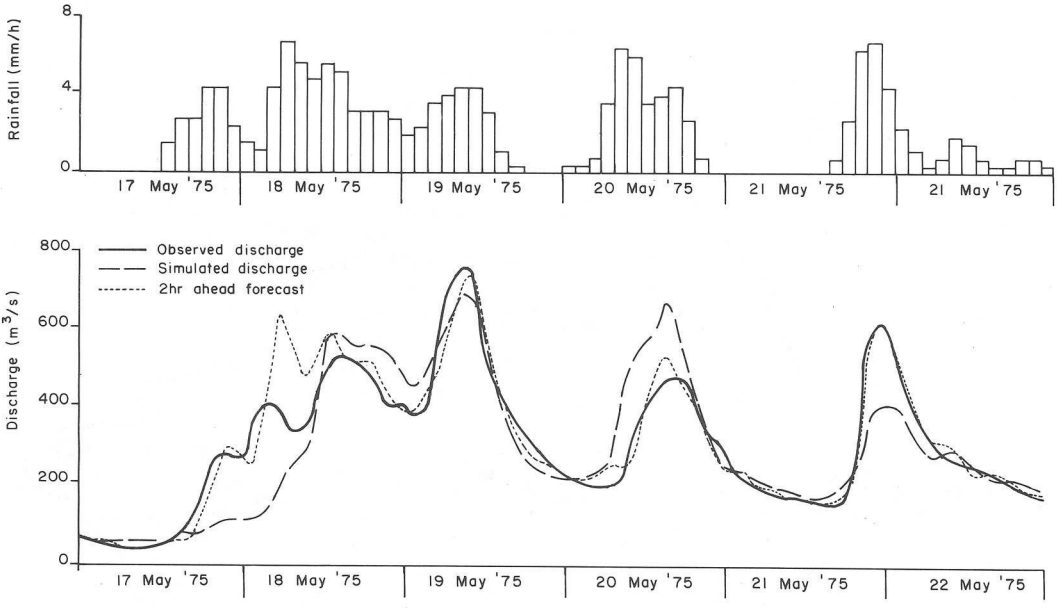

Fig. 14 Comparison of two-hour ahead forecast and simulated discharge with observed discharge of the Grey River at Waipuna for storms over the period 17–22 May 1975.

3. Flood Routing

Forecasts of the timing of flood peaks and peak discharges before they occur are needed for flood warning purposes. Hence the Group is involved in developing and testing techniques for such forecasts.

Using linear systems analysis the translation of a set of upstream hydrographs to the corresponding set of downstream hydrographs can be resolved into a set of waves with different frequency and phase relationships. Examination of some 6–10 hydrograph pairs provides sufficient information to be able to determine the main wave frequencies present. Thus a new upstream hydrograph can be routed using the wave frequencies to form a forecast hydrograph for the downstream station. This technique has been refined to accept data that is not of high precision. Visits were made to Hauraki, East Cape and Hawkes Bay Catchment Boards, all of whom have expressed an interest in applying the technique. Work on the rivers of interest to these boards is continuing. Work has begun on translating the actual routing programs to other computer languages (e.g., from FORTRAN to HPL) for use on other makes of micro-computers.

4. Raingauge Network Analysis

During 1979/80 the Group developed a computer program (MEDIA) for estimating catchment mean rainfall using a digitised catchment boundary and a set of digitised isohyetal lines. This program can also generate and analyse a set of isohyetal lines using raingauge positions and totals. The potential for using this development for checking raingauge networks has now been examined using the network of raingauges in the Inangahua catchment above Blacks Point (catchment area 234 km^2). Some 15 gauges operate within or on the watershed, while a further 7 Meteorological Service gauges are located around the catchment. Of the 15 gauges operated by Water and Soil Division, 14 are storage gauges (measured approximately 12 times/year) and 1 is automatic. The Meteorological Service gauges are read daily.

The raingauge totals for the same month were used for all analyses. Using all 22 gauges MEDIA estimated the catchment mean rainfall for the month to be 400 mm while the Thiessen polygon estimate was also 400 mm and the arithmetic mean was 390 mm. MEDIA was then used to estimate catchment mean rainfall from the automatic gauge, the 7 daily gauges and 9 of the 14 storage gauges. This was repeated 4 more times, each time randomly selecting another set of 9 of the 14 storage gauges. Five trials randomly selecting 4 of the storage gauges were also done. For each set of 5 the mean and standard deviation were calculated. Figure 15 summarises the results.

One problem in the analysis leading to Fig. 15 was the widely differing isohyetal patterns that were obtained and the possible conclusion that while little variation in the catchment total was detected wide variation in subcatchment totals could occur. To check this the catchment was subdivided into 45 parallel strips and the mean volume falling on each strip and its standard deviation were calculated for the 2 sets of 5 trials. Values using the Thiessen polygons were also derived. From Fig. 16, which shows the mean volume for each strip using selections of 9 stations out of 14, it can be seen that the values obtained using Thiessen polygons are within about ± 1 standard deviation. Thus, although the isohyetal patterns appear considerably different the effect on sub-areas is minimal. Since Fig. 16 offers a viable way to check existing raingauges, much of the tedium involved in producing it is now being eliminated by adapting MEDIA to carry out the analysis.

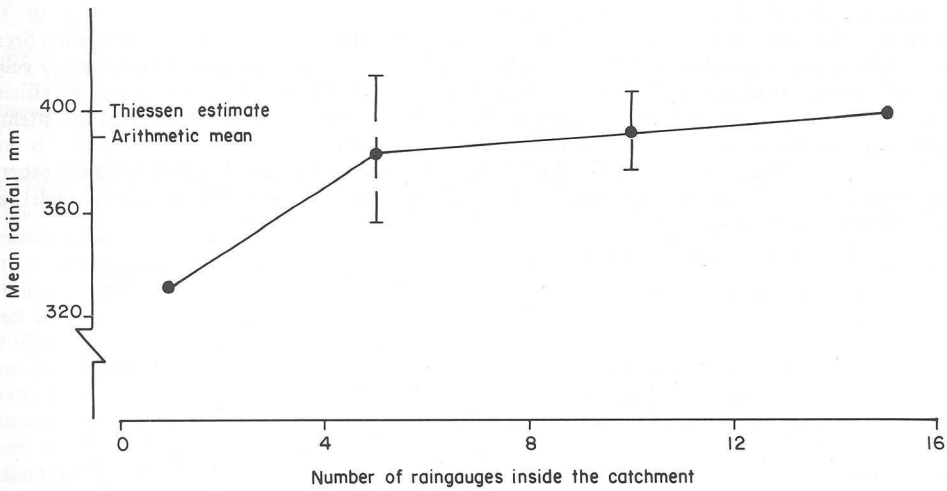

Fig. 15 Variation of the Inangahua Catchment mean rainfall with number of raingauges used to estimate the isohyets (bars show ± lsd).

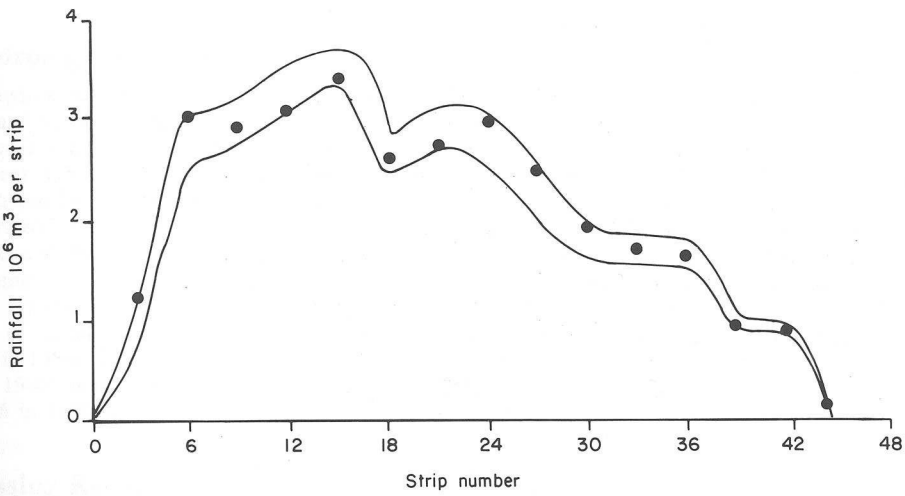

Fig. 16 Variation in rainfall across the Inangahua catchment. The lines show ± lsd from the mean of 5 values calculated by taking 5 different combinations of 9 raingauges. Points are volumes on the same strips from the Thiessen network of all 15 raingauges.

5. Shallow Water Flow

Shallow water flow, which is defined as flow in which the depth is small compared to the characteristic horizontal extent of waterways, occurs widely in nature in rivers, lakes and estuaries. A mathematical model known as FEMSHALL (Finite Element Model of Shallow Flows) which has been developed by the Group to model 2-dimensional (depth and width) shallow water flow has been applied to a number of practical situations. These include calculating the natural modes of oscillation of several New Zealand lakes, flow around a 180° bend, flow through the Lowburn Inlet, tidal flow in Cook Strait and flow through the Rangitata Diversion Race (RDR) sand trap.

The RDR sand trap is an enlargement, just downstream of the entrance to the race, that reduces water velocities sufficiently for sand to settle. There is a low outlet for flushing sand out of the trap as required. FEMSHALL is being used to assess the effect of changing the geometry of the sand trap in an effort to increase its efficiency. The velocity distribution of the as-built sand trap under full flow, as calculated by FEMSHALL, is shown in Fig. 17; the velocity at various points is represented by a vector with the direction being indicated by the arrow and the magnitude by the relative length of the vector. The velocity distribution calculated by FEMSHALL agrees well with the measured velocity distribution and with the pattern of deposition of sand in the trap. This shows the problem with the sand trap in its present configuration —the velocity of the flow on the left hand side near the bend is too high, and thus a significant portion of the sand is transported straight through the trap.

The velocity distribution shown in Fig. 17 was calculated on rather a coarse grid. The Irrigation Section, Ministry of Works and Development, Christchurch is refining the grid to compute twice as many velocity vectors and making a series of tests with various geometry changes in an effort to improve the efficiency by reducing the velocity uniformly across the trap. This effort to analyse alternative designs was attempted using an actual model of the trap but was prevented by problems of scale. Mathematical models do not suffer from scale problems. Thus, FEMSHALL is being used for a design task which could not otherwise be carried out. It is enabling the engineers to use a trial and error process in the office on a model rather than in the field on the prototype.

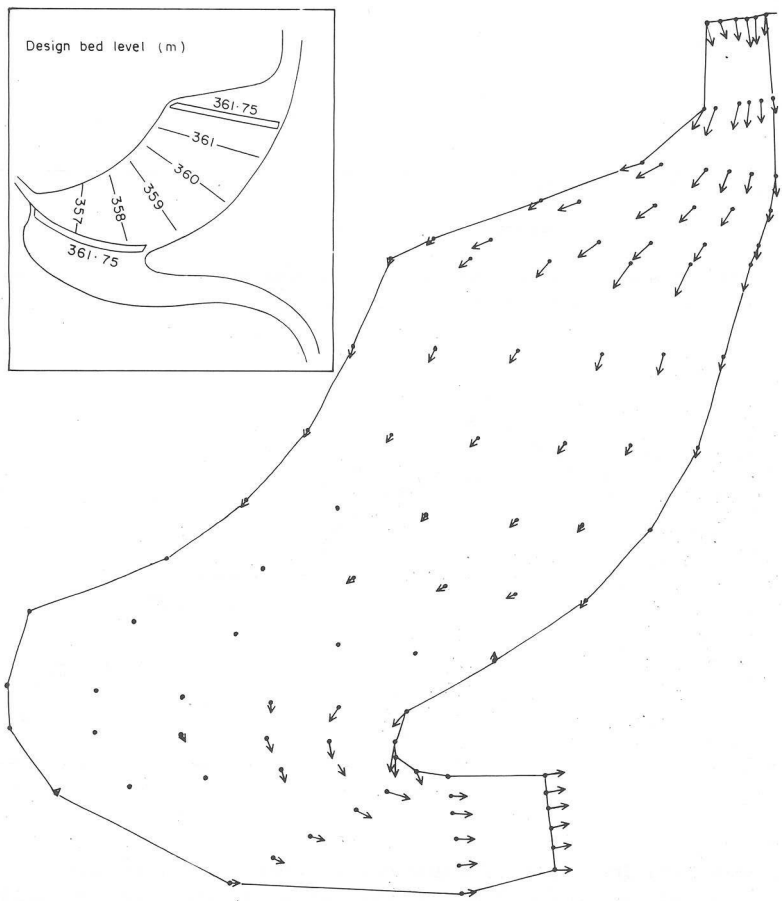

Fig. 17 Velocity distribution in the Rangitata Diversion Race sandtrap.

6. Other Work

Staff of the Group have also related climate data to its location for use with land resources information; reported on flood estimation for Otago-Southland, and produced a flood design manual; modelled land use changes in Puketurua; prepared a computer procedure for generating tidal records around New Zealand; investigated the interaction of flood waves with tides, a consequence of which has been the development of a more economical system for storing such data.

HYDROLOGY NETWORK

J. R. Waugh (Group Leader), MA

Network

S. E. Close, BSc (Hons)

A. Davoren, MSc (Hons), PhD (overseas study leave)

Equipment Development

D. E. Cottle, BE, MNZIE

M. W. Rodgers, ME Elect

Sediment

G. A. Griffiths, BE, PhD

Instrument Service Centre

R. A. Moore (Officer in Charge)

The Group's principal responsibility is to oversee the activities of the 7 district hydrology groups with particular reference to flow and rainfall data collection from a network of recording stations and thus is responsible for ensuring that the technical quality of the data meets appropriate standards.

In its surveillance of the data sets and data collection procedures, the Group's verification and inspection service is also available to catchment authorities for data which they collect and which are stored in the national data archive.

The objectives of the network of recording stations are to provide data for research, design, and water resource planning and management. The data are used for diverse purposes including water allocation plans and water right decisions, information on flood levels for flood warning, engineering design of structures in watercourses (such as dams, weirs and bridges), design and operation of hydro-electric power and irrigation schemes, and for design of flood protection/river control works.

Within the Group there is a section which carries out instrument designing and testing. The instruments that are worked on are all designed toward making more precise measurements and/or to make measurements more effectively in terms of speed, ease and cost of operation. The dominant project of this section is the automation of routine data acquisition for the hydrology network.

Also associated with the Group is the Water and Soil Instrument Service Centre (located at Belfast).

1. Hydrology Network

The hydrology network has continued to expand and the 1981 Index to Hydrological Recording Stations (Water and Soil Miscellaneous Publication No. 27) provides the following statistics. As at 1 January 1981 the network of water-level recorder stations totalled 800, an increase of 3.2 percent over 1980 (775 at 1/1/80). Catchment authorities now operate 423 stations (53%) of these compared to 349 in 1980, while the Ministry of Works and Development operates 331 stations (41%) compared to 380 in 1980. The remaining 46 stations are operated by other agencies. This represents a considerable change from 1978–79 when the Ministry of Works and Development operated over 50 percent of the network. Transfer of local interest stations to catchment authorities, termination of research projects (e.g., Lakes Taupo and Rotorua) and closing of some investigation stations have all contributed to this trend. There has been continued growth in the number of digital recorders in use; 414 stations (52%) being equipped with digital recorders in 1981 (397 or 51% in 1980). The number of Foxboro stations (circular chart recorders) has increased slightly to 229 (212 in 1980), while other chart recorders decreased to 154. Recording raingauge stations now number 282 (276 in 1980) and groundwater recording stations increased to 117 (85 in 1980).

2. Missing Record Survey

A missing record survey of 387 Ministry of Works and Development operated water-level recorder stations covering the period 1/7/78–30/6/80 (232 229 days of record) showed only 7300 days or 3.1 percent of missing record. All Ministry of Works and Development districts had less than 3 percent missing record, except

Napier which had 6.4 percent missing. For digital water level recorders 35 percent of missing records were between 0 and 5 days long, 21 percent of missing records were between 6 and 10 days long, and in total 78 percent of missing records were less than 20 days duration. Significantly, there was no peak in the distribution of missing records around 30 days which is the normal period for change of recorder tapes.

For automatic raingauges the situation is less satisfactory. For 117 Ministry of Works and Development rainfall recorders there were 4745 days of missing record from 60 308 days of record, i.e., 7.9 percent were missing. A computer program (TORRENT) is being tested as a tool to calculate a synthetic record for the part of a record which is missing.

3. Technical Information on Hydrology

A report was prepared and distributed with information on commercially available winches for slackline cableways, a summary of some potential accident situations in hydrology (with comments on avoidance or prevention), and vertical angles in stream gauging and a metric air-line correction table.

A draft flow map of New Zealand was prepared and circulated. It is at a scale of 1:2 000 000 and marked with mean flows at 50 major river sites and "ensemble" monthly means at 8 of these sites. Many catchment authorities have responded with notes on the data that were used, the presentation and other information which could be added to the map.

4. GOES Satellite System

Satellite relay Data Collection Platforms (DCP) are installed on the Hurunui River, North Canterbury to test the feasibility of the GOES satellite system as an alternative to a VHF telemetry system. Whilst the platforms appeared to be operating satisfactorily no data were received for some months due to failure of the Datel link between the New Zealand Meteorological Service, Wellington and the GOES Computer in Maryland, USA. The Meteorological Service revised their Datel computer program and the system is operational. However, further problems occurred with the DCP when the aerial was damaged by wind. This has been repaired and the system's suitability is being assessed.

5. Electronic Water-Level Recorder

A recorder with a pressure transducer and a magnetic memory is being developed to replace recorders which have a float in a stilling well and record the float's level on a punched tape. A transducer evaluation board has been built to test pressure transducer probes for their warm-up time, repeatability and temperature dependence. Experiments have shown that the pressure transducers can be compensated to the required accuracy of 1 part in 10 000.

6. Instrument Service Centre

R. A. Moore (Group Leader)

During the year, the Centre has continued to service instruments for the Water and Soil Division, catchment authorities and others. Servicing included 1054 instruments for Ministry of Works and Development, 708 for catchment authorities, 84 traffic counters for Roading Division, Ministry of Works and Development and 110 instruments for other agencies. In addition to servicing instruments, the following work has been carried out:

(a) A prototype small bore point sampler for use by the Water Quality Section at the Science Centre for well sampling has been manufactured and is undergoing field tests.

(b) Production of solid state timers, 30 event rainfall recorders, battery chargers and dischargers.

(c) Tests in both Northland and Southland to further improve the power supply of recorders by using solar panels to charge batteries in the field. These tests have proved most successful and will be extended.

(d) A Manning water sampler coupled to a Fischer and Porter event water-level recorder has been developed which, in response to predetermined increments of water level change, activates the sampler via its flow input mode, and records the stage and time when each sample is taken.

(e) The construction of a system for automatically monitoring the turbidity of water in the Oakden canal at the head of Lake Coleridge. A continually pumped sample from the canal water is passed through a Hach falling stream turbidimeter in which light transmitted through the sample can be measured to denote the turbidity measured. A Leupold and Stevens 7001 digital recorder every 15 minutes triggers a light to be turned on in the turbidimeter. The light goes through the water on to a photo-electric cell the output of which is punched into the recorder's tape. The turbidity measurements are field rated by normal suspended sediment gauging techniques.

ENVIRONMENTAL HYDROLOGY

M. P. Mosley (Group Leader), MA, MSc, PhD

This is a newly formed group whose principal work is to study the form and behaviour of river channels and the interaction of channels with their catchments with the objective of defining how the character of a river will change in response to the activities of man (e.g., by changes in flow regimes from dams or diversions) or natural events (e.g., flood damage to riparian lands).

1. Characterisation of River Channels

A procedure has been adopted for characterising river channels in terms of their hydrology, geomorphology, sediment, vegetation, and general environment, along with a manual of procedures for data collection. It will provide catchment authority and Ministry of Works and Development district staff with a standardised method for collecting the data needed for describing rivers for purposes of environmental impact assessment, and ultimately for predicting river response to changes in hydrologic regime. The procedure relies heavily upon survey of cross-sections, measurement of water depth and velocity by current meter, and sampling of bed sediment material by the "Wolman method". The Wolman method entails the random collection from within each selected sub-environment of 60–70 particles and estimation of the size of each particle by comparing it with square holes cut in an aluminium or plywood plate which have the same dimensions as the mesh of a set of sieves. A 5-page form has been designed which, when completed in the field, provides a semi-quantitative picture of the survey reach's appearance. In addition, methods have been developed for characterising such factors as cover for fish and the attributes of aquatic sub-environments such as riffles and pools.

Sites suitable for inclusion in the classification phase of the project have been selected, and district hydrology groups asked to commence data collection. A project on the Rakaia River, in conjunction with the Fisheries Research Division of the Ministry of Agriculture and Fisheries and the Christchurch District Hydrology Group, has surveyed the largest river selected. Field work on the Hurunui River has also been completed. The data for the Hurunui River and for 2 reaches of the Ashley River have been analysed.

Data are currently being collected by staff of Ministry of Works and Development district offices, using a simplified version of the characterisation procedure mentioned above. The project is being supported by the Fisheries Research Division, who see its results as providing a means of extrapolating data from a given river to other rivers with similar character. Two hundred and eight sites which have adequate hydrological data have been selected and these should cover a sufficient range of river regimes to give a reliable statistical base on which to classify the selected river channels. Some modification to the procedures and sites selected is expected as results are analysed from the data sent in.

2. Water Temperature Regimes

Water temperature measurements made at 233 water-level recorder sites throughout the country have been analysed and the temperature regime throughout the year at each site has been defined by fitting a sine curve to the data. The parameters of the sine curves have then been related to easily measured catchment characteristics (elevation, latitude, etc.) to provide a simple method of prediction for sites at which no data are available. There is a wide diversity of temperature regimes, but, although some sites are clearly distinctive (e.g., Hooker River, a glacial melt-water stream, and several sites around Lake Rotorua, which are spring-fed), there seems to be some possibility of predicting regime from simply measured physical variables. For example, mean annual temperature ($\bar{x}$) may be predicted by the equation

$$\bar{x} = 43.1 - 0.517 \text{ latitude} - 3.82 \log \text{mean catchment elevation}$$

3. Ohau River Study

The shallow waterflow project of the Hydrosystems Group included field surveys on the Ohau River and the Environmental Hydrology Group participated in these surveys. A study of the data has shown how aspects of the aquatic environment in a braided river change with discharge and represents a first step towards an ability to predict changes in braided river character due to flow manipulation. During January 1981 the New Zealand Electricity Division varied the discharge down the Ohau River at the request of the Ministry of Works and Development thus permitting data collection at discharges of 500, 250, 100,

57 and 27 m³/s. Surveys of 8 cross-sections were carried out, and measurements of depths and velocity were made at each flow along as many cross-sections as time permitted. New methods of presenting hydraulic data were developed (Fig. 18) which effectively show the changing character of a braided river with changing discharge. The results indicate that, for all life stages of the salmonid species present, the lowest discharges

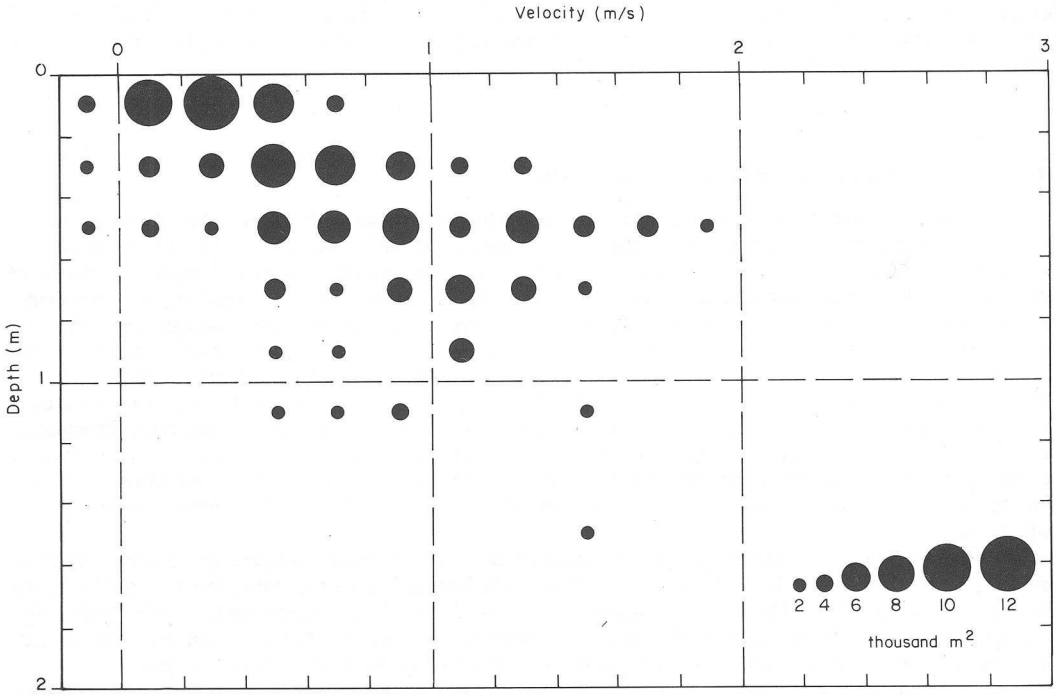

Fig. 18 Distribution of water surface area in the Ohau River study reach by depth-velocity class for a discharge of 56.7 m³/s. For each class, the area of the circle is proportional to the water surface area in that class in m² per kilometre of channel. The far left column is for areas with still water (velocity = 0 m²/s).

that naturally occur in the river provide optimum usable area, but that the area suitable for fish passage shows a surprisingly high degree of stability (Fig. 19). This is because, as discharge increases and existing channels become wider, faster and deeper, additional channels are created whose characteristics are similar to those of the earlier channels.

The opportunity was also taken to use the controlled flow of the Ohau River to extend some earlier flume experimental work on scour at branch channel confluences. Measurements of the dimensions of holes scoured at selected confluences in the Ohau and the discharges of the confluent channels tended to confirm the experimental flume results, although the diverse form of the confluences introduced a degree of variability not present in the flume. There appears to be a simple relation between relative scour depth in a branch channel confluence and combined discharge (for confluences where confluent channels are of roughly equal size); the relation in Fig. 20 passes precisely through the experimental flume data, and therefore seems reliable over 7 orders of magnitude. Since observations in the Ohau indicate that branch channel confluences are the location of deepest bed scour anywhere on the river bed, the relation in Fig. 20 may, when further tested, provide a simpler means of predicting bed scour in braided rivers than is given by the Ministry of Works and Development Civil Division's Publication CDP 705/B—"Code of Practice for the Design of Bridge Waterways".

4. Other Work

Development of a methodology for assessing the impact of river control works on the river environment (channels plus riparian and berm lands) has been proposed for the 1982/83 programme. Staff of the Ministry of Works and Development and the North Canterbury (NCCB), South Canterbury, Nelson and Marlborough Catchment Boards have shown interest in such a project. Preliminary survey work has begun on the Waimakariri River, where it will be of benefit to NCCB. This project is seen to be important as a means by which wildlife aspects of the river environment may be incorporated in river management schemes.

A study of erosion along a forest road system in granitic terrain (Motueka State Forest) is being undertaken with New Zealand Forest Service co-operation. Detailed survey work at the field site near Motueka was carried out in September and results are being collated. Most of the active erosion sites occurred along the cutslopes, water tables and culvert outfalls.

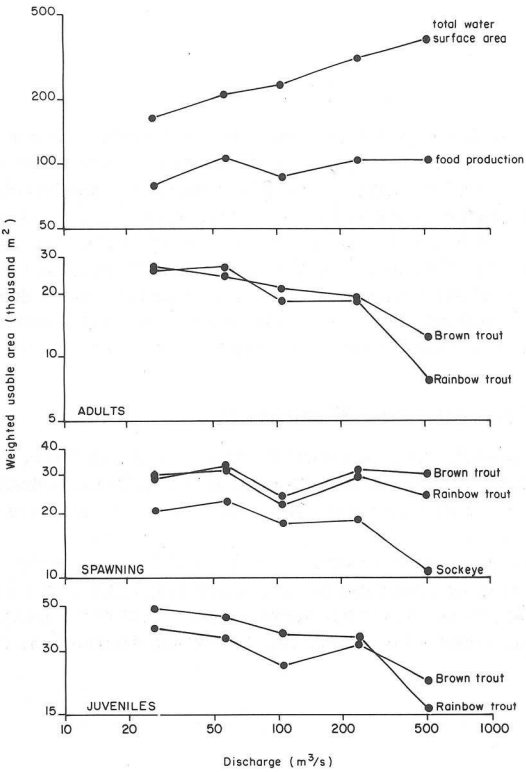

Fig. 19 Weighted usable areas per kilometre of channel computed for the Ohau River study reach for flows between 26.5 and 507 m³/s.

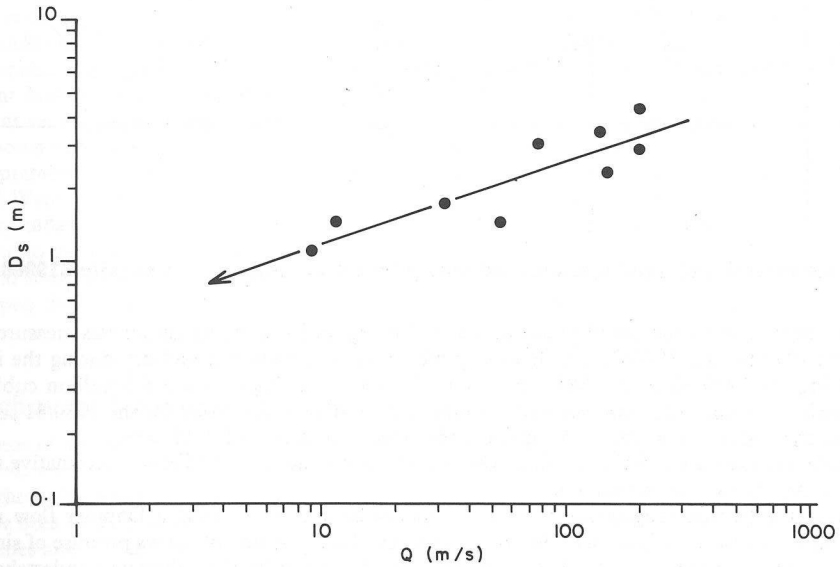

Fig. 20 Relation between scour depth in confluence (Ds) and combined discharge (Q). Regression line Ds = 0.531 $Q^{0.343}$ fitted by least squares.

GROUNDWATER

H. R. Thorpe (Group Leader), BSc, ME, PhD (Aberd)
R. J. Burden, MSc
A. D. Fenemor, BE Agr, MS (Ohio State)
D. M. Scott, ME Agr
P. A. White, BSc (Hons)

The objectives of the Group's work are to develop and apply techniques for studying and evaluating the groundwater resource. To this end the Group's work programme includes the introduction of new practices and techniques such as down-hole logging and groundwater tracing, surveys and hydrological interpretation of groundwater systems including mapping hydrogeological structures, analysis of pressures and flows and computer archiving of well data, and studies of the entry and migration of contaminants in aquifers. Furthermore, because the Group's activities are primarily directed toward improving the management and utilisation of groundwater resources, the studies often are concluded with mathematical models of aquifer systems. The Group also has a close involvement with catchment authorities who are endeavouring to establish as rapidly as possible their own expertise for assessing groundwater resources.

1. Ashburton—Rakaia Groundwater Resources

The objective of this study is to quantify the groundwater resource in this area and to gain an understanding of the physical nature of the aquifers. This will provide information of benefit to the designers of an irrigation scheme proposed in the area, and to the local regional water board who have the responsibility of managing the resource.

Field work has been completed. A steady state single aquifer model for the region has been calibrated such that the maximum error between observed and model calculated heads is about 2 m (Fig. 21). Several other modelling approaches are being tested and further improvement in calibration is expected. One approach has leakage zones that allow for some connection between the shallow and deep aquifers in the region adjacent to the Rakaia River.

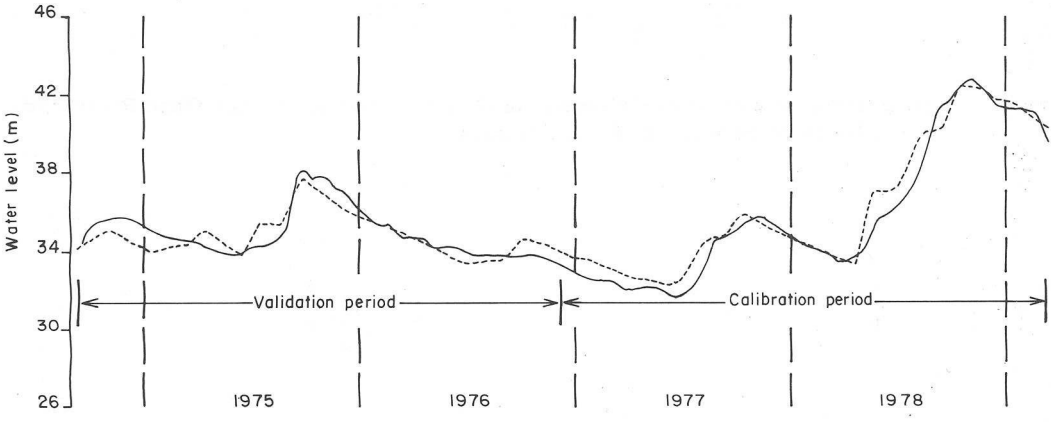

Fig. 21 Observed and model simulated water levels at Charing Cross (site 3199001).

As part of the field work the use of groundwater in this region for spray irrigation was measured during the 2 seasons 1979/80 and 1980/81 which were respectively unusually wet and dry during the irrigation season. During the 1979/80 season 587 mm of rain fell and 92 irrigators used 8.3 million cubic metres of water which represents a seasonal abstraction rate of 0.45 m^3/s. The rainfall for the 1980/81 season was 306 mm and the water usage was 26.6 million cubic metres at a rate of 1.45 m^3/s.

Based upon the field data and the finally developed computer model, the effects of alternative irrigation development options will be simulated.

In association with this programme the Group calibrated and field tested a Doppler flow meter for measuring pipe flow rates without breaking into pipelines. This instrument shows promise of simplifying and speeding up such measurements. Advice on, and general oversight of, drilling was undertaken for the Irrigation Section, Ministry of Works and Development, Christchurch, in search of supplementary irrigation water in the Eiffelton area of mid Canterbury.

2. Waimea Plains

The Nelson Regional Water Board has completed TIDEDA computer storage of the lower confined aquifer water use survey data. The Group's interpretation of the data and its extrapolation to the other aquifers of the system have been discussed with Board staff and development of a mathematical model of the system has commenced.

A simulation study suggests that introduction of the proposed Waimea East irrigation scheme will increase nitrate-N concentrations in Richmond Borough water supply by about 16 percent. This predicted rise is a relatively minor addition to a potentially serious problem of nitrate contamination. Nitrate-N concentrations at present exceed 10 g/m^3 in large regions of all the major Waimea aquifers and range up to 42 g/m^3. Local authorities need to be aware of this as a potential threat to public health and may need to give consideration to providing an alternative water supply.

A high precision thermister borrowed from Victoria University of Wellington was calibrated and field tested. Temperature profiling of bores on the Waimea and Motueka Plains has been done to identify aquifers and establish vertical rates of leakage between aquifers. One further bore in Christchurch has also been logged. Based on this work, a project proposal for a more systematic research programme is in preparation.

Earth resistivity measurements at the top of the estuary have identified layers of only slightly brackish water beneath the very saline surface layer. Further work is in progress.

3. Groundwater Archive (WELLARC)

To provide for efficient storage, retrieval and analysis of well data, a groundwater archive (compatible with, and complementary to, the national "water level" archive (TIDEDA) and other appropriate archives) is being developed. It will be designed to operate on regional water board micro-computers. Storage will be of a standard form for easy retrieval and manipulation in national and regional aquifer management and research. There are separate programs for data entry, editing and retrieval. A listing of WELLARC and disc copy of the programs in IBM format were sent to Waikato Valley Authority for them to assess the difficulty in translating WELLARC to DEC-BASIC for their PDP 1123 computer.

A set of well log codes has been adopted which consist of 24 stratal composition codes defined in the categories, Unconsolidated Sediments, Consolidated Sediments and Volcanics, to be preceded for any one stratum by up to 6 descriptor codes from a list of 39. The latter include descriptions of colour, volcanic rock type, permeability, hardness, weathering, angularity, inclusions and stratal mixtures. The well log codes have been developed for computer storage of historic logs rather than for use by drillers in the field.

4. Geophysical Methods

Geophysical downhole logging equipment is being evaluated. The equipment has been used in the field for the Auckland Regional Authority on their investigations of non-alluvial volcanic lithology. A geophysical survey capability which includes both downhole and earth resistivity services is being made available to catchment boards on a charge-out basis. Using a Hewlett Packard micro-computer and accessories, a permanent record of logged data is kept on a floppy disc and from this the logged data can be replotted to any chosen vertical and horizontal scale. This is of considerable assistance for interlog comparison during the interpretation process and useful for report preparation. One deep hole has been logged for the Hauraki Regional Water Board at Ngatea. Resistivity soundings in the Rakaia area have been done, where good logs exist, in order to gauge the capability of this method in alluvial gravels. Resistivity traversing has also been done to assist in well location; initial results are interesting but inconclusive and it is intended to return and complete a more extensive traverse. Resistivity field work for the Nelson Regional Water Board has mapped the salt water/fresh water interface at the lower end of the Waimea Plains.

5. Catchment Authority Liaison

A system of liaison between the Groundwater Group members and regional water boards has been established, with each group member being a contact person for 4 boards. Problems raised by boards are directed through the contact to whichever member in the group has the particular expertise. In this connection visits have been made to Hauraki, Bay of Plenty and Wairarapa Regional Water Boards to discuss groundwater programmes and specific local problems such as freezing works and dairy factory effluent disposal; to the Marlborough Regional Water Board to discuss their general groundwater programme and their preparation of a submission for funds; and to the Taranaki Catchment Commission to advise on a wastewater disposal monitoring system for the ammonia-urea plant at Kapuni.

6. Other Work

A new thermistor head has been calibrated by the Industrial Development Division, DSIR, and has been tested by applying a curve fitting technique to borehole temperature profiles in order to compute vertical groundwater velocities in a borehole beneath Christchurch. Pressure transducers have been evaluated for aquifer testing in conjunction with a Tasman data-logger. The main problem is obtaining satisfactory output from the logger.

Optimisation procedures (developed for raingauge networks by R. P. Ibbitt of the Hydrosystems Group) have been applied to data from groundwater level measurement sites in North Canterbury. The North Canterbury Catchment Board supplied water level records for the area between the Rakaia and Ashley Rivers. If a reduction in the number of recorders is feasible this will save considerable money for purchase of recording equipment and reduce the amount of data that the Board's staff will need to collect and analyse.

In the process of advising the Irrigation Section, Water and Soil Division, Christchurch, on well drilling and testing at Eiffelton, 3 step-drawdown tests have been done on 2 wells. A trial has been made in using high velocity water jets for well development. After thorough development, first by air lifting and then by surging, the well was step-drawdown tested. Water jetting was then tried and the well re-tested. The result was an 8 percent increase in well yield despite the fact that the water jetting equipment was makeshift. Water jetting has been used overseas but seldom in New Zealand, even though it shows distinct advantages.

The program SOLMNEQ (Solution-Mineral Equilibrium Computations), developed by Yousif Kharaka of the U.S. Geological Survey, has been tested using the Vogel computer. The program computes the equilibrium distribution of up to 162 inorganic aqueous species generally present in natural waters over the temperature range 0° to 350°C. States of reactions of the aqueous solutions with respect to 158 solid phases (minerals) are also computed. Output from the program will be useful for interpreting the natural composition of groundwater and the fate of some chemical contaminants entering groundwater.

ALPINE PROCESSES

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The series of individual projects undertaken by this Group are aimed toward developing understanding of the ways in which catchments at high altitude respond to the forces of nature and to land use. The Group also has an involvement in New Zealand's Antarctic research programme.

1. Alpine Climatology

As part of the Group's project of measuring climatic characteristics of the Southern Alps, long-term normal rainfalls have been estimated from the short-term data obtained from a transect of recording sites across the Alps from the Rakaia River. Thirty-year normals for the period 1941–1970 have been estimated by the New Zealand Meteorological Service for 22 sites within, and south-west of, the transect area; most of these sites have 30 years of record. The 12 months between March 1978 and March 1979 has the most complete record for the most sites in the transect, and rainfall for this period can be used to estimate 30-year normals for the transect, by calibration, against the 22 sites. To estimate 1941–70 rainfall normals in the high rainfall zone of the western Southern Alps the ratio P41–70: P78–79 = 0.92 ± 0.03 estimates rainfall normals over the range 900 to 6250 mm/an.

An extrapolation 100 percent beyond the calibrated range is shown on Fig. 22; the estimated 1941–70 normal rainfall for Noisy Creek (10 650 mm/an) is compared with the record of rainfall for that site over the last 5 years. The early period until March 1978 is known to have been substantially drier than normal with a marked deficiency of north-west precipitation; comparison with the estimated 1941–70 normal suggests a deficiency of about 30 percent. Since 1978, precipitation appears to have remained within ± 10 percent of normal. This pattern is consistent with that of long-term Meteorological Service sites in the surrounding regions.

The Group provided storage raingauges and advice to the Westland National Park Board who have set up rainfall transects in the Franz Josef and Fox Glacier valleys. Results from the first year of record are available for the Franz area (Table 5) and indicate that the gauges do not go far enough east to catch the 10–12 m annual rainfall zone. The Board has recently installed 3 m raingauges at Chancellor Hut and Luncheon Rock to define where the maximum rainfall zone is located on the Franz Josef Glacier. Measurements at Luncheon Rock in a storm on 3 June 1981 gave a 24-hour rainfall of 700 mm.

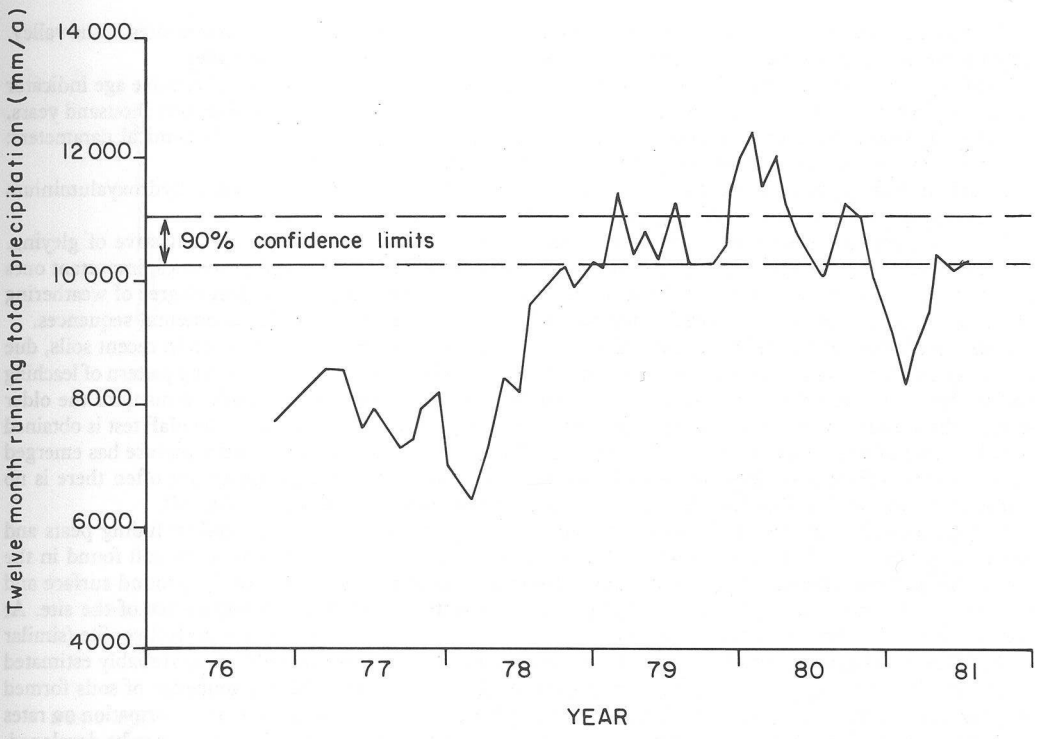

Fig. 22 **Time trend of precipitation at Noisy Creek (annual totals plot at end time). Also shown are 90% limits for an estimated 1941–70 normal.**

Table 5: Franz Josef transect: rainfall 27/6/80 to 26/6/81.

Site	Rainfall (mm)
1960 Terminal	8985
Sentinel Rock	7253
Douglas	6647
Deadmans	6307
Forks	4573

2. Cropp River

Studies of selected small and large drainage basins provide opportunities for developing and testing new techniques for erosion assessment, and for understanding the effects of various erosion processes on catchment condition. One such area is the Cropp River where the following are measured:

(a) rainfall at 4 sites (4 storage gauges throughout the catchment and 1 automatic event rainfall recorder at the hut site);
(b) river flow (3 Foxboro pressure bulb recorders and 1 Stevens water-level recorder);
(c) temperature (air temperature at 1.5 m and ground temperature at 0.5 m);
(d) wind (wind run and direction).

Investigation of geomorphology, soils and erosion has also been conducted. The landforms of the valley indicate extreme fluvial and mass movement modification of a formerly glaciated valley. In simple terms, with increasing age of the landscape (from headwater cirque to valley outlet and from valley bottom to ridge crest) the degree of modification increases. Over the lower (i.e., downstream) part of the valley and high on the valley walls, most ground surfaces are a result of fluvial dissection or mass movement processes. Consequently many of the soils are young. However, remnants of ground surfaces of assumed glacial origin are present and their greater age is reflected by the more developed soils present on them. Within the headwaters of the valley the ground surfaces have been formed dominantly by glacial activity with some post-glacial fluvial and mass movement modification. A good record of deglaciation and post-glacial erosional modification of the valley is preserved in the headwaters of the valley. Peat samples, which upon dating

will provide minimum ages for deglaciation, have been collected from 2 widely separated sites in the valley. The dating will allow reliable estimates of the rate of fluvial dissection of the valley.

Pedologic investigations have confirmed that the soils provide an extremely useful relative age indicator in this environment for ground surfaces, ranging in age from a few tens of years to several thousand years. A test kit has been built up that allows determination in the field of several useful chemical parameters:

(a) pH (by narrow range indicator paper — pH 3.8–7.0);

(b) pH in NaF (approximated by use of the Fieldes and Perrott test for reactive hydroxyaluminium compounds) — indicative of stage of weathering;

(c) ferrous iron test (using α, α'-dipyridyl which forms a red Fe^{++} complex)—indicative of gleying.

These chemical parameters extend greatly the interpretation of morphological properties, important ones being horizon sequence, colour and colour patterns (mottles), and texture (including degree of weathering of clasts, structure and consistence). They also allow soils to be placed in developmental sequences.

Soils tested thus far have shown that pH's fall very rapidly and are low (<5.3), even in recent soils, due to the extreme leaching in this environment. The pH's in NaF have revealed an interesting pattern of leaching and weathering. Even the youngest soils show evidence of active weathering, while in many of the older soils all the aluminium has been leached right through the soil, so that no reaction to the NaF test is obtained (i.e., leaching of even the most immobile chemical elements is very strong). A similar picture has emerged from the ferrous iron test. Morphologically the older soils are very strongly gleyed yet often there is no reaction to dipyridyl, indicating that most of the iron has been leached out of the soil.

A range of soils from recent through gley recents, and gleys to gley podzols, and including peats and peaty soils, occurs within the catchment. The dominant factor controlling the types of soil found in the area is the extreme rainfall. This dominating influence is modified by the age of the ground surface and the topographic position within the landscape, which affects the drainage characteristics of the site. At one site in the headwater cirque of the valley the time necessary to develop a gley podzol profile (similar to the Okarito soils on the pakihis of the West Coast plains) in this environment will be reliably estimated from the C^{14} age of the base of a nearby peat deposit. This site, along with the sequence of soils formed on progressively younger ground surfaces below it, will provide extremely interesting information on rates and pathways of soil formation in an extreme environment, and allow a model of soil genesis to be developed.

The types of erosion processes affecting the valley walls have been examined. Fluvial erosion by both confined and unconfined flow is evident throughout the catchment, including areas that have a lush vegetation cover that hides any sign of active erosion. Rills, gullies and large bare areas are indicative of this type of erosion. Mass movement processes including rock falls, debris avalanches, and soil creep (often at a rate fast enough to disrupt the ground surface) are also common. Much of the sediment carried by the river would appear to be derived from active present-day processes rather than from reworking of material held in storage (as in many eastern South Island rivers).

3. Rock Avalanches in the Central Southern Alps

Forty-six large rock avalanches have been identified in the central Southern Alps (Fig. 23). These occur mainly in the eastern Southern Alps in well indurated sandstone and mudstone of the Torlesse Group. Commonly, the avalanches form large hummocky deposits in valley floors.

Transverse ridges are common and longitudinal ridges or grooves may be present. Where not confined by local topography the deposits have lobate form. These features are indicative of high speed and complex fluid-like flow, characteristic of rock avalanches. On aerial photographs the deposits may resemble moraine but can be distinguished from these by their asymmetric down-valley form, by indications that the deposit swashed up valley sides, and by the presence of a scar on the mountainside above the deposit. River gradients are commonly low above the deposit with marked aggradation, while deeply incised gorges may occur below or through the deposit. Rock avalanches may also impound lakes.

Rock avalanche deposits commonly contain crushed rock of all sizes within a 'matrix' of fault-gouge-like material. Boulders are angular and usually very fractured, sometimes loosely fitting together as in a jigsaw puzzle so that bedding continues from boulder to boulder. Coherent, though highly fractured, bedded blocks of up to 10 m × 20 m × 20 m may be present. Trains of boulders of identical rock types from the break up of original bedding in the source may be visible across the deposit.

The schist terrain of the western Southern Alps does not appear to fail as rock avalanches. Much smaller debris avalanches and debris slides, usually associated with high intensity rainstorms, are common and whole mountainsides sometimes fail as very large but very slow landslides.

Weathering-rind thickness, radiometric dating and historical records indicate that over half of the dated avalanches are less than 2000 years old. This is most likely a function of the ease of identifying young avalanches on aerial photos, rather than a recent increase in avalanche frequency. With time, deposits become subdued, buried or removed entirely. The record of the last 2000 years indicates that at least 10 major rock avalanches occur every 1000 years, and that 1 to 3 of these have volumes in excess of 25×10^6 m^3.

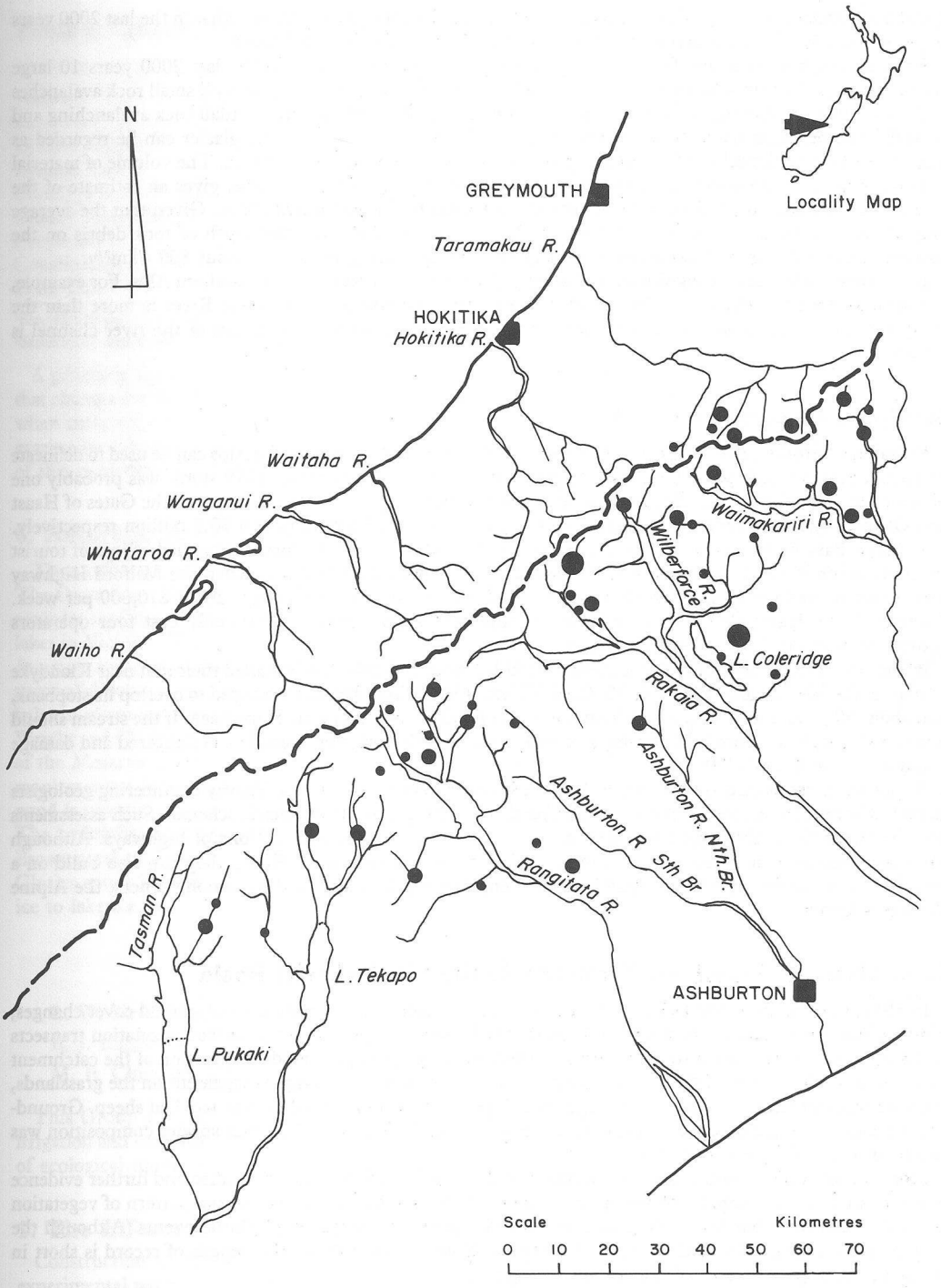

Fig. 23 Location of large rock avalanches in the central Southern Alps.

Large rock avalanches are probably triggered by large earthquakes which implies that in the last 2000 years large earthquakes have occurred in the area at least once every 100–200 years.

Rock avalanching is a significant slope process in the Southern Alps. In the last 2000 years 10 large rock avalanches have moved about 1×10^9 m³ of material, equivalent to 100t/km²/yr; small rock avalanches and rock falls probably move a similar amount. A crude estimate of the rate of small rock avalanching and rock fall can be made using flow measurements of the Tasman Glacier. The glacier can be regarded as a conveyor belt, with rocks falling on to it to be transported on or near the surface. The volume of material passing through a cross-section in the ablation zone, in a given period of time, gives an estimate of the rate of rock avalanching and falling from the ice-free areas of the catchment above. Given that the average annual velocity for a 2000 m wide section at Ball Hut is 54 m/yr, that the depth of rock debris on the surface is about 0.5 m and assuming a density of 1.5 t/m³, this gives a rate about 800 t/km²/yr.

Large rock avalanches are significant sediment sources for major rivers in the Southern Alps. For example, the average annual yield of 36 000 t eroded from a rock avalanche in the Jollie River is more than the measured annual suspended sediment yield of the river, and massive aggradation of the river channel is apparent.

4. Alpine Hazards and Risks

Research on erosion, hydrological and climatological processes operating in the Alps can be used to delineate physical hazards which place both life and property at risk. The December 1979 storm was probably one of the most damaging recent climatic events in the Southern Alps. Bridges and roads in the Gates of Haast and Otira Gorge were severely damaged, with repairs costing $2.5 million and $0.5 million respectively. The Haast Pass Road was closed for over a month, but while tour operators complained of loss of tourist revenue, no estimate of the amount was made. In 1976 it was estimated that when the Milford Highway was closed by avalanche, the cost to the tourist industry in loss of revenue was about $10,000 per week. Closing of the Haast Pass at the peak of the summer tourist season undoubtedly cost tour operators considerably more than $10,000 per week.

In the same December storm, 4 trampers were killed when a debris flow engulfed their tent near Klondyke Corner in the Waimakariri River. At Mt Cook Village, Black Birch Stream threatened to overtop its stopbank, and about 60 people were evacuated from houses on Black Birch Fan to the Hermitage. If the stream should overtop its stopbank, about 25 houses, a school and a MWD workshop would be endangered and damage could easily be $1,000,000.

At present most hazard assessment in the Alps is carried out by Geological Survey engineering geologists as part of investigations for *specific* structures, particularly proposed hydro-electric schemes. Such assessments are also made for other large construction projects such as bridges and sections of highways. Although these assessments usually require extensive field work and often some drilling, they can also build on a wealth of geomorphic, geologic, hydrologic and engineering data acquired by, among others, the Alpine Processes Group.

5. Analysis of Grassland Transects in the Waimakariri Basin

In 1947, in response to the lack of quantitative data on vegetation composition and ground-cover changes, North Canterbury Catchment Board staff established a series of permanently marked vegetation transects and fenced enclosure plots through montane, subalpine and alpine grasslands of a section of the catchment of the Waimakariri River. Of particular interest were the effects of grazing management on the grasslands, thus the transect sites were located on vegetated slopes customarily grazed by fine-woolled sheep. Ground-cover records (using a point sampler) were collected annually from 1947 to 1963; species composition was recorded at less frequent intervals.

More recently, discussion about the condition of these grasslands has been rekindled and further evidence has indicated that the imprint of European man on the erosion states and the general pattern of vegetation cover of these lands has been minor in relation to longer-term natural and cultural events. Although the 17-year record of the North Canterbury Catchment Board is substantial, this length of record is short in terms of the apparent rates of change in this terrain.

In 1980, Science Centre and North Canterbury Catchment Board staff relocated and resurveyed 7 of the transects. They were revisited in 1981. Seven hundred and fifty thousand individual ground-cover records have been summarised and some initial analysis has been completed. From 1947 to 1953, the percentage vegetation cover appeared to decline on most transects, but no clear longer-term trend emerged. The significance of the long-term changes in vegetation cover was tested by linear regression analysis. One transect showed a significant linear decrease in living vegetation cover from 1947–1963, while from 1947–1981, one showed an increase and another a decrease (Table 6). In all cases the change is slight and no widespread clear trend is apparent. This result is supported by comparison of oblique "landscape" photograph pairs taken in 1948 and 1981 which featured the slopes containing the transects.

Table 6: Linear regression of percentage living vegetation cover (V) with time (t)

Transect	Linear regression equations	
	1947–1963	1947–1981
Lyndon Upper	$V = -0.36\ (\pm 0.22)\ t + 35$	$^1V = -0.15\ (\pm 0.07)\ t + 34$
Lyndon Lower	$V = -0.17\ (\pm 0.3)\ t + 73$	$V = -0.05\ (\pm 0.17)\ t + 72$
Cloudy Knoll Middle	$V = -0.17\ (\pm 0.18)\ t + 52$	$V = 0.0\ (\pm 0.08)\ t + 51$
Cloudy Knoll South	$V = -0.17\ (\pm 0.14)\ t + 43$	$^2V = 0.19\ (\pm 0.06)\ t + 43$
Purple Hill	$^1V = -0.32\ (\pm 0.1)\ t + 31$	$V = -0.04\ (\pm 0.01)\ t + 29$
Constitution	$V = -0.07\ (\pm 0.19)\ t + 46$	$V = 0.15\ (\pm 0.1)\ t + 45$
Leith Hill	$V = -0.05\ (\pm 0.22)\ t + 35$	$V = -0.13\ (\pm 0.1)\ t + 36$

[1]Statistically significant negative gradient (at the 90% level)
[2]Statistically significant positive gradient (at the 90% level)

A generally significant correlation of percentage cover changes, year by year, between transects suggests that changes are non-random, but causes for change have yet to be investigated. Species composition records, when analysed, may help characterise trends in the grasslands. Two of the transects have been retired from grazing by domestic stock and continued monitoring of these transects is important to determine the effects of this conservation management.

6. Antarctic Research Programme

The monitoring programme carried out over past seasons in the Dry Valleys area was continued in 1980–81. The Onyx River flows at the Lower Wright and Vanda weir sites were measured. Automatic water-level recorder readings were taken at Lake Vanda together with ice thickness and ablation. Levels of 9 enclosed lakes in Victoria, Wright and Taylor Valleys were measured at both the beginning and end of the season. Attempts made on all lakes to drill through the ice cover to gain early season water levels were only partially successful because a number of the lakes appeared to be frozen completely through to the lake bed. Mass balance measurements were continued on the Heimdall and the Lower Wright Glaciers and the Upper Wright and Clarke Glaciers were subjected to comparative ablation measurements. Recession measurements of the Meserve Glacier snout were also made. A water-level recorder was installed at Don Juan pond to monitor water-level fluctuations from the beginning of the summer season and throughout the winter. This pond is unusual in that its high salinity content normally prevents freezing during the winter, at −57 °C. The hydraulic geometry of the Onyx River was measured at 10 selected sites along its course from Lake Brownworth to Lake Vanda. Where the Lower Wright Glacier enters Lake Brownworth, and the Taylor Glacier enters Lake Bonney, ice samples were taken to determine the location of the transition from glacier ice to lake ice.

WATER QUALITY

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M. E. Close, BSc (Hons)

This Group's research programme is directed towards 2 main interest areas: to examine the effects of irrigation and land disposal of effluents and wastes on groundwater quality, and to develop and apply methods of ecological monitoring in rivers.

1. The Effects of Septic Tank Systems on Groundwater Quality

Construction of the research facility at Burnham (near Christchurch) was completed. To date, the experimental work has aimed to establish the chemical and microbial signature for septic tank effluent in groundwater. This has involved monitoring the array of experimental wells for nitrogen species (TKN, NH_4^+, NO_3^- and NO_2^-), phosphate species (total and dissolved P, soluble P), chloride, conductivity, pH, potassium, sodium, dissolved oxygen and BOD, as well as the usual microbial indicators of faecal contamination in groundwater (coliforms, faecal coliforms, faecal streptococci and *Clostridium perfringens*).

Because household detergents (anionic surfactants) may characterise household wastes, a number of analytical methods to detect them were considered. The chloroform extraction/methylene blue active substances (MBAS) technique was selected but, because interferences were a problem with this method, background levels of MBAS or MBAS-reacting substances in the groundwater had to be established. Faecal streptococci may also characterise household wastes. Some authors have reported that certain streptococcal

species are found only in the human gut. However, the biochemical characterisation of these species is time consuming and could not be undertaken concurrently with other microbial analyses. Accordingly, long-term storage methods were examined to allow the identification of a randomly selected sample of faecal streptococci after the completion of the site work.

A number of washing powder components may be used to trace domestic waste. Unfortunately borax is no longer used in most washing powders. A sample of Hiltamine Arctic White, the fluorescor used in many washing powders was obtained and its peak excitation and emission wavelengths were determined to be 360 and 440 nm respectively. Preliminary results from fluorometric analysis of the septic tank effluent and contaminated groundwater at the Burnham site indicated that fluorescors and other fluorescent substances in domestic effluent may have some potential as tracers. Sodium tripolyphosphate is present in almost all washing powders and may also have potential as a tracer. A chromatographic method for isolation of this particular phosphate species is under investigation.

Having established background groundwater quality levels, effluent application to the boulder pit at the experimental site commenced. The first phase of the sampling programme involved studying the effects of boulder pit leachate on the surrounding ring of 6 shallow (10.5 m) wells in the unconfined groundwater layer. That boulder pit leachate had reached 2 of the 6 wells was shown by increases in indicator bacteria, NH_4^+, TKN, TP, and DRP. There also appears to be a trend towards higher methylene blue active substances levels in the contaminated wells.

2. The Effects of the Waiau Plains Border Dyked Irrigation Scheme on Groundwater Quality

The first stages of the irrigation scheme were commissioned in December 1980 and the collection of samples on a monthly basis from the 5 lysimeter sites was commenced. Placing interpretations to the data is premature at this time.

Two new investigation wells were drilled in the study area. A series of chambers will be inserted in these wells to prevent vertical water movement and to enable monitoring of changes in water quality over the top 20 m of groundwater.

3. The Effects of the Proposed Upper Clutha Valley Irrigation Scheme on Ground and Surface Water Quality

A sampling programme involving approximately 25 groundwater sites in the valley was completed in June. Groundwater concentrations of HCO_3^-, Na^+, Ca^{++}, K^+, Mg^{++} and Cl^- appear to be higher in the southern end of the valley where there is a preponderance of saline soils and where the climate is classified as "semi-arid". A desk evaluation of the probable effects of irrigation on salt leaching from the solonetzic soils in the valley has indicated that the effects on river water quality from salt leaching would be minimal.

4. Upper Clutha Valley Biological Studies

A 2-week 1980–81 summer sampling programme was carried out in the Upper Clutha River and major tributaries. The invertebrates appeared to be considerably more abundant, at least in the tributaries, than in the February 1980 samples. Aquatic weed distribution in Lake Roxburgh was also surveyed. This showed that the number of beds of *Lagarosiphon* has increased since the July 1980 survey. Substantial areas of the littoral zone have been colonised since the lake was last lowered for weed control in 1974. Secchi disc observations, measurements of suspended solids concentrations, and determination of the lower growth limit of *Lagarosiphon* were made at successive intervals along the lake. The extent of weed growth currently appears to be limited by turbidity.

A winter sampling programme was carried out in the Clutha River and the benthic invertebrate samples are still being sorted. Flow in the Hawea River was too high for it to be sampled. Die-back of the weed species *Ranunculus fluitans* in some backwaters of the river was noted. In contrast, the weeds *Elodea canadensis* and *Lagarosiphon major* appeared to be actively growing. Invertebrate density appears to be similar to the summer samplings, in contrast to results from Northern Hemisphere rivers. In Lake Roxburgh *Lagarosiphon major* beds appear to have increased in extent over the autumn-winter period. The likely effects of increasing lake water clarity on weed distribution are being assessed and will assist in predicting weed distribution in the Kawarau and lower arm of Lake Dunstan.

5. Laboratory

The first stage of the development work for the Group's autoanalytical facilities has been completed. The auto-analyser consists of a Technicon carousel sampler, a Technicon and ChemLab 3-channel colorimeter linked to chart recorders.

The system is now in use for dissolved reactive P, total P, $NO_3^- - N$, total Kjeldahl nitrogen and SiO_2 but further development work is required for $NH_4^+ - N$ analyses. The total P automated method has resulted in increased accuracy over the previously used manual method and has also considerably enhanced sample throughput. A dialysis block has been incorporated into the nitrate manifold to enable measurement of $NO_3^- - N$ in the 1–10 g/m³ range, the range frequently encountered in groundwater samples. For optimum efficiency Cl^-, $NO_2^- - N$ and some low level $NO_3^- - N$ analyses will continue to be manually performed.

LAND RESOURCES AND PLANT MATERIALS

Land Resources

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Plant Materials

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There are two land resource projects which are based at Christchurch: New Zealand Land Resource Inventory computer storage and retrieval, and investigation of the relationships between landforms and erosion processes. Comments on other land resources and plant materials projects on which Christchurch based staff are involved are given as part of the Aokautere review.

1. New Zealand Land Resource Inventory Computer Storage and Retrieval

Many organisations and planners are benefiting from the computerisation of land resource data for storage on the Ministry of Works and Development's computer. The national set of worksheets contain about 90 000 map units and for each map unit, boundary information (stored as New Zealand Yard Grid Co-ordinates) and 8 descriptive factors are recorded. This is too much information to be manipulated manually, thus the LADEDA (LAnd DEpendent DAta) program has been developed to enable selective extraction and display of data according to user requirements. Single factor and multi-factor summaries and correlations between factors can be prepared as tables and plots (maps).

An important and complex step in preparing data for retrieval has been the "segmenting" of map unit boundaries; a segment is a line separating 2 adjacent map units. With segmenting completed, an exact overlay programme enables the area of map units intersected by an enquiry boundary (for example, a county) to be exactly apportioned, part inside and part outside the boundary. Previously, intersected map units were entirely included or excluded, depending on the position of their "centroid". This resulted in area calculation errors. Segmenting has also enabled improved computer generated maps produced by LADEDA to be plotted. For plots prepared using less than all map fields (for example, a vegetation or a land use capability map), redundant segments are not plotted. This simplifies the plots. Although basic plots at a scale as small as 1:5 000 000 have been produced, the problem of handling undersized map units at reduced scales has yet to be resolved.

Requests for land resource data have involved a variety of "regions" and the following sample from the library of frequently used digitized "arbitrary" boundaries is some measure of the wide range of users of data: counties, united council regions, catchment authorities and major river catchments, New Zealand Forest Service conservancies and planning districts, state forest, Ministry of Agriculture and Fisheries regions, various primary industry planning areas, national parks and Pest Destruction Boards.

2. Investigation of the Relationships Between Landform and Erosion Processes

The objectives of this project are firstly to investigate the erosion processes, geological structure and slope stability in rural hill country; secondly, to develop the codes and depiction techniques for landslide field mapping; and thirdly, to develop landslide and other erosion hazard zonation maps as derivatives of the field maps.

Field work is under way in North Canterbury on farmland that is predominantly class VI hill land, but includes class III and IV rolling land. Field mapping was initially undertaken at 1:5 000 and 1:15 840 scales but has now settled on 1:25 000. This scale has been chosen as a compromise; to provide sufficient detail for mangement planning and yet allow mapping to proceed at an acceptable rate. It is anticipated that the first erosion hazard zonation map will be drawn at 1:63 360 scale.

Many slope failures in the test area are in the 'creeping' earthflow category and occur in the regoliths of severely shattered or crushed argillite and greywacke, or in flow-failing mudstones of upper Cretaceous to lower Tertiary age. Rotational slumps are comparatively rarer but occur, particularly where Tertiary or Cretaceous strata have lost support on steep slopes, by the flowage of underlying mudstones which carry bentonite clay. Regolith slides and gully erosion forms are common on muds, silt and sandstones underlying the downlands and lower hill slopes. Loess is also present on much of the downland and as veneers on older terraced alluvial deposits, but channel erosion (open gullies, tunnel gullies, or rills) appears to have developed impartially, both in recognisable loess and in colluvial mudstone regoliths.

HAMILTON

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Hamilton.

The Centre is situated in temporary accommodation both within and adjacent to the University of Waikato Campus and extensive co-operation occurs between the organisations. It is the national centre for research and survey work for the National Water and Soil Conservation Organisation to develop quantitative understanding of the processes of the water cycle as these affect the quality of water.

The Centre's work is undertaken by 21 scientists and 12 technical staff in 5 groups to investigate problems in the fields of lakes and land use, rivers, coasts and estuaries, modelling and systems, and laboratory servicing. There is also a water quality group of 3 scientists and 2 technicians located at the Christchurch Centre but with functional responsibility to Hamilton. A water resources group is located at the Centre, but has functional responsibility to the Centre at Christchurch. In association with a field party at Rotorua it is responsible for field hydrology in the Hamilton Ministry of Works and Development District.

Towards achieving the Centre's general objective of being a source of information and expertise in the field of water quality management for the National Water and Soil Conservation Organisation and regional water boards the work at the Centre is mainly concerned with:

(a) devising techniques for water quality sampling and the measurement of physical, chemical and biological parameters in both fresh and saline waters;
(b) initiating systems for the efficient handling of water quality data throughout the country;
(c) developing numerical models which can adequately quantify the interactions between natural processes of importance to water managers. Using such models, to evolve methods of predicting changes in natural water quality in response to pollution loads from point and diffuse sources. Some of the models are designed to predict the changes in water quality in response to the management of impoundments by varying conditions of flow, temperature and draw off;
(d) developing methods of measuring and predicting changes in estuarine and coastal water conditions, including beach erosion and sewage pollution.
(e) servicing district operations relating to hydrological investigations of the Christchurch Science Centre, and also of MWD Bridge Design, MWD Power Design and the Ministry of Energy;
(f) disseminating information on water quality management using papers, handbooks, manuals, seminars, workshops, etc. In this regard, the Centre runs a workshop each year on some area of its activity that has direct relevance to regional water boards. The 1981 topic was "Mixing in Rivers and Estuaries".

LAKES AND LAND USE

R. A. Hoare (Group Leader), MSc, PhD
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R. J. Pittams, MPhil
W. N. Vant, MSc (Hons)
R. B. Williamson, MSc (Hons), PhD

The Group's research has 2 overall objectives. One is to develop a quantitative understanding of how catchment characteristics and land use affect the quality of water exported from the catchment, and the other is to research and apply methodologies for defining and quantifying the processes taking place within lake systems which affect their water quality.

The first objective above is dealt with in terms of 2 different land uses; pastoral agriculture and urbanised.

The second objective initially involved the determination of the nutrient loads on Lakes Rotorua and Taupo, partly to aid those concerned with having to make decisions of immediate lake management concern but more importantly to become familiar with the problems involved and to develop suitable sampling, analytical and data handling strategies. The project work is now primarily directed towards establishing the relationships between nutrient load on a lake and the concentrations occurring in its water, the relationship between nutrient concentrations and algal growth, and the preparation of a handbook on lake water quality management.

1. Water Pollution From Urban Runoff

Water quality parameters and flow are being measured in a number of urban catchments to assess the effect of urban land use on water quality. Amongst other things, its potential for harm to aquatic organisms has been examined by measuring the concentrations of toxic metals associated with vehicle emission, wear and corrosion.

Table 7 shows the mean and range of concentrations found in runoff from a 1.1 km² residential catchment in Hillcrest, Hamilton. Concentrations of lead, zinc, and copper are high, particularly in comparison to common water quality criteria, while chromium, nickel and cadmium were mostly undetectable and were only observed on a few occasions when suspended solid concentrations were very high. The predominant sources of the metals are lead from petrol, zinc from tyres, copper from brake linings, chromium and nickel from corrosion, and cadmium as a contaminant in zinc.

Table 7: Mean and range of total concentration (mg/m³) of heavy metals in the Hillcrest Drain.

Parameter	Mean	Range	No. of samples
Lead	210[a]	1 - 2600	104
Zinc	192[a]	20 - 1820	110
Copper	60[b]	2 - 250	31
Cadmium	-	<0.5 - 3	20
Chromium	-	<3 - 40	20
Nickel	-	<2	20

a = flow weighted, b = arithmetic mean

Figure 24 shows the typical variation of lead and zinc over a storm event. Highest concentrations occur with rise in flow, especially during the beginning of a storm (first flush effect). The variation of metal

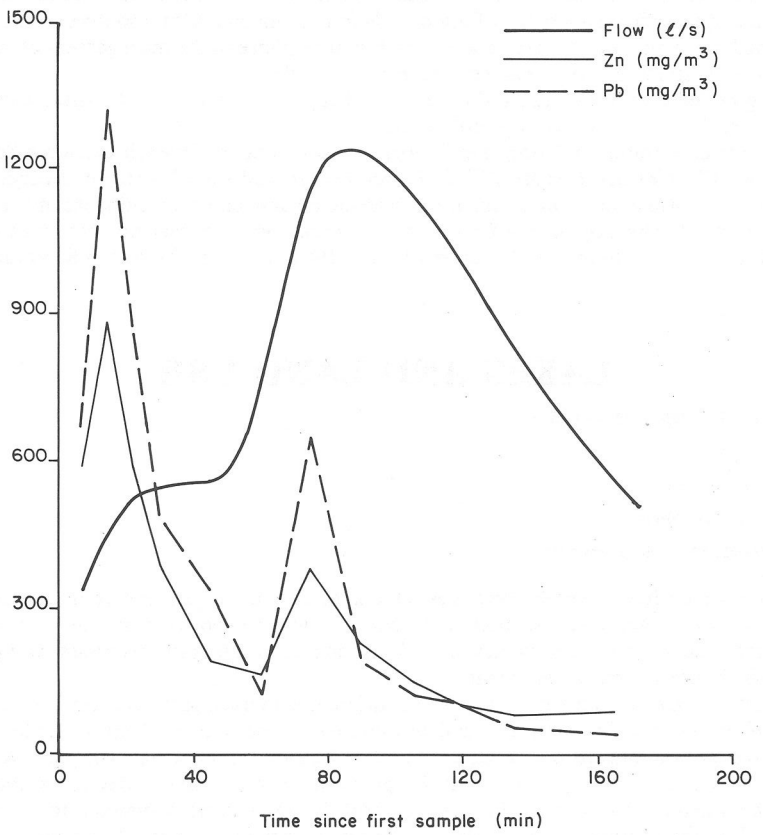

Fig. 24 Lead and zinc concentrations in the Hillcrest Drain during the storm runoff event of 1 March 1981.

concentration with flow is due to much of the metal being associated with particulates. This is demonstrated most clearly in Fig. 25, which summarises the particle size distribution of the suspended solids and the percent of the lead, zinc and copper in the different particle size fractions.

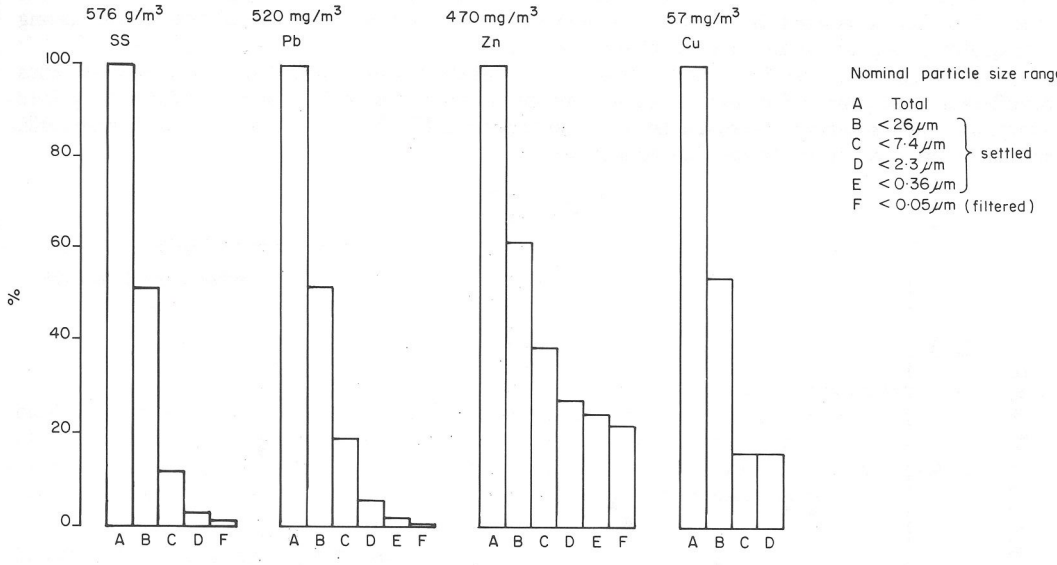

Fig. 25 Particle size distribution of suspended solids and percent of the lead, zinc and copper in the different particle size fractions.

These observations allow one to:

(a) predict lead, zinc and copper concentrations in the runoff during storms;

(b) estimate the magnitude of the increase in heavy metals associated with urbanisation, by comparison with background soil levels;

(c) make some comments on the potential toxicity of the metals in runoff.

Lead, zinc and copper in urban runoff can be predicted from suspended solids or turbidity data. Because the concentration of metals within the particulate material can be shown to be independent of particle size and seasonal factors, prediction can be made using relatively simple equations. The advantage of this is that the fate of these metals can be described from the behaviour of suspended material, measurements of which can be made using relatively simple techniques.

Comparisons of the metal concentrations in the particulates from runoff from the Hillcrest catchment with background soil concentrations show that zinc levels are much higher, copper and chromium levels are similar or slightly higher and nickel levels are lower than expected background levels. Although no data are available on lead and cadmium in the soils, it appears likely that lead would be quite low. Zinc and lead levels have been significantly increased by urbanisation.

The toxicity of metals is determined by their biological availability. Because the metal is concentrated in the particulate fraction, it is directly available only to sediment feeders. Concentrations of the dissolved phase in the water are too low to be acutely toxic to other organisms, and are likely to remain so in most receiving water situations. Examination of the macroinvertebrate fauna (e.g., insects and worms) of the Hillcrest Drain show a large population of certain species of sediment feeders, and so the metals cannot be toxic to these species. However, there is concern for the possibility that the metals can exert chronic effects either directly through the exposure of organisms to the very low concentrations in water or indirectly through the food chain. Further work on this aspect is required.

2. Nutrient Concentrations in Lakes

Some New Zealand lakes are sufficiently eutrophic that measures to improve them are being contemplated. The problem is that nitrogen and phosphorus concentrations in the lakes are too high, leading to excessive plant growth. It is necessary to improve these conditions by making changes to the loads of nutrients in the waters entering the lakes.

There are 2 factors defining the in-lake nutrient concentrations; the major one is the average concentration in the lake inflows, and the minor (but still important) one is the proportion of the load which is trapped in the lake sediments each year (usually called the retention coefficient, R). Thus lake nutrient concentration = inflow nutrient concentration (1 − R).

To design lake management plans, and to predict lake nutrient changes one needs to understand how R varies with changes in inputs of nutrient and water to the lake. Many overseas studies have dealt with this problem for phosphorus, but most suffer either from confusion in the concepts involved, or from a lack of appreciation of what information a lake manager has and what he is trying to do with it. These studies have been examined, and their data re-interpreted to show how best to use information on existing lake quality as a guide to any assessment of future lake quality.

This investigation revealed that although different workers had described R for phosphorus in terms of different mathematical functions of the outflow rate from the lake and its area or volume, they were all trying to put a straight line through data of the sort shown in Fig. 26. Little of the variation is systematic, so that different equations fit the data equally well.

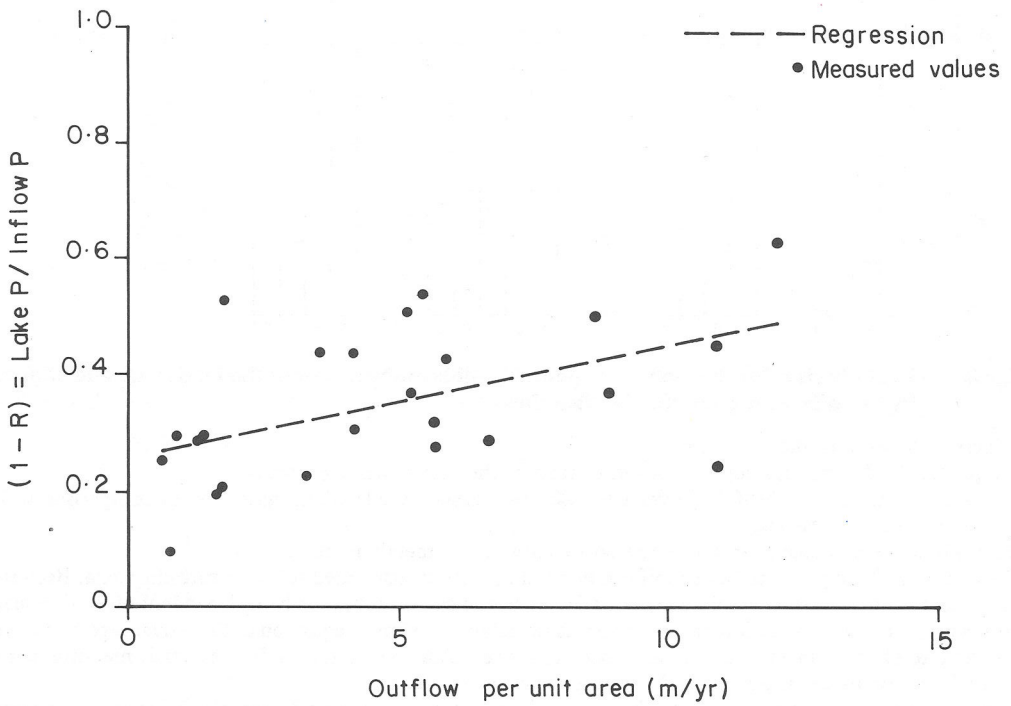

Fig. 26 Phosphorus reduction in lakes.

It is probably sufficient for most applications to realise that for phosphorus the retention coefficient is usually between 0.8 and 0.4. Direct measurements are necessary if any greater precision is needed. This coefficient appears to be independent of in-lake phosphorus concentration, to be at the high end of the range if the outflow per unit area is around 1 m/yr and to be at the low end at outflows greater than 10 m/yr. If the outflow rate per unit area is greater than 20 m/yr, then R is likely to be less than 0.4.

These concepts have been applied to the problems at Lakes Tutira and Alexandrina. For instance, at Lake Tutira the major inflow stream has been diverted. Some streams will still supply water to the lake and, as a first approximation, we can assume that they have an average phosphorus concentration the same as the diverted one, so that the effect of diversion is to decrease the flow into the lake without changing the average inflow concentration. This will decrease the outflow rate per unit area and therefore decrease $1-R$ (Fig. 26). Diverting 90 percent of the flow of the main Lake Tutira tributary would be expected to decrease $1-R$ from about 0.5 to about 0.3. So, the in-lake phosphorus concentration would drop to about 60 percent of its previous value by this effect alone. Further reduction would depend on the way the diversion actually does affect the average inflow concentration. Flood flows usually contain a higher total phosphorus (TP) concentration than base flows. The diversion means that little water input from base flow will remain, so a greater proportion of the total input of water will be flood flows after diversion, possibly leading to higher average inflow phosphorus concentrations. These could override the change in R and lead to worse water quality. On the other hand, the particulate phosphorus — a large fraction of the TP in floods — may sediment out very quickly and not contribute to algal growth. Considerations such as these mean that modelling can only go part-way to predicting likely changes to lakes resulting from management decisions.

3. Other Work

The instrumentation of a hill country pasture catchment has been completed to enable the nutrient transport processes to be studied. Improved understanding of the processes is expected to show which catchment management practices can be changed to reduce the amount of nutrients reaching streams, and where these streams enter lakes to thereby help improve lake water quality.

The Group is also obtaining information from 12 lakes, the analysis of which is expected to provide a better understanding of the relationship between nutrient concentrations in lakes and other manifestations of water quality, such as algal growth.

RIVERS

G. B. McBride (Group Leader), MSc
R. J. Davies-Colley, MSc (Hons), PhD
C. W. Hickey, MSc
R. J. Wilcock, BSc (Hons), PhD

This Group's work has the aim of developing methods for defining and quantifying the chemical and biological processes taking place within river systems which affect their water quality. The particular concern has been to enhance the present ability to predict the extent to which oxygen depletion will occur in rivers subjected to discharge of waste. Hence the main thrust of this Group's research is the study of the dissolved oxygen balance in rivers that do now, or may in the future, receive discharge of organic wastes.

1. Dissolved Oxygen Studies

The New Zealand public expects that the quality of waters in our rivers should be kept high, which means that there should be careful control on the amount of waste permitted to be discharged to them. Most of these wastes are organic in nature; the wastes arise for example from meatworks, piggeries, dairy factories, pulp and paper mills and municipal sewers. They have many effects on the physical/chemical/biological character of river waters, one of the most important being on the amount of the dissolved oxygen (DO) in the water. The DO in the river commonly decreases for some distance downstream of such discharges until reaching a minimum, after which it recovers. This depletion of DO may also be aggravated by withdrawals of water upstream from the discharge and by downstream impoundments in which, because the river water travels slowly, natural re-aeration is reduced.

Dissolved oxygen is essential to most aquatic life and is an indicator of the net condition of river waters. If DO is absent, or present in low quantities, desirable forms of aquatic life are absent and the forms that do appear are generally considered to be objectionable (they are often unsightly, and produce smells). Given this, and that DO is relatively easy to measure, it has been used both in New Zealand and overseas as a major water quality characteristic upon which decisions on the permissible level of waste discharge to a river are made.

Study has shown that New Zealand rivers tend to deoxygenate rather more rapidly than may be expected by comparison with overseas rivers. This has led to a number of projects being initiated to study some of the important in-river processes that make up the oxygen balance in New Zealand rivers. These include studies on: methods of prediction (modelling techniques); river re-aeration; and on the rate at which bacteria in the river water and on the bed and banks remove oxygen from the water when breaking down the organic material. It appears that a major cause of rapid deoxygenation in our rivers is the activity of micro-organisms on the river bed and banks.

Progress on this work up to the end of 1980 was reported at a major seminar held at the Science Centre in November 1980 (now published as Water and Soil Miscellaneous Publication No. 29) with staff of the Group being sole or joint authors of 9 papers. Work has since progressed to the point where a draft of a handbook on estimating dissolved oxygen depletion in polluted rivers has been prepared; it is aimed to publish this handbook in 1983 as a Water and Soil Miscellaneous Publication. This handbook describes how to use mathematical models to estimate DO depletion.

Figures 27–29 display some examples of the sorts of predictions that can be made using these handbook methods. Figure 27 shows the depletion of oxygen in the lower Tarawera River (Bay of Plenty) below the waste discharges from large pulp and paper mills. The deoxygenation coefficient used is much higher than is common in overseas studies. This appears to be attributable to intense bacterial activity on the pumice sediments of this river. Figure 28 shows depletion and recovery of oxygen in the Mataura River (Southland). The data shown on these 2 figures were used to validate a mathematical model, the results of which are also shown on the figures. Models can then be used to predict river DO under alternative patterns of waste discharge, as given on Fig. 29 for the Mataura River. These predictions are most useful to persons responsible for implementing remedial actions.

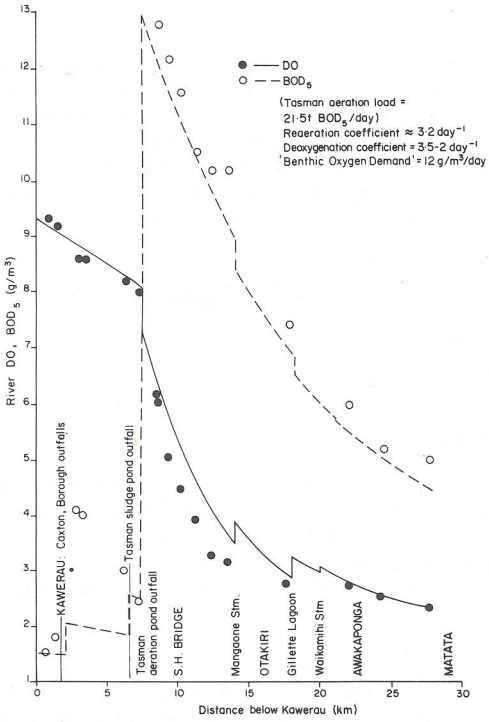

Fig. 27 Actual and predicted DO in the lower Tarawera River.

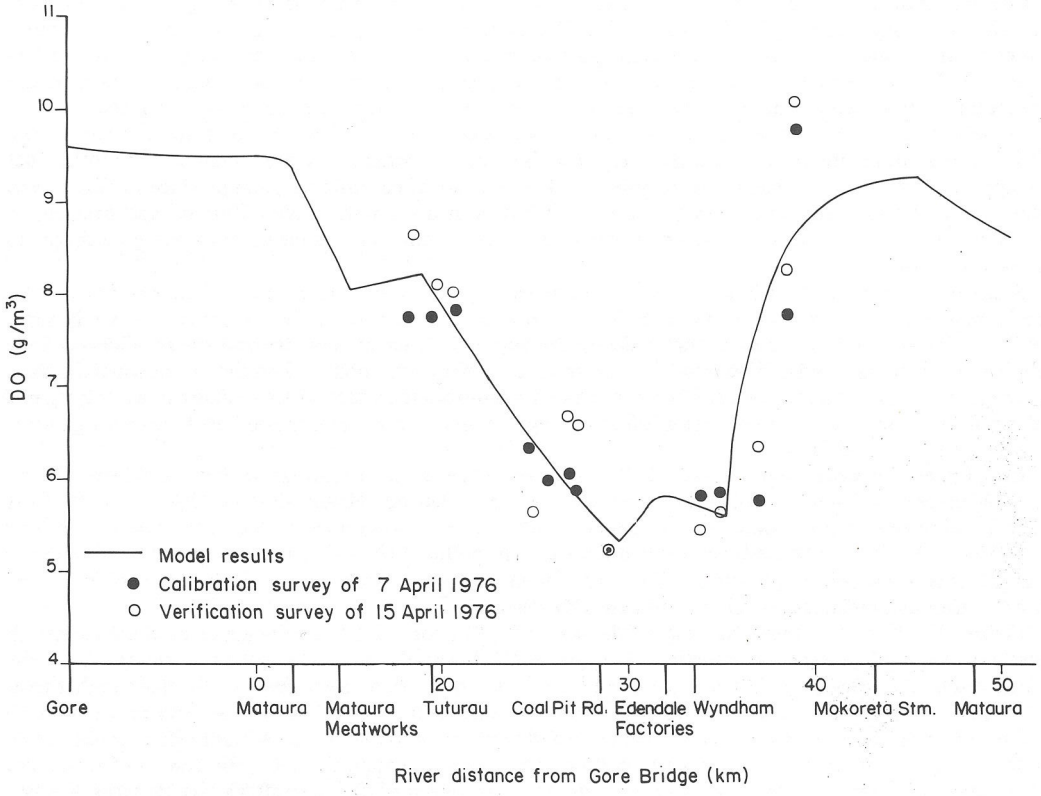

Fig. 28 Model DO results for April 1976 conditions in the Mataura River compared to survey results.

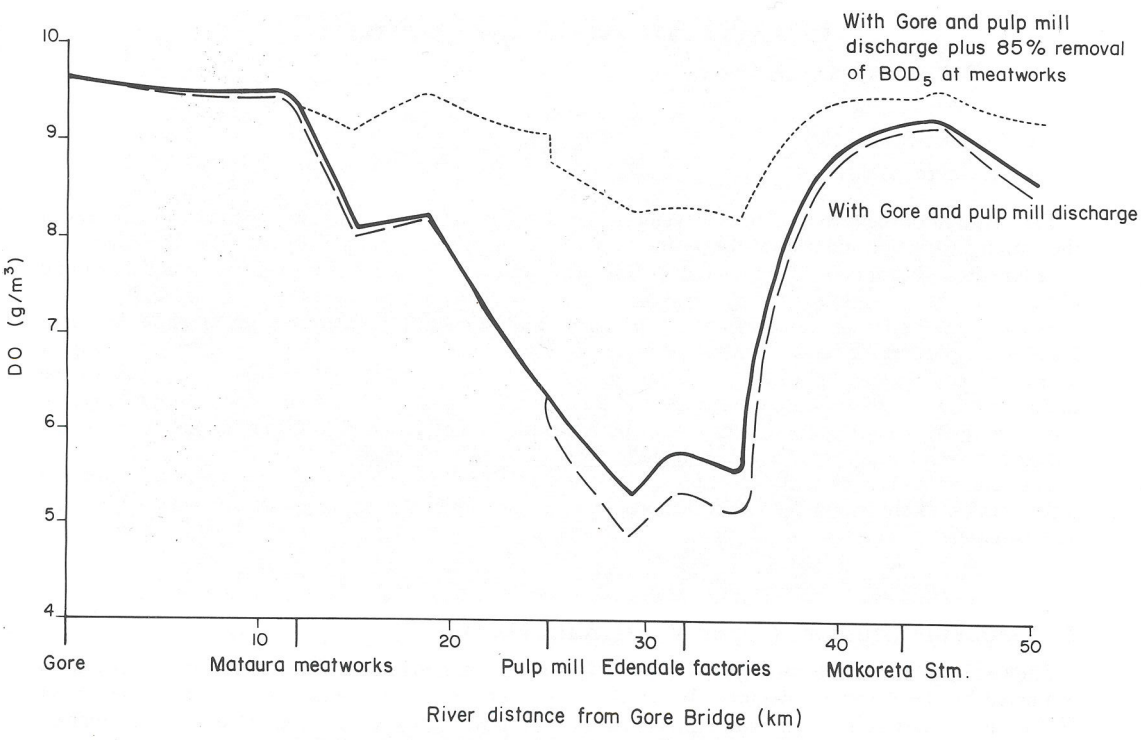

Fig. 29 Model predictions for April 1976 low flow in the Mataura River and 2 alternative regimes of waste discharge.

Meanwhile more detailed studies of in-river processes are being made, the results of which should be incorporated into a future update of the handbook. For instance, during October/November some measurements of benthic oxygen demand (BOD) were made in the Waitoa River. The dairy factory at Waharoa was then processing the peak milk production. The large volumes of variable quality waste discharge resulted in in-stream BOD_5 values in excess of 30 g/m^3 being recorded. This large amount of waste had developed a very healthy population of sewage fungus which literally carpeted the river bed. During the development and testing of techniques for field study of benthic metabolic processes benthic oxygen uptake rate in this region has been recorded at 50 g/m^2 per day with 40 g/m^2 per day being common. Downstream the uptake rates ranged between 15–25 g/m^2 per day and upstream the rates ranged between 8–24 g/m^2 per day. These variations appear to be caused by changes in the stream flow at this time of the year and by differences in benthic particle size.

2. Other Work

The Group has commenced studies designed to examine the factors affecting the appearance of river waters. A literature review has indicated that the best means of quantifying colour is by spectroradiometry. An assessment of available spectroradiometers is now under way to establish the appropriate apparatus for the project. It is planned to conduct studies of the dissolved, colloidal and particulate constituents which cause scattering of light (and foam and slick formation) in both natural and waste waters. These studies will aim to quantify the relative optical effects of different constituents and to define sources and behaviour in the aquatic environment of these constituents.

The Group has also been involved in the monitoring of water quality in some rivers with potential for hydro-electricity development, e.g., Motu River. Another important aspect has been to give advice and assistance to regional water board staff on such matters as the calculation of river dissolved oxygen depletion and consequent effluent standards, and setting up laboratory methods.

COASTAL AND ESTUARINE

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T. M. Hume, MSc, PhD
R. K. Smith, MA (Hons)

The research of the Group aims to develop techniques for the assessment and prediction of changes in the nation's shoreline and coastal zones, and to develop and apply techniques for studying the movement of sediments and contaminants in coastal and estuarine waters so as to lead to a quantitative understanding of these.

Estuaries are important components in the marine ecosystem and some are subject to waste discharge loads, such as domestic sewage, industrial wastes and waste heat from power stations. Before the impact on marine ecology can be assessed, the mixing processes within and flushing from estuaries must be understood. Open coastal waters are subject to a lower degree of stress but an understanding of physical mixing is again essential to ensure adequate and economic outfall design. The Group is therefore actively engaged in developing expertise in both these areas.

The relative impact on sediment transport in coastal and estuarine zones of natural and man induced influences needs study and definition and the Group is therefore engaged in research on selected beaches and estuaries.

1. Estuarine Studies, Upper Waitemata Harbour

The Group is one of the participants in the "Upper Waitemata Harbour Catchment Study" that is co-ordinated by the Auckland Regional Water Board and which aims to assess the impact on the Upper Waitemata estuary (Fig. 30) of alternative long-term proposals for the development of the catchment.

The Group is studying the flushing and mixing characteristics of the estuary with a view to predicting the distribution patterns of pollutants discharged into the estuary under a range of conditions. This has entailed the collection of estuarine hydrological data, and conducting dye injection studies and determining the salinity of the estuarine waters over tidal cycles. These data will be used in the calibration and validation of a mathematical model being developed under a NWASCO contract with the Department of Theoretical and Applied Mechanics, University of Auckland (see p. 62).

Estuarine sediments were examined by surface sampling, coring, echo sounding, laboratory analysis and theoretical evaluation to: (1) establish baseline data against which to monitor future change, and (2) develop an understanding of the sedimentological processes so that the nature, location and magnitude of potential problems could be foreseen.

2. Beach Surveys

This work has involved the assessment of historic shoreline changes from aerial photographs and land surveys, and detailed surveys of nearshore beach profiles. Areas specifically studied have been East Clive (Hawke's Bay), Poverty Bay, Bream Bay and Ocean Beach (Northland).

The beach profile data are being analysed to determine the impact of man induced influences on erosional and accretion patterns. Historical shoreline changes are being interpreted in terms of the long-term incident wave and wind climate (e.g., wage heights and their persistence, wave periods and frequencies, wave energy and direction of approach, and the association of these with weather systems) which generate the transport of sediment.

Using this work and that of other workers in the field, the Group will be preparing a coastal survey handbook for publication.

3. Coastal Outfalls

A handbook for use by those concerned with coastal waste discharge schemes is being prepared for publication as a Water and Soil Miscellaneous Publication. Contributions from personnel outside the Group form a major part of the handbook. The opening section deals with the relevant knowledge on the topics of coastal oceanography, coastal ecology and public health issues. This is followed by discussion and illustration of practical techniques for oceanographic, ecological and water quality surveying, and for the estimation of dilutions of effluent immediately near the outlet and at selected sites remote from the outfall. The handbook concludes with a discussion of water quality standards and monitoring requirements.

Fig. 30 **Upper Waitemata estuary at low tide. View from the west with Hobsonville air base and suburban North Shore at right centre and upper background respectively.**

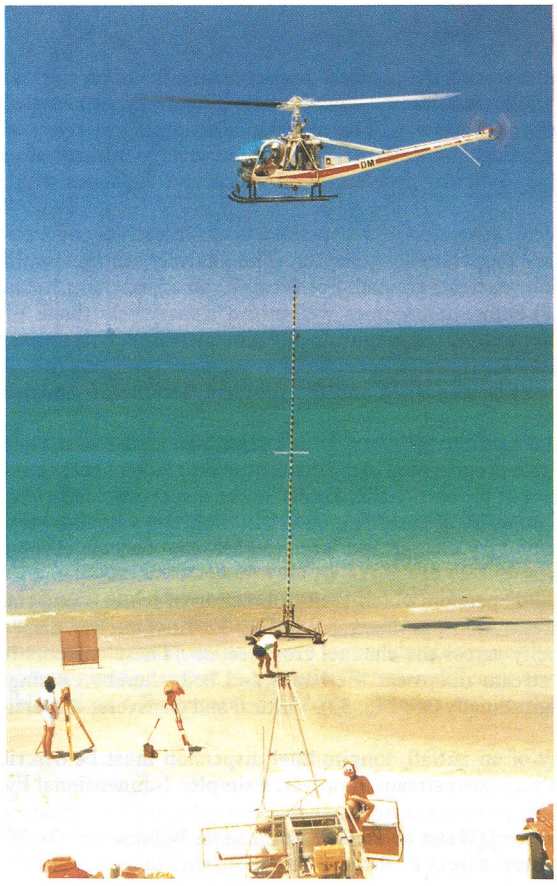

Fig. 31 **Sea sled about to be lifted out to sea.**

4. Other Work

Bibliographies are being prepared to collate the published and unpublished knowledge on the oceanography and sedimentology of selected coastal regions. Existing data can then be usefully employed and undue duplication of data acquisition avoided.

Investigation techniques developed during the course of projects are proving to have wider application. Therefore, considerable effort is made to refine techniques and communicate their features. Examples are the sea sled (Fig. 31) for sea bed surveying in the nearshore zone of beaches and the method of estuarine tidal gauging.

MODELLING AND SYSTEMS

A. G. Barnett (Group Leader), BE, PhD

T. S. Hughes, BSc

J. C. Rutherford, ME, PhD

This Group researches analytical mathematical techniques and develops and verifies mathematical models related to water quality studies, and provides mathematical expertise and computer programming assistance to other groups to aid in understanding the processes affecting water quality. For instance, the Group is involved in investigation, calibration and application of models of:

(a) dissolved oxygen and biochemical oxygen demand in rivers;
(b) vertical, transverse and longitudinal dispersion in rivers;
(c) nutrient enrichment in lakes;
(d) nutrient flushing and enrichment of estuaries in response to urbanisation in their catchments.

In the main, the above modelling is carried out in collaboration with other groups at the Centre.

1. Mixing in Rivers

One of the first steps when assessing the potential impact of an effluent on river water quality is to estimate the concentration of potentially troublesome constituents. This requires knowledge of the velocities and rates of mixing in the receiving waterway. The mechanics of mixing in rivers are complex and have so far defied a complete mathematical description. There are, however, a number of semi-empirical techniques which can be used to analyse particular problems, and which give estimates within a presently-acceptable accuracy.

In the most general problem, advection and dispersion occur in each of the 3 co-ordinate directions, and the governing equations are comparatively complex. The analysis can be simplified, however, if any of the velocities or concentration gradients is small. For example, an added tracer becomes well-mixed vertically (from water surface to bed) before it becomes well-mixed transversely (bank to bank), and well-mixed transversely before it becomes well-mixed longitudinally (downstream). This means that vertical, transverse, and longitudinal mixing can sometimes be considered as separate problems (i.e., 1-dimensional). At other times longitudinal mixing can be neglected and the problem becomes 2-dimensional in the vertical and transverse directions.

In many situations the net transfer of tracer from a region of high concentration to a region of lower concentration proceeds at a rate proportional to the concentration gradient between the 2 regions (i.e., "Fick's Law"). However, the constant of proportionality known as the dispersion coefficient, may be highly variable, partly because the size and intensity of turbulent eddies in the waterway may vary considerably and partly because the velocity gradients may change and larger eddies may become involved in mixing as the size of the tracer patch increases.

For example, longitudinal dispersion which is the spreading of tracer along the axis of flow, results in the attenuation of peak concentrations, as illustrated in Fig. 32. Longitudinal dispersion is largely the result of non-uniformities of velocity across the channel cross-section. These currents transport material downstream faster in the main stream than near the banks and bed, thereby causing the cross-section mean concentration to spread longitudinally (see Fig. 33). Vertical and transverse dispersion counteract the effects of velocity gradients.

In the immediate vicinity of an outfall, longitudinal dispersion must be described by complex models in 2 or 3 dimensions. Some way downstream, however, a simpler 1-dimensional Fickian model can be used as shown in Fig. 33.

A handbook has been published (Water and Soil Miscellaneous Publication No. 26) which describes several Fickian techniques, lists typical values of dispersion coefficients to facilitate desk study estimates of the impact of effluents on water quality, and gives worked examples. Such preliminary estimates may be sufficient to indicate whether or not an effluent will have an adverse effect on water quality, or they may indicate

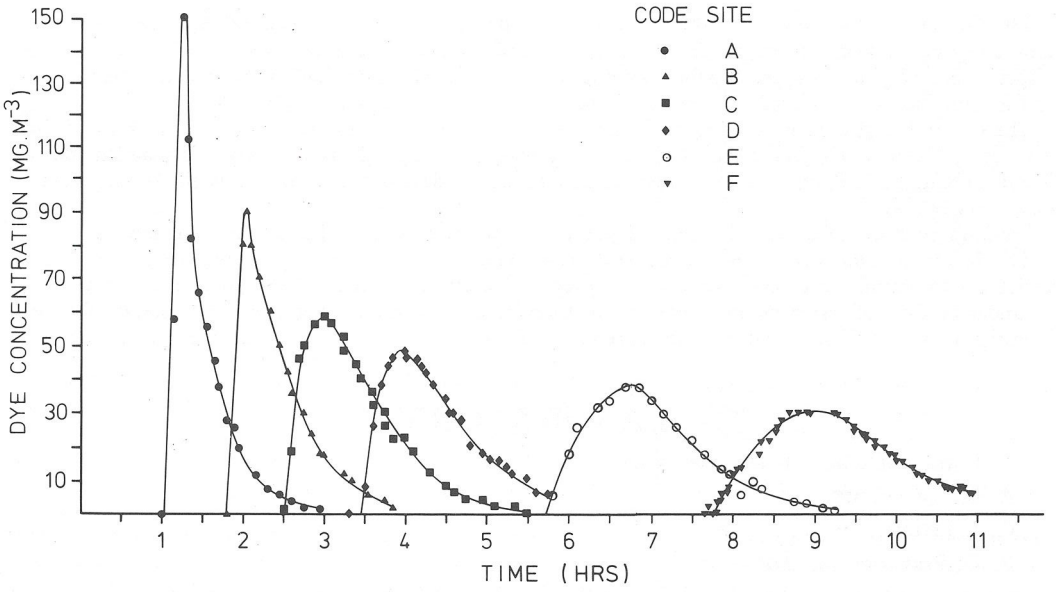

Fig. 32 Longitudinal dispersion of dye in the Waikato River showing that as the dye patch moves downstream it becomes more spread out.

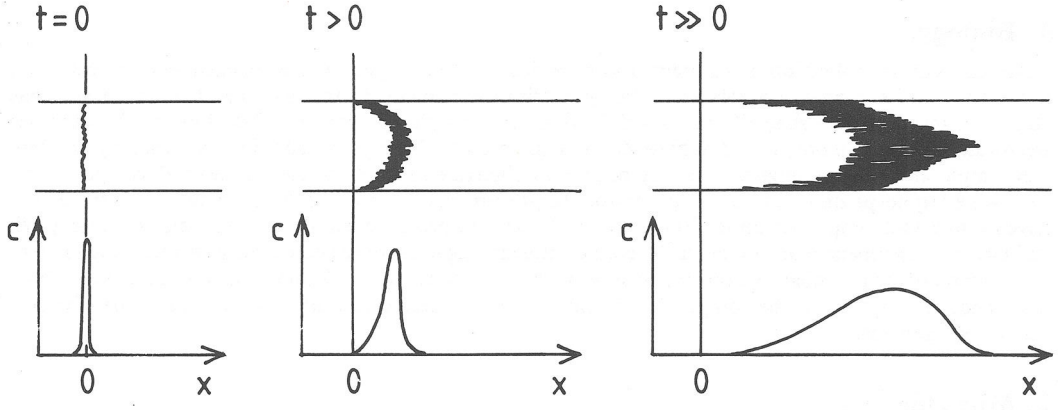

Fig. 33 The effect of transverse velocity gradients and dispersion on longitudinal dispersion.

that further investigation is necessary. More sophisticated analysis may require field tracer studies, advanced computer modelling and physical modelling.

At a workshop held at the Science Centre in November 1981, the uses of simple Fickian models, field tracer techniques, physical models and advanced computer models in New Zealand were discussed widely. The conclusions of this workshop were that new mixing problems can usually best be tackled using a combination of field and modelling techniques, and there is considerable expertise available in New Zealand to tackle major mixing problems given adequate co-operation between different organisations. The Workshop proceedings are to be published as a Water and Soil Miscellaneous Publication.

2. Other Work

On the systems side of its work the Group has evaluated and given advice on mini-computers to catchment authorities, investigated the design and specification for a regional water quality data management system and the Aquatic Quality Unified Archival Library (AQUAL) which will cater for water quality data on a systematic national basis, and the development of a multi-user laboratory data logger to support multiple automated chemical analysis systems.

The Group has collaborated in the work of the Department of Theoretical and Applied Mechanics, University of Auckland, to model the flushing action of tides in the Upper Waitemata Harbour and the dispersal and washing out to sea of pollutants entering the Upper Harbour. Staff have also made contributions to the handbook on dissolved oxygen that is being prepared by the Rivers Group.

The Group has also been called upon for advice on dissolved oxygen problems in the Waikato, Waipa, Tarawera, Mataura, and Manawatu Rivers, and on dispersion in the Waikato, Waipa, Manawatu and the Taranaki Ring Plain Rivers and in connection with industrial development adjacent to the Whangarei and Otago Harbours.

Preliminary study of dissolved oxygen depletion in thermally stratified lakes has commenced.

The data management facilities now under development are expected to support rigorous studies of data variability to permit more extensive testing of proposed scientific models. The consequent improvements in understanding of water quality systems can then be used to refine measurement strategies for field investigations as well as assisting in interpretation of results.

LABORATORY

J. B. Macaskill (Group Leader), MSc, PhD

A. B. Cooper, MSc, PhD

G. J. Latimer, MSc

R. D. Pridmore, BSc, PhD

The Group's prime responsibility is to maintain chemical and biological analytical systems and quality assurance programmes to assist other research and survey groups and catchment authorities in carrying out water quality investigations. In addition to this servicing role it carries out biological studies of factors affecting water quality.

1. Biology

An algal culture collection is maintained as a service function to government departments, researchers, universities and secondary schools and is being continually expanded. An algal identification manual has also been recently published (Water and Soil Miscellaneous Publication No. 39). This guide identifies freshwater algae commonly found in New Zealand and reports observed distributions recorded up to 1980.

A simple and reliable bioassay test for nitrogen deficiency in fresh waters has been developed using adenosine triphosphate (ATP) as the indicator. Improvements to accepted ATP analytical methodology have led to a 3-fold improvement in test sensitivity. A standard procedure for the determination of chlorophyll "a" has been documented for use by the Science Centre and regional water boards. Such method development was a prerequisite to embarking on an intensive study of algal/nutrient relationships in some North Island lakes and, although yet to be completed, the findings are expected to lead to simple guidelines for lake water management.

2. Microbiology

Routine analyses have been performed in support of Centre projects and for staff at District Offices. A study has been completed on the contribution of bacteria to total biomass in some lake waters. This study has also evaluated the use of *Aeromonas hydrophila* as an indicator of lake trophic status. Levels of this microbe correlate well with total nitrogen, total phosphorus and chlorophyll "a" levels, hence this approach shows some promise as a ready index of the trophic status of lakes.

A series of studies is under way on the role of bacteria in the transformation of nitrogen species in waters. One of these studies concentrated on the importance of bacterially controlled oxygen demand, where nitrifying bacteria residing in sediments can contribute to the general problem of oxygen deficit in waterways receiving wastes. The study has shown that nitrogenous oxygen demand does not contribute significantly to the oxygen deficit in the region of maximum oxygen demand caused by a mixed carbonaceous/nitrogenous waste, but does contribute 60–70 percent of the total oxygen demand in the oxygen recovery zone further downriver. This better understanding of such processes improves our ability to predict mathematically the impact of waste discharge on water bodies. By way of contrast to the above, a suitable population of denitrifying bacteria can transform wastes or their oxidation products to ecologically harmless nitrogen gas. This phenomenon is site specific and its significance in New Zealand aquatic systems is not yet completely understood. Further work is planned to study these denitrifying processes.

Another current project is assessing the importance of the various sources of waste to waters suffering from growths of sewage fungus and to define the conditions under which such growths flourish. The results will be of value in the preparation of guidelines for controlling such nuisance growths.

3. Instrument Design

As a new section in the Group, most effort has been devoted to advising regional water boards on instrument purchase and application. Other work is to modify and enhance the Centre's existing laboratory instrumentation to better meet required needs.

A hand operated tape reader for processing hydrological data tapes has been designed and constructed. A device based on this design could probably be produced commercially by local industry at a cost of approximately $2,500/unit compared with $4,000 for currently available imported equipment.

Future activities will include a study of the national demand for continuous monitoring water quality equipment, and the design and construction of such equipment if a need is identified. The feasibility of interrogating such remotely situated instruments by telemetry will also be investigated.

4. Analytical Chemistry

The major duty of this section is to maintain analytical facilities to support the Centre's wider activities. Analytical capabilities are generally limited to inorganic species, with measurements being made by automated colorimetric equipment where appropriate or by atomic absorption spectrophotometry for metal analysis. Changes in the direction of research by the Centre have led to demands for both analytical expertise to detect the determinands of interest at increasingly lower levels and for the implementation of techniques to measure less common parameters. Accordingly techniques for measurement of soluble and particulate organic carbon, low level total phosphorus (<5 ppb) and low level zinc (<5 ppb) recently were implemented. These techniques will support studies of lake eutrophication, water appearance and urban stormwater quality.

Considerable effort is also directed towards advising regional water boards on analytical methods, instrument purchase and quality assurance procedures for their laboratories. Special analyses are also done for regional water boards as appropriate. Training courses are held at the Centre as required, to instruct regional water board laboratory staff on laboratory and field methodologies in chemistry and biology.

RESEARCH CONTRACTS

The research contract scheme of the National Water and Soil Conservation Organisation is aimed at encouraging research relevant to the Organisation's fields of interest and responsibility. Applications from the universities are called for once a year and preference is given to funding those projects which involve advanced student training. The scheme also provides for special purpose contracts which require special skills above student level which are available either within or outside the university situation.

The objectives of, and a summary of progress achieved to March 1981 with research contracts that are under way, or were completed during the preceding 12 months, are given below.

WATER QUALITY

1. An Engineering Evaluation of Alternative Systems of Dairy Waste Treatment —Massey University (Department of Agricultural Engineering)

A system of waste disposal involving 2 lagoons (aerobic and anaerobic) is being tested. A pilot scale vegetative filter for land application is also being monitored. Preliminary conclusions are that:

(a) 80ℓ/day per cow would be a satisfactory basic design figure for lagoon input but might be reduced to 65ℓ/day per cow for herds over 300 cows;
(b) the average daily load, based on data over a limited time period, was 0.14 kg BOD/cow day with 89 percent of this loading being removed by the lagoons;
(c) a regression to predict BOD of the raw waste from COD values has been established;
(d) the ability of the lagoons to treat shock loads suggests that they can receive up to 3 days' milk production from 300 cows without excessive problems.

2. The Effects of Benthic Algae on the Water Quality of the Manawatu River—Massey University (Department of Biotechnology)

The main objectives of the research are to determine the standing crop and rates of photosynthesis and respiration of benthic algae in the river, to assess the nutrients limiting their growth, and to provide baseline data concerning the algae.

Studies involving dissolved oxygen are still in the early stage so factors involved in algal metabolism have yet to be quantified.

It has been observed that associated with the benthic algae are large populations of phytoplankton; there is also a noticeable population present in open water.

Because the phytoplankton may have considerable impact on the oxygen fluctuations they are also to be investigated.

An extensive literature review has been carried out, and some preliminary laboratory work to determine the chemical parameters of the river water and for bioassay and tissue analyses.

3. Eutrophication of Lake Ellesmere : Investigation of Phytoplankton — University of Canterbury (Department of Botany)

The main objectives of this study are to monitor the phytoplankton population to indicate the rate of trophic change or the extent of the present eutrophic conditions in Lake Ellesmere and to use a knowledge of the phytoplanktonic algae communities as indicators to ascertain the trophic status of the lake. It was hoped that these would be achieved by monitoring environmental parameters to allow interpretation of seasonal changes in phytoplankton populations, determining the tolerance of all major phytoplankton species present to levels of inorganic nutrients in the lake, and determining primary productivity of the phytoplankton in the lake.

During the past year the regular monthly sampling programme was completed, all chemical and biological data were computer filed and the analysis of data commenced. Work with cultured organisms to determine limiting factors for growth was commenced. A bloom of the toxic blue-green alga (*Nodularia spumigena*), said to be the most extensive ever observed on the lake, was monitored.

4. Nutrient Status and Primary Productivity of Hawke Bay Coastal Waters with Particular Reference to Sewage Disposal from Marine Outfalls — University of Canterbury (Department of Zoology)

The main aims of this research are:

(a) to compile a nutrient budget for the coastal waters and to estimate the relative contributions of nutrients from marine outfalls and rivers entering the system;
(b) to determine the effect of nutrient input on primary productivity;
(c) to determine if there is any significant trace metal pollution of the coastal waters;
(d) to assess the extent, if any, of undesirable environmental effects from the discharge of sewage to the coastal waters.

Sampling surveys have been carried out and samples analysed. Data analysis and interpretation is now proceeding.

5. Dispersion in Natural Rivers — University of Canterbury (Department of Civil Engineering)

The main objective of the research is to investigate the effects of bed roughness and channel embayments on the dispersion of effluent in a natural river. At present simple analytical methods for predicting rates of mixing in open channels are only available for the rather hypothetical case of uniform velocity and dispersivity. This study is attempting to develop a method applicable to the more realistic non-uniform situation. To date emphasis has been on the mathematical analysis phase with analytical forms for the moments of the concentration being obtained. Some progress has been made towards concentration profiles from these moments although some mathematical work remains to be done to refine these techniques. Work has commenced to prepare equipment for the laboratory studies to verify the mathematical findings.

6. Methods of Enumerating and Identifying Coliform Bacteria with Special Reference to their Survival and Significance in the Assessment of Water Quality—Lincoln College (Department of Microbiology)

Deficiencies in existing methods of testing for the presence of coliform bacteria and the ability of the bacteria to survive and multiply in certain aquatic environmental conditions has led to the following investigations:

(a) examination of other characteristics, such as serotypes, antibiotic resistance patterns and bacteriocin production, which are additional to the usual test criteria;
(b) determination of the mutability or stability of the bacteria's lactose fermenting characteristics;
(c) the ability to grow or survive in different environments.

Most of the work during the year has been the subculturing for purification and identification of 1000 isolates from sewage, data evaluation and data analysis. Some progress has been made with writing thesis chapters, e.g., methods used for characterising and grouping sewage isolates. The literature review has been updated to the end of 1980. A further 6 months is required to complete the contract.

7. Survival and Detection of Enteric Virus in Water and Waste Water — University of Otago (Department of Microbiology)

This study aims to establish a method for detection of viruses in waste water based on centrifugation and adsorption techniques and, following its establishment, to use it to determine viruses present in a variety of effluents. Sterile bentonite has been settled upon as the adsorption material. Emphasis during the year has been to develop the complete procedure, i.e., concentration, recovery, isolation and identification of viruses from naturally contaminated effluent.

Recovery and isolation of viruses proved to be a problem in liquid culture due to bacterial contamination and the difficulty of isolating more than 1 viral type from each sample. In an attempt to overcome this problem, a modification of an agar suspended cell system was tested leading to the use of BGM cells in an agar suspension in the procedures. The developed method is now being used to determine viruses present in a variety of effluents including Hamilton and Dunedin sewage.

8. Effect of Land Development and Fluctuations in Water Level on the Phytoplankton Productivity of Lake Mahinerangi — University of Otago (Department of Zoology)

The main objectives are:

(a) to investigate the relationship between land development and eutrophication of the lake;
(b) to relate phytoplankton productivity to specific nutrients and their specific source;
(c) to model the effects of fluctuating water levels on the release of nutrients from lake margins and hence on phytoplankton productivity;
(d) to obtain an organic carbon budget for the lake.

Routine fortnightly monitoring of phytoplankton production has begun. Production was generally comparable with that during other summers since land development began, but in March-April levels were higher than any previously recorded. Earlier studies had revealed a trophic gradient during autumn-spring with increasing production from the uppermost basin to the main sampling station and then no further change along the lake. Preliminary studies suggest this gradient may no longer exist now that land development has been started in the Waipori River catchment which feeds the upper basin. Data on nitrogen (N) and phosphorus (P) in the lake reveal fairly high levels of total P, and a continuation of a previously noted tendency to increased soluble reactive P levels. The ratio of inorganic N to soluble reactive P is very low suggesting a nitrogen-limiting system. Inputs of total P appear to reflect in a general way the levels of agricultural activity in the catchments. An important result was the very high levels of P occasionally recorded in 2 small streams draining agricultural land. Many such streams enter the lake, and these results suggest that, notwithstanding their low flows, they may be potentially important sources of P. These are early results and more monitoring data are still required. A seasonal series of nutrient bioassays has been started.

9. Denitrification Processes in Aquatic and Terrestrial Systems — Cawthron Institute

The main objective of the research is to investigate the microbial reduction of oxidised forms of nitrogen and determine the rates of evolution of nitrogenous gases which are important in several natural and man conditioned systems. Three fields are being concentrated on, these being marine sediments, denitrification in streams, and denitrifiers capable of fermentation.

A literature background to the 3 sub-projects has been prepared from which rationales and aims have been developed. The major concern during the year was the construction of a denitrification assay system and development of a suitable method for estimating denitrification in marine sediments. First results obtained with a muddy, predominantly heterotrophic sediment from the Delaware Inlet near Nelson indicate a very low *in situ* denitrification rate compared with similar data cited in the literature. More than 50 strains of fermenters capable of nitrate reduction have been isolated and will be tested for their specific pathway of nitrate reduction. Methods for assaying river denitrification are in the early stage of development.

10. Reservoir Dynamics — University of Canterbury (Department of Civil Engineering)

This study aims to test the applicability of a computer model, which simulates the temperature and salinity profiles in lakes and reservoirs, to a New Zealand reservoir and provide field verification of the theories incorporated in the model, and to increase the understanding of the effects of selective withdrawal on reservoir dynamics.

One part of the study has been to determine why the thermocline in the Upper Huia reservoir from which water is supplied to Auckland is always found at the level of the middle off-take (the sink) in profiles measured close to the sink. It was thought that perhaps the thermocline might be at a different elevation in the rest of the reservoir, a level determined mainly by the balance between wind and net radiation, but that the withdrawal was drawing the thermocline either down or up into the sink. Temperature profiling over the past summer showed this was not the case. From the profiling the isotherms were found to be remarkably flat, with a very sharp temperature jump across the thermocline occurring at the same elevation throughout the reservoir at the same level as the sink. There was no trace of any draw-down. Rather, selective withdrawal continually sharpened the stratification at the level of the sink. It is proposed to conduct laboratory experiments to help quantify and clarify this process. Over the summer period inflows to the reservoir were small and had little influence on the reservoir's temperature structure. It is planned to install a gauging station on an inflow so that the effects of high flows can be more accurately assessed and incorporated into the computer simulation.

The stability of the water column established by selective withdrawal and surface heating was so strong that wind over the summer period had little influence on the depth of the main thermocline. Strong winds served only to keep the warm upper layer of water in the reservoir mixed.

The computer simulation model is now operating on the University computing system.

COASTAL AND ESTUARINE

11. Instrumentation for the Measurement of Coastal Current Patterns — University of Auckland (Radio Research Centre)

The system being developed will enable the measurement of coastal current patterns by tracking oceanographic buoys that have small transmitters on them. A modified hyperbolic navigation system that requires the use of 3 receiving stations on the shore is employed to track the buoys.

A suitable design of the radio drogue has been developed and proved durable, withstanding periods of several weeks in the Cook Strait and Taranaki Bight areas without structural damage.

The on-shore receiving and recording system is in the final stages of development.

Field trials will soon start with the component parts of the system being gradually brought together to evaluate the overall performance.

12. Ocean Wave Characteristics, Hicks Bay — University of Auckland (Department of Physics)

This is consultancy work which involves analysing existing data from a wave measuring accelerometer buoy off Hicks Bay and establishing correlations with weather patterns so that characteristic spectra can be identified.

A comprehensive report has been presented which sets out the work completed under the major headings of previous wave studies, the data and processing, results, possible applications of the findings, and use of spectra in sediment transport models. Detailed results are reported in terms of changes with time of spectral energy for representative atmospheric pressure patterns (e.g., midlatitude and Tasman depressions), characteristic spectra, significant wave height — energy relationship, direction of wave energy approach, and persistence of waves. As an example of the types of results obtained the persistence data show that storm waves greater than 3 m never persisted for greater than 36 hours and above 4 m no greater than 12 hours. On the other hand periods of low waves less than 1.5 m could persist for 300 hours. For the full period of observations the storm waves persisted for 3.5 percent of the time and waves under 1.5 m for 63.5 percent of the time.

13. The Impact of Fluvial Processes in the Upper Waitemata Harbour Catchment with Particular Reference to Urbanisation and Sediment Generation — University of Auckland (Department of Geography)

The research aims:

(a) to identify the processes leading to generation of sediment load in a stream from a small grassland catchment;

(b) to identify and explain changes in the processes of sediment generation in a neighbouring similar sized catchment as land preparation for urbanisation proceeds;

(c) to monitor and explain any differences in sediment discharge that may arise due to the implementation of management measures designed to reduce sediment output from the catchment as urban development proceeds.

An extensive study of the literature on runoff generation, hillslope erosion and the impact of urban development on stream channel siltation and scour was undertaken. This led to the development in greater detail of the research strategy to be adopted. Work has subsequently focused on the selection of field sites, and the design and installation of the field equipment. Stream flow from 3 catchments is to be continuously monitored (grassland, developing urban and developed urban). A grassland and a bare clay slope have been selected for the monitoring of factors controlling the fluvial processes of runoff generation and hillslope erosion. Their instrumentation is part completed.

14. Mathematical Model of the Upper Waitemata Harbour Estuarine System — University of Auckland (Department of Theoretical and Applied Mathematics)

The objective of the research is to adapt an existing model (a 2-dimensional finite difference model developed in 1974) to be applicable to the whole of the Upper Waitemata Harbour estuary, including the creeks, in order to be able to:

(a) predict concentration distribution so that the loading that can be accepted before certain threshold values are exceeded can be determined;

(b) to evaluate ways of managing the disposal of wastes so as to minimise their impacts.

Prediction of pollutant concentration requires the solution of 2 sets of equations: firstly a set of hydrodynamic equations which yields water levels and velocities, and secondly an advection/dispersion equation which uses velocities to predict pollutant movement and concentrations. These equations are being intensively studied in 2 co-ordinate frameworks: 1 dimension (1D) (including a network of branching channels), and 2 dimensions horizontally (2DH). The equations can be solved by either of 2 methods: finite difference (FD) or finite element (FE) numerical schemes.

Each model has been programmed and applied to simple test problems on artificial estuaries of regular geometry. The 1D and 2DH FD and FE models produce comparable answers to the test problems. The FD models are 15–20 times faster than the FE models but it is anticipated that on real estuaries of irregular geometry the FE models will tolerate a coarser computational grid and may become computationally more efficient than the FD models.

The 1D and 2DH models are at present being applied to Lucas Creek, a tidal arm of the Upper Waitemata Harbour.

The hydrodynamic equations of the 1D FD model are being calibrated and tested using water level and velocity data obtained from field tests and when this is complete the advection/dispersion equation will be calibrated and tested using dye concentration data gathered during field tests on 11 March 1981. Various salinity data are also available to test the model.

When the 1D model has been calibrated and tested on Lucas Creek the next step will be to calibrate and test the 2DH FE model on Lucas Creek using the same field data and then to compare the results of the 1D and 2DH models. This will indicate how effectively Lucas Creek can be modelled by 1D equations especially in regard to dispersion.

At the same time it is proposed to develop the 1D network model to the stage where it can be used to address management problems in the Upper Waitemata Harbour.

15. Mobile Sand and Gravel Resources Between Cape Palliser and Wellington — Victoria University of Wellington (Department of Geology)

Field and laboratory work for the project has been completed and data analysis and compilation is under way. Monitoring of the tracer experiments was continued at 2-weekly intervals until August 1980 after which the interval was increased to 1 month until December 1980, when the observation period ended. Tracer samples collected during the experiments have been analysed for size, shape, and rounding.

A set of beach and river samples, collected between Turakirae Head and Cape Palliser on 11 November 1980, have been analysed for shape and roundness. This information, along with the results from the beach tracer experiments and a laboratory abrasion experiment, will be used to assess quantitatively the importance of gravel abrasion in the sediment budget of Palliser Bay.

The 3 tracer experiments show how differently the beaches on the north-south oriented, rocky coast at the sides of Palliser Bay behave when compared with those on the smoother coast at the head of the bay.

At Washpool Creek (on the east coast of the Bay) beach gravel was moved predominantly northwards by large waves from the south, but some minor reversals were caused by locally generated north-west waves. During the year the tracer moved an average distance of 1.6 km and gradually spread out over 4 km of beach. At the sites in the head of the bay gravel was moved in unison both east and west by large southerly waves. Overall the net transport was small, even though the tracer fields spread out very rapidly at each site to cover about 4 km of beach.

Although shape-sorting was observed in the first week of detailed observation at Washpool Creek, pebbles recovered from the full width of the intertidal beach were of similar average shape to the input pebbles, but coarser. At the head of the Bay, the slightly coarser tracer pebbles recovered from the intertidal beach were, right from the start of the experiment, both less spherical and more oblate than the input pebbles. This suggests the existence of a sorting process that removes the more easily rolled pebbles to the subtidal area. In this connection it is interesting to note that the recovery rate at Washpool was roughly 2–3 times the rate of Whangaimoana and Ocean Beach (along the head of the Bay).

Some size-sorting was observed during the first week of the experiment at Washpool Creek, but it does not seem to have had a significant effect in the long-term transport of the tracer material.

Daily beach observations were made during March and August 1980, and were supplemented by observations in conjunction with the monitoring of the tracer experiments. Visual wave observations were made daily until late December 1980. These will be used in conjunction with Meterological Service hindcasts to construct wave refraction diagrams which will enable estimates of the net longshore component of wave power to be computed for intersurvey periods at each tracer experiment site for the duration of each experiment. These estimates can then be compared with the movement of the tracer material in an attempt to establish empirical relationships between wave energy and gravel movement.

Additional surveys were carried out for diverse purposes. The shape of Lake Onoke spit has been surveyed to compare the present volume with that in 1950 when it was surveyed by the Navy. A series of profiles across the beach at Whatarangi Point were established and resurveyed 4 times to measure the size of a pulse of gravel that was introduced to the beach system after a heavy rainstorm in March 1980. A transect extending 1300 m offshore from Whangaimoana was sounded and sampled on 13 March 1981. Gravel extended for only 50 m beyond the break point and then rapidly graded into fine sand, which forms a veneer less than 10 cm thick on a mudstone terrace on the outer part of the transect. It is therefore probable that the gravels have a fairly limited seaward extent.

WATER RESOURCES

16. The Mechanics and Dynamics of Storm Runoff Producing Regions in Some Lower Order Channels — University of Waikato (Department of Earth Sciences)

The main objectives of this research are:

(a) to identify and define the mechanisms of storm runoff production operating in a watershed for varying slope, aspect and vegetation;
(b) to measure the quantities of flow contributed by each of the runoff forms;
(c) to determine the factors affecting the relative contributions of each runoff form;
(d) to determine the contributing source areas and define indications that may be used in the field to predict runoff-producing zones;
(e) to relate the contributing source area to catchment management, both present and future.

Significant progress was achieved in all aspects of the research programme, namely collecting, reducing and analysing data sets of overland flow, throughflow, soil moisture, field hydraulic conductivity and infiltration and throughfall. This is giving an insight to the various subcomponents of the study but synthesis of explicit relationships will not be possible until 2 years of data are available and its analyses are completed later in 1981.

17. Investigation of Water Flow and Sediment Movement in Step-Pool Streams — Lincoln College (Department of Agricultural Engineering)

The aim of the study is to contribute to the understanding of the hydraulic processes which occur in steep mountain streams. Arising out of the work completed and reported on in previous years a paper titled "Origin of Step-pool Systems in Mountain Streams" was prepared and submitted to the Journal of the Hydraulics Division of the American Society of Civil Engineers. The paper describes that part of the research which shows that in steep mountain streams a bed-deforming process exists giving the low-flows a step-pool apperance and that steps and pools are the result of a combined action of self armouring and anti-dune formation which results in an important increase in flow resistance.

The present phase of the study has involved the establishment across a laboratory channel of baffle plates at 0.5 m spacings to form an idealised step-pool system and carrying out the following tests:

(a) with no sediment between baffles and with no sediment input, measure mean flow velocity for a range of bed slopes;
(b) with sediment between baffles but no sediment input, measure mean flow velocity and shape of the scour field for a range of slopes;
(c) with sediment between baffles and with constant sediment input, measure mean flow velocity and shape of the scour field for a range of slopes.

The programme for only the second of the above tests has been completed, the main results of which are as follows:

At a given slope, the volume of scour increases with flow rate until just before the limit between stable and unstable tumbling flow is reached at which point scour volume is a maximum. Scour volume then decreases with increasing discharge until a local minimum of scour volume is attained just beyond the limit between unstable tumbling and shooting flow. Thereafter scour volume tends to increase with increasing discharge.

The magnitude of mean bed shear stress for any constant discharge increases with increasing gradient of the bed.

Mean velocity shows no marked difference in magnitude for all slopes. For any given slope, the mean velocity tends to increase linearly with increasing discharge.

The above lead to a modification of the previously held hypothesis of drowning of step-pool systems. It is seen that in fact the stream system, with no sediment transport, is potentially erosive before the fully "drowned" state (which corresponds to the shooting flow regime) occurs.

EROSION

18. Slope Stability, Erosion and Potential Hazards in Relation to Geologic Structure, Lithology and Geotechnical Properties of Rocks and Soils in the Albany Basin and Paremoremo Area of the Upper Waitemata Harbour Catchment — University of Auckland (Department of Geology)

The main objectives of the research are:

(a) to map and document the surficial and bedrock geology in sufficient detail to show any relationship between these and erosion processes (including susceptibility to landslip);

(b) to provide basic engineering geological data in support of the subdivisions into the units mapped;

(c) to identify hazardous and potentially hazardous areas within the catchment.

A summary of the results from the final report is as follows.

(a) Mass movement is widespread on slopes in the area and constitutes the main geologic hazard and the fundamental erosion process.

Different forms of mass movement occur. Lithology, topography and structure are shown to be important controlling factors. Lithologies are predominantly low strength muddy sandstones and mudstones of the Waitemata Group, in which 4 weathering grades have been recognised, ranging from residual soil to unweathered rock.

(b) the following are the main associations recognised between mass movement, lithology, topography and structure:

Creep, progressive creep, sheet slides, and debris slides develop in steeper areas under both bush and pasture. They usually involve movement of the top 1–2 m of residual soil or colluvium overlying moderately weathered Waitemata Group rockmass. The basal shear surface can be either concordant or discordant to bedding within the rockmass.

Regolith slides are deeper seated and occur over whole slopes believed to be large-scale fault scarps. They develop in moderately to completely weathered Waitemata Group materials.

Basal and side shear surfaces are often structurally controlled by bedding planes and joints respectively.

Amphitheatre-shaped basins are found at the heads of most streams in steeper terrain. They occur under both bush and pasture and are thought to be older slump features.

Earthflows are found in present day water courses, often being formed as the end result of a debris slide.

Relict, deeper seated failures are found along the coastal section, and are thought to be related to a lower sea level.

(c) Holocene residual and Pleistocene alluvial soils (silts and clays) of similar appearance are found over the area. Soft compressible organic soils occur within buried channels below the surface of terrace remnants.

(d) Soil and strength profiles are different depending on relief. Some soil units are more prone to erosion than others once residual soil cover has been removed by excavation.

19. Slope Stability, Erosion and Geologic Hazards in Relation to Geologic Structure, Lithology and Geotechnical Properties of Rocks and Soils in the Western Sector of the Upper Waitemata Harbour Catchment — University of Auckland (Department of Geology)

This is an extension of the previous contract and has the same general aims. In the short time since the contract was entered into most of the Rangitopuni Catchment has been mapped in terms of bedrock structure and lithology, surficial deposits and mass movement. The lithologies identified have been described and some preliminary comment given on slope failures and hazards related to structure and weathering.

20. Geological Erosion in the Southern Ruahines — Massey University (Department of Soil Science)

The research investigates the topics of physiography and climate, stratigraphy and structures, fault zones, and mass movement in relation to faulting particularly as associated with the Ruahine and Mohaka fault zones. The final report is accompanied by a map and table giving the location and description of large scale slump features in the study area which are associated with the Ruahine and Mohaka fault zones. The study findings may be summarised as follows.

The strata comprising the bedrock of the southern Ruahine Range consist of 3 relatively undeformed flysch-like lithotypes, to the west of which is a fourth lithotype comprising a highly deformed melange sequence. Each lithotype is in conformable contact with adjacent lithotypes and each occupies a consistent stratigraphic position throughout its exposed length.

21. Effect of Bedrock Geology on Sediment Yield in an Alpine Area Subject to Extreme Rainfall — University of Canterbury (Department of Geology)

The main aims of the research are:

(a) to assess erosion processes and rates in a rapidly uplifting area of extreme rainfall;
(b) to determine the controls of erosion and the type of deformation occurring within the uplifting schist belt;
(c) to relate the high sediment yield from the catchments of the Lake and Cropp Rivers to downstream aggradation rates and problems;
(d) to assess the validity of using suspended sediment yield as a measure of erosion in an alpine catchment.

Data have been collected and observations made on water levels, river flows, sediment movement and development of sediment sources over a 1-year period. Geological mapping has been completed but final maps are still to be drawn. Analytical work completed includes grain size analysis and experimental abrasion of bed samples, K-Ar dating of bedrock (by Institute of Nuclear Sciences), and preparation and petrological examination of over 100 thin sections.

Results to date suggest that geological uplift is active, was initiated at about 5×10^6 years BP, and may be accelerating. Geomorphologically the area is being modified very rapidly. Overall erosion rates are very high, and locally they are extreme. In catchments with geologically unstable, deeply weathered and highly jointed bedrock, rates of slope modification and sediment yields are very much higher than for catchments with stable rock types and slope configurations. Suspended sediment is by far the greatest erosional product of the area. Estimates of bed load yields from sediment data suggest a yield in the order of 300 tonnes/km^2/yr. The suspended sediment yield was 42 000 tonnes/km^2/yr.

The lithotypes represent a relatively continuous, non-repetitive northward-striking, westward-younging and steeply eastward-dipping sequence of clastic sediments of Jurassic age. The bedrock is of low metamorphic rank (prehnite-pumpellyite facies) and forms part of the Torlesse Supergroup.

Two major fault zones roughly parallel the strike of the Range. The Mohaka Fault Zone marks the eastern margin. Its surface trace indicates that it has been active during late Quaternary times. Isolated slumps of flysch-like bedrock lithologies and overlying Quaternary to Recent deposits are found along the fault zone at the eastern base of the Range. The Ruahine Fault Zone strikes across steep reaches of catchments between 750 m to 1000 m altitude, where large-scale slumps together with other forms of shallow mass movements are numerous. Slumping in most instances is restricted to where the fault zone has extensively brecciated the melange lithotype in areas up to 0.5 km wide. Other slumps are the result of failure, at depth, along a discontinuity particularly where the strike of the discontinuity parallels valley slopes and dips downslope towards the free face. These discontinuities are either bedding planes or fault planes.

The frequent occurrence of fault planes or zones of brecciation in association with slumps is interpreted to indicate that they are a major causal factor in the development of large-scale mass movements. Triggering mechanisms resulting in collapse of catchment slopes by slumping are principally of climatic origin. Intense rainstorms are known to have triggered slumping within historical times. Slumping as a result of earthquake activity or movement along the Ruahine and Mohaka Fault zones has not been documented. Geomorphological factors conducive to slump formation, particularly within the Ruahine Fault Zone, are the altitudinally high and steep catchment slopes across which this fault zone strikes. A relationship between fault zones and the occurrence of slumps is recognised; thus these fault zones are potential sites for further slumping and other forms of mass movement. Mapping of faults in relation to bedrock structure, slope angle and slope aspect is of major importance if predictions of future failure sites are to be delineated.

22. Regolith Development in Relation to Mass Movement at Selected Sites on the Kaikoura Coast — University of Canterbury (Department of Geology)

The main objectives are:

(a) to determine geological and geotechnical properties of the regolith developed on various bedrock lithologies in the area;

(b) to investigate the processes of regolith development at selected sites;

(c) to assess regolith stability criteria for the soil/bedrock associations at the selected sites;

(d) to determine those regolith parameters of importance in erosion mapping and land use capability studies.

All field mapping and sampling has been completed for the 8 sites finally settled on. These are located on 4 lithologies: Torlesse sandstone and argillite, Pliocene siltstone, grey marl (Tertiary limestone), and Cretaceous mudstone. At 1 site on each of the "Torlesse" and "Pliocene" lithologies neutron probe casings and standpipes were installed in order to measure soil moisture and groundwater levels. Most of the laboratory work for geological and geotechnical characterisation of the regolith, colluvium, debris, and bedrock materials has been completed.

Preliminary conclusions indicate that in all the lithologies studied the geomorphic history of the area to a greater or lesser extent has influenced the nature and complexity of slope deposits. This in turn controls the types and severity of slope instability. For instance for the Torlesse sandstone and argillites the following has been observed.

(a) On slopes mantled with shallow (less than 2 m) regolith deposits, failure surfaces are usually irregular. They lie immediately above a narrow zone in the soil profile where the block to matrix ratio and degree of block interlocking markedly increases.

(b) In deep regolith colluvium or debris mantled slopes, permeability barriers such as more compact paleosols, colluvial, alluvial or debris deposits act as failure surfaces.

(c) Large scale deep seated failures generally include bedrock material and are related to highly crushed faulted zones and/or highly weathered argillite beds.

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