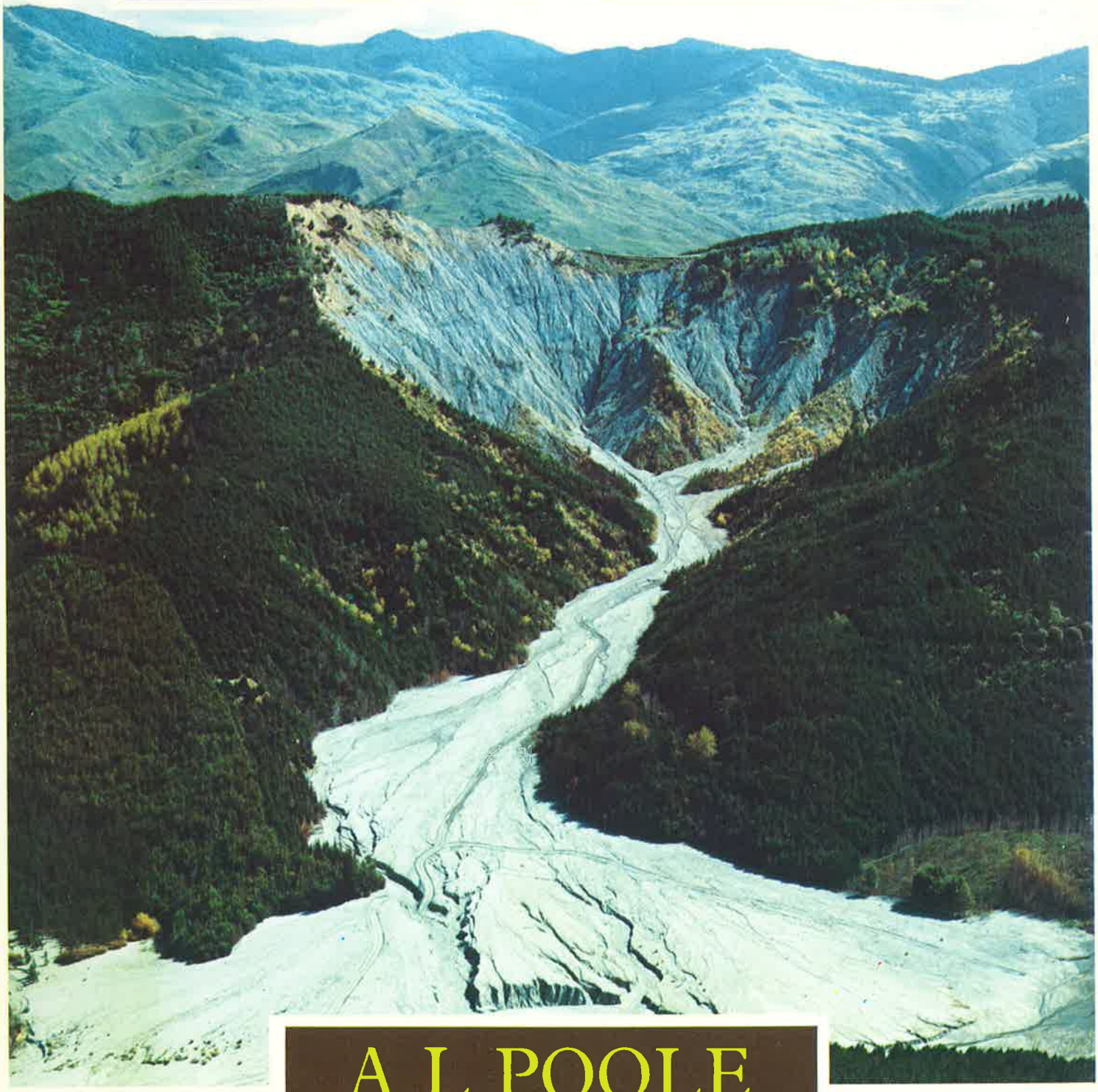
CATCHMENT CONTROL IN NEW ZEALAND



A.L. POOLE

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CATCHMENT CONTROL IN NEW ZEALAND

By A. L. Poole

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Water and soil are New Zealand's most valuable natural resources. After tracing the use and abuse of these resources in a world setting, and discussing the general history of water and soil conservation in New Zealand, this book examines each of the 20 catchment districts in turn, reviewing flood control, soil protection and water management work of the catchment authorities/regional water boards. Illustrated with over 160 black and white photographs.

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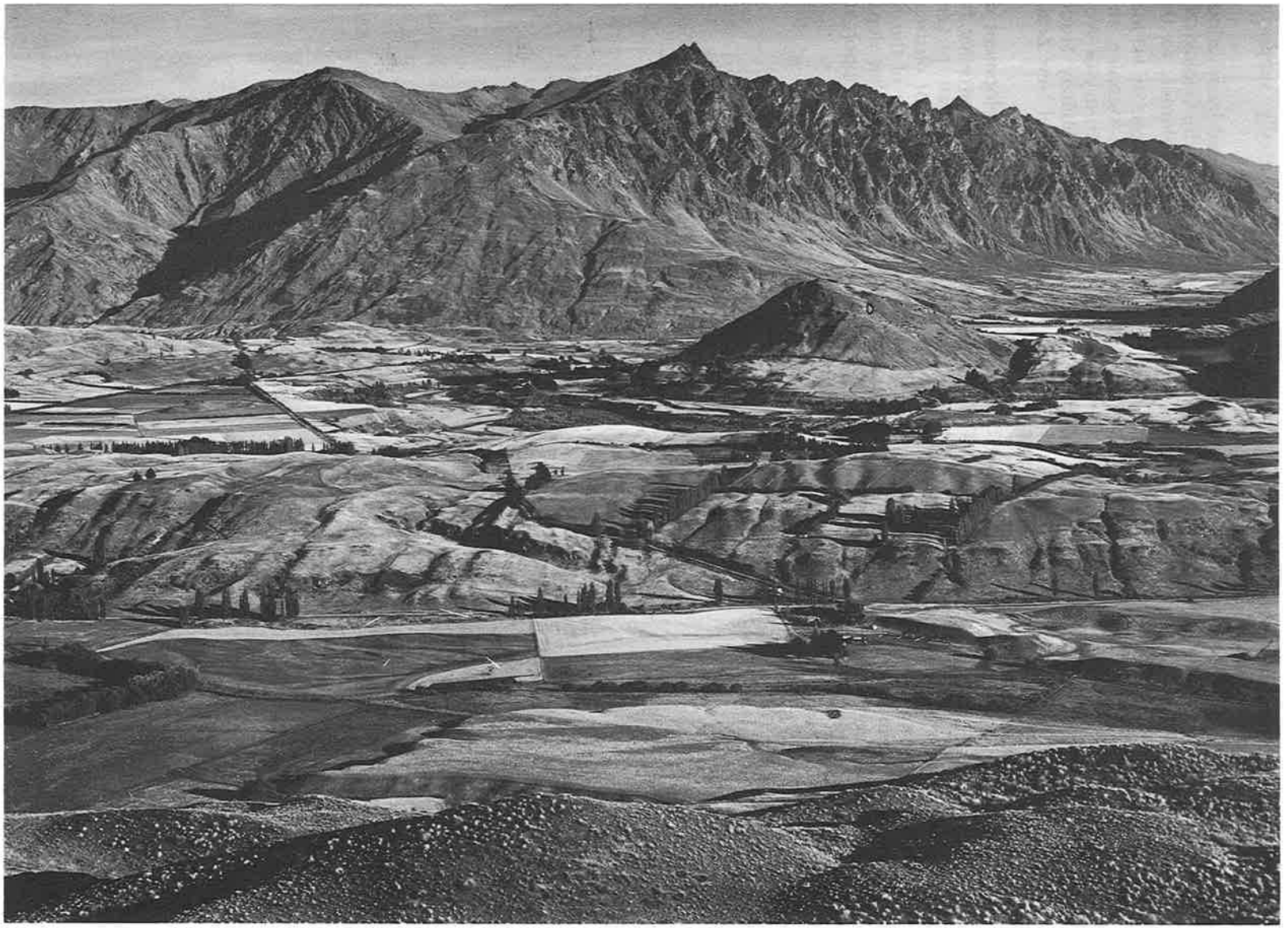
PREFACE

River and soil erosion control and water management in New Zealand are unusually complex. To present an account of them has required the co-operation and help of many people and organisations. The essential background has been obtained throughout a period of more than 30 years; first as the New Zealand Forest Service representative on the Soil Conservation and Rivers Control Council, then as its chairman of the Council and in that capacity a member of the National Water and Soil Authority. Throughout this period the Council and Authority undertook many field trips with Catchment Authorities to inspect and discuss works.

In the process of compiling the text, Catchment Authority members and staffs have read sections concerning their regions and work, have made corrections and alterations and have supplied illustrations. Many people must be thanked for these tasks as must the central body, the Catchment Authorities Association, for wholeheartedly supporting the project.

Illustrations have been obtained from various quarters. Special thanks are due to the Geological Survey for the photographs of D L Homer, to the New Zealand Forest Service for those of J H Johns and others, to New Zealand Aerial Mapping, the Alexander Turnbull Library, the Ministry of Works and Development, the National Publicity Studios, the New Zealand Railways, the Royal New Zealand Air Force and others.

The Ministry of Works and Development must be thanked for drafting work and D Lawrence, formerly a cartographer with the Department of Lands and Survey, for the series of catchment district sketch maps. The Water and Soil Division of the Ministry of Works and Development and that department generally must be thanked for their support and help in a number of ways.



INTRODUCTION

Water wears away rock and helps to form soil, but it also carries that soil away. Water collected in rivers transports rock and soil to the sea, from which, in time, they are raised again and folded into mountains and then eroded by more water. This is a never-ending cycle.

Men cannot live without water. Early men set up their communities around water supplies and organised themselves to master it for their use. They fought over it and established rights to certain usages. Whole nations became dependent on supplies of water.

The mastering of water has been no simple task. In the form of rain, ice and snow it constantly changes. At one time it is helpful, at another destructive. When it gathers in rivers it can be a most powerful erosion agent; but with the eroded material it forms flood plains which men everywhere seek because of their fertile, moist soils. The control of water on these has exercised some of man's greatest ingenuity.

In New Zealand we usually take our water supplies or granted. We have forgotten the difficulties our pioneers faced with floods, river crossings and journeys through swamps. We have little appreciation of the increase in production from land protected by a flood control scheme; the revolution in land use in the Waikato, the Manawatu plains, Inchclutha, the Heretaunga plains and many other flood plains. Nor do we comprehend the key part that water is bound to play in the country's future.

Nearly all of us work soil at one time or another if only in the garden. Many of us are involved with soil through our work. We may come to understand not only how to use the soil but something of its origin and formation. Soil conservation measures—efforts directed towards erosion control and perpetual use—are usually not so well understood. Rapid settlement of New Zealand by the Pakeha and the urgency to bring land into production has led inevitably to mistakes, some that will be with us permanently. Yet because settlement has been so recent we have been able to use the growing knowledge of water and soil management. Moreover, the wealth of water and soil we inherited has given us an excellent base to manipulate.

In 1967 a Water and Soil Conservation Act (see page 24 for details) was passed in New Zealand. This Act, together with a forerunner, the Soil Conservation and Rivers Control Act 1941, provided for the control of flooding, erosion, drainage and the management of natural water.

The Acts provided for the setting up of an organisation that has come to be known as NWASCO (National Water and Soil Conservation Organisation). An Authority at the top guides two Councils, one dealing with floods and erosion and the other with management of natural water. The Councils operate through Catchment Authorities across the country. These design, execute or supervise river control schemes and drainage, soil erosion and conservation schemes, and they survey, measure and manage water resources. The first part of this book sets the scene for water and soil conservation by describing a few world examples. The rest deals with the score of New Zealand Catchment Authorities, their physical districts, early history and major works.

1. The restless land. Many forces are at work shaping this landscape. Mountain building has pushed up the Remarkable Mountains beside Lake Wakatipu. Glaciers in the past have gouged out the valleys. The elements of a severe climate and water have eroded the mountains. Water has laid the flats in the valleys. Men must work with these forces if they are to occupy this country successfully. (J H Johns)

Rainfall, Runoff and Rivers

The subject is water and soil in New Zealand, the natural resources that have been primarily responsible for the economic wealth of this country. They will, if cared for, continue to produce that wealth in increasing quantity.

> "Speaking of disasters, some people were inclined to say, 'This will never occur again in our lifetime'. It reminded him of a statement that the first engineer he worked under used to make: 'You have never seen it rain so hard that you could not imagine it raining a little harder or a little longer; only one of those conditions is necessary to make a bigger flood than you have ever seen'." (F W Furkett *Proc. N.Z.I.E., Vol. XXI*: 81)

Many characteristics of water can only be understood in terms of quantities and flows. A mental picture of these can best be formed by making comparisons. Measuring static quantities of water we talk of litres and cubic metres ($1m^3 = 1000$ litres). Rainfall is measured in millimetres (mm). Flows are expressed in cubic metres per second (cumecs or m^3s). This is a measure of the amount of water flowing past a given point in one second. (If 1000 Kiwis each drink one litre of beer in one second that is a cumec).

The city of Wellington used in 1976 the equivalent of a flow throughout the whole day of 2.25 cumecs. The figure for the city of Auckland was 2.0 cumecs. The Waikato River has an average flow at the Taupo outlet of 129 cumecs. In theory it could, therefore, supply over 60 Aucklands if all the water were used for that purpose. The Buller, our river with the largest recorded volume of water, has an average flow of 501 cumecs, but a peak flow of nearly 12 500 cumecs.

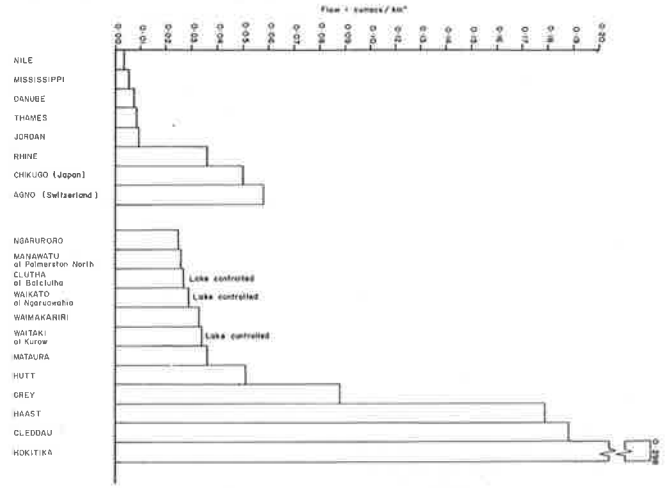
Another important measure is the flow of a river in relation to the size of its catchment. It is known as the specific annual average discharge, and is measured in cubic metres per second (m^3s) of flow per square kilometre (m^3s/km^2). This is the relationship

2. The power of water. A rainstorm has unleashed this raging torrent of water and boulders in the Whitcombe River, part of the headwaters of the Rakaia. (MWD)

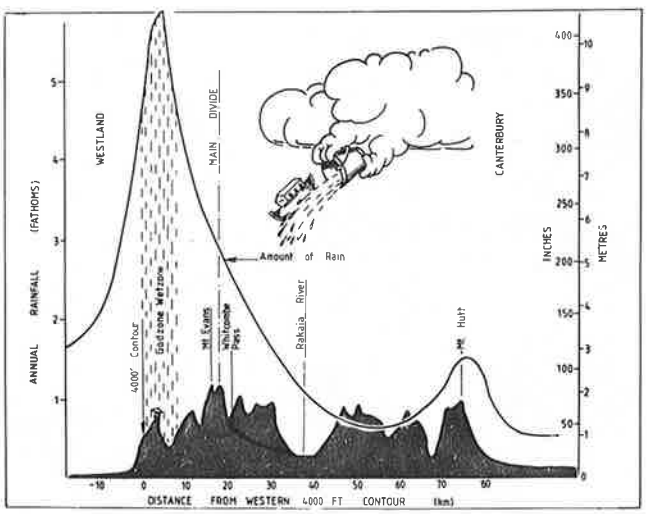


between rainfall, and/or ice and snow melt, and runoff over the whole of a river catchment. Apart from a few limited areas in the world, New Zealand rivers have the highest specific discharges. The accompanying graph gives a comparison of our rivers with some others around the world.

Rainfall throughout most of the New Zealand lowlands averages between 600 and 1600 mm per year. In parts of the east of the South Island in the rainshadow of the Southern Alps, it is less. There the average can drop to 350 mm per year and droughts of a few months' duration can occur (even in winter, as we saw in 1982).



3. Specific annual mean flows (cumecs of flow per km²) of a few overseas rivers compared with those of some main New Zealand rivers. (MWD)



4. Rainfall measurements taken across the Southern Alps from Waitaha Valley to Mt Hutt "... at 4000 feet contour .... rainfall reaches a near world peak of 12 metres per year .... enough to reach the 5th floor of most tall buildings .... drops off steeply toward the divide .... eases off east of divide. High rainfall zone is very narrow indeed." (From T J Chinn, NZ Alpine Journal 1979, *Vol. 32).*

On the windward slopes of the mountains rainfall increases rapidly with altitude, reaching several thousand millimetres per year. Recent studies show admirably the effect on rainfall of the Southern Alps. Measurements were taken along a line across the Alps roughly between Hokitika and the Rakaia River. Rainfall 40 kilometres west of the main divide—on the wet West Coast—was in excess of 2000 mm, the peak was 9000 mm just west of the divide, and there was a drop to less than 1000 mm, 70 kilometres east of it.

Precipitations of 12-13 000 mm have been measured in some New Zealand mountain areas. For those who still think in terms of imperial measurements this is nearly one inch per day: tremendous rainfall, matched in few other temperate localities in the world.

It is, of course, rainfall (or other precipitation, such as snow) and the shedding of it by the earth, that causes rivers to form. The total amount of rainfall gives a base flow to a river. But it is often the rate of rainfall and the speed with which it is shed that determine the size and variation of the river flow. Floods occur when rainfall is so heavy and runoff so rapid that a river cannot contain the flow within the banks it has formed during average flows. The highest floods occur when the ground is saturated from previous rain and more falls, or when rapid snowmelt adds to the runoff.

Rivers are continually changing. In the mountains, where their gradients are steep, they erode rock which they grind up as they carry it along and then drop when gradients ease. By that time boulders may be reduced to shingle which can form fans when the rivers reduce their gradients as they emerge from the mountains. Rivers can change their courses down the sides of these fans as they are built up. Sometimes the fans can be spread out



5. Measuring precipitation at high altitudes. (MWD)

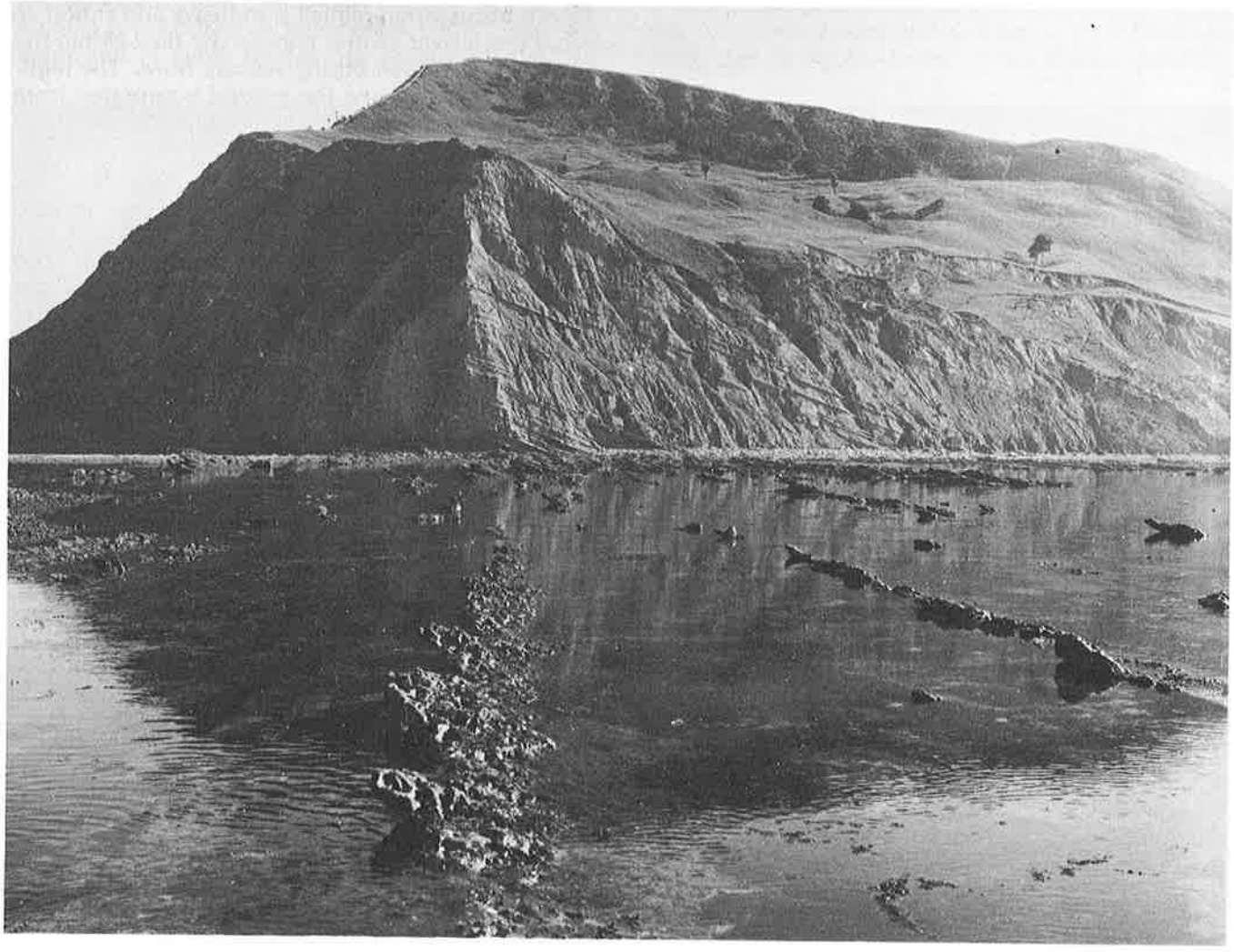
as gentle slopes stretching for many miles from the mountains as has happened in the formation of the Canterbury Plains.

Shingle may become finely ground to form sand and silt, especially if the original mountain rock is soft. Given the appropriate length and gradient the river changes from a shingle to a silt phase. In the latter, silt is carried along in suspension. During floods it is taken over the banks and dropped as the water becomes still. Over very long periods silt accumulates to form flood plains. The banks where the coarse sand or silt is dropped first are raised and these (known as levees) can sometimes rise until the river is flowing above the flood plain. During floods rivers may breach the levees and change their courses across lower parts of the flood plain.

In the shingle phase the energy of a river is taken up by moving its massive bed-load along. In the silt phase energy is dissipated by forming meanders, usually across gently sloping or almost flat flood plains.

During the building up of flood plains old river beds of shingle and sand can be buried. If the present bed of a river crosses above these, water may percolate down to them. This underground water then flows through the old bed material, provided it has remained permeable. Heavy rain can also soak through to become underground water if the ground is porous enough. Throughout New Zealand there are a great many underground sources, fed mainly by rivers. In places they have become of considerable importance in yielding water supplies for irrigation and urban needs. Underground water, like surface water, can readily be overdrawn or polluted.

6. Cliffs at Tatapouri, East Coast. Rapid sea erosion of the soft rocks is demonstrated by the shore platform which has been formed over the last several thousand years. Land is slipping down towards the cliff. (D L Homer, NZGS)



Resources require detailed and careful study, which is difficult to carry out. Substantial research programmes on these subjects are now underway.

The seas around the coast of New Zealand are rough, with strong currents. Four-fifths of the 11 200 kilometre coastline is exposed to the open sea. Of this nearly 20 percent is accreting but 25 percent is eroding, as witnessed by the cliffs and movement of sand.

Sand and silt brought down by the rivers to such rough seas does not build out in deltas as it does in calm seas or lakes. Some is dropped to form bars at river mouths. Some is washed along the coast to form beaches and sand bars out in the sea. Behind these, quiet estuaries may be formed. The mouths of rivers can migrate along these sand bars depending upon currents, storms, tides and floods. In this way river mouths can move rapidly and for distances of several kilometres. Trying to stabilise the mouths of New Zealand rivers is a difficult and costly operation because works are constantly threatened by floods and high seas.

The same forces eat into soft and unconsolidated coastal rock or sediment formations. Vertical tectonic movements are also rapid enough to have local effects. Severe coastal erosion can occur at unpredictable intervals.

Remarkable changes are occurring at many places around the coast. Farewell Spit accumulates sediments from the West Coast rivers and is extending further into Golden Bay at the rate of almost 70 metres a year. North of Milford Sound sediment has helped fill in former fiords and has smoothed out the coast from Martin's Bay to Farewell Spit. On the opposite side of the South Island, along the South Canterbury coast, Upper Pleistocene conglomerates are being eroded at the rate of one or two metres per year with serious results.

In many places and in many ways man's activities have interfered with sediment supplies, resulting in artificially created rapid erosion or accretion. Coastal habitations have often been threatened or destroyed. The Soil Conservation and Rivers Control Council has been burdened with problems of coastal erosion. Great pressure is put on it from time to time by those whose properties are threatened, even though it might be well known that halting the erosion process is impossible. Some attempts to do so have been bottomless pits for sinking money into.

Through the Ages

A few examples from overseas will illustrate how people through the ages and in comparable situations have managed their water and soil resources for their wellbeing, or mismanaged them, often to their great disadvantage.

While men remained nomadic hunters soil was not greatly important to them, but water was; they could not live without it. They had to have clean water for drinking and bathing. Other animals also needed water, so the best place to hunt was along rivers and around lakes and water holes. Here men could also begin to fish. The making of boats enabled men to extend their range of hunting and fishing. Waterways facilitated communication and trade.

Ability to hunt and fish and gather food developed long before agricultural skills, which progressed painstakingly in more recent times. The most responsive soils were the rich silts deposited by rivers along their lower reaches. The water adjacent to these areas could be carried to the cultivations, but this required hard labour for little result. An easier way was to lead water along ditches to the crops. Systems of ditches and dams were formed and were constantly improved to become intricate systems of irrigation. The first great civilisations were based on the cropping of irrigated land, and, ever since, the rich silt flood plains have been sought after the world over.

Cultivation produced more food than hunting. It therefore paved the way for a more rapid growth of population and for the concentration of it in closer and larger settlements. This in turn gave people opportunities to diversify their skills and to trade in the results of craftmanship.

Water assumed increasing importance as these developments took place. It was essential for cropping, it was the medium of transport, and, as urban communities developed, it had to be collected and distributed for daily domestic use. As highly developed civilisations appeared along rivers the Nile, the Tigris and Euphrates, the Indus and Ganges, the Yangtze, the Yellow and other rivers, the management of water in these rivers provided the springboard from which mankind took gigantic leaps forward in achievements.

The Nile

We read about the great dynasties of Egypt; the building of intricate and vast monuments in the pyramids and sphinx, the working of metals and the invention of all manner of things. This civilisation was bound to the river Nile. We are usually taught little about that, beyond the fact that the river floods annually, and that these floods provided the water for the cultivated land in its lower reaches and fertilised it each year with a deposit of silt. How did this inter-dependence evolve?

Early rulers were the managers of water as well as of people. They were all-powerful in controlling distribution of water for irrigation. How did they administer this great reserve? During this century

astonishing changes have been taking place in the management of the Nile. These demonstrate the wide range of matters that must be taken into account in manipulating a river upon which countries are so dependent.

A major attempt to improve and expand Egyptian agriculture was made by building the first Aswan dam at the beginning of the century. This stored water and regulated floods. Results were so successful that subsequently the level of the dam was raised to 36 metres. In the 1930s the Sudan also built a major irrigation scheme using the Nile water. By the 1950s nine dams and barrages controlled the Nile within the two countries.

In 1969 the Aswan High Dam was completed, a huge structure 110 metres high. It impounded such a large volume and weight of water that unexpected problems of seepage and evaporation were encountered. It also prevented the flow of river silt that had fertilised Egyptian agricultural land for so long.

These developments have involved technical, social, economic, political and environmental problems as well as difficult negotiations between countries. The result would seem to be that Egyptian agriculture, whatever its improvements, has come to rest on a precarious base. The management of the Nile water is now making even more demands on the rulers of Egypt than it did in ancient times.

East Asia

Other great rivers have equally complex histories of inter-dependence with human populations. The Yangtze flows for 6000 kilometres across China emptying into the sea at Shanghai. Between one quarter and one third of the huge Chinese population, or one twelfth of the people in the world, live in its basin and depend on the river for survival.

One unusual water resource occurs in Cambodia (Kampuchea). The monsoon rains bring summer flooding of the Mekong river. It overflows into a major tributary, the Tonle Sap, which then reverses its flow into central Cambodia where it expands the lake system 7 or 8 times for several months. The heat causes plankton to multiply rapidly in the shallow lakes, and, "fish have only to open their mouths to feed themselves". Over 170 species are caught and give the highest fishing yield in the world.

The Thames

London grew up along the river Thames because it provided water the population needed, a convenient drain for disposing of refuse and a sheltered stretch of tidal water for the development of a port and trade. All uses were developed together. There are many lurid descriptions of the once deplorable state of the river and its surroundings. Royalty often complained because the "dung, lay-stalls and other filth" along the banks created difficulties in getting along it. Dwellers on its banks resorted to devices such as hanging cloth saturated in ammonia over their windows to counteract the stench. In spite of these conditions water continued to be drawn from the Thames for drinking until quite recently. If there was any treatment at all it was an ineffective filtering. One of the results was cholera epidemics that continued in London until after the middle of the 1800s. During that century the relationship between the disease and the impure water supply was first postulated. The Thames had then reached an advanced stage of pollution. Fish and birds died along with the population.

Royal Commissions in Britain investigated river pollution and water supplies more thoroughly than ever before. Urban authorities began to look to the pure water available from the hills and mountains. Before they could harness these areas they had to know a great deal more about their hydrology, rainfall, river flows, and storage possibilities. "Within no more than a quarter of a century a thoroughly disorganised and irresponsible state of affairs had been replaced by standards that are high", noted a subsequent report.

Nowadays if you walk into the offices of the Greater London Council on the banks of the Thames you can see a fish tank containing many species of fish all caught in a river which not so long ago was "dead", devoid of fish. It was international news when two rare species of smelt were caught in 1979.

The history of the Thames is a lesson for all because it has been estimated by the United Nations that at least half the population of the developing world does not have safe water to drink and three-quarters have no sanitation facilities. At least 10 million children die of waterborne diseases every year and the World Health Organisation blames inadequate water and sanitation for 80 percent of disease.

The Greater London Council has completed another important task: the prevention of possible tidal flooding by the Thames of the huge capital investment along the lower reaches. The Council says: "There are two continuing reasons for the danger and one special threat which occurs from time to time. The continuing reasons are that London is slowly sinking and that the tides in general are rising and the special threat is from surge tides". When a city is 2000 years old these geological processes become significant.

Men, Mountains and Erosion

Men moved into the mountains first for hunting, later for cultivating the easier land and herding domesticated animals in the forests and on the tops.

They extracted wood from the forest for fuel and for building material. Gradually, greater and greater quantities of wood were sought for industry.

This was happening before the effect of vegetation on water and soil was understood, and long before anything was known about management of forests for perpetual (sustained) yields of wood. Between accidental burning, over-cutting and overgrazing, huge tracts of forest were destroyed and erosion on a severe scale was induced. Soil was stripped away and the rivers into which it was washed were soon affected.

In Mesopotamia populations that grew up along the Tigris and Euphrates drained swamps and established an intricate network of canals. But deforestation in the headwaters to supply the great cities with fuel and timber caused the rivers to become more unreliable and floods more damaging. Silt filled the irrigation channels and canals and in something like 5000 years the delta of the rivers extended 300 kilometres into the Arabian Gulf.

In mountainous Greece heavy demands were made on wood for small industries, such as boat building. The deforestation that these uses and overgrazing caused brought in its train widespread erosion. Rivers built up their flood plains and deltas built out the coastline. The sites of some of the battles of classical times fought on the coast are now several kilometres inland.

In central Europe, where the last glaciation has left narrow valleys and steep mountains, settlement is constantly threatened by torrents and avalanches. To prevent this situation from deteriorating, control of tree-felling in the forests on the valley sides was introduced as early as the thirteenth and fourteenth centuries. Sometimes felling was totally forbidden in forests perched above villages. Animals, principally goats, were nevertheless allowed to graze in these forests, and in time the constant browsing destroyed some, thus threatening settlements. Long and bitter experience taught the lesson of the vale of protection forest.

Today in these central European countries, forests are retained and management regulated although they are, for the most part, privately owned. In Switzerland the forest area has remained unaltered since the last century and over 80 percent of it is designated "ban-wald". In many of the mountains of Europe, especially at high altitudes, such is the protection value of forest that it is being re-established at great cost.

The USA

The Dust Bowl of the Great Plains States of North America was once held up as an example of what could happen when soils were maltreated. Rapid occupation of the land by people who did not recognise the hazards led to the trouble. Control measures have curbed this erosion, but while it occurred it depleted millions of hectares of light soils in low rainfall areas. In some severely depleted tracts of land depopulation occurred.

Experience which coincided with the Dust Bowl period, but in another area, made the USA a model for other countries. The western slopes of the Appalachians were denuded by mining, milling and cash cropping. By the 1930s dangerous and costly flooding down the tributaries of the Mississippi, and especially the Tennessee and its tributaries, required urgent action. In an unusual enterprise combining federal and state agencies, the Tennessee Valley Authority was established. Twelve major dams and 15 smaller ones, hydro electric stations, fertiliser works and soil conservation programmes were among the TVA's undertakings. New industries were attracted to the region by the cheap electricity and improved communications, recreational use of the new reservoirs increased tourism and a depressed area moved ahead. Although TVA did not bring all the social benefits that had been hoped for, it remains a classic example of the benefits of integrated soil and water planning over whole catchments.

Israel

In the State of Israel land use is controlled by the allocation of water, the supply of which is about 1 percent of the fresh water resource available to each person in New Zealand. Apart from costly desalination of sea water additional water can only be obtained by improving management practices, by reclaiming sewage water, recharging underground sources and collecting every possible litre of run-off.

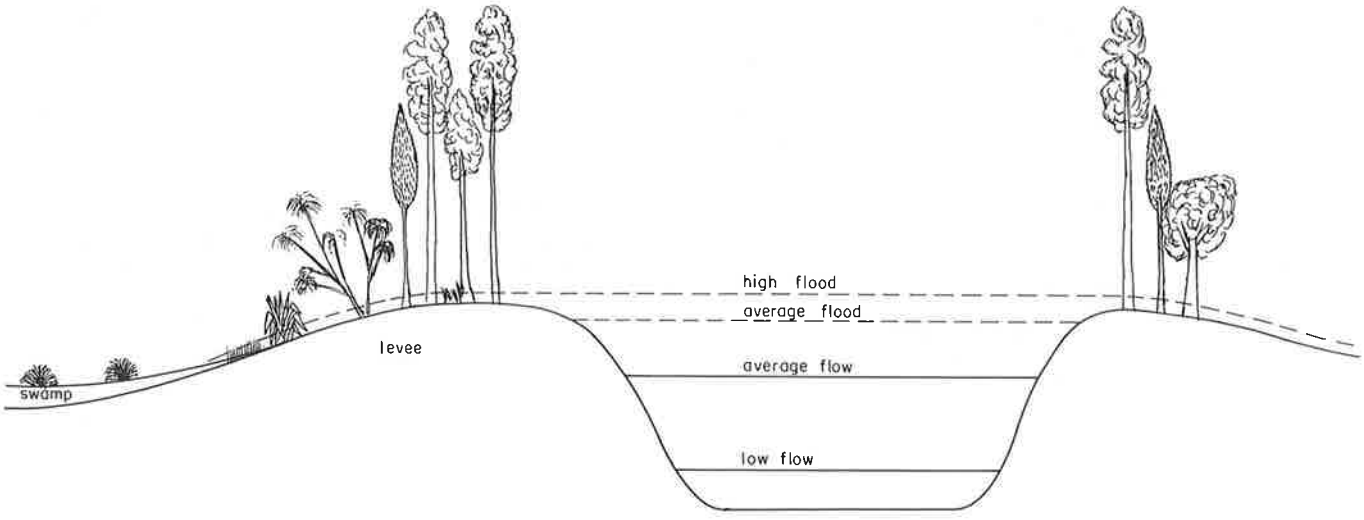
THE SETTLEMENT OF NEW ZEALAND

We now turn to New Zealand where there have been no millenia of adjustment between mankind and the environment, such as those we have been discussing.

High hills and mountains occupy three-quarters of New Zealand; one quarter only lies below the 200 metre contour. This large area of high country acts as an efficient condenser of the moisture collected by the prevailing westerly winds blowing across the Tasman. The succession of anticyclones and depressions brings winds from the east and south as well, the latter sometimes bringing snow.

This precipitation supplies over 70 main rivers rising in New Zealand's mountain chains. Besides these, many smaller rivers and innumerable streams flow directly to the sea from hills between the large rivers. Even the main ones are short, the longest, the Waikato, being little over 400 kilometres long, including its source the Tongariro which flows into Lake Taupo. The Clutha river, which is 340 kilometres long, has the largest catchment: 20 00 square kilometres, or about 12 percent of the country.

Maoris penetrated the whole country in their search for indigenous produce and the rivers provided them with important thoroughfares into the interior. The Maoris were fishermen, hunters of birds and gatherers of natural foods, cultivating very small areas only (partly because few of their traditional crops would grow in the cold New Zealand climate). They were expert canoe-makers, using the fine native timbers to perfection for this purpose. They established some of their villages on river banks where they had access to water and fishing.



7. The bed of a river in its lower reaches as it flows across a floodplain. The bed carries an average flood but a high flood overflows the banks and drops the heaviest material to form a raised bank or levee. There the ground becomes dry most of the time. Kahikatea and totara forest might grow on it. Away from the levee the water ponds to form swamps in which phormium, raupo, sedges and rushes may grow. (MWD)

Minimum disturbance to the land by cultivation was offset by fires which destroyed large areas of forest in the drier, eastern parts of the North and South Islands. A few million hectares of tussock grassland and shrubland, the result of fire, replaced forest on the east of the South Island and probably in parts of the North Island as well.

A somewhat similar effect to that brought about by the fires had occurred in the central North Island where some of the world's largest eruptions of recent geological times had spewed out volcanic ash and pumice over thousands of square kilometres, sometimes burying the existing landscape under several metres of new deposits. Vegetation, probably largely forest, had been smothered or burned. The fresh pumice was colonised by grasses and scrub, although in time forest returned from surrounding areas and a mosaic of grassland, shrubland and forest resulted.

Even taking account of the changes brought about by fires, and by glaciation and eruptions, it is thought that about two-thirds of the whole country was covered by dense, evergreen forest when large scale settlement began in the nineteenth century.

The first whalers, sealers and traders used the coast for habitation and shelter. Although amazingly mobile in sailing the world they did not penetrate far inland, keeping to the lower reaches of rivers, bartering with Maoris and building ships from totara and kahikatea growing along the banks. The sea was their life.

But from the 1840s onwards came a stream of immigrants seeking new lives. They were different and had a compelling urge to own land. In the settlement of their new country were they going to repeat the mistakes made down through history? Could they benefit from the studies and experience elsewhere in the world that were beginning to unravel the relationship between plant cover, soil erosion and natural water? This knowledge was very new, and by no means widespread.

The tussock grassland suited settlers admirably in their quest for pastoral land. Only burning was necessary to make it suitable for sheep. Throughout most of the remainder of the country dense forest protected the plains and hills and the mountains behind them. Rivers provided the only easy access to all this country and the only means of moving heavy possessions. Ships, therefore, braved the dangerous bars at the mouths and sailed into the quiet estuaries and inlets behind. From there people occupied the high banks of the rivers and worked their way inland.

The draining of swamps and clearing of the dense forest growing on the rich soils of the flood plains was gradual. Along the river levees settlements were formed just as the Maoris earlier had built theirs, and just as men for thousands of years had done in other parts of the world. The first crops were grown along the banks.

Settlers built some of the first boats on the rivers to transport themselves, their harvests and timber cut from the forest. The rivers provided them with water and took away their refuse.

Further up the rivers they penetrated hills and mountains. Settlement here was sparse compared with that which grew up adjacent to the rivers where there was the water that everybody needed.

This was the sequence of events wherever the rivers had forested floodplains in their lower reaches. Only in the already grassed regions of the South Island and around harbours where topography was gentler, was occupation easier. Around the Waitemata and Manukau Harbours, for example Maoris had already built up dense settlements. Pakehas followed them.

The Rivers—Boons and Barriers

Rivers provided access, but at the same time they presented great hazards because of their frequent flooding, ever-changing courses and impassable lower reaches. During floods lives and homes might be lost, stock drowned, bridges and roads washed away, land eroded and whole townships inundated. Drowning was a major cause of death during the early years of settlement. Early newspapers contain many accounts of serious floods and their consequences. If the lower reaches of the rivers that flowed across the fertile plains could be controlled then settlement would become much more stable and productive.



8. Reconnaissance of forest resources on the West Coast in 1923. Crossing the river by means of a 'belt and braces' type of transport; a matter of necessity because of the absence of bridges. (NZFS)

The Onset of Erosion

The settlers' energies were thus early directed towards the solving of river problems, but while the lower reaches were slowly being confined to their courses, settlement, with its accompanying clearing of forest, was spreading out to hills and mountains—to the sources of the rivers. Attempts, not always successful, at conversion to pastures proceeded apace. People in the lower parts of river catchments, where towns and villages were expanding, watched this process. They maintained that changes were bringing down more frequent and larger floods. As clearing proceeded higher and higher, criticism became louder; "Look after the catchments and the rivers will look after themselves", was a cry often heard. What the facts were was then impossible to prove, except that violent floods had always occurred even in fully forested catchments.

Changes that did occur, however, were that indiscriminate clearing and burning led to the onset of soil erosion, which not only depleted the soil that the farmers were clearing the forest to uncover but clogged the streams and rivers as well. The development of erosion has been summarised by L W McCaskill in his book *Hold This Land*.

The central North Island volcanoes had deposited loose ash over very wide areas of the Island. There had scarcely been time for nature to form a consolidated soil on these highly permeable deposits before agricultural land development on an extensive scale commenced. The broken surface allowed heavy rains to eat away the pumice even on gentle slopes or flats, and the heads of waterways ate back in perpendicular-sided gullies.



9. Clearing forest from the soft, tertiary rocks, already shattered by deep tectonic movements, on the East Coast set in train the most rapid and severe erosion in the country. Land wastage on a substantial scale took place and many waterways turned into 'rivers of mud'. (MWD)

In the South Island, within a few years of settlement, fire in the tussock grassland reduced the vegetation. Sheep ate it out still further. Wild animals introduced from Europe, North America and Australia in a fervour of acclimatisation found a congenial home and multiplied prodigiously. Rabbits adapted themselves most successfully. At the height of their infestations large areas of these grasslands could be fittingly described as "moving with rabbits".

Reduction of the protective tussock cover allowed soil erosion to take place throughout the steep country. Natural erosion also occurred widely in the South Island. Glaciation had left a legacy of screes, perched shingle and bare rock. Before the introduction of animals, vegetation and soils were gradually forming a stable cover over the country except where rapid uplift of the mountains and a harsh, particularly wet climate kept natural erosion at a high level. The new erosion removed the soil at a rapid rate and in the harsh climate it would take a long time to be replaced.

There were soon two problems, river flooding on the one hand and soil erosion on the other, connected by one basic factor, heavy rainfall. Events gradually led to legislation for the control of both matters.

The Taming of the Rivers

The need to protect homesteads and crops along rivers led to the construction of artificial banks—stopbanks. Unhappily these banks were at first in short stretches, and often deflected currents on to a neighbour's section of the river, so that as much bad blood as protection was generated by such



10. A familiar scene on the Hauraki Plains where early river control schemes were inadequate and constantly threatened by floods: a breach in the stopbank of the Komata Stream being repaired with sandbags, September 1960. (NZ Herald)

efforts. At the same time drainage of the swamps behind the river banks commenced; a difficult operation, because getting rid of the water often meant putting it on to a neighbour's property. Sometimes swamps were lower than the river bed so that costly pumping was required.

It soon became clear that success could only be achieved by stopbanking both banks and long stretches of rivers, and by draining larger areas of swamp—lessons the Egyptians and other civilisations had learned thousands of years earlier. Settlers, however, could not develop these methods until they had more money, equipment and labour, better communications, and were more highly organised.

Accordingly, under the system of provincial government, River and Drainage Boards and River Trusts were formed from the 1860s. In 1884, the Central Government passed a River Boards Act laying down the basis for the constitution of these bodies. The Land Drainage Act 1893 ensured that the functions of river control and drainage were interchangeable because they were usually related, often having to deal with the same water.

Numerous amendments and new Acts followed, in particular Acts to allow the Government itself to develop large and difficult areas of flood plains and swamps. Money, adequate engineering designs, and big machines had to be provided for such undertakings. Under one of these Acts, flood protection and drainage of 50 000 hectares of the Hauraki Plains was commenced—a mosaic of low-lying dry land, swamps and peat bogs, most of it flooded frequently by the Waihou and Piako Rivers, and near the coast by high tides.

In spite of the efforts of River and Drainage Boards flooding continued, because the bodies set up still could not deal with large enough sections of rivers. One Board might plan to control a section of bank on one side only and another Board the other side. Sometimes there were two and three River Boards to one river and a number of Drainage Boards involved in the swamps flooded by the river.

Because of growing investment in farms, drainage, roads, bridges and urban property, the Government was called more and more frequently to help finance restoration following flood damage. The increasing toll caused mounting pressures for still more comprehensive control. Enquiries set up to investigate flood disasters became common.

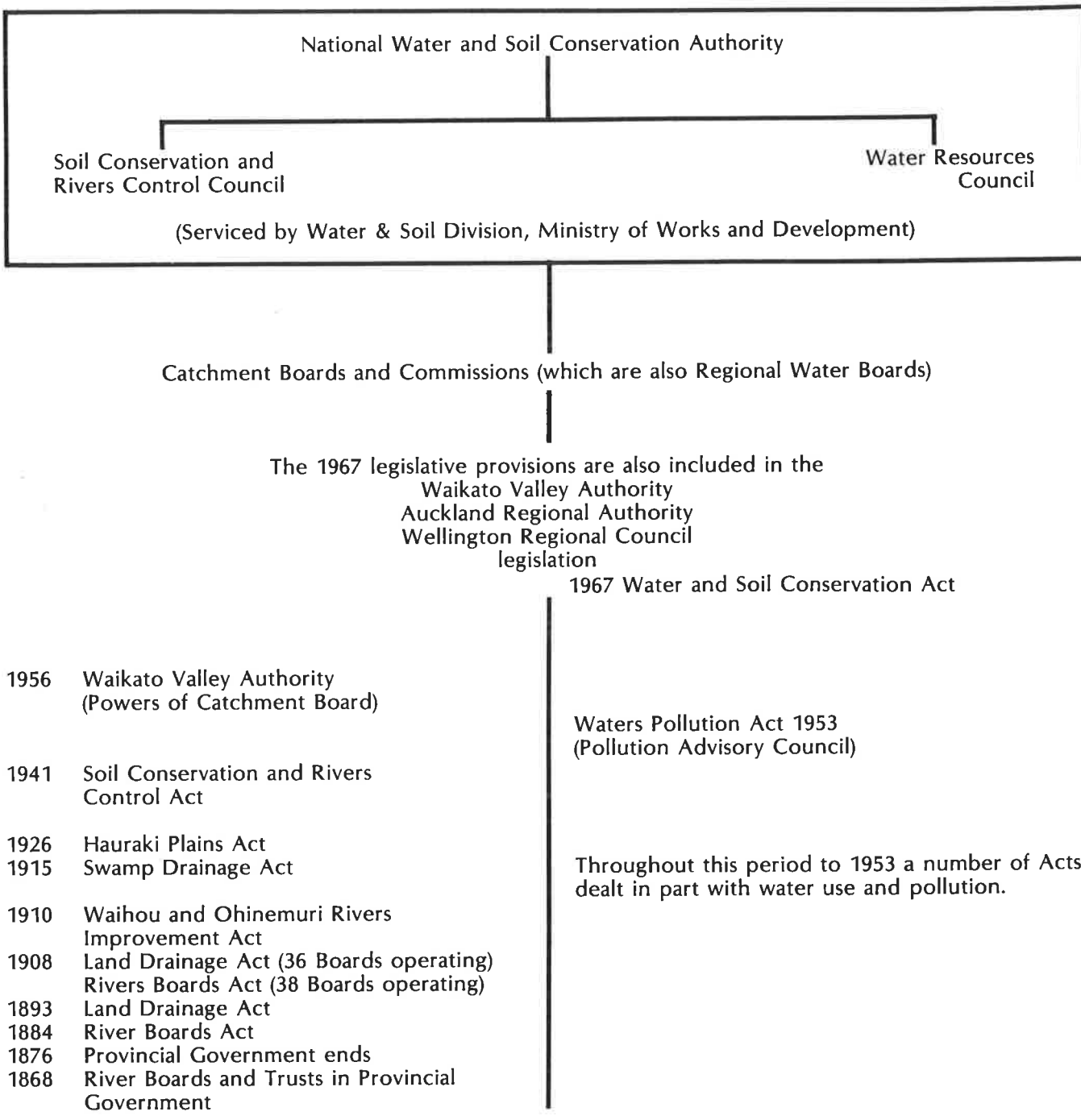
The need to arrest and cure soil erosion was becoming equally urgent if more and more hard-won land was not to be destroyed and rivers were not to be overloaded with silt and shingle. The one affected the other. If the two forms of control could be combined something effective might be achieved. What was wanted were groups of people, representing large districts, having the power to examine whole rivers and their catchments, and authority to collect money to finance extensive control measures.

From time to time recommendations of this nature were made in reports of Commissions and enquiries on river control. In New Zealand worldwide experience was simply being repeated showing that to change any part of a river or catchment affected other parts.

TABLE 1

Water and Soil Conservation Legislation

National Water & Soil Conservation Organisation (NWASCO)



Note: Legislation affecting river control commenced from the first days of settlement and incorporated soil erosion control in the Soil Conservation and Rivers Control Act 1941. Legislation in respect of water use and pollution grew up from other directions but was eventually linked with that for river control and soil conservation in the Water and Soil Conservation Act 1967 to form a basis for the coherent management and conservation of our most important natural resources.

THE SOIL CONSERVATION AND RIVERS CONTROL ACT, 1941

Comprehensive Legislation at Last

In a pioneering and imaginative piece of legislation the Government passed the Soil Conservation and Rivers Control Act 1941 "... to make provision for the conservation of soil resources and for the prevention of damage by erosion, and to make better provision with respect to the protection of property from damage by floods."

Catchment Boards were set up under this Act, each to exercise control over one or more major catchments. They were a combination of representatives elected by residents because of their local water and soil interests, and public servants who had regional experience in engineering, land management, agriculture, forestry or scientific matters—all things connected with the use of catchments. This combination had not been tried before, and it proved very effective. Administration by the Boards was financed by a general rate levied over each Board's district.

The Boards set to work to recruit river engineers and to train soil conservators. At that time there was very little experience in the country on soil erosion control. Soon comprehensive schemes for the control of flooding of the most troublesome rivers were being designed. The work would be paid for by rating everybody affected and by a subsidy from the Soil Conservation and Rivers Control Council, the central body established under the Act.

Thirteen Catchment Boards were formed between 1943 and 1955. Three Catchment Commissions were added, the difference being that the representatives on these were appointed by the territorial local authorities in the region rather than directly elected. In 1956, an authority for the Waikato, the Waikato Valley Authority, was set up under a separate Act.

Two further additions should be noted. The cities of Auckland and Wellington were involved in providing water for their growing populations. As the cities expanded problems of drainage and land stability also became increasingly difficult. When, therefore, their water supply Acts were revised provision was made in them to operate the provisions of the 1941 Soil Conservation and Rivers Control Act. Thus the Auckland Regional Authority and the Wellington Regional Water Board (now the Water and Soil Management Committee of the Wellington Regional Council) became in effect catchment authorities.

The areas of all these Catchment Authorities combined to cover 90 percent of the country. This rapid development was a reflection of the extent and severity of the river problems and soil erosion, and of the strength and acceptability of the legislation designed to provide a basis for control. This was not another transition stage but a consolidation of approaches which had evolved through more than a century of endeavour.

Soil Conservation Tools

Land Use Capability, Land Use Resource Surveys, Farm Plans, Run Plans—A multiplicity of titles; but they all add up to information directed towards the use of land in perpetuity, and, where applicable, sustained production. They have particular meaning

TABLE 2

Land Use Classification

Suitable for cultivation for cropping; increasing limitations and erosion risk	Class I	Very good land with few limitations to cropping.
	Class II	Good land with minor limitations.
	Class III	Good land with moderate limitations.
	Class IV	Reasonably good land but with severe limitations.
Unsuitable for cultivation for cropping; increasing erosion hazard.	Class V	Land with slight erosion hazard; unsuitable for cultivation.
	Class VI	Land with moderate erosion hazard.
	Class VII	Land with severe limitations and erosion hazard.
	Class VIII	Land with very severe limitations; unsuitable for productive uses.

where land is being degraded through erosion or where erosion is likely to be induced because of management malpractices.

In implementing the 1941 Act the Soil Conservation and Rivers Control Council introduced a system of erosion control based on Land Use Capability surveys and farm and run plans. The system has been described by McCaskill in *Hold This Land*. Briefly it consists of producing a map showing the land use capabilities—or barriers to land use—of various parts of a farm or run. Erosion control measures, for cure or prevention, are then integrated into a plan of management and finance for the whole property. Agreement to this plan is a firm contract between the farmer and the Council because grants are given to help finance the soil conservation measures.

Benefits to the landowner come through the curing of erosion accompanied usually by increased production over the whole farm.

Farm or run plans are powerful tools in erosion control and land management generally. They might well be used more widely for a number of purposes.

The essential basis of the system is the production of a map showing classes of land that are eroding or would be subject to erosion if used in certain ways. Eight classes (within which finer distinctions are made for individual areas on a farm) are used. They are shown in Table 2.

Many factors determine the use to which land can be put. The problem becomes how many of these can be combined on one map if the map is to remain intelligible. Land use capability mapping nowadays is based on a combination of geology, soils, relief, erosion, vegetation and land use. Other matters enter into land use capabilities, but those listed are usually the most important.

Since farm plans proved successful, the extension of this sytem to catchments or even whole Catchment Authority districts has been a logical step. Erosion in particular and land use in general affects streams and rivers and these in turn affect water quantities and quality and communications. Hence the need in some places for a whole catchment approach.

Recently a new tool has been developed for resource analysis, with the compilation of the New Zealand National Land Resource Inventory. This presents, at a mile to the inch scale for the whole country, the rock types, soil, slope, erosion, vegetation and land use capability. This information is published as worksheets and is stored by computer to provide rapid access for either tabulated or graphically presented data. Appended to the data base is further information on stock and fertilisers and on forestry potential.

11. A landscape showing land capability classes described in the text. In this picture there are no Class I and II areas (that is land with few limitations to cropping). Such mapping can help to provide a basis for improved and stable land use. (MWD)



WATER MANAGEMENT AND MISMANAGEMENT

The story was by no means ended. The number of domestic stock New Zealand farmlands carry is a wonder to all visitors. Pastures nurtured by good rain are a major influence, but plentiful drinking water from natural supplies has been another. Farm stock drank—and still drink—directly from streams and rivers throughout the country and this became at one stage the largest established use of natural water.

The wash from milking sheds and effluent from a vigorous dairy industry usually went straight back into ditches, streams and rivers. At the same time, fishermen were busy stocking lakes and rivers with trout and salmon. Angling and boating were growing sports demanding clean water.

Urban water supplies were often drawn from rivers, especially those with forested catchments, because the filtering effects and regulating powers on water of the native forests were quickly discovered. Some urban communities were fortunate enough to have discovered bountiful underground water supplies.

Industries, including the dairy factories and numerous freezing works, established themselves alongside rivers from which they could draw their water and return their effluents. Mining used large quantities of water and then poured it back, laden with silt, into rivers. Gold dredging churned up river beds thus changing the natural flow.

Hydro-electric schemes grew from small beginnings—the first station was constructed at Bullendale on the Shotover in 1866—to the artificial control of large lakes and rivers, often pre-empting use of the best water resources.

In response to all these demands on water, there evolved a bewildering amount of legislation covering water uses and effluent disposal. Some was countrywide in application, but some dealt with specific uses of a particular water resource, such as the Tasman Pulp and Paper Company Enabling Act 1954 authorising the taking of water from, and the discharge of trade wastes into the Tarawera River.

There were provisions under the Counties and Municipal Corporations Acts to allow local authorities to construct and operate waterworks. The large municipalities often had their own individual Acts dealing with water supplies, and some had control of the land yielding those supplies.

The Wildlife Act provided for wildlife sanctuaries which included water as well as land. The Lands, Forests, Public Works and Mining Acts all included major provisions dealing with water. There were dozens of other Acts and regulations involved.

It is relevant to read the list of departments included on a committee set up by the Government as late as 1963 to 'see through a glass darkly'. They were Works, Agriculture, Electricity, Forest Service, Health, Internal Affairs, Lands and Survey, Marine, Mines and Treasury; a reflection of the all-prevading importance and use of water.

"A halt must be called to the increase of water pollution", became a public battle cry. An alarming state had not yet been reached except in limited localities; certainly nothing to be compared with that found in some other countries. New Zealand did not have, or want, a Rhine or a Lake Erie. Nevertheless, dangerous trends were there.

The first concerted move to put these matters right came in 1953 when the Waters Pollution Act set up a Pollution Advisory Council and made provision for restricting pollution, though not for reversing it. The wording of the Act said it was to prevent the pollution of natural water "as far as possible". Alarm about fisheries, mainly freshwater fisheries, was one of the principal reasons for this changed thinking. The move towards improvement, therefore, was organised through the Marine Department because it was responsible at that time for fisheries. The Pollution Advisory Council operated under that department.

Ten years later the Water Pollution Regulations followed. They made provision for the classification of waters according to their uses. A standard against which the use of water could be measured thus became possible. Was the water safe to drink? Was it safe to swim in? What would a polluting discharge do to a certain class of water? These questions could be answered if the water being used had a classification. The provisions for classification were repeated in subsequent legislation.

These were tentative steps which could be understood only in the light of the widely accepted thinking, developed out of necessity by pioneers, that natural water was the most readily available and best means of diluting and dissipating pollution, and was there to be used for that purpose. It had been maintained in earlier years that New Zealand had ample, fast-flowing natural water, so that the danger of undue pollution was remote.

The measures taken to improve the situation up to the 1960s were palliatives and dealt with one aspect of water use only—pollution. The next steps were to be as bold as the previous ones were half-hearted. They were to provide New Zealand with the most constructive water legislation of any country in the world by bringing together all management of natural water, including flood control and drainage, water supplies and pollution, as well as the conservation of soil.

The Water and Soil Conservation Act 1967

The basis was laid in the Water and Soil Conservation Act 1967. It was linked with the 1941 Soil Conservation and Rivers Control Act. After preliminary measures, the new structure took full shape in 1971.

There were now two councils, the Soil Conservation and Rivers Control Council dealing with erosion prevention and flood control and drainage, and the Water Resources Council handling the management of natural water. Another body, the National Water and Soil Conservation Authority, was placed over the two councils to co-ordinate their policies and provide a link through its Chairman, the Minister of Works, with the Government. The whole structure, called the National Water and Soil Conservation Organisation (NWASCO) was serviced by a Water and Soil Division of the Ministry of Works and Development. That department had had much to do with flood control since early times, with bridge building and road making which were often affected by floods, and with aspects of water use. It already provided technical services to the Soil Conservation and Rivers Control Council.

The long title to the 1967 Act was an expansion of that introducing the 1941 Act. Its significance is far-reaching, so it is quoted here. The last lines are those inserted in an amendment in 1981 to give added emphasis to the recreational uses of water. Hitherto the use particularly of rivers and streams had been mainly for stock water supplies, urban water, hydro-electric developments and irrigation. These uses had grown rapidly and brought about changes to rivers, some of them major. But now there was a growing body of recreational users including boaters who wanted long stretches of rivers reserved. They sought complete reservation. But the management of a river has to have regard for its whole length and its continuous flow for all purposes. The solution was found by making the amendment to the 1967 Act.

> "An Act to promote a national policy in respect of natural water, and to make better provision for the conservation, allocation, use and quality of natural water and for promoting soil conservation and preventing damage by flood and erosion, and for providing and controlling multiple uses of natural water and the drainage of land, and for ensuring that adequate account is taken of the needs of primary and secondary industry, *community water supplies, all forms of water-based recreation, fisheries, and wildlife habitats, and of the preservation and protection of the wild, scenic and other natural characteristics of rivers, streams and lakes.*"

The new task to be undertaken was consideration of water in the natural state for comprehensive management. Somebody had to be allocated the work in the field. Who better than the Catchment Authorities, already part-way there? They controlled rivers, carried out drainage and sought to control water that caused soil erosion. They were therefore given the new task, but were called Regional Water Boards when they were dealing with water management—a somewhat clumsy chameleon.

Water management was too important a subject to allow local influences to affect control, so Regional Water Board boundaries were adjusted to cover the whole of the North and South Island and coastal waters. (The 1941 Act continued to apply only to about 90 percent of the two islands in respect to soil conservation and river control).

The complete structure is undoubtedly complex and not fully comprehended except by people working within it. This is to the detriment of public understanding. It must be remembered, however, that it has come together from markedly different directions. The practical result is the co-ordinated management of two naturally inseparable resources, soil and water, to the great benefit of the country. Simplification leading to better understanding is bound to come in time.

The 1967 Act introduced another policy of fundamental importance. All natural water was vested in the Crown and was to be controlled through a system of rights, both for taking water and for discharges into natural water. The general management and administration of the water right system was given to the Regional Water Boards. Although this system was to prove full of legal pitfalls in operation because there could be many claims on the one body of water and many uses of it already in existence, New Zealand was fortunate in being able to avoid any system involving riparian rights.

At last pollution trends could be reversed because an effective basis for water management was contained in the Act. To this end, provision for the classification of natural water was continued in the new legislation, which defined the classes and set out the criteria by which they were to be determined.

In the minds of many people once a class was set it became an immutable standard. A widespread move was made therefore to classify all natural water but in attempting to do so complexities soon appeared. Not the least of these were long-term changes brought about by land use within catchments and the effect of damming river flows causing nutrients to accumulate in the retained water. Other questions were raised by the diverse methods with which domestic and industrial wastes are assimilated and dispersed in natural water.

A committee given the task of making recommendations for possible changes in the legislation had this to say; "Classification is a subordinate and

optional measure which may be applied by a regional water board in a localised situation where its management position will be strengthened by such application."

From the outset Regional Water Boards were faced with difficult problems of management and costly programmes of investigation if that management was to be soundly based.

NORTH ISLAND CATCHMENT AUTHORITIES

The greywacke mountain ranges of the North Island stretching from Cook Strait to East Cape, with a branch to Cape Colville, are interrupted by the central volcanic plateau. Of the many remarkable aspects of the plateau the gathering of water is perhaps the most important. The plateau is the source of most of the large North Island rivers. From it and the adjacent mountains they flow to all points of the compass.

The Waikato flows north-west from the heart of the plateau. To the north, four rivers flow into the Bay of Plenty and two others, along a fault depression, to the Firth of Thames. To the east, four more flow into Hawke Bay, and to the south and west the Wanganui and Rangitikei flow to the west coast.

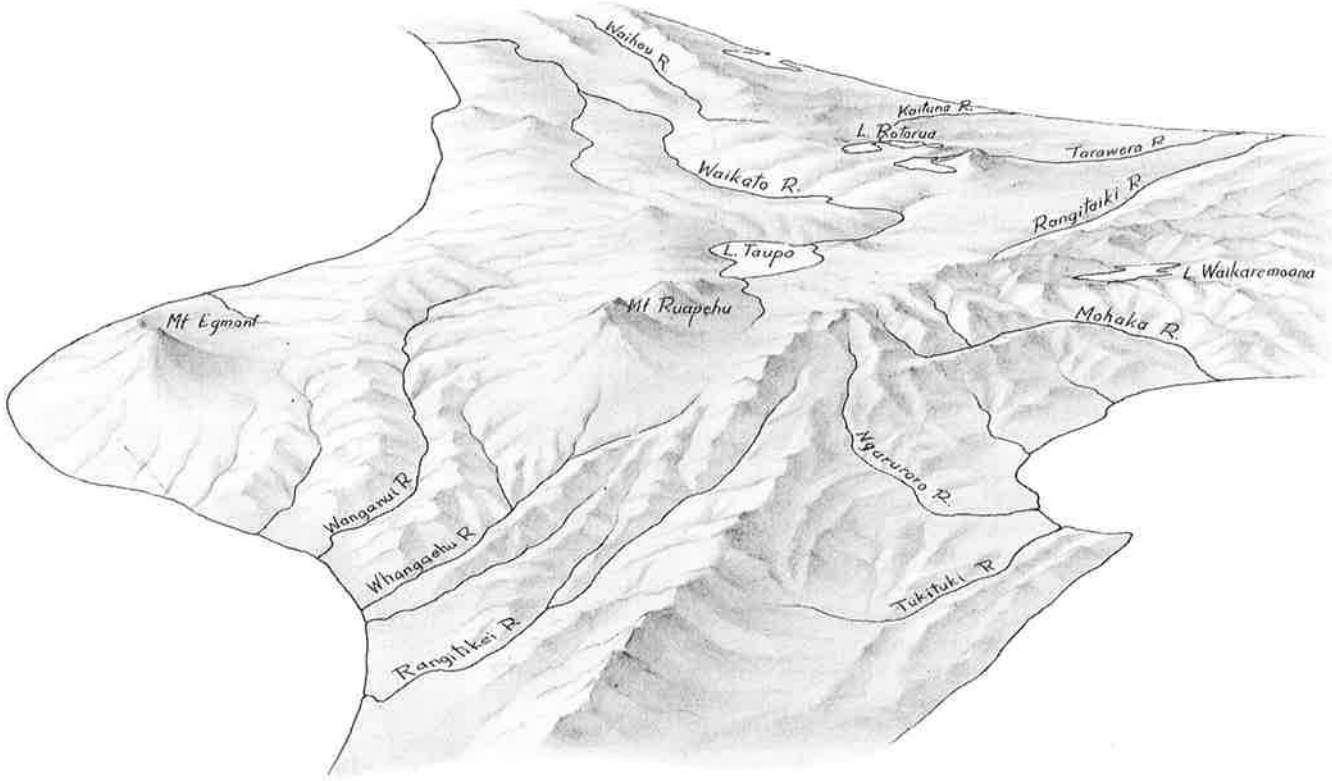
South of the plateau the mountain chain gives rise to other large rivers, including the Manawatu that takes an unusual course from east to west through a gorge in the mountains. Near Cook Strait the Hutt and the Ruamahanga take southward courses along fault depressions.

Mount Egmont stands isolated to the west of the volcanic plateau and collects moisture from the winds that blow from any direction around it. The result is a close pattern of consequent streams and rivers flowing down all sides.

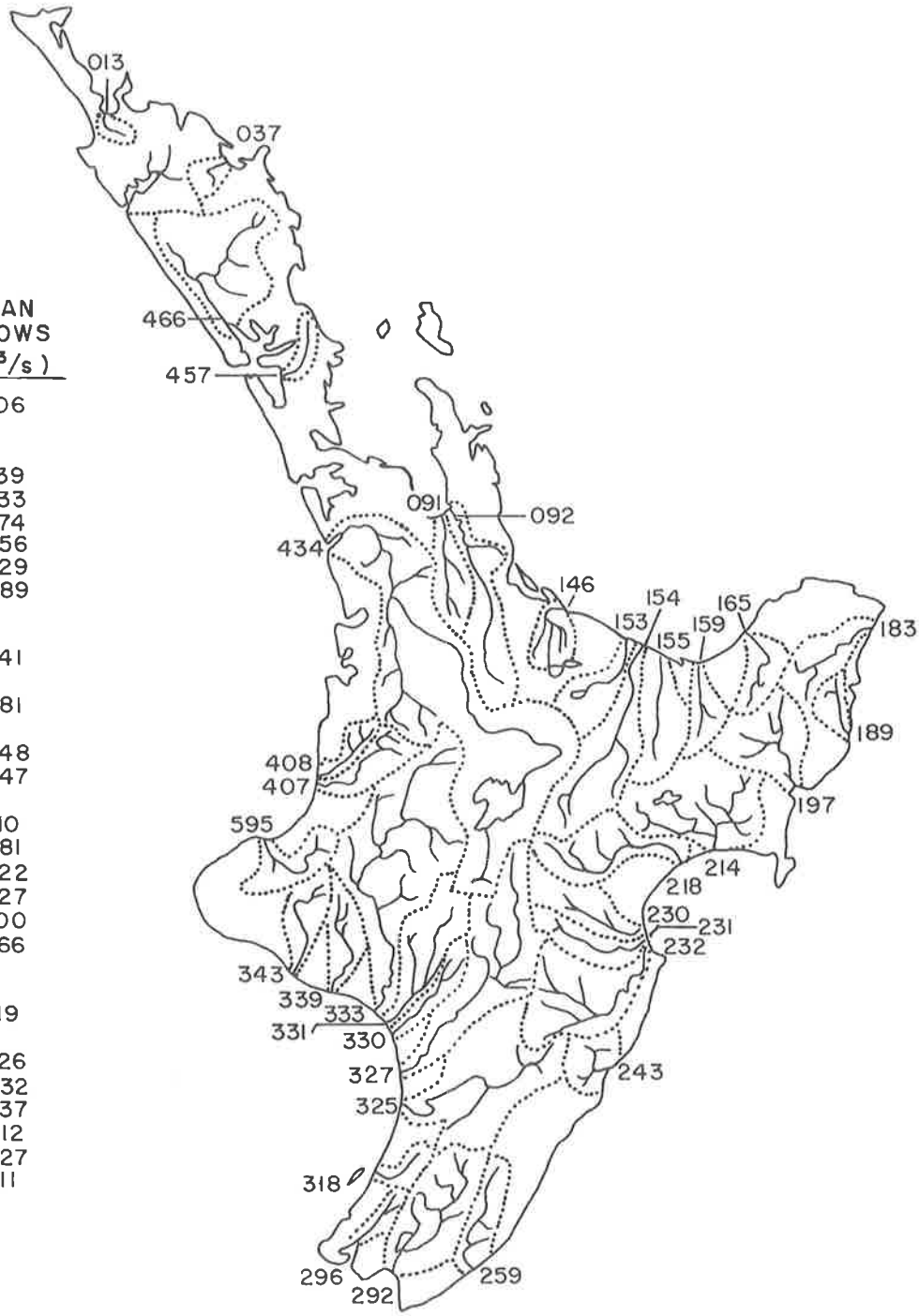
The long, narrow, North Auckland peninsula has no large rivers.

Most of the large North Island rivers have floodplains in their lower reaches, some of them extensive by New Zealand standards—up to 80 000 hectares. The long struggles to protect these from flooding and to deal with erosion and water management have led to the formation of 10 Catchment Authorities. In addition two urban regional bodies in Auckland and Wellington undertake the same functions in conjunction with the distribution of water supplies.

12. The volcanic plateau is the source of most of the large North Island rivers. (D W Lawrence)



No.	CATCHMENT	MEAN FLOWS (m^3/s)
013	*Awanui*	006
091	*Piako*	
092	*Waihou*	
146	*Kaituna*	039
153	*Tarawera*	033
154	*Rangitaiki*	074
155	*Whakatane*	056
159	*Waioeka*	029
165	*Motu*	089
183	*Waiapu*	
189	*Hikuwai*	
197	*Waipaoa*	041
214	*Wairoa*	
218	*Mohaka*	081
230	*Tutaekuri*	
231	*Ngaruroro*	048
232	*Tukituki*	047
243	*Porangahau*	
259	*Whareama*	010
292	*Ruamahanga*	081
298	*Hutt*	022
318	*Otaki*	027
325	*Manawatu*	100
327	*Rangitikei*	066
330	*Turakina*	
331	*Whangaehu*	
333	*Wanganui*	219
339	*Waitotara*	
343	*Patea*	026
395	*Waitara*	032
407	*Mokau*	037
408	*Awakino*	012
434	*Waikato*	327
457	*Hoteo*	011
466	*Wairoa*	



13. North Island main river catchments and mean flows. (MWD). (Reference numbers are those used by MWD).

MANAWATU CATCHMENT BOARD

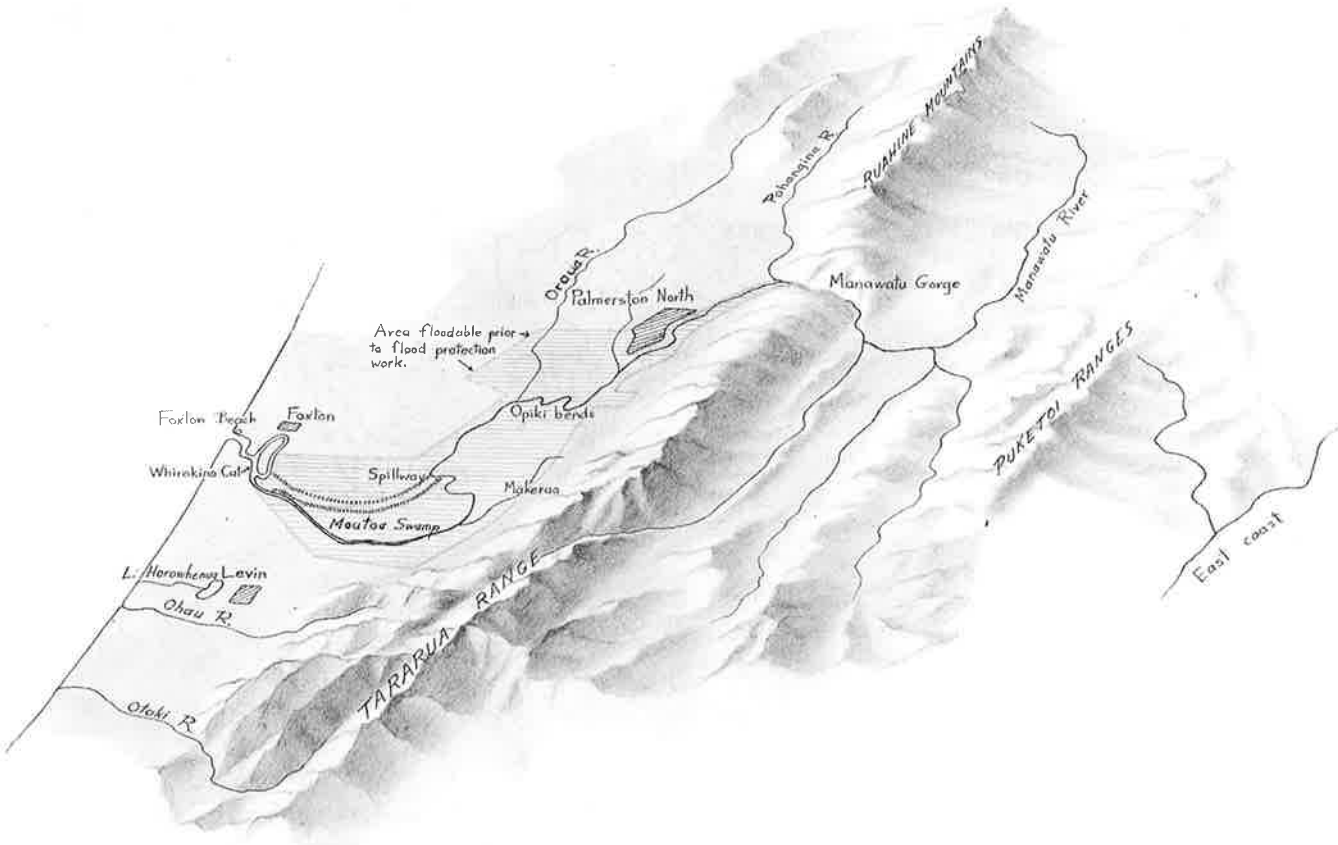
The Catchment District

The Manawatu Catchment Board was formed in 1943. In its present form of Catchment/Regional Water Board it administers water and soil matters in the entire catchment of the Manawatu River (5992 km²) together with adjacent smaller catchments; a total area of 7770 km².

If you asked a person on the streets of Palmerston North what the Board does, as likely as not you would receive a vague answer or none at all. He has probably never experienced one of the floods that in the past affected the city and drowned stock and sometimes people on the Manawatu Plain. He probably does not realise that even now, if the banks of the river protecting Palmerston North broke, one third of the city would be flooded.

The headwaters of the Manawatu River are in the Puketoi Ranges on the East Coast. Maori tradition says:

> "Away upon the slopes of the Puketoi Ranges there grew in the days of old a giant Totara tree into which the spirit of a God called Okatia suddenly entered, and endowed it with the power of motion, whereupon it gradually wormed its way over the land, gouging out a deep bed as it went, until it came to the mountain chain which separates the East from the West Coast. Then it clove a course for itself through this huge barrier, which the mighty Okatia split asunder as easily as a child would break a twig, and on passed the inspired tree, ploughing its irresistible way with many serpentine wanderings towards the sea, leaving the turbulent waters and still reaches flowing in its wake." (L T Buick, in *Old Manawatu*.)



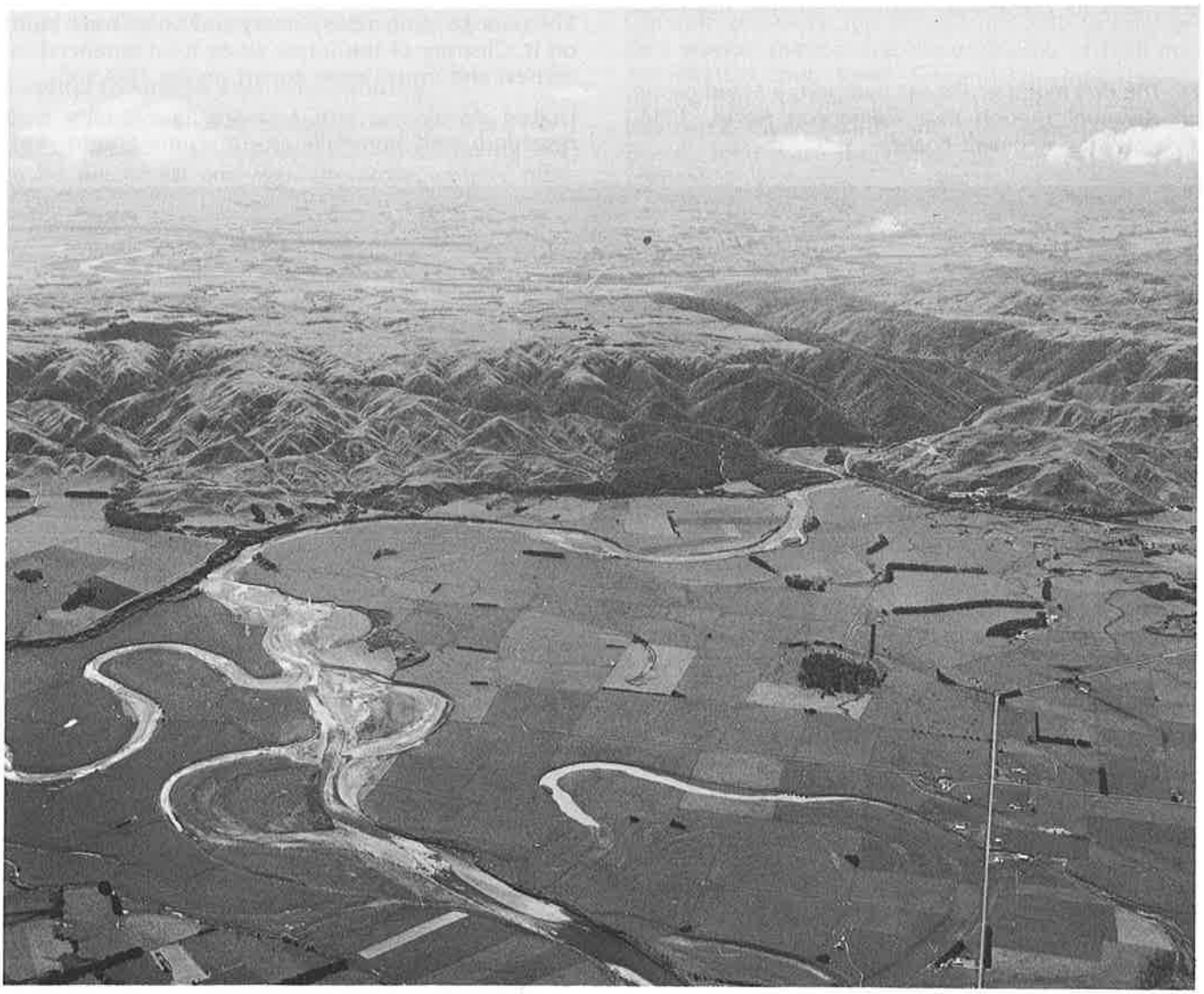
14. Manawatu Catchment District

The Manawatu River system occupies most of the district but small catchments of the Ohau, Otaki and Waikanae (not shown on this map-it was added to the Manawatu district in 1982) Rivers lie to the southwest of it and small streams flow to the east coast. Most of the water finding its way into the Manawatu gathers on the eastern or western flank of the Tararua and Ruahine Ranges. West of the Manawatu Gorge which separates the ranges, the river flows across floodplains extending from Palmerston North to Foxton. The main river control works, which include a major spillway and floodway, protect this area from flooding. (D W Lawrence)

The Manawatu catchment is thus divided into two roughly equal parts by the line of the Ruahine and Tararua mountains which rise to 2000 metres, the river having been able to maintain its course, through a spectacular everdeepening gorge, throughout the period during which the mountains were being pushed up.

The mountains act as efficient catchers of rain from the east and the west. The gorge, however, is a restriction to floods building up in the complicated catchment of the eastern tributaries and the maximum flows it has passed so far have ranged up to about 4600 cumecs. The river also collects water from the western side of the mountains and meanders in great loops across a flood plain built partly by the river and partly by uplifted seabed deposits. It then forms an estuary meeting the sea at Foxton Beach. It is tidal for some distance in its lower reaches.

Eighty percent of the catchment has been cleared of native forest; only on the mountains does it remain. Most of the catchment is now a landscape of well developed farms, with the city of Palmerston North just to the west of the Manawatu Gorge and a number of other towns and villages sited mainly on the rivers. On the small floodplain to the east of the gorge and the large one stretching from the west of it almost to the sea, farming and cropping have become intensive.



15. The Manawatu River has carved its way through the Tararua and Ruahine mountains as they have been uplifted. Viewed from the east, the river can be seen commencing its journey across the floodplain in the west. A small floodplain has been formed before the river enters the gorge. (S N Beatus, NZGS)

Early Settlement

Maoris found fish, birds, flax, totara and many other natural products in their searches along the Manawatu River. Moreover, it was readily navigated in the lower reaches by large canoes. Small ones could penetrate the gorge, and reach the network of rivers and the forest east of the mountains. It is little wonder that Maoris had built many pas along the river and its tributaries. The first Pakehas to settle along the west coast, not far from the mouth of the Manawatu river, were whalers about the 1820s. By the time organised Pakeha settlement began this part of the coast was reasonably well known.

In 1840 the New Zealand Company inspected the Manawatu looking for land suitable for settlement. The report was: "Altogether it is a most valuable district and its possession removes all that has been objected to at Port Nicholson on the score of the limited extent of land available".

Organised settlement began at a place called Paiaka on the Manawatu River levee, 15 kilometres or so from the mouth. The settlers had brought with them their domestic animals and crops, so they wanted land, good land, and much of it.

No doubt discouraged at first by the restricted amount of dry land on the narrow river banks, the frequent flooding of this, and the seemingly interminable swamps behind them, the settlers retreated closer to the mouth and established a township, Foxton. The land about there was poor, but higher, lying within the belt of sand blown inland from the boisterous west coast. A port was formed and a regular trade with Wellington sprang up.

The river became a busy artery and boats were built on it. Clearing of the forest along it commenced in earnest and crops were grown on the rich soils.

Foxton developed into a strong community and regarded itself hopefully as the coming centre of

16. The first mode of Pakeha transport, a Maori canoe on Awapuni Lagoon near Palmerston North, 1888. (Manawatu Catchment Board)



the lower Manawatu. But it was not to be. Settlers were looking for richer land than surrounded Foxton; land that lay in plenty along the river, in the swamps and under forest and lakes. Palmerston North seemed a more promising centre. Although 40 kilometres from the coast it was on the river and accessible by waterway, if not at first by road.

As early as the 1870s a road through the Manawatu gorge connected Palmerston North with Hawke's Bay. In the 1880s a railway link with Wellington was completed by the Manawatu Railway Company which was given a large grant of land, part of it on the Manawatu River flood plain. The line traversed this in spite of all the flood hazards. Nothing then stood in the way of Palmerston North's development, provided the rich surrounding land could be made productive. Drainage of swamps and freedom from flooding were essential steps to progress.

Swamp Drainage and Stopbanking

To achieve drainage and flood protection was a herculean task for a small population. Stopbanking had to be piecemeal and was, therefore, readily outflanked by floods. Only the edges of the extensive swamplands could be drained. The swamps were mainly large basins and drainage required the joint agreement and efforts of all landholders in each one. Such grouping was finally organised through Drainage Boards. The Manawatu Drainage Board was formed in 1894 with jurisdiction over some 14 000 hectares. Others followed in the early 1900s. River Boards also were established, one to protect Palmerston North and one the lower Manawatu, both widely separated and working independently. Both set to work enthusiastically to examine and record the piecemeal protection that had already been built, and to plan better, bolder and more continuous works.

Drains were gradually successful in getting rid of water but the basins continued to be filled by floods. It was a rigorous period of settlement, people, animals and roads being constantly under threat.

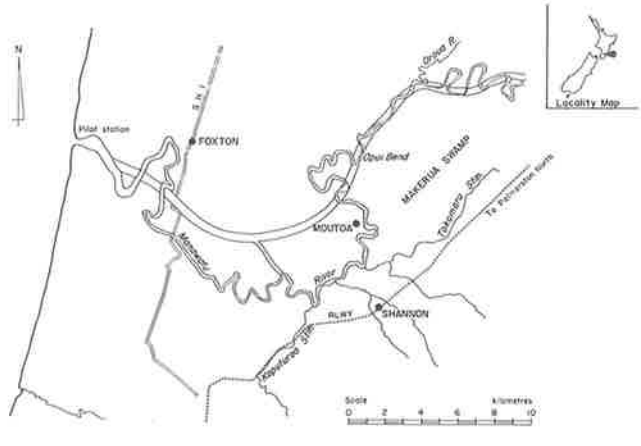
Because stopbanking of long stretches of river proved difficult to co-ordinate, some individual landowners raised their own protection and sometimes built groynes out into the river. Such works deflected the river in unexpected directions, often towards neighbouring landholdings. Feuding then followed the same pattern that it had taken for thousands of years in other countries.

More comprehensive planning was necessary if the potential of the flood plain was to be realised. But the River Boards found themselves hampered by lack of money because much of the land was, as yet, far from productive. It was a 'chicken and egg' situation: if the land was protected it became more productive and could then yield more rates; without protection there was little to rate.

The first attempt at continuous stopbanking was carried out by the Makerua Drainage Board for the Makerua Basin of some 8500 hectares. It was successful as far as that area was concerned, but water that would have entered the Makerua was diverted to other basins. There were surreptitious attempts during floods to cut the new banks. On one occasion the culprits were disturbed so suddenly at night that they left their tools behind them in their hurried flight. There was continuous rivalry between individuals and between groups of settlers in the basins.

Commissions were appointed from time to time to seek ways of overcoming the problems. In 1926 the Manawatu-Oroua River Commission interviewed people from 15 local bodies, including 5 Drainage Boards, 2 River Boards and the Foxton Harbour Board. Such were the numerous interests in river control.

At one stage a scheme was proposed for cutting out the bends and loops and taking the lower Manawatu River in a great sweep to the sea. Fortunately such a radical design was not adopted, for it could have led to disastrous scour of the soft banks, caused by an increase in river flow speeds. The engineer to the Manawatu River Board did make the sensible suggestion, "... that the whole of the land in the watershed of the Manawatu River and its tributaries should be included in the River Board's area."



17. Sketch map contained in the report of the Manawatu-Oroua River Commission 1926. The river realignment was proposed by F C Hay, consulting engineer to the Manawatu-Oroua River Board, and consisted of a huge sweep, nearly 30 kilometres long, across the floodplain.



*18. Moutoa Basin, part of the Manawatu floodplain. When this was first drained the New Zealand flax (*Phormium tenax*) that grew in the swamps, mixed with other vegetation, rapidly became dominant. The leaf was harvested about every four years and stripped for fibre. Before stripping machines were invented, Maoris used shells to strip the fibre out. Flax fibre was one of the most important items of trade in the early European settlement period, and remained an item of commerce until the 1930s. The Moutoa flax swamp, the last in the Manawatu, has now been drained and converted to farmland. (A L Poole)*

New Zealand Flax—A Bonus

During the draining of swamps an unexpected development occurred. Whalers had eagerly sought the fibre stripped by Maoris from the leaves of the New Zealand flax and a trade in it had grown up even before settlers arrived. The plant was plentiful enough in the Manawatu swamps for the settlers to join in the trade. It provided a sorely needed source of cash and unexpectedly provided a bonus when drainage was seriously attempted.

A mixture of flax and raupo was the commonest form of vegetation throughout the swampy floodplain. If conditions were very wet, raupo flourished; if somewhat drier, flax. Water changes brought about a fluctuation in the proportion of the two plants. Drainage often resulted in an increase of stands of flax, and thousands of hectares appeared following the first drains dug into the lower Manawatu swamps. When mechanical stripping of fibres was invented in the 1870s many flax mills sprang up bringing added income and employment to the district. Some of the best and most extensive stands were in the Makerua, and the money they generated helped to finance the drainage and stop banking of that basin.

The last flax swamp to be retained was that growing in the lowest basin of all, the Moutoa. It was purchased by the Government in 1940 to provide fibre for the spinning of woolpacks in Foxton. When hemp replaced flax, the swamp was converted to pasture by draining the low-lying areas with pumps.

Forest Clearing

While settlers were struggling with the difficulties of the river and its flood plain, others were spreading out into the hills and mountains of the catchment. At the time of their arrival, these were almost entirely forest-clad except for the limited areas of alpine vegetation. With vigour, axes and matches, settlers made short work of the dense forest.

The change was not only from forest to pasture, but in some places from stability to instability. The many tiers of trees, shrubs and ferns with a thick spongy floor of seedlings and all manner of lowly plants absorbed rain and kept soil in position. As clearing continued up the mountain sides on steeper and steeper slopes, soils were washed away in different forms of erosion; slumps, slips, sheet wash and screes were formed from loosened rock. The nature of some streams changed rapidly as beds became filled with rock.

Before such damage had reached very serious proportions a halt was called, by the Forests Act 1921, to forest clearance along the mountain chains. From then on the backbone of protection forest became State forest and was left largely intact. What damage had been done had still to be put right. In addition, other serious changes were still taking place inside the forest.

Domestic stock from the cleared farm land below had had free access into it. Goats kept by settlers for weed control on reverting farm land had soon escaped and established themselves permanently inside the forest and on the mountain tops. Introduced wild animals, European red deer and Australian opossums, which were liberated as early as 1890 to 1900 around the ranges, quickly spread and increased. They found the combination of plants much to their liking and brought about degeneration, and in places, destruction of the forest and mountain top vegetation.

Farmers who had struggled to win their land along the lower reaches of the river had to contend with

floods which were aggravated by this activity in the headwaters. They anxiously watched the denuding of the hills and mountains. Floods seemed to come more quickly and reach higher peaks and the river carried more silt and shingle—at least that is what they maintained. There is no doubt that changes were taking place but major floods had always occurred. They came whenever everything was saturated and soils, forest and grass could absorb no more.

Protection of Roads—The Whirokino Cut

The river, once a highway, became an obstacle to communications. One of the main roads crossed the river near Foxton. Floods threatened bridging and frequently interrupted the use of the road as it traversed the flood plain. A long trestle bridge was built across the river well above flood levels. In addition, a long loop of the river on which Foxton was sited was bypassed in 1940 by a diversion known as the Whirokino Cut.

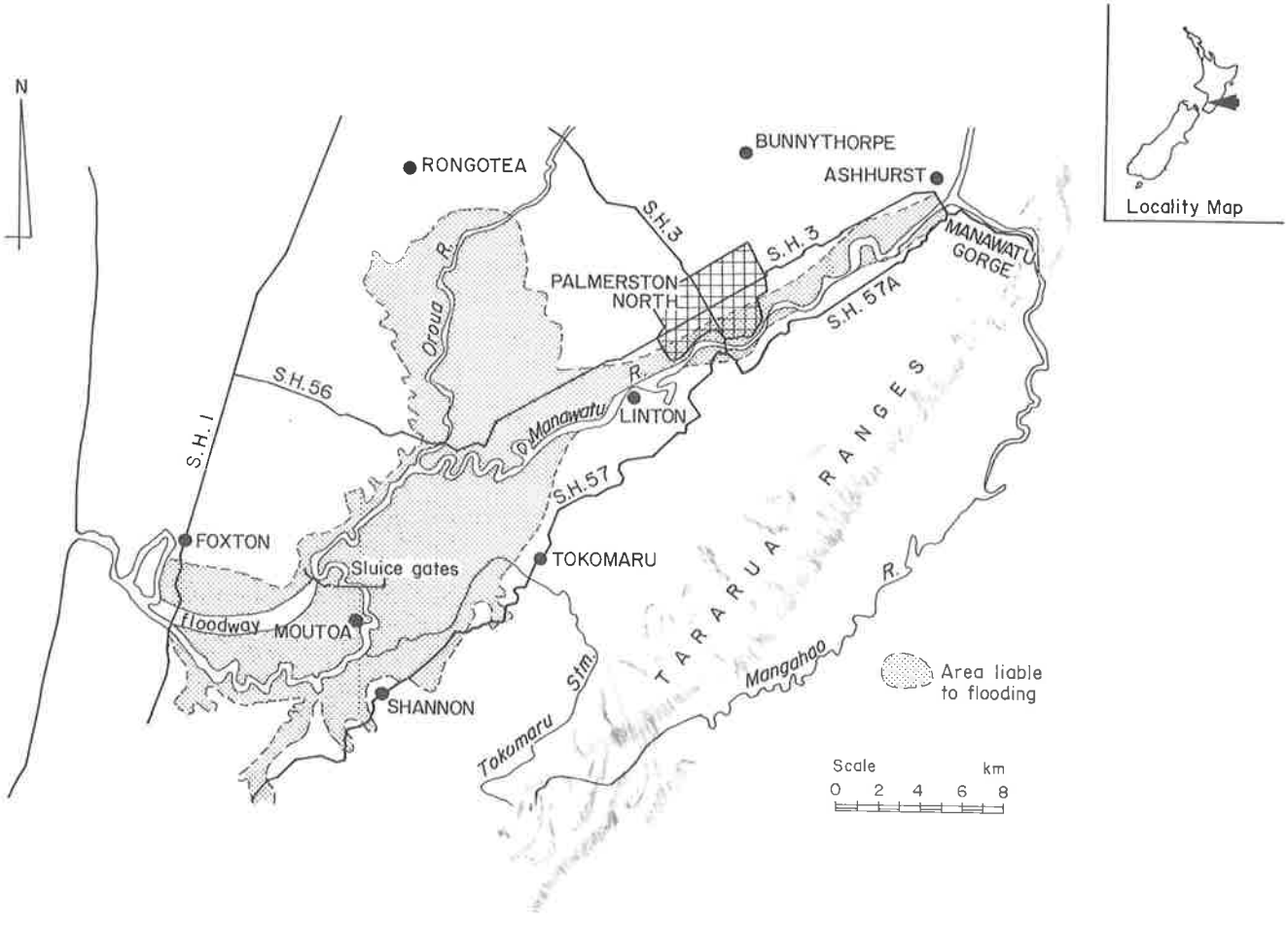
Flood levels in that part of the river were lowered by a metre because of the shortened course, but it was a single purpose work designed to protect the road and had no relationship with any comprehensive lower river scheme. Moreover, it was the crowning indignity to Foxton, which, by that time, was no longer used as a port and had already lost its railway to Palmerston North. It was now on a backwater of the river. Very strong objections were lodged but the work went ahead.

Rivers flow relentlessly, and to adjust itself to this severe piece of surgery the Manawatu is developing undesirable changes 40 years later. These will be difficult and costly to control.

The Catchment Board and the Lower River Scheme

The River Boards had failed, partly through faults of their own and lack of co-ordination but also because of insufficient powers and means of financing large-scale works.

19. The area liable to flooding at the time the Lower Manawatu River Control Scheme was designed in the 1960s. (After P G Evans, NZ Engineering, 19(11): *411-2, 1964)*



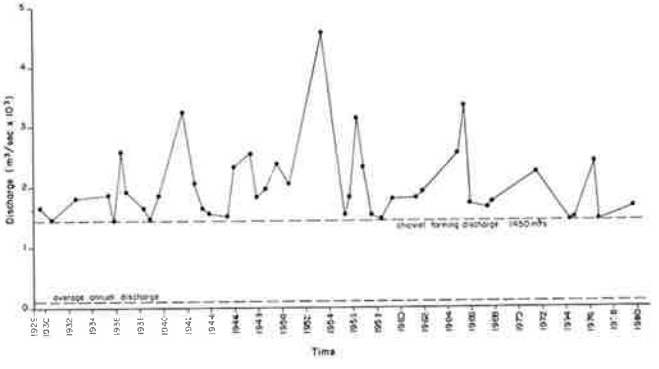
In 1941 a flood inundated parts of Palmerston North, washed away bridges, cut the railway line and caused heavy stock and crop losses. A century of settlement had seen growth of farming and townships, but such calamities continued to occur and the damage was increasing as capital investment rose.

Pressure from Makerua farmers brought the Hon. Bob Semple, the forthright Minister of Works, to the scene. When he surveyed the damage from the Makerua banks and listened to pleas for a bolder scheme, he burst out: "You'll have your scheme all right, but you'll have to take the whole bloody catchment". By that time the Soil Conservation and Rivers Control Act had been passed. No doubt the Hon. Bob's remark laid the foundation for the setting up of the Manawatu Catchment Board in 1943, the first in New Zealand.

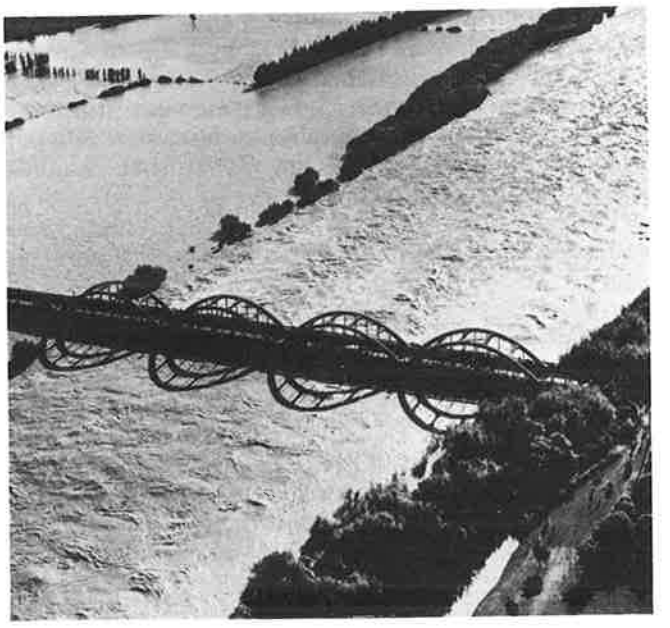
Its immediate task was the design and construction of a comprehensive lower river flood protection scheme. Other works were not forgotten, but would have to follow.

River engineers were scarce so the Board was fortunate in recruiting, early on, P G Evans, an engineer with overseas river control experience. New Zealand rivers are noted for the great range between average and peak flows, (the Manawatu's total range is considerable, varying from a low flow of about 8.5 cumecs to peaks of 4600 cumecs in floods of 1902 and 1953). But Evans had worked on a river in Sri Lanka in which the range of flows was 3 to 4 times that of the Manawatu. Moreover, he had seen examples of the way invaders had been able to conquer a country by destroying river works. Because of his experiences he also understood the river feuds.

Urged on by the new Board, engineers produced a design to protect all the areas liable to be flooded, some 30 000 hectares. Then the land to be protected had to be classified for rating to finance the proposed work. There is nothing like rating proposals to bring feuds to the boil, and this is just what happened.



20. Manawatu River floods above 1450 cumecs 1929-80. Also shown is the average flow for the whole period. (MWD)



21. The Manawatu River at Fitzherbert Bridge, Palmerston North, at the height of the flood 28 January 1953 during which the peak flow reached 4600 cumecs. (Manawatu Catchment Board)

Submitting the scheme to the people led to a 5-year drama. Strangely, farmers in the most severely flooded areas were the principal objectors, some because they did not understand the scheme, and others because they ran cattle in the swamps and did not want their way of farming changed.

Legal proceedings were resorted to and dragged on through lower courts to the Court of Appeal. There when the chief objector was about to give evidence, he died suddenly. The classification was finally approved and another strong objector later became Board chairman.

Evans profitably used the long delay to improve the scheme. Model studies were made of difficult stretches of river, particularly the Opiki Bends where the bed changed direction in an extraordinary manner. These were at first to be straightened, but, as a result of the investigations, the original bed was retained as closely as possible. Without doubt the 5-year pause enabled a sounder scheme to be produced.

In broad outline the scheme operates as follows. Improvements to the channel and construction of stopbanks enable the total flood coming through the gorge to be contained to a point 40 kilometres from the mouth. From there on, the flat gradient, 1:25 000, and long meanders of the channel allow 1000 cumecs to pass without overflowing the banks.

A spillway and a channel formed across country to meet the river again at the Whirokino Cut, takes the excess.

Nine sluice gates control the spillway. These allow the greatest volume of water down the river and are only opened when it is predicted that the flow will exceed the channel capacity downstream of the control structure. This system allows the maximum use of the grassed floodway for pastoral farming. There are 10 kilometres of banks up to 6 metres high along the floodway.

When the sluice gates were tested at the first flood after completion, a board member stood watching, and being unable to contain himself any longer, exclaimed: "Why, it works!" And work it did, for little has been heard of major flood damage since. The success of the scheme has actually allowed people to forget the danger that once existed.

While the Catchment Board was showing its capacity for river control work, Drainage Boards remained in existence in order to maintain the closest contact with farmers and to carry out extension and improvement of drainage that was part of the scheme design. Extensive pumping had to be resorted to because sections of the basins were below river level. The lower river scheme increased the demand for drainage by changing land use. It led to a great extension of and changes in cropping and that could only be maintained by efficient drainage.

Other River Control Work

With the major river scheme underway the Catchment Board could look at other work. There was no point in having control over the lower river, no matter how spectacular the immediate results, unless action was taken in the tributaries and upper catchment. The intricate system of rivers east of the gorge had its problems. Moreover, the Board was responsible for the smaller catchments of the Ohau, Otaki and Waikanae Rivers to the south of the Manawatu.

These 3 rivers gather on the western flanks of the Tararua Range and flow across narrow plains to the west coast. They are small compared with the Manawatu but they cause some troubles. In June 1931 the local press recorded. "Three floods in eight days, and five since the beginning of April is a record of which Otaki is not proud". The Board now has control schemes on both these rivers.

Altogether there are in the Board's district some 65 rivers and streams, with a total length of 1900 kilometres, on which work has been done, and is being maintained.

Commercial quantities of shingle and sand are extracted from all the major rivers. Until recently the operations were sited haphazardly and did not fit in with river management. There appeared to be ample supplies in the rivers and more coming down from the mountains. Amounts have not been as great as anticipated, however, and extraction is beginning to upset planned bed levels and to undermine banks and bridges. The Board is studying resources available and planning to re-direct operations to fit in with river management.

Much of the information that the Board possesses about rivers and streams is needed for planning by other local authorities of which there are 20 throughout the district. For example, flood channels through urban areas determine, or should determine, where buildings are sited.

Erosion Control

West of the Ruahines the old seabed, forming parts of the Manawatu plains, has been arched up in low domes or ranges of hills. These look attractive potential farmland, but developers have to be wary because of the loose nature of the seabed deposits. Some formations, mainly of sand, are particularly susceptible to erosion, and gullies can grow rapidly once started. In one notorious area, the Goulter-Belmont sand gullies, nearly one third of a small catchment of about 500 hectares was eaten away in a short time. It was recorded that during one storm headwater gullying moved upstream at walking



22. Low ranges of loose former seabed deposits west of the Ruahine Mountains are particularly susceptible to erosion unless farmed in conjunction with erosion control measures. Here an eroding gully has eaten back rapidly. The face is 12 metres high. (Manawatu Catchment Board)

pace. The stabilising of the deep washouts that result is a particularly difficult task.

Soil erosion had to be halted. Sir Bruce Levy, Director of the Grasslands Division, DSIR, was on the Board. He had an unshakable faith in grass and clover. If they wouldn't work in holding the soil then they had to be made to work. His one concession to trees was the possible effect of spaced planting. He put his considerable ability into working out how to control erosion, and conducted experimental work to this end. The Board set up a Research and Afforestation Committee with Sir Bruce as chairman. Under it early work was done demonstrating the efficiency of well established and well-managed pastures on certain erodible hill soils, for holding the soil and at the same time increasing stock yields. This dual result, which can be achieved in most parts of New Zealand, has been of inestimable value in getting erosion control methods accepted.

Erosion that is readily apparent and measurable is not the end of the story. Erosion processes, difficult to detect, are proceeding in our hill country all the time. These may in the long run be of concern and must, therefore, be matters of detailed study—as they are at the Water and Soil Science Centre, Aokautere.

Some measurement of these processes can be obtained in the Manawatu River itself which is not considered to be an unusually dirty river. The following measurements have been taken:

(a) During average flows the equivalent of one 5 tonne truckload of dry soil is carried by the river every 13 seconds (an average denudation rate for the whole catchment of 1 mm per year).

(b) During an annual average flood flow the rate is one 5 tonne truck every second.

(c) During eight-year flood flows the rate is two 5 tonne truck loads every second.

The Ruahine Ranges

The Catchment Board also set in train an intensive study of the problems in the Ruahines. These mountains run northwards from the Manawatu Gorge. Their greywacke rocks are intensely shattered by faulting. The range is steepsided, especially on its eastern flanks where some of the severest flood-producing rains strike. This makes a likely combination of characteristics for producing trouble.

After collecting evidence that had been growing over a number of years the Board's study group concluded:

"It is postulated that in the Southern Ruahines at least, the introduction of browsing animals has probably initiated a series of events leading ultimately to widespread destruction of the forests. This has modified plant, soil and water relationships, possibly making slopes more sensitive to storm events leading to an increase in the frequency of slips."

More rapid run-off from the bared and compacted forest floor caused streams to cut deeper courses. This in turn brought slips and shingle slides down the undermined, steep valley sides. The erosion scars in the Pohangina, a main tributary of the Manawatu, increased 60 percent in 17 years. Streams became choked with boulders and gravel which moved down in huge waves with each rain storm.

These waves of rock and shingle found their way out of the forest onto the cleared farmland and across roads and the railway. In the process water supply intakes were threatened and water polluted. Steams emerging onto the flat land did so in rapidly building shingle fans. Control was essential if much farmland was not to be lost and communications severely disrupted.

The obvious place to start control was at the source of the trouble, the accelerated erosion in the mountains. For many years wild animal control operations had been carried out in the Ruahines and, more recently, replanting of eroded areas had been added. It is, however, very difficult to stop erosion on steep slopes and along streams that are cutting down once a cycle of accelerated erosion has commenced.

Apart from the originating troubles, shingle already accumulated in the streams kept moving down with storms and landowners wanted protection from this. It proved to be very difficult to measure the danger accurately enough for control schemes to be designed. A number of years were required to determine the facts.



23. Scree erosion, Makaroro Catchment, Ruahine Range. (MWD)

Eventually a South East Ruahine Management Scheme was designed and put into operation in 1980. It covers 78 600 hectares including mountain headwater catchments in the Ruahine State Forest Park. Fourteen stream systems are involved. Measures proposed include work inside the forest and the exclusion of domestic stock from it, fan stabilisation, willow clearing and stream channel stabilisation, gravel excavation from streams and the formation of gravel reserves, planting riparian strips, and drainage. The programme of works is to extend over a 20-year period.

Coastal Sand Erosion

Along the west coast in the Manawatu Catchment Board's district there are more than 50 000 hectares of sand dunes—nearly twice the area of country that has been protected by the lower river flood control scheme. The task of halting and fixing the blowing sand in these tracts is a formidable one. Rebuilding the fore dune in the worst sectors, and dealing with the belt of drifting sand immediately behind it, finally fell to the NZ Forest Service. The work had to be done on a large scale and was costly, but the Service could combine it with production forestry once the sand was fixed. The Board could then proceed to assist farmers to fix the sand on their farmlands.

What had been a desolation of drifting sand where some of the first settlers had attempted to farm has become a productive sector of the coast.

The Regional Water Board and Water Management

When the additional duties of Regional Water Board came to the Catchment Board in 1968 intensive farming already extended over more than four-fifths of the Manawatu catchment. There were also a dozen sizeable townships, many smaller ones, and a city. With settlement, water use had developed at an astonishing rate, which had been little noticed because there seemed to be plentiful supplies. People had had to deal with excess water, with rainstorms and floods. The 1967 Act was to make them think in terms of low stream and river flows because these had to be shared among users. There was a requirement to manage water resources. The existing laissez-faire attitude towards use made this difficult to accept at first.

When the Regional Water Board came to survey the situation it found few records of water use—a situation similar to that in most of the country—and discovered that very little was known about minimum flows. Hydrological measurements had been collected mainly for flood control calculations. A formidable task of searching, recording and measuring lay ahead.

Palmerston North emptied its stormwater and sewage directly into the river up to the 1970s. Such a method of disposal avoided the costs of treatment, but at times of low flow the river was unable to dilute the discharges sufficiently. The polluted water became dangerous to the increasing number of people using the river for recreation.

Meat works and dairy factories had been sited on the rivers in order to draw their water from them and to discharge their effluents into them.

Irrigation of crops and pastures was a rapidly growing practice especially on the now-protected flood plain. Where better to get the water than from the stream that flowed through the farm or the river that flowed past it—in effect, an assumption of riparian right? But a large use for crops at a dry time of the year soon competed with stock and users further along the stream.

Readily detectable underground water was also being tapped for irrigation and farm supplies. There were several thousand wells throughout the district. These needed to be recorded and extraction of water from them measured. The location and extent of the underground resources themselves and the effect of the extractions taking place had to be studied.

If the various uses were to be effectively controlled and managed, and the water shared, the Board had to record them all, including effluent disposal. It also had to survey the resources and draw up water allocation plans. Several years were needed to complete these tasks even in a preliminary way.

However tedious, time consuming and costly, all this was necessary before another warfare commenced, this time not over flood protection or drainage but over the sharing of minimum flows.

Conclusion

This brief account traces, broadly, progress through 140 years: the draining of swampy basins, the flood control of the lower Manawatu River, control and training in the tributaries and other rivers, soil and sand erosion control and water management. The aim throughout the period has been fuller and sustained use of soil and water. Results are to be seen in the intensive cropping on the Manawatu flood plain, the safely farmed hill land and the introduction of water management and pollution control. It is the Catchment/Regional Water Board's task not only to maintain and progress with this work but also to weld it together.

"... continuing our journey we reached Wairakei and making it our headquarters, we examined the Waikato watershed [catchment] visiting the following places: Atiamuri Rapids, Rainbow Falls, Gorge below Orakei Korako, Orakei Korako Rapids, Aratiatia Rapids, Huka Falls, Lake Taupo and Rotoaira. In this region, which is quite unusual in many ways, immense quantities of power can be developed ..."

(Extract from Report of L M Hancock to the Minister of Public Works, 1903).

The Waikato River and Catchment

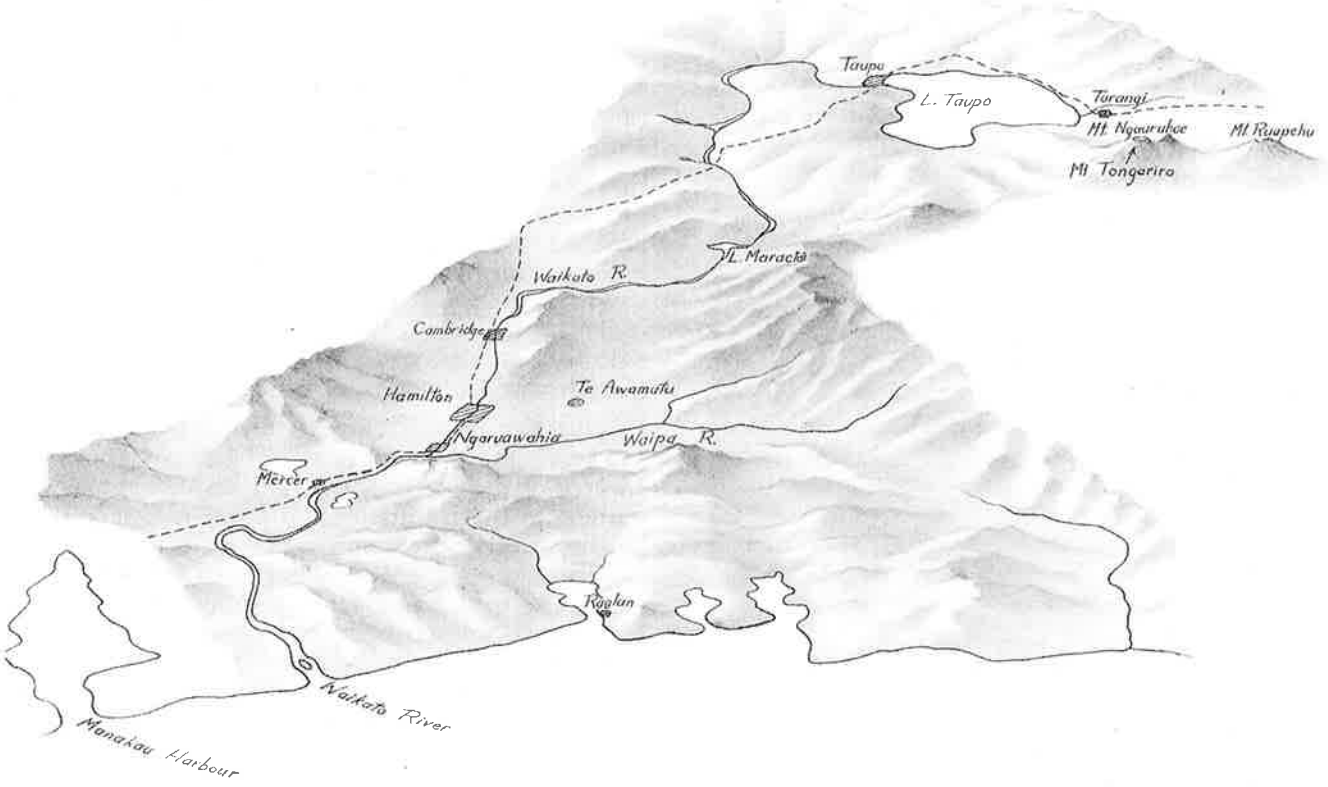
We turn to a river markedly different from the Manawatu, flowing from a catchment of an extraordinary nature. The Waikato is a superb water resource. But how stable? In geological time most unstable; in human time nobody knows; so we take risks with its use as we develop the bulk of the North Island power supplies along its course.

As recently as 10 000 and 2000 years ago a series of eruptions took place in the Taupo-Rotorua area. It ended in a violent one sending pumice over thousands of square kilometres. Erupted material blocked Lake Taupo and, for a time, raised it about 30 metres above its present level. Altogether the outpourings which have created the volcanic plateau must be measured in hundreds of cubic kilometres.

These events have certainly not been those to bring about stable flows of rivers or allow consolidation of rocks and formation of soils. The pattern of vegetation also had to adjust itself to successive eruptions. Grassland occupied the areas affected by the more recent events, but pockets of forest survived and slowly spread.

The subsidence (the geologist's caldera) in which the 650 km² Lake Taupo lies is a very large basin with mountains around much of its perimeter. This basin is a wonderfully effective catchment for the lake. Down its sides flow a great number of rivers and streams. They are crystal clear, as are all streams in this pumice country because the pumice beds act as highly efficient filters to the rainfall. When stocked with rainbow trout, the clear Tongariro River and other local streams and lakes soon became world renowned for sport fishing.

Lake Taupo and its basin thus provide the Waikato River with an excellent supply of very high quality water. As it emerges from the lake the river flow is normally around 130 cumecs which is about the average flow of the lower Manawatu River. During



its course to the sea it flows for over 300 kilometres and drops about 350 metres. At first it flows swiftly in a well-defined valley. Not far from the lake it tumbles over the Huka Falls and cascades down the Aratiatia Rapids, two sights which became regular tourist attractions.

At one time it flowed into the Firth of Thames, and there may have been other major changes to its course.

From each eruption of pumice huge quantities of material have been floated down the river to the sea and along the coast. Telltale deposits mark the last Taupo eruption—about 2000 years ago—in particular. The lower Waikato as we now see it has been built up by the river from these rafts of pumice. Before settlement it consisted of a mosaic of large swamps, shallow lakes and dry land, formed, in part, by great deposits of the washed pumice. Of this wilderness, probably exceeding 50 000 hectares, floods could inundate about 20 000 hectares. The last 35 kilometres of the river, from Mercer to the sea, are subject to tidal influences which increase the risk of flooding.

When white settlers from Auckland began exploring southwards they went from the Manukau Harbour down to the mouth of the Waikato and crossed the difficult bar; or took the main Maori route and portaged from Waiuku to the Awaroa River and thence rowed to the Waikato delta. Travel by steamer was possible up the Waikato to where Cambridge is now situated. This was the easiest way of crossing those great lower Waikato swamplands. From Ngaruawahia the main tributary, the Waipa, gave access to more country. In the early Pakeha settlement period the lower river saw a fleet of their boats. In the wars of the 1860s, these included gunboats. At one stage Port Waikato at the mouth was designated a naval dockyard, and engineering shops, stores and barracks were erected.

Hochstetter, a noted Austrian geologist who explored part of New Zealand including the Waikato in 1857, gave an enthusiastic description of the river. He wrote "... no second river of New Zealand has such importance as a grand thoroughfare for the interior of the country. The Waikato is in truth the main artery of the North Island ..."

Trade with Australia in flax, collected along the river, had begun as early as 1828. In the 1850s wheat grown by the Maoris in the Te Awamutu district was exported to the Australian gold fields by the same route.

The first attempts at development in the Upper Waikato did not prove so successful. The attractive areas of open grassland proved to be a disappointing lure. There were many failures in attempts to farm them because a trace element, cobalt, was missing from the pumice soils. Its absence caused 'bush sickness', a wasting disease leading to death of cattle and sheep.

On the other hand, introduced forest trees flourished. In the pumice they found sufficient nutrients for their requirements and ample moisture. The failure of agriculture left the way open for exotic afforestation, mainly with radiata pine (*Pinus radiata*). Large areas of forest were established in the upper Waikato catchment before the cause of bush sickness was discovered about 1935. When it was, and bush sickness combated by the addition of very small amounts of cobalt to the soil, the way became clear for a burst of activity in land development for agriculture. By that time the period of most vigorous afforestation was over, so there was no conflict in land use.

24. Waikato Valley Authority District

The Waikato River catchment, including the Lake Taupo basin, makes up the greater part of the district. The remainder is the land between the catchment of the Waipa tributary and the west coast. The light pumice soils that cover most of the area are easily eroded but improved land use including erosion control measures keeps this under control. The Waikato River system is the most intensively used water resource in the country. Water collected from around the mountains, Tongariro, Ngauruhoe and Ruapehu, is led into Lake Taupo through two power stations. There are then eight more stations in the middle reaches of the Waikato River. From the lower reaches and the main tributary, the Waipa, water is drawn for urban and industrial purposes and treated effluent put back into the river.

The resource is destined to become of increasing importance as land use in the valley becomes more intensive and as urban communities, including those adjacent to the valley, especially Auckland, grow.

The lower river used to flow into an intricate system of swamps and lakes. A flood control scheme now prevents this and has enabled drainage to be undertaken. (D W Lawrence)

River and Drainage Boards and Commissions

The Great South Road from Auckland, started early in the 1860s, had been followed by a railway line well before the end of the nineteenth century but both road and rail were constantly cut by flooding from the Waikato, sometimes for lengthy periods of time. During a flood in 1907, one of the highest that has occurred, railway passengers between Auckland and Hamilton made part of the journey in boats provided by the Railway Department.

Flood control schemes were investigated early on, to protect road and rail, to free the lowland of flooding and to allow the drainage of the extensive

swamplands. The conditions were, however, exceptionally difficult. A Waikato River Board was formed but could make little headway because of the extent of the problem. A large number of Drainage Boards were also formed to attempt the drainage of individual swamps, but constant inundation from the river made this work difficult. Many of the swamps also contained peat which consolidated and sank unless drainage was carefully managed.

Conflicts which arose between the River and Drainage Boards occasionally had to be resolved through judicial channels. Main drains from swamps naturally had to empty into the river. On the other hand the River Board was responsible for protecting banks and trying to prevent flooding. At one time it built groynes in part of the river which interfered with the outlet of drains. Even though both operations had the same objective this conflict had to be settled by a Commission set up especially for the purpose, the Waikato River Commission of 1917.

Plans to link harbours and waterways in the vicinity of Auckland were formulated at an early stage of settlement. In 1921 an Auckland Canals and Inland Waterways Commission was set up to enquire into possible canal links between various points, including the Manukau Harbour and Waikato River, and the Waikato River and Firth of Thames. Changes in transport methods overtook these ambitious schemes.

The 1921 Commission also inquired "into the navigation and possible canalisation or improvement of the Waikato River and its tributary creeks and as to the effect of the works carried out by the Waikato River Board." It roundly condemned the Board, and made a recommendation of prophetic significance:

> "... the present Waikato River Board should be abolished, and a new River Conservation Board constituted, consisting of members having power to deal with all questions relating to river improvement, land drainage, or other matters, within the whole watershed of the Waikato and its tributaries. If it is deemed desirable to permit Drainage Boards to deal with special districts, then the powers of such boards should be limited to carrying out such work as has met with the approval and sanction of the proposed River Conservation Board."

Forty more years passed before the body envisaged, the Waikato Valley Authority, was set up.

Electricity Generation

While the River Board and Drainage Boards were grappling with the problems of the lower river, engineers had realised the value of the upper and middle Waikato for the production of hydro electricity. A regular volume of water in a fast-flowing river; natural control by a large lake; a fall of over 300 metres between the lake and the river's lower reaches; a valley that could be drowned without affecting too much productive land; what seemed to be secure places for dams: what could be a more ideal set of circumstances?

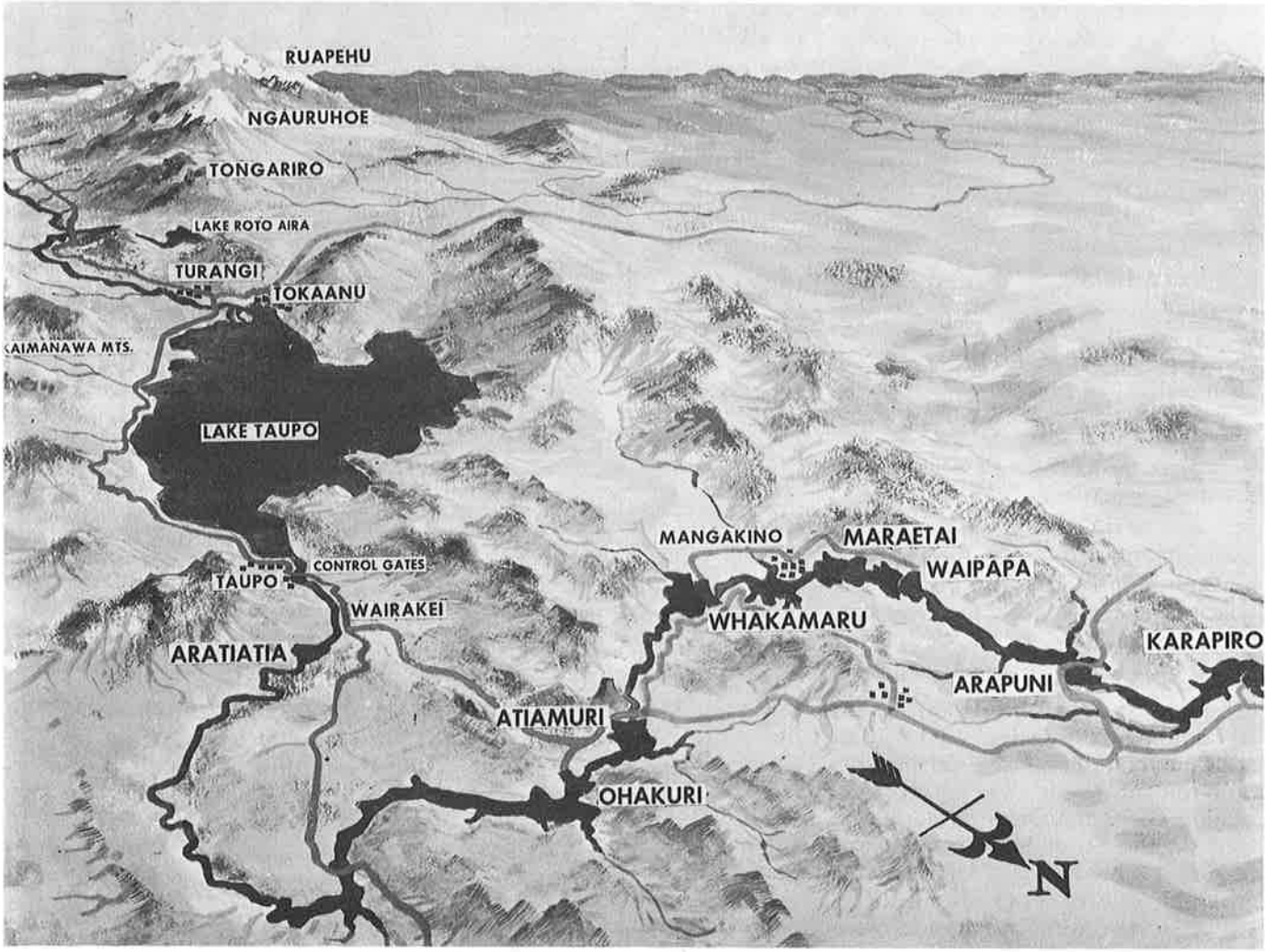
Still wider horizons could be dreamed of. It would be possible to collect together the water from the highest country as it flowed down the sides of the Taupo basin, so making use of the fall to the lake. Looking still further afield, it would be possible to behead rivers flowing across the volcanic plateau to other parts of the North Island. That water could be sent on down the Waikato. Every additional drop of water meant more electricity as it flowed down through future power stations. There was ample to excite the imagination of engineers.

All this and more happened. The first dam was built by private enterprise—the Waihi Goldmining Company—in the period 1910-13. The Government then stepped in to develop the great potential for the nation, and by 1929 had commissioned the Arapuni Power Station. This was followed by control gates at Lake Taupo in 1941. From then on great activity took place. Seven more dams were built in the middle reaches of the river. In the 1960s a start was made to behead three rivers—the Wanganui, Whangaehu and Rangitikei—and divert some of their water to the lake and down the Waikato through its eight power stations.

In addition to the generation of hydro-electricity, coal formed from ancient buried peat swamps in the lower Waikato and geothermal steam near Taupo have now been used to produce electricity in plants on the banks of the river. Both need large volumes of cooling water from the river. A second coal station is now being built, a third thought about and a second geothermal station planned.

So absorbed were the planners with these developments that they forgot the flooding problems of the lower river. Use of the river became markedly unbalanced. While millions of dollars were being poured into the upper reaches, creating an artificial waterway, the problems of the lower river continued. The most severe recorded flood had occurred in 1907. In 1953 the next worst, up to that time, struck. Low-lying areas amounting to thousands of hectares were inundated and many farms were completely covered with water. Lakes filled and expanded alarmingly, low stopbanks were overtopped, the Auckland-Hamilton highway was flooded and the railway was closed for two weeks.

In 1956 another large and longer-lasting flood did considerable damage. Another occurred in 1958. These floods provided ample proof that what little flood control capacity had been built into the huge works in the upper river was ineffective for the lower reaches. Pressure for action became extreme from farmers, townships and travellers.



25. Mountains and water. The Tongariro Power Development. Water collected from around the three mountains, including some from the beheaded Wanganui, Whangaehu and Rangitikei Rivers is used for the production of hydro-electricity before it reaches Lake Taupo. (MWD)

The Waikato Valley Authority

The Government responded to the situation, and in 1956 the Waikato Valley Authority Act was passed. This empowered the Authority set up under it (the WVA) to carry out all the functions of a Catchment Board. There was no acknowledgement at that time that erosion in the catchment was becoming a problem, but control of flooding was urgent. A Catchment Board under the 1941 Act was, therefore, not favoured, but a river authority, made up of local authorities affected by the river, was sought.

Could such a body, made up of strong district interests, weld itself into an organisation having regard for the whole complicated river system and its catchment? Previous Drainage and River Boards had not been able to. Co-ordination this time was materially assisted by the fact that the Government was persuaded to contribute finance towards the running of the WVA because of the intensive use the nation was making of the river.

Why shouldn't the nation pay for all the work? It had been ready enough to support the harnessing of the upper river without giving thought to the lower. Now was the time to adjust matters. People along the lower reaches would, however, receive many benefits from river control. Negotiations led to a compromise, and a method of financing the proposed flood control measures was worked out. This was no easy task for a scheme that took more than 20 years to build.

The WVA immediately commenced the most urgent task, the design of a comprehensive lower river flood control scheme. It included flood protection for the townships on both the Waikato and the Waipa, as well as for flood-prone farmland, and the improved drainage of swamplands. The total

area to be protected from flooding was almost 20 000 hectares. When fully protected an additional area of not much less would benefit from better drainage and access.

It was unreasonable to expect a protection scheme in the lower reaches of the river to absorb the whole of the floods. There were eight dams and artificial lakes, and a Lake Taupo control structure sitting in the upper river. Still more water would be added later to the flow. An essential part of the design had to be provision for the retention of flood waters throughout the whole river system and its artificial structures.

The accumulation of hydrological data already collected for hydro-electricity purposes was of great benefit to the designers of the control scheme. It was essential to know how a flood behaved as it proceeded down through the series of lakes and dams. Many flow measurements were needed to find out. Nowadays there is computer centre at Whakamaru System Control which co ordinates and controls lake storage and levels and river flow. Flood routing has become an automatic part of the control scheme.

The flow of water throughout the total river system is complex. Permeable beds of pumice absorb rainfall and complicate the relationship between rain and run-off. The large water storage capacity of Lake Taupo keeps the river fed during times of drought, but on the other hand retains water when floods occur in the basin. The variation in flow is thus dampened. The result is that the maximum flow at the Taupo outlet is only a little more than twice the mean flow—the smallest variation of any major river in the country.

Further complications arise from the variations in flow that can take place in the Waipa River and in the smaller tributaries joining the lower Waikato. Peak flood flows in the lower river have been of the order of 1700 to 1800 cumecs. This is some five times the average flow, a small variation when compared with the Manawatu River, for example, in which the range is some 70 or 80 times. One of the attractions the Waikato had for engineers in designing works on the river was the good average flow and the comparatively small variation between high and low flows.

The Waikato floods might not run very high but they spread out widely in the lower reaches of the river, filling the complicated system of lakes and swamps and inundating the low-lying land. Sometimes the water lay there for a long time because Lake Taupo kept on releasing its store. High tides also held back flood waters. Until river engineers carried out their studies, only the residents could follow, from long experience, the maze of channels and changes in flow. They had to adapt their farming to cope with these difficult conditions.



26. One of the pleasures naturalists derive from exploring swamplands. Australasian bittern in a typical 'frozen' pose adopted when first disturbed in a lower Waikato swamp. (J Cheyne, Wildlife Service)

A number of possible flood protection alternatives had been suggested from time to time. Most of these schemes were based on engineering works that were too costly. The Waipa tributary, for example, could be taken on a shorter route out to the Raglan harbour on the west coast. Or the Waikato river could be taken through to the Manukau harbour as in one of the early canal proposals.

The system the river had developed itself was finally settled on as the most satisfactory. This meant a series of stopbanks on the main river and along some of the tributaries; the clearing of the Waipa River channel; the use of ponding areas; rearrangement of commercial sand and shingle removal from the river bed to increase channel capacity where required, and to fit in with river management; pumping to drain the low-lying, swampy areas; and flood gates on the drainage outlets.

Soil Erosion and Catchment Schemes

The tables were soon to be turned on those who had opposed the setting up of a Catchment Board, maintaining that there was no erosion in the catchment. Once bush sickness was overcome a rapid



27. King Country floods 1963. This is what can happen when valleys become floodways. (20th Century Photography, Taumarunui)

change in land use took place over the tens of thousands of hectares of remaining undeveloped land in the Lake Taupo basin and the river catchment.

Here was an Eldorado for farmers, the last sizeable area for development. Moreover, most of it was gentle country; no more struggling with forest on steep mountain sides. The pumice was exceptionally light to plough and work with implements, and provided an excellent seedbed. When established, the pastures responded remarkably to artificial fertilisers.

The Government itself undertook the initial breaking in. Tractors and implements starting in one place disappeared over the horizon in their march across this easy land. It was done with little consideration of the light and permeable nature of pumice, or of what happened when the surface of the land was broken, or of the effect on streams when the vegetation was changed; broad vistas of pasture was the aim.

The reckoning came when the surface consolidated under stocking. Increased run-off during heavy rains broke through this surface layer. The loose pumice underneath melted like sugar and moved down the waterways, clogging streams. Much reached the choice fishing rivers and trout spawning stretches, and even the famous fishing waters of Lake Taupo. More found its way into the artificial lakes where it was a threat to the power station turbines. Settlers established on steeper developed land sometimes experienced complete disruption of their farming.





28. Torepatutahi catchment control scheme. Washout of farmland established on deep volcanic ash slopes and later rehabilitation by planting, stream work and resubdivision of some farmland. (Waikato Valley Authority)

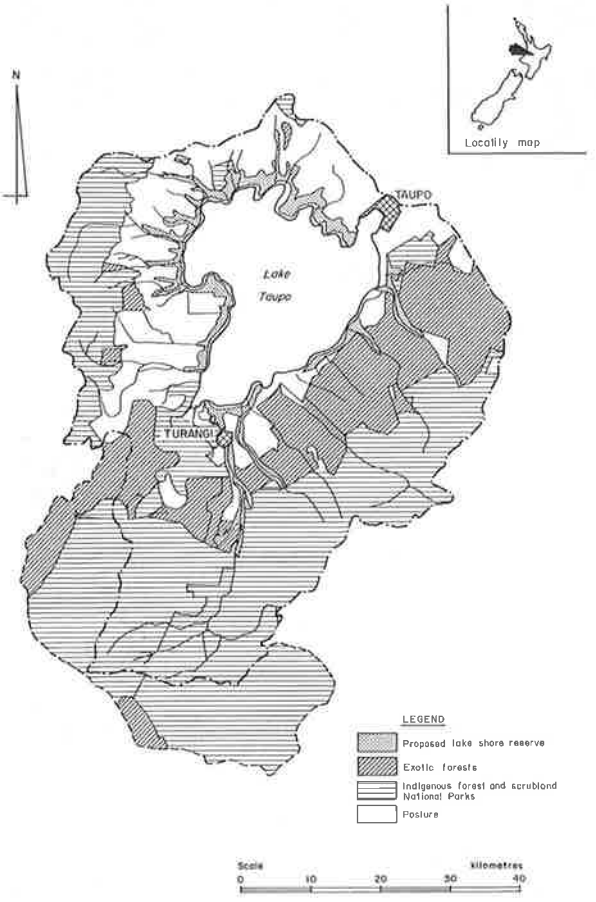
Erosion control in the catchment had, almost overnight, become urgent. Local people were most conscious of the danger, and local authorities led the way in organising action. No doubt the deterioration of Lake Rotorua over the years stimulated thinking about the need to prevent the same thing happening to Taupo. The two lakes were close enough in distance and setting for people to make comparisons. This great asset had to be safeguarded.

The Government had to be involved because it could encourage and guide good land use which would provide the major safeguards. The WVA had to be brought in because it would need to repair many of the past errors and, in the future, manage the natural waters to safeguard their present and future uses.

The WVA therefore quickly developed this side of its activities. Measures were introduced into land development aimed at preventing the calamities that were occurring. Still bolder measures were planned, and the WVA began to negotiate control for whole stream catchments and the Taupo basin itself (which comprises 23 percent of the total Waikato Catchment).

The WVA scheme for the whole Taupo basin proposed a number of important measures: erosion that had already occurred on the blocks of land development was to be cured by planting trees and excluding areas from farming; potential erosion was to be prevented by excluding waterways from development and by demarcating sensitive slopes and pumice deposits; some river works would be undertaken to prevent both erosion and flooding of land near the lake.

During forest operations, particularly logging, erosion prevention measures already introduced by



29. Lake Taupo Basin broad land use categories. Deliberate policies to keep the water of the lake unpolluted have played an important part in determining this pattern. The retention of native forest, encouragement of exotic afforestation and creation of lake shore reserves are all considered to help keep water as free as possible from pollution. (MWD)

other catchment authorities were taken up by the WVA. The first burst of afforestation, plus a second development now under way, will eventually see 30 percent or more of the Waikato catchment under exotic forests. It is essential that this area be worked without accelerating erosion of the pumice beds.

Regional Water Board Responsibilities

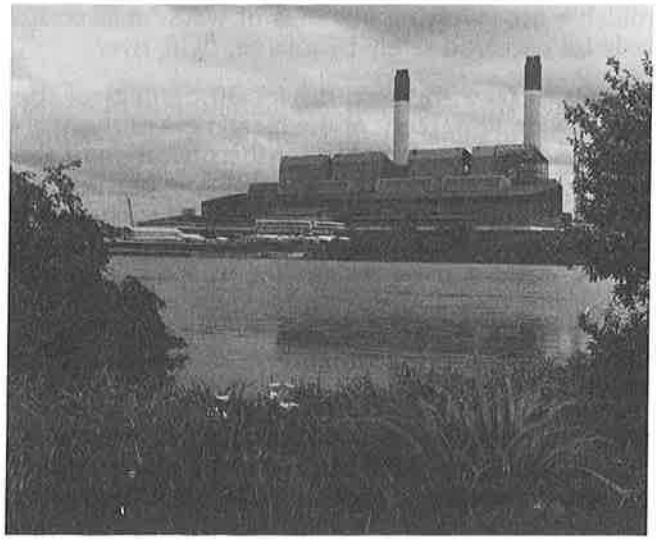
The WVA was included under the Water and Soil Conservation Act 1967 along with other catchment authorities, for the management of water. A complex situation now faced it. Hitherto its attention had been focused at first on a difficult flood control scheme and later on soil conservation. But while intensive development of hydro-electricity by the State occupied the middle and upper reaches of the river, and a world-renowned trout fishery had spawned in the headwaters, the river was also used as a sewer for the effluent from a pulp mill, from farmland, dairy factories, meat works and from Hamilton city and a number of other municipalities. Geothermal activity pollutes sections of the river, and thermal power stations affect the river by their warm water discharges.

There was an early commencement of this trend. About the beginning of the century comment was made on the waste from flax mills that was poured into the river. An observer wrote; "There has been no controlling body [and] consequently no attempt has been made to preserve the river." In the intervening 60 years pollution had mounted because there was still no controlling body prepared to take strong action.

Apart from attacking the problem which all these uses of the river caused, many future uses had to be



30. Recreational use of the Waikato River at Hamilton. The Hamilton regatta. (Alexander Turnbull Library)



31. Huntly Power Station on the banks of the Waikato River. This plant, capable of eventually generating about 1000 megawatts of electricity, will use 10 percent of the mean flow of the river for cooling purposes. One of the conditions of the water right is that the temperature increase caused by the return of the cooling water to the river must be limited and the warmer water be spread as rapidly as possible. (MWD)

planned for. Auckland looks towards the Waikato River for future domestic water supplies. Major industries such as the steel mill may also need Waikato water. These extractions will have to be drawn downstream of the polluting discharges.

The WVA had to weigh up these conflicting uses. In addition it had to undertake the task imposed by the new Act on all catchment authorities of surveying the water resources throughout its whole area. Water in the Waikato could not be improved until there was some knowledge of what changes were taking place. Polluting effluents often changed the colour and turbidity but were unmeasured. Each artificial lake has a different effect on the water. A crude yard-stick of what had already happened was provided by the degree of treatment of water taken for urban purposes. Water for Taupo required chlorination only, while water drawn below the last dam downstream, Karapiro, required coagulation, sedimentation and filtration.

A number of abstractions and discharges were so large that they needed to be measured continuously to follow their effects. These included the cooling waters used at the Wairakei geothermal and Meremere thermal power stations; the effluent discharged from the Kinleith mill into Lake Maraetai; freezing works effluent at Horotiu; dairy factory waste at Reporoa and Te Rapa; and Hamilton city sewage—subject to primary treatment only. To these must be added many smaller discharges: a for-

midable list involving volumes of water that could only be received safely by a large, swift river.

A right to take and to put back 30 percent of the low flow or 10 percent of the mean flow of the Waikato has now been granted for the operation of the Huntly power station. This is an example of the magnitude such uses can reach. A right for such a high proportion of the flow must safeguard many things. As the water is used for cooling its temperature is raised, but this, and the overall increase when the water is returned to the river, must be limited, to prevent side effects. Altogether, 26 conditions are attached to the Huntly right.

Another example of the potential magnitude of problems was provided by a reversion to the 'good old days' which occurred in 1979. Milk delivered from farms to the dairy factories at Te Rapa and Te Awamutu could not be processed because of an industrial dispute. Two million litres were released into the Waikato and the Waipa over 5 days. Discolouration and scum occurred for 20 kilometres downstream. The biological effects were considerable, and a major fish kill occurred, together with environmental contamination and economic effects on eel processing. Too many incidents of this kind could have permanent, adverse results in the river.

The management of water has involved the WVA in a multitude of issues of which the above are examples. Its response will affect much of the development throughout the region. Use of the Waikato river resource will be the key to many things both within its own catchment and throughout the whole of the Auckland and South Auckland region.

HAURAKI CATCHMENT BOARD

The Land of Two Rivers

From Mount Te Aroha—a 1000 metre high mountain in the Kaimai Range—there is a commanding view of the Hauraki Plains and beyond. A wide valley stretches from the sea at the Firth of Thames to the Mamaku Plateau.

A close pattern of dairy farms, interspersed with small townships, is visible over an area of 200 000 hectares. Together with the adjacent Waikato it forms the most productive dairying area in the country, producing twice as much dairy produce as Taranaki.

A low range of hills separates the Waikato catchment about Hamilton from the Hauraki where the Piako and Waihou Rivers flow into the Firth of Thames. In their middle reaches these two rivers are themselves separated for some distance only by the Kopuatai peat dome, the crown of which is a bare 6 metres above sea level. The preservation of this dome as an essential feature of flood control is a matter of considerable importance.

From its headwaters on the Mamaku Plateau, the Waihou flows along the western edge of the steep Kaimai Ranges as they flank the plains and then proceeds in serpentine loops past the foot of Mount Te Aroha. From the Karangahake Gorge between the Kaimai and Coromandel ranges emerges the Ohinemuri, a tributary of the Waihou. It rises close to the east coast near Waihi and severs the ranges on its westerly course.



32. Hauraki Catchment District

The catchments of the Piako and Waihou Rivers, which together with the Coromandel Peninsula make up the district, virtually join to form a broad valley and the Hauraki Plains. The valley is bounded by the Kaimai and Coromandel Ranges, the Mamaku Plateau and low hills to the west separating it from the Waikato. Flooding and ponding on the Hauraki Plains occurred readily and was aggravated by the low-lying land—substantial areas along the lower reaches of the rivers are below high tide levels. For a long time the low-lying swamps defeated attempts to reclaim and settle them but river control schemes and very extensive drainage works have now transformed the plains. (D W Lawrence)

Looking across to the west from Mount Te Aroha one sees the lower hills through which there are gaps leading to the lower catchment of the Waikato. It needs little imagination to reconstruct an old course of the Waikato river when it flowed through one of these gaps and on to the Firth of Thames.

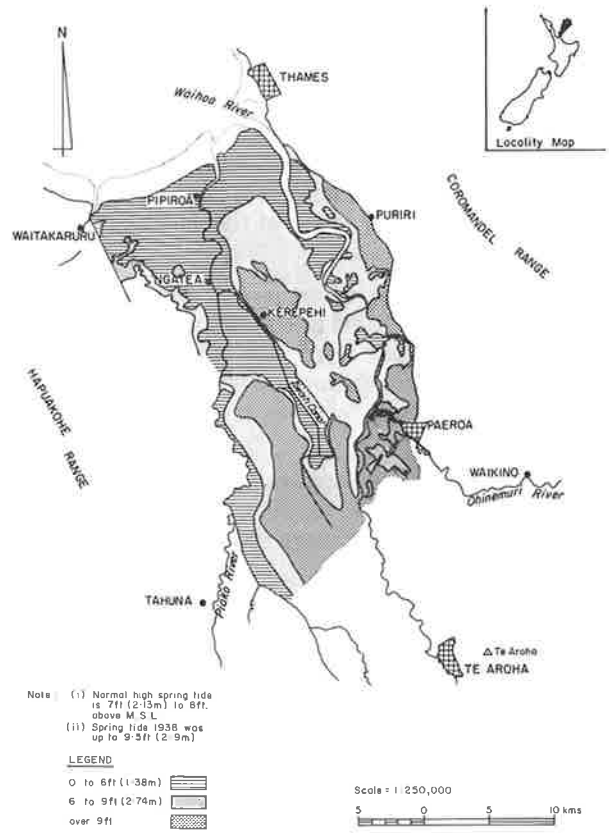
When it changed its course to the west coast, it left to the Piako and Waihou (which between them are about the same size as the Waikato) a floodplain of 80 000 hectares, greater than that of the present lower Waikato.

The plain occupies a down-faulted valley between the mountains and the hills. It has become filled with volcanic ash material brought down by the old Waikato and by the Waihou and the Piako Rivers. The northern end of the plain is in the nature of a delta. Some of it was under the sea in the not very distant past and old marine beds are interspersed with the volcanic material.

From Mount Te Aroha the intricate pattern of drains between the Waihou in the east and the Piako in the west can also be seen. There are almost 1000 kilometres of main drains as well as innumerable farm drains. Without these there would be little farming in this area of former swamps, peat bogs and shallow water.

This superb view, embracing the infilled valley, the hills and the mountain chains, forms the district of the Hauraki Catchment Board.

Seeing the intensively farmed land now, it is difficult to imagine the huge extent of swamp that once stretched right across the valley. For a long time, it defied attempts at settlement. Kahikatea forest, admired by Captain Cook when he rowed up the Waihou in 1769, grew along the river levees and limited areas of high ground. Otherwise the lower valley was filled with swamp vegetation.



33. Lower Thames Valley contour plan. The whole of the area shown is below the highest recorded spring tide (1938) that rose 2.9 metres above mean sea level. Flooding as a result of spring tides is now prevented by stopbanks along the shore of the Hauraki Gulf and the flood control stopbanks along the Piako and Waihou Rivers. (Hauraki Catchment Board)

Draining the Swamps

The flax in the swamps and the kahikatea forest attracted the Pakeha and industry to the region. In 1869 sawmilling commenced on the banks of the Waihou and sawn timber was sent to Auckland and to Melbourne. The river was used for floating logs and became the vital communication for the industry. From the 1850s gold discoveries in the Coromandel-Thames area, at Waihi and around Te Aroha added to the river's importance for communications and for water for mining operations.

Large numbers of potential settlers came to the district but the swamps could not be drained. Nor could roads be successfully formed across the valley, so travel to the district remained by sea. Not until the early 1900s was a series of levels taken to determine the contours of the swamp. It was a day's journey for surveyors to walk the 10 kilometres between the mouths of the two rivers. "Sometimes the surveyors worked in water up to their waists, at other times they struggled through soft peat or through raupo above their heads." They slept on boats because there was no dry land. But the survey was essential before drainage could be planned.

The rivers had to be controlled. Although not large they constantly flooded low-lying surrounding land. Both rivers are tidal for almost 50 kilometres and for all that distance the channel slopes are about 10 centimetres in one kilometre. Land along these reaches is below high tide levels, as is land behind the shore of the Firth of Thames. Very high tides—or even average high tides combined with floods in the river—kept the lower part of the plains constantly wet.

Some progress in making the plains farmable was achieved by draining around the edges, but this was often rendered ineffective by flooding from the two

rivers. Moreover, there were large deposits of peat along the western side of the valley and peat was too difficult to develop so long as flooding occurred.

Government Schemes and the Coming of the Catchment Board

It was inevitable that the Government be drawn into planning the development of such a complex area. Difficulties placed it beyond the physical or financial capabilities of individuals. The Government had already become involved with the rivers in another way. During the gold mining days the Government had declared the Ohinemuri and lower Waihou sludge channels to take mine tailings and water that had been used for sluicing. Before long, deposits of silt were left on the land along the river banks after each flood. If this aggradation of the river beds continued increased flooding was bound to occur.

The Government was therefore drawn into matters concerned with both settlement and the state of the Waihou and Ohinemuri Rivers. It passed the Hauraki Plains Drainage Act 1908 and the Waihou and Ohinemuri Rivers Improvement Act 1910 to deal with them.

Under the first of these Acts, the Department of Lands and Survey commenced a river improvement scheme on the lower Piako with the primary aim of land development and settlement. Under the second, the Public Works Department set to, to control the lower Waihou and the Ohinemuri. The two operations between them resulted in the erection of about 325 kilometres of stopbanks and extensive channel works, very large operations for those days. Included were stopbanks along the shore of the Firth.



34. Early drainage work on the Hauraki Plains. (Hauraki Catchment Board)

The development of the Hauraki Plains was advanced greatly by these schemes and by the drainage of individual farms which accompanied them. By 1920, 16 000 hectares of Crown land had been settled. Two steamers were running two return trips weekly between Auckland and Kerepehi on the Piako River, the centre from which operations were carried out. Fifteen wharves on the Piako River were in use by launches serving the new farmers. Substantial drainage districts were formed around 1925 and these carried on with the day to day running of the drainage schemes.

Despite all these signs of progress, however, one writer has reported:

> "In the 'forties' the Hauraki Plains could be described as a depressed farming area. Cattle wallowed up to their knees in mud in the spring while the ryegrass and white clover fought a losing battle with water grasses, buttercup and penny royal. Pasture which survived to the autumn was eaten out by crickets and the cycle was then repeated."

After the passing of the 1941 Act the Government became anxious to involve local people in the river works and communal drainage works. A Catchment Board was set up in 1946, a year or so after most of the others. Unlike some boards its task was not to resolve competing claims for river control works, but to carry on with schemes which were already proving their value.

The Piako Scheme

It took some years for the Board to resolve its position because of the involvement of staff of Government departments in schemes already being developed and the lack of trained staff of its own. Eventually a Piako River Improvement Scheme was designed by Board staff. Work commenced in 1961 and was completed about 1975. Although the previous Lands and Survey work had functioned well, stopbanks were becoming dangerously low in places because they were sinking into soft foundations. Control was also needed further up-river because, by that time, the whole of the Piako catchment had been developed except for some peat areas. The original scheme, therefore, needed expanding and adequate provision had to be made for maintenance.

The improvement scheme included reconstruction plus new stop banking amounting to 160 kilometres in length; river and stream clearing of about the same length; and construction of 30 flood pump stations and 60 flood-gated culverts. A striking feature is that this complex and costly scheme has been profitably carried out on a small river whose flow can drop as low as 0.5 cumecs during dry spells.



35. 'Touch and go'. A Piako River flood a few inches below the stopbank near Morrinsville, 1960. (NZ Herald)

The Waihou Scheme

Two high floods in 1960 and 1961 which inundated a large area (and emphasised the urgency of the Piako scheme) occurred on the Waihou as well, where a life was lost and considerable damage done. Following these floods the Government formally asked the Catchment Board to act as its agent in maintaining the existing Waihou river scheme. The agency was to operate until the Board could review the river works and the conditions of the catchment and formulate its own improvements.

The Public Works Department scheme had proved to be reasonably beneficial in protecting farmland and townships against moderate floods. The 1960 high floods, however, frightened people and revealed defects, the main one being the closeness of the stopbanks. The narrow floodways could not contain large floods.

It soon became clear to the Catchment Board that a revised Waihou scheme had to embrace the whole catchment, a complex area of 2000 km². Not only that: on the plains, any extension or modification of river works, or the network of drains, was going to affect roading and bridging, water supplies and the planning of urban areas. Wide-ranging changes were involved. The Government therefore set up a committee to co-ordinate these.

Catchment Board proposals were complete by 1975. The Government accepted them and declared them to be works of National and Local Importance because of the threat that major flooding constantly presented.

'Work of Local and National Importance' is a legal category of works which can be undertaken by the Minister of Works or a local authority without conducting a loan poll. The idea is to speed up the execution of essential public or local body works. The procedure has been used for river works in some cases when a delay in construction could allow undue damage if flooding occurred.

The basis of the scheme was that the Board would assume responsibility for nearly 900 kilometres of streams and main and subsidiary waterways, plus measures for the control of run-off and erosion throughout the Waihou catchment.

The benefits that would be obtained included reduction or control of flooding over an area of more than 30 000 hectares and improved drainage and farming conditions throughout an area more than twice this size. Urban areas would be protected, especially Paeroa, where flood waters in the adjacent river flowed above the level of the town's main street. Parts of the town of Thames were affected in the same way.

Clearing and improving the main river channel would increase navigability and recreational use. The Waihou would become a pleasant river to sail up from the sheltered Hauraki Gulf. (There is no bar to cross at the mouth, and the river offers pleasing views with the mountains along its eastern side).

The next most important long-term benefit after flood protection would be safeguarding the river as the major water supply of the plains. Improvements in farming, once the land was free of floods, were bound to bring greater demands on water and the river was by far the best as well as the only large supply.

The immediate economic justification for the scheme was the increased production it would bring to the land and the elimination of flood damage restoration costs. The former was estimated to be an annual amount of about one eighth of the cost of the total scheme at that time. This was ample economic justification, and there was little doubt that it could be achieved.

Just as the river and drainage schemes at the beginning of the century had produced a remarkable leap forward so the Waihou valley scheme was expected to produce a similar jump. When promoted it was the most ambitious catchment and river control scheme in the country. Twenty years was the time set down for completion.

36. Paeroa on the edge of the Hauraki Plains and on the banks of the Ohinemuri River, close to its junction with the Waihou. When the Ohinemuri is in high flood the main street of Paeroa can be several metres lower than flood levels. (NZ Aerial Mapping)





37. The township of Te Aroha, pinned against the mountain by the Waihou Rover, here seen in flood. Streams descending the mountain flow through culverts under the main street. Blockages may result in floodwaters flowing down the streets. (Aerial Surveys Ltd.)

The risk had to be taken that no major flood would occur during such a long period of construction. Unfortunately one did, in April 1981. Previous floods had not been contained by the old control scheme. Nor was this one contained, although the damage it did was lessened to a considerable degree by the partially completed work of the new scheme.

As it was, flood waters entered both Paeroa and Thames and damaged some 400 houses as well as business premises. About 8000 hectares of farmland were inundated, fortunately for short periods only. The most spectacular effect was in the Ohinemuri River. Held back at the Karangahake Gorge, it rose several metres and obliterated the small village of Waikino except for its post office. Total damage was estimated to have been in excess of $30 million (1981).

The Mountain Torrents

The comprehensive character of the Waihou proposals was commendable, but perhaps their most interesting feature was the plan to control the mountain torrent tributaries. Europeans have a descriptive term for this work—'the extinction of torrents'.

The Mamaku Plateau and the Kaimai and Coromandel Ranges feed an unusually large number of torrents into the river system. The steep gradients of these is in marked contrast to the sluggish main river. At the junctions where the gradients change, bedloads in the streams tend to be dropped. In this way barriers are built up in the main river which, if they are allowed to remain, increase flooding.

Farming on the steep flanks of the ranges and forest together with damage by domestic stock and wild goats increases runoff, causing even more bedload to be carried down by the torrents. By the time the Waihou scheme was prepared, the river was severely threatened and shingle had spread across valuable flat land adjacent to it. Some of the tributaries from the Kaimai Range were bringing down boulders the size of large rooms. The effectiveness of the river control would be greatly reduced if the aggradation brought about by these streams continued.

By 1980 work was being undertaken on 59 of these streams. Thirty-four more have a potential need for control work in the future.

Three of the streams descend the steep sides of Mount Te Aroha itself and flow through the township of Te Aroha at its base. There have been difficult problems getting the water across the main street. Pipes under it became blocked by detritus carried down by floods and flood waters then careered through parts of the township. The water in two of these streams is polluted by tailings from mines that operated on the mountain side. The town's water supply was once drawn partly from one of these streams but had to be moved to an unpolluted stream. The tailings are poised in such a position that a heavy rainstorm could wash them down through parts of the township. Such is the legacy of mining.

Changes from forest to farming on the Mamaku Plateau also gave concern to the Catchment Board, not because this led to erosion—the land on the plateau itself is relatively flat—but because rainfall there provides a base flow to the river. The geology of the area is such that rainfall is absorbed and released as springs. Until it is known whether a change from trees to grass will alter the manner of absorption it is not safe to make the change.

Land use throughout the catchment is now watched carefully for its effect on the river system and on soil erosion. A close examination has been made of the effect of forest clearance high up the mountain sides. Some erosion has resulted from this and there is potential for more. Part of the overall Waihou scheme therefore includes proposals to purchase and reforest the land affected. The Forest Service has undertaken this work.

The Regional Water Board

In 1977 the Chief Executive Officer reported to his Board:

> "... Another summer season is with us, and the Thames Valley Rivers are again badly polluted by organic waste... the collective organic waste load from the Thames Valley Dairy Factories might approximate that of a city with a population perhaps of 200 000 persons. Less than half of this loading is receiving treatment or alternative disposal."
>
> And dairy factories were only one source of pollution.

The situation was full of difficulties. The two rivers were reduced to low flows—one of them very low in dry periods—and their sluggish nature made them easy to pollute. Moreover, in their lower reaches they were connected to every farm by a system of drains which became increasingly polluted as stock numbers grew. While stock made the greatest demand on water, the dairy industry was not far behind. In the mild climate, drains became choked with water-weed. Chemicals used to clear this added to the pollution. The recreational value of the rivers declined markedly.

It was reported that:

> "... surface waters are the only major water resource, and in real volume are limited to the Waihou River System. Therefore it is important to re-appraise the situation and formulate both policies and investigation to enable the provisions of the Water and Soil Conservation Act to be properly administered and allow for good water management".

Farm drains and wells provided the stock water but these sources could dry up. Dairy factories depended on the rivers. There was some underground water but the shallowest was heavily polluted by iron and other chemicals. The possibilities of uncontaminated supplies from deep wells required expensive investigations. Schemes were needed to combine existing withdrawals with reticulated water supplies to farms.

The growing of horticultural crops and their irrigation was just beginning at that time. The total area that could be considered for irrigation in 'the near future' was estimated to be about 166 000 hectares—possibly a highly optimistic figure. The water requirements for even a more modest area would be a great deal more than the total low flows of both rivers. Large-scale irrigation was thus a pipe dream unless intensive harvesting and management of water could be made a practical proposition. Even in the absence of irrigation the immediate future requirements for other uses could amount to something approaching two-thirds of the low flows. The system could not tolerate this level of use if it was at the same time to cater for recreational demands and absorb even a low level of pollution.

An impetus for a rapid increase in production from the land protected from flooding will follow the river schemes. Water will set its limitations. Where can additional supplies come from? Deep bores may reveal more underground water; water harvesting could add to supplies; and more efficient uses will save some water. It is possible however, that Hauraki may, before long, look to the Waikato for supplies, as Auckland is doing.

The Coromandel Peninsula

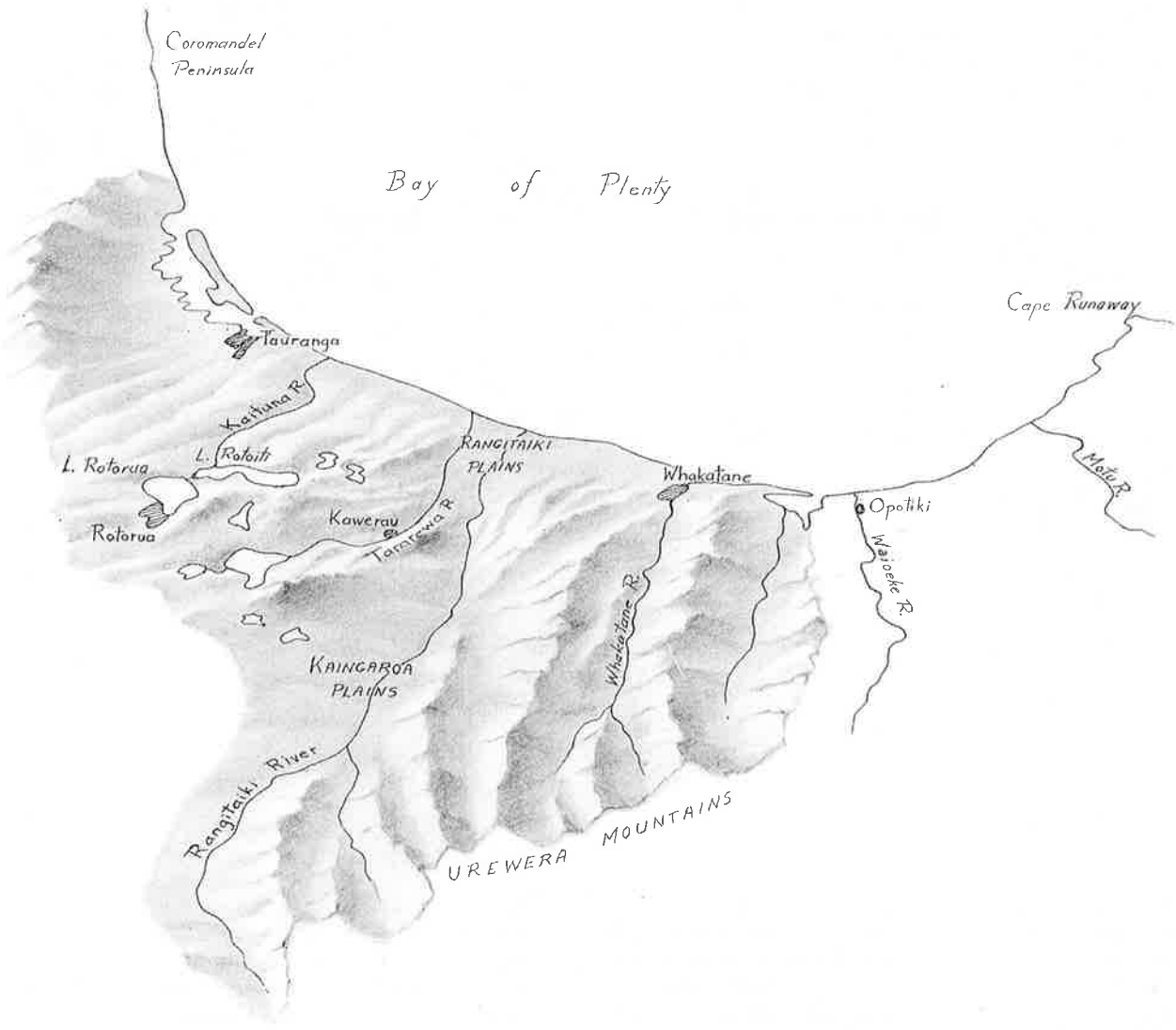
The Hauraki swamps remained isolated and undeveloped for a long time, but it took even longer for people to realise the asset that they had in the Coromandel. Poor roads and a lack of farming land held development back, even though, in early

times, the district had yielded gold and large volumes of kauri timber which had been floated from its many harbours to Auckland. (The peninsula is named after the ship *Coromandel* which collected kauri spars there in 1820).

There was little to persuade the area to join the district of the Hauraki Catchment Board when it was formed but it had to be included "for Regional Water Board purposes" following the 1967 Act.

Meantime in the 1960s and '70s a boom in development took place. Road access encouraged a very rapid expansion of settlement around the beautiful coast. Farming expanded on to whatever land it could and afforestation, which had been going on for some time, also expanded.

Increasing water supplies were needed. These are not easy to obtain because the short, steep streams flow from the rugged Coromandel Range directly to the sea with little in the way of easily-tapped lower reaches. The Coromandel Peninsula, no less than the Hauraki Plains, will continue to present challenges to the Catchment Board.



38. Bay of Plenty Catchment District

The country leading down from the volcanic plateau and the Urewera Mountains to the Bay of Plenty is drained by six large rivers and a number of smaller ones. Of the main rivers the Motu and the Waioeka are in the East Cape Catchment District, while the Whakatane, Rangitaiki, Tarawera and Kaituna are in the Bay of Plenty District.

These rivers differ markedly in character and all have had major influences on the development of the region. Floodplains of the Whakatane, Rangitaiki and Tarawera merge to form the Rangitaiki Plains. River and drainage schemes have been undertaken to reclaim these. The river control scheme on the first also protects the town of Whakatane. In the Kaituna River and its associated lake complex, schemes aim to control erosion in the lake basins, levels of the lakes, pollution of the lakes and flooding of a small floodplain. (D W Lawrence)

A Bay and Six Rivers

From Mount Te Aroha on the Kaimai Range from which the grand view of Hauraki is obtained, one catches glimpses also of the great sweeping bay stretching from the Coromandel to Cape Runaway, prophetically named by Captain Cook the Bay of Plenty. Into it flow six large rivers, the Kaituna, Tarawera, Rangitaiki, Whakatane, Waioeka and Motu. All have strikingly different catchments, as seen from Table 3, a diversity reflected in the development of the region. (The table omits the Motu and the Waioeka, which are in the East Cape Catchment District).

TABLE 3

Bay of Plenty Main River Catchments and High and Low Flows

River	Catchment Area	100 yr Flood Flows	Low Flows	Nature of Catchment
	km^2	cumecs	cumecs	
Whakatane	1748	2550	12	Urewera steep mountains, mainly forest clad
Rangitaiki	3017	990	140	Deep volcanic detritus (pumice)
Tarawera	997	110	34	Lake-controlled
Kaituna	1243	1250	62	Half lake controlled; half steep country forest clad

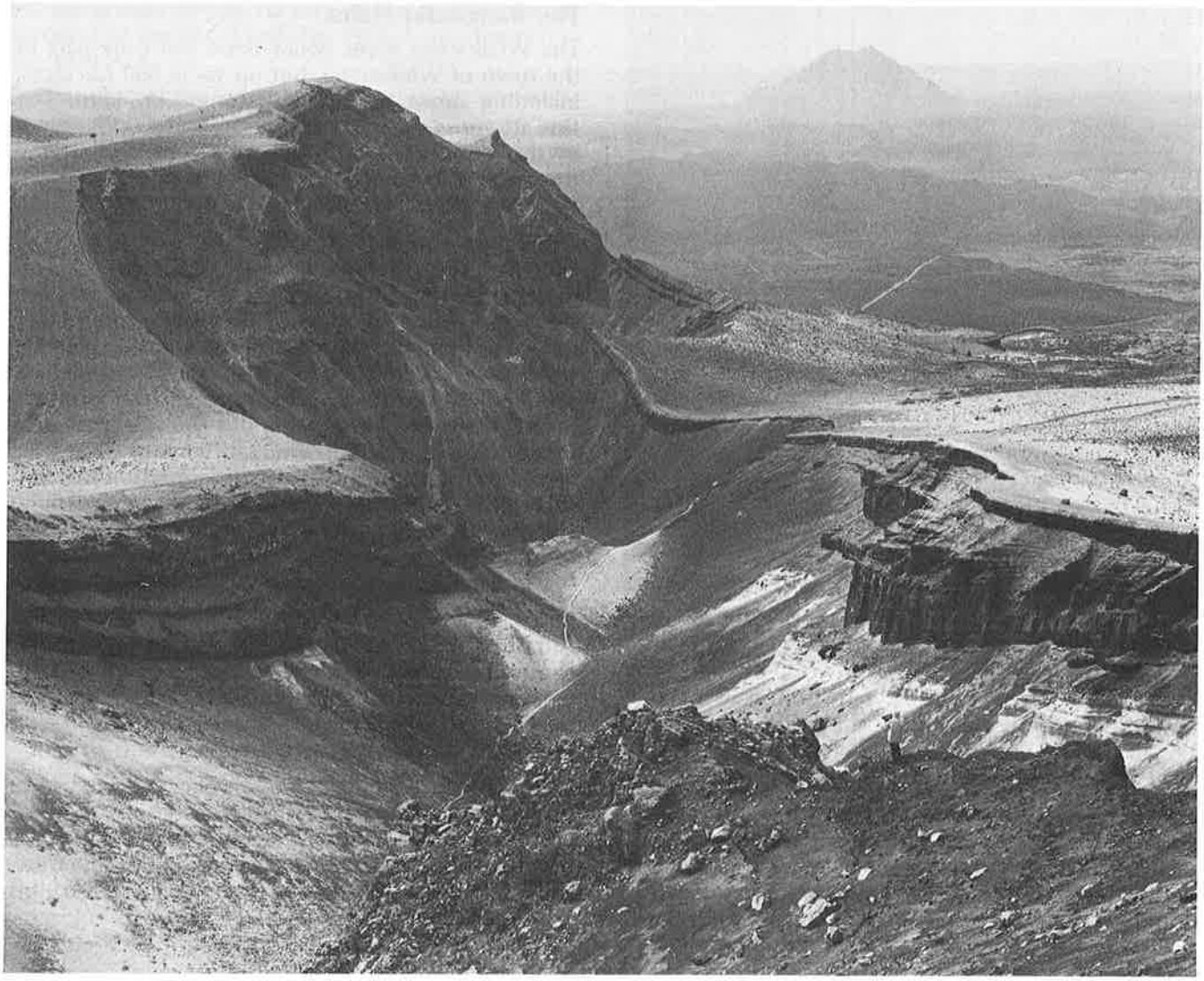
The first two rivers, the Tarawera and Kaituna, flow from lakes formed on the edge of the pumice plateau; the Tarawera from Lake Tarawera and the Kaituna from Lakes Rotorua and Rotoiti. The lake influences dominate the flows of both rivers.

The Rangitaiki River rises on the watershed of the Lake Taupo basin, flows across the Kaingaroa Plains and continues between them and the Urewera. In its middle reaches it has formed the Galatea Plains from which it emerges onto the Rangitaiki Plains, an extensive flood plain shared with the Tarawera. In total, these plains are not far short of 40 000 hectares. For the greater part of its length the Rangitaiki passes through thick deposits of ash which act as a sponge and help to regulate its flow in the same way that they do the flow of the Waikato.

The Whakatane and its main tributary, the Waimana, emerge from the forest-clad Urewera onto a flood plain formed partly from the volcanic ash washed from the mantle that covers the mountains. Until it had a flood control scheme the river frequently flooded the town of Whakatane on the coast and the Rangitaiki Plains to the west.

In a number of ways the Bay of Plenty is linked with the volcanic plateau. There is a general slope of the country to the bay. Much of the area is covered with pumice and volcanic material from the eruptions that formed the plateau or from volcanoes around its periphery. Some of the lakes in the region, notably Rotorua, have been formed in the same way as Taupo. Geothermal activity and the remains of volcanic activity occur in several areas.

Pakeha settlement was attracted throughout the region, already quite densely inhabited by Maori standards, for various reasons. Rotorua with its geysers and other thermal displays and lakes was a clear choice as a tourist centre. Farming and forestry quickly extended through the open pumice country. The elevated Kaingaroa Plains were first selected in the last century for the planting of exotic forest trees on a large scale, the land being too elevated, deficient in water and cold to attract farming. The flood plains along the coast invited agricultural development. Tauranga soon became the harbour for the area.



39. Mount Tarawera crater, formed by the eruption of 1886. This was one of the many eruptions that helped to build the Volcanic Plateau. (D L Homer, NZ Geological Survey)



40. Kaingaroa Forest, in the catchment of the Rangitaiki River. A stand of yellow pine (Pinus ponderosa) felled with a tree feller. The stream is protected from possible erosion by a riparian strip. (Bay of Plenty Catchment Commission)

Opotiki and Whakatane grew up on the courses of wild rivers. Opotiki seemed anxious to expose itself to the maximum danger. It expanded in a small space between the main channel of the Waioeka and a major tributary. Escaping from floods became a well organised exercise. Whakatane showed a preference for expanding on to flood-prone areas rather than moving up onto the hills behind.

The East, the West and Catchment Commissions

The Soil Conservation and Rivers Control Council at first considered that the whole of the Bay of Plenty region should be included in a Catchment Board district. This would have been a logical arrangement from their point of view. The immediate problems, however, were all in the eastern part—the flood problems of the Waioeka, Whakatane, Rangitaiki and Tarawera Rivers together with improvement of drainage of the Rangitaiki Plains.

Rotorua and Tauranga, and the counties around them, maintained that they had no river or soil erosion problems. Why should they contribute towards the river and drainage work of the east? That river control schemes were bound to have a considerable effect in raising the value of production, and that Tauranga would benefit possibly more than any other place, was an argument that fell on deaf ears.

After nearly 20 years of difficult endeavour, an Eastern Bay of Plenty Catchment Commission was set up in 1962 so that comprehensive schemes of work could be undertaken on the troublesome rivers. (It will be remembered that a Catchment Commission includes representatives of local authorities rather than representatives directly elected by ratepayers). In 1964 the Tauranga and Rotorua areas relented and joined a Bay of Plenty Catchment Commission. The individual members of the whole group were, however, uneasy bedfellows, and not until water management was added to their duties by the 1967 Act did they become better integrated. That legislation highlighted pollution and other problems such as were evident in the lakes of the western area.

Opotiki was always unhappy about its position in this organisation even though it was part of the Bay of Plenty. It could see no progress with its quarrelsome neighbours. It took advantage of the direct link with Gisborne along the Waioeka road and chose to join that Catchment Board rather than the local Commission, so becoming part of the Poverty Bay—now East Cape—Catchment Board district. Because the Motu catchment and river lay to the north of the Waioeka they were also included in the East Cape district.

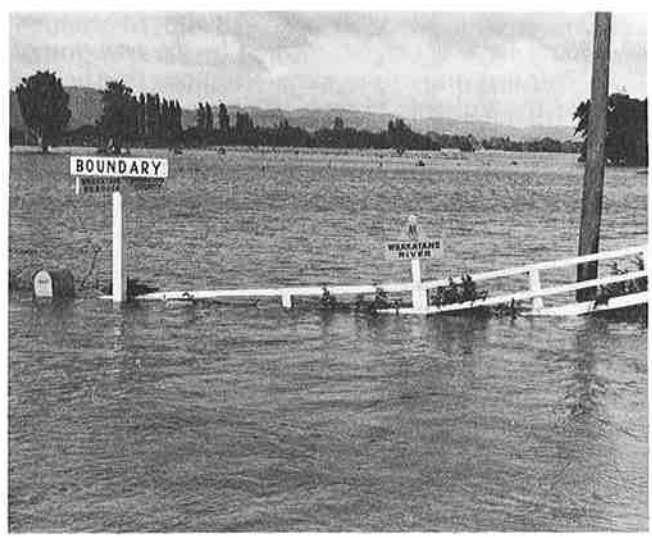
The Rangitaiki Plains

The Whakatane River could flood not only part of the town of Whakatane, but up to 10 000 hectares, including about 5000 on the Rangitaiki Plains. The first attempts to protect this area were undertaken by the County. Some headway was made, but the threat to Whakatane Borough increased as more flood water was sent down river.

There was also fear that the river was aggrading. Much of the catchment was in the Urewera and remained under forest because the country was too steep to clear. The rugged, greywacke mountains, however, being on the edge of the volcanic plateau, were covered with a mantle of ash. This began to erode when red deer spread through the Urewera in the 1930s and '40s, eating out the lower tiers of protective vegetation. Animal control measures were instituted soon after the deterioration became severe, but the task seemed well-nigh impossible. Deer were very difficult to shoot because they remained inside the forest and were only visible on the limited open areas of river flats and mountain tops.

Although the forest was not cleared for agriculture, about one quarter of it was in Maori tenure and the owners were making plans to allow logging at the time when concern for flooding in the lower reaches was at its height.

Opposition to logging proposals became one of the early conservation issues, highly charged with emotion, and widely debated at meetings and in the press. Finally the Soil Conservation and Rivers Control Council agreed that logging could proceed if it



41. The Whakatane River in flood, 1964 (before a complete lower river protection scheme was in operation). (Bay of Plenty Catchment Commission)

was supervised by the Forest Service and regulated pursuant of section 34 of the 1959 Amendment to the 1941 Act.

Operations on the land sometimes call for controls or area prohibitions. Nobody likes restrictive or 'big stick' legislation, but it is sometimes advisable to have it ready for use where, for example, operations cause or threaten erosion or endanger watercourses. Restrictions on such practices are included in section 34 of the Soil Conservation and Rivers Control Amendment Act 1959. These have been widely applied and the effect of their use has been most successful.

The first occasion on which this legislation was used was in the Urewera in 1961. It was introduced with a fanfare. The Minister of Forests, Hon Sir Eruera Tirikatene, a colourful personality and skilled orator, held a meeting with the Maori owners on the Ruatoki Marae to explain the scheme. Addressing them in Maori he began:

> "To this sacred Marae, greetings. Salutations to this distinguished and sacred land, especially reserved by the chiefs and leaders of the past and decreed by them to be the place for expressing welcome and greetings.
>
> It is fitting that we pay tribute and homage to those who have passed beyond the veil. Greetings to this meeting house "O te Nuku". Within your walls is the storehouse of works of wisdom and guidance which have been delivered by the orators and the songbirds of the past . . . "

The Minister's oration lasted for four hours, as he tried to convince the owners of the need to preserve the forest they had inherited. He succeeded. From then on the operation proceeded most satisfactorily. Timber trees on some classes of land were felled but logging left the main body of the forest intact. Felling was prohibited on other, mainly very steep, land. Watercourses were left clear of debris.

Downstream, settlers struggled to drain the wilderness of swamps and lagoons that made up the Rangitaiki Plains. Little progress was made beyond the margins and the high ground along the Rangitaiki and Tarawera Rivers. Both had built up substantial levees across the swamps to the sea. On the coast their mouths migrated and sometimes met in a common outlet.

The task of drainage had early proved too great for individual farmers or even for groups of them. In 1894 they had formed a Drainage Board, but it lacked money. In 1910 the Government was persuaded to take over the work, which it did under the Rangitaiki Land Drainage Act.

The Department of Lands and Survey then designed a scheme to drain nearly 35 000 hectares. The two rivers were provided with channels straight out to sea. The success of the drainage operation was marked, but there remained the problem of flooding.



42. An exclosure in the Horomanga Valley, Urewera, demonstrating the effect of wild animals—mainly red deer—on the forest floor. Throughout the whole of the Urewera forests, totalling some 400 000 hectares, wild animals destroyed the ground vegetation at one time and caused extensive erosion of the pumice mantle within the forest. Very difficult and persistent animal control is reversing this trend. (Bay of Plenty Catchment Commission)

The Catchment Commission took over this scheme, built flood protection works for both rivers and added refinements to the drainage of the plains. Over half the soils are peaty and cause trouble by sinking when drying or under the weight of the stop banks. One tenth of the area must be kept dry by pumping.

Drainage had already been far advanced and farmers were able to amalgamate and make a joint proposal to manage their own affairs. The Rangitaiki Land Drainage Act 1956 provided for this local control. This, together with the Commission's river schemes that followed, have brought to a most satisfactory stage over 100 years of struggle to farm the plains.

In addition it has introduced an era of rapidly changing land use from farming to horticulture. Such a change could not take place without the river control schemes, drainage and now irrigation from management of the plentiful water resources for multiple uses.

Lake Rotorua and the Kaituna Scheme

"Your lake is an open sewer"—a remark, exaggerated somewhat, made by a tourist; but it jolted Rotorua into looking more closely at one of its cherished attractions; a lake that yielded more than 45 tonnes of trout a year to fishermen.

Things were happening around the basin of the lake and were polluting the water. The township had become a city, and close settlement was sprawling all around the catchment, especially on the attractive lake edge. Sewage and stormwater were conveniently discharged into the lake. Farming was intensifying and farm drainage found its way into the many streams flowing down the sides of the basin. Rapid run-off from the pastures caused the streams to cut down and erode, and pumice was washed down to form deltas out into the lake.

Except for stream erosion the Catchment Commission, when first formed, had no reason to be concerned with this problem. Its hands were full with schemes of river control and flood plain drainage. It was, however, involved with flooding in the lower Kaituna River.

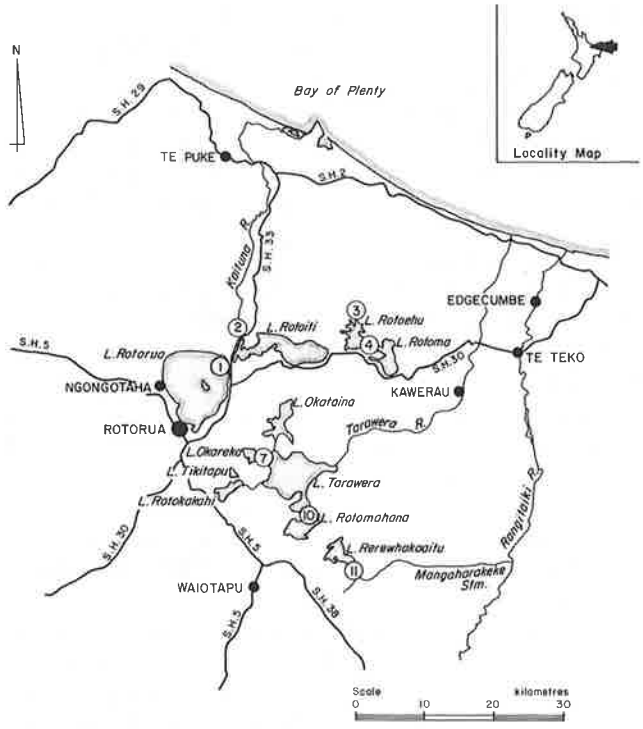
The total catchment of the Kaituna is 1250 km². It is divided into two almost equal parts. The catchments of Lakes Rotorua and Rotoiti form the upper half, and the catchment of the river after leaving Rotoiti, the other half. Rotorua empties into Rotoiti through the short Ohau Channel, and the river tumbles from the lake over the Okere Falls which at one time were harnessed for electricity. After dropping rapidly it flows through a small flood plain and in its untouched state emptied into the sea through the Maketu estuary.

Having made good progress with the 3 more easterly major rivers the Commission was soon in a position to draw up a scheme for the benefit of 6000 hectares of floodable land; not a large area in comparison to the Rangitaiki Plains, but important to the district. The new scheme involved, as had the earlier ones, a new channel for the river mouth, which since 1956 has been directly onto the coast at Te Tumu instead of through the estuary.

By the 1970s Lake Rotorua had become markedly enriched with nutrients, which caused the growth of undesirable plants in and around the lake, (a process known as eutrophication). Such growth, if unchecked, would lead to further and more rapid deterioration.

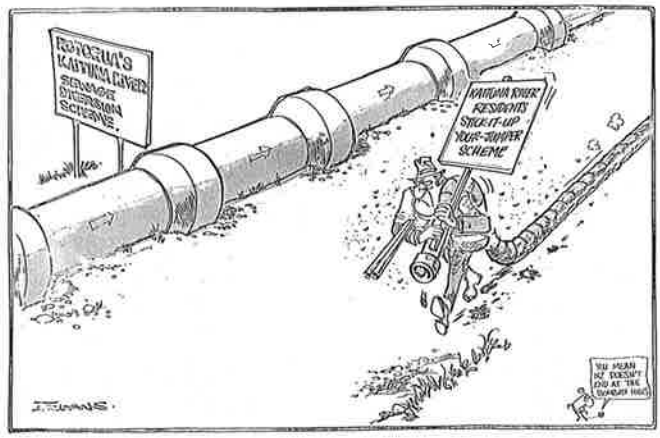
The Commission by now was responsible for water management. It therefore co-operated with the National Water and Soil Conservation Authority and its two councils in a complex investigation of schemes to prevent, or slow down, eutrophication.

This was complicated by another result of recent development. People had sought to dwell on the



Lake	Area km²	Height above sea level (m.)	Outlet
1. Rotorua	69·41	280	Control structure (Ohau Channel) to L. Rotoiti
2. Rotoiti	33·41	279	Control structure (Okere Falls) to Kaituna R.
3. Rotoehu	7·51	295	Tunnel outlet to Waitahanui Stream (proposed)
4. Rotoma	10·88	316	Control structure to L. Rotoehu
5. Okataina	11·03	312	
6. Tarawera	44·03	299	
7. Okareka	3·19	354	Control structure to L. Tarawera
8. Tikitapu	1·55	418	
9. Rotokakahi	4·66	397	
10. Rotomahana	7·77	335	Control structure to L. Tarawera
11. Rerewhakaaitu	7·51	438	Control structure to Rangataiki R.

43. Lakes in the Rotorua region and control structures regulating their levels. (MWD)



44. Applications for water rights for the Kaituna Scheme crystallised differences between those who dwelt around the lakes and those who lived along the lower Kaituna. The former had to rid themselves of their sewage but the latter did not want it in the river that had become part of their lives.



45. The Upper Kaituna Scheme. Erosion and stream control work necessary to help reverse lake pollution processes. (after Bay of Plenty Catchment Commission)

very lake edges, to enjoy the facility of a boat moored off one's own property allowing fishing whenever the inclination arose. This was fine, if the lake remained at a steady level. But during flood or continuously wet seasons as sometimes happened, lakes rose, land became inundated and houses were flooded.

It was possible to affect the level of Lake Rotorua by exercising some control over the Ohau Channel. A much more difficult problem, however, was to agree on levels which suited all parties: lakeside dwellers, boaters, fishermen, sightseers and others. This was finally achieved and partial control has been exercised since 1974.

Logic dictated that the whole Kaituna catchment should become involved in a comprehensive water and soil scheme. Why should lake dwellers receive benefits while farmers along the lower river were struggling with floods? What of the nutrients? Sewage effluent must be kept out of the lake at all costs. Where was it to go? The many streams entering the lake must be made to run clear again. A comprehensive scheme had to include the lakes, the river, and local as well as national issues. After much investigation, expert reports, wide-ranging negotiations, and ministerial visits flavoured with some acrimony, agreement was reached.

The proposed levels of expenditure and subsidies were such that approval was required from the Cabinet. This was given in 1980. A list of the items is set out in Table 4 to demonstrate the breadth of a scheme of this nature, involving a catchment, its lakes and its rivers.

Execution of the work had to be subject to the granting of the necessary water rights, and the period of construction allowed for was 10 years.

TABLE 4

Kaituna Scheme Costs (1980 Figures)

	$
Soil Conservation and erosion control	4 270 000
Lake level control	802 000
Flood protection (Rotorua area)	1 800 000
On-farm forestry protection	260 000
Nutrient pipeline (to carry Rotorua sewage away from the lake)	5 668 000
Flood protection (lower Kaituna)	4 720 000
Drainage works (Kaituna swamp)	780 000
	$18 300 000

Water Rights, Power Schemes and Hot Water

The Kaituna scheme, because of the attention it demanded and the publicity it attracted, overshadowed other important water management developments. An extensive and unusual range of water resources is, however, contained in the district and use is made of all of them. Apart from the rivers and many lakes there are at the western end of the district beds of underground geothermal steam and hot water.

Major water rights include those for freezing works, 3 large dairy companies, 3 pulp and paper plants, and the sewage effluent and stormwater from 2 cities, Tauranga and Rotorua.

46. Ruahihi Canal, constructed as part of a power scheme to use water from the Wairoa River, Bay of Plenty, failed in 1981. The escaping water rapidly ate away the highly erodible land it traversed. (Kerry Grant Photography)



By 1980 about 150 water rights were being processed each year. The majority of these were related to irrigation for horticulture on soils protected from flooding. The development of horticulture in many parts of the Bay of Plenty has been rapid and this tempo is likely to increase. There is ample water for irrigation, and the use of natural hot water and steam will provide a major stimulus for certain types of horticulture.

Geothermal steam resources are also being tapped for generating electricity, for manufacturing processes, and for industrial and domestic heating. The Commission is not involved in the taking of this steam, but is responsible for the discharge of water once the steam has been used.

Most of the lakes are at altitudes between 300 and 400 metres. The regulated flows that come from them attract the planners of power schemes. In no way does the potential match that of the great resources of the Waikato, the Waitaki or the Clutha. But they are eminently suitable for smaller schemes. The Commission is closely involved in assessing resources for this potential.

For the Benefit of All

In spite of a divided beginning the Bay of Plenty Catchment Commission has achieved a marked degree of success. Will this lead to a district finally welded together for soil conservation and water management purposes? The benefits derived from the river schemes, the reclamation of the Rangitaiki, Kaituna and other swamplands, and the extensive use of river and lake water, steam and hot water, benefit the whole district.

Will the waters of Lake Rotorua be improved? Measurement of the quantity and quality of all the water entering and leaving is now being undertaken. Processes going on in the lake are also being studied. Many scientific disciplines are involved in this, and a Scientific Co-ordinating Committee of the Commission collates the results.

The remarkable current development of the Bay of Plenty is attributed to an intensive dairy industry, to the utilisation of the large exotic forest of Kaingaroa and elsewhere, and to the growth of horticulture. None of these industries can flourish without ample supplies of water.

EAST CAPE CATCHMENT BOARD

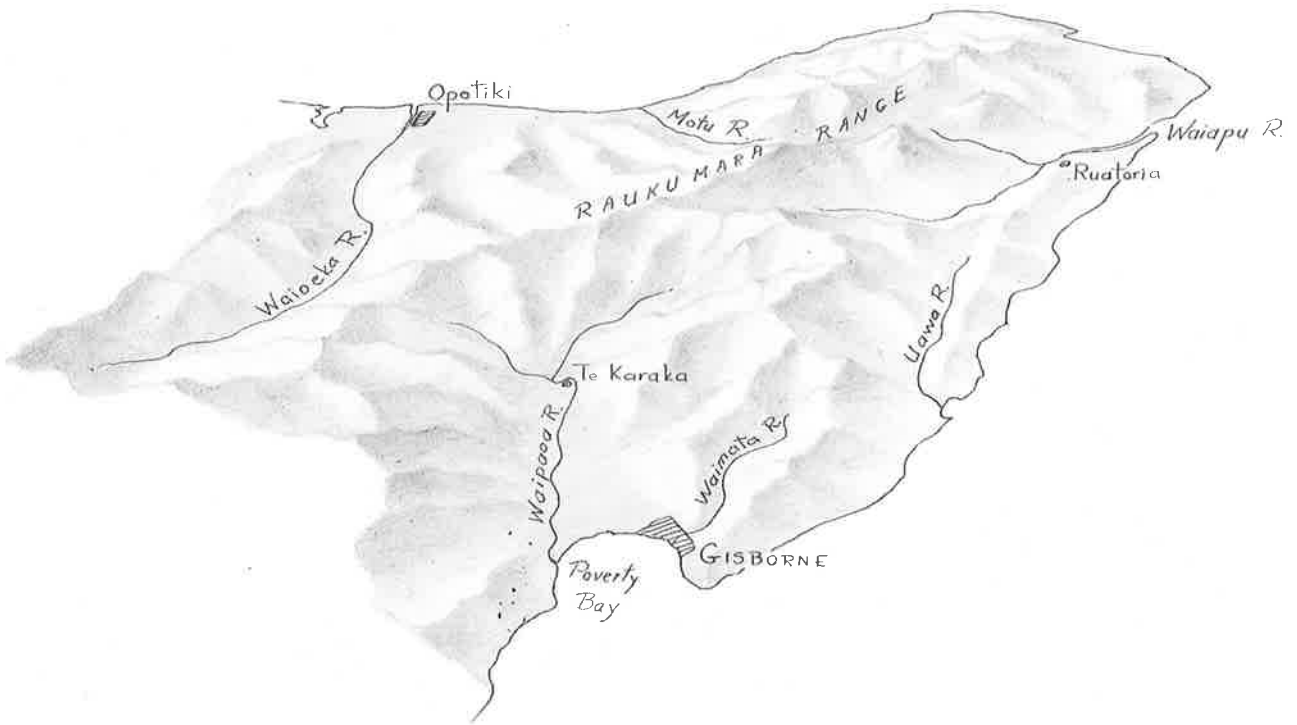
The Country's Most Severe Erosion

Slips and slumps bedevil the lives of the people who live in the area between Gisborne and East Cape. Flows of mud, sometimes kilometres wide or long, are fed by erosion and earth movements. They fill the streams and send great quantities of silt down the rivers to the sea. The soft and shattered mudstones in an area affected by intense rainstorms lend themselves to this kind of damage.

Originally the cover of native forest masked the instability, and, judging by early records, controlled most of it. Captain Cook was impressed by the 'verdure' surrounding Tolaga Bay when he called here after being discouraged in his attempts to land at Poverty Bay. There was fresh water aplenty and a supply of sweet potatoes and yams available from the Maoris who grew them in the rich soils and warm climate.

But the land was so rough and unstable when cleared of forest that, until the turn of this century, there was no continuous road north of Gisborne. Some of the softest mudstones were impossible to drive roads through—and keep them there. Settlement of the East Coast was, therefore, held up. When it began in the 1880s, people brought their stock with them in small coastal vessels. They anchored off-shore in the open bays. Everybody and everything—people, stock and merchandise—had to be lightered to and from the beaches. Unlike many other parts of the country, there were no harbours or river estuaries. Villages were established in the bays where Maoris already had their pas.

From these beach-heads, the forest was cleared and the country stocked with sheep and cattle. There were initial setbacks, but, in spite of them, production reached substantial levels, since the soils from the mudstones were rich.



47. East Cape Catchment District

A greywacke mountain chain extends from the hinterland of Hawke's Bay to East Cape. Slopes descend steeply to the sea in the north. The south-east slopes are flanked by tertiary mudstones and sandstones. The greater part of these are highly erodible and prone to mass movements right to the coast. Two main rivers flow northwards through greywacke, the Waioeka and the Motu. The latter is deeply entrenched and is one of the most inaccessible rivers in the country. Two main rivers, the Waipaoa and the Waiapu, rise on the south-east flanks of the mountains and flow through the soft tertiary rocks. They have formed floodplains which are important to the district, that constituting the Poverty Bay flats being a key to the economy. Deforestation over the soils on tertiary rocks led to such severe erosion that only major reafforestation can cure and prevent it. (D W Lawrence)

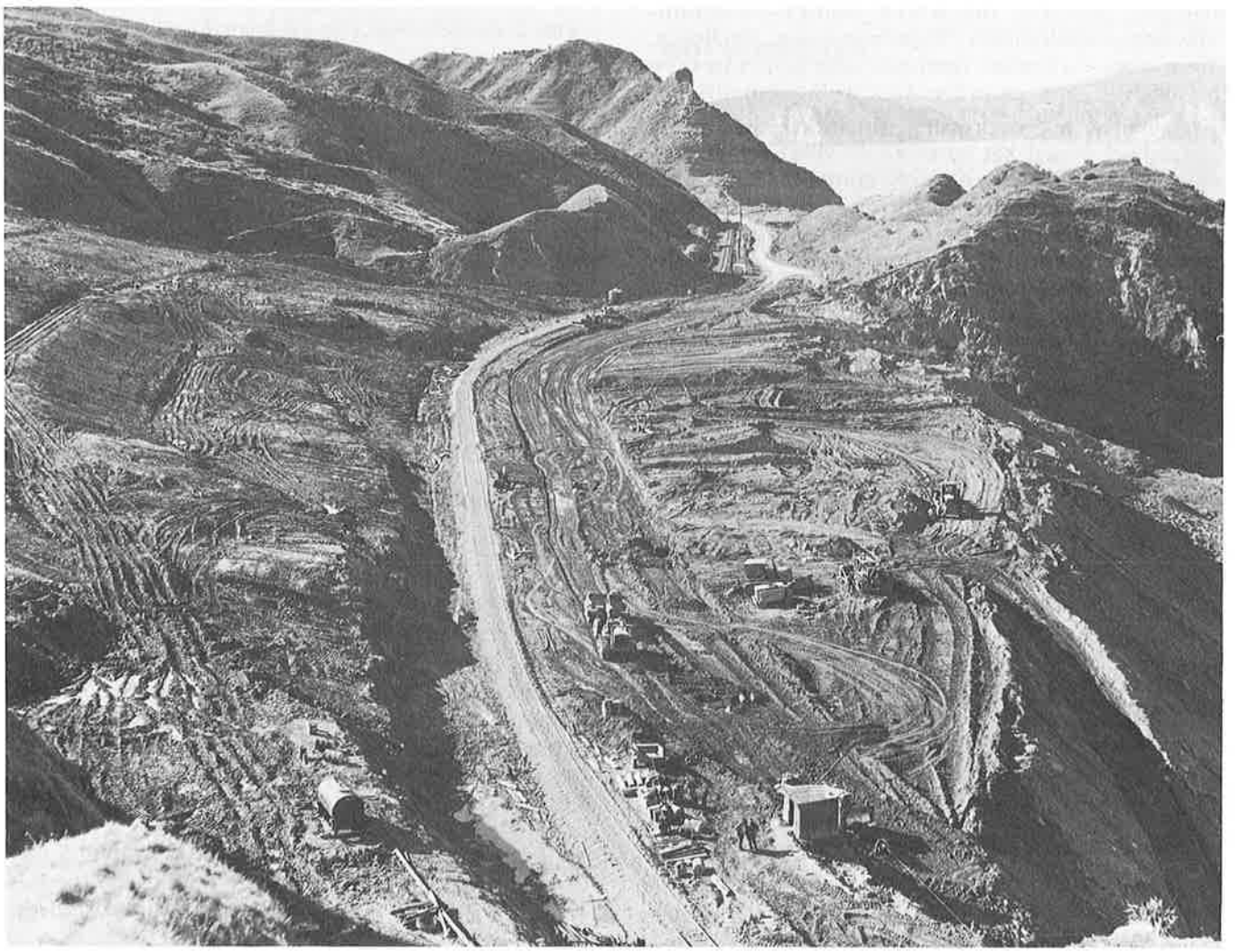


48. East Coast transport. Loading wool at Waipiro Bay for sale in Napier in the days before there was a continuous road linking East Coast settlements with Gisborne and Gisborne with Napier. (Alexander Turnbull Library)

Erosion, however, was not long in developing, and, in the short space of 30 to 40 years from the clearing of the forest, it became the most severe in the country—severe even by world standards. Moreover, once started, it kept accelerating.

The scarcity of stable or flat country meant that homesteads often had to be sited in precarious positions. Fences were damaged by slips or moving country, thus preventing close subdivision. Stock losses, in the quagmires caused by erosion, were high. Bridges, on what roads there were, often had to be raised as streams and rivers became filled with silt. Rapid accretion along some sections of the coast followed intense deforestation between 1890 and 1910.

49. The main hazard to road and rail communications on the East Coast is movement of the country. Here the Waikokopu slip between Napier and Gisborne has destroyed substantial lengths of road and rail. (NZ Government Railways)



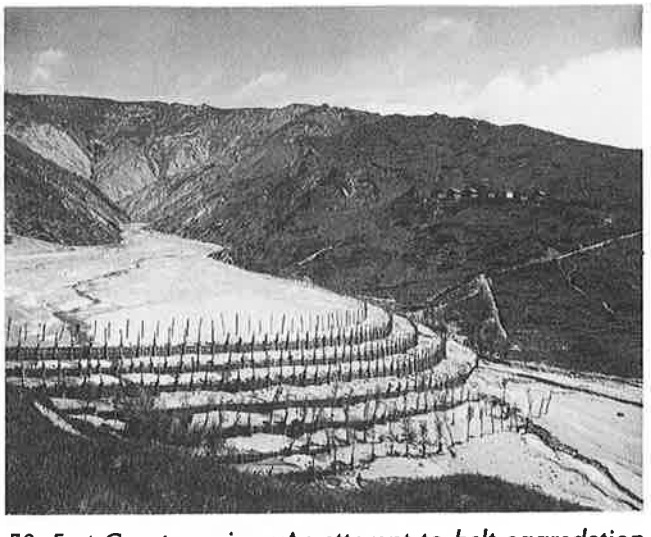
Bold and comprehensive measures were needed to stem this erosion, but these were quite beyond the means of individual farmers. Sometimes huge erosion scars affected two or more properties. A joint approach to control this was essential, but each owner was busy enough with his own problems. One settler, A B Williams, on his nearly 3000 hectare station, Puketiti, inland from Waipiro Bay, set to work to combat the problem. He approached this mainly by tree planting and damming some streams to prevent slipping along their sides as they cut down. A lot of erosion was prevented by these methods but by no means all of it.

The Catchment Board

The Poverty Bay (now East Cape) Catchment Board came into existence in 1944, one of the earliest established. It embraced all the land from the catchment of the Waipaoa river (the boundary with the Hawke's Bay Catchment Board district) to the East Cape. It therefore included all of this unstable country.

By now, erosion had reduced productivity, thus adversely affecting the whole district—economically and sociologically. Population was declining. There were no known methods with which to cure the gigantic slips, or prevent earth movements.

Faced with this depressing situation, the newly established Board set to work to discover appropriate approaches to erosion control. Planting of trees in blocks around slips, planting of trees widely spaced across slipping country and the building of dams were eventually used on an extensive scale. These and other methods were developed over a number of years, but the most deep seated erosion continued. The major task was beyond even the Board.

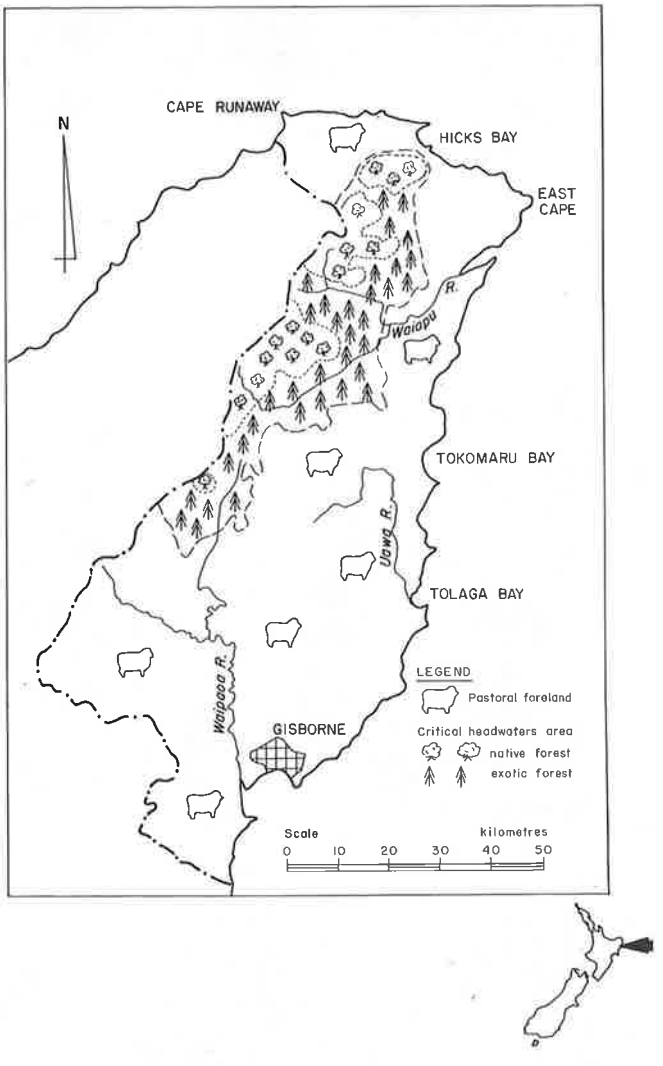


50. East Coast erosion. An attempt to halt aggradation downstream, but unsuccessful because of the rate at which erosion upstream is proceeding. (MWD)

The East Coast Project

Almost 20 years passed, during which time there was a growing realisation that nothing short of radical changes in land use were likely to succeed. If the land had been reasonably stable under native forest then, perhaps, it would return to stability under exotic forest.

In 1963, the Soil Conservation and Rivers Control Council appointed a technical committee with wide



51. The broad plan, known as the East Coast Project, separating the "critical headwaters"—mainly of the Waipaoa and the Waiapu Rivers—from the "pastoral foreland". The original proposal was to afforest the former and develop the latter more intensively for farming. Since the scheme was approved by the Government in the 1960s such rigid division of the land has been found neither possible nor desirable. Some farming is viable in the critical headwaters and there is a substantial amount of erosion in the pastoral foreland requiring afforestation. (MWD)

terms of reference to investigate the problem. The chairman was N H Taylor, Director of the Soil Bureau, DSIR, who had an intimate knowledge of New Zealand soils and their capabilities. The scope of the enquiry included agricultural alternatives, forestry, finance, and other matters related to the land use and production of a region of almost 650 000 hectares. The committee's findings—the results of 4 years of investigation—have been published as *Wise Land Use and Community Development.*

A bold approach was required. The first decision was to divide the area approximately into two land use categories separated by what came to be known as the "blue line". This divided the "critical headwaters", consisting of the most eroded and erodible land in the headwaters of streams and rivers, from the "pastoral foreland", the easier and less eroded country where farming incorporating conservation measures could safely continue.

The committee examined five possibilities, ranging from maintaining the status quo to adopting a proposition which involved tree planting over the whole of the critical headwaters—about 100 000 hectares. The intermediate schemes included varying amounts of planting. The proposal advocating the greatest area of afforestation was recommended. The case was so convincing that it was readily supported by the Soil Conservation and Rivers Control Council and then approved by the Government.

This was the most revolutionary decision ever made on soil conservation in New Zealand. It would have far-reaching effects, the most predictable of which would be an increase in population accompanied by development of urban centres, upgrading of roads and construction of a new port. Money was likely to pour into more intensive farming, as well as farm conservation measures. The Catchment Board would become increasingly involved in the promotion of better land use practices, especially for safe urban development and the use of an unstable coast (along which a swelling population would want to find its recreation).

The simple division by the blue line emphasised the problem initially. As time has passed it has come to be seen as too rigid. More precise divisions are now being based on detailed land use capability surveys carried out by the Board.

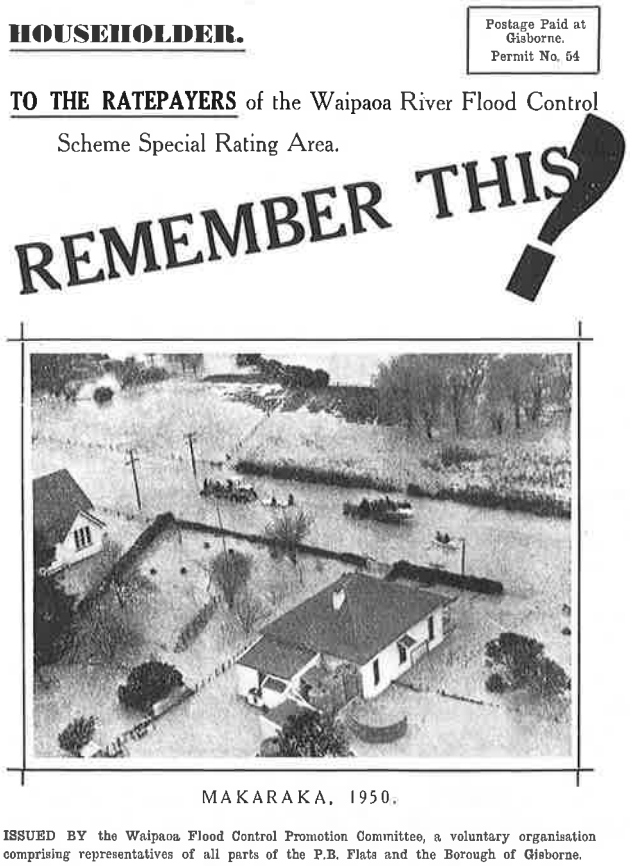
The hill country (pastoral foreland) erosion problem unfortunately still exists. Stream activity and heavy rain cause much of the surface erosion. But a more serious phenomenon is what has come to be known as 'mass-wasting'. This is caused by the slipping, shearing and folding of the soft tertiary rocks. It takes the form of slumping, sliding and mass flow movements.

The erosion processes that are going on can usually be determined by the appearance of the land surface. It is highly disconcerting and sometimes economically disastrous to landowners and managers to discover that these movements can, at times, proceed at rates of up to 30 metres per year.

The processes are so important to planners and so interesting to technical people that the region has been subject to intense investigation. There is now an accumulation of knowledge on rock formations and their movements, erosion—including coastal erosion, and mass wasting.

The Waipaoa River Control Scheme

The stimulus to set up the Board had not come from consideration of these problems but from the urgent need to control the lower reaches of the Waipaoa River and so protect the Poverty Bay flats—the only substantial area of flat land in the whole district—and the town of Gisborne.



HOUSEHOLDER.

Postage Paid at Gisborne. Permit No. 54

TO THE RATEPAYERS of the Waipaoa River Flood Control Scheme Special Rating Area.

REMEMBER THIS!

MAKARAKA, 1950.

ISSUED BY the Waipaoa Flood Control Promotion Committee, a voluntary organisation comprising representatives of all parts of the P.B. Flats and the Borough of Gisborne.

52. A pamphlet issued by the Waipaoa Flood Control Promotion Committee, after the Poverty Bay Catchment Board had been formed, in support of endeavours to promote a flood control scheme.

The centre of the East Coast region is the Poverty Bay flats and Gisborne, the city that nestles on their northern side. On the fertile soils are many vineyards and orchards, some growing semi tropical fruits. In summer, the land not under fruit carries maize and crops for canning.

Across the flats flows the Waipaoa River. This is now contained between stopbanks, some of them up to 5 metres high and constructed for more than 26 kilometres along a total river length of 120 kilometres. It is an innocent looking river at its normal flow of 20 cumecs. It can shrink to as low as 2 cumecs during dry spells.

But in flood, it is far from innocent. Although the catchment is little over 2000 km² in area, it has yielded a peak flood flow of 4000 cumecs. That is why the stopbanks are there. It is estimated that even a flood of up to 5000 cumecs could be contained by them. This flood level is estimated to be only likely to happen once in every 200 years.

Deposition on the Poverty Bay flats during the last 3500 years has been studied in detail. It was possible to do this with some accuracy by using marker beds of airborne volcanic ash laid down by eruptions of known age.

Throughout this span, five distinct periods were recognised. During two of them infilling was rapid which, it is surmised, was caused by catastrophic storm damage and earthquakes. One period of two hundred years, from about 1450 to 1650 AD, produced negligible deposition, but from 1932 the rate of infilling was 5 to 10 times greater than at any other period.

When the Poverty Bay Catchment Board designed the present scheme in the 1950s, it was following in the footsteps of Drainage Boards and a River Board which had been in existence since the last century.

Flooding was frequent and at times devastating, but, in spite of this, settlement attempts were persistent. The township of Gisborne grew, not on the banks of the Waipaoa, but on two other much smaller rivers that flow into the most sheltered part of Poverty Bay. The Waipaoa flooded into these rivers on occasions, and into parts of the young town.

A most unusual feature of the River Board was that the boundary of its district proceeded along the middle of the river for part of its length—no doubt the result of a quarrel as to who should pay rates! The only effective work the Board could do was to locate flood overflows along the banks and put up short lengths of stopbanks in attempts to contain them. It was able to do little effective work in the face of peak floods that drowned land from one side of the flats to the other.

In the 1930s and early 1940s there were approximately 30 floods. A 1938 storm that caused one of them extended into Hawke's Bay and brought about the Kopuawhara disaster.

Mr J R Hair like other farmers in the area was compelled to rebuild his house on higher ground following the flooding. While the family was now safe, the farm and stock were still exposed to flooding.

Not far away, after the 1914-18 War, the Lands Department had developed a returned soldiers' settlement which was on low-lying land. These would-be farmers suffered so much loss from floods that they were unable to pay land rents.

An official of the Department persuaded Hair to travel to Wellington to "see what this new legislation [the 1941 Act] on river control was all about." The upshot, upon his return, was the formation of the Poverty Bay Catchment Board, to which he was elected chairman. He was a man of vision and soon became the deputy chairman of the Soil Conservation and Rivers Control Council.

It was not difficult to get a comprehensive flood control scheme for the Waipaoa accepted by ratepayers. This was done in 1952 and the main part of the work was completed by 1961. A major diversion cut failed to develop satisfactorily but, to complete the scheme, the work was done artificially by further excavation between 1970 and 1973. The flats extend over some 10 000 hectares and scheme works protect 9700 hectares of this. Intensive development of the protected land soon began. Mixed cropping, market gardens, orchards and vineyards now occupy nearly 60 percent of the flats. The Board is increasingly involved with detailed problems arising from the results of this work.

The river scheme cured part of the problem only—flooding. A more serious part lay in the catchment of the river.

The same type of mudstone formations that occurred further north gave rise to the same erosion, with even more serious effects.

'Rivers of mud' could well describe some of the tributaries, for these had been filled to depths of 10 metres with debris. What had previously been confined streams of clean water were now muddy flows, many metres wide. Water often disappeared under the debris and only flowed over the surface, carrying more silt and gravel, during heavy rains.

The filling process moved down-river, and in places in the middle reaches the bed became half a kilometre wide. Low terraces, important for farm access and intensive stocking, were buried. The village of Whatatutu was originally sited on the banks of the middle Waipaoa. Each fresh (small flood) left mud in the houses and shops and eventually the whole settlement moved to its present site on a high terrace. Gigantic slips and slumps kept feeding this aggradation and, at the same time, severely complicated

farm management and threatened access to land in the headwaters of the catchment.

The Catchment Board engineer, A D Todd, who had designed the Waipaoa flood control scheme, reported that he would not guarantee its effectiveness for more than 30 years unless measures were taken to control erosion in the catchment. To some extent he may have had his tongue in his cheek when he said this, but the statement was a warning to the Board and to the Soil Conservation and Rivers Control Council. The latter appointed a committee, of which N H Taylor was a member, to study the problem.

Amongst its recommendations for erosion control was one to plant the worst country in trees: an area of 7000 hectares (later expanded) or 3.5 percent of the catchment. The Council and the Government approved this measure and in 1960 the Forest Service commenced planting the Mangatu State Forest. Although the reason was primarily erosion control, it was recognised that in this fertile country much of the planted forest would grow commercial wood. Indeed, the early promise of Mangatu led to the more extensive proposals prescribed later for the East Coast as a whole.

Bearing in mind Todd's warning, the river control scheme is being subjected to a detailed technical review after 20 years of operation. Recent flooding has also been a warning. Enormous quantities of debris lie in the middle reaches of the river where protection is for an 8-10 year flood return period only. Between 30 and 40 million cubic metres of silt and shingle are estimated to be deposited in the middle and upper river. Any major movement of this could endanger the lower river scheme and hence the Poverty Bay flats.

When J R Hair in the 1940s moved his home out of floods' reach on the Poverty Bay flats he little realised what changes he was setting in train. He was the main inspiration behind them.

> ". . . and because the despoilers were endeavouring to remedy the damage they had wrought in Tane's kingdom he had called a truce and henceforth there was hope that people could live secure in the knowledge of his benignity." (*The Story of Mangatu*).

The Opotiki Area

It has already been noted that this area opted for joining the East Cape district, which it did in 1962. It wanted prevention of flooding of Opotiki as well as control of the Waioeka and Otara Rivers. Drainage improvement schemes following this work have burgeoned with the rapid development of horticulture.

53. Early planting in the Mangatu forest. A blanket of exotic trees now covers the most severely eroded area in the Waipaoa catchment. The erosion control objective has been achieved. In addition the forest is capable of growing good commercial wood. (J H Johns, NZFS)



When the East Cape Board accepted responsibility for this additional area it was well aware of the flooding problems in it. But it was scarcely prepared for the claims concerning the Motu River which followed the 1967 Act and still less prepared for events following the 1981 amendment.

The entrenched and inaccessible Motu had long been on the list for electricity production but had been left until major resources had been developed. More recently the river had been used to test the skills of canoeists and others. When, therefore, water rights were applied for in connection with engineering investigations many people concerned about the growing loss of national recreational assets made representations. There was a widespread desire to leave this river as 'wild and scenic', an apt phrase that came to be adopted. The Government hastened the 1981 amendment and the Motu River has become one of the testing grounds under it.

54. The Motu River deeply entrenched in the forested Raukumara Range. It flows through rugged country of this nature for its whole length. It is one of the 'Wild and Scenic' rivers which some would like to see preserved in its natural state. On the other hand it has potential for hydro-electric development. (D L Homer, NZGS)



HAWKE'S BAY CATCHMENT BOARD

The Region and Its Water and Soil Problems

South of the unstable East Cape District lies Hawke's Bay, enclosed by a ring of mountains. To most people the best known feature of the Bay is the Heretaunga Plains, 30 000 hectares in area. They provide the common background to the rival cities of Napier and Hastings. One is surrounded by and one sits on the side of this rich land of orchards, vineyards, farms and vegetable crops. Whatever the negative effects of the rivalry might be, it is a smiling land blessed in many ways and provides much of the wealth of both cities. This was not always so.

Great efforts have been made to win the present safety of the Heretaunga Plains from the rivers that once flooded them. The Ngaruroro, Tutaekuri and Tukituki Rivers often converged to flood, and, at the same time, to build up the area. The three rivers empty into the sea within a few kilometres of one another. Final control of them was one of the main reasons for setting up the Hawke's Bay Catchment Board in 1943 and was one of the first tasks undertaken by the Board: Its district extends over 15 000 km² and includes the catchments of five major rivers.

Near Takapau travellers cross, imperceptibly, from the catchment of the Manawatu to that of the Makaretu, an upper tributary of the Tukituki. This river rises in the central Ruahines where erosion is even more severe than it is in the headwaters of the Manawatu. Aggradation of shingle in the middle reaches of the Waipawa River into which the Makaretu flows, is such that a recently completed flood control scheme has had to be revised.

Continuing northwards, the travellers pass by the common mouth provided by a flood control scheme for the next two rivers, the Ngaruroro and the Tutaekuri. As they speed over the Waitangi Bridge spanning this channel just south of Napier the visitors may recall the words penned in 1846 by William Colenso, the missionary and naturalist, who then lived at the mouth of the Ngaruroro: ". . . quite out of the way, low, damp, cold and unhealthy surrounded by morasses . . . In fact there is nothing whatever to recommend it—no water, no wood, no good harbour, no shelter from stormy winds."

Colenso had chosen this spot because it was too undesirable for any Maoris to claim. A century and a quarter later, large parts of the Heretaunga Plains are only habitable because of the river control and drainage works which have been undertaken.

The Ngaruroro flows for 130 kilometres from the northern Ruahine and the Kaweka Mountains on

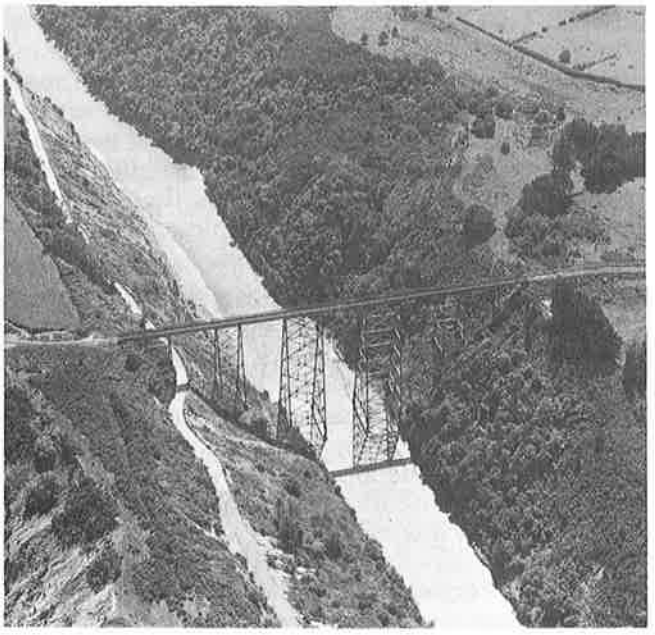


55. Hawke's Bay Catchment District

Hawke's Bay has been notorious for repeated flooding of the Heretaunga Plains and for severe and widespread erosion of the volcanic ash cover of the mountains and hill country ringing the Bay. Both troubles are now substantially controlled, the river flooding only after a long period of wasteful altercation.

The five rivers that flow into the Bay are important water resources, particularly the Ngaruroro and Tutaekuri that flooded the Heretaunga Plains and Napier and Hastings. All five will become increasingly important as time goes on.

Hastings and Napier draw their water from one of the best underground resources in the country, fed by the Ngaruroro. (D W Lawrence)



56. Road viaduct across the lower Mohaka River which rises near Lake Taupo basin and is entrenched for its whole length. (D L Homer, NZGS)

57. The township of Wairoa on a bend of the Wairoa River just before it enters the sea. The steep hilly catchment can produce some of the largest flood flows in New Zealand. (D L Homer, NZGS)



the eastern edge of the volcanic plateau. The eastern flanks of the Kawekas give rise to the Tutaekuri. This river has often changed its lower course, at one time flowing around Napier where part of the estuary was made use of as a harbour by the first Pakeha settlers.

A few kilometres north of Napier the road passes the valley of a small river, the Esk. A storm in April 1938 caused severe erosion here and flooding left deep deposits of silt in this valley. The sudden devastation in the Esk and adjacent catchments had a strong influence on the passing of the Soil Conservation and Rivers Control Act. It is difficult to recognise the scene of devastation today when travelling past this valley of well-tended vineyards.

The road then passes into steep, erodible country, difficult to stabilise. Measures taken by the Catchment Board and the Ministry of Works and Development have been necessary here to prevent frequent washing away of the road by storms.

About half-way around the curve of the bay the Mohaka River is crossed. It rises on the volcanic plateau not very far from Lake Taupo and is deeply entrenched throughout its course. The road then crosses over into the northern-most of the five catchments, that of the Wairoa. North of that again the country becomes markedly steep, broken and unstable—the highly erodible mudstones of the East Coast and the area of the East Cape Catchment Board.

The catchment of the Wairoa, about 4000 km², is one of the largest of any river in the country. Numerous headwater tributaries descend steeply from the jumbled, mountainous Urewera. One falls from Lake Waikaremoana, perched 600 metres in the mountains. The level of this beautiful lake is controlled to generate electricity.

The central North Island volcanic eruptions spread a mantle of ash and pumice over most of the mountains, hills and valleys of Hawke's Bay particularly in the central and northern areas. The same material brought down by the rivers helped to form the Heretaunga Plains and another plain of about the same size formed where the Tukituki River emerged from the mountains—the Ruataniwha Plain.

The same eruptions destroyed, either by fire or smothering, large areas of forest, and fires in Polynesian times destroyed still more. The open scrub and tussock that replaced the forest was ideal for sheep when settlers moved in. In their search for productive land they cleared much of the remaining forest. The friable, volcanic mantle became exposed to the forces of erosion of which heavy rain was the most severe. Parts of Hawke's Bay became noted for erosion, particularly of the type that occurred in the Esk Valley during the 1938 storm. On the Kaweka Range, for example, which was occupied by sheep right to the summits, the mantle was eroded down to bare rock over large areas.



58. The Kaweka Range in the hinterland of Hawke's Bay. Erosion, much caused by wind, has stripped away the light volcanic ash cover over the greywacke rock. Vegetation on these mountain tops was at one time burned to prepare the way for sheep grazing. (MWD)

Storms can cause severe erosion in the Wairoa catchment and generate large floods which spread over the small flood plain in the lower reaches of the river. The town of Wairoa sits on the bank without any protection and, so far, without undue trouble from floods. When the floods reach peaks of 12 000 cumecs or more, as they sometimes do, the town looks decidedly precarious.

The state of the river mouth which sometimes becomes obstructed by a shingle bar can also affect flood levels.

Warm, moisture-laden winds condense on the hills and mountains all round Hawke's Bay. Rainfall intensity can, over a few days, be as great as that occurring in the wettest parts of the country. On 15 February 1938 intense rain falling on ridges about 600 metres high at the north end of the district caused the Kopuawhara River, the normal flow of which is less than 1 cumec, to reach nearly 1000 cumecs. A railway construction camp in the valley was engulfed and 21 lives were lost—so rapid was the rise of the torrent.

The Hawke's Bay Catchment Board faced control problems generated by difficult rivers, the need to protect flood plains, and erosion on steep country carrying away volcanic ash deposits. Some progress had been made by the River and Drainage Boards that preceded it, but they had had a particularly turbulent history, as we shall see.

The Three Rivers and Flood Control

Napier became an early centre of vigorous settlement in Hawke's Bay because of the port and the rich flood plains next to it. Hastings was also soon established to make better use of the Heretaunga Plains, but frequent floods plagued the area.

In 1867 a severe flood caused the Ngaruroro River to change its course from one side of Hastings to the other. This frightening experience triggered off the first of many public meetings to discuss flood prevention. It was recorded of this particular occasion: "The meeting was inconclusive, a stating of opinion rather than an attempt to find a solution. It was a pattern that was to become all too familiar as the years went past and the rivers spilled over again and again—endless meetings, endless talk, no agreement."

River Acts were passed in 1868, 1870, 1872 and 1876, the last making provision for the setting up of Boards of Conservators. One was formed for Taradale. The first comprehensive approach to the problem was made in 1877 when the Minister of Public Works called for a report. The engineer carrying out the examination recommended that the Ngaruroro and Tutaekuri Rivers, be channelled together in their lower reaches and emptied into Port Ahuriri (Napier). Fortunately this never proceeded. The effect of the 1931 earthquake in raising the estuary would have been calamitous.

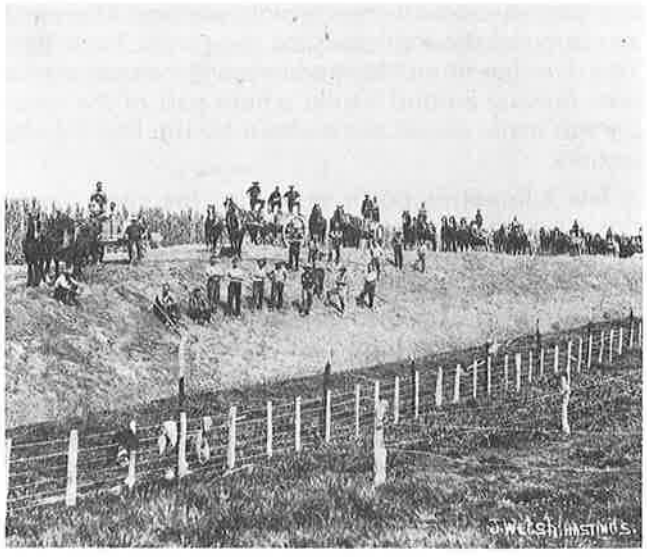
In 1877 the Hawke's Bay County entered the fray only to add to the confusion, as history records:

> "The pattern for decades was to be—call a meeting, argue hotly, call for an expert report. It would be interesting to know just how many reports and pieces of professional advice have been called for . . . The number would only be exceeded by the number of uncalled-for, gratuitous and totally unskilled reports which have been showered upon the authorities by every amateur engineer in Hawke's Bay."

The county introduced the practice of using willows for river bank stabilisation. It took only 18 years for the practice to boomerang, for in 1894 the county set up a sub-committee to, "rid the County of the willow nuisance." The willows continued to be a "nuisance" through the next half-century.

Ten people were drowned in a devastating flood of 1897. Stock losses were high, roads and railway were washed away and parts of Napier were flooded to depths of over a metre. It was estimated that three-fifths of the Heretaunga Plains were under water. By that time there were 4 River Boards and a number of Drainage Boards.

A single river body, the Hawke's Bay River Board, was formed in 1910. Meanwhile the Central Government became more and more involved. The Prime Minister was asked by one deputation to take



59. The importance of protecting Hastings and the Heretaunga Plains is well demonstrated by the building of this substantial stopbank about the mid 1930s. (Hawke's Bay Catchment Board)

certain action, by another not to. On one occasion the Minister of Public Works was reported as being unco-operative, and when asked if it was possible to get a Government report his terse reply was: "A flood is the best report you could get."

The unified River Board could make no progress and in 1917 a Local Bodies River Control Conference was held: "To finally decide on a definite scheme to deal with the three Hawke's Bay Rivers as the work done by the Rivers Board is not even sufficient for maintenance, never mind improvement."

In 1931 another calamity struck. This is a minute from a meeting of the Hawke's Bay River Board:

> "Napier, 3 February 1931.
>
> A meeting of the Hawke's Bay River Board was held this day in the Hawke's Bay County Boardroom at 10.30 am.
>
> A chairman was elected.
>
> A violent earthquake terminated the proceedings at 10.45 am."

The earthquake flattened most of Napier and disrupted all lines of communication. Amongst the spectacular results was the raising of the Ahuriri Lagoon by nearly 3 metres, leaving most of it dry. Included in this great uplift was the inner harbour where small coastal shipping was grounded.

These drastic changes decided the issue as far as the Tutaekuri was concerned and a year later the ratepayers agreed to a scheme to divert the river southwards to meet the flood overflow of the Ngaruroro. Flood protection of the lower Tukituki was also undertaken.



60. The Ahuriri Lagoon and Western Spit before the 1931 Napier earthquake. (Hawke's Bay Museum)

The Esk floods of 1938 were not confined to that valley. Some other major catchments were affected by very high floods and immense damage was done to roads and railways. People were jolted, yet again, into a realisation of the dangers of flooding. In addition, they became thoroughly alarmed about the amount of silt the flood waters carried.

Still another committee was formed, this time a regional one, the Hawke's Bay Afforestation and Drainage Committee. It had a combination of objectives which emphasised two of the main problems facing the region, erosion and freedom from flooding. At its first meeting resolutions were passed asking the Government for a survey of the rivers in the Hawke's Bay district and for appropriate schemes of afforestation in the headwaters of the rivers that



61. A much used illustration showing the erosion scars caused by the 'Esk flood' 1938.

flooded. It also asked that "... the question of destruction by deer be taken into consideration and be dealt with." The secretary of the committee was D A Campbell who had taken a special interest in soil erosion and became the first Chief Soil Conservator to the Soil Conservation and Rivers Control Council. With his vivid imagination and eloquence he was a driving force behind the evolving soil conservation measures.

Formation of the Catchment Board

It was not difficult to persuade the people of Hawke's Bay to agree to a Catchment Board after this series of calamities through a period of nearly 100 years. It was set up in 1943, and the chairman of the River Board, C Lassen, became in addition first chairman of the Catchment Board.

The River Board carried on with its work for some seven years after the Catchment Board came into existence, but during that time the foundation was being laid for a comprehensive scheme of river control and drainage on the Heretaunga Plains. The Catchment Board saw this as one of its first tasks. In 1955 an approach was made with proposals to the Soil Conservation and Rivers Control Council. A group of experienced engineers, including the chairman of the Council, L W Newnham, and the Board's own engineer, R G Drummond, reported on the proposals.

Following model studies a scheme was designed to deal with what were calculated to be 100-year floods. It included new and improved stopbanking, sometimes to heights of 4 metres, and channelling to bring a combined mouth of the Ngaruroro and Tutaekuri as close to the sea as possible. There the

62. Development of the Heretaunga Plains after river flood control had been achieved. (D L Homer, NZGS)



design was to cope with a maximum flow of nearly 6000 cumecs. The combined flow would be strong enough to keep the river mouth stable and prevent it from wandering northwards along the coast.

The river schemes were soon underway. It would take more than 20 years before the final touches could be put to them and the low lying areas adequately drained. Attention was also given to the catchments. Although the high-intensity rains would run off any vegetation, the Esk flood had shown how soil could be lost and silt and shingle carried down by the rivers. The Waipawa was an example of how aggradation could be caused by a severely eroding catchment.

The Regional Water Board

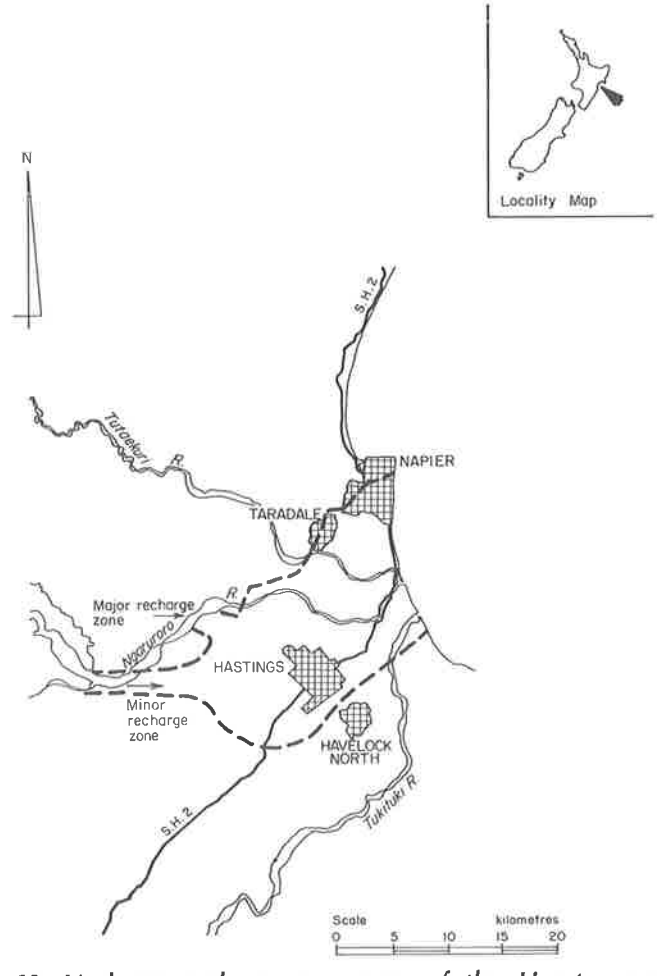
By the time the Catchment Board assumed the tasks of a Regional Water Board, work on river control, swamp drainage and soil conservation extended throughout its region and successful results were to be seen in many places.

The management of the water resources was a different matter. There appeared to be ample water since the major rivers between them carried an average flow of 300 cumecs to the sea, but the distribution and variation in flows was not so favourable.

The best water resource rivers, the Mohaka and the Wairoa, were in the north and not where water was needed most. It is true that a tributary of the Wairoa had been harnessed for hydro-electricity and the Mohaka was being investigated for this purpose. But more and more water was wanted in the south. Now that flooding no longer inundated the Heretaunga Plains, cropping was becoming intensive and required irrigation. When the demand was greatest, during dry summers, the flow in the Tukituki disconcertingly disappeared under the deep beds of silt and shingle that it had laid down.

A large part of the water 'lost' in this way forms one of the best underground supplies in the country. The availability of this, some of it as artesian water, was one of the main factors influencing the early growth of Napier and Hastings, and the settlement of the plains. As early as 1887 Napier was supplied with water from six artesian wells.

It is now known that the Ngaruroro is the main supplier of water flowing under the Heretaunga Plains. Some 5 cumecs, equivalent to the water use of two Wellingtons, flow through the shingle deposits of buried river beds. Part of this underground flow is covered by permeable shingle beds—what is known as an unconfined aquifer. Land use on top of this resource is a highly controversial local issue, because it would be easy for noxious substances to be leached through to the water that is so valuable for local supplies. Hastings is truly on the horns of



63. Underground water sources of the Heretaunga Plains.

a dilemma because the city draws its water (and of such high quality that treatment is unnecessary) from the underground source, but, at the same time, wants the poor shingle land to expand on to. The city rubbish dump was also on that land.

There is, at present, not a great margin between loss of water from the underground source through use and natural leakage, and recharge of the aquifers. However, demand is increasing rapidly, especially for irrigation. Investigations are turning to the possible use of water from the Ngaruroro for the artificial recharge of the underground beds.

Under the Ruataniwha Plains there is another, more complex but much less productive, system of aquifers. The potential yield of water from these is far outstripped by demands, mainly for irrigation.

These easily tapped, high quality resources must be studied and managed for the many demands made on them both now and in the future. The Regional Water Board has to deal with these major issues as well as many minor matters that arise throughout its district.

WAIRARAPA CATCHMENT BOARD

The District

> "The fine district of the Ruamahanga with its immense tract of land ... amply refutes the reports that our neighbourhood was deficient in extensive districts and justified the choice of Port Nicholson as the Company centre."

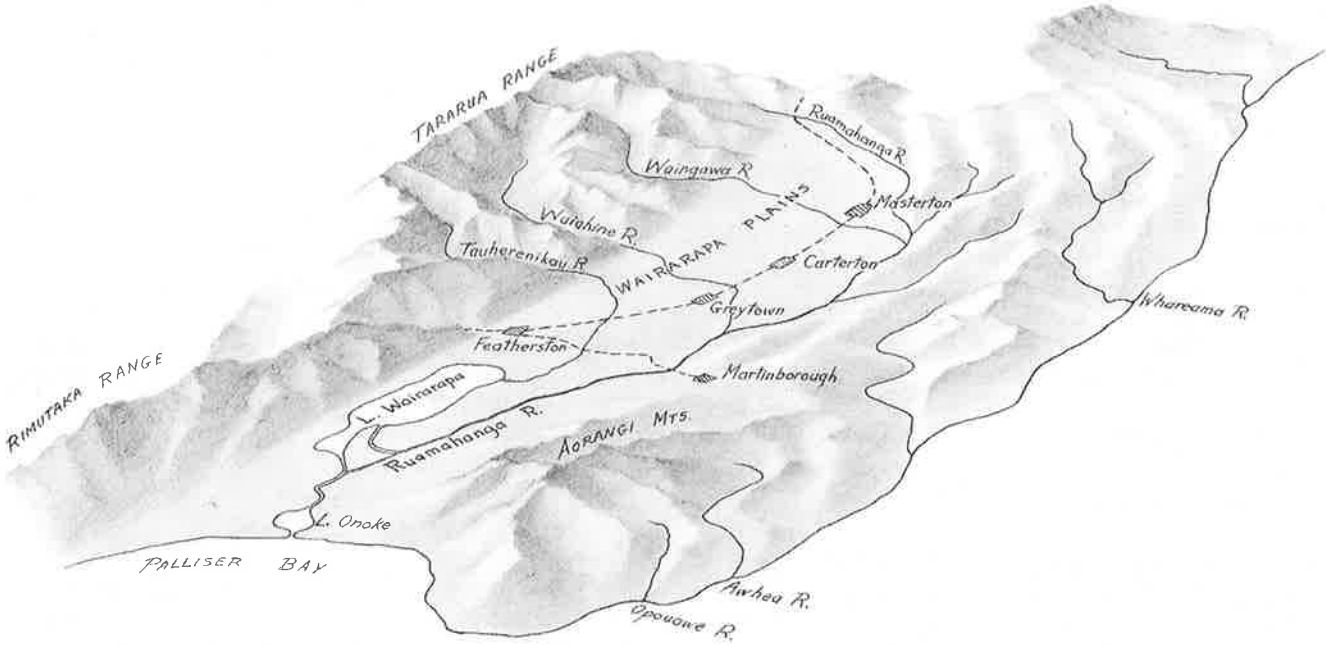
Thus Edward Gibbon Wakefield introduced the Wairarapa to London in 1841 sending copies of the reports by the New Zealand Company surveyors, Brees and Kettle. He explained that settlers in Wellington were becoming restive for land, and large cargoes of livestock made it imperative for their owners to form stations.

The southern Wairarapa had open stretches—'grassy plains', as they were described—and low-lying, damp silt soils. Settlement, once it started in the 1840s, was rapid and a road from Wellington over the Rimutakas was formed by 1859.

South of the Manawatu River catchment, water falling on the east of the main divide, the Tararua and Rimutaka Ranges, gathers mainly in the Ruamahanga River which flows southwards into Cook Strait at Palliser Bay. Tributaries have brought down a great deal of material, largely the result of glaciation, forming gentle fans almost imperceptible to the eye—the Wairarapa Plains.

The eastern edge of the plains, or of the Ruamahanga Valley, is formed by a wide belt of low hills and mountains composed of limestone and soft sedimentary rocks, stretching to the east coast. Rain falling on them finds its way to the Ruamahanga or gathers in small rivers flowing to the coast.

Near the bottom end of the Ruamahanga Valley, Lake Wairarapa has been formed along a fault. The Ruamahanga and a smaller river, the Tauherenikau, flow into it and thence into Lake Onoke which is, in effect, a lagoon dammed back from Palliser Bay by a bar of shingle.



64. Wairarapa Catchment District

The catchment of the Ruamahanga River occupies the greater part of the district. Its gathering grounds are the Rimutaka and Tararua Mountains to the west and lower hills and mountains in the east. The river system is complicated in the lower reaches by the presence of Lake Wairarapa and Lake Onoke, the latter formed by the movement of shingle along the shore. Both lakes pond, according to the state of the shingle bank and flooding. An intricate flood control scheme operates in the lower reaches of the system and along some tributaries. The hills in the east, formed from sedimentary deposits, erode severely when a dry period is followed by intense and prolonged rain.

Although the Ruamahanga River and its tributaries constitute a substantial water resource, very low flows can occur and progress in the Wairarapa is impeded by the lack of readily harnessed water. (D W Lawrence)

The process of mountain building in the adjacent Tararuas has been described as follows:

> "The Tararuas have sharp peaks and rugged slopes, are cut by deep gorges with swift rivers and are traversed by large earth rents (faults) that show the mountains have been rising rapidly in geologically recent times. The Tararuas of today are the product of earth movements and long continued erosion, culminating in intensive erosion under a glacial climate, which carved out many of the craggy higher peaks. Wearing away of the ranges continues even now as freak storms (eg in the early 1930s) and man-introduced factors (fires, exotic animals, etc) strip vegetation and expose rocks to erosion".
>
> (Graeme R Stevens, *Rugged Landscape*)

Very early in Pakeha settlement, people experienced shattering earth movements of the type that have given rise to the backbone mountains and to the faults along the Wairarapa Valley. In 1855 the most severe earthquake that New Zealand has yet experienced occurred along the West Wairarapa Fault. Uplift to the extent of nearly 3 metres and sideways movements of up to 12 metres occurred. The most damaging effect as far as rivers and erosion were concerned were the numerous and extensive slips caused in the Rimutaka Mountains.



65. The Lower Wairarapa. Lake Wairarapa and its connection with Lake Onoke which at the time of the photograph was open to the sea. When Lake Onoke is closed, floodwaters brought down by the Ruamahanga River which joins the reach connecting the lakes can back up to Lake Wairarapa. The movement of water in and out of that lake is now controlled by a barrage. (D L Homer, NZGS)

Flooding

This substantial and intricate system of rivers and lakes extends over a catchment of nearly 3500 km². Floods pass along the tributaries and upper river rapidly but gather around the lower reaches and the lakes. The highest floods occur when the shingle bar becomes blocked and holds water back in Lake Onoke and even as far as Lake Wairarapa. The latter, being normally little more than 3 metres deep and surrounded by flat land, changes its area substantially in these circumstances. Settlers trying to make use of the surrounding silt lands and swamps found difficulty dealing with these fluctuations.

Flooding takes place, too, on the limited silt flats formed by the small rivers flowing to the east coast. Flooding and siltation were constant threats to the isolated settlements that grew up in those valleys in the days before road access, when communications were by small vessels along the coast.

All told, five River Boards were formed to deal with river control in the Ruamahanga River and its tributaries. The first, the South Wairarapa Board, initially had as its main function opening the outlet from Lake Onoke to the sea. This reduced the levels of both lakes.

In 1880 a flood occurred that was later estimated to have been of the order of 3000 cumecs in the lower reaches of the river; not large by New Zealand standards, but affecting an area of probably more than 20 000 hectares. As late as 1947 another large flood affected 24 000 hectares of land—an area not far short of the total Heretaunga Plains—so the efforts of River Boards had not been very effective in dealing with these major calamities. Between 1880 and 1947 there were many other floods. Although smaller, they did increasing damage as the country became more closely settled and townships grew. South of Martinborough up to 12 000 hectares could be affected by a major flood. This occurred on average every 2 to 3 years. Some areas could be flooded up to eight times a year.

Most of the work of River Boards consisted of constructing groynes and stopbanks in efforts to confine river beds and reduce flooding. Possible major schemes of control were examined and there was much talk of draining Lake Wairarapa; a superficially attractive idea since at normal levels the lake bed covers 7000 hectares.

The Ruamahanga River Control Scheme

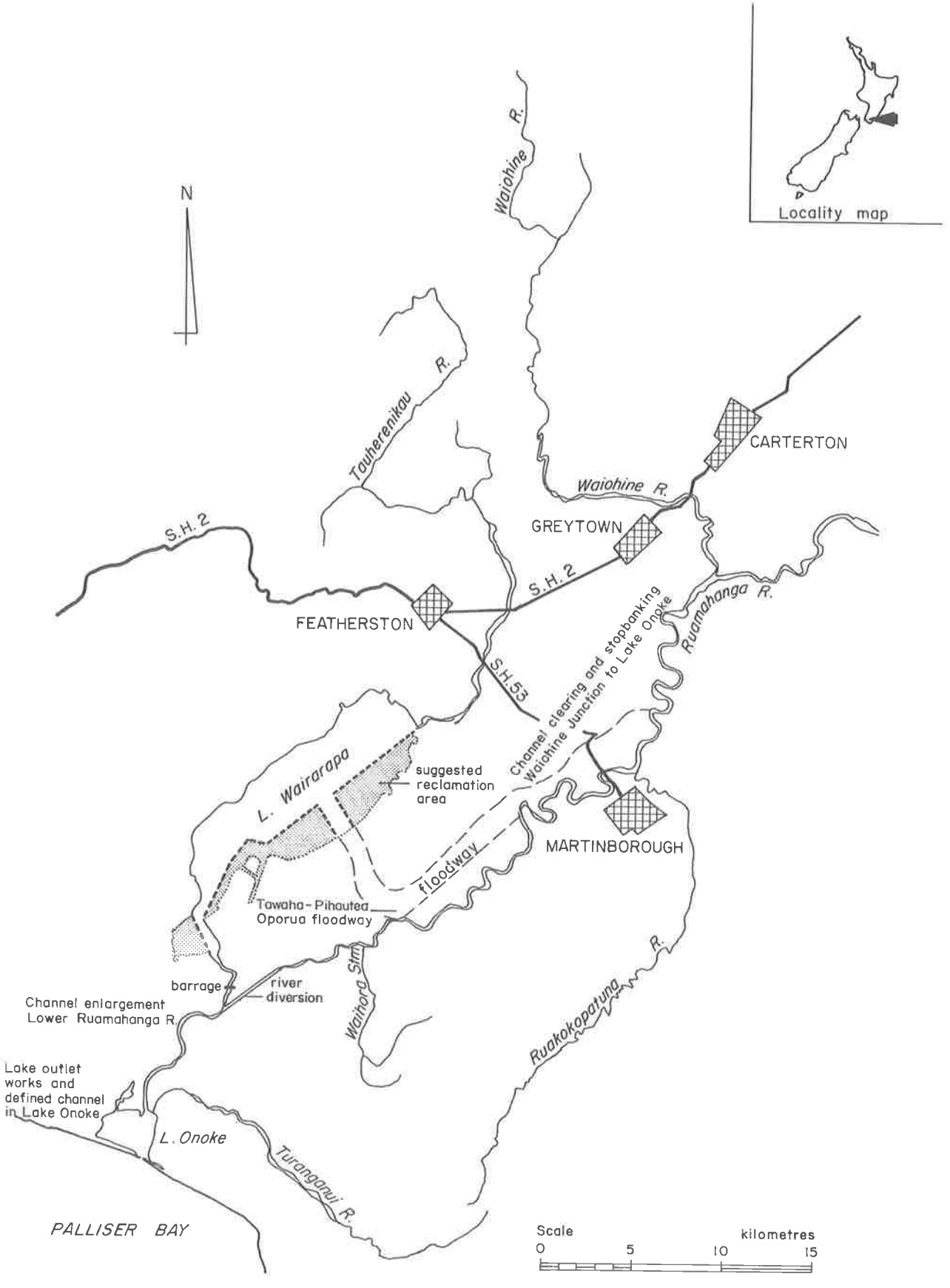
When the Wairarapa Catchment Board was formed in 1944, it acknowledged at its first meeting the urgency of a comprehensive river control scheme, and, therefore, the need to take over the work of the River Boards. The scheme would take some years to design and promote.

A lower Ruamahanga control scheme could not be confined to flood plain, river protection and associated drainage work. There were the two lakes to be integrated into any plan. Farmers wanted numerous lagoons and swamps along the lower river and around the lakes drained, while people interested in wildlife and duck shooters wanted them preserved.

Eastern tributaries of the Ruamahanga, sweeping down from the Aorangi Mountains, brought immense loads of shingle—the result of erosion occurring in a forest that had been devastated by wild and domestic animals. The shingle was rapidly forming fans down the sides of which the rivers changed their courses, depositing more shingle on farm land. The shingle even reached the channel of the Ruamahanga itself where it could not be cleared by water action because of the low gradient. Flood capacity was reduced and bank erosion occurred.

The scheme finally adopted by the Board in 1960 was designed to provide protection against a 50-year flood. It provided for channel clearing and stopbanking of 48 kilometres of the river bed; taking the main flow of the Ruamahanga directly into Lake Onoke; building a floodway for high flows to spill into Lake Wairarapa (there are now 3 points at which floods in the main river can spill into the new channel); constructing floodgates between the lakes so that Lake Wairarapa could be used as a ponding area for flood overflows; draining some swamp lands but reserving others for wildlife; constructing outlet works from Lake Onoke to the sea in an endeavour to facilitate opening the lake; and soil conservation, catchment control and river works in the eastern tributaries and those running from the Rimutakas. Also included for consideration at some time after the main scheme had been completed was a proposal to reclaim part of the bed of Lake Wairarapa. The matter is raised from time to time but engineering difficulties and claims for wildlife habitat have to be resolved.

66. The Lower Ruamahanga Flood Control Scheme. This ambitious and complex scheme was adopted in 1960 to realise the agricultural potential of the Lower Wairarapa. Clearing and stopbanking of the main river, diversion of it into Lake Wairarapa, use of this lake as a ponding area, improvement of the Lake Onoke outlet to the sea and drainage of swamps formed the basis of the scheme. In addition there were many smaller works connected with it. Reclamation of part of the shallow Lake Wairarapa was also proposed. Although not included in the original scheme, this proposal is revived from time to time. (after Wairarapa Catchment Board)


Locality map
N
Waiohine R.
Tauherenikau R.
CARTERTON
Waiohine R.
GREYTOWN
S.H. 2
S.H. 2
FEATHERSTON
S.H. 53
Channel clearing and stopbanking Waiohine Junction to Lake Onoke
Ruamahanga R.
L. Wairarapa
suggested reclamation area
floodway
MARTINBOROUGH
Tauwhā-Pihautea Oporua floodway
Waihora Stm
Ruakokopatuna R.
barrage
river diversion
Channel enlargement Lower Ruamahanga R.
Lake outlet works and defined channel in Lake Onoke
L. Onoke
Turanganui R.
PALLISER BAY
Scale
kilometres
0
5
10
15

Sig 6

The scheme was complex to design, construct and finance and was the largest river control and drainage work in the country when initiated. Construction time was to be 20 years.

In 1981 when work was 90 percent complete 2 floods occurred, one in May of 1690 cumecs (a 60-year flood), and one in June of 1440 cumecs (a 30-year flood). During the May flood, the peak flow was half as great again as anything measured since records began 25 years before. The June flood was the second biggest during that period.

Flooding affected all the Wairarapa Valley. In Masterton itself, during the second flood, almost 100 mm of rain fell in 24 hours. Flooding of property occurred there. In Featherston the storm left the town without a water supply. Many roads became impassable and Martinborough was isolated.

Although the flooding was widespread and accompanied by considerable damage, it was not nearly as devastating as it would have been without the almost completed works. Moreover, flood waters receded much more rapidly than they would otherwise have done. Nevertheless, such events compel critical examination of both the design and capacity of river schemes. The most difficult aspect of all is that ratepayers who have been burdened for a long period of years, and have not yet received the benefits of full protection, tend to suffer the greatest damage.

In parts of the Wairarapa more than half the average annual rainfall fell over the 2-month period in which the 1981 floods took place. There has been a suspicion for some time that the Tararua Range section of the Wairarapa can have high-intensity rains or very high total rainfalls. In order to gather accurate data a series of raingauges have been installed and are serviced by helicopter. Records so far include, in some localities, annual rainfalls as high as any that have been obtained in Southern Alps studies. Falls above 10 000 mm have been measured in the catchments of the Waingawa (11 200 mm at Arete Bivvy) the Waiohine and the Tauherenikau.

Soil Erosion

While the Board developed the river control scheme, soil conservation measures were also required. Farmers who had watched the Wairarapa develop were in support of these and were backed by strong Government department Board members. Forests had been cleared from well up the flanks of the Rimutakas and Tararuas, the mountains where the greatest amount of water is collected. It was time to call a halt, and at the Board's first meeting a finger was pointed at the Forest Service for allowing milling at Te Maru in the Tararuas. This brought to the actual site both the Commissioner of Forests and the Permanent Head of the department.

After a few more meetings the following resolution was proposed: "That representations be made to the Soil Conservation and Rivers Control Council that all remaining State Forests in virgin bush in the Catchment Board's area be reserved as Soil Conservation Reserves . . ." Although this resolution was lost it achieved its purpose because, before long, all native timber milling in the Wairarapa State forests ceased.

This achievement was a case of 'better late than never', because by that time, except for the State forest on the mountains, most of the native forest, held privately, had been cleared from the Wairarapa. The continuous stretch of forest in the upper Ruamahanga Valley, and the forest on the eastern Wairarapa hills except the tops of the Aorangi Mountains had all but disappeared.

F C Daniell, a member of a Wairarapa sawmilling family, and one of the first members of the Catchment Board, produced for other members an account of the district. In it he wrote, "It is almost incredible that such a vast area as the forty mile bush (part was in the catchment of the Ruamahanga) should have vanished from sight in a single life-time, save for very dismal remnants . . ."

It was in the eastern hills that most trouble was starting. An unusual range of sedimentary rocks and the extreme wetting and drying of the soil was producing many types of erosion. A dotting of small slips occurred like a rash over the country whenever there was prolonged, heavy rain. Very extensive erosion damage occurred during the stormy winters of 1947 and 1953. One storm in 1947 affected 23 000 hectares and exposed nearly 500 hectares of it in slips.

The results of this erosion could be measured in lack of increased farm production. No areas were worse hit than the catchments of the small rivers flowing to the east coast. The areas were isolated enough, but damage to communications, erosion and flooding were making farm life uneconomic and intolerable.

Farmers themselves, together with local authorities concerned, approached the Catchment Board for assistance in 1956. By that time the Board had a Chief Soil Conservator who could clearly see the need to plan control throughout whole catchments—farms, rivers and all. He planned a catchment control scheme for the Whareama—Tinui Rivers. This was amongst the first of such schemes in the country and was accepted by local people, the Soil Conservation and Rivers Control Council and the Government. It has proved highly successful in protecting settlements and communications, preventing soil erosion and raising production.

Shortly after the Whareama scheme was started a second catchment scheme was promoted. In 1959





67. Blairlogie Gully in the Whareama Catchment. Severe gully erosion was successfully checked by retirement from stocking, and tree planting. (MWD)

the Awhea and Opouawe Catchment Control Scheme was approved. This covered an area of about 400 km². In the original report the scene is well described:

> "Bridges have had to be raised, roads relocated, farm buildings, including a substantial house, moved and valuable river flats have been buried with silt and shingle. Even moderate storms will cut off access for periods of up to several days. In the hills, gullies and erosion cirques are destroying an increasing area of farm land, cutting fences and disrupting farming operations. The greatest damage, however, is being done downstream by the deposition of debris usually well away from the site of the initial erosion and generally on a property other than that on which the detritus originates. This, and the magnitude of the problem, makes the communal approach to its solution imperative."

Other complete catchment schemes were added later. Apart from them, many individual farm plans have been put into operation.

By the time farmers face up to doing something about erosion it is usually severe, or a sudden storm has hit the area and caused damage overnight. The presence of erosion complicates management as well as reducing production. Measures to correct the situation usually involve altering the subdivision of the farm, reorganising fencing and water supplies and improving stock carrying capacity on the unaffected part of the farm. This work plus the cost of erosion control has to be budgeted for carefully over several years. Apart from subsidies, the 'carrot' held out to the farmer is increased returns when erosion is healed, and improved overall management of his farm.

There is little doubt that the farm plan is a powerful tool in soil conservation. It has reached its highest development in the Wairarapa Catchment Board district where there are 380 plans currently in operation.

In spite of progress in the Wairarapa, erosion continues to occur and the reasons are, as yet, not well understood. 1977 had a wet winter, particularly during August and September, when widespread



68. Slumping of good farmland in the Wairarapa following heavy rain. This type of movement alters drainage, destroys fencing and disrupts farming generally. (Evening Post)

flooding and erosion occurred. This happened in southern Hawke's Bay as well as the Wairarapa and was so severe that the region was declared a disaster area.

Within this region 1350 km² of land were studied and it was found that in this area slips of various sizes averaged almost one per hectare, while in the worst affected area the number rose to five per hectare. Such a catastrophic movement of soil affected farming most adversely—almost threatening its extinction in the hardest hit localities. Although the slips could be brought back into production in the long run, it was discovered that the carrying capacity on the healed land was much reduced.

For many years the Wairarapa Catchment Board has been insisting that erosion in the soft sedimentary deposits of the east coast and elsewhere should be subjected to basic research. Only by this means are the erosion processes likely to be understood and techniques of control developed. The Board itself has done what it could and has been most successful in evolving and applying controls, but it cannot yet cope with such calamities as occurred in 1977. Various organisations are now being engaged in this field of research, which is coordinated through the Water and Soil Science Centre at Aokautere.

69. Eastern Wairarapa Hills. Communication with the small settlements along this coast was originally by sea. Present day road access can be threatened by the flooding and aggradation of streams and small rivers flowing through sedimentary rocks to the coast. The small river flats can also be inundated. The condition of these rivers and their catchments is therefore of great importance to local communities. (D L Homer, NZGS)



The Regional Water Board

Since the 1840s the 'fine district' described by Wakefield has been developed for farming and townships have sprung up along the broad Wairarapa Valley floor. A small amount of industry has become established, the largest units being a freezing works and two dairy factories. Yet progress has not been as rapid as might have been expected, considering the proximity to Wellington.

In spite of the many rivers and streams carrying an abundance of water most of the year, dry summers bring shortages of water at critical times. There are also shortages of readily available water for expansion of industry or cropping. Much progress will depend now on improved availability of water for all purposes; for rural and urban supplies, for irrigation and for recreation.

These needs will have to be met by more efficient use of water and the harnessing of further supplies. Fortunately not only the Regional Water Board is aware of this situation: the Regional Development Council in its studies of the area is fully conscious that water is the key commodity for progress.

Ample supplies are there, but they must now be harvested. The Regional Water Board has drawn up allocation plans for all the main rivers and come to the conclusion that no more water can be drawn from them at low flow without seriously affecting recreation and wildlife. On the other hand it would be possible to dam rivers, especially those coming from the Tararua mountains, and use the water for multiple purposes. Underground resources are also being examined and the Board has a scientific committee to advise it on these matters. Much water escapes underground in the shingle rivers. Some of this is already being tapped. The underground aquifers are intricate, however, and need much more study before they are sufficiently understood.

RANGITIKEI—WANGANUI CATCHMENT BOARD



The Region and The Rivers

To the south and west of the Taupo basin rise two large rivers, the Rangitikei and the Wanganui and two small ones between them, the Turakina and the Whangaehu. These four rivers drain an area of 14 800 km² and flow to the Tasman Sea just north of the Manawatu River, all of them within 50 kilometres of one another.

The Whangaehu, which starts on the slopes of Mount Ruapehu, is notorious because of the flood that occurred in it on Christmas Eve, 1953. Water from the crater lake suddenly found its way into the river and the tumultuous flow that resulted destroyed a railway bridge on the main trunk line. An express train plunged into the current and 151 people lost their lives.

The Wanganui and Rangitikei are deeply entrenched. They have cut down through soft sedimentary rocks as the country they drain has been uplifted. The Wanganui flows through rugged terrain, which scarcely reaches 1000 metres anywhere, but is steep and jumbled with very limited flat land.

The Wanganui is one of the best known rivers in the country. The redoubtable Polynesian explorer, Kupe, is said to have sailed into it and it became for the Maoris and early Pakeha settlers a main thoroughfare to the centre of the North Island, losing that role only when road access was formed. The river is one of the best remaining resources for possible hydro-electric generation. (Upper tributaries of the Wanganui, the Whangaehu and the Rangitikei have already been beheaded and flow to the Tongariro scheme and so down the Waikato River).

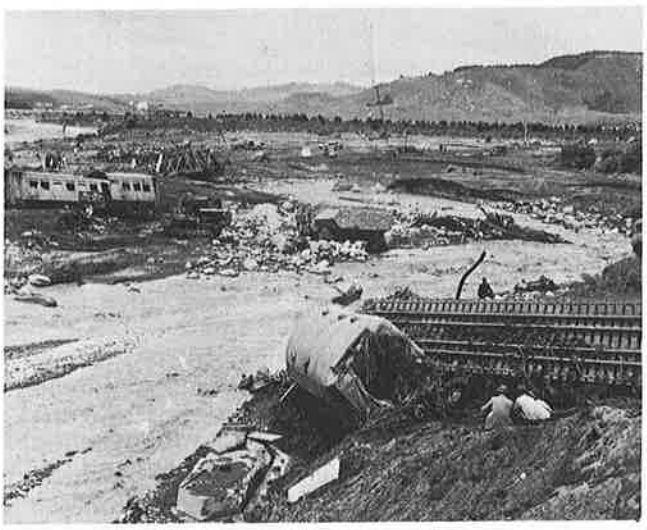
70. Rangitikei-Wanganui Catchment District.

Within 50 kilometres of coast, north of the mouth of the Manawatu River, four rivers empty into the sea; the Rangitikei and Wanganui Rivers, and the smaller Turakina and Whangaehu between them. All mainly rise around the Volcanic Plateau and flow through a variety of sedimentary rocks.

The catchment of the Wanganui occupies more than half the district. While the river is entrenched and has few flooding problems, almost the whole catchment is steep and jumbled. Farming such difficult country has been partially successful and has led to some erosion.

The Rangitikei in its middle reaches flows through somewhat similar but richer country. There farming has led to widespread but not severe erosion which has largely been cured and held at bay by control techniques. In the lower reaches is a small floodplain for which a control scheme operates. A considerable length of the valley is important for main communications. (D W Lawrence)

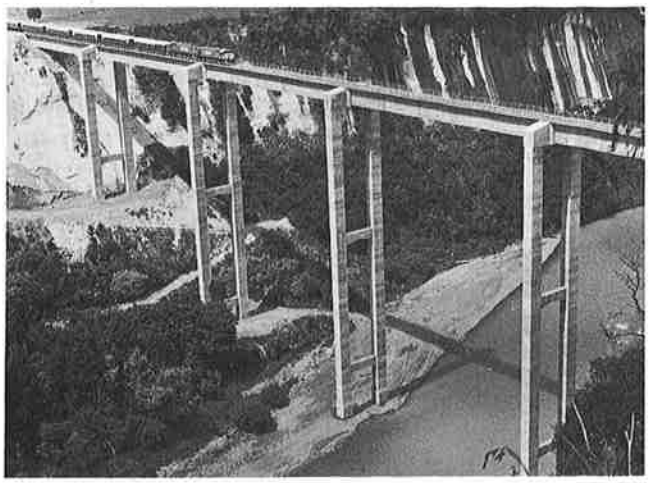
The main road north from the Manawatu crosses the Rangitikei River at Bulls and runs along high terraces up the valley of that river for the greater part of its length. For half the distance the valley is scarcely more than 10 kilometres wide. From the road the river is seldom visible because it flows in a canyon-like valley often 100 metres deep.



71. The Tangiwai disaster 1953. An unpredictable escape of water from Mount Ruapehu crater lake carried with it a great load of debris and ice. No bridge could have withstood the tumultuous flow that came down the relatively small Whangaehu River. (NZ Government Railways)



72. Makatote Viaduct, one of several crossing rivers descending from Mount Ruapehu in the centre of the North Island. At the time of construction native forest was being milled and cleared to make way for farmland. (NZ Government Railways)



73. A railway viaduct erected in 1981 across the deeply entrenched Rangitikei River. (NZ Government Railways)



74. The Bulls bridge collapse, 1973. (MWD)

Above Mangaweka the catchment widens out and becomes steep and hilly. The mudstones and sandstones produce good but erodible soils. Making roads through the combination of soft rock and rugged hills has been especially troublesome, as travellers using the main highway once knew. Between Taihape and Waiouru the catchment spreads onto the flanks of the volcanic plateau and other tributaries gather in the Ruahine and Kaimanawa Mountains. Most of the 58 000 hectare military reserve, stretching north and east from Waiouru, lies in the catchment.

The Rangitikei Catchment Board

When it came to the setting up of a Catchment Board for this region, Wanganui remained aloof. Its river flows in a deep bed and causes the city little trouble even when carrying floods that have peaked at 6300 cumecs. Land in the Wanganui catchment was poor and sparsely settled. Farmers were busy struggling against great odds, so they had little energy to consider soil conservation even though there was erosion.

In 1945 the Rangitikei Catchment Board was formed to cover the catchments of that river and of the two smaller ones. A small floodplain in the lower Rangitikei River did suffer from severe flooding. The damage caused and the destruction of highway bridges, combined with the onset of widespread erosion of the dissected, soft sedimentary rocks in the central catchment, were sufficient to persuade people that a Board was necessary.

River Control

The heart-breaking losses caused by a flood in 1897 have been graphically described for a property, Poyntzfield, that has since become the Flock House farm training centre. Few attending courses there now would realise the severity of flooding that once occurred:

> "After the flood, where the garden and orchard stood some hundreds of drowned sheep were lying. Two dead pigs were in the drawing room and a yearling steer, half on a sofa and half on a ruined carpet, was the occupant (dead) of the dining room. Six miles of fencing with out-houses were swept away, 1000 sheep were drowned and the major part of the farm had a deposit of mud varying from a few inches to many feet overlying it. A hundred acres of wheat (in stack) was six feet under water and the grain ruined. From the cliff top we looked over a width of three miles of torrent, which tossed mighty, green timber trees, end over end, as a box of matches might be treated in a mill race".

The 1897 flood also destroyed the Bulls bridge, the main road bridge crossing the Rangitikei at Bulls township. In 1973 a later one was damaged; not by a flood but by an absence of adequate communication between the people responsible for controlling the river and those who put structures in them. The damage was spectacular. Like a gigantic see-saw a span of the bridge tipped on its piles and a bus plunged into the water. Fortunately the only occupant, the driver, was rescued immediately.

The 1897 flood was the largest experienced in Pakeha times on the Rangitikei River. Accurate measurements could not be made at the time but

subsequent investigations have placed a figure of between 4300 and 6600 cumecs on the peak flow. Calculations based on the data available place a return period of 500 years on these estimates. Return periods are, however, notoriously unreliable.

No River Board was ever formed to deal with the flood problems, but the Rangitikei County did what work it was able to. This consisted of river channel training in the lower reaches, a small amount of stopbanking and making pilot cuts across loops. The river was swift-flowing and the greatest damage it did was bank erosion. Farmers could ill afford to lose even a few hectares of the limited area of silt land.

The Catchment Board soon set in train investigation of a scheme of more complete control in the lower 65 kilometres, from Rewa to the mouth. This proved to be too costly for the amount of land to be protected, so a more limited scheme, known as River Scheme No.1, was promoted. A more comprehensive scheme, No.2, got under way in 1963 and is now in its final stages of completion. The degree of protection is for a 100-year return period or a peak flow of 2000 cumecs.

What happens if an 1897 flood is repeated now that there is so much more valuable investment in the lower reaches of the river? The damage would be catastrophic. This is always the question that Catchment Boards have to pose to their ratepayers.

The Porewa Stream

The high terraces of the Rangitikei were formed by the main river in ancient times, but they now tend to become flood plains for small tributaries which drop over the terrace edges. Descending from the surrounding hills these smaller rivers spread out over the flat land when they flood.

One such stream is the Porewa, normally an innocuous little stream that can dry up. It flows for less than 40 kilometres in a catchment of 150 km^2. It has valley flats of about 1000 hectares, but along these proceed the main road, the railway and the main telephone and electric power lines. A dairy factory has been built on the flood plain and the township of Hunterville is in the stream valley.

This little stream can produce a flood of 300 cumecs which, at one time, was most effective in disrupting main communications, apart from any other damage caused. The Catchment Board, therefore, designed and built a control scheme including the whole catchment. The main part of it, stream control, consisted of a series of 24 earth detention dams to retain the bulk of the flood flows. This was the first comprehensive detention dam scheme in the country. It is being followed by others in the Rangitikei on streams similar to the Porewa.

Erosion Control

The first chairman of the Catchment Board, K A Williams, was an eloquent lawyer from Marton where the Board's headquarters were established. He quickly summed up the strength of the 1941 Act and was able to see future benefits that it could bring. Encouragement came from one of the Government members, Dr L I Grange, the first director of the Soil Bureau, DSIR, who had previously been head of the Geological Survey. This background enabled him to assess the river and the soil problems. Moreover, the volcanic plateau had been one of his special areas of study. Although he was a realist, cynicism was part of his make-up. When asked at a public meeting when the next major central North Island pumice eruption was likely to take place, he replied that all you could tell, "was that the longer you are from the last one the closer you are to the next!"

Dr Grange was much more helpful with soil erosion questions in the Rangitikei catchment. The second meeting of the the Board was held in Taihape, the centre of the erosion problems. Following it, the Soil Bureau undertook a soil and erosion survey of that difficult country. Dr Grange worked closely with Sir Bruce Levy, who was a member of the Manawatu Catchment Board and who, in his determination to make pasture secure on steep hill country, could see a great deal more scope in the Rangitikei than in the Manawatu catchment.

Soil conservation work therefore got off to an early start. Although erosion was not severe, it was widespread. Methods of control used at first consisted of over-sowing surface slipping following storms, and widespread planting of poplars and willows to stabilise hillsides prone to slipping.

In 1961 a particularly severe storm devastated an area of 5000 to 6000 hectares and left a trail of damage over a much wider area. Prompt over-sowing of slips by the Board encouraged farmers to listen to advice about farm plans. From then on the Board's soil conservation work became consolidated. It was ably encouraged by one of its chairmen, E H Simpson, himself a farmer, who also became president of the Catchment Authorities' Association (1971-75). He helped to develop the work in a methodical manner. Today one third of all the farmed hill country in the catchment district has had a soil conservation farm plan prepared for it. In addition, many thousands of trees are planted annually for stability purposes throughout the steep hills.

On the military reserve in the headwaters of the catchment, some particularly obvious erosion scars had appeared where the pumice surface had been broken. The Board paid special attention to these. This erosion proved to be not as threatening or severe as the Board had feared, but another problem of a very different character was appearing in the area.

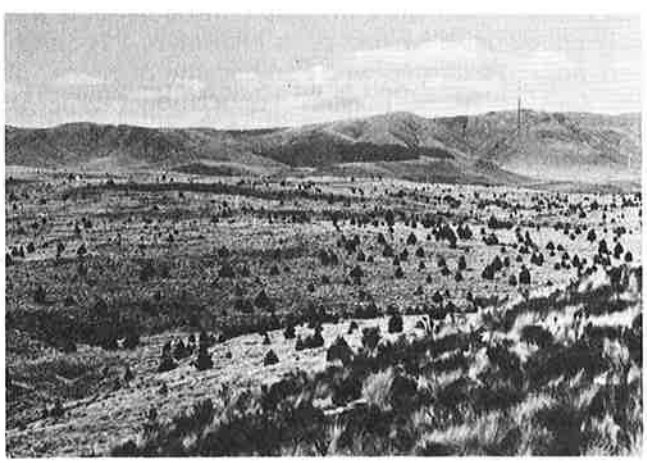


75. In the Rangitikei catchment erosion, although not severe, has been widespread in soft tertiary rocks. Space planting with trees has cured and prevents much of it. This is a good example of space planting with poplars, the usual tree for this practice. (Rangitikei-Wanganui Catchment Board)

The March of Contorta Pine

Karioi State Forest, on the tussock-covered slopes of Mount Ruapehu, was planted by the Forest Service during the boom planting period of the 1920s and '30s. It lay next to the Tongariro National Park and the military reserve. The altitude was generally too high for radiata pine, the most widely planted tree during that period, so hardier species were used.

One of them was the North American lodgepole pine (*Pinus contorta*), a tree that seeds prolifically even when only a few years old. Trees began to appear along the direction of the prevailing wind eastwards from Karioi and invaded the national park and the military reserve. The tussock grassland proved to be ideal vegetation in which seedlings could germinate. There was nothing to halt the progress of contorta pine through tens of thousands of hectares of tussock country—in the national park, the military reserve and the Kaimanawa Mountains. Such a pine forest would be especially vulnerable to fire in the mountains, and open to the devastation of storms (for the tree is especially prone to windthrow). The prospect was alarming to those who could visualise the ultimate scene.



76. Contorta pine on Military Reserve land, Waiouru, in 1961. (J H Johns, NZFS)

The National Park Board quickly cleared the infestation on its land, but the Army preferred to let the trees grow. In the 1950s the author asked the Minister of Forests to take the matter to Cabinet with a view to encouraging the Army to eliminate, or at least control, the invasion. It then occupied less than 2000 hectares. The Minister declined, and suggested a visit to the Army. The Army was very polite, produced a couple of pink gins, and said the trees looked to be a good prospect for tank warfare training. Twenty years later the infestation had spread over 20 000 hectares and was truly on the march. The Army had 2 tanks and the trees were mostly too dense for them to penetrate.

By that time a number of organisations, including the Rangitikei Catchment Board, had become thoroughly concerned. The Board could see the long-term effect that a widespread and uncontrolled infestation of trees could have. It therefore used the soil and water legislation to co-ordinate the parties concerned (a purpose for which it is ideal) and ultimately persuaded the Army to set to work to rid its



77. The coastal sector of the Rangitikei-Wanganui district where drifting sand inundated much farmland before it was halted. Sand is seen here invading a plantation of radiata pine. To prevent this kind of drift, control works must be commenced at the shore. (J H Johns, NZFS)

reserve of contorta pine. Meanwhile the Forest Service undertook to deal with the source of the trouble in the Karioi forest and replace the tree with species less aggressive.

The Coastal Sands

From the Manawatu Catchment Board's district to Wanganui the belt of drifting sand dunes continues along the coast. In places dunes moved over farmland at a rate of 25 metres a year for lengthy periods. The inexorable march of sand buried everything.

The Forest Service has stabilised a large section of this belt, but, in addition, the Catchment Board has introduced successful stabilisation measures into farming operations. These have been complex because of competing claims from the many interests that arise along coastal areas.

The Marahau-Wainui Sand Stabilisation Scheme was planned over an area of nearly 5000 hectares and included 11 farms and various leases. A 10-year programme will be required to complete the work. In addition to Catchment Board stabilisation, the Department of Lands and Survey has carried out a coastal review survey to plan the basis of a regional park. Recreation, plant and sea bird areas and a geological reserve to preserve ventifact beds have all been demarcated. A Marahau-Wainui Landscape Report has been prepared so that stabilisation measures can blend in with domain board proposals. The Waitotara County Council must take account of all this planning in drawing up its district scheme. Overplanned? Not so long as past mistakes are rectified, drifting sand stabilised and farming improved.

Wanganui

For the administration of natural water management the Wanganui area was amalgamated with the Rangitikei Catchment and Regional Water Board. Soon after, the Wanganui Valley joined the Catchment Board for soil conservation and river control. Taumarunui near the top of the river remained independent, as did Wanganui, a city that seemed to think that few benefits were likely to come from supporting a valley struggling with farming, much of which was barely above subsistence level. As late as the 1960s some 30 percent of the farm houses in the valley had been abandoned. Between the effects of erosion and reversion to scrub much steep land was impossible to keep clear for farming.

The Wanganui catchment is the second largest in the North Island. Covering 7382 km² it is twice the size of the Rangitikei catchment. There must be considerable potential for improvement in such a large area and the people of Wanganui stand to benefit from the further development of their hinterland. The Catchment Board is likely to provide the key.

Various measures to improve the valley are underway. An example of progress has been the designing of a scheme for the catchment of the Matarawa, a small tributary joining the main river almost at the eastern limits of Wanganui City. The Matarawa drains an area of about 100 km² of which less than one tenth is flat land in the valley bottom where its use is essential for farming. Down the centre of the valley runs a main access road and the Marton-New Plymouth railway.

Floods frequently affect the flat land and communications as well as part of East Wanganui. There are also many scars of past erosion, and on these, even after a lapse of years, production is less than half what it is from unaffected land. There are good reasons, therefore, for a catchment control scheme. One has been planned, and is underway, to include flood control, using not only stream bed improvement, but detention dams as well, contour drainage and silt traps, and soil conservation measures.

Similar schemes are possible, but much of the Wanganui Valley is undeveloped and is likely to remain so because of its extreme steepness and susceptibility to erosion.

The river itself is regarded as a fine scenic attraction from Wanganui to Taumarunui, and from Wanganui to the sea as a convenient sewer. Its great value as a versatile water resource is, however, now being increasingly realised. The hydro-electric potential of the river has been studied for a long time. If it were to be harnessed, however, the district, and possibly the nation, would have come to terms with the conflict between such development and present scenic and recreational values.

The river has a long history of these uses which led to the Wanganui River Trust being set up in 1892 to deal with navigation and to protect scenic values. In 1903 the Trust adopted an official list of 239 rapids from Taumarunui to the tidal limits. These have become the Mecca of canoeists. At present the Catchment Board maintains navigation works while scenic and recreational values are primarily the responsibility of the Wanganui River Reserves Board. Changes in administration are underway because of widespread interest in the river.

Cowpats and Chemicals

Mount Egmont, the Rain-Maker, is the lonely sentinel of Taranaki. Its 2518 metres reach up to collect the moisture in all the winds that cross the country. At the upper levels precipitation is as high as in almost any part of the mountains of New Zealand. The gradient of fall-off down to the lower elevations is then remarkably uniform all around the mountain. The result is an evenly distributed pattern of streams flowing down on all sides.

Dense forest once grew on the flanks up to the timber-line—about 1500 metres. As this was being cleared to make way for agriculture the value of the well-distributed water supply was recognised, and also the beneficial effect on this of the forest and other vegetation in the upper catchments where the heavy rain fell.

As early as 1881, therefore, all the land within a circle having a radius of 10 kilometres around the summit, plus the Pouakai and Kaitaki Ranges (older, eroded volcanic cones sitting on the north-west side of Mount Egmont) was reserved. In 1900 all this land was included in the Egmont National Park with an area of 33 379 hectares of which 80 percent is covered in native forest.

Mount Egmont dominates half the Taranaki district and provides a remarkably uniform setting. From the eastern boundary of this influence, the other half, the hinterland, stretches to the boundaries of the Rangitikei/Wanganui and the Waikato catchment districts. It is the same type of country as in the Wanganui catchment; the same soft, sedimentary rocks have been deeply cut by rivers, some of which are joined by tributaries from the mountain—Waitara in the north and Patea in the south are such.

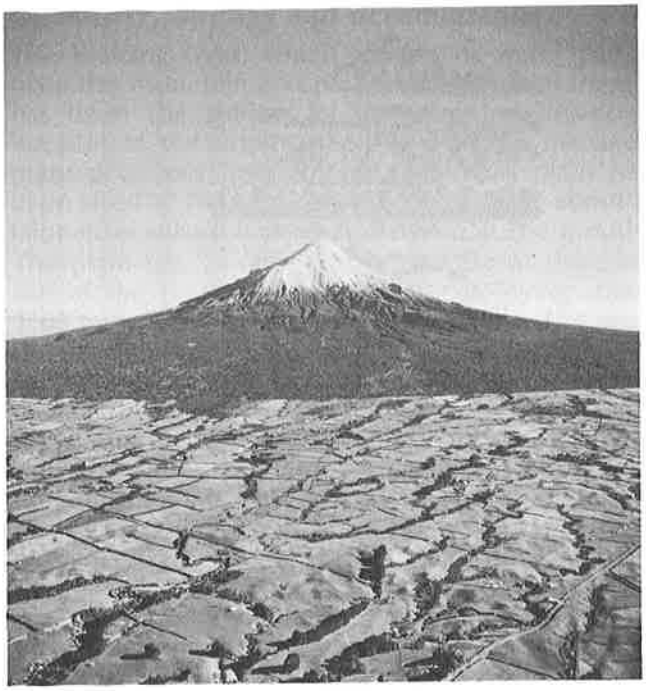
While there are many rivers throughout the whole region, they are small, entrenched and have quite limited flood plains, if any at all. There are no large river problems. No erosion has developed in the dense grass swards on this easy country. Reaction of the region, therefore, to the 1941 legislation was that already established local government could continue to attend to whatever small river problems there were. The limited amount of erosion in the hinterland could be looked after by the Central Government as it had been up to then.

The deep volcanic ash soils on the gentle, well-watered, lower slopes of Mount Egmont provided ideal conditions for the development of dairying. This land, extending right around the mountain, has been termed the 'ring plain'. On it there are now some 3000 dairy farms and a number of townships from which they are serviced.



78. Taranaki Catchment District

Mount Egmont and its long, gentle lower slopes—known as the 'ring-plain'—make up half this district. The other half, the 'hinterland' is Wanganui-type country. There are no large rivers or serious flood problems and no extensive erosion problems. But the water resource, especially Egmont, which has always been of basic importance to the Taranaki dairy industry, has assumed greater importance with the establishment of petro-chemical industries. (D W Lawrence)



79. On the lower, flattish slopes of the andesitic cone of Mount Egmont, thriving dairy farming has developed. Part of its success has been brought about by bountiful water supplies obtained from the many streams flowing down all sides of the mountain. The headwaters are protection forest retained in the Egmont National Park. (National Publicity Studios)

Down the mountain side and through the farms flow many streams and rivers. The plentiful supply of water provides for stock and homesteads and once took away the effluent from dairy pastures, dairy sheds and factories.

The Water and Soil Conservation Act 1967 required water management to be undertaken, and pollution could not continue to be treated leniently. A Catchment Commission and Regional Water Board covering 7195 km² was therefore set up soon after the 1967 Act was passed, but this was at first serviced by the local authorities already in existence. Under such an arrangement there was no provision made for assessment of water resources, or of pollution, or of dealing adequately with water rights. When a second filing cabinet was installed in the office it was light heartedly reported to be an important day in the history of the Commission.

The Kapuni gas field was struck in 1959 and the offshore Maui field in 1969. Treatment of the harnessed gas, pipelines across the country and the prospect of local petrochemical industries transformed the outlook of the Commission. Competition with the established rural uses of water had to arise. Likely pollution had to be forecast and its nature and possible dangers understood. It was high time that current rural and urban pollution was examined more critically.

Another demand for water was growing in the north of the ring plain where horticulture was becoming established, looking to irrigation to ensure production. Taranaki had been called "the garden of New Zealand" as early as the 1850s. Now its good soils and a mild climate encouraged the growing of a wide range of crops, including the native poroporo (*Solanum aviculare*), used for the production of steroids. By 1985 the area under this crop alone is expected to be 1000 hectares.

Pipelines

The first indications that complications were going to arise from the finding of gas came with plans for the pipelines needed to distribute it. Lines were to be constructed from Kapuni around the mountain to New Plymouth and to Auckland and Wellington. No doubt there would be other connections in the future. The lines were constructed across farms, up hill and down dale, through forest and across streams and rivers. There was plenty of potential for erosion in the loose volcanic soils and the soft sedimentary rocks. The flow of water in streams and rivers could easily be interfered with.

Part of the 1967 legislation set the rules for this type of operation, so the Commission drew up guidelines to prevent erosion and interference with watercourses and flows. Under their supervision no problems have been experienced since teething troubles were overcome.



80. Pipelines conveying chemicals and gas cross the country in many directions. They have to be carefully sited and laid to avoid erosion and drainage problems.

Next came the planning of petrochemical industries using gas. These required water and a means of disposing of liquid effluents. Their water rights would be much more complex than any that had been granted in the past in Taranaki. An unusual range of chemicals had to be considered, some of them highly toxic to organisms that live in water, both fresh and saline. The industries were large and would grow. Moreover, they were based on strikes to date, and the odds of finding further gas or oil in the locality were favourable.

If the Commission was going to manage its water resources to cope with these developments and not jeopardise current users or recreation and conservation, it had to know a great deal more about them, both the quantity and quality.

Water Resources Surveys

From the Egmont National Park boundary more than 100 streams flow across the ring plain at intervals averaging less than 5 kilometres. Forty of them have a 10 year low flow in excess of 100 litres per second. This group has been selected for detailed flow studies because of its significance for water supplies.

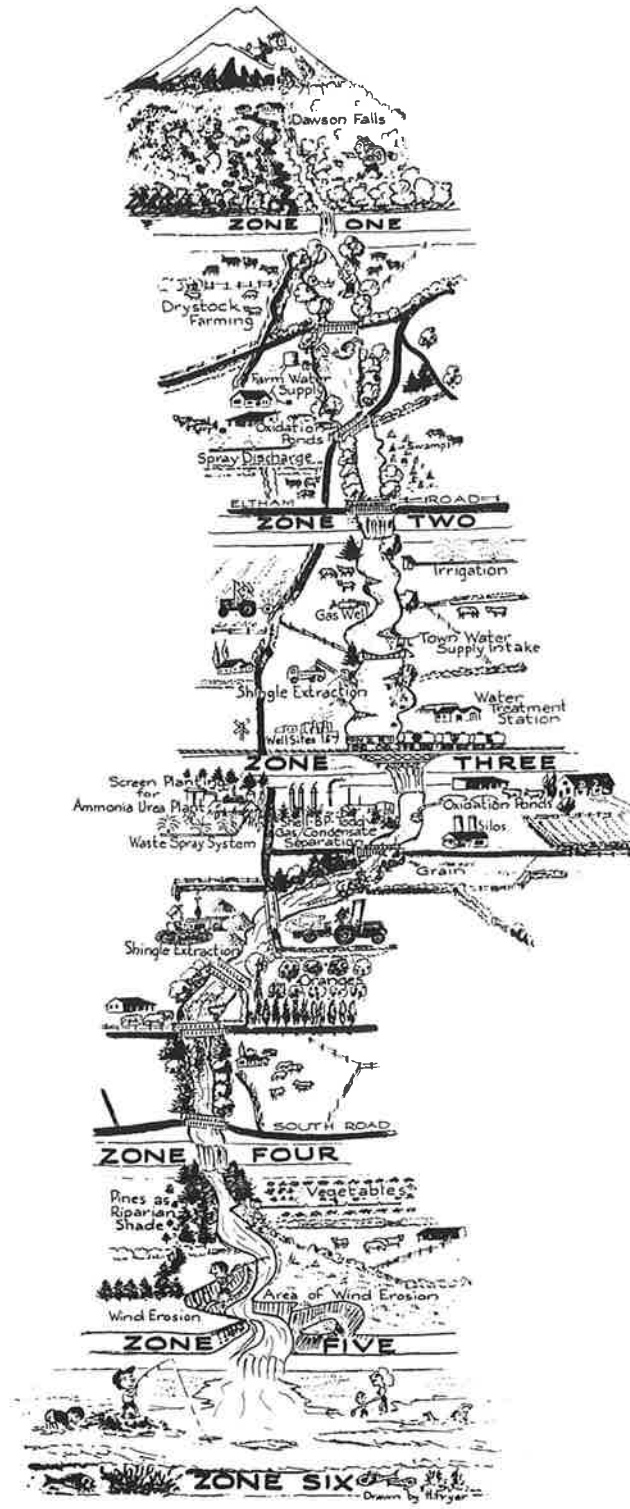
Catchments on the flanks of Mount Egmont lend themselves conveniently to detailed study of the relationship between water and land use. One such investigation was carried out for the Timaru Stream.

This stream is on the north-west side of the mountain and rises on the Pouakai Range. Of the 52 km² hectare catchment, 22 km² is in the National Park. The remaining area contains 42 farms engaged in dairying or a combination of dairying, drystock and horticulture (over 70 percent is dairying). There is one cheese factory in the catchment. The beach at the Timaru mouth is a popular recreation area, and the stream itself is used for swimming, whitebaiting and trout fishing. It also has scenic appeal.

Streams are the most important source of water used in the Timaru catchment. In 1980, the factory and 31 of the farms extracted an average of 373 050 litres per day. In addition, there were 13 wells and 5 bores in the catchment from which was taken somewhat less water than was extracted directly from the streams.

The discharge of cowshed wastes was mainly by spray irrigation onto pastures. Twenty farms used this method. Four used oxidation ponds—the Commission assists farmers to locate and design these. On 2 farms, wastes were drained into swamps.

Similar information to the above is being obtained for the whole ring plain. This, together with hydrological studies being undertaken on selected streams, will give the Commission valuable information. All the Egmont streams are used for stock water; some are good fishing streams; some feed underground supplies that are already being tapped by farmers; there are hydro-electric schemes on some; two rural water supply schemes are operated from others; many factory and urban supplies are drawn from them.



81. Water resource use along the Kapuni River.

Chemistry, biology and oceanography

The Waitara River, which gathers its water partly from the mountain and partly from the hinterland, has been the subject of intensive investigations because of the urgent need to draw up management proposals for it. A petrochemical plant has been sited at Tikorangi on the lower river, about 3 kilometres inland from the township at the mouth. The plant has, as one option for effluent disposal, use of the township sewage line, emptying some 1200 metres out to sea in an embayment. The possible addition of toxic chemicals to the sewage was something that had to be investigated. The Commission therefore initiated in the lower river and the embayment studies of the water movements caused by tides, currents, winds, depths of sea and flows of the river. The effects of traces of chemicals on marine and river life were included. The complex investigations were much more detailed than anything that had been carried out along the Taranaki coastline up to that time (or, for that matter, on almost any part of the country's coastline).

Much less detailed investigations than the Waitara ones were carried out when the New Plymouth Thermal Power Station applied for water rights in 1972. Sea water only was required for cooling purposes. The station uses natural gas and the water does not come into contact with any other fluids. The temperature is, however, raised 9°C in passing through the condensers.

Planning of the station had commenced well before the 1967 legislation, so that the requirement for sea water produced a 'fait accompli' situation. The best the Regional Water Board could achieve was to predict major changes, including detrimental effects, that might take place, then introduce possible safe guards into the water right. Monitoring the situation, both before and after the station started up, was the most important step to take, and this was done.

At Kapuni some of the natural gas will be used for producing ammonia-urea. In this plant 100 litres of water per second will be needed for boiler water, cooling, and other purposes (that is, more than 20 times the water use in the Timaru catchment described above). An application for this amount was made by the Natural Gas Corporation of New Zealand and three possible sources of supply were indicated; all three, Egmont streams, already used for a number of purposes.

The use of one stream was ruled out because it already supplied farming plus a lactose factory, and further extractions would deplete flow. Further depletion of an already small flow also ruled out the second stream. In the catchments of both these streams the need for water to supply possible future irrigation schemes was also introduced as an objection.

Proposed extraction from the third stream (the Waingongoro) amounted to 8 percent of the 10-year low flow. This was taken as being acceptable to other users and to the biota of the stream. Moreover, the report of the Tribunal hearing the objections noted, "the topography outside the Park boundary is more uneven and still contains small areas of bush, wasteland and swamp which result in a more stable stream flow pattern".

The application also sought rights to discharge stormwater and effluent: altogether, a complicated series of rights, requiring careful consideration of the conditions that should be placed on them. These in turn required investigations for which there was all too short a time.

Apart from these new industrial calls on water, urban authorities are planning expansions of their water supplies, and water rights are being sought for them. Rural supplies drawn from shallow underground sources are declining in quantity and quality. As yet, little is known of the deeper sources, so withdrawal from them is limited. Because of the shortages and the lack of quality, a great expansion of rural water supplies is being sought. Water for them must be drawn from the Egmont streams.

To a large extent, further development of Taranaki depends upon plentiful supplies of pure water; for the farmer and horticulturalist to increase production from the fertile soils as well as for industrial developments based on the new hydrocarbon discoveries.

Soil Conservation

Water and pollution problems have engaged most of the attention of the Commission up to now. There has, however, been time for it to realise that it does have soil conservation problems in what it terms its 'back country'—mainly that land lying between Mount Egmont's influence and the plateau of the central North Island. It is not very high, but very broken, with steep-sided valleys. The streams and rivers have very limited valley floors, and these can be readily flooded or eroded away.

Erosion is inevitable on farm land in this steep country. While it is not severe, control is necessary.

Through the use of good farm plans there is little doubt that production from the whole region could be lifted appreciably.

Investigations to this end are underway, and a catchment control scheme for the Waitotara is being planned. The next major catchment north of the Wanganui, it covers an area of 113 km^2. More than half the catchment is forest, largely State forest, which it is intended to retain, primarily for protection purposes. Catchment control measures include



82. Egmont coast with low cliffs created by recent uplift of the land. Old, consolidated sand dunes beyond the cliffs have been loosened during farming and have to be stabilised with marram grass to prevent destruction of land.

farm plans, river channel clearing and bank protection works, construction of detention dams and water investigations to determine water quality.

The coastal sand dunes of the Manawatu and Rangitikei-Wanganui districts extend along parts of the Taranaki coast, but in an unusual form. The coast, both north and south of Cape Egmont has been eroding at rates up to 1 metre per year. What remains of the dunes are now perched on cliffs up to 50 metres high. These sandy areas are useful to farmers, but the tendency has been to over-graze them, so loosening the sand. The Commission has been encouraging farmers to re-fix these areas by fencing them off and applying additional conservation measures where appropriate.

City Streams

Streams from the mountain's northern slope flow down through New Plymouth. These had quite adequate channels to cope with all flows until commercial buildings were built beside and even astride the Huatoki and Mangaotuku streams. Floods, constricted on their way through the city did considerable damage in 1961, 1969 and 1971. Control schemes were planned and constructed. Diversions and flood detention dams were necessary. To avoid future trouble, one of the most important measures was the inclusion of flood zone designated areas in the city's district scheme.



83. Flooding in New Plymouth, 1961, by the Egmont streams which flow through the city.

84. Northland Catchment District

No part of the Northland peninsula is more than 40 kilometres from the coast and the country is mostly composed of low, rolling to steep hills seldom more than 2-300 metres high. There are no large rivers except the Northern Wairoa. Erosion is neither widespread nor severe except in coastal belts of sand dunes. Long dry spells can occur during which there are water shortages. Northland is not as well endowed with water resources as is the remainder of New Zealand. Stiff clay soils have posed difficulties in land use but the indented east coast attracts increasing numbers of people. (D W Lawrence)

NORTHLAND CATCHMENT COMMISSION

Wasteland

Northland has water and soil problems differing in many respects from those found in the rest of New Zealand and its history of control is a chequered one.

At Kerikeri in the Bay of Islands 300 mm of rain fell during 6 hours on 20 March, 1981. The resultant flood waves, up to 5 metres high, swept down the Waipapa Stream and Kerikeri River, carrying along huge loads of debris torn from the riverbanks. This was deposited on bridges in the lower reaches and in the Kerikeri Inlet. Low-lying orchards were devastated, yachts swept from their moorings, a house was floated into the inlet and a woman was drowned.

Storms of a similar degree of intensity strike some parts of Northland on an average almost annually. They emphasise a number of North Auckland problems connected with its soils and its high intensity rainfalls.

No part of the Northland peninsula is more than 40 kilometres from a coastline abounding with harbours, estuaries and bays or long sweeps of sandy beach. Most of the land is rolling and hilly but seldom more than 200 or 300 metres high. Mountains are limited in extent and none reaches 1000 metres.

The climate is mild. The ingredients for close settlement and intensive agriculture seem to be there, but good production has only been achieved through patient and persistent efforts.



Northland has been termed the cradle of Pakeha settlement in New Zealand. Those who came to seek kauri timber found magnificent forests throughout the area and plenty of sheltered coast from which to work them and ship the timber. There were also pockets of rich volcanic soils formed on recent basalt eruptions and suitable for development. But these were scattered and limited, only 1.4 percent of the whole area. When settlers began to clear instead the cut-over kauri forest to sow pastures, they had to contend with poor, heavy soils, derived from deeply weathered sedimentary rocks.

An unusually wide and intricate variety of difficult soil types had formed in Northland. Kauri trees themselves had made the soil more intractable by a process of degeneration known as podzolisation. The soils baked in summer and bogged in winter. Under these circumstances regrowth of scrubland and invasion by weeds—an unusually wide range of them—soon took over from burned forest and poor pastures. Northland rolling country became a wilderness of wasteland with pockets of high quality farming and isolated settlements. Roads were difficult to form, so communications were poor. The scene was a marked contrast to the conversion of forest to pasture and productive farming in many other parts of New Zealand.

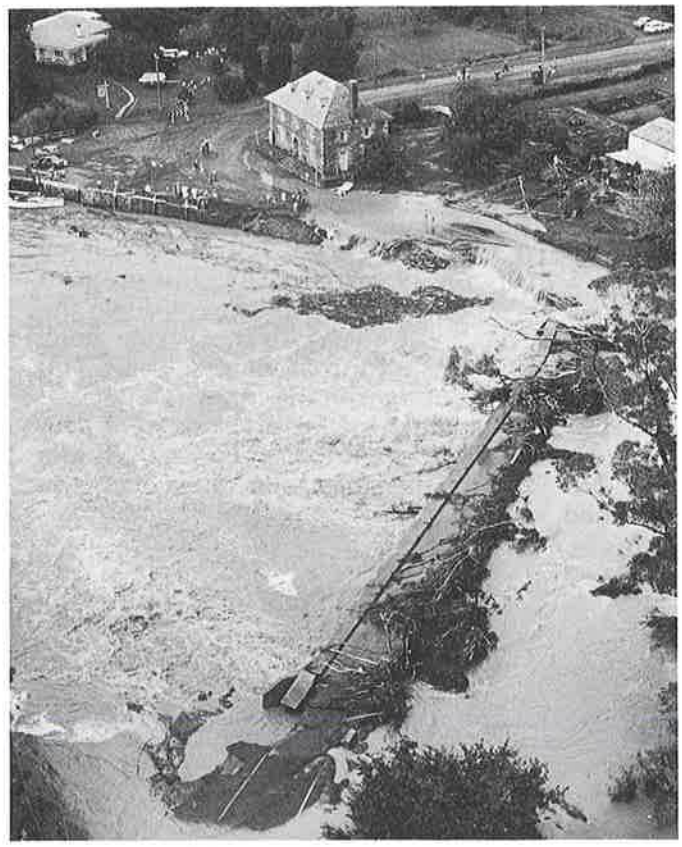
Redevelopment of agriculture on these wastelands has gradually taken place. Individuals have played their part but, in addition, the Government has undertaken the most extensive land reclamation outside the pumice soils of the central North Island.

By 1982 the Department of Lands and Survey had developed or had under development almost 70 000 hectares throughout the area roughly coinciding with the Northland Catchment Commission district. In the whole of Northland almost the same total area had been developed and settled in more than 500 farm units.

Early Land Use Schemes

The location of the Kerikeri storm was also the site of a land development company in 1927. Its operations included the planting of passion fruit and citrus and some afforestation. An account of conditions at the time recorded a lack of roads and no electricity. Main access was by water. A settlement was to be called "Kerikeri Garden City". Most of the first orchards failed for one reason or another, but careful rebuilding has produced the promising results we see over 50 years later.

At one time the wastelands of Northland were a Mecca for land development speculators. Areas, usually the poorest, were bought to promote the growing of orchards, tung oil and forest plantations. Most failed; tung oil completely so (the promotion



85. The March 1982 flood in the Waipapa Stream and Kerikeri River when debris in the catchment was swept across roads and bridges. (Northern Advocate)



86. Northland clay soils, if left bare, soon erode under the influence of heavy rain. (MWD)

story was, that because it was supposed to grow on poor land in China the poor soils of Northland were eminently suitable).

Exotic afforestation, using principally radiata pine, persisted. The State as well as land companies joined in this. One of the early State afforestation projects was at Riverhead at the top of the Waitemata Harbour. (This is in the neighbouring Auckland catchment district but the soils are the same as those found in Northland.) This discouraging wilderness of poor soils, weeds and native plants had been subject to frequent burning. Radiata pine was planted about the 1930s. Growth was extremely variable, ranging from good in the valley bottoms to stunted bushes on the hilltops. In the 1950s it was discovered that an application of phosphate would produce normal growth on nearly all soil types and sites. Afforestation then began to develop throughout the North and now competes with agriculture for land.

The Swamps

Other than the (Northern) Wairoa which drains one third of Northland, rivers are short and small and have little in the way of flood plains. On the other hand 2 extensive swamplands have formed: the Hikurangi Swamp north of Whangarei, caused by the damming of a tributary of the Wairoa by a lava flow, and the Kaitaia Swamp, formed mainly by sand dunes forcing the Awanui River northward to discharge to the Rangaunu Harbour. There are also a multitude of smaller swamps scattered throughout the north. Altogether they covered about 2 percent of the land.

These swamps contained kauri gum—the hardened and fossilised resin exuded from kauri trees. Attempts were soon made by gum diggers to drain them in order to win the gum, which was used for varnish and other industrial and decorative purposes. Settlers also drained them for farming, but encountered great difficulties in the larger swamps where flooding was frequent and persistent.

The Government was finally drawn into the drainage of both the large swamps. In 1913 it formed the Kaitaia Drainage Area covering about 25 000 hectares and in 1934 the Hikurangi Drainage Area covering about 20 000 hectares. The combined area was comparable to or greater than some major river flood plains that were being reclaimed around the country. Hence their importance to Northland. The Government also undertook the draining of a swamp at Mangawhai on the east coast, but the object there was to assist the winning of gum.

Where did a Catchment Board fit into this Northland scene? Nowhere, in the opinion of territorial local authorities. There were no substantial river problems, other than along the lower reaches of the Wairoa. Nor was there any severe erosion. Widespread sheet wash occurred in the clay soils but was only readily apparent to a trained observer.

The Hikurangi Swamp Scheme

There was, however, growing impatience from settlers around the Hikurangi Swamp. The Department of Lands and Survey had ceased development operations in 1939. Since this difficult basin was plagued with frequent flooding, reversion soon set in once major work and maintenance ceased.

In its natural state the main Hikurangi Swamp plus the valley bottoms in the tributary streams amounted to some 13 000 hectares. The river that meandered through the swamp was 2 to 3 times its straight line length of 10 kilometres. Its outlet was constricted by both the lava flow and a narrow valley through limestone and was insufficient to cope with the flows brought about by heavy rains. Water, ponded in the swamps, could remain in low-lying parts all winter, and in other parts for long periods of time.

Early work had improved drainage in areas of the swamp itself, but to increase flows along the main river and through the outlet was a much more difficult task. Some enlarging of the outlet had been done, but the effect of producing more rapid flows to the Wairoa had to be carefully gauged.

If the situation were to be retrieved and further development carried out, there must be a distinct effort made. Realising this, a body calling itself the Northern Wairoa Watershed Committee was formed. It wanted, amongst other things, the development of the swamp. The most satisfactory way it could see of getting this was to have a Catchment Board that could plan a scheme for the whole river.

The final upshot was the setting up in 1962 of the Northland Catchment Commission whose district was restricted to a small area—mainly the Hobson and Whangarei counties. The northern counties of Mangonui (containing the Kaitaia swamp) Hokianga, Whangaroa and Bay of Islands remained out. This compromise was, in a number of ways, most unsatisfactory, although Hokianga and Mangonui counties later joined the Commission and the whole region was included under the Commission for the purposes of the 1967 legislation.

The scheme designed by the Commission for the Hikurangi Swamp, and now completed, is a complex one. River-straightening and stopbanking to cope with flood flows followed conventional methods, but internal drainage could only be achieved by dividing the swamp into 7 sections and constructing a pump station in each.

The scheme finally brought into production hitherto completely undeveloped swamp; it improved,

in great measure, the grassland already there and it made cropping safe in some areas where it had been unsafe before. Nevertheless, the scheme is only a stepping-stone to future improvement. It is not complete protection, but is designed to cope with floods with a return-period of 5 years. One of Northland's intense rainstorms could still flood areas severely. No doubt the improved economic position of farmers brought about by development will encourage demands for still greater protection in the future.

The (Northern) Wairoa River

The Kaipara Harbour is in part the sunken lower valley of the Wairoa. The river is therefore tidal for almost 100 kilometres if the distance is calculated from the Kaipara Heads. Tidal effects combined with intense rainfall can cause spectacular flood rises, making farming of the many small areas of swamp and flood plain along the river's lower reaches difficult to achieve and to maintain.

The spread of Manchurian wild rice (*Zizania latifolia*) along the lower river banks and into main drains has further complicated development operations. This introduced giant grass grows 3 metres tall and forms very dense thickets. So far it has resisted all attempts at control other than mechanical.

The largest and most successfully developed area is Ruawai Flats on the river bank almost where it widens to form an arm of the harbour. Here 8200 hectares have been reclaimed from tidal and swamp land. They were originally subject to overflow from both spring tides and river floods. Initial reclamation was carried out by the Department of Lands and Survey, but by 1905 the Raupo Drainage Board was formed to take over the works and extend and improve them. When recently still further improvements were sought the Catchment Commission was drawn into collaboration.

Isolated flood control works are continuously being undertaken along the river. They are complicated because they have to take into account the highest tides as well as the highest floods that occur and the effect of the Manchurian wild rice. The works are designed to eventually link up and form a more complete river control scheme. By then the reclamation of about 16 000 hectares of swamp and flood plain will have been achieved.



*87. Manchurian rice grass (*Zizania latifolia*) growing on the banks of the Kaihu River, Northern Wairoa catchment. Dense growth of this giant grass affects the free flow of flood water. (Hobson County Council)*

Changing Land Use and Water Needs

More intensive land use lies ahead for Northland. Afforestation, horticulture and coastal urbanisation are all playing a part, but the major change has been the rapid development of agriculture from wasteland. In the large blocks being broken in by the Department of Lands and Survey, new techniques are coping with the intricate pattern of difficult soils and the danger from erosion both during and after development. Unusual acidity (pH 3 compared with a neutral acidity of pH7) is a characteristic of some Northland soil types. If they become eroded the greatest difficulty is experienced in getting vegetation of any sort established on the bared surfaces.

Although only a limited number of farm plans are in operation, soil conservation practices of one sort or another have been carried out on more than 600 farms. This, and other farm improvement, has helped to build up stock numbers and increase production very substantially in recent years.

Following the discovery of the effect of phosphate on the growth of radiata pine, rapid forestry development has taken place throughout Northland. In addition, the wide stretches of drifting sand along the coast lend themselves to afforestation and their encroachments onto farmland make it imperative that they be planted or fixed by some means. Forest plantings along Ninety Mile Beach (Aupouri State Forest), along the Kaipara Heads and at Mangawhai on the east coast have halted the moving sand. They will also produce a large volume of wood. Radiata pine forests will become of greater importance to Northland than the kauri forest once was.

Citrus and semi-tropical fruit have long been grown on the rich volcanic soils around Kerikeri but lack of rainfall in the summer hindered progress. Plans were, therefore, formulated over a number of years for an irrigation scheme to improve crops and allow expansion of orchards. The storm of March 1981 hit as the main earthwork on the first of the two dams

to be built was up to half full height. The works escaped the main storm and little damage resulted.

Other pockets of good soils will sooner or later be turned to horticulture, but the change will depend upon the availability of water for irrigation.

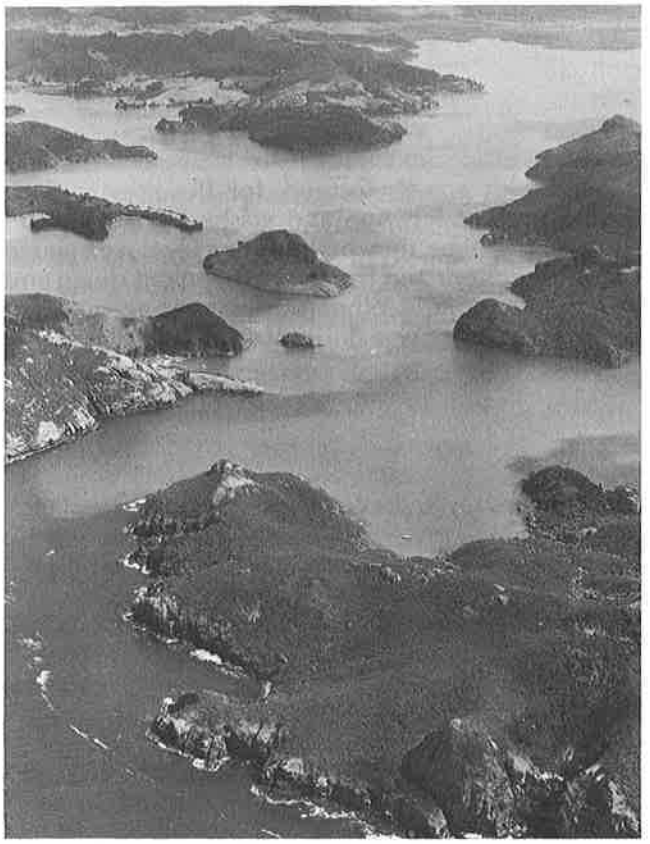
Beside the sheltered bays and waters and the areas of coast with incomparable views, urbanisation is taking place rapidly. With this arise problems of earth stability in deeply weathered soils —there have been a number of failures in large excavaions— coastal erosion affecting settlement and the provision of adequate water supplies.

Where does the Catchment Commission fit into this scene now? There is a shortage of readily available water, so water harvesting and careful management must play a major part in the future development of Northland. Present and proposed uses in the near future require the Commission to spend more than half its available resources on water management and water use control.

Its help has become essential in guiding safe changes in land use; in assessing, studying and allocating water resources; and in preventing pollution, especially around the settled coast.



88. Drifting sands of the Ninety Mile Beach. Sand loosened by stock has been driven by the westerly winds over farmland. The main belt is being fixed by planting marram grass followed by afforestation with radiata pine. (J H Johns, NZFS)



89. The indented, eastern coast of Northland makes it one of the most attractive areas in New Zealand for urban settlement. The hazards that go with this settlement are the danger of polluting the sea water and excavation of the clay soils leading to erosion. (D L Homer, NZGS)

THE WELLINGTON REGIONAL COUNCIL WATER AND SOIL MANAGEMENT COMMITTEE

The Hutt Valley

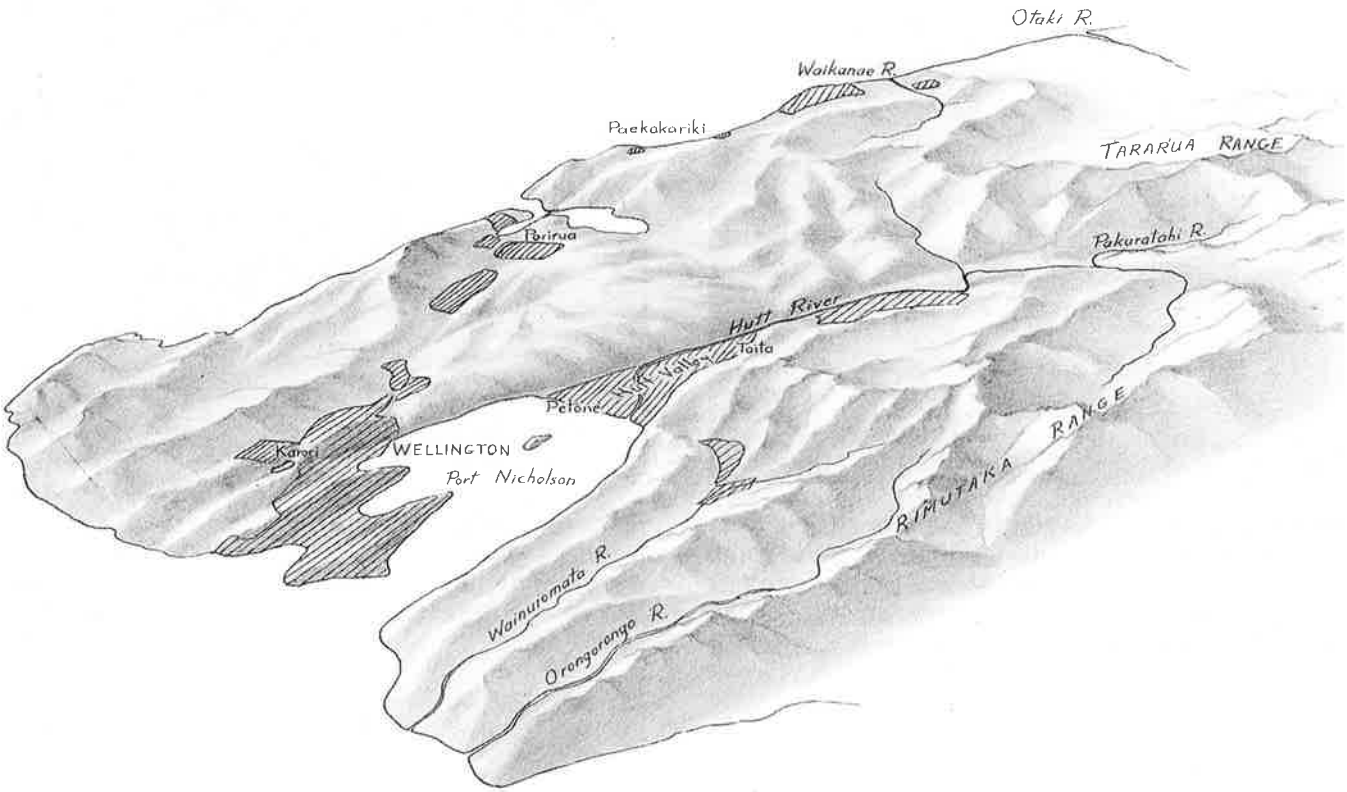
The sheltered water of Port Nicholson, the promising, open shore at Petone and the wide flat valley beyond were promising enough to attract many of the New Zealand Company's first settlers. The Hutt River also offered access part-way up the densely forested valley.

Constant flooding soon dispelled this early promise. The river rises in the Rimutaka Range and the southern end of the Tararua Range where heavy rainfalls send down frequent floods and freshes. The valley is filled with gravels formed, for the greater part, during the last Ice Age and washed down by the river. At one time they built up to a level well above the present floor and have since been cut down and re-sorted by floods. When settlement began a large part of the valley was flood plain.

Settlers, driven away by a period of severe floods in the 1840s and '50s, retreated to the shores of Wellington. There they found little flat land. They began exploring the Wellington west coast and the Wairarapa and Manawatu, but boat journeys were needed to get to the last two. The flat land of the Hutt Valley remained an irresistible alternative and people kept returning to it.

Forest clearing was undertaken and market gardening began on the rich silt soils to supply growing Wellington. Gardens, farms and small settlements soon filled the area despite the dangers from flooding.

Great hardships were endured. C A L Treadwell in his book *The Hutt River*, describes a disastrous flood in 1858. "It was in respect of loss of human life and destruction of stock and garden produce the worst that ever occurred though it was not the highest flood since". Nine lives were lost.



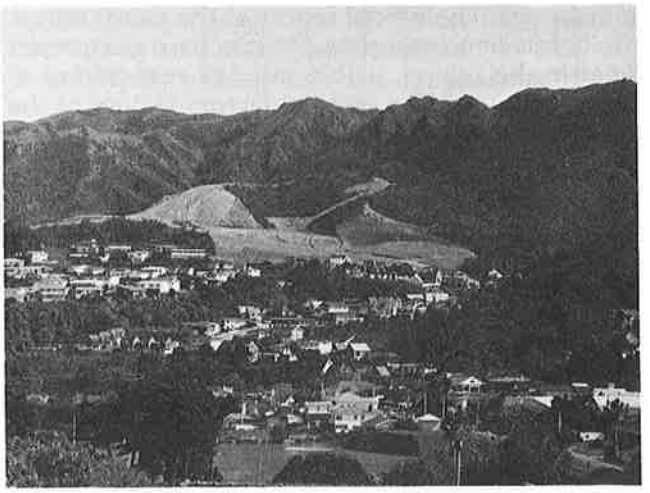
90. Wellington Catchment District

Wellington has expanded around the slopes of Port Nicholson but lack of flat land has impeded growth. The valley of the Hutt River at the head of the harbour has therefore always had an attraction for settlers. Used at first for market gardening and farming the flat land, which is largely floodplain, was eventually built over. Flood prevention control of the Hutt River has been a major operation. Ever-increasing water supplies are drawn from forested catchments, including that of the Hutt River, and underground water fed by the Hutt. The greywacke hills in the Wellington district are mainly stable even when cleared of forest. Urbanisation has therefore spread over them with safety except from high intensity rains. (D W Lawrence)

An ineffective River Board was set up in 1878 in an attempt to co-ordinate individual works, but not until 1899 was the Hutt River Board set up to deal with the river in a comprehensive manner. Helped in large measure by extensive commercial extraction of shingle, which lowered the river bed, it gradually brought flooding in the lower river under control by major stop banking and channel training, although this was not satisfactorily completed until the 1950s.

Even before the river was safe a remarkable transformation of the valley took place. Industry and housing encroached all over it. Market gardening, which had obtained a very strong hold, withdrew to the west coast north of Wellington.

Flood control of the Hutt River has enabled two cities to be built largely on its flood plain. Water drawn from it helps to supply a population in excess of 300 000. Water from neighbouring rivers is linked to this supply, but the Hutt catchment and the underground water the river feeds yields 75 percent of the total supply. The Hutt River, from being a source of trouble, has become a valuable supply of water and a focus for increasing recreation.



92. The Wellington greywacke hills are stable except where loess or other loose deposits lie on them. Present day practices of moving large quantities of earth in shaping land for close urban development appear to be secure if properly designed. Problems do arise below such excavations, by run-off into stormwater systems which were not designed to take such increases, and from flash flooding of streams. (MWD)

The 1976 Rainstorm

The river had been tamed and a well-planned, bulk water supply system was in operation. The Wellington Regional Water Board, formed in 1972, could pay more attention to recreation throughout its extensive reserves, to afforestation and to the wider requirements of water management. Then came the rainstorm of 1976; a rude shock, reminding people of the devastating effects wrought by high-intensity rainfalls in this country.



91. Wellington rainstorm damage, 1976. Flooding of a 'dry' waterway in Stokes Valley where houses had been built. The debris in the valley was washed down destroying or damaging the houses. (Evening Post)

Rain is usually driven across Wellington by northerly or southerly winds, sometimes reaching high speeds. On 20 December 1976, two moist air streams, one flowing almost from the north and the other from the south, converged over the Hutt Valley. The cooling of this mass of moist air led to very high rainfall. Moreover, the mass remained unusually stationary over parts of the Hutt-Wellington area. Rain continued for 10-12 hours and included two torrential, 3-hour periods. In the first, 100 mm fell on some of the Hutt Valley areas, saturating everything and filling watercourses. In the second, a further 100 mm fell, and in parts up to 50 mm fell in 1 hour.

Severe damage to property resulted and a Civil Defence Emergency was declared. Some 900 landslides were triggered off. High floods occurred in the streams and dry watercourses of small catchments. The stormwater system proved quite inadequate, most of it being rendered inoperative because of the blocking of culverts. Huge amounts of debris were moved along watercourses which had been encroached upon by gardens, trees, private bridges and buildings. A breakdown of the functioning of a good part of the region occurred during and for some time after the storm. The direct financial cost of the storm damage that resulted was close to $20 million (1977). In addition there were considerable indirect costs and one life was lost.

Judging from historical data, similar rain—200 mm in 24 hours —could occur anywhere in the Wellington-Hutt Valley region in a theoretical return period

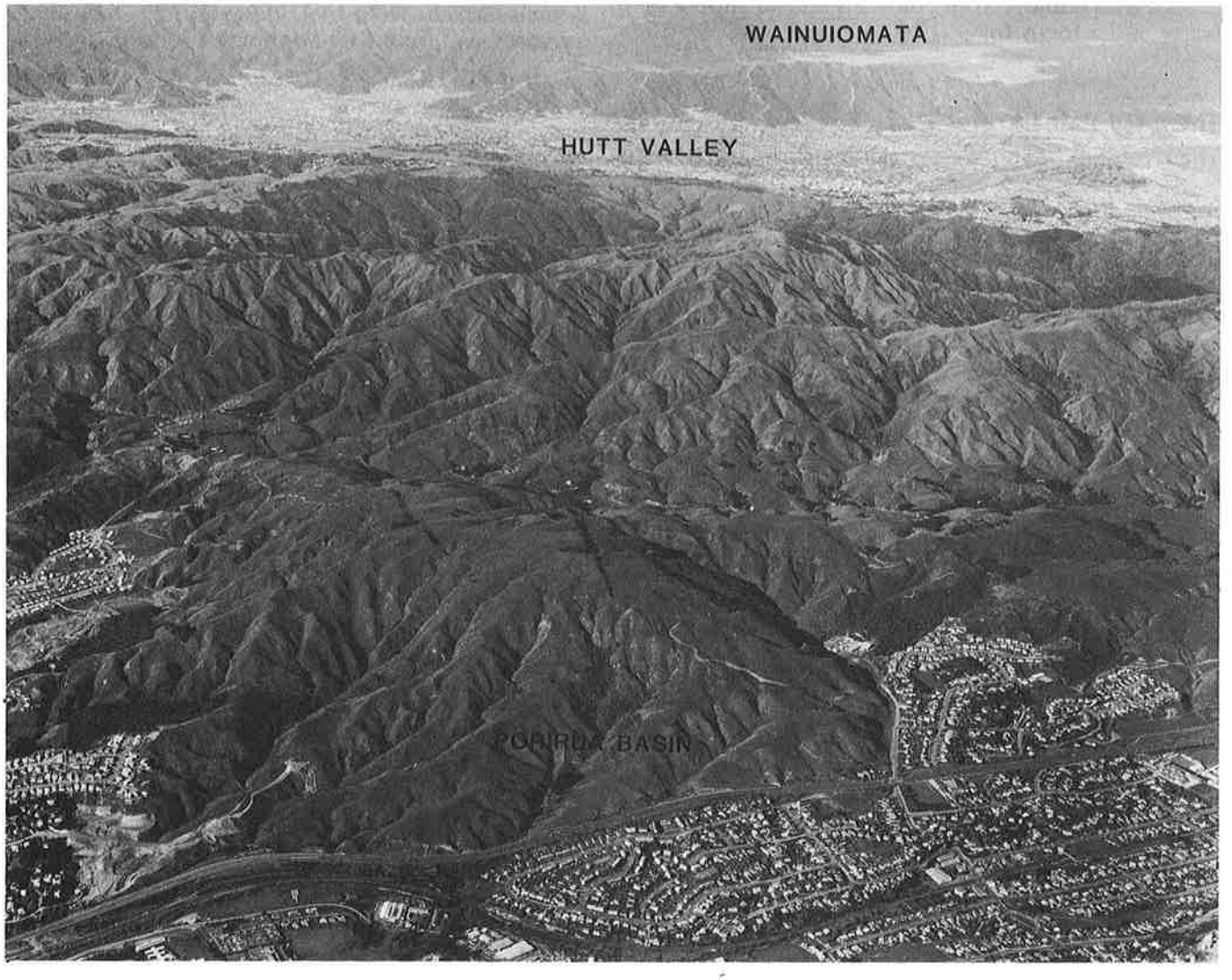
of 100 years. The official report of the storm stated: "Daily falls of greater than 200 mm have occurred 5 times in the region, within the 113 year period of the record . . . ." The one satisfactory feature of the event was that the Hutt River was contained quite safely in its control system throughout the storm.

The complete protection of property and services against very rare events is usually not economically justifiable. On the other hand, many safeguards can be taken to lessen damaging effects. Watercourses can be kept accessible and clear and banks protected. It is aesthetically pleasing for property owners along them to plant trees and build structures and gardens, but these provide the very materials that block culverts. When this happens floods must flow overland.

Another difficult and costly problem is the upgrading of storm water systems on the lower slopes of settled hills when further subdivisions are established above them.

Slips occur as readily on urban as they do on rural land—some times more readily, because of extensive interference with soil surfaces. In the 1976 storm, loess and unconsolidated deposits turned to mud flows and wrecked many houses. Urban settlement should clearly avoid such unstable areas.

During recent years storm damage has revealed weaknesses throughout the country in planning urban development. The Abbotsford disaster, and lesser events on the Port Hills in Christchurch, at Greymouth, Nelson, the Hutt, Gisborne and Auckland, apart from numerous coastal areas, all point to the urgent need for better planning.



93. In the Wellington region the valleys and floodplains have been filled with urbanisation while most of the hills still remain in farmland. In the distance can be seen the Hutt Valley, now containing two cities, and Wainuiomata, and running across the foreground the Porirua Stream Valley. Control of flooding by the Hutt River has been achieved but high intensity rains can do damage by flooding from the narrow valleys of the hills. (D L Homer, NZGS)

Local authorities are clearly in the front line in this whole field of activity. They must direct the community's efforts. But the water and soil organisation also has a part to play because of effects on whole river systems and catchments. Immediately following the 1976 storm the Wellington Regional Water Board began the detailed planning of flood control measures for the major waterways in the Wellington-Hutt region. Some areas are to be upgraded to protect them against 100-year events.

Seeking Water Supplies

A spring at the foot of Tinakori Hill, which supplied mainly Parliament and surrounding buildings, was the first communal water supply in Wellington. The next came from small valleys, in which the native forests had escaped fire. Some planting of exotic trees was done around their perimeters to complete the forest cover. Remnants of this planting, and disused dams and reservoirs, can be seen around the Wellington hills today.

This phase of water supply included the building of a dam at Karori in 1874. It was to impound 130 000 m^3 of water; in modern use, less than two days' supply for Wellington City. At the time it was hailed as "the ultimate answer to all the city's water problems for all time." The building of the dam was a major effort for those days.

But Wellington was not to stop growing and there were bigger and better supplies not far away, close to the expanding Hutt Valley population. Two small rivers, the Wainuiomata and the Orongorongo, coming from the southern end of the Rimutaka Range, were the closest. The upper catchments of both rivers were completely forested.

In 1884 a dam was built on the Wainuiomata, and in 1911 the storage capacity of this and of Karori were doubled. In 1925 a supply was drawn from the upper Orongorongo River. The Hutt River itself in the vicinity of Kaitoke was harnessed in 1956 and three other tributaries were studied for future supplies.

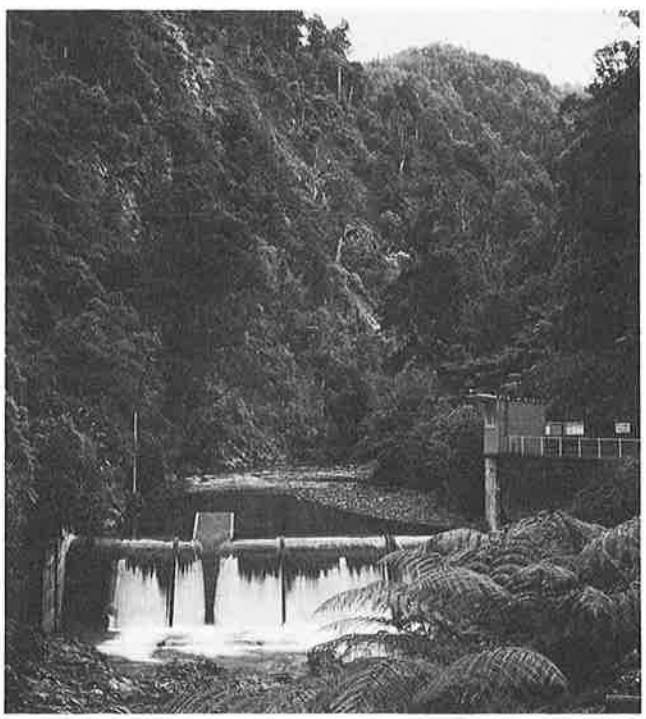
On the flat land of the Hutt Valley the presence of an ample supply of underground water, a large part of it artesian, had been discovered early. Wells were sunk in the 1880s and within 50 years there were several hundred of them. Industry came to depend on underground water. Near the beginning of the century, the settlement of Lower Hutt used this source. Later Petone turned to it and in 1935 Wellington also tapped it.

This extensive and uncontrolled use was bound to put undue strain on the resource. At the Taita Gorge more than half the flow of the Hutt River seeps through the gravels and flows through the underground beds, reappearing near the entrance to Wellington harbour. Pressure of the underground flow normally prevents sea water from entering the beds. Fears grew, however, that sea water would penetrate if extractions of fresh water kept increasing. Other pollution risks were also present when piles were driven, or wells carelessly put down.

Clearly, a single controlling body was necessary if such a valuable and accessible resource was to yield perpetually. In 1959 the Hutt Valley Underground



94. Building the Karori reservoir, 1874, the first major water supply for Wellington. (Wellington Regional Council)

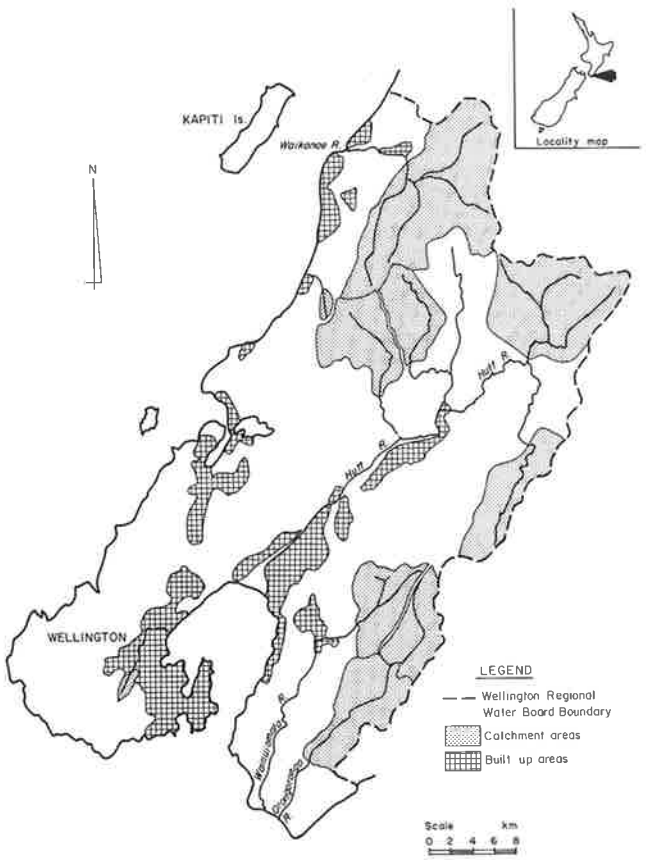


95. Wellington water supply intake, Kaitoke weir, on the Eastern Hutt River. The catchment above the intake is completely forested which helps to regulate the flow and allows it to be tapped in this manner. (Wellington City Corporation)

Water Authority was set up. Conservation and pollution control were its watchwords and remained so until it was absorbed by the Wellington Regional Water Board in 1972.

As Wellington grew the population escaped, whenever it could, to the somewhat more pleasant climate of the west coast from Pukerua Bay northwards. Weekend and commuter townships grew up, depending mainly on tanks and rain for their water supplies and on deliveries of water by truck during dry spells. Not until 1976 was an intake from the Waikanae River and a treatment plant built by the Wellington Regional Water Board able to supply Paraparaumu in Kapiti Borough as well as Waikanae. (As noted elsewhere administration of water and soil matters in this area was transferred to the Manawatu Catchment Board in 1982).

Today bulk water for the Wellington region is drawn from catchments extending over 16 000 hectares plus underground water. This is the result of long-term, continuous and efficient planning, even though there have been a number of changes in the administering bodies.



96. Water supply areas and the Wellington region (1981 boundaries). Substantial catchment areas have been set aside to supply the demand for water from the built up areas around the harbours and up the Hutt Valley. (after Wellington Regional Council)

Wellington Regional Water Board

The parallel activities of water and catchment management paved the way to the setting up of the Wellington Regional Water Board in 1972 which had under its Act to undertake the requirements of the Water and Soil Conservation Act and the Soil Conservation and Rivers Control Act for the whole of the Wellington region, stretching north to Waikanae.

As far as water management and supply, catchment and river control were concerned, the pieces of the jig-saw puzzle were fitting together in a logical and effective manner. The final step came with the formation of the Wellington Regional Council which took over the functions of the previous Water Board, and thus has, among its responsibilities, the management and conservation of water and soil—the two basic natural resources in regional planning. One of its committees, the Water and Soil Management Committee, manages water from catchment to consumer and so is vitally concerned with the state of the region's catchments and rivers.

With the brave forecast made in 1874 about the Karori reservoir ringing in their ears the Wellington Regional Council is in the process of installing the largest off-river water supply scheme in the country. This time it is not the final answer to Wellington's needs, but the "cornerstone of water supply needs for decades to come."

In the middle reaches of the Hutt River at Te Marua, just north of Upper Hutt city, reservoirs are being built to hold 10 times the quantity of water held by the Karori reservoirs. Public reserves and amenities are to be formed around them.

Native and Exotic Forest

At all times the condition of the catchments from which water is drawn has been of primary concern. The various bodies in charge of water supply have, therefore, pursued a policy of eventual ownership of the areas themselves.

One of the transitory administrative bodies was the Wellington City and Suburban Water Supply Board established in 1928. Some State forests in the catchment of the Hutt River were transferred to it. At that time logging was proceeding in the forests.

The newly established Board undertook the management of logging, ensuring that the extraction of native timber trees was carried out so as to cause the least damage to the remaining forest. Full recovery of vegetation was necessary if water yield was to be the aim following timber yield. Revenue from logging was to finance the establishment of exotic forest trees in the cutover forest and on open land possessed or acquired by the Board.

All these operations had to be included in a forest working plan—a legal document containing a description of the forest and prescriptions for management—according to the Act setting up the Board. This was the first operating working plan for any forest in New Zealand.

The policy of afforestation pursued by the Board has been followed by subsequent bodies. The Regional Council is expanding the operation and now has some 2000 hectares of production forest in various stages of growth. Wellington and the Hutt Valley are surrounded by steep hills on which afforestation is an obvious use. The total available area is large enough to grow substantial wood volumes for future Wellington, and the Regional Council is well situated and organised to manage planting and harvesting.

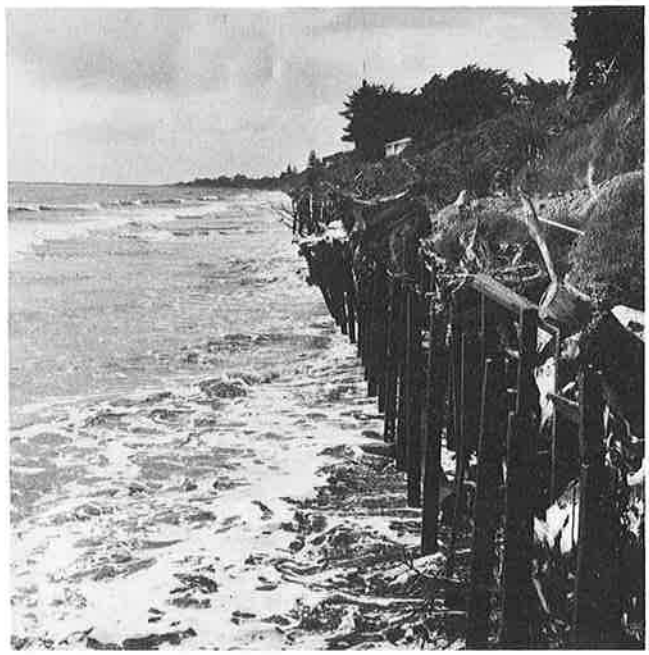
What commenced as the planting of a few trees around the boundaries of small water-yielding catchments of native forest has become a substantial afforestation scheme based on good land use.

Coastal Erosion

The Regional Water Board was faced with severe urban erosion problems, the result of the December 1976 rainstorm. A few months before that in September 1976 it had had to deal with damage caused by a surge storm that eroded populated sand dunes along the Paekakariki-Raumati coast, north of Wellington. One house was lost, 20 seriously endangered and temporary, makeshift protection, with which residents had tried to protect their properties from previous storms, littered the beach.

Building had been permitted right up to the foredune even though there was a history of erosion along this section of coast. Records of erosion go back to 1906 at the time the first development began. Following the 1976 storm a wooden seawall was built and subsidised on the condition that the local authority precluded development and redevelopment along the foredune. At the same time the Soil Conservation and Rivers Control Council expressed its lack of faith in the ultimate effectiveness of the protection, but approved the subsidy as a temporary expedient.

The Wellington west coast is but one example of many unwise developments on unstable sand.



97. Raumati Beach, Wellington west coast, where sea erosion has been occurring by stages at least since the beginning of Pakeha settlement. Nevertheless building has been allowed almost to the shore. Erosion has then encouraged owners to attempt protection of the type seen here. The result is destruction of public beach and expenditure of public money in attempting protection. (MWD)

AUCKLAND REGIONAL AUTHORITY

The ARA and Regional Water Board Work

In Auckland the function of the Regional Water Board was given to the Auckland Regional Authority (the ARA). The Board became a committee of the Authority and also operates the Soil Conservation and Rivers Control Act in its district of about 5180 km² between the Northland Catchment Commission's district just north of Wellsford, and the Waikato Valley Authority's and Hauraki Catchment Board's districts to the south over the Hunua/Bombay/Pukekohe ridge.

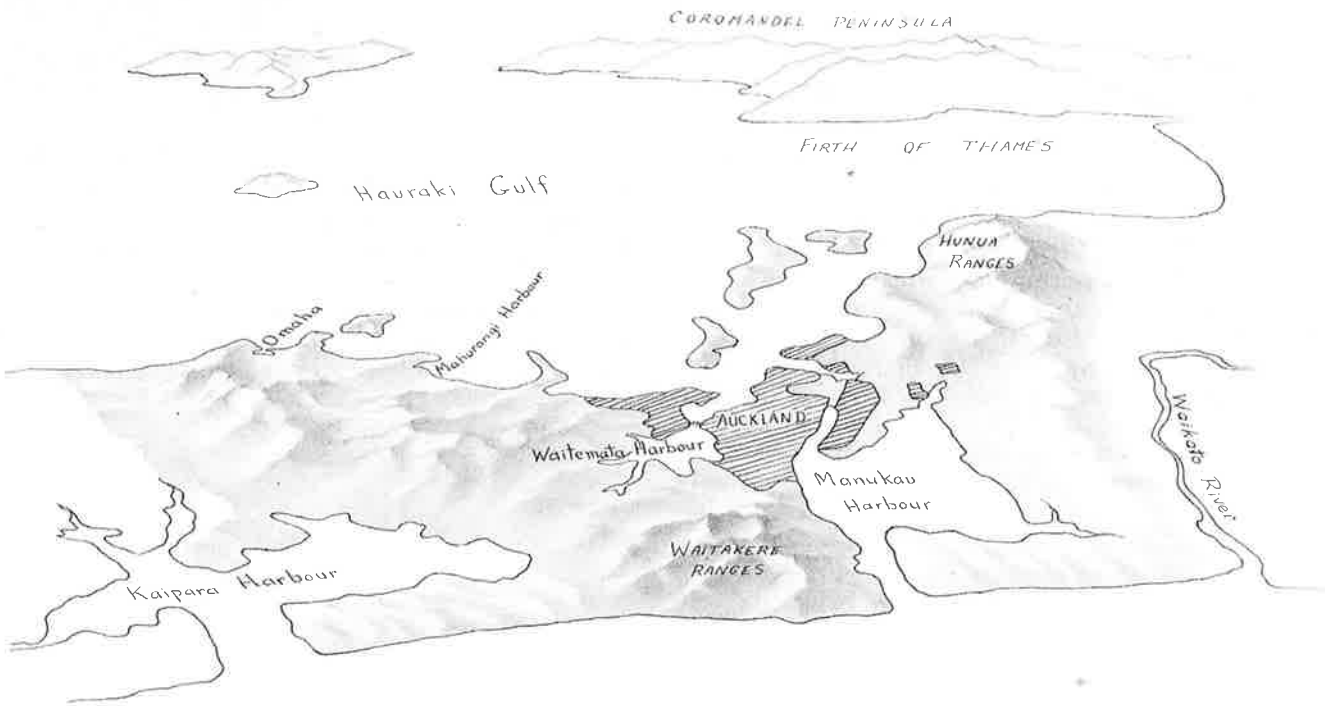
Previously the Ministry of Works and Development district office had been carrying out the functions of catchment authority and regional water board. Apart from some limited hydrological data collected by the Ministry, the ARA took on this responsibility with virtually no historical water and soil information, or experience.

Setting up a staff structure to cope with the immediate need of processing water right applications was the priority. Some 300 unprocessed water right applications were inherited from the MWD and new applications were being received at the rate of approximately 1 per day (a pattern that has continued).

However, the ARA was not ignorant in the business of water resource management for municipal bulk water supply purposes. Soon after its establishment it had taken over from the Auckland City Council the responsibility for bulk water supply to the metropolitan area. In this respect there are distinct similarities between the Wellington Regional Council and the Auckland Regional Authority.

From Polluted Wells to Potable Water

The development of Auckland's water supply goes back to the earliest years of European settlement. Many pleasant features attracted settlers to the Auckland isthmus, but they had difficulty in finding adequate sources of water. Rainwater and springs provided the main supplies at first. The area is studded with basalt volcanic cones and lava flows of



98. Auckland Catchment District

The Auckland isthmus has proved to be the most attractive locality in New Zealand both for Pakehas and Maoris before them. Water supplies for a population that grew rapidly were first obtained from springs fed from aquifers under the volcanic cones that stud the isthmus. When these failed to supply enough, water was collected in the forested country of the Waitakere and Hunua Ranges. The only source from which further supplies can be drawn in the long term is the Waikato River to the south. Problems concerning the effects of land use on the quality of sea water and the use of sea water itself abound around the isthmus. (D W Lawrence)



99. Mount Eden, one of the volcanic cones dotting the Auckland isthmus. Underneath some of them underground water collects and appears as springs around the edges. Such springs supplied the first water to Auckland. (D L Homer, NZGS)

recent origin. Between these and the rocks beneath them, underground water gathers and reappears as springs around the edges of the flows and cones.

Droughts and devastating fires, however, soon created a demand for better water supplies. During a dry year in 1872 hawkers sold water for more than the price bulk water cost nearly one hundred years later—20 cents per 4500 litres. Such was the value placed upon water at critical times. Moreover, inadequate drainage and sewerage facilities soon polluted springs and public wells.

In 1866 the first piped water supply was brought downtown from springs in the area now included in the Auckland Domain. It did not take long for this supply to become inadequate. The Western Springs and Onehunga Springs were turned to, and underground water was also tapped.

In the 1860s Charles Heaphy, the surveyor and artist, made the suggestion that water be collected from the forest-covered Waitakere Ranges, 20 kilometres to the west. Rainfall there was heavier and the water could be brought down by gravity. This forward-looking suggestion was not acted on for nearly 30 more years, by which time the city had outgrown its supplies of spring and easily tapped underground water. From that time on a continuous policy of harnessing water in the Waitakeres and in the forested Hunua Ranges, 40 to 50 kilometres south of Auckland, has been pursued. Auckland City purchased a total of 174 km^2 of catchment areas in the Waitakere and Hunua Ranges. These sources of supply have



100. Auckland's water is now drawn mainly from forested catchments in the Waitakere Ranges to the north of the city and the Hunua Ranges to the south. This photo shows the Mangatangi reservoir in the Hunuas. (D L Homer, NZGS)

been ideal because they are situated on the outer perimeter of greater Auckland. They too, however, have their limits which have nearly been reached.

The ARA now supplies bulk water to 22 authorities and this in turn reaches 84 percent of the total population in the area. The total available supply from the Waitakeres and the Hunuas is estimated to be a safe mean yield of some 400 000 m^3 per day. At the present time Auckland's water use can reach 356 000 m^3 per day which is the equivalent of 515 litres per head for the 690 000 population supplied. In 1978 the average daily use was 351 litres per head per day. Division between uses was:

dwellings—39%
industry and commerce—35%
other—10%
losses (includes fire-fighting plus wastage)—16%.

Household uses were:

toilet—31%
showers, baths, laundry—49%
outdoor—20%

Almost 100 years of harnessing forested catchments near Auckland will see the water yield from these two areas matched by the demand. Before, however, proceeding to draw from the Waikato River, the ARA has examined possible ways of conserving present supplies, and of harnessing more water from the catchments within its territory.

A detailed examination of some 40 catchments revealed that only 3 (and those were small and partly urbanised) had possibilities. The situation in occupied catchments is very different from that in the Waitakere and Hunua forest catchments, wholly owned by the ARA. There, water yield is the principal, or even sole, objective of management. The remaining unexploited catchments are complicated for municipal water supply by private and public land ownership and useage. In-catchment demands and water quality control are major problems for the exploitation of further catchments within the Auckland water region.

In preparation for drawing water from the Waikato, intake points have already been protected by gazetting a stretch of water from near Mercer to Tuakau for public water supply purposes.

Pollution

The Hauraki Gulf, the shallow Waitemata Harbour and the even shallower Manukau Harbour surround the beautiful isthmus of Auckland. If adequate sewage and trade waste disposal were not provided to the densely populated metropolitan area, serious pollution of the Waitemata and Manukau Harbours could result.

The first sewerage scheme to serve Auckland discharged into the Waitemata Harbour off the Orakei Wharf (Hobson Bay). Serious pollution and degradation of the harbour waters demanded an improvement of the situation. Plans to discharge into the harbour off Brown's Island were quashed by very strong local opposition which demanded that the place of discharge be removed completely from the Waitemata. This resulted in a scheme which discharges effluent into the Manukau Harbour from a treatment plant at Mangere.

A major improvement to the water quality of the Waitemata Harbour resulted. There is, however, no room for complacency, as contaminated urban runoff during storms and illegal sources of pollution still occur. A combined sewage and stormwater system serving the central isthmus, a legacy of early development, continues to cause serious pollution in parts of urban Auckland and the Waitemata Harbour during periods of heavy rainfall.

Problems of Urban Development

The ARA has had to face a large number of diverse water and soil problems which are analagous to those confronting other Regional Water Boards in the country but, as would be expected, have their own particular stamp.

Contrary to a commonly held belief most of the region is rural with a relatively high proportion of high class soils on which traditional farming of grazing animals is giving way to horticultural and more intensive agricultural uses. This results in increasing rural pollution and in higher demand for water.

There are not the problems of river flooding and of erosion in this region that necessitated the establishment of catchment boards elsewhere. There are, however, many areas of urban development situated where there is considerable risk of local flooding. Urban developments, even in relatively new areas, have either ignored the predictable hazard of building on flood plains, or have soon outstripped the ability of the drainage systems to provide an acceptable level of protection against damage and hazard from flooding.



101. North Shore, Auckland. Clearing and 'shaping' land by large machinery in preparation for urban subdivision. During such preparation, the land is vulnerable to erosion and quantities of silt can be washed onto old settlement areas or into streams—in some cases onto North Shore beaches. Here silt traps have been built but heavy rains could soon fill these with silt. (MWD)

Modern practices of subdivision and the building of large blocks of housing often reshape the landscape by clearing vegetation, changing valley slopes and filling waterways. Neat suburbs with well-paved streets and rapidly established gardens are the result. All works well except when, during development, heavy rain occurs on the bared land; or, after development, waterways cannot take the changed flow that occurs with urbanisation. Then the waterways become choked with silt and debris that can affect property well beyond the confines of the development. Much worse things can happen when unstable rocks are exposed and strata lubricated by rainfall. Landslides on a large scale can then occur.

The setting up of the Auckland Regional Water Board in 1973 was only just in time to act upon the problems of bare earth land development resulting in gross silt pollution of drainage systems, streams, beaches and harbour waters.

The ARA drew up guidelines for erosion control in urban earth works based on similar but more detailed ones produced by NWASCO.

These contain plans for silt retention dams and silt traps, contour drains and the adequate control of siltation from subdivisional development. When planned at an early stage some of these structures can be designed to serve later amenity purposes such as decorative ponds, reserves, or flood peak detention basins. As urban development extends more and more from flat land to hills this marriage of town and country planning and water and soil management requirements becomes essential.

A modest soil conservation service is now available to farmers also, for improvement of productivity by the stabilisation of slips, and the prevention of soil erosion by storms, rainfall, or excessive wetting and drying of soils.

The Upper Waitemata

The 'sparkling waters' of Waitemata are the venue of one of the largest yacht regattas in the world. During this event thousands of boats preen themselves on the harbour. Gone are the days of sailing in a 'sewage pond'. Pollution could, however, reappear only too easily in the upper harbour which is shallow. Low tides leave wide areas of shoreline exposed. Land in the surrounding catchment is undergoing rapid changes. Urbanisation is spreading on to it, horticulture is taking over from farming, farming itself is becoming more intensive, and forests are being harvested.

Auckland will continue to spread around the upper harbour. Extensive areas of 'scraped earth' are bound to appear, accompanied by the washing of silt into the shallow waters. Such damage is costly to repair, as has already been proved during similar developments on the North Shore. The ARA therefore promoted a study of the Upper Waitemata Harbour. It is hoped that this will lead to the provision of design data for planners and engineers that will eliminate or minimise costly mistakes and set standards of environmental quality. The ARA has drawn on a particularly wide range of knowledge and interest to advise it on these matters.

Lake Pupuke

There are a number of small lakes within the metropolitan area, the most intensively used being Pupuke on the North Shore. Here 110 hectares of water occupy an explosion crater. The surrounding lava contains it and water escapes through cracks. No major streams flow into it, but rainfall and urban stormwater do.

The first settlers—and, no doubt, Maoris before them—used the lake for water supplies with little understanding of water quality. Rural activities followed by urban development increased pollution while the Health Department standards for water use rose. In 1941 it was decided that no further water supplies could be drawn. A vigorous growth of seasonal water plants has now developed, interfering with the growing use of the lake for recreation and causing nuisances such as smells.

Water rights are now required, as the 1967 Act prescribes, for discharges to the lake. There are stormwater discharges and emergency sewage overflows. The ARA has set up a Lake Pupuke Mangement Committee to try and integrate the many conflicting uses. Such is the value of even a small body of water within an urban area.

Mahurangi Harbour

This scenic gem lies 40 kilometres north of the Waitemata. It is small and not well known, but it is the centre of the oyster farming industry. Every New Zealander would agree that this must be protected! The complications of doing so are great.

Some 21 oyster farm leases were in operation in 1980, and other parts of the harbour are suitable for expanding this promising industry. Against any large increase, however, strong opposition comes from other harbour users. The sight of oyster farms is displeasing to recreationists and they also restrict access to the foreshore. Apart from oyster farmers, commercial fishermen and pleasure boats use the harbour. The mooring of these vessels and use of the harbour for recreational pursuits could be seriously compromised by excessive development of an oyster farming industry. There are holiday residential settlements on its shores and Warkworth lies at its head on the Mahurangi River. Disposal of sewage

effluent from these settlements is another complicating factor.

The harbour waters are currently of relatively high quality except after extended heavy rainfall in the contributing catchments. Land and water use are as complex here as they are in the Waitemata, or on any other part of the coast. The ARA is involved through water rights in decisions concerning the use of the harbour and of the surrounding land.

Omaha

What better place for a seaside resort than a sandspit? Living with immediate access to the beach, coupled with an attractive outlook, is a compelling temptation to many lovers of the seaside.

The Omaha Spit has been formed across the entrance to the Whangateau Harbour just 60 kilometres north of the Waitemata. In the space of 7 years, from 1971, a substantial part of it was subdivided and three-quarters of the sections sold.

But the spit was still sand, formed by sea currents and under constant change by those currents. Various happenings, including 3 hurricane-force storms coinciding with consecutive spring high tides in 1978 caused rapid erosion of most of the sea-front sections. Since then costly protection measures have been executed; but who can predict the vagaries of sea currents and the effects of storms?

Legal actions resulting in out of court settlements have involved undisclosed, but large, sums of money. The anguish and cost of such mistakes seem to be too easily forgotten.

Not to build houses on shifting sands is something that New Zealanders have yet to learn, even though NWASCO has devised techniques that help to specify where and at what magnitude and frequency coastal erosion is expected to take place.

Associated with the Omaha Spit development the Rodney County Council applied for water rights to take groundwater from under nearby Point Wells for the supply of potable water, after treatment, to the spit subdivision. There are no significant or economically viable surface water supplies in the area as an alternative. The Point Wells area, however, contains a large area of fertile soils which are being progressively developed for horticulture and which require water.

The ARA's assessment, yet to be confirmed by further study, has been that there is insufficient water to supply the potential demand for irrigation once the high class soils are fully developed. With this in mind the ARA declined granting a right to take water from the underground source for subdivisional development, on the basis that the dwellings have an alternative in roof water storage. Horticulturists have no such choice. By this decision an important principle of priority for access to an insufficient water resource was established. This has been an important precedent. It establishes for the time being a general policy to protect, where applicable, the water resources of the region for horticultural and agricultural development.

Parakai and Waiwera

The thermal water resources, enjoyed by local landowners and the public alike, at Parakai near Helensville and Waiwera on the Hibiscus Coast, are being over-exploited, resulting in a depleted water level, a lowering of the temperature and salt water intrusion. Studies of these areas have resulted in the formulation of management guidelines and a basis for water allocation.

Pukekohe and Bombay

The Pukekohe Plateau in Franklin County comprises high class volcanic soils on which there has been intensive horticultural production for many years. This use is spreading onto adjacent high class soils. The only source of water is underground. There is evidence that the demand, mainly for irrigation, is nearing the yield of the resource. A joint study being conducted by the ARA and the WVA should result in groundwater and surface water allocation and management plans covering a wide area around, and including, the plateau.

To the east of the Franklin study area are the high class volcanic soils on the Bombay slopes above Drury. Here also horticulture is increasing. The demand for water now exceeds its availability during drought periods. This area does not appear to have a reliable source of groundwater and the surface water comes from a very small catchment area. A preliminary water allocation plan for this has been produced. Surface water storage and a communal irrigation scheme are seen as the long term solutions to further development.

The future holds some perplexing problems for the ARA as the Regional Water Board, particularly in the conflict between the needs of urban and rural areas. If the district is to continue to grow as an economically and environmentally strong region, the availability of water will be an important factor.

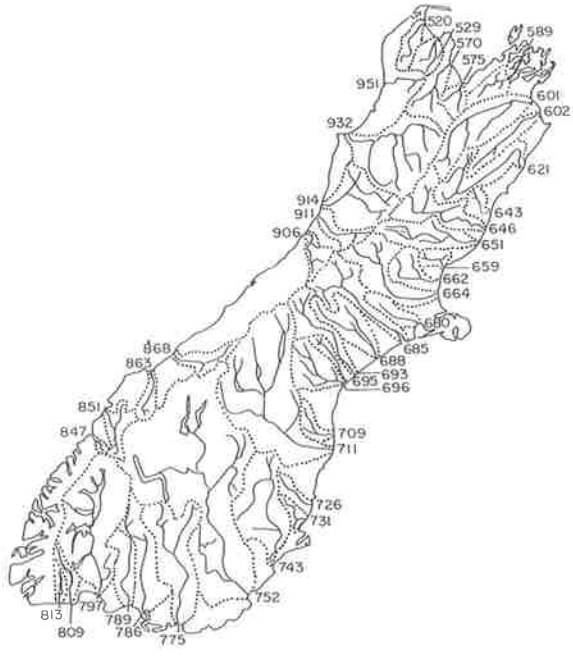
SOUTH ISLAND CATCHMENT AUTHORITIES

The Southern Alps determine much that happens with water, rivers and soils throughout the South Island. Next to this major influence is the effect of past glaciation. Ice and snow fields that blanketed the Alps and spread out from them affected the greater part of the South Island in one way or another. Great glaciers gouged out deep valleys as they descended to the lowland. They loosened, ground and moved huge quantities of rock in the mountains. When they retreated, some eroded material was left high up on the valley sides; greater quantities were deposited as moraines, often blocking valleys and forming basins for lakes filled with the melted ice. Material washed in sheets by water flowing from the melting snow and ice also formed plains and gentle fans or filled basins between mountains.

During dry periods the wind whipped up the fine material, as it does on the Canterbury river beds even now, and left it gathered in deposits of loess. Deep beds of loess are present in many places: the hills behind Blenheim, downlands in North Canterbury, Banks Peninsula, extensive downlands in South Canterbury and Otago, the valley of the Clutha and a large part of the Southland plains all have deep soils formed from these deposits. Lesser deposits have been laid on almost all the country east of the divide and on the West Coast terraces.

Except for the high mountains where there was rapid natural erosion and harsh climates, vegetation soon covered the landscape as the ice retreated, but settlement later uncovered a great deal of it. One of the difficulties in the South Island still is to segregate natural erosion—much of it a follow-on from glaciation—and man-induced erosion.

A combination of high precipitation and substantial remnant glaciers ensures that large rivers flow down both sides of the Southern Alps. To the west coast, numerous short rivers carry huge quantities of water and detritus to the sea. Flood flows are some of the highest, and certainly the most frequent, in the country. To the east coast fewer rivers descend from the divide, sometimes feeding the lakes already mentioned before crossing plains built up in gentle fans. Between the large rivers many smaller ones rise in the foothills.

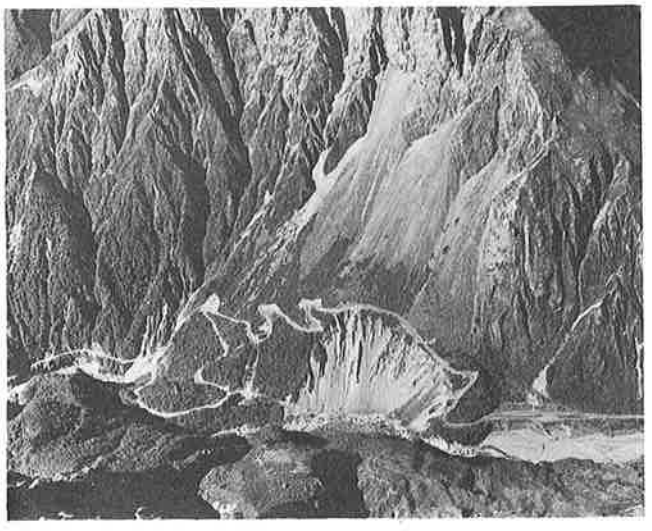


No	CATCHMENT	MEAN FLOWS (m^3/s)
520	*Aorere*	
529	*Takaka*	017
570	*Motueka*	054
575	*Waimea gauged at Wairoa*	017
589	*Pelorus*	020
601	*Wairau*	118
602	*Awatere*	019
621	*Clarence*	
643	*Conway*	
646	*Waiau*	096
651	*Hurunui*	050
659	*Waipara*	
662	*Ashley*	
664	*Waimakariri*	108
680	*Selwyn*	
685	*Rakaia*	196
688	*Ashburton*	
693	*Rangitata*	089
695	*Orari*	
696	*Opihi*	
709	*Waihao*	
711	*Waitaki*	328
726	*Shag*	
731	*Waikouaiti*	
743	*Taieri*	032
752	*Clutha*	543
775	*Mataura*	095
786	*Oreti*	052
789	*Aparima*	021
797	*Waiau*	437
809	*Wairaurahiri*	
813	*Waitutu*	
847	*Cleddau*	029
851	*Hollyford*	
863	*Arawata*	
868	*Haast*	183
906	*Hokitika*	105
911	*Taramakau*	
914	*Grey*	337
932	*Buller*	417
951	*Karamea*	117

102. South Island main river catchments and the mean flows of the rivers. (MWD). (MWD reference numbers).



103. Natural erosion processes in the mountains. Dart glacier, Otago. Naturally eroded rock gathers in moraines on the moving ice. The glacier is melting and as it does so it leaves the loose rock perched on the sides of the valley and in the valley bottom. Vegetation eventually grows over it. If this is cleared away the perched rock is exposed to erosion. Mountain building movements also trigger off huge rock avalanches which feed detritus to rivers over long periods of time. (D L Homer, NZGS)



104. Otira Gorge and Arthurs Pass over which a main road, between North Canterbury and Westland, passes. Rainstorms and avalanches often damage it. In addition this section negotiates an old rock avalanche. Instability here must eventually compel the seeking of a new alignment. (D L Homer, NZGS)

Where the Southern Alps give way to a series of mountain ranges in the north, rivers follow fault depressions (for example the Wairau and the Clarence) or descend as steep mountain torrents to the sea (like the Nelson rivers).

The flood plains created by the South Island rivers are not often as large as those formed in the North Island. However, when considered in conjunction with the plains of shingle and glacial detritus and the inter-montane basins they constitute large and important areas for agriculture. Moreover, irrigation is possible from the high summer flows resulting from snow and ice melt in the large rivers flowing eastwards from the Main Divide.

Within this simply explained setting many variable factors confront the 8 catchment authorities in the South Island, making each a distinctive entity.

105. Porter's Pass on the Christchurch-Arthurs Pass road. Photographs taken 1902-1978. Material in the shingle slide is of glacial origin. How much of it has been uncovered by Polynesian and Pakeha fires and animal browsing and grazing is unknown. (MWD)





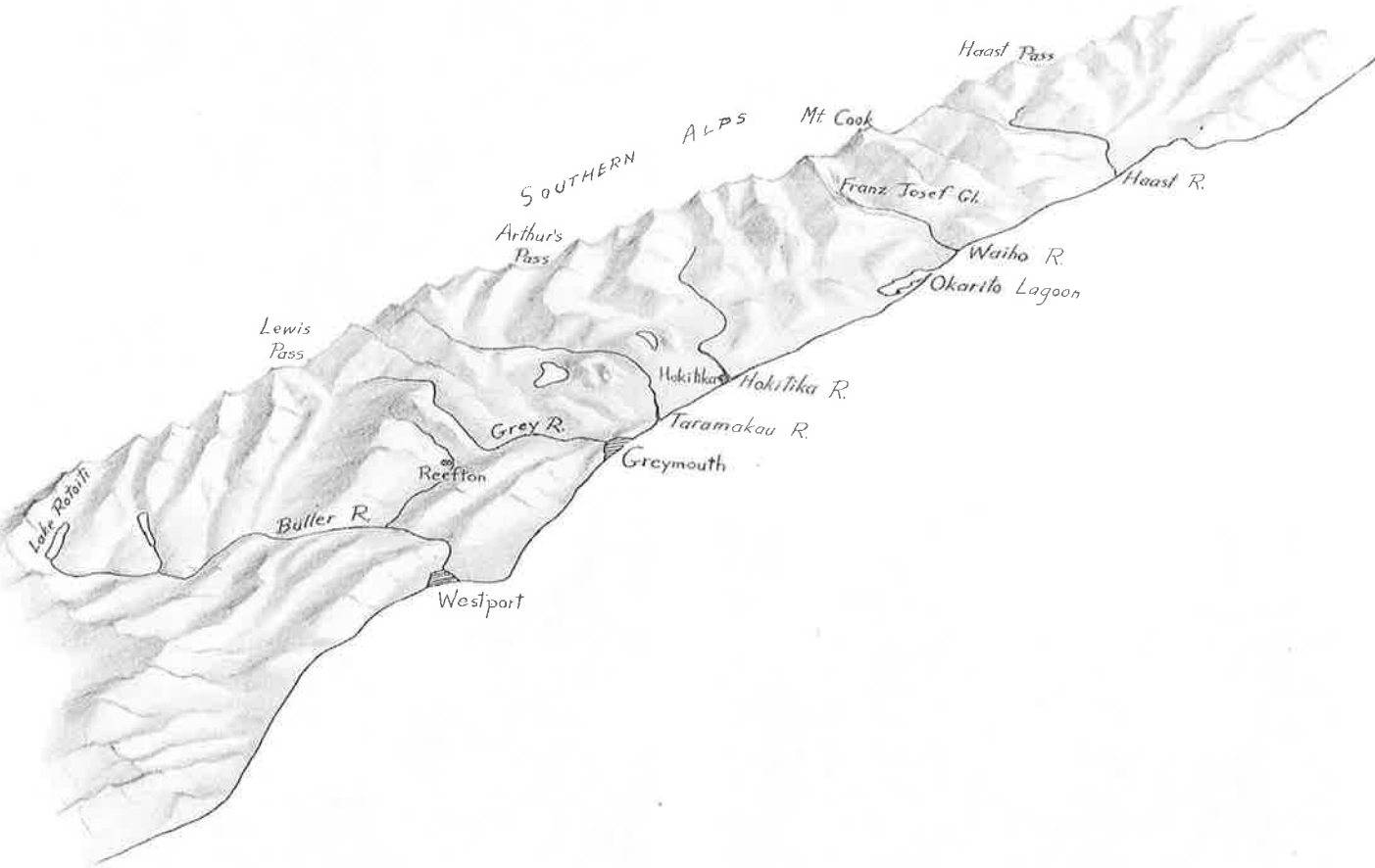
WESTLAND CATCHMENT BOARD

Rain and Rivers

Where better to start looking at South Island water and soil problems than the West Coast? Here they are accentuated by the prevailing westerly winds and the high Southern Alps. When Captain Cook saw the great range of mountains as he sailed at a safe distance up the west coast of the South Island he described them as of 'prodigious height' with no 'Vallies'. It was soon found that they do, indeed, collect a prodigious amount of water which gathers in a large number of rivers with intricate valley systems.

Rainfall measured at high elevations in one part of the Alps has reached 8000 mm per annum. There is every reason to believe that it can, in some seasons, be in the order of 10 000 mm which places this coast amongst the wettest areas on earth. At least 20 large rivers, reckoned in terms of flow, not length—for they are mostly short—carry this water down to the sea.

The great Alpine Fault has created steep western faces to the Alps down which the rivers cascade. They debouch from the mountains and carve their way across a series of terraces of gravels left by receding glaciers. Old moraines, and lakes locked behind them, interrupt these terraces. From the divide to the sea is seldom more than 50 kilometres, and the width of the terrace land 10 to 15 kilometres. There are no true flood plains, only pockets of recent gravel and silt deposits along the banks of the steep and swiftly flowing rivers. These are constantly flooding and changing their shape.



106. Westland Catchment District

The steep western flanks of the Southern Alps together with a narrow belt of terraces formed by receding glaciers, and small floodplains made by present day rivers, make up the district—the 'wet West Coast'. Forest on the mountains holds in place large amounts of detritus left on valley sides by glaciers. Rivers are numerous and flood frequently. Good farmland is confined to the limited floodplains and reclaimed swamps. Flood protection is so costly relative to the value of the land protected, that there is as yet no complete protection scheme in operation. On the other hand flooding is so vicious that small river works are constantly needed to protect what farmland there is as well as to safeguard communications. (D W Lawrence)

The Buller in the north of the district reached a peak flood flow of 11 300 cumecs in 1926, the highest of any river in the country. In the south the Haast can have peak flows almost as large.

The Hokitika is one of the many rivers rising between these two. Its headwaters are almost opposite the Waimakariri River that flows across the Canterbury Plains. The catchment of the Hokitika covers 1153 km^2; that of the Waimakariri approximately 5000 km^2. In spite of this difference, peak flood flows in the 2 rivers have been of much the same order; if anything those in the Hokitika have been higher. But whereas the Waimakariri might have a severe flood on an average once every 10 years, the Hokitika can flood once a month during wet spells—at one period in 1957-58 it flooded 6 times in 4 months.

The Waiho, which flows from the Franz Josef Glacier, flooded severely in January 1968. Blocks of ice were rafted down the river—it was dubbed a 'river of ice—right to the sea. The erosive effects of these blocks were so great that the standard heavy stone rip-rap that had been placed to protect the banks was demolished by their impacts.

A flood in the Grey River in 1872 inundated the young town of Greymouth and swept one house out to sea with the lights still burning—candles or kerosene, no doubt—a tale that has been embellished in various ways.

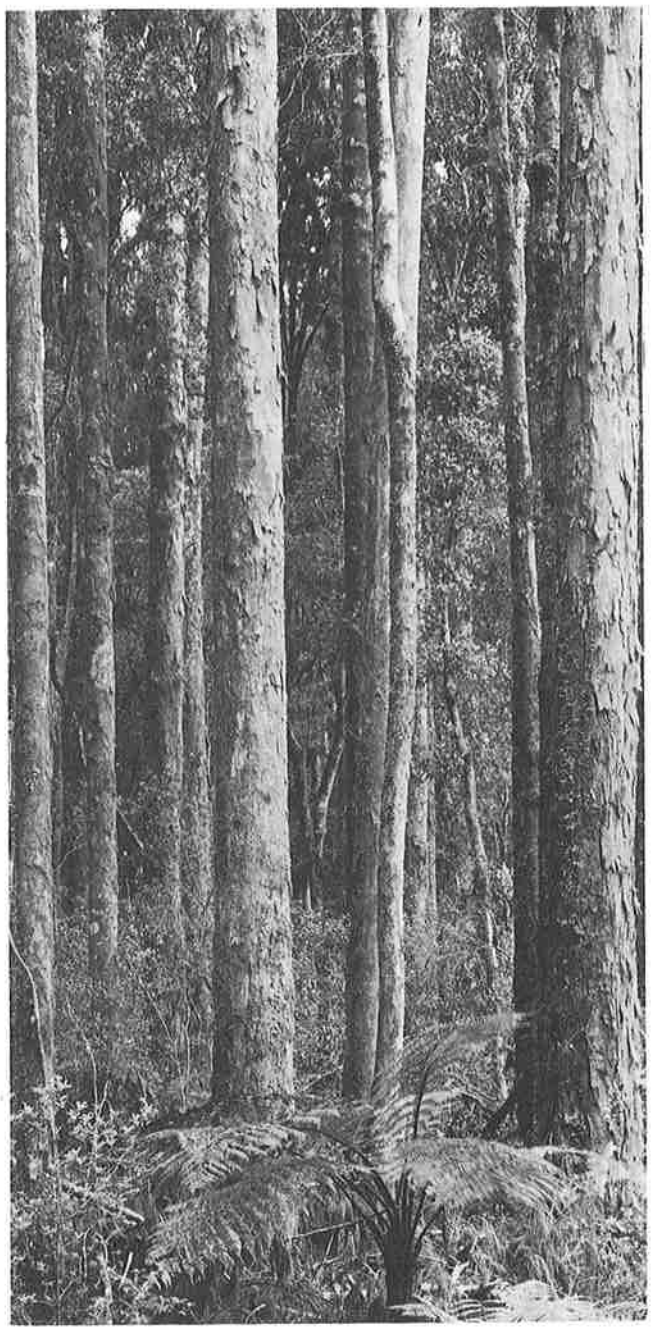
These are a few examples of the innumerable problems that have to be faced in the control of West Coast rivers.



107. Forest on the mountains is dominated by southern rata and kamahi. The former can be damaged and often killed by opossum browsing. This has to be prevented because it is important to keep such protection forest growing strongly. (J H Johns, NZFS)

Protection Forest

The wet climate encourages forest to grow up to 1000 metres or more on the mountain sides and impenetrable scrub and mountain vegetation above that. The forest is dominated by southern rata and kamahi except for southern beech to the north and south. The natural vegetation of the terraces and moraines is mainly rimu (*Dacrydium cupressinum*, a podocarp) forest.



108. Mainly rimu forest grows on the terraces. If clear-felled, it gives way to bog vegetation. (J H Johns, NZFS)

The southern rata roots scramble long distances over the surface of the ground allowing the trees to cling to the most precipitous valley sides. The constant moisture keeps the forest floor densely covered with plant growth of all kinds. Even this type of dense forest cannot affect the total rainfall run-off, but it does affect the nature of the run-off by providing an excellent means of absorption.

The mountain forest is aptly termed 'protection forest'. It is the safety cover holding the huge amount of glacial detritus sitting on the valley sides from being washed into the rivers. Even with this cover large amounts of debris do slide down and are carried along in waves by floods. As a result the beds build up, occasionally to the extent that during floods a river might overflow across a terrace and take a new course.

The Hokitika catchment is all forest and mountain vegetation except for about 12 000 hectares of fertile river silts; a small area by national standards, but critically important locally. In 1958 a survey was undertaken principally to gauge the extent that opossums and red deer—which had become acclimatised even in this extremely wet climate—were eating out the forest.

The party found the condition 'profoundly disturbing'. In addition it reported:

> "There could at any time be collapse into a valley of one of the great deposits of rock debris that are perched high on the valley walls. The bursting of a temporary dam formed in this fashion might well result in complete devastation of the Kokatahi-Kowhitirangi lowland . . . Such things have happened in the past and they will happen again . . . These rivers cannot be expected to behave in well regulated fashion."

This report might prove to be exaggerated, but it serves to emphasise the dangers in these recently glaciated steep valleys.

Land Use

The West Coast was scarcely an attractive proposition for those interested in the land and farming. The restricted areas of suitable soils, their swampy nature, flooding and river bank erosion, and the isolation of the whole region, all made farming more of an uphill struggle than in any other part of the country.

It was other things that attracted people to Westland. Maoris went there for greenstone, though very few lived there permanently. In the 1860s gold was discovered and within a few years it attracted some 30 000 people who came over the Southern Alp passes or by ship to the West Coast river mouths. About the same time coal mining began.

Both gold and coal brought permanent settlement, and with it the development of agriculture as well as of sawmilling. The rimu forests growing on the coastal terraces carried heavy stands of timber. An industry was soon based on them.



109. Valley of the Inangahua River, a tributary of the Buller River. The limited flats along the narrow valley constitute the only farmable land. Farming has not become established on the hills which have reverted to second growth. The flats are particularly vulnerable to flooding. (J H Johns, NZFS)



110. Harihari, south Westland, is situated on flats formed by the Wanganui and Poerua Rivers. Limited areas of farmland have been formed from recent river soils and swamps. Soils on the higher terrace, to be seen here, are so difficult that farming on them is primitive. A sawmill cuts logs harvested from the terrace and lower hill forest. Terraces are covered by rimu forest and the Southern Alps by southern rata, kamahi forest. Lake Ianthe in the foreground. (V C Browne and Son)

The terraces themselves, made up of glacial boulders, are covered by very fine silts that are almost impenetrable to water. When the forests are cleared, bogs develop. Farming on them has only been possible with heavy expenditure on drainage and fertilisers, often with an uncertain return. Otherwise agriculture is limited to the recent river alluvium deposited during floods along the beds of the wild rivers.

The Catchment Board

The setting up of a Catchment Board in 1945 was welcomed because of the difficulties the extraordinary series of rivers presented, and the need for a comprehensive approach to the drainage of farmland. Soil erosion, apart from river bank erosion, was scarcely a problem because settlers dared not clear the hills. If they did, erosion caused by heavy rain, or rapid regrowth of shrubs with which farm animals were unable to cope, soon beat their efforts.

The Board found itself with an elongated territory, greater in length than the distance from Auckland to Wellington, and in size the third largest of all the catchment districts—over 26 000 km^2. Over the Main Divide 5 Catchment Authorities share responsibility for the length of mountain chain which the Westland Board watches over. In this beautiful but difficult district farming occupied only 10 percent of the land with possible additions of, at most, a further 10 percent. The remaining 80 percent was in forest, rivers, lakes and mountain tops.

A road extended the length of the district and has since reached the Haast River in the south, and so the Haast Pass and Otago. Along its length it crosses every river and hundreds of streams between them. From Westport to Haast, State Highway 6 crosses more than 200 bridges with a total length of nearly 10 kilometres; approximately 1.8 percent of the distance is bridging. In addition there are innumerable culverts.



111. State Highway 6 along the West Coast has many bridges such as this, to span the rivers. This one crosses the Haast River in which a flood peaking at about 14 000 cumecs has been recorded. (MWD)

The Board and River Works

At the Board's second meeting a request was received for river bank protection for farmland. This was the beginning of a pattern that was to grow over the years. It was impossible in the beginning to think in terms of comprehensive river control schemes. Farming lands to be protected were so limited, rivers so swift and damaging, floods so frequent, that only 'fire brigade' works could be carried out. Even these were all too often destroyed by floods.

The best that could be hoped for was that isolated works could be constructed in patterns that would eventually link into comprehensive control schemes. This goal is being approached now on some rivers; but the problem remains of limited farmland to be protected by costly schemes followed by costly maintenance.

The tremendous odds stacked against the Board were spelled out from time to time in flood reports presented to it. In August 1970, for instance, the worst flooding for 25 years occurred, and less than a month later just as heavy flooding came again. Damage done in the second flood was greater because weaknesses had been developed by the first. During these floods the Buller rose to a peak flow of close to 8200 cumecs. Flooding in Westport was extensive. Erosion on the lower river bends was common. Greymouth was flooded as the Grey reached its highest peak for over 30 years. Any person standing on the wharf deck (against which the Grey River laps when it floods) must wonder why all Greymouth has not been swept out to sea long ago, rather than that one house with the light that was carried off in 1872.

The Taramakau River is just south of the Grey. Stretching along 12 kilometres of it is a pocket of farmland 2282 hectares in area. About half of this is subject to flooding. A scheme has been designed to protect the area by stopbanks and train the river in a meander to prevent it from eroding the banks. It was estimated that the alternative, to allow flooding and erosion to continue, would destroy a fifth of the total farmland over a 50 year period. Peak flood flows in the Taramakau can exceed 4400 cumecs, so any river works and their maintenance must be costly—very costly in relation to the production of the farmland.

The Hokitika River had a tendency to change its course across the flats it had built up before recent, more extensive river control was undertaken. During a series of floods in 1963-64, which affected a number of rivers, the Hokitika took an old channel into Lake Mahinapoua, cutting a 30-metre gap in the State Highway on the way. Since then, through stopbanking and river training, a complete control scheme for the lower river has been brought within view.

The same storms that caused the damage in the Hokitika flooded Otira in the headwaters of the Taramakau on the route from the West Coast to Christchurch. Stopbanks were breached and floodwaters rampaged through the township. Road and rail links over Arthur's Pass were cut. These communications are constantly under threat from storms, and in 1980 3 linked locomotives plunged off a washed-out railway line into the Otira River, killing a driver.

In January 1982 the press reported "Otira people optimistic that worst is over." Otira had received the following rainfall during the previous few days:

January 22—103.4 mm
23—240.9 mm
24— 17.4 mm
25— 6.0 mm
26—252.2 mm

"Otira looks like a training ground for road construction crews," added the press.



112. A combination of geologically unstable country and very high rainfall is a constant threat to communications through the mountain passes between the east and west coasts. The washing out of the railway line in Arthurs Pass is also a danger as shown here. (Christchurch Press*)*

In March of the same year the southern access to the West Coast was severely damaged by major washouts and bridge damage on the recently constructed Haast Pass road and the old road further north. "Workmen toiled from dawn to dusk during the weekend clearing away slips and filling gaping holes along almost 200 km of South Westland's storm-battered highway from Harihari to the summit of Haast Pass," was the press report.

The river of ice that the Waiho became during the flood in 1967 demonstrates the mechanisms that were at work thousands of years ago as the ice age closed and glaciers and ice sheets were melting. Part of this river starts at the snout of the receding Franz Joseph Glacier. As the ice melts, gravel and boulders become available in very large quantities to build up the river bed. By 1967 the bed of the Waiho had reached a level from which the large flood overtopped banks constructed to protect a pocket of farm land. The whole river then flowed in a braided pattern over almost the complete pocket of about 1500 hectares, leaving a swathe of shingle and boulders.

The report to the Catchment Board on this read:

> ". . . the Board opened up a pilot cut and formed a temporary stopbank to turn the river back to the original course before beginning to build a substantial embankment protected with heavy rip-rap and located on a set back alignment. The pilot cut and temporary embankment had no sooner been completed than they were overwhelmed and destroyed by another flood. They were reinstated and a substantial part of the main embankment completed when a third flood carried away all that had not been protected by rip-rap . . ."

The final work was a massive 550 metre stopbank up to 2 metres high, protected with 4500 m^3 rock, some pieces of which weighed more than 17 tonnes.

In March 1982 the Waiho experienced yet another heavy flood which destroyed protection works, including the above, and eroded and flooded farmland. During its height 445 mm of rain was recorded at Franz Josef in a 24-hour period. The storm was widespread and damage extended from Harihari to the Haast Summit, some 200 km. One report read: "The storm transformed rivers into torrents that gouged out stopbanks, bridge approaches, high tension powerlines and telephone links, isolating residents of South Westland and some 800 tourists . . . Numerous bridges were swept away including half the new Waitangi-Taona bridge."

Between the 1967 and 1982 events there were several other large floods. Going back over the years

there have been repeated encroachments of farming on to the Waiho riverbed and repeated devastation of this land by the river and its bedload.

The Lure of Gold

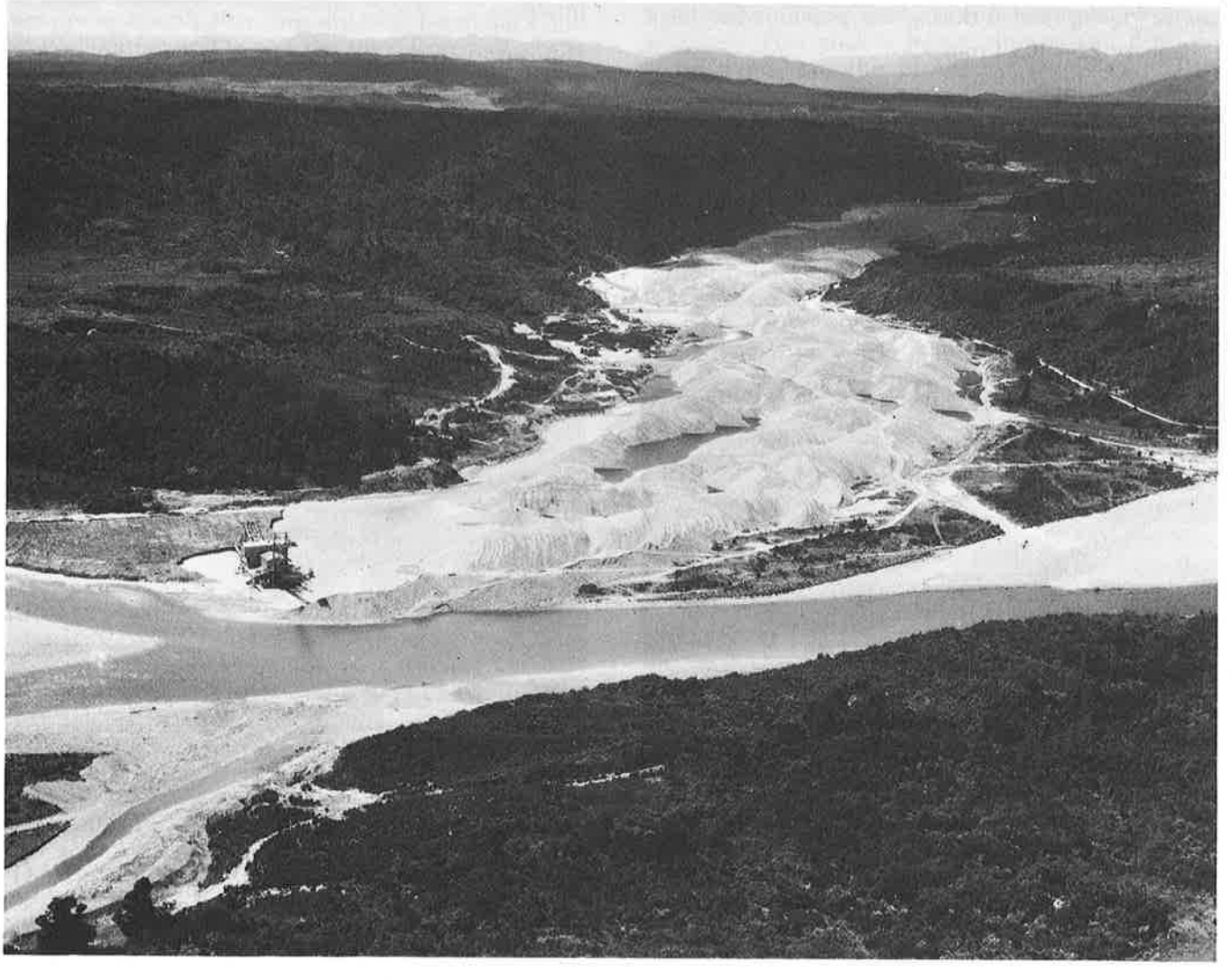
The lower valley of the Grey River offers the best prospects for farming. The rainfall is less than in most other parts of the West Coast and the extent of farmable land, including recent river silts, is greater than along any other river. Isolated river protection works have reached a stage at which they can, in the near future, be amalgamated into an overall scheme.

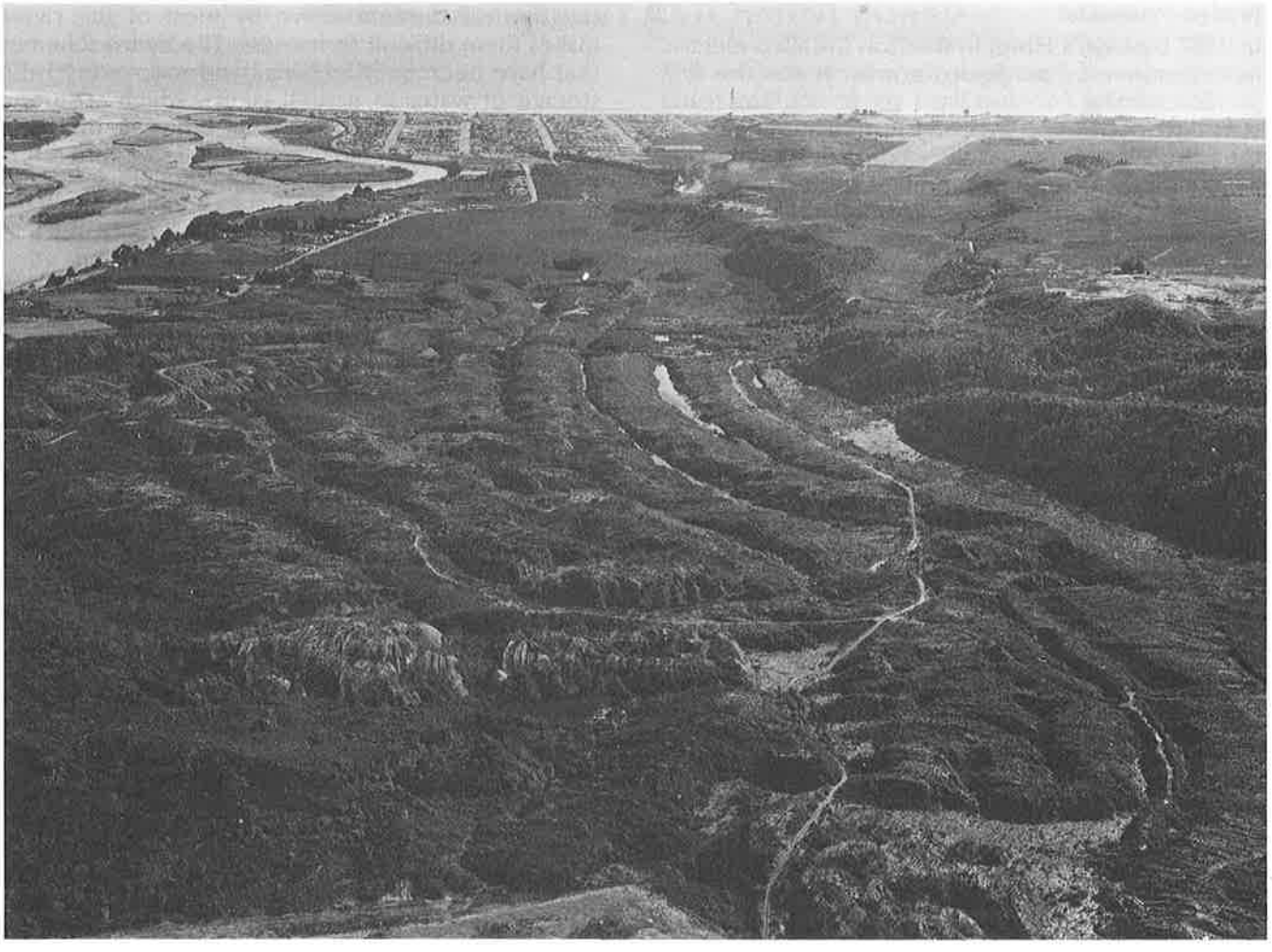
However, in 1980 a gold dredge was granted a licence to operate over 375 hectares of the river bed and adjacent land. A condition was that a protected flood channel would be formed first and any farmable land destroyed in the process of dredging would have topsoil—or fines—replaced over the dredge tailings.

Scars left by past gold dredging are plentiful on the West Coast. At the height of the activity, about the turn of the century, the tranquility of the place was disturbed by about 80 of these screeching monsters. Conditions were attached to licences that land was to be resoiled or money paid in lieu of this operation. Money was usually paid but then it seemed to be nobody's task to reinstate the land. The result is to be seen in the herring-bone pattern of boulders brought to the surface from deep down.

Whether or not an operation of the magnitude now proposed can be carried out without damage to a major river remains to be seen. What will be the effect during floods, that can exceed 5000 cumecs? The Board will certainly be keeping a close watch on developments.

113. Gold dredge on the Taramakau River. (V C Browne and Son)





114. Hokitika at the mouth of the Hokitika River. The higher river terraces cannot yet be farmed because the wet soils on them have so far resisted drainage. Past gold dredging, indicated by the tailings seen here, has eliminated any possible future use. Recent dredging is planned to leave behind a usable surface. (D L Homer, NZGS)

Land Drainage

The West Coast has a special problem in the drainage of farmland. Swamps abound; farmland is kept wet for much of the year by heavy rainfall; terraces become bogs when rimu forest is felled. To make progress with farmland development under these difficult conditions the Department of Lands and Survey has undertaken the draining of some of the larger swampy areas. The individual farmer, however, is then faced with the problems of costly drainage on his own land.

The usual conditions of large river schemes in other parts of the country, whereby the farmer copes with his own internal farm drainage to main communal drains and outlets to the river do not operate. In Westland internal farm drainage works are now subsidised. There is no doubt that this will be of marked benefit to farming along the whole length of the Coast, and the Catchment Board is busy servicing the scheme.

The Regional Water Board

Plans to control flooding by the huge quantities of water that come down the rivers occupy most of the attention of the Catchment/Regional Water Board. Uses of water, on the other hand, are limited, and pollution remains a very minor problem.

A recent example of expanding use, although it is still minor, is connected with the resurgence of gold mining which has brought with it a deluge of applications for water rights. In 1980 nearly 1000 were made. At one time water was taken in races, sometimes for long distances, to the site of sluicing. Now it is pumped from the nearest source. The granting of rights on the West Coast, with all its water, is no great problem apart from the time involved in inspecting so many.

Hydro Potential

In 1887 Dawson's Hotel in Reefton installed electric light generated from hydro power. It was the first public building in Australasia to do so. This early start did not develop as promised and at the present time the West Coast produces only one seventh of its electricity in spite of the huge quantity of water and the many rivers it has. This is largely because the detritus brought down by most of the rivers makes them difficult to harness. The hydro schemes that have been built are small and make use of the storage of water in natural lakes—which are none of them large—and the low fall between the lakes and the sea. There remain possibilities of generating large quantities of power from the Buller and Upper Grey Rivers.

NORTH CANTERBURY CATCHMENT BOARD

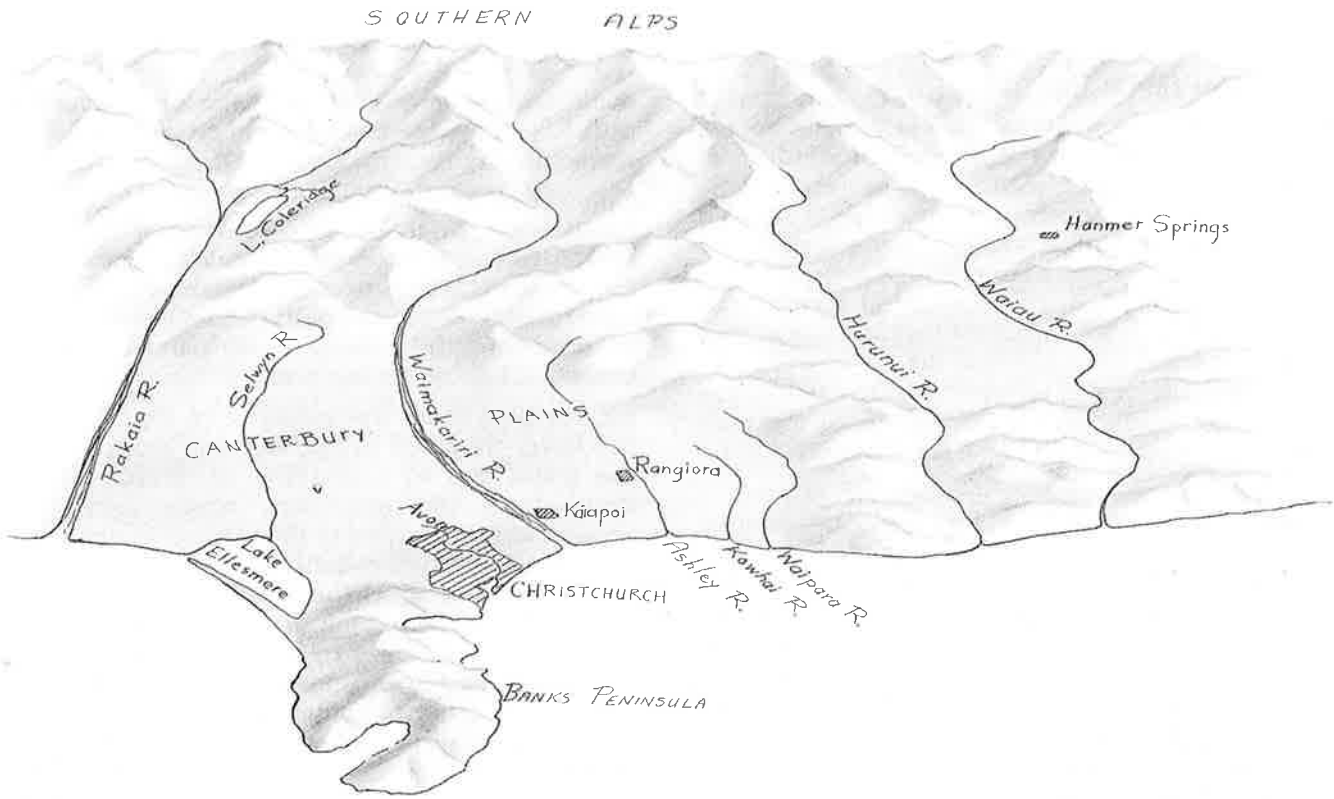
Christchurch and its Early Dangers

At Avonhead lived one Mister Bray
Who every morning used to say
I should not be much surprised today
If Christchurch City were swept away
By the rushing, crushing, flushing, gushing
Waimakariri River.

The danger of being flushed out by the Waimakariri River did not deter settlers from choosing the site of Christchurch for the centre of the Canterbury Association settlement. It had the advantage of the good soils of a flood plain, even if they were swampy in parts; there was an excellent harbour not far away and for expansion, wide plains, some access to which could be obtained through the Waimakariri mouth at Kaiapoi.

The settlement was not likely to be washed away, but it could certainly be flooded. A person walking across Cathedral Square today would wonder what you were talking about if you suggested that water from the Waimakariri might join that of the Avon. But in 1868 a flood did so and reached Cathedral Square. In times past the river has taken many courses, sometimes as far south as Lake Ellesmere. As early as 1859 the *Lyttleton Times* wrote, "It would appear from unmistakable indications that the Waimakariri River, for about the first twenty miles of its course upstream, has not been in the habit of sticking to one bed; in colonising the country we must civilise the river." Bold words!

No doubt the spirit of Christchurch dwellers was raised when they gazed over the plains and had an uninterrupted view of the mountains leading up to the Southern Alps where the Waimakariri River rises. Opposite its source, on the western side of the



115. North Canterbury Catchment District

The district comprises the North Canterbury Plains, the catchments of four large rivers rising on the main divide, others rising on the lower mountains and hills between them, and Banks Peninsula. The choice of Christchurch as the main centre of Pakeha settlement for the region led to the construction of protective works to prevent flooding by the Waimakariri River. All four rivers are good water resources and two of them, the Waimakariri and Rakaia, feed substantial underground supplies. Severe accelerated erosion in the high country is being combated by the operation of run plans, and fire and animal control. (D W Lawrence)

mountains, rise the Taramakau and Hokitika rivers in the central section of the Westland Catchment Board's district. Not all the rain and snow is caught in their catchments; much is driven by the winds across the divide to feed the Waimakariri. During storms in the mountains this river and others in the east flood, although they flow mainly through country in the rain shadow of the mountains.

The Waimakariri as it approaches the sea flows through a flood plain nearly 36 000 hectares in extent. The Rakaia River south of it has a small flood plain but the remaining large rivers crossing the plains, the Waiau, Hurunui and Rangitata, have none.

Christchurch is by far the largest urban settlement in New Zealand situated mainly on a flood plain. There is, therefore, a double incentive for flood control: the need to protect the area so that settlement can grow safely, and the need to protect the best soils. Control measures began early, because the capital investment that grew rapidly, but was threatened by floods, provided money for the work.



116. Christchurch City built largely on the floodplain of the Waimakariri River. The path of the Avon River through the city can be detected by the line of trees bordering it. (National Publicity Studios)

Control of the Waimakariri River

Mr Bray had every reason to be worried, but he was soon employed to advise the Canterbury Provincial Government on possible control measures. Drownings occurred in floodings during the 1850s and '60s. Communications across the river were difficult and had to be changed as the braided river channels continually altered. In the 1868 flood a very large overflow went down through other streams as well as the Avon into what are now the north-west suburbs of the city. It also seriously affected settlement that was beginning on the north bank of the Waimakariri around Kaiapoi. Some land there had to be abandoned.

A South Waimakariri River Board of Conservators from 1881 to 1923 dealt with maintenance but undertook little new work. It did not have the stimulus provoked by major floods, for during that 42-year period only 2 occurred and no overflows reached Christchurch.

The Board received a Crown grant of endowment lands along the river. This has proved beneficial in several ways by providing the area on which to plant a wide belt of trees between the river and Christchurch, to erect stopbanks and groynes and to carry out other river work.

Prevention of overflows through Christchurch was amongst the first works undertaken by the Board. Its control was confined to the south bank. The northern boundary of the Board's district was a line along the centre of the south branch of the river. The north bank was left to fend for itself, a task made increasingly difficult as the river flow was pushed by early stopbanking and groyne work from the south to the north bank.

Complacency might have set in south of the river, but this was far from the case to the north. As a result of a Commission hearing, a Waimakariri River Improvement Act was passed in 1922 and the Waimakariri River Trust set up. Its district included lands on both banks from the sea nearly to the gorge, a distance of about 70 kilometres.

By that time there was evidence of aggradation in the lower river bed caused by bank erosion across the plains and by deposition of detritus carried down from the mountains where accelerated erosion was now added to the very active geological erosion. The Trust undertook the construction of groynes and river channelling in an attempt to reduce this but, more importantly, it commissioned a comprehensive lower river control scheme. Much good work had been done in the past and a considerable measure of control achieved, but this was the first time an overall basis for control had been proposed (F C Hay's No 2 Scheme). The scheme was at first rejected by ratepayers in 1926 but a major flood 7 months later and another a few months after that quickly changed people's minds.

The design was such that a maximum discharge flow of 4300 cumecs could be contained within stopbanks and other works. Subsequent floods proved it to be under-designed in places. Nevertheless, the plan laid the basis for all future control measures and was, therefore, of lasting importance.

North Canterbury Catchment Board

The North Canterbury Catchment Board, constituted in 1944 and the first in the country to meet, absorbed the Trust but carried on with its plan until 1960 when it produced the Waimakariri River Improvement Scheme. In the meantime there had been two floods, in 1950 and 1957, that had overflowed by breaking the banks. The 1960 scheme aimed at raising the level of protection to contain floods of 4770 cumecs.

By the late 1960s flooding in the lower reaches of the river had been controlled, and a basis for improving the high country had been laid. The link between the catchment condition and river behaviour was now sought. This was a much more complex problem.

A survey of the catchment revealed formidable gaps in knowledge of the natural processes going on in the area. There was insufficient evidence to determine the trend in plant cover and erosion, especially following heavy reductions in wild animals and sheep and the control of fire. There was insufficient information on the effect of both Maori and European occupation of the land. The contribution of flood waters from the various tributaries was unknown. And much more. The final report concluded: ". . . the survey has revealed vast fields of ignorance and that future control of the catchment must be accompanied by scientific investigation into these fields." This is continuing.

The Catchment Board inherited the Waimakariri as its main immediate problem, but it also acquired many others. Its district initially stretched from the Rakaia catchment in the south to the Kowai in the north. The northern boundary was later extended to include the catchment of the Waipara, Hurunui and Waiau, giving a total area of 19 051 km^2. The western boundary now extends along 230 km of the Alps.

The Selwyn River and Lake Ellesmere

Ellesmere is a shallow lagoon shut off from the sea by a bar of sand and shingle carried northwards along the coast. The Selwyn River, which gathers in the foothills between the Waimakariri and Rakaia Rivers, flows into it. When the lake water rises to about 3 metres above mean sea level the water breaks out to the sea naturally, but at that level it occupies 30 000 hectares. When lowered to 0.3 metre above mean sea level it occupies about half that area. Keeping the level down, therefore, is an important economic operation.

Our Mr Bray of Avonhead wrote a comprehensive report in 1875 about the complexities of Lake Ellesmere and drainage of the surrounding land. In the 1870s the Selwyn County undertook lake opening and drainage and in 1905 a special Ellesmere Drainage Act was passed. The opening of Lake Ellesmere became one of the early tasks of the Catchment Board. This regular operation keeps dry about 10 000 hectares of land around the lake and improves the drainage of an even larger area of fertile flat land.

The High Country

The Canterbury Association began the serious settlement of the region in 1850, but the 'pastoral invasion of the South Island' was already well underway in Marlborough and Otago and to a minor extent in Canterbury. Graziers, many of them Australian, with money and merino sheep, obtained cheap pastoral licences and rapidly stocked the tussock-covered mountain and foothill country east of the divide. It was a prosperous period, particularly for Canterbury, where crops could be grown on the best plains' soils and a wool clip shorn from the merinos in the several million hectares of tussock-covered mountain run country.

1886 saw 5 million sheep in Canterbury, but from then on deterioration in the mountains set in. This was widespread, applying to virtually all the tussock country in the hills and mountains of the South Island. There were two basic causes: the uncontrolled use of fire, and over-grazing by a combination of domestic and introduced wild animals. The widespread natural erosion was soon aggravated by these factors.

Samuel Butler gave an account of the first burning of the natural vegetation:

> "We burnt the flats as we rode down, and made a smoke which was noticed between 50 and 60 miles off. I have seen no grander sight than the fire upon a country which has never before been burnt, and on which there is a large quantity of Irishmen. The sun soon loses all brightness, and looks as though seen through smoked glass. The volumes of smoke are something that must be seen to be appreciated. The flames roar and the grass crackles and every now and then a glorious lurid flare marks the ignition of an Irishman." (The Irishman being the thorny shrub, matagouri or *Discaria toumatou*).

Butler also gave advice on the need to take care with burning. Otherwise there was a danger of destroying a neighbour's tussock and, with it, his sheep. But he maintained that burning was essential—"Burnt feed means contented and well-conditioned sheep."

So far so good; but over-burning eventually killed tussocks and the other vegetation and fires also escaped into what little forest had survived earlier Polynesian or naturally-caused fires.

To the other scourge, wild animals, the mountains were as attractive as they were to sheep. Rabbits

made the utmost use of the reduced vegetation. They infested all country up to mid altitudes. Red deer roamed all the mountain land. Chamois from central Europe and thar from the Himalayas changed, and sometimes destroyed, the mountain-top vegetation. It was impossible to separate the effects of these animals from those of the sheep. Between them they produced accelerated erosion. Not until both domestic and wild animals were controlled could countermeasures be successful.



117. Harper-Avoca forest in the Rakaia River catchment. Polynesian fires brought about a change from forest to tussock grassland which provided a good vegetative cover on mountainsides not subject to natural erosion. Frequent burning, stocking with sheep, and the spread of wild animals reduced this cover and destroyed much of it. Accelerated erosion then became severe and widespread. Depleted alpine vegetation uncovered glacial detritus which at these high altitudes joined natural erosion and turned steep mountaintops into screes. Lower down, natural and accelerated erosion made its way down through grassland or remnant forest. Exposed soils at all altitudes soon became eroded, often down to bare rock. (J H Johns, NZFS)



118. Hares as well as rabbits thrived in the dry South Island climate. A North Canterbury hare hunt in the 1930s. (Unknown)

Emphasis on Soil Conservation

A tract of mountain land of this size is much more to a nation than the means of livelihood of those who occupy it. The exploration of new country, the beauty of its scenery, the mountaineering and snow sports potential are irresistible attractions to many people. The Southern Alps are playgrounds of pre-eminent excellence.

By the 1940s the deteriorating condition of the tussock grasslands and mountain vegetation was attracting adverse comment throughout the country. The strongest criticism came from Christchurch, where people viewed with alarm the state of the Waimakariri River catchment. They were paying for the control of the lower course of the river where, it was considered, aggradation was taking place. How much faster was material going to be fed in from the upper catchment? Was it going to add to the aggradation? Some maintained that if nothing were done Christchurch would, before long, be buried under shingle. Canterbury became the main sounding-board in New Zealand for those bent upon soil conservation, not only for the South Island, but the whole country.

The Catchment Board was an exceptionally strong one as far as the development of soil conservation measures were concerned. The first chairman, W Machin, was manager of the Canterbury Farmers Co-op. L W McCaskill, the driving force behind soil conservation, was a member as was George Jobberns, Professor of Geography at Canterbury University. The departmental members were also strong, widely experienced civil servants and provided a broad, technical basis to the Board's deliberations and planning.

At its second meeting the Board decided to appoint K B Cumberland, then Lecturer in Geography at Canterbury University, to "organise and control its investigations related to soil erosion and conservation."

Towards the end of 1944 McCaskill presented a scheme for training soil conservators for the whole country:

> "... he considered that Canterbury offers the best facilities for imparting the training desired and that Canterbury Agriculture College and Canterbury University College would be the principal contributors to theoretical training and that practical training could be carried out under the guidance of the officers of the North Canterbury Catchment Board."

Runholders, concerned about the plight of their high country, were anxious to have an organisation to collect and disseminate information and stimulate research. One was set up on the Lincoln College campus and was called the Tussock Grasslands and Mountain Lands Institute. It was financed by the Soil Conservation and Rivers Control Council and the Wool Board and later by the Department of Lands and Survey, the landlord of most leasehold run country. L W McCaskill was its first Director. It has now merged with the Joint Centre of Environmental Sciences of the University of Canterbury to form the Centre for Resource Management.

Having laid the basis for facing up to its soil erosion problems, the Board turned its attention to the control of tussock grassland burning. This was done in close association with the runholders themselves to whom a questionnaire was sent. (A run is a farming unit, usually large by New Zealand standards, almost entirely pasturage in mountainous country). Many and varied were the answers; some almost confessions, as was this one:

> "Soil erosion is not caused from deer or any other stock. The great cause is fires getting away in the hot summer and burning the guts out of the land; in other words getting to the roots and leaving the ground bare for a real good downpour to come and wash out all the surface and scour all the creeks etc."

The same person bemoaned the fact that there were many fellows in the back country who, "could not catch a cat in a kitchen let alone go through shale have dogs that could head a norwester and know how to light a fire in snow or make a feed out of nothing."

This kind of honesty enabled the Board, within a few months, to adopt a policy and rules for burning that were acceptable to runholders. The situation changed to one of limited burning, carried out under permits with subsequent treatment of the land to obtain a cover palatable to stock.

Early meetings were also called with the High Country Committee of Federated Farmers and other groups of runholders. Through these channels, through practical and theoretical approaches, experimental work, surveys and demonstrations, the basis of run plans was gradually hammered out. Today there are well over 200 run plans in operation covering 50 percent of the high country in the Board's district. The way has been paved for the gradual improvement of the deteriorated high country and, with that improvement, an increase in production.

Methods used through run plans to achieve soil conservation are similar to those employed under farm plans but emphasis changes because runs are greater in size with lower carrying capacities, and natural erosion is usually a special feature to be dealt with. Extensive fencing is often necessary to separate eroded and uneroded land. The improvement by oversowing and topdressing of what are usually large areas of impoverished country requires treatment from the air. Without the aeroplane, improving high country would become well-nigh impossible. Where there is severe natural erosion being increased by grazing on top country, destocking is carried out. This is accompanied by improving country lower down so that displaced stock can be carried.

An upswing in production still would not have been possible without control of the wild animals. Fortunately this came soon after the Board was set up.

Rabbits, the 'grey plague' of the eastern South Island, reached their highest numbers during and immediately after the Second World War. In the mountains red deer numbers also became very high. From the late '40s the new method of aerial saturation poisoning over very large areas reduced rabbit populations to small numbers. This was an amazing feat after 70 or 80 years of ineffective dog and gun control and the result in the return of vegetation was immediate.

In the 1950s the Forest Service took over deer control. Shooting campaigns were intensified. These together with helicopter shooting which developed later, followed by the capture of animals for deer farming, finally controlled that animal as well.

The City and the Catchment Board

Christchurch, in the process of growing up, contented itself with drainage of the swampy land it extended onto. Waimakariri flood plain drainage problems are complicated by the effect of high water tables caused by the underground water. During prolonged wet spells water can rise to or above the surface in places in spite of intensive drainage.

The disposal of sewage under these conditions is also a complex operation. When the Catchment Board was set up, the city continued to deal with both sewerage and drainage, latterly through the Christchurch Drainage Board. The Catchment Board maintains close links with this body because drainage problems on new areas as the city expands involve catchments that extend well beyond the city boundaries.

On the Port Hills of Banks Peninsula even closer links have been forged between the City and the Catchment Board. Native forest on the peninsula was soon cleared to make way for farming, exposing the deep loessial soils that cover most of it. These escaped severe erosion, to which they are extremely prone, because dense swards of grass established readily following deforestation.

Urbanisation on these soils was a different matter altogether. Excavations, even of a minor nature, opened the structureless loess to rain. The result was rapid erosion that sometimes became a threat to buildings. The danger was not great, however, so long as development took place slowly and carefully and on a limited scale. But the threat became evident through widespread damage to property in the wet winters from 1974 to 1978, a period coinciding with large-scale urban development and earthmoving.

The Catchment Board stepped in with section 34 of the Soil Conservation and Rivers Control Amendment Act 1959 and no excavations can be undertaken in loess soils on the Port Hills without a permit. A detailed survey of these soils and their proneness to erode has paved the way for safer use.

Water Resources and Irrigation

Christchurch City and nearby farmland have been nurtured by water readily extracted from underground supplies. The metropolitan area depends entirely on these sources which supply it easily and lavishly and in addition feed the springs that supply the Avon and Heathcote Rivers, outstanding assets to the city. By the mid 1970s an average of 100 000 m^3 per day, with a maximum of 150 000 m^3 of high quality water was being drawn for domestic users and about the same amount for industrial needs. At that time the total volume was greater than the amounts used in either Auckland or Wellington, a reflection of the size of the resource and the ease with which it can be tapped. (The population of Christchurch at that time was about half that of Auckland).

This outstanding underground water resource has been studied for a long time, particularly by the Geological Survey of the Department of Scientific and Industrial Research. Its general nature is understood and the fact that it is mainly recharged from



119. The peaceful Avon in Christchurch is fed by springs coming from underground water percolating through shingle from the Waimakariri River to the north of the city. Once the Avon took some of the overflows from floods in the lower Waimakariri. (National Publicity Studios)

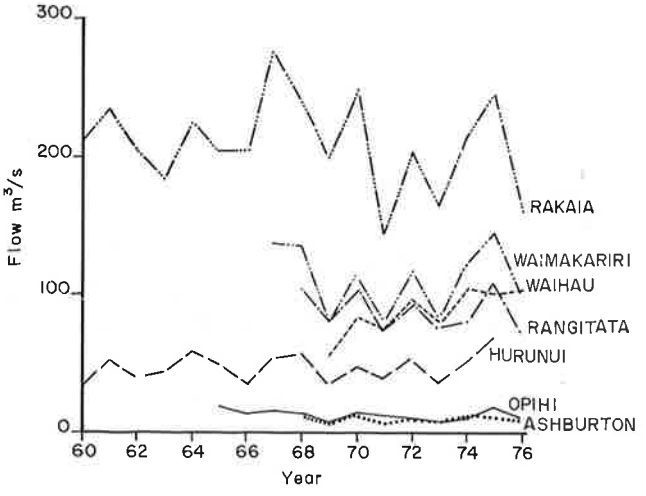
the Waimakariri has been determined. It is thought that about one third of this annual average recharge is now being used. There is no evidence of any permanent lowering of water levels or pressures, although short-term declines occur following heavy use.

The Regional Water Board must be responsible for the permanent management of this resource. Although much knowledge concerning it has been accumulated, the complete dependence of the city and its industry can only rest safely on an intimate understanding of its workings. Pollution through unconfined aquifers is always a threat. Another is the possible intrusion of sea water where aquifers extend out to sea and pressure of fresh water in them is reduced. The Board has undertaken further detailed studies on these and many other matters relating to the resource.

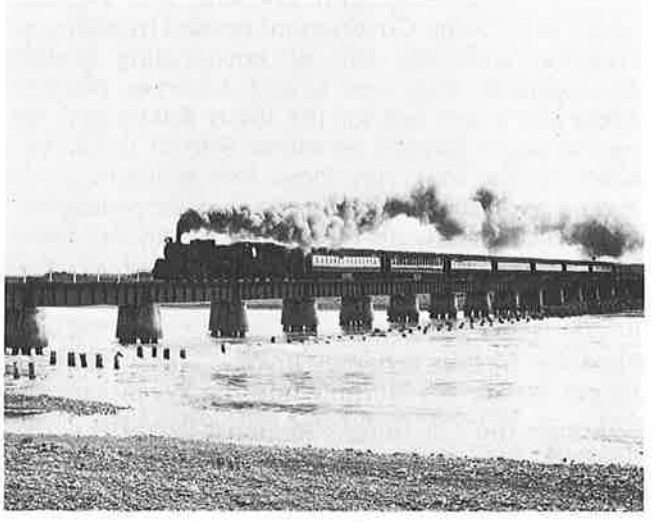
While the Waimakariri flood plain is fortunate in both soils and water resource, the remainder of the North Canterbury Plains does not have the same extent of good soils nor the quantity of groundwater. But there are very good surface water sources in the three rivers, apart from the Waimakariri, that flow from the Main Divide and cross the dry plains.

To the south the Rakaia has a mean annual flow of nearly 200 cumecs, twice that of the Waimakariri. Its water is as yet mainly uncommitted but a number of interests are now looking at the resource and making tentative claims. The important developments so far are the diversion of some water for power production at Lake Coleridge, the receiving

of water through the Highbank Power Station from the Rangitata Diversion Race, the extraction of rural and stock water supplies, the maintenance of a good salmon fishery, and the extraction of water for limited irrigation schemes from the lower reaches of the river. Water also finds its way into some underground beds on both sides of the lower river. In deciding future uses there will be a struggle between economic claims, mainly extractions for irrigation, and conservation and recreation claims—an application for a water right was lodged on behalf of the wry-billed plover (*Anarhynchus frontalis*) a vulnerable species of bird nesting, in New Zealand, only on the Canterbury rivers.

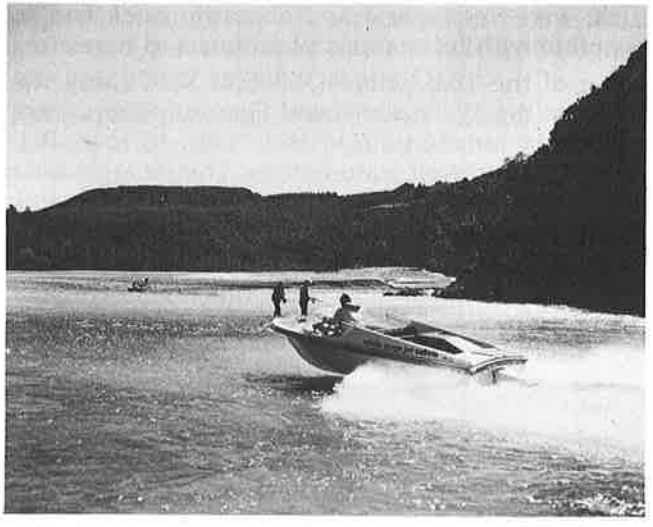


120. Mean annual flows of the main North Canterbury rivers. (MWD)



121. Railway bridge across the Rakaia River, North Canterbury. Piling which carried previous bridging remains a hazard to recreationists. (NZ Government Railways)

North of the Waimakariri flow the Waiau and the Hurunui. The first has about two-thirds the average annual flow of the Rakaia and the Hurunui flow is somewhat less. The Waiau drains an 80 kilometre length of the Main Divide. It is well entrenched for much of its length of 168 kilometres, but also flows through Hanmer and the Amuri Plains, where an irrigation scheme is now supplying water to over 11 000 hectares and will soon provide 17 000 hectares with water. The Hurunui, which drains 24 kilometres of the Main Divide, has several lakes in its upper catchment which affect the flow and water quality. Some stretches of the river are scenically very attractive. There is a potential for hydro-electric development and the middle section of the catchment is dominated by the Amuri Plains.



122. Jet boating and salmon fishing, two important recreational uses of the Rakaia River. (National Publicity Studios)

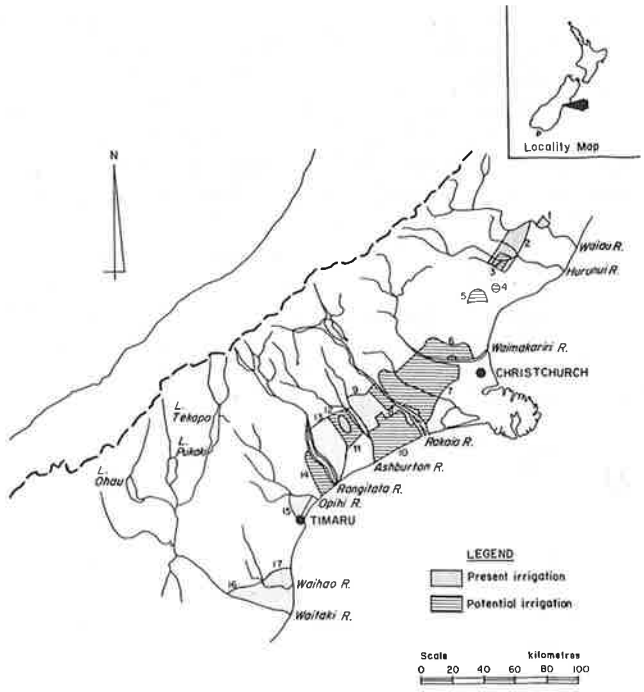


123. Dust storm on the Canterbury Plains. An indication of how loess was at one time deposited over many areas of the South Island. (MWD)

These three rivers rising on the Main Divide must, between them, become of immense value to North Canterbury, as the Waimakariri already is. They have all the attributes needed for many forms of recreation and use. They require detailed study, which the Catchment/Regional Water Board is now giving them, so that all uses can be developed to the best long term advantage. Perhaps the greatest immediate importance and call on the water is for irrigation.

The better soils of North Canterbury, even where water could not be got to them, were soon ploughed and sown to crops. Farmers threatened with droughts and high winds had to take chances with the weather. The poorer soils were turned to dryland farming. Pastures, if they could be called such, were very sparse and domestic stock had to compete with infestations of rabbits and hares.

Some of the very poorest, shallow soils along the banks of the Waimakariri and Hurunui Rivers were planted in radiata pine in the 1930s, to form Balmoral and Eyrewell State Forests. The struggle here was trees against rabbits, droughts, shallow soils and,



125. Present and potential irrigation schemes on the Canterbury Plains made possible by drawing water from the Canterbury rivers or underground water fed by them. (MWD)



124. Wind was one of the reasons for the widespread planting of shelterbelts very soon after Pakeha settlement of the Canterbury Plains began. Periodically exceptionally strong winds wreck them as well as plantations. Here wind damage has occurred in a 15 year old stand of radiata pine in Ashley forest on the edge of the plains. (J H Johns, NZFS)

when the trees were high enough, winds. It is no wonder that one person committed to establishing trees against these odds described the dismal scene as, "a land of brush, boulders and bastards." He forgot the rabbits!

The scourge of rabbits was conquered and dryland farming improved greatly. Little further progress could be made without water. In mid and north Canterbury there is both dry land and available water. In 1973 the Government revised its policy on irrigation with the aim of encouraging greater development. The two largest schemes planned under this policy are for the lower Rakaia and the central plains located on either side of the Rakaia River. In the long run these two schemes could extend over 200 000 hectares—thus extending irrigation over nearly all the land between the lower Waimakariri and the Ashburton Rivers—or about 40 percent of the land in New Zealand thought to be irrigable.

Plans for further schemes involve water from the Upper Waiau, the Hurunui and the Waimakariri.

Although the Catchment/Regional Water Board is not responsible for irrigation, it is involved with the granting of water rights with which to carry it out; and since irrigation uses very large quantities of water, almost all of which is not returned to rivers and most of which is extracted at low flow times, great care must be exercised.

SOUTH CANTERBURY CATCHMENT BOARD

Water, Water, But Not Enough

The boundaries of the South Canterbury Catchment District are the Rakaia and the Waitaki catchments and the Main Divide. The total area is just over 11 000 km² of which about one third is plains. Across these flows one of the large, South Island eastern rivers, the Rangitata, commencing on the divide, and seven smaller rivers rising from the mountains or downlands.

Like the large rivers in North Canterbury, the Rangitata has helped to form the plains. It is entrenched in a very gently sloping fan and has formed limited flood plains only in its lower reaches. The smaller rivers between them have formed 4275 km² of flood plains. These are the most important cropping area on the whole Canterbury Plains.

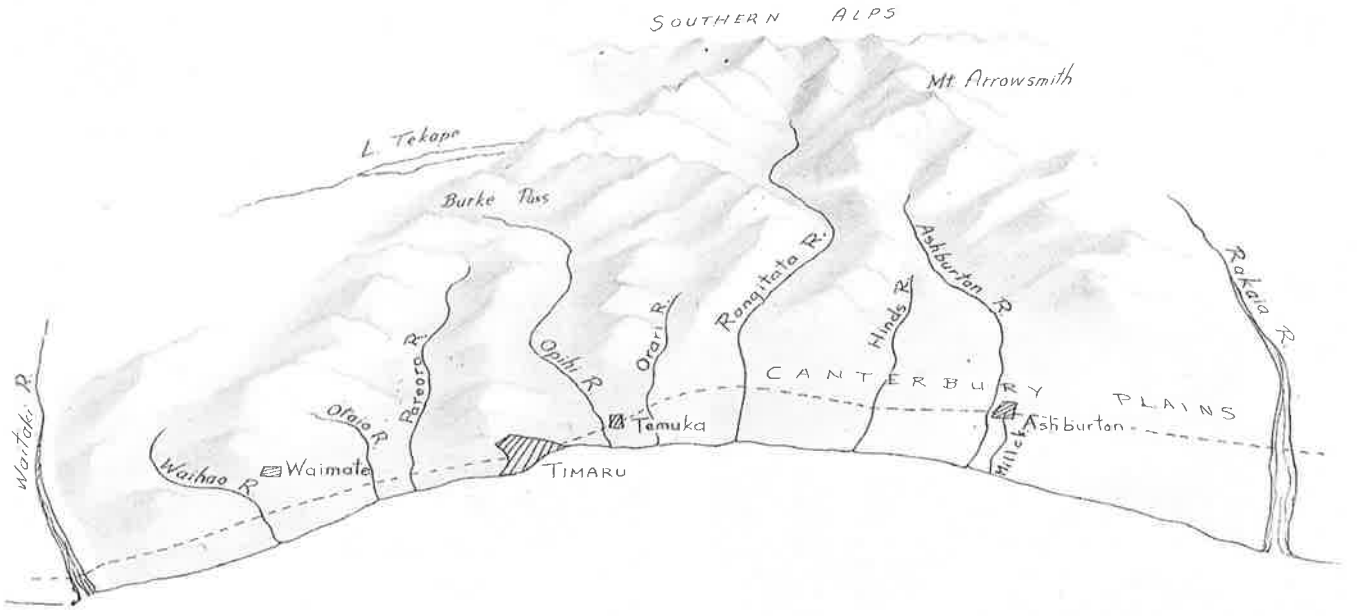
Water taken from all the rivers and from underground sources fed by them can irrigate 84 000 hectares of land besides yielding other rural as well as urban supplies and producing electricity. Of the total water resource of the district almost 200 cumecs, about one third, is committed for agricultural and industrial purposes.

The total resource is now over-committed at times of low flow. If the water were available, however, a further 400 000 hectares could be irrigated. Water collecting and harnessing are clearly amongst the most important matters for the Catchment/Regional Water Board to investigate.

Early Flooding

Townships that sprang up on the plains nearly all suffered from flooding except Timaru which established itself in a safe, elevated locality on a partly sheltered stretch of coast. Ashburton lay right in the flood path of the Ashburton River. Temuka and adjacent towns established themselves in the flood paths of a group of small rivers which, in the lower reaches, gather together in the Opihi.

Across the plains all these rivers flowed near the surface and could readily spill over to flood large areas. The little Hinds River lost itself near the coast and the water, having no fixed course, spread out into swamps. South of Timaru the Pareora, Otaio and Waihao, little more than streams, could all flood extensive areas and cut main communications.



126. South Canterbury Catchment District

One large river, the Rangitata, gathers on the Main Divide and flows across the South Canterbury Plains, but several smaller ones, including the Ashburton, rising in lower mountains and hills also cross the plains. The floodplains of all these rivers form the most extensive area of high quality soils on the Canterbury Plains. They are now protected from flooding by a series of river schemes. Water is drawn from the rivers and from underground sources for irrigation. Widespread accelerated erosion in the high country has largely been halted by the operation of run plans, fire control and animal control. (D W Lawrence)

Although the rivers that caused the most widespread flooding were small, they proved very difficult to control. Large amounts of detritus were fed into them from their steep and deeply dissected hill and mountain catchments. The normal flows of water were not strong enough to carry this along continuously as was the case in larger rivers. Only floods moved the material, and when they receded they left it to choke the river beds and make conditions yet easier for overflow.

The Opihi Flood Control Scheme

The district had every reason, because of flooding, to welcome the Soil Conservation and Rivers Control Act. Small River Boards had been formed earlier; one for part of the lower Rangitata, one for Rangitata Island on which farming had a precarious foothold, and one for a small area along the Ashburton (the Wakanui River Board). Otherwise the counties struggled with what river work they were able to do.

The South Canterbury Catchment Board was set up in 1944. Possibly the most urgent problem facing it was control of the Opihi River system. Apart from townships, up to 50 000 hectares of land were in danger of being inundated during floods—the largest threatened area in New Zealand. As far back as 1868 a tributary, the Orari, changed course during a flood and flowed directly to the sea. From time to time after that, however, it overflowed into its old course.





127. Two forms of irrigation, border dyke and spray irrigation, are used on the eastern South Island plains and inter-montane basins. They make heavy demands on the summer flows of the rivers, particularly those in Canterbury, and on the underground water derived from the rivers. Fortunately the summer flows are fed partly by melting snow and ice. (MWD)



128. Bridges across rivers and streams that flow near the surface of the Canterbury Plains are vulnerable to damage during floods from the logs and debris washed down by them. (MWD)



129. The 1945 South Canterbury floods triggered off the final preparation of the Orari-Waihi-Temuka flood control scheme. When it started it was declared 'Work of Local and National Importance'. During this flood, water up to 1.5 metres deep flowed through Temuka. (South Canterbury Catchment Board)

Shortly after the new Board was set up, the River Boards and counties passed their river control operations over to it. The wisdom of a combined approach became apparent when a flood in 1945 affected all the rivers of South Canterbury, particularly the Opihi system, which sent flood waters up to a metre and a half deep through Temuka.

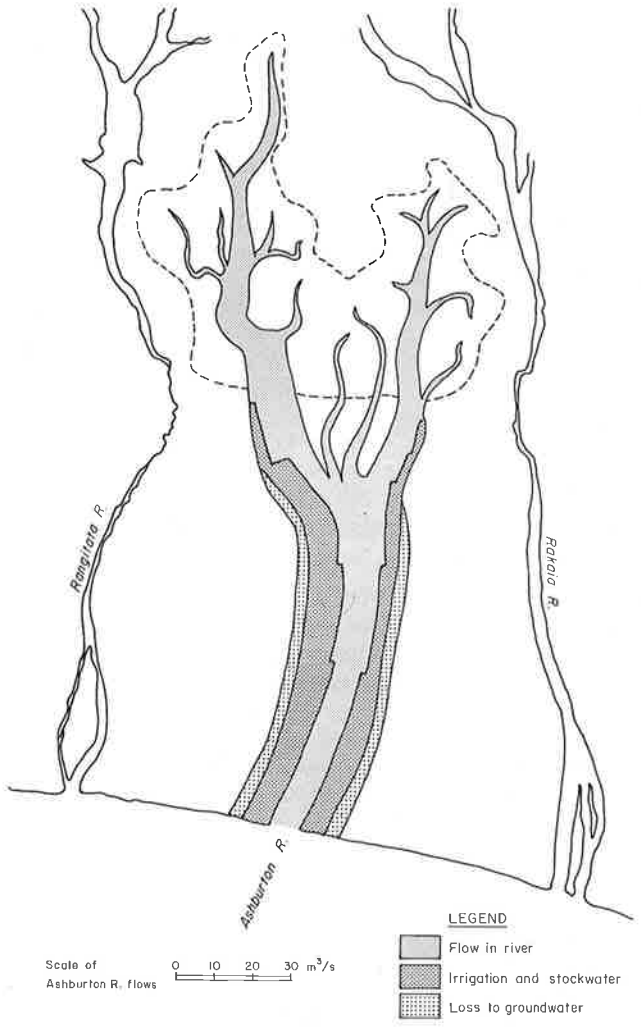
A preliminary scheme of control was commenced in 1950 on the lower river channels. It was designed to separate, once and for all, the Orari from the Opihi. Control of erosion deep in the catchments was included in the plan because it was estimated that 160 km of gravel-bearing streams required attention.

A year later further severe flooding in the Opihi caused the Board to modify the control scheme, which was then declared work of national and local importance. This scheme contained wider provisions than the first for erosion control and was one of the earliest in the country planned as a comprehensive catchment and river control work.

The scheme had considerable beneficial effects. When the time arrived to revise it in the 1970s, the cost of flood damage was estimated to have been reduced to one tenth what it would have been without the scheme.

Of the total Opihi catchment—1812 km² in extent—over half is alpine and tussock grassland. The greater part of this, plus some of the downland, is now in run or farm plans.

Once flood control was achieved, attention turned to the Opihi as a water resource. Over the years it had become of ever-growing importance to the district. "A revised and extended Opihi scheme should include water resource planning and management requirements for the catchment", it was noted in 1970 at the time of the scheme revision. The river system feeds aquifers and from them water for Temuka, Geraldine and Winchester is drawn as well as numerous smaller supplies. Study of this resource has continued.



130. Diagrammatic representation of what happens to water in the Ashburton River. Losses to groundwater amount to about 25 percent, extractions for irrigation and stockwater 50 percent and the remaining flow averages about 25 percent. Water use emphasises the importance of such a river in a relatively dry climate. (South Canterbury Catchment Board)

Ashburton River Schemes

The two branches of the Ashburton River, the North and the South Ashburton, do not commence on the Main Divide. There are, however, a number of peaks well over 2000 metres high and one, Mt Arrowsmith, of about 3000 metres, within the catchment. Of the total catchment area (1730 km² over half is in mountain country and the remainder is on the Canterbury Plains. Across the plains the catchment is narrow. It includes a small floodplain of about 5000 hectares on which lies Ashburton itself. Mill Creek passing through the town is an old flood channel.

There is a long history of lower river control proposals in the two branches—which join just west of Ashburton—and the short length of main river. The history of dissension is just as long. It took the Catchment Board a number of years to devise a satisfactory scheme acceptable to all ratepayers. At one stage it presented them with five options. The main problem was aggradation in the North Branch at a point where the gradient was reduced—almost halved—as it descended from the mountains to the plain. The possibility of diverting the flow to the South Branch, and so improving the gradient, was examined, but this had too many complications.

A scheme of channel clearing and stopbanking was finally designed and constructed. The section in the upper reaches was put to the test almost immediately on completion by a flood in 1978. No overflows occurred.

The old floodway, Mill Creek, is an example of the problems that can be caused by apparently insignificant features in an urban area. Its tiny catchment of 340 hectares has an urban section that has required expensive control works. The channel is used to take away stormwater which has increased with urbanisation, but the flow is impeded by residents' well-meaning "improvements" which include trees, gardens, water wheels, and so on.

The Ashburton-Hinds Drainage District

The little Hinds River, with an average flow of 1 cumec, spread out into a morass of swamps and bogs with some strips of dry land before it reached the coast. These low-lying wetlands occupied an area of 30 000 hectares between the Rangitata and Ashburton.

In 1864 John Grigg of Longbeach undertook the drainage and development of not much less than half this area (13 000 hectares). Remembering the long history of difficulties and dissension that beset the mastering of the Manawatu (about the same size as the Hinds swamps), the conquering of the Ashburton-Hinds area was an epic of imagination, organisation and achievement.

By the 1870s and 1880s, 30 000 sheep were being shorn at Longbeach, 3000 pigs fed and 1000 head of cattle fattened. In one year 2000 hectares of wheat and 1200 of oats were harvested; all in all a very substantial contribution to the progress of the district.

In the 1880s Grigg's property was subdivided. The loss of undivided control of the intricate drainage pattern that had been carefully planned led to its deterioration and to gradual reversion to wet conditions. There was a marked rise in the watertable and a drop in production. The Hinds River itself became choked with debris, willow and weeds which led to increased flooding.

Control of the Ashburton-Hinds drainage scheme passed to the Catchment Board in 1946. Work to clear the bed of the river and restore drainage was put in hand immediately. Production was restored and then increased by using some of the water in the drainage canals for irrigation.

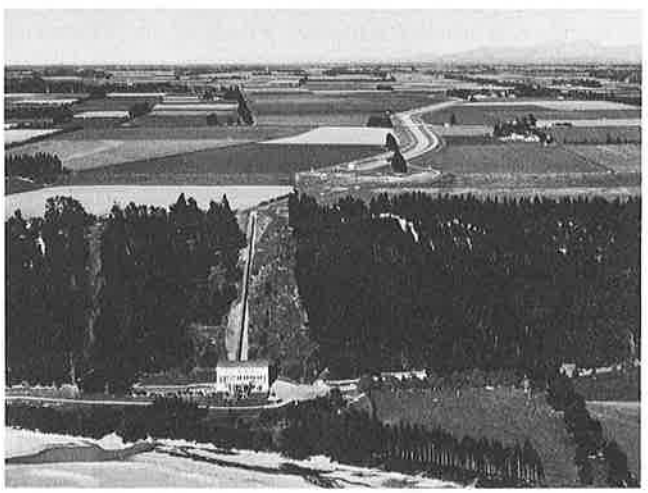
Now there is an Upper Hinds Scheme to clear the Hinds River where it flows in a defined channel, and to prevent erosion in the 12 000 hectare catchment.

The Rangitata River

"As soon as I got to the riverside I liked it even less than I thought I should. It was muddy, being near its parent glaciers. The stream was wide, rapid and rough, and I could hear the smaller stones knocking against each other under the rage of the waters, as upon a seashore". (Samuel Butler, *Erewhon*).



131. The Rangitata River is the largest water resource in South Canterbury. Here are its middle reaches with its wide braided bed as it emerges from the mountains onto the Canterbury Plains. Water is extracted for irrigation and for the Rangitata Diversion Race in which 28 cumecs are taken across the plains to the Rakaia River. Supplies from the Ashburton River join it on the way. The water in the race is used for irrigation or is taken through a power station, Highbank, on the banks of the Rakaia, depending on the season. (D L Homer, NZGS)



132. Highbank Power Station, on the Rakaia, with the Rangitata Diversion behind it. (MWD)

This river, draining 40 km of the Main Divide, and made famous by Samuel Butler, has a catchment about the same size as the Ashburton and flood peaks of about the same level. The nature of its flow is affected by the storage of moisture as snow during winter and its melt in spring, and by glaciers which occupy 2.6 percent of the catchment and give it a good summer flow. Across the plains the river is entrenched in its gentle fan. During floods the main damage it causes is bank erosion along the bed and on Rangitata Island which occupies an area between two branches in the lower reaches. In the past it was very troublesome in this way and in cutting main communications.

The potential of the Rangitata as a water resource was early recognised by engineers. When irrigation of the plains was seriously considered, the Public Works Department constructed a diversion race 67 km long from the gorge of the Rangitata to the Rakaia River. In excess of 28 cumecs was diverted along this race and on the way approximately another 7 cumecs was extracted from the Ashburton. (By comparison this total flow of some 35 cumecs is the equivalent of an average summer flow in the Manawatu River). Water is extracted from the race during the summer months to irrigate three schemes amounting to nearly 70 000 hectares. Extensions planned to two of them, also using water from the race, will double this irrigated area. The Government's extraction of water from the race can be restricted according to the flow in the Rangitata River.

In the winter months, when there is no demand for irrigation, the water drops into the entrenched Rakaia through a hydro power station, appropriately named Highbank.

The Board and the High Country

The success of the South Canterbury Catchment Board with its river schemes has been due in no small measure to its control work in the upper catchments.

From the outset the Board was acutely aware that it must study the catchments as well as the lower rivers that caused the immediate trouble. There would be increasing complications as long as detritus was fed into the lower reaches of the small rivers. Could it be stopped? It had always come down naturally, but was it increasing because of man-made erosion?

The state of the high country had become critical. At the highest altitudes chamois and thar reduced what alpine vegetative cover there was and in the Hunters Hills to the south an increasing and expanding population of red-necked wallaby added to the competition for grazing.

The Board's task was clear; to carry out the intention of the 1941 Act and examine complete catchments—rivers, vegetation and soils. It was well constituted to do this.

The first chairman was Dr P R Woodhouse, a medical practitioner-cum-runholder who had an excellent background from which to size up the problems and guide the Board. Amongst the strong group of Government representatives was J D Raeside, a soil scientist who had assisted with a South Island high country erosion survey.

The first meeting of the Board requested each county to supply a report on conditions of the high country, the low country and river control. At the next meeting Raeside read a report on the effect of burning on soils. The first Conservator to the Board, who was appointed in 1946, was given the title of Pastoral Liaison Officer. His first task was to get to know the runholders and their high country problems.

In less than a year from the Board's first meeting Woodhouse had written a brief, setting out the scope of the activities that the newly constituted Board should cover. This comprehensive document discussed soil conservation on all land (including high farming land), river control and land drainage. No board could have wished for a better plan of attack. To Woodhouse a long term approach was paramount and to achieve this, sound records, investigation and research, as well as good practice, were essential.

Progress with rehabilitation was assisted by the selection of "demonstration" properties on which erosion control measures could be put in train and the results observed closely. Shenley, a small run of 3300 hectares in the Opihi Catchment, was selected as one of these.

There a number of practices, some of which the owner was already trying, were included in an overall plan. Over the years these added up, not only to erosion control, but also to markedly increased production as the vegetative cover improved.

Oversowing and topdressing were the basic measures that brought this about, but a number of other measures also helped. Fencing to segregate different types of country, rank growth utilisation by cattle, control of burning, and provision of access tracks, all helped to heal and improve the country. Progress over the whole area has been continuous until, today, over 100 plans cover nearly 87 percent of the South Canterbury high country.

Burning is now carried out under strict control through permits. Up to the early 1960s about 100 permits a year were issued with an average of nearly 20 000 hectares burned. Permits have now dropped to something over 20 each year and the average area burned is of the order of 2500 hectares. Moreover,

all the fires are below the 900 metre contour and most are for the control of weeds or to prepare the way for oversowing and topdressing.

In spite of this success the severest erosion scars, some man made, have not been healed and are continually reactivated by heavy rainstorms. These are among the principal sources of detritus to the streams. They can usually be cured only by engineering work plus tree planting, special and costly work that is separate from the type of work done under a run or farm plan.

Now that erosion control in catchments is well underway, attention is being directed to the relationship between vegetative cover and water yields. This is a vital matter because of water shortages that occur in the lower rivers during prolonged dry spells.

Wind and Shelter

To prevent the loss of loessial soils during cultivation, and to give shelter to stock, farmers have established shelter belts almost from the time of the first settlement. Persistent attempts have produced a wide range of results, including some successes, but many failures. Establishment is difficult in the dry soils; some of the species chosen have been attacked by diseases; management throughout the life of a shelter belt has seldom been applied. The commonest tree planted, radiata pine, grows to such a size that belts are often blown over by the strong winds.

So pressing was the problem that local bodies were encouraged to engage in this activity. Under the 1941 legislation Catchment Boards saw the need to establish better shelter as part of their task of soil conservation. In wind-prone areas and on certain soil types, Boards have designed schemes to cover whole districts.

The South Canterbury Board has made a special effort in this field and is paying detailed attention to the design, establishment and continuous management of shelter belts. It is estimated that a total area of 400 000 hectares requires this form of soil conservation. As has been reported by the Board: "There is need to elevate shelter to a level of technology similar to other forms of agriculture such as irrigation".

The Regional Water Board

Woodhouse became President of the Catchment Authorities' Association and during his term of office he foreshadowed water legislation that was to come later. He could visualise the critical need for water management in South Canterbury if flooding could be controlled. In the broader field of water use he expressed his opinions to the Association as follows:

> "The Boards should be required to protect the sources of supply of water for use, perhaps, in the distant future.
>
> The point of utilisation of water may be far removed from the source whence it originates. The powers of a regional authority should be available to conserve the water until it reaches its point of utilisation .... Water conservation should be considered in the same way as soil conservation."

The statement has been well borne out. Demands for water in South Canterbury are increasing rapidly. Freedom from flooding has encouraged more intensive cropping of the flood plains and this in turn increases the call on water. Irrigated areas are being extended and further expansion is possible. The use of the low flows in all the rivers is a critical issue because extractions at that time affect fisheries and other recreation.

Where can extra water be obtained?

The most obvious place to look is through Burke's Pass to Lake Tekapo and the Tekapo River, in the headwaters of the Waitaki system. Here is part of the incomparable water resource originating in the highest parts of the Southern Alps. The rivers are partly glacier-fed, snow is stored during the winter to be released in the spring and summer, and large lakes store the water.

This resource is being diverted in a most complex manner for hydro-electricity generation and irrigation of the Mackenzie Basin. Why not send a small fraction through Burke's Pass and down the Opihi, the most used river in South Canterbury? The Rangitata diversion race illustrates what could be done. Why not a Tekapo diversion? This possibility is being seriously considered, but before decisions are made a critical assessment of the resources in the district itself is being undertaken.

Water from the Opihi is used for irrigation, rural, urban and industrial water supplies, and for recreation. Ten water races in all have been drawn from it, and 7000 hectares developed for irrigation. But five times this area within the Opihi catchment alone could be irrigated.

The detailed study is showing where and how water could be used more efficiently or more extracted. One of the most economic ways of increasing the yield immediately would be to store excess flows in the Opihi by constructing a dam or dams at suitable points.

Whatever is done, increased agricultural production in South Canterbury will depend largely on increased availability of water and continued improvements in the high country. In both of these the Catchment/Regional Water Board has key roles to play.

WAITAKI CATCHMENT COMMISSION

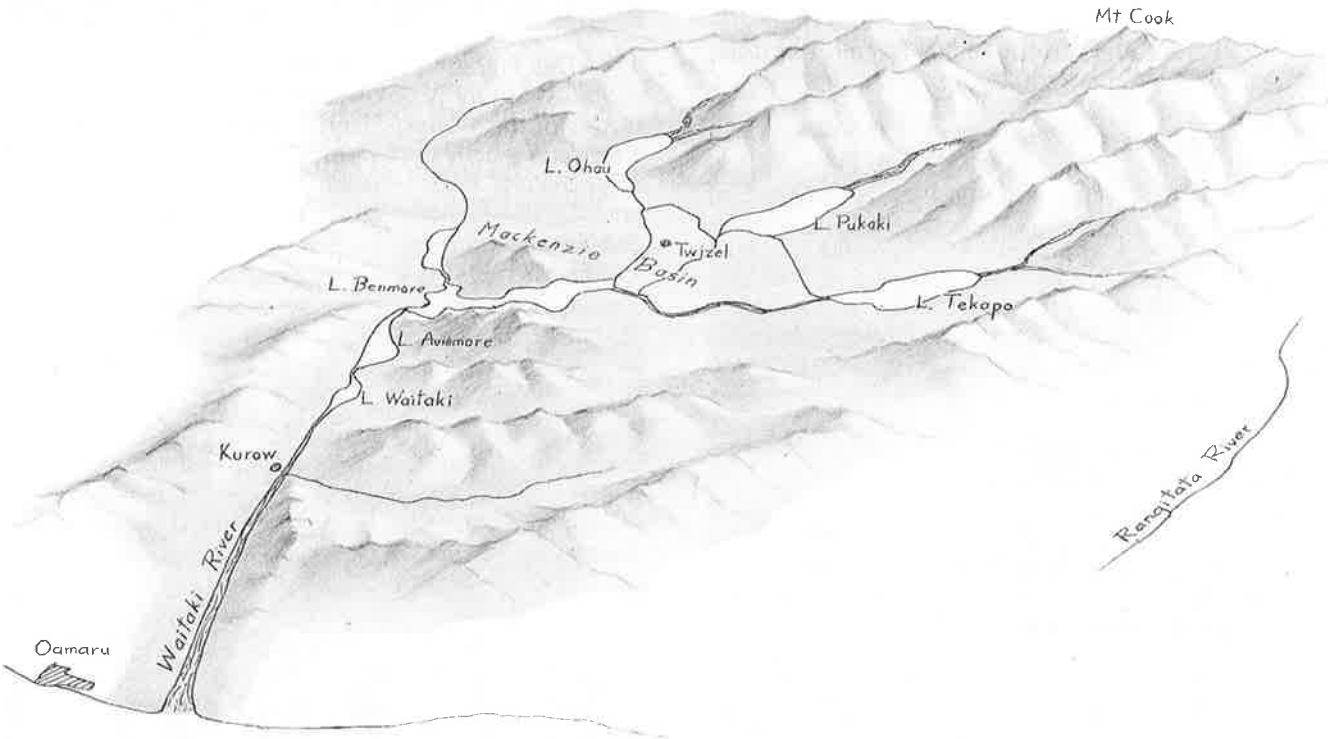
A Pre-eminent Water Resource

The 150 km long section of the Southern Alps between the Rangitata in South Canterbury and the Clutha in Otago, gives rise to the Waitaki River. This is the highest part of the Alps, containing the 3762 metre high Mount Cook. The head of the Waitaki Catchment itself has 45 percent of the total South Island ice resources and the largest glacier in the world outside the polar regions.

From this mountain land, watercourses flow into three lakes. Trapped in glaciated valleys, Tekapo, Pukaki and Ohau occupy in their natural state about 239 km². The outflows from the lakes once made their way across the Mackenzie Basin, itself an infilled area some 1000 km² in extent. Its surface is marked by a multitude of shallow channels left by the melt-water of receding glaciers and ice sheets. Here and there, old moraines break the surface. The outflows, bearing the same names as the lakes, joined on the eastern side of the basin to form the Waitaki River which flowed for 90 km along a depression (graben) to its mouth at the southern limit of the Canterbury Plains.

This glacier, lake and river system has a catchment area of close to 12 000 km². It is the third largest catchment in New Zealand after the Clutha and the Waikato. There are some flood plains in the upper tributaries, and some of limited extent in the lower river, but altogether they amount to only 4 percent of the whole catchment. Another 13 percent is occupied by terraces and fans.

The total permanent population in the catchment is only 10 000 and apart from the hydro-electric construction town of Twizel there are no substantial communities. The mountain section between the Southern Alps and the lakes is wet but the remainder is possibly the driest catchment in the country.



133. Waitaki Catchment District

The district comprises the Waitaki River catchment, the third largest in the country. The river rises in a long section at the highest part of the Main Divide. The tributaries there, forming about one third of the total catchment, gather in three lakes impounded by glacial morainic material. The lake outlets flow across the Mackenzie Basin, a plain formed by infilled glacial detritus, and join to form the lower river which flows down a straight fault line. There are no floodplains, but limited areas of high terraces. The middle and lower parts of the catchment are amongst the driest areas in the country and suffered probably the most extreme accelerated erosion in the South Island. The usual combination of run plans, fire control and animal control has improved this situation immensely. The water resource is probably the best in the country for the production of electricity and has been taken mainly for this purpose and for some irrigation. (D W Lawrence)

The mean annual discharge of the whole catchment is 350 cumecs (compared with the Waikato flow of 285 cumecs, or the Buller of 501 cumecs). Of this water, 93 percent comes from the western mountain section, occupying only 38 percent of the catchment area. The main flows come in summer, partly from melting snow and ice.

From the 1850s, all the available country was occupied by runholders and their sheep. The area, almost entirely tussock grassland, lent itself to pasturage on a grand scale. Some of the runs were the largest in the country. Even a century later there were no more than 80 properties in the whole of the upper catchment—four-fifths of the total area—and only 4 of these were under 1000 hectares. The dry climate, lack of good land and erosion had hindered closer settlement.

Explorers and tourists soon followed the pastoralists to admire and climb the mountains. The Mount Cook National Park—based on reserves that had been made before the turn of the century—was formed in 1953 around the mountains and their glaciers. The park covers about 70 000 hectares and has 145 peaks higher than 2300 metres.

It was not long before the lakes and rivers were stocked with trout and salmon, and the Waitaki became noted for its salmon fishing. The head of the catchment became one of the choice recreational and wilderness areas in the country.

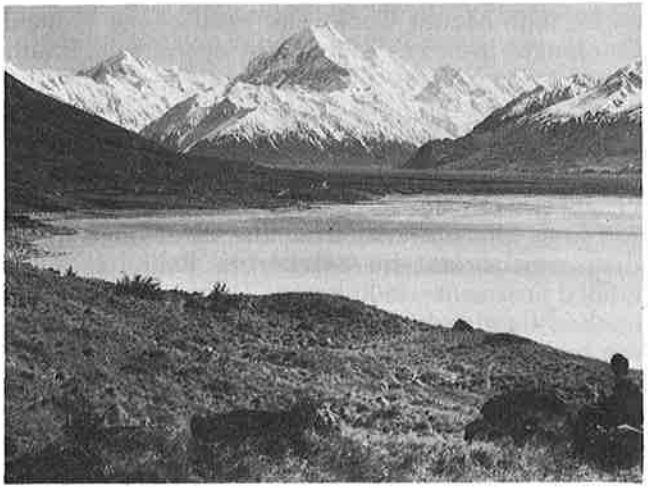
The quantity of water, the lakes and the river, soon excited the imagination of people involved in hydro-electricity generation. Visions of manipulating water on a grand scale opened before their eyes.

First, before large earth-moving machinery was available, the river itself was dammed. In 1928, the Waitaki dam and power station were begun 65 kilometres from the mouth of the river. When large machinery appeared, Aviemore and Benmore were built, the last forming a lake 79 km² in extent and submerging sizeable areas of terraces and gentle fans.

These developments used the fall of the river from the Mackenzie Basin to Waitaki. Flooding the 'bottom lands' of many sheep stations adversely affected their viability and production and covered much potentially irrigable land.

Now the skills of the engineers came into full play. Because the natural lakes, Tekapo, Pukaki and Ohau, occupied valleys, they could be dammed to hold more water. Moreover, they were at different levels. It would be possible to move water from one to the other, generating electricity on the way. This would also make irrigation water available to a large area of the Mackenzie Basin, which would be a benefit of very great importance locally, although the scheme was not principally designed for this purpose.

The whole complex scheme to impound water and divert it from one lake to the other includes a total



134. The highest part of the Southern Alps, which includes Mount Cook—seen here—is in the headwaters of the Waitaki River. The melting of snow, icefields and glaciers provides a good summer flow, and three natural lakes—Pukaki to be seen here, Tekapo and Ohau—provide large water storage. (National Publicity Studios)



135. Waitaki River salmon fishing provides much sought-after recreation. (Unknown)

of 9 power stations. The heart of the project is Lake Pukaki which provides 40 percent of the river flow. Damming it has doubled its water-holding capacity, and increased its surface area from just over 11 000 to 17 680 hectares. The Pukaki Canal can pass a flow of water greater than the average flow of the Waitaki River itself. It is wide enough to float two Cook Strait ferries side by side.

There remains the fall in the river from Waitaki to the mouth; almost 200 metres in all, over a distance of 65 kilometres. This has a potential for further electricity generation and has been investigated for that purpose. The river flows almost in a straight line and there are no flood plains of any extent.

If fully developed, the total capacity of the river will be about 1600 MW.

A Catchment Commission is Formed

When the 1941 legislation passed, the state of the Waitaki Catchment was similar to that in the remainder of the South Island. Devastated by over-burning, and over-grazed by wild and domestic stock, it presented a sorry picture. Because of the high altitudes and the glaciation, both past and present, natural erosion was more severe than in any other section of the Alps. Almost 20 percent of the catchment was barren land caused by glacial erosion, high alpine natural erosion and man-induced erosion.

Flooding in the lower river affected little land. The main damage was bank erosion. In any case, major changes were being wrought on the river system and any detrimental effects caused by these had to be regarded as partly the concern of the Government.

Growth of willows and weeds in the 65 kilometres of wide shingle fairway in the lower river had become a difficult problem. Power station operations caused large daily fluctuations in flow, ranging between 85 and 595 cumecs. These increased flooding and bank erosion. The cost of controlling the effects was completely beyond the rating capacity of the limited number of farmers, even if it had been their concern.

The water resource itself was generally regarded as a national one, and planners of the hydro-electric schemes had been given free rein. Claims from fishermen and from those who wanted to irrigate land could be heard but faintly against the clatter of machinery excavating great canals from one lake to another.

This would have been an unpromising background for the operation of a Catchment Board even if there had been a much larger population living along the river. As it was, the tiny population and its small investment made it impossible.

What of its two neighbours? The South Canterbury Board was absorbed with its extensive flood problems and the state of its own high country. It was uninterested in taking over territory that would produce very little in the way of rates, but present it with soil erosion problems as great or greater than its own. The Otago Board was not formed until 1949, mainly because of the difficulty of getting town and country to think and operate together. The problem of the Waitaki seemed remote to those immediately to the south.

The Soil Conservation and Rivers Control Council, on the other hand, could not stand by and watch such a large area of deteriorated country become steadily worse. Under the Act, there is provision to declare Soil Conservation Districts where there is no Catchment Board. The Waitaki Soil Conservation Committee was accordingly appointed in 1947 with a district to include the whole catchment of the Waitaki River. In 1961, the Committee was succeeded by a Catchment Commission.

The Committee set to work promptly to grapple with the formidable task of soil conservation and this work has been carried on and expanded by the



136. In its lower reaches the Waitaki River flows between low banks. Maintenance of the bed consists of keeping the islands between the braided river channels free of willows and weeds and preventing the banks from being eroded. Eventually this section of the river will be harnessed for the production of electricity. (D L Homer, NZGS)

Commission, with outstanding success. The Committee and Commission pioneered some of the techniques which, in time, came to be included in run plans throughout the South Island.

Irrigation

The dependence of the nation on the water resources of the Waitaki—as well as on others in the south-east of the South Island—for electricity generation is unquestionable. What is not generally realised is that the same water is essential to agricultural production in this dry catchment. In fact, no region in the country is more dependent on water for its development.

The quantities required for agriculture, while vital, are small compared with those used for electricity generation. Nevertheless, the two need to be co-ordinated.

Diversion of water to races and irrigation means loss of power production. But if the two can be planned together, double uses can sometimes be devised. One major complication is that while water for irrigation or rural supplies may not be required for many years after the installation of a power scheme, provision must be made for it from the beginning of planning.

In such dry country provision of adequate water for stock is always a difficulty. Natural water is invaluable and often the key to initial development of a run or farm. The most satisfactory constant and concentrated supplies nowadays are obtained through piped rural water supplies. These have been so successful that water from within the Waitaki catchment serves more than 100 000 hectares of land, some of it in the neighbouring South Canterbury and Otago districts.

The terraces along the lower reaches of the Waitaki lend themselves to irrigation. Settlers soon took advantage of this and the first scheme, Redcliffs—irrigating 2000 hectares on the north bank of the river—came into operation in 1935. Others soon followed.

Recent ones—Lower Waitaki and Morven-Glenavy, near the mouth of the river—extend from the Canterbury Plains to Oamaru and serve nearly 30 000 hectares. In addition to these large Government designed and subsidised schemes, there are a number of small, private ones.

Open races still exist to supply some rural needs. One, drawing water from the Waitaki, at one time served the borough of Oamaru and some irrigation needs on the way.

Further schemes for rural water supply and irrigation on the Waitaki terraces and in the valley of the Hakataramea (a tributary joining the Waitaki at Kurow) are being investigated and constructed. The main potential, however, lies in the Mackenzie Basin and the Omarama Plains.

Of the total plains area of 100 000 hectares, suitable soils and location make about one-fifth potentially irrigable. Around the plain are areas of dry-land, hilly country amounting to some 130 000 hectares. Fuller use could be made of this with the provision of stock-water supplies and pockets of irrigation.

Steep mountain tussock land, adjacent to the basin, amounts to about 200 000 hectares. Any increase in its production would depend largely upon developments in the other two zones. By intelligent and efficient use of water alone, the stock-carrying capacity of the Mackenzie could be increased several times.

Hitherto, the severe and dry climate and the ownership of land in large blocks have prevented rapid development, but some progress has been made with irrigation and more intensive production. The time is now ripe for more rapid progress. Provision has been made for the supply of up to 30 cumecs of water to irrigate the plains. The canals can be tapped for this irrigation water and there is accumulated knowledge on stock and crop production that can be put to good use. Integrated farming of mountain country, hill and plain-land offers a promising future. The key is water.

Under the 1967 legislation the Commission, along with other Catchment Authorities, assumed the responsibilities of a Regional Water Board. It was immediately caught up in the net of national, large-scale planning. But a separate Act in 1968 stated that the primary use of the Upper Waitaki water was for the generation of electricity and that it was of national importance. It broadly allocated the resource between energy production, irrigation and stock and domestic needs for the next 21 years. Ninety-five percent of the Upper Waitaki water was likely to be harnessed for electricity. Then the lower river was to be investigated for its potential.

What could the Commission do in this situation? It is true that other demands were relatively minor compared with electricity generation. But they could easily be overwhelmed by the huge power schemes. It was up to the Commission to see that they all received proper consideration during the planning processes.

The Commission set to work to survey resources, both land and water. This would show the ultimate potential area that could be irrigated and its likely water requirement. It would forecast stock-carrying capacities and the needs for stock and domestic water. It would assess the recreation, wildlife and fish situation. (It had been estimated that the earlier Waitaki dam had reduced the salmon population by 90 percent.)

The Commission came late upon this scene, but it is fulfilling its functions in integrating water management, bearing in mind the restrictions placed upon it. Water management is the main route to land improvement, so the Commission influences this; added to which are land improvements brought about through soil conservation measures.

All these matters have been brought together by the Commission in a water and soil regional management plan. This document is available for public discussion and will assist local authorities in the integration of their planning with that for soil and water. The Waitaki Catchment Commission, the unwanted orphan, has produced the first such planning document in New Zealand.

One might say, the orphan has come of age.

OTAGO CATCHMENT BOARD

The District

The Otago Catchment Board was not constituted until 1949 partly because Dunedin was hesitant to join in. Its district is by far the largest in the country, over 36 000 km², stretching from the Waitaki Catchment to the southern boundary of the Clutha Catchment and westwards to the West Coast taking in the northern part of Fiordland.

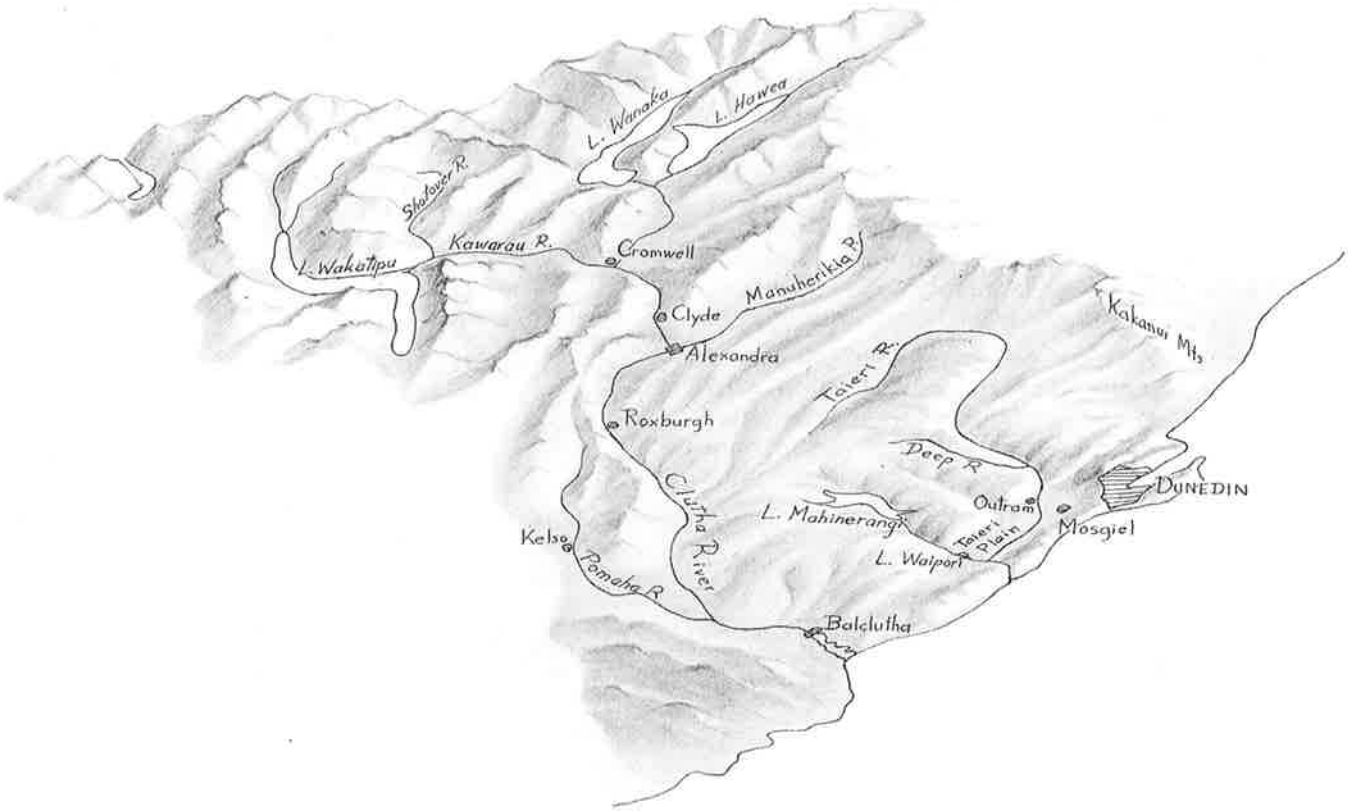
A great part of the district comprises the catchments of the Clutha River, the largest in the country, and the Taieri River, the country's most overtaxed water resource.

The Waters of Leith

Amongst the problems facing the new Board was a long-standing one of Dunedin's own. The Waters of Leith gather in the hills immediately behind the city. In a short course of 12 kilometres the stream descends nearly 400 metres to the harbour.

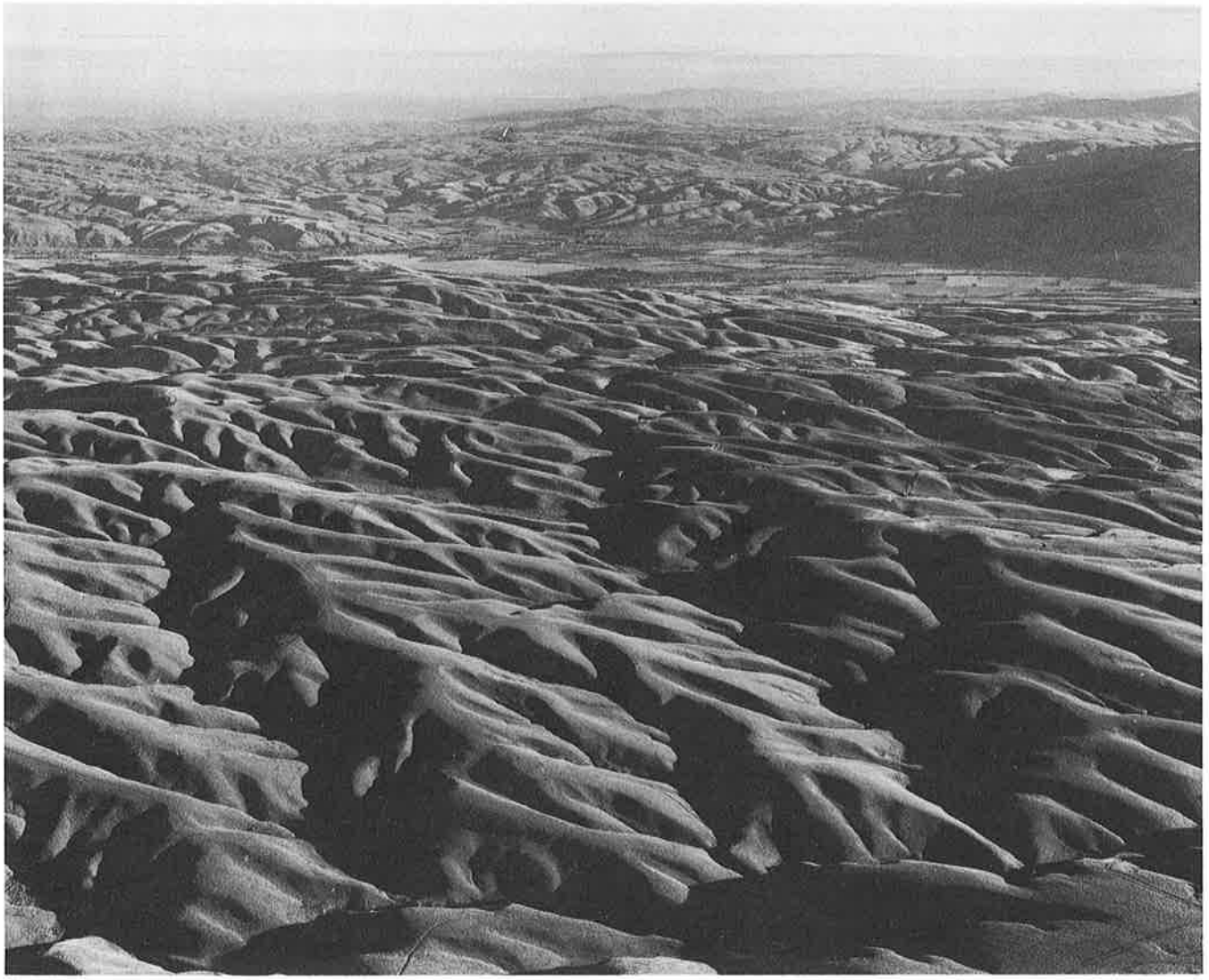
Through the city there is a small flood plain. Floods arise from short-duration, intense rainstorms, and come hurtling down the precipitous valleys bringing a load of debris. Peak discharges have reached 200 cumecs.

The small flood plain was soon used and built over.



137. Otago Catchment District

The largest catchment in New Zealand, that of the Clutha, occupying eight percent of the country, and the catchment of the Taieri River, the fifth largest in the South Island, make up most of the district. The Clutha tributaries gather on some of the highest parts of the Main Divide. Fed by high rainfalls and glaciers, they carry swift, turbulent flows, loaded with detritus, to Lakes Wakatipu, Wanaka and Hawea. Rivers from the lakes join to form the Clutha which flows through dry Central Otago, then through downlands and eventually divides into two branches as it crosses a small floodplain, Inchclutha. Altogether it is one of the largest water resources in the country. The very much smaller river, the Taieri, rises in lower mountains and flows across the Taieri Plain before it reaches the sea. Parts of the floodplains of both rivers can still be flooded because of incomplete flood control schemes. Natural erosion in the mountains is extreme, and induced erosion in the high country has been widespread but run plans have produced great improvements. Central downlands have to be farmed carefully to avoid loss of loessial soils. (D W Lawrence)



138. The Lammermoor Range and downlands in the catchment of the Taieri River. This country, once covered by dense tussock grassland, is being developed for agriculture before it is known what the effect will be on the heavily overtaxed water resource. (D L Homer, NZGS)

A botanic garden was established on part of it. Floods in 1868 swept part of this away, and one in 1877 swept a house out to sea. "At the Universal Bond about £2000 worth of sugar has been damaged and it is reported that the proprietors intend taking action against the City Corporation for not having perfected the general drainage scheme". Little did they realise that a century of problems were to follow.

As late as 1923 a flood washed away roads, eroded banks, undermined a concrete bridge, flooded houses and the botanic gardens, damaged a water main and cut new channels.

Voluminous reports were written and many control schemes tried. In the 1950s the city and the Catchment Board produced a solution in the form of a high velocity concrete channel with debris traps. This, however, was not the end. In 1959 it was reported; "A new block of 16 houses has just been erected in the area where 12 feet of boulders were deposited in the 1929 flood and the pre sent channel is quite incapable of transporting the design flood . . . . " The situation was somewhat improved when a flood destroyed a weir. This was followed by the natural degrading of the channel giving it greater capacity.

The Taieri, an Over-Taxed Resource

The Taieri is a small river with an average flow of around 32 cumecs, but it is 275 kilometres long,



139. Upper Taieri scroll plain. Due to a geological feature downstream, the upper river has a very low gradient, and meanders widely across the plain. In spring freshes old ox bows fill again.

with a sizeable catchment of over 5000 km². It takes an unusual course. The headwaters are less than 40 kilometres west of Dunedin, but instead of flowing directly to the coast it takes a long horseshoe loop northwards, returning south to enter the Taieri Plains at Outram. From here on its course across flood plains it is connected with two shallow lakes which are in effect ponding areas. Leaving the flood plain the river has cut its way through the range of coastal hills south of Dunedin. The plains, therefore, have the nature of a very large basin with one exit only, the Taieri Gorge, through the coastal hills. This exit acts as a restriction to flood waters.

The Taieri Plains, although only 16 000 hectares in extent, are of immense importance to Dunedin. They are the only sizeable area of flat and fertile land in the proximity of the city.

Gold sluicing along the Taieri from the 1860s washed great quantities of silt into the river bed. The Waipori tributary was designated a sludge channel for mining. Silt was deposited in the two lakes on the plains and in the lower river, complicating already difficult drainage. Mining also led to the granting of many rights for the extraction of water from the river system.

Over the years, with costly drainage and some river protection work, the plains were brought into farm production. Townships and an airport were established on them.

In 1929 Dunedin City Council dammed the Waipori, forming Lake Mahinerangi, and built a power station on the river. Since then the dam has been raised twice and there are four power stations. An artifi-

cially created, uneven flow through the stations causes river problems lower down. The council also has rights to extract substantial quantities of water from the Taieri at Outram and to take all the water from Deep Stream, the Taieri's major tributary. A somewhat similar situation applies to another tributary, Silverstream.

An irrigation-cum-power scheme is now under construction in the Maniototo area of the upper river. There are a number of other calls on the river and further ones are planned. Many years of study and negotiation will be needed to unravel the tangled skein. The more important rights and problems—these are by no means all—are listed below:

Dunedin City Council's right to take 0.8 cumec plus some unspecified quantity for water supply from the Taieri at Outram;

The city's right to take all water from the Silverstream catchment upstream of, and including, Powder Creek, for water supply;

The city's right to take all water in Deep Stream for water supply;

The city's right to "impound, collect, divert and take away" all the water of the Waipori River and its tributaries for electricity generation;

The Maniototo Irrigation/Power Scheme;

The Mosgiel sewage discharge, which affects water quality in Silverstream and the Taieri and contributes to the eutrophication of Lakes Waipori and Waihola;

Tidal effects in the lower river and lakes affecting water quality;

Groundwater use on the Taieri Plains and by Mosgiel;

Fisheries, wildlife and recreational requirements. (The fish have to survive in a low flow which can be reduced to 1 cumec.)

The conflicts in this list alone would perplex any administering body.

The Taieri Flood, 1980

The Taieri River Trust—an early river control body—was left in existence in 1949 to deal with the complications of part of the lower Taieri; a sorry decision. An impossible task was made even more hopeless by the extraordinary boundary of the Trust's district. Part of it ran along the centre line of the river itself.

Very heavy rain about the middle of the catchment in June 1980 brought down the highest flood ever recorded on the river—2600 cumecs at Outram. This was the first major flood for 50 years. It raised the lakes, and water from them backed up the Waipori River and got behind stopbanks. Some 30 million m^3 of water flowed onto the plain, inundating about 5000 hectares to a maxi mum depth of 1.6 metres. Because of the low-lying nature of the country, the constriction of the gorge, and the difficulty of pumping—part of the area is below mean sea level and 27 kilometres of the river are affected by the tide—some water lay there for nearly two months. Momona Airport was unserviceable for almost the same length of time.



140. Saving a pedigree bull during the 1980 Taieri flood. (Otago Daily Times)

The overall cost of the June 1980 flood over the Taieri Plain was in excess of $15 million (1980 figure); all because of a remnant of past river control administration which should have been superseded when the 1941 Soil Conservation and Rivers Control Act was passed. A comprehensive Taieri Plains control scheme is certainly required. This must include all the lower river and tributaries, the two lakes and plains drainage. Use made of the upper river must also be part of the scheme. All the more reason for a total approach, because over the years, the Taieri

River has, after the Waikato, been subjected to the most complicated use of any river in the country.

The Clutha River

To the south and west of Dunedin and the Taieri is the catchment of the largest river in New Zealand, the Clutha, draining 21 022 km², or about 8 percent of the country. To Dunedin it is more remote than the Taieri but it forms an all-important backdrop.

Extensive headwaters, rising in the Southern Alps, gather in three large lakes impounded by glacial deposits. Lakes Wakatipu, Wanaka and Hawea still the turbulent mountain rivers and catch the detritus they bring down. The rivers from their outlets join to form the Clutha which flows in an entrenched bed until it reaches a small, infilled flood plain, Inchclutha, of 9300 hectares. Across this the river divides into two main branches, the Matau and the Koau, which empty into the sea separately. At one time the two branches joined and flowed a short distance southwards to the sea at Port Molyneux where the first settlers had high hopes of forming a harbour. A major flood in 1878 altered the mouths. Derelict wharves and a shallow estuary are the only remains of these early hopes.

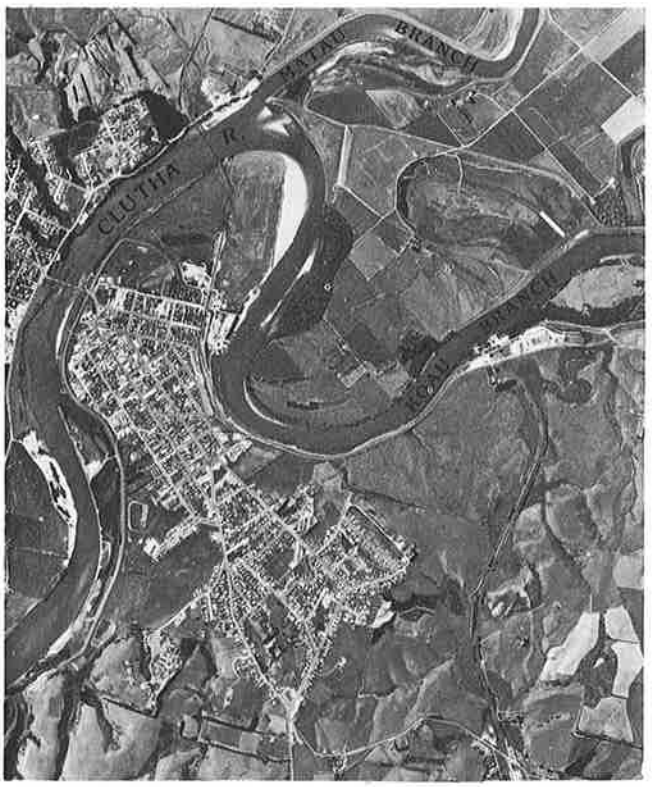
The 1878 flood is the largest recorded in the Clutha. It is thought the flow reached 5700 cumecs. Without control measures floods of this size, or even half the size, could inundate the flood plain, including all the settlement that has slowly encroached on to it.

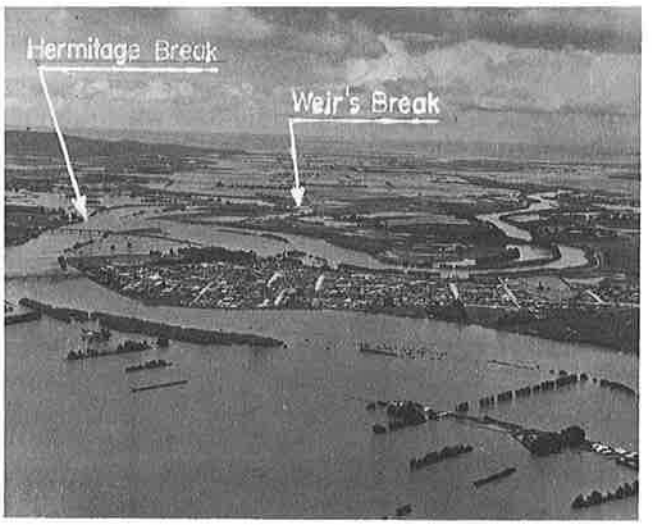
In spite of the buffer effect of the three lakes, rapid melting of the winter accumulation of snow can bring down floods. This happened in 1878. A great depth of winter snow was melted by a warm north-west wind and 36 hours of continuous warm rain were followed by two further periods of rain. The flood, which peaked three times, continued for three weeks. Lurid descriptions have been written of the effects. One reads;

> "... its angry surface strewed with dead horses and cattle, houses, bridges, furniture, timber and farm stacks. Some days the spring sun shone with a ghastly pleasantry on the devastated towns, while 100 miles away more heavy rain on the mountains was preparing still greater strength for the flood".

The Otago Catchment Board's control scheme consists of stopbanks from up-river of Balclutha and below it along both the Matau and the Koau, extensive drainage works, and pumping. Altogether, a total of 114 kilometres of stopbanks up to 6 metres in height and nearly 230 kilometres of drainage channels have been formed. The effectiveness of the scheme and the behaviour of the complicated mouths have been investigated by means of models.

The nation has become involved with the Clutha because of its hydro-electric potential—the second best in the country after the Waitaki. In 1956 the





141. Balclutha has grown up around a river and the crossing over the Clutha River. Stopbanks protect it from floods having a calculated return period of 500 years. Nevertheless the pressure of floodwaters forces some water under the banks and then it wells up as springs in the town. (NZ Aerial Mapping, Otago Catchment Board)

Roxburgh dam was built, and a series of others are planned. Operation of the Roxburgh station changed the flow of the river below it, introducing daily fluctuations of considerable magnitude. At present Roxburgh is used as a peak station. Consequently the daily peak flows "are of a size approaching the previous dominant discharge and their rapid repetition never permits banks to recover naturally", a thoroughly unsatisfactory situation.

The behaviour of the river mouths was altered by the power station operation in such a manner that flood waters could be held back, adding to the existing flood problems in the lower reaches of the river. In 1978, just 100 years after the devastating floods of 1878, this danger made itself clear. The Clutha broke its banks near the mouth and flooded two-thirds of the delta.

The small flood plain of Inchclutha and adjacent country, amounting to less than 0.5 percent of the total catchment, has proved to be one of the most difficult areas in the country to protect from flooding. Not only is farmland at risk, but Balclutha, situated in a horseshoe bend of the river, is a frightening place when a large flood is on the rampage. The strong currents of huge quantities of water have great power. Some water even finds its way into the town through layers of permeable sands under the stopbanks. The place is protected against a flood of the size of 1878 which, if it did happen to break the banks, would inundate some areas by up to 4 metres. What happens if a bigger flood occurs? It is essential that the series of dams to be built on the river system be designed for flood protection as well as electricity generation.

Some of the main tributaries of the Clutha are large rivers in their own right. The gold-bearing Shotover



142. Central Otago mountains well covered with modified tussock grassland. (J H Johns, NZFS)



143. Shotover River Catchment, Otago. Snowgrass tussock, severely burned, was later oversown to produce a cover productive for sheep. With the snowgrass was lost its water gathering capabilities. (J H Johns, NZFS)

joins another main tributary, the Kawarau, just below the outlet from Lake Wakatipu. The Shotover drains soft schist country, especially prone to erosion. Added to this has been the extensive churning up of the river bed by mining operations. The total result is a heavy bed load of schist sediment which is moved down-river to Lake Roxburgh.

Another tributary, the Pomahaka, flows through some low-lying land particularly prone to flooding. Small townships along it suffer frequently, and in a June 1980 flood the press reported:

> "Kelso was evacuated for the third time since the last '100-year-flood' in 1978"

Kelso is a prime example of the persistence of people living on flood plains. Even the dousing they have had over the years has not prevented restoration of buildings after each flood. Moreover, there is little prospect of a flood control scheme because the cost of one would be substantially greater than the value of the assets at risk.

Hydraulic Modelling

In order to help solve some of the difficult river problems the Otago Catchment Board has developed hydraulic modelling facilities. (It is the only catchment authority to do so). The lower Clutha control scheme, behaviour of the Clutha mouth, problems of the Taieri and a number of other control matters have all been studied by these means. Other organisations have taken advantage of the facilities, including the Dunedin City Council and the Board's neighbour, the Southland Catchment Board. The use of models has given greatly added confidence to designers of schemes and has resulted in substantial savings in capital works.

Vegetation, Rabbits and Soil Conservation

Over the years the Central Otago block mountains and inter-montane valleys have become noted for the paucity of vegetation that has replaced waving tussock grasslands. Much of the plant life that managed to persist consisted of flat-growing plants—native *Raoulia* in particular, that came to enjoy the name of 'scab-weed' because it covered the ground like a sore. Rabbits were undoubtedly the basic cause of this deterioration. Low rainfall did not help, but rabbits found a particularly congenial home in Central Otago.

The headwaters of the Clutha and about one third of its catchment is in a high part of the greywacke Southern Alps. Like the rest of the eastern Southern Alps the area was subjected to fire and over-grazing by a mixture of domestic and introduced animals. The huge amount of natural and induced erosion detritus brought down is trapped by the 3 natural lakes.

Between these lakes and Roxburgh lies more than another third of the catchment, mainly the block mountains and valleys. This area was subjected to the same treatment, but also became the special home of the rabbit. Below Roxburgh, and in the catchment of the Taieri, there are low mountains and downland, mostly covered by loessial deposits. Some erosion took place there where tussock or forest had been destroyed.

The Board soon after its formation recruited staff to survey its whole district and to introduce measures to restore vegetative cover. Similar approaches to those used all along the eastern Alps were used, but the Board had two special problems, the schist block mountains and the loess-covered downlands.



*144. Central Otago during the rabbit scourge. The effect of this animal plus fires and grazing by domestic stock led to the degeneration of the tussock and scrub cover to 'scabweed' (*Raoulia *spp.) and other weeds seen here. The elimination of rabbits, control of fire and stocking, and the introduction of run plans have allowed improved vegetation to come back. (MWD)*

Tussock on the flat tops of the block mountains and in the valleys had been transformed by misuse. On the mountain sides, the vegetation was more persistent. It was here that efforts were first made to improve the cover in order to bring the animals off the tops and to allow the runholders and farmers to improve the valley land.

No real headway could be made with this work until rabbits were controlled. This happened about the time soil conservation work was planned to go into operation. Subdivisional fencing used in soil conservation run plans permitted the controlled movement of stock out of harm's way and in this manner assisted materially the "killer" policy of the Rabbit Destruction Council. Within a few years rabbits were controlled and rapid progress was then made with farm and run plans.

In the downland country north of the Taieri—the catchment of small rivers coming from the Kakanui Mountains—rich farmland has been formed, but the area is subject to prolonged droughts. During these the dry loessial soils are readily blown by wind and the first rains may then erode the soils loosened in this manner.

A conservation programme has been planned for this area. Since water must be the key, irrigation forms the main part of the plan. The Waitaki River to the north is the proposed source. Other measures include establishment of shelter belts and community afforestation on the worst eroded land (Classes VI and VII). The proposed period of operation is 15 to 20 years.

Run and farm plans now cover 27 percent of the Board's district, a fine achievement in such a large and diverse area.

The Regional Water Board

When Regional Water Board duties were added to the Catchment Board's in 1968 there were already well-established uses of water, not only over resources like the Taieri but especially in the dry parts of Otago. It was clear from the outset that problems in drawing up allocation plans, as a basis for fair use, were going to be as difficult as those that had faced the Catchment Board when it undertook river control.

When gold was discovered in New Zealand it was of such economic importance that it affected the administration of water—not only for sluicing, but for other needs as well. Wardens, under the early mining Acts, had the power to grant water rights. In the dry areas these soon acquired value. Often the water had to be taken long distances in races

and licences were granted for these as well. Central Otago is noted for the number of races tapping the scarce supplies of water and traversing the dry country. When the gold ran out, some races were acquired for irrigation, with the result that there are now many small, private schemes scattered around Central Otago.

When the Regional Water Board took over it received 2706 notifications of existing uses granted under the mining legislation. Each of these had to be inspected to see if, in fact, it existed, and, if it did, to determine to what extent it was being used.

Another test of the new water legislation came when plans for further harnessing of the Clutha for electricity production were announced. It takes many years of investigation to produce final plans, and the Clutha had already been investigated for a long time before the 1967 legislation was even considered. The Government had the legal right to proceed but decided to apply for water rights. The procedures to be followed would then ensure that both national and regional aspirations would be aired.

The Board produced a Clutha Catchment Water Allocation Plan setting out what was known of the resources and their main features. The step was a notable one, but as may be imagined, because of the advanced stage that planning had already reached, it created great complications. Nevertheless, differences of opinion that had been surfacing for some time were now heard through legal and public procedures.

The first water rights applied for were for a proposed dam at Clyde. Objections, consolidated through environmental procedures, were mainly: that the proposals were single purpose and not multi-objective (this had applied earlier to the Roxburgh dam, to the great detriment of many people affected on the lower river); that the margins of the artificial lake would be difficult to manage; that fertile land would be lost; that scenic and historic attractions would be lost; and that stirring up the sediment lodged in the river in goldmining days would affect the lower river.

For a variety of reasons the situation became complex. Hydro-electric potential requires long-term investigation and planning. The interpretation of new legislation by law also takes a long time. Moreover one interpretation can be upset by another. Preliminary work on proposed sites can lead to complications.

To resolve the extreme complexities that arose around the Clyde dam proposals the Government decided to take special action. Whatever the pros and cons of this, the situation that had arisen served as a warning to all that it would no longer be possible to pre-empt a large body of water for a single use. The time for multi-purpose planning of the use of water, even if such planning included a dominant use, had arrived.



145. The narrow terraces along the Cromwell Gorge of the Clutha River proved suitable for growing pip and stone fruit, especially apricots, mainly because of a favourable micro-climate. The development of the river for hydro-electricity will drown these areas but irrigation will be supplied to land at higher elevations where orchards can be established on a much larger scale. (D L Homer, NZGS)

Tussock Grasslands and Water

An important part of the water story concerns tussock grassland. The essential functions of mountain tussock grassland are the catching and regulating of water, the protection of soil and the retention of detritus in its place. If the tussock land is to be used for production, however, which is the more valuable, animal production or water?

In the mountains, fog is an important moisture carrier. The large snow tussocks with their multiplicity of fine leaves catch moisture from fog, and in this way rainfall is supplemented. Professor A F Mark, a member of the Otago Catchment Board, has been examining this phenomenon for a number of years.

His work has shown that increased water supplies under large snow tussock are the result of substantial gains of moisture by the interception of fog. Before large snow tussock is replaced by other—usually lower sward—plants, consideration should be given to the question posed above.

There is little doubt that water is the most valuable product in many high mountain areas. Is this so in lower mountains where low alpine snow tussock is disappearing to make way for pastures? In a catchment like the Taieri this needs testing on a large

scale. Once gone, the snow tussock association cannot be replaced.

Abbotsford

In July 1979 a 7 hectare block of hillside at Abbotsford in Dunedin slid downslope at the rate of 3 metres per minute. "A graben [an area of subsidence resulting from tension] opened on the uphill side of the block as it slid away. Twenty-one houses dropped into it and lay wrecked in the torn earth". Altogether 69 houses were destroyed or damaged beyond repair in the landslide; a high toll for a calamity that should have been avoided.

Such slipping of large blocks of land is not uncommon where soft sedimentary rocks contain layers that can be wetted. The North Island East Coast has many of them, some extending over hundreds of hectares. But none have housing suburbs on them like Abbotsford, so they receive little attention.

Abbotsford demonstrated the forces at work in urbanisation. The most economic expansion of concentrated settlement is onto adjacent land from an area where services such as roads and water supply are already established. The economic arguments usually override technical objections. This happened in the development of Abbotsford. The insecurity of the area was known, but ignored. The process is somewhat similar to that of people persisting in inhabiting flood plains; the danger is known, but, "It can't happen to us".

It takes calamities such as Abbotsford or floods to bring together urban authorities and the Catchment Boards which have the technical background to advise on the safety of areas for development.

SOUTHLAND CATCHMENT BOARD

The Southland Catchment Board's district is made up of widely contrasting regions: rugged Fiordland National Park in the west, in the centre the Southland Plains crossed by rivers flowing from mountains in the north; and the Catlins, low mountain country, in the east.

Farming with Floods

"Given a good shake, drain pipes under the Southland Plains would rattle", so the saying goes. There are few more pleasing sights in the country than the green plains of Southland, excellently farmed, with sheep flocks in concentrated numbers on closely cropped swards. These and the neighbouring plains of Five Rivers to the north, the Waimea to the east



146. Southland Catchment District

The Southland plains, the high production of which has been achieved by difficult and intensive drainage, are the most important feature of the district. Much more striking, however, is Fiordland to the west. There, glaciation has left its distinctive deep, steep valleys. Heavy rain and many lakes make it possibly the wettest area in New Zealand. The lakes on the eastern side of Fiordland have been used for the production of hydro-electricity.

To the east of the plains is an area of low bush-clad mountains called the Catlins. Between the north of the plains and the Otago district are tussock covered mountains which contain rivers flowing southwards. These rivers flow near the surface of the plains and have often flooded them. (D W Lawrence)

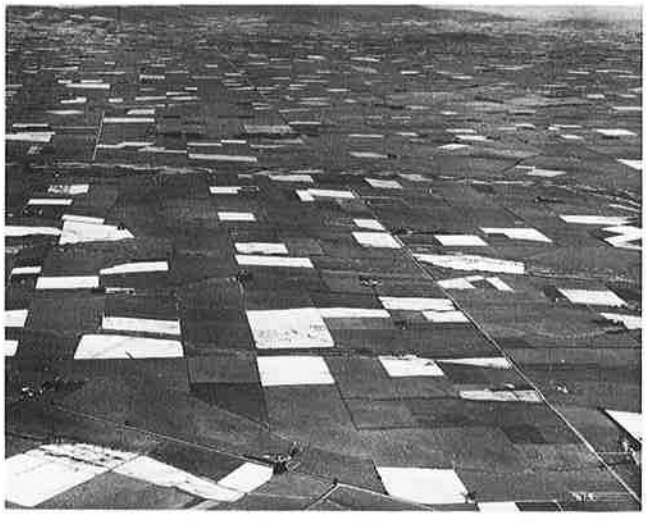
and the Waiau to the west, cover an area of 645 600 hectares, the largest high-fertility area in the country.

The plains have been formed by the shingle and silt deposits of melting glaciers and rivers flowing southwards from them to Foveaux Strait. In parts, very gentle fans were formed and rivers flowed close to the surface down these. Between the fans, and behind other glacial material, swamps were formed.

The cool climate encouraged extensive bogs of mosses. Over a long period of time a succession of bogs and swamps were covered by fresh river deposits which then compressed them to form lignite coals. The most extensive coal resources in the country are here, underlying top-quality pastures.

In their original state the Southland Plains were covered with a mosaic of vegetation. Forest had become established where ground was high enough for flooding not to affect it; bog where it was low-lying and constantly wet; and red tussock on sour, wet soils. No other region in the country had such an extent of this distinctive-looking red-tussock grassland. Plants were two metres or more high and grew close together. The areas on which it grew looked ideal for converting to agriculture, but drainage was the key.

The plains are ringed by mountains. In the north a series of ranges lie between them and the huge glaciated valley, over 100 kilometres long, containing Lake Wakatipu and the Dart River. At one time the water from the lake joined the rivers crossing the plains (the Aparima, the Oreti and the Mataura) and helped to form them. Now it adds to the waters of the Clutha flowing eastwards.



147. The Southland plains, reclaimed from bogs, red tussock and forest after a long struggle with drainage problems. One of the rivers that crosses them and used to flood regularly is to be seen through the centre of the photograph. (V C Browne and Son)

It was not until settlers began arriving in numbers from the mid 1850s onwards that penetration of the plains and swamplands began. Many townships sprang up along the Southland rivers but they suffered from constant flooding setbacks. The north to south flow split the district and made communications difficult. The Mataura in high flood could pond areas up to 4 and 5 kilometres wide. All the rivers could flood at once after several days of continuous rain around the mountains.

The nature of the Southland Plains was such that the first drainage produced fertile farmland, although much of it was floodable. Drainage here came before flood control, the reverse of events along most rivers in New Zealand. As a result capital investment is now there to help finance major river works.

The frequent floods resulted in stock and other losses, which were often high. The shingly riverbeds became choked with crack willow, gorse, broom and other noxious weeds. Floods had to find their way through these infestations and were all the higher for that reason. Sections of the beds aggraded to the level of the plain through which the rivers flowed. The townships along the rivers occasionally had to be evacuated.

The Catchment Board

Flood protection was at first attempted through River Boards and drainage was co-ordinated through Drainage Boards. These bodies proliferated. In the little township of Winton on the Oreti, 3 River Boards came into existence. At Otautau on the Aparima, a River Board was set up in 1910 with two subdivisions. In 1925 a third was added and, in 1929, a fourth.

A special Southland Land Drainage Act was passed in 1935 to provide for a higher standard of drainage and extensions of it. The Act was effective in bringing about widespread improvements to farmland. Nevertheless, the total number of boards had grown to about 15 by the time the 1941 Soil Conservation and Rivers Control Act was passed. The Southland Catchment Board set up in 1945 had the task of absorbing these and of assessing the widely scattered individual work.

There was plenty of hopeful support for the new Board, but confused thinking as to just what its role would be in the midst of the numerous River and Drainage Boards. The *Southland Times* expressed the feeling when it reported; "There are so many boards,

councils, committees and subsidary organisations that the plain man knows them scarcely by name and feels only a ripple of interest when a new and important body is elected".

The new Board found the Drainage and Rivers Boards, in the main, willing for their work to be taken over. Some did remain in existence but operated through the Catchment Board. That body initially put its greatest effort into land drainage, enlarging, deepening and straightening deficient watercourses. This activity received the maximum support from landholders because of the great increases it made to primary production. Some 1500 kilometres of watercourses have now been dealt with in this manner.

Drainage works are organised into drainage districts for planning and financing and for the sake of the maintenance that is so essential. In 1981 there were 93 drainage districts, a number which emphasises their importance.

The first meeting of the Catchment Board was attended by a member of the Soil Conservation and Rivers Control Council who advised: "The chief work will be the control of rivers, particularly in the lower reaches". But this nettle was not grasped for many years, so deeply engaged was the whole district in drainage and land improvement.

Floods, therefore, continued to take their toll and during severe ones in 1957 the local press forlornly wrote:

> "With the rampaging Oreti, Mataura and Aparima Rivers spewing their muddy, foaming torrents across the plains of Central Southland, the province was yesterday in the midst of what could well have been one of the most disastrous floods in its history".

Strong words in view of the fact that some of the earlier floods had been even larger. But still higher floods were yet to come.

A spate of floods hit Southland during the period 1975-80. A flood in 1978 was termed the One-Hundred-Year-Flood because the previous largest had been in 1878. But in 1980 another 'one-hundred-year-flood' occurred. Over these years, townships and farms have been evacuated, stock lost and much capital investment damaged. Costs of restoration have been high.

Major flood damage in the rest of the country is now uncommon because floods are contained by river works. So, questions are frequently asked; "What has happened in Southland?" "Why is river control not working?"

Improvement of the land and production has brought with it increasing demands for river protection schemes. For while improvement of the land was making great strides, the major riverbeds were deteriorating and becoming blocked with weeds and willows. The Board had been pointing this out for some time but it took the damage caused by the floods of the late 1970s to bring home to people the seriousness of the situation.

During this period almost every riverside farm on an 80 kilometre reach of the Oreti suffered from floods to an extent greater than at any time since 1935. Blockage of the major rivers was almost complete in some reaches, and floods overflowed previously safe banks and spilled onto the highly delevoped plains.

The position became so serious that urgent Government approval was obtained for major clearing schemes on the Mataura, Oreti and Aparima. Eighty kilometres of the Oreti and 60 of the Aparima were cleared in 18 months. This work set the stage for the follow-up stopbanking schemes which were designed for the three rivers.

The Makarewa-Hedgehope Drainage Scheme and the Oreti

The Board's first large-scale drainage scheme integrated with partial river protection was carried out on the Makarewa, a tributary of the Oreti and formerly the concern of the Makarewa-Hedgehope River Board. The Oreti has an average flow of about 52 cumecs. It rises in the mountains between Lakes Wakatipu and Manapouri and flows to the New River estuary on which Invercargill is situated. The Makarewa drains 1090 km^2 and although it has an average flow of only 7 cumecs, the flood plains along its lower reaches could be flooded up to 20 times a year. The scheme was designed to drain this land and at the same time reduce flooding to about once in 5 years. It included work on 160 kilometres of main channels, the shortening of these by some 10 kilometres and the excavation of more than 4 million m^3 of soil.

The scheme did nothing for the Oreti itself, except possibly to add slightly to the speed of flooding in its lower reaches. During the 1975-80 period it experienced 8 floods. One in October 1978 resulted in the closure of Invercargill Airport for more than 2 weeks and the evacuation of residences in the western suburbs of the city. These events strengthened the many approaches which, by that time, were being made by landowners to the Catchment Board for a flood protection scheme. Prior to 1975 a 50-year flood on the Oreti had been calculated at 500 cumecs. Over the next six years eight floods were experienced ranging from 525 to 815 cumecs.

The Catchment Board has now prepared a scheme which will "include all facets of water and soil conservation from the Eyre Mountains to the sea and will embrace all the existing or partly prepared scheme work in the catchment".

A remarkable diversity of work is required, as is exemplified by only one part of it: a proposal to build a flood detention dam on the Winton Stream, a small tributary of the Oreti. Forty millimetres of rain is enough to flood over 2000 hectares of the best farmland. The stream channel is clogged and bridges act as constrictions, (there are 24 bridges in all crossing the stream: 16 road, 7 farm and 1 rail).

The upper Makarewa is being examined in the same detail, because, to improve the flood return period of 5 years, similar types of works will have to be done.

The Aparima River

West of the Oreti a smaller river, the Aparima (with less than half the average flow of the Oreti), drains a catchment of 1260 km². It rises in the Takitimu Mountains and low hills near them. Its flood peaks are not large; the highest reached being 1000 cumecs. Nevertheless, in the lower reaches floods spread over the western part of the Southland Plains.

The late 1970s floods on this river drove farmers to petition the Catchment Board for a comprehensive flood control scheme. The Catchment Board has undertaken works along the river which will eventually join up in a complete scheme. This is the same plan of attack as that adopted for the Oreti.

The Mataura River

The Mataura is the most important river in Southland. It drains 5360 km² between the catchments of the Oreti and the Clutha and has an average flow about the same as that of the Manawatu. It flows across the plains, and has flood plains of its own extending over 30 000 hectares—about the size of those in the lower Manawatu.

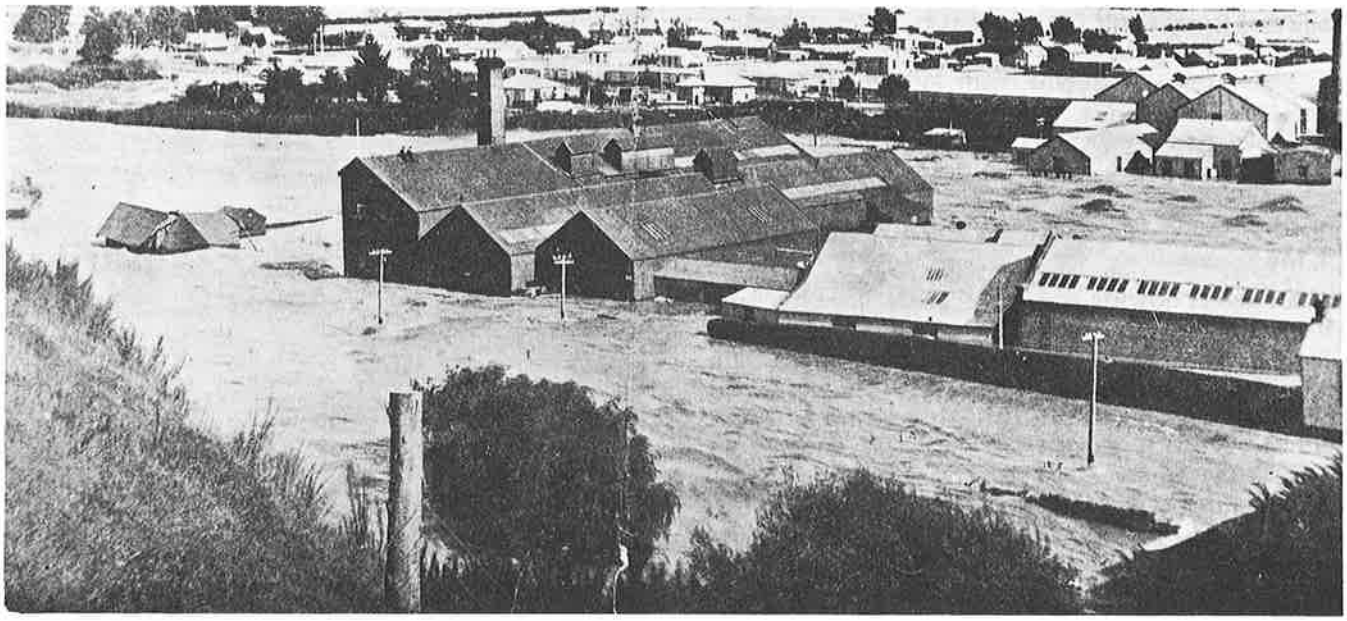
The highest point in the catchment does not reach 2000 metres. The greater part of it is developed, including much recent cultivation of wet tussock grassland in the upper reaches. Erosion has developed in the mountainous part of the catchment.

Several townships including Gore, Mataura and Wyndham have grown up along the river, all of them partly on flood plains. A substantial part of the capital invested in the Mataura Catchment is within flood reach, behind stopbanks erected in the past, but never adequately protected against major floods. Many emergencies have occurred and much damage been done to farmland, townships and industries. During the October 1978 flood virtually the whole of Mataura township was under water. Ninety percent of properties were affected one way or another and 60 percent of homes damaged. In excess of $9 million of immediate damage (1978), plus long-term damage, was the burden placed on the small community. This township and that of Wyndham had to be evacuated for several days.

Apart from the threat of general flooding, Mataura township has special problems. It draws urban and industrial water supplies from the river, which flows here through a rock channel with a freezing works on one side and a paper mill on the other. From time to time both industrial works have suffered flood damage, sometimes extensive. Moreover, during large floods they add to the flood hazard because they constrict the flow. To overcome this problem will be a difficult and costly part of any river control scheme. The Southland Catchment Board has commissioned the Otago Board to construct a model of that section of the river. It will be used to test the effectiveness of a number of channel improvements between the two industrial plants.



148. A paper mill and a freezing works on either side of the Mataura River as it flows through Mataura draw large quantities of water at a convenient site where the river is constricted by rocks. Both factories were built in the days when it was legitimate to dispose of raw effluent into rivers. Both suffer from flood damage. Model studies are required to produce adequate flood control measures. (MWD)



149. 1913 Mataura River flood waters outflanked the freezing works and the paper mill. (Southland Catchment Board)

The 1978 flood and others in the 1975-80 period alerted a nation that had become complacent about flooding. Throughout most of the country river works contain these events. They were no longer news. The Southland—and the Otago—floods were a rude shock and a reminder of how difficult our rivers are to control. Piecemeal works are totally ineffective at these times; or even worse, give a false feeling of security.

Why were the Southland rivers not controlled? What had the Catchment Board been doing? The Board had, as explained above, been doing a great deal, including gathering information for a total catchment control scheme for the Mataura. In the presentation of it, however, the Board could not move faster than electors were prepared to go. They seemed to have become inured to flood damage, possibly through having lived with it so long; but recent flooding was too much. In the face of these calamities the Board obtained ready acceptance for the principle of a whole catchment scheme and soon obtained Government approval for it.

The following problems that the Board was initially confronted with illustrates the complexity of its the task on the Mataura: inundation of the flood plain at frequent intervals (30 000 hectares in 1957, 1968, 1972); serious growth of willows in the main channels and tributaries; a diminishing resource of low flow, high quality water for industry and for recreation; lack of co-ordination of earlier catchment works; serious erosion in the upper catchment; wind erosion on the Waimea/Waikaka Plains; loss of effectiveness of earlier schemes due to subsequent farming development; loss of recreational amenity and wildlife resource areas.

The Board planned the total catchment scheme in 2 phases: first, the clearing of the river, protection of the banks and management of a floodway; secondly, the development of 8 subregions in which erosion (including wind erosion), the possible erection of flood detention dams, and so on, would be dealt with.

Separate rating was to cover the different groups of works, but of particular interest was the proposal to have community funding for a flood warning system, recreational improvements and strategic firebreaks across mountain tussock land.

The most difficult problem of all arose in the peaty farmlands along the lowest reaches of the river. They flooded much more frequently than any other section and in winter became a quagmire. Some of the land had sunk since development and in places foundations for stopbanking were impossible. The Board, therefore, purchased part of the farmland and now manages it as floodway.

Work on the scheme is well underway. One of its pleasing features is that a change in public attitude since the serious flooding has enabled the Board to rate the hill country for works to correct river problems. It is now recognised that these have been accentuated by increasing development for pasture of a considerable area of foothill country. The conversion has often been assisted by the ready avail-

ability of Rural Bank finance that is not matched by an input of Government funds for improve ments necessary for the downstream farmer. The rating district for the whole scheme extends over an area of 545 000 hectares, a rewarding co-operative effort.

The Regional Water Board—Problems on the Plains

All the rivers flowing across the plains have become vital regional water resources, for which under the 1967 Act the Catchment Board is responsible. The rivers supply the rich farmland with stock water and the townships and Invercargill with domestic water. Industries, in particular freezing works, draw from them. They are widely used for recreation, especially fishing. The importance of managing this resource has become as great as that of flood control.

During a drought in 1956, the whole of the low flows of the Mataura and the Oreti could have been extracted under existing water rights. Droughts can occur in any year and affect any of the rivers.

Extensive land development has recently taken place in the rolling tussock grasslands of the middle and upper catchments of the rivers. These damp, swampy and boggy grasslands act as water reservoirs and help to feed the low flows of the rivers. In addition, the tall tussocks collect extra water during foggy weather. The loss of these areas will, therefore, affect the nature of the river flows, but to what extent nobody is yet in a position to predict. It is known that in the Aparima, for example, 65 percent of the low flow originates in the mountainous tussock area making up 17 percent of the catchment. These problems give additional emphasis to the importance of the high altitude tussock investigations at Otago University.

A River Lost

In the west of Southland is the magnificent Fiordland mountain country, carved by ice out of hard gneiss rocks. Even though these are still ice polished, and have formed little or no soil, they have become covered with vegetation since the ice retreated. Here are all the classic shapes of an ice-formed landscape: U shaped valleys with sides sometimes sheer and hundreds of metres high; cirques; hanging valleys and deep fiords where the sea has penetrated. Innumerable lakes have been shut in by moraines containing boulders as large as houses between which the water pours as through a gigantic sieve.

The general altitude of Fiordland is lower than most other parts of the Southern Alps, the highest point being little over 2000 metres. Nevertheless, rainfalls



150. More than one million hectares of hard rock was gouged out by ice during the last ice age to form Fiordland. Vegetation clings to the steep valley sides and covers the valley floors but this does not prevent rainfall of 10 000 mm or more per year from frequently flooding rivers and lakes. Fiordland probably receives a greater concentration of water than any other part of New Zealand. Water flowing to the east accumulates in a series of lakes, including Te Anau and Manapouri, where it is harnessed and sent through to Doubtful Sound on the west coast. (NZ Aerial Mapping)

are as extreme. During high intensity falls, water moves over the whole surface for it cannot find its way down through the hard, polished rock. Lakes rise and fall rapidly. It is country for only the hardiest.

Water falling to the west of the Main Divide flows into the fiords, but that falling to the east of the watershed flows into a series of lakes, the two northern ones, large and well known, being Te Anau and Manapouri.

There are also three sizeable lakes to the south of these: Monowai, Hauroko and Poteriteri. Te Anau empties into Manapouri and this in turn flowed into the Waiau River which collected the water from Lake Monowai on its way to the sea. The Waiau was a short river with a large, swift flow—an even flow, too, because of the regulating effects of the lakes.

As early as the 1890s, many years before the Regional Water Board was formed and a stocktaking could be made of water resources of Southland,

plans were afoot to use this resource for electricity generation. What more simple than to dam the Waiau, using the bed as an overflow channel, and send the main flow of water through the mountains to a neighbouring fiord, Doubtful Sound, generating power from the fall of 180 metres on the way? The Manapouri-Te Anau Development Act 1963 authorised the use of the lakes and the diversion of the Waiau for just such a scheme.

A few years later, under the 1967 water and soil legislation, the Southland Regional Water Board found itself the body charged with the local management of natural water in Fiordland. It had to be concerned with the water resources of its whole district and their best use and the effects of that use. The production of electricity was only one of many uses, and the Board was charged with studying the interaction of all of them. To complicate matters still further, the lakes are within the Fiordland National Park and subject to the National Parks Act which has definite prescriptions concerning conservation.

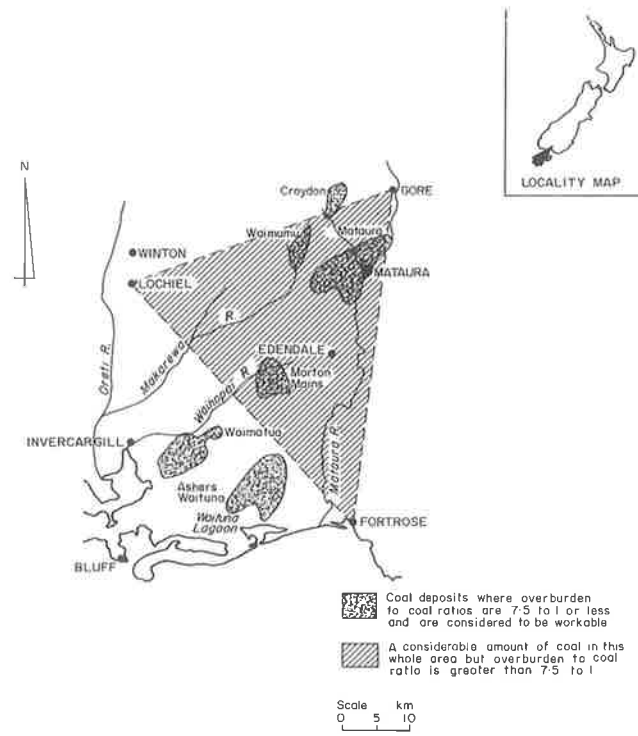
But this was rather shutting the stable door after the horse had bolted. Electricity generation inevitably imposed severe restrictions on some other uses and the 1963 Act overrode the National Parks Act. Only the persistence of the Save Manapouri Campaign prevented the raising of Lake Manapouri by a further 27.4 metres to produce a greater head of water for power production.

Even so, in this development Southland lost its best water resource. People's eyes were fixed on the two lakes; they overlooked the strong, swift river that emptied them. Now it is a puny thing, deprived of all the lake water except in times of overflow. What could have been future uses of the river are now lost.

The lakes and the river are but part of an extremely diverse catchment. About half is in Fiordland National Park, but the other half is easy to rolling country with at least 65 000 hectares of fluffy soils formed following glaciation. These have been developed by the Department of Lands and Survey. The Catchment Board has made provision for shelter belts to prevent wind erosion of the light soils and to protect watercourses which can deteriorate rapidly because of changed run-off conditions. Streams will be fenced to preserve natural vegetation along the banks.

Lignite

Southland and Otago lignite deposits are known to be extensive. Those in Southland could be of the order of 4.4 billion tonnes in six major fields, all of them under good farmland and some of them as deep as 300 metres, so that substantial mines will be necessary if they are worked.



151. Lignite coal deposits lying under the Southland plains.

If mining does take place, what of the land? Can the overburden be replaced so as to restore productivity? Can the expensively developed drainage, which must be destroyed during mining, be restored afterwards? A considerable depth of material could be removed. Some current shallow excavations are already filled with lakes. Are parts of the Southland Plains going to become a series of artificial lakes? Groundwater movement would be altered by mining. How would this affect flows and water supplies drawn from rivers that are already overtaxed during low flows?

The Catchment Board has a key role to play in presenting the issues of land use and water use in relation to drainage and river protection and control. It has already had to face additional costly problems where past dredging and sluicing for gold have complicated flood protection measures in river beds. The extraction of lignite could bring infinitely more severe problems.

Planning

Major efforts are made by the Board, in both the water resource and soil conservation fields, to assist planners in district and regional planning. This is

especially important in avoiding the siting of buildings in floodways. The Board is asked to comment on every building permit applied for where a potential for flooding exists. Aerial photographs taken during floods have assisted many landowners, lending institutions, local authorities and insurance companies to make decisions which take into account dangers in the future.

Water resource studies have been made to assist investigations into possible new industries such as pulp and chipboard mills, peat, lignite and gold mining, and silicon and gravel recovery.

The Board has established itself as the major regional source of information in planning for the wise use of water and soil.

MARLBOROUGH CATCHMENT BOARD

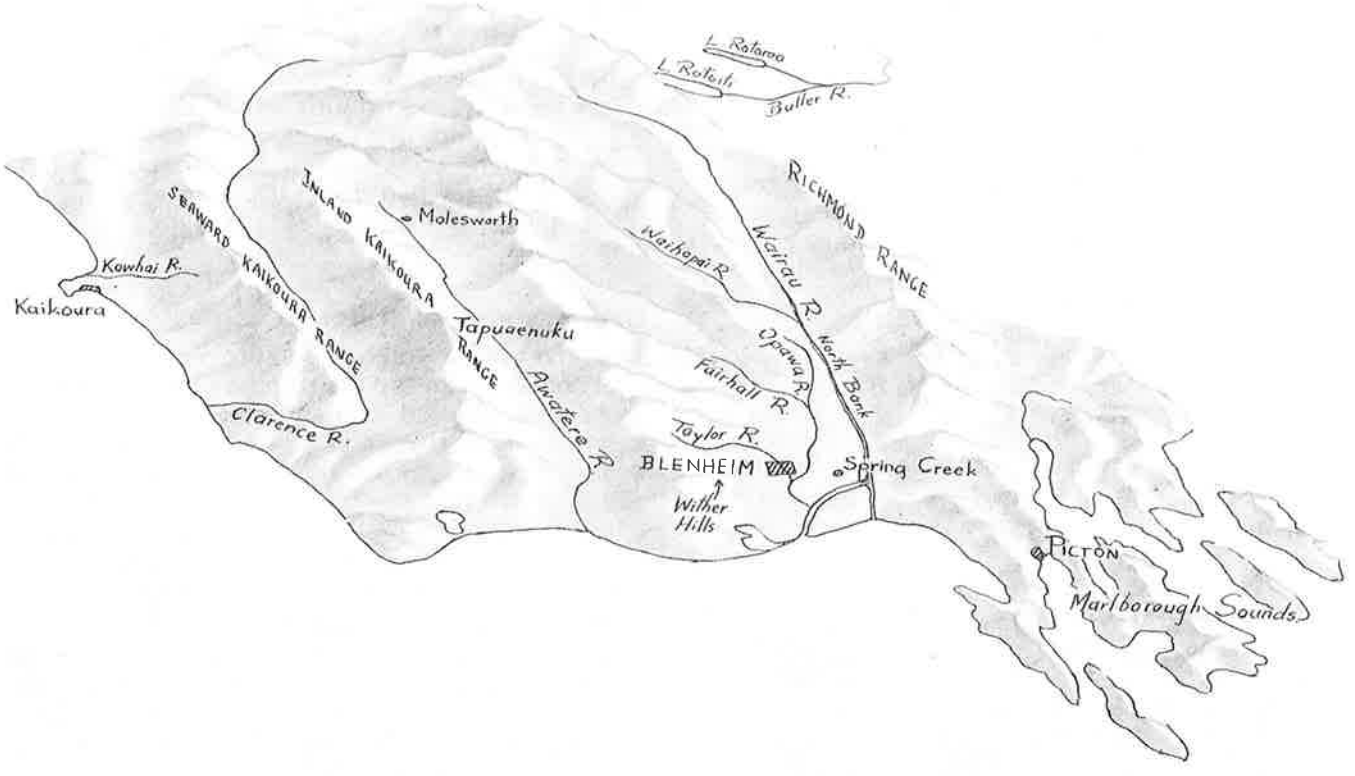
The Rising and Sinking Land

On a clear winter's day snow-covered Tapuaenuku in the Inland Kaikoura Mountains can be plainly seen from Wellington, over 130 kilometres away. Rising to nearly 3000 metres its peak heralds to the North Island the chains of mountains diverging to the east from the Southern Alps. They extend parallel to long fault lines that are thought to cross under Cook Strait to Wellington and the Wairarapa. One of them, the Wairau Fault, is connected with the Alpine Fault that continues the greater length of the South Island. Land has been sliding apart along this for millions of years. Features once opposite each other on the two sides, are now separated by 450 kilometres, For example, the same type of rock that can be found on the north bank of the Wairau River in Marlborough appears also in Otago.

Between the mountain ranges, rivers flow along the fault lines: the Clarence between the Seaward and Inland Kaikouras, the Awatere to the north of the Inland range, and still further north, the Wairau, the largest of them all with an average flow of 118 cumecs. It rises near Lakes Rotoiti and Rotoroa but does not drain their water. The Buller does that, flowing in the opposite direction to the west coast.

Faulting, mountain building and extensive glaciation have formed the rugged high country of this north-eastern part of the South Island. The lakes, the steep valleys, the remnants of talus slopes, the loose rock and boulders, the shingle rivers with steep gradients, all testify to the extent of ice age effects. In addition deep loess soils occur here and there.

Only the Wairau has formed any extent of flood plain and this occupies but 4 percent of its catchment of about 4000 km². The river flows for 150 kilometres and for two-thirds of this length its course is almost a straight line along the fault and across the small plain formed from glacial and river-borne material.



152. Marlborough Catchment District

Ranges of mountains alternating with major faults occupy most of the south-eastern part of the district. The remainder is taken up by the Marlborough Sounds, a sunken mountain area. Three large rivers flow down the faults. One of them, the Wairau, has formed a sizeable floodplain in the lower reaches. Blenheim sits on one side of it. There are good supplies of underground water under the plain. The mountainland is relatively dry and was severely eroded before control measures were introduced. Land use in the Sounds is complicated by the general lack of water and by a variety of seawater uses which require unpolluted water. (D W Lawrence)

Near the mouth the river changes direction to the south and enters an estuary. Gravel—from coastal cliffs and the Awatere River to the south—has been moved northwards by currents to form a long gravel bank. The Wairau has over time broken out at various points, but evidence suggests that the present mouth has not moved for many centuries.

Settlers crossed the bar and rowed in long boats up the Opawa, a small, meandering river that emptied into the Wairau estuary. They settled on land that seemed to be above the flood plain. Although virtually surrounded by swamps, it had a fan of high land giving good access to the pastoral lands of the Wairau and Awatere Valleys.

Their township took the august name of Blenheim, but surveyors who laid the plains off about 1847 quickly dubbed it "The Beaver". The high ground proved to be the fan of a small river coming from the Wither Hills behind the site. Heavy rains flooded down the sides of this fan into Blenheim, joining flood waters from streams feeding the Opawa, which itself acted as an overflow channel for floods from the Wairau. When the flood waters all met, which was frequently, Blenheim was inundated.

Other tribulations were to appear. An earthquake in 1848, centred under the Wairau Plains, and the 1855 earthquake that affected the lower Wairarapa and Wellington, dramatically damaged the Wairau Valley. From 21 January 1855 the earthquake "continued more or less continuously for nearly three weeks. Nearly every mud whare in the Wairau came down". Land was lowered by the earthquake, "but of greater consequence than the depression of the land was the corresponding deepening of the Opawa River" (*Marlborough*, edited by A McIntosh). This benefited navigation in the long run as it was found that schooners could cross the bar and sail up the river to Blenheim. On the other hand the earthquakes lowered the Blenheim side of the valley by perhaps nearly 2 metres and this may have aggravated flooding.



153. A novel way of 'going through Customs' during a flood in Blenheim, 1911. (Marlborough Catchment Board)

In spite of these odds, settlers persisted in developing the township. From the beginning a battle had to be waged against water. In February 1868 there occurred a 'Great Flood' throughout the north-eastern part of the South Island. WTL Travers, a lawyer and naturalist, travelling on horseback between Christchurch and Nelson, has left us a description of the event. In it he comments on yearly burning, deforestation and the erosion following burning of the beech forest. Then he describes the flood, in which the water extended right across the flood plain:

> "From hill to hill there stretched an unbroken sheet of water, which swept on towards the sea, carrying upon its bosom the dead and drowning sheep, the ripened corn sheaves, and even goods and chattels of the water-logged farmers".
> (quoted by T L Buick in *Old Marlborough*).

The local newspaper tells the town's tale of persistence. During one especially severe period in 1893 this account appeared:

> "Again the town has been inundated with Opawa back-water, and this time to a greater height than has been the case during winter. We have now had nine floods in 11 weeks, each of them being of sufficient size to entirely suspend business operations for two days". (*Daily Times* , September 1893).

Drainage and River Boards

The prizes to be won by flood prevention were the safety of Blenheim and the safe use of the flood plain in a climate blessed with an even better record of sunshine than its neighbour and rival, Nelson. A Drainage Board and two River Boards were formed about 1874. The Drainage Board set itself the task of safeguarding Blenheim, and the two River Boards concentrated on protecting the development of farmland and a much smaller settlement, Spring Creek, on the banks of the Wairau itself.

One way of reducing the flood threat to the Spring Creek area was to send more floodwater down the Opawa from the Wairau. An enthusiastic settler enlarged the overflow channel. The flow cut into the shingle banks and began to form an increasing threat to Blenheim. " . . . successive floods rushing through this opening quickly enlarged it, forming a channel 20-30 chains in width, carrying away many hundreds of acres of good land and causing disastrous floods". (Report of the Wairau River Commission.) A major flood could, at any time, have enlarged the channel still further and diverted the Wairau main flow into the Opawa. It would have

been impossible for the bed of that river to have passed such a flow. All manner of complications followed this action, including a court injunction to prevent the breach from being closed.

Many partial works were undertaken without adequate basic data or engineering design. Fierce competition over protection works developed between individual settlers, between the Boards, and, more tragically, between town and country who depended one upon the other. Structures were interfered with and, at one stage, the Lower Wairau River Board posted a 'rabbiter', armed with a shotgun, on a work it had constructed but feared would mischievously be destroyed.

Rivalry sometimes ended in the courts, and it was during a Court of Appeal case in 1917 that the local bodies of the area persuaded the Government to set up a Wairau River Commission.

One of the members was F W Furkert, an inspecting engineer of the Public Works Department, who was widely experienced in river problems throughout the country. The Commission recommended a board with a district which "shall include the whole of the watershed of the Wairau River and its tributaries". The amalgamation of the existing Boards took place in 1921. While neither the conditions of the time nor the law allowed its region to include the whole of the Wairau catchment, the unified body did achieve a considerable measure of river control, and support for it was strong enough to cause opposition to the setting up of a Catchment Board under the 1941 legislation.



154. The Wairau River pouring over a stopbank at Spring Creek during a flood in 1962. (Marlborough Express)



155. Gully erosion in loess soils on the Wither Hills on the outskirts of Blenheim. This erosion was destroying the farming of the Wither Hills and at one time constituted a threat to Blenheim. (MWD)

The Marlborough Catchment Board

Floods in 1954 and 1955 and a growing appreciation of the extent of erosion throughout the hill and mountain country changed attitudes, though not without a fight and an Act of Parliament to annul the first scheme proposed.

By now the thick loessial soils on the Wither Hills behind Blenheim had become full of deep channels and under-runners. The fine silt washed out of these kept filling drains constructed to protect the town and even affected part of the town itself.

The Marlborough Catchment Board was formed in 1955, the thirteenth such board, and more than 10 years after the first was established. It absorbed the local River and Drainage Boards, but the Sounds and Awatere areas remained out. The Awatere is a deeply entrenched river with few protection problems. The runholders there chose to ignore the extensive and serious erosion in its catchment. In the neighbouring country the Molesworth and Tarndale runs occupied some 200 000 hectares in which degeneration had become so severe that the land had reverted to the Government.

Farming occupation of the Sounds was sparse. Communications were difficult, depending often on boats. Water supplies were very poor. There were no rivers and few streams. Farmers considered they had no erosion problems—or perhaps they had no time to consider them.

The Wairau Flood Protection Scheme

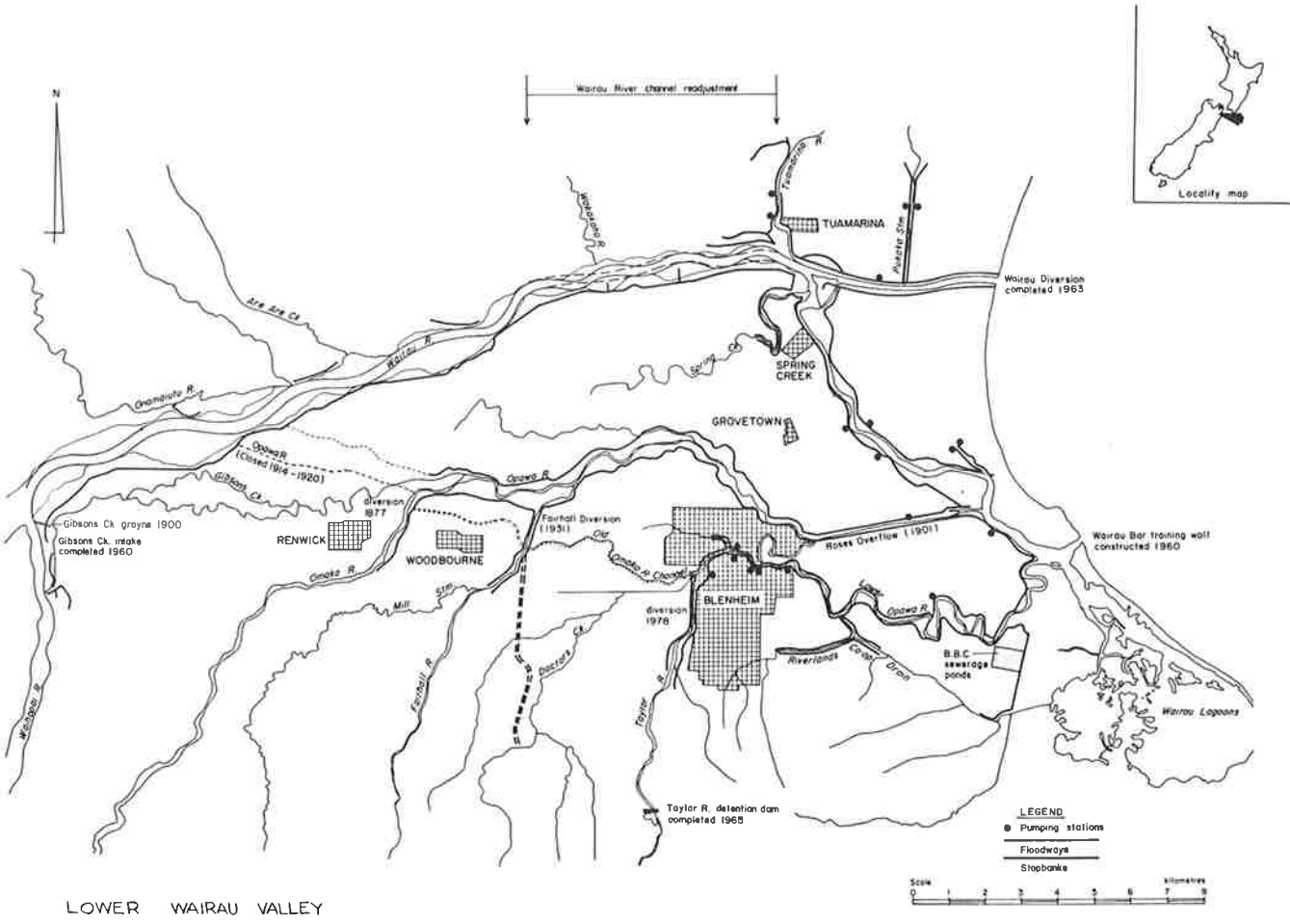
The Catchment Board lost no time in designing a flood protection scheme for the Wairau and Blenheim. There was a long history of the effect of disasters and of the results of partial control to guide the planners. By 1959, a scheme had been approved. Work was commenced at once and some structures were in operation by 1960. The day following the completion of major works in 1975 the largest flood since 1868 (4700 cumecs) tested the system, which came through with flying colours.

The total scheme included many works, amongst the most important of which were: channel clearing, stopbanking and other work along the main river channel; sending the river along a straight course to a northern sea outlet instead of letting it turn south to the Wairau bar; major drainage works which include some 25 pumping stations with 40 pumps; and the building of a detention dam on the Taylor River.

Blenheim and an area of about 16 000 hectares are now free from major flooding. Extensions to the scheme are continually being undertaken—especially training of the river to a defined channel. When this is successful, much of the wide shingle bed can be reclaimed for farming which must never be regarded as permanent because of need to retain an ample flood channel.

Soil Conservation in the Wairau Catchment

The Wairau catchment constituted 80 percent of the Board's original district. It is similar to the catchments of many other rivers that rise on the east of the Southern Alps. A land use capability survey of the Wairau Valley undertaken almost as soon as the Catchment Board was formed revealed problems common to the greater part of the South Island high country. Only one-fifth of the catchment is flat or gently rolling; the remainder is steep to very steep.



156. An outline of the main features of the complex scheme of flood control works safeguarding Blenheim and preventing flooding of the lower Wairau plain. In addition, pumping stations achieve the drainage of both areas. (Marlborough Catchment Board)

One difficult and important measure was first introduced in a plan for the Rainbow Run near the head of the catchment. This was fencing off stock from the badly eroded top country. The animals displaced were accommodated by improving part of the lower country. This destocking measure, necessary for the economy of the runholder, has been introduced into many other run plans.

A cover of trees was considered necessary to hold some of the most heavily eroded high country. Experimental planting has been undertaken by the Catchment Board on Crown Land and by the Forest Service on State forest land. It is too early to tell the long term effects of this, but one of the short-term effects has been to demonstrate the possibility of the spread of contorta pine on to grazing country. Runholders have become alarmed and demanded its elimination or control. Unless controlled the tree could certainly spread over large areas of inaccessible country as it did in the central North Island.

Wairau North Bank Afforestation

The north bank of the Wairau is separated from Nelson by the Richmond Range which rises to about 2000 metres. The rainfall is higher than throughout most of Marlborough and in pre-European times the land was covered with mixed beech forest. From the time of settlement forest was cleared up to 600 or 700 metres; rapid reversion led to frequent burning, which, in turn, led to the spread of weeds, particularly gorse, and the onset of erosion.

In the Wairau Valley Scheme, steep country of the north bank was demarcated for afforestation. The Catchment Board negotiated with a number of Marlborough local bodies to form the Marlborough Forestry Corporation. As agent for this organisation the Board developed the Edwin Meachen Forest, named after its first chairman.

Afforestation by the Forest Service and other bodies is also taking place along the north bank. The whole scheme is a good example of the influence that a Catchment Board can have on the development of improved land use. (The Nelson Catchment Board has moved along the same lines but has not become involved in afforestation itself).

The Marlborough Sounds

While the mountains in the north-eastern part of the South Island region have been rising and gathering rivers, the land in the northern extremity has been sinking and forming the Marlborough Sounds.



157. Picton on Queen Charlotte Sound. Largely cleared at first for farming, the land on the ridges between the Sounds reverted to second growth because of poor soils, lack of water, difficult communications and the very limited flat land. Now land use must be carefully replanned because of many differing demands on both the land and the sea. (V C Browne and Son)

There, the mountain tops rise to little over half the height of the Kaikouras. The ancient river beds are now under the sea, and the steep sides of the drowned valleys form intricate shorelines with bouldery beaches.

Pioneer farming in this intricate area largely failed. Lack of access and communications, absence of flat land, the presence of poor soils and steep country, reversion to second growth, and, above all, the scarcity of good water supplies were obstacles that could not be overcome.

Over the years, boating and fishing have increased throughout the area, and the shoreline has become occupied by settlements and cribs. The farmland behind has reverted and has since been sought for afforestation or reserves.

Land use has now been complicated by the cultivation of green mussels in parts of the Sounds. By 1982 there were more than 300 mussel farming licences, averaging about 3 hectares. The sea water in which mussels are farmed must be uncontaminated. Can the water be kept clean if the land leading to it is farmed or managed for forest or occupied by dwellings?

The Sounds area joined the Catchment Board district in 1977. Throughout the area, the Board has an increasingly important role. Where farming is successful, there is some sheet erosion. Farm plans containing measures to cure this also help farmers with their overall management. Conservation measures to improve water supplies include the fencing from stock of pockets of bush to improve their water catching and regulating ability.

Use of the Sounds is bound to become intensive for farming, forestry, fishing, recreation and residence. The foundations for good water and soil conservation practices in the midst of these developments are now being laid.

Kaikoura Problems

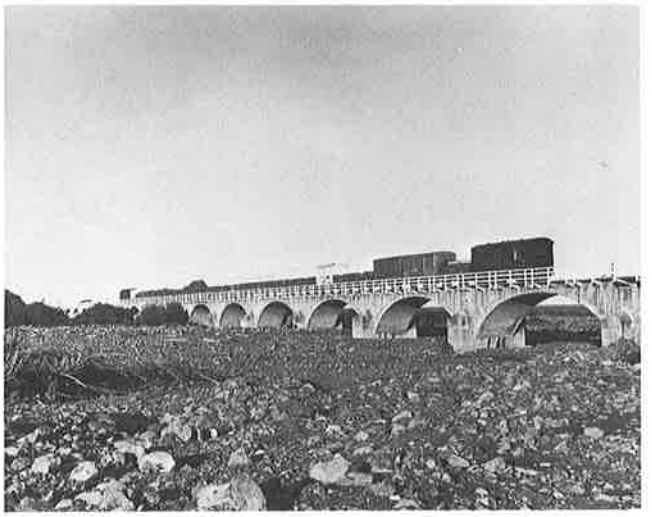
In 1966 the Kaikoura area came in with the Catchment Board. It wanted to be included initially but had been omitted. The small peninsula, jutting out from the Seaward Kaikoura Range, and the 2000 hectares of flattish land beside it, had been the home of Maoris, whalers and then settlers. Fans formed by torrents cascading down the mountains made up the flattish land.

Mount Fyffe immediately behind this area rises to 1500 metres. On its inland faces the Kowhai River rises. Gathering water from a catchment of little more than 6000 hectares, the river flows down bed slopes with a fall averaging 20 metres to the kilometre and is perched precariously on top of a fan. Flooding is frequent and brings down a large bed load, ranging from silt to boulders 2 metres or more in diameter. Side overflows readily occur and complicate both the flow of the river and the movement of bed material.

The Kowhai is typical of thousands of streams and rivers that issue from the South Island mountains, but few others are in such a position that they constitute a constant threat to townships and communications.



158. Kaikoura, an 'oasis' of flat land on the east coast between Blenheim and Canterbury. The town's communications are threatened by the Kowhai River, seen to the left. It emerges from the Seaward Kaikouras and flows in a steep gradient down a fan which the main road and railway have to cross. (MWD)



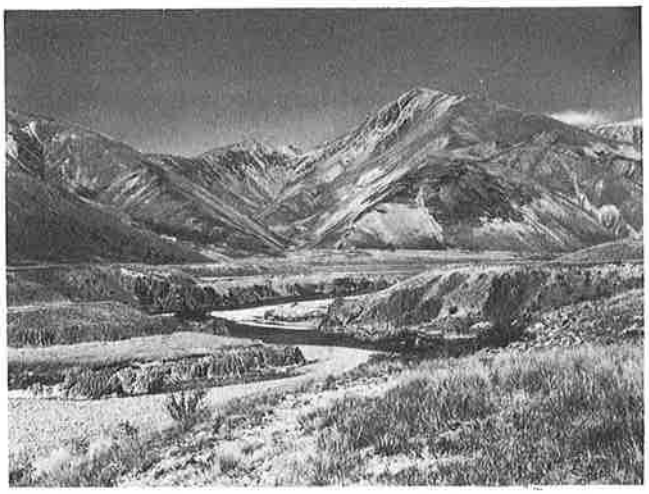
159. A railway bridge crossing the Haupuka River, north of Kaikoura. The river carries very large quantities of detritus down a steep fan, which creates difficult problems of control. (NZ Government Railways)

"Work commenced on this river 100 years ago and today only a minor degree of control has been attained". This was the summing up of the state of the Kowhai River when the Catchment Board, in 1969, drew up a scheme report for Kaikoura. The township, the main trunk railway and State Highway 1 were all threatened when this little river flooded.

Protection of Kaikoura township and drainage of the limited area of farmland—the only flat land for 70 or 80 kilometres along the coast—were vital to the area. Storms could hit Kaikoura severely. In the 1868 storm which had flooded the Wairau, houses and farmland at Kaikoura were washed out to sea. Work is now being done on both the catchment (to improve the cover) and on river control. No matter how much the cover increases, this river will always be an exceptionally difficult one to tame.

The Regional Water Board

In 1901 the River Board had put a groyne on Gibson's Creek, an offshoot of the Waihopai, for flood control. The overflow was prevented, but the groyne also held back the water that made up the surface flows supplying both rural and urban needs and underground recharge. The situation was later aggravated by the closing of the Wairau's Opawa channel and the subsequent degrading of the Wairau. The effect on groundwater availability was substantial. The Catchment Board in 1960 restored the source of water to the aquifer with highly beneficial results. This was in effect a forerunner of Regional Water Board activities.



160. On the Molesworth and Tarndale runs, partly in the headwaters of the Clarence and Awatere Rivers, more than 250 000 hectares of tussock grassland became so degraded through fire and overgrazing by animals, especially rabbits, that the two runs reverted to the State. Since then the land has been rehabilitated by eliminating wild animals and fire and running cattle in the place of sheep. (MWD)

When the first Chief Engineer to the Catchment Board, C C Davidson, submitted the control scheme for the Wairau Valley he concluded his introduction by saying; "Management of the watershed to attain maximum sustained yields of usable water will possibly become the major objective". Davidson's successor, P A Thomson, in discussing the design of the river control scheme estimated that the return period of 200 years for the peak flow could become as short as 70 years if deterioration of the catchment continued, or lengthen to 500 years if it were improved.

The area of high mountains and large lakes which provides the sources of the Wairau, Buller, Clarence and Awatere is a fine gathering-ground for water. The Buller has been investigated over a long period to assess its hydro-electricity production potential. Additional capacity for this could be obtained by diverting the headwaters of the Wairau down the Buller.

The results of doing so need to be carefully analysed. The underground water supplies flowing through the lower Wairau Valley in river beds laid in ancient times are now used for all the urban communities in the valley and for the irrigation of some 5000 hectares of land. Further use, especially for irrigation of the land now protected from flooding, is increasing at a rapid rate. Changes in cropping, especially to viticulture, have been spectacular. How would diversion of water in the upper river affect these developments?

Even before it became a Regional Water Board the Catchment Board used its own resources to start a study to answer this question. More recent, intense study of the Wairau water resource is now being finalised and will, no doubt, lead on to a water management plan for the valley. Underground water is one of the prime resources of the district and should never be jeopardised.

NELSON CATCHMENT BOARD

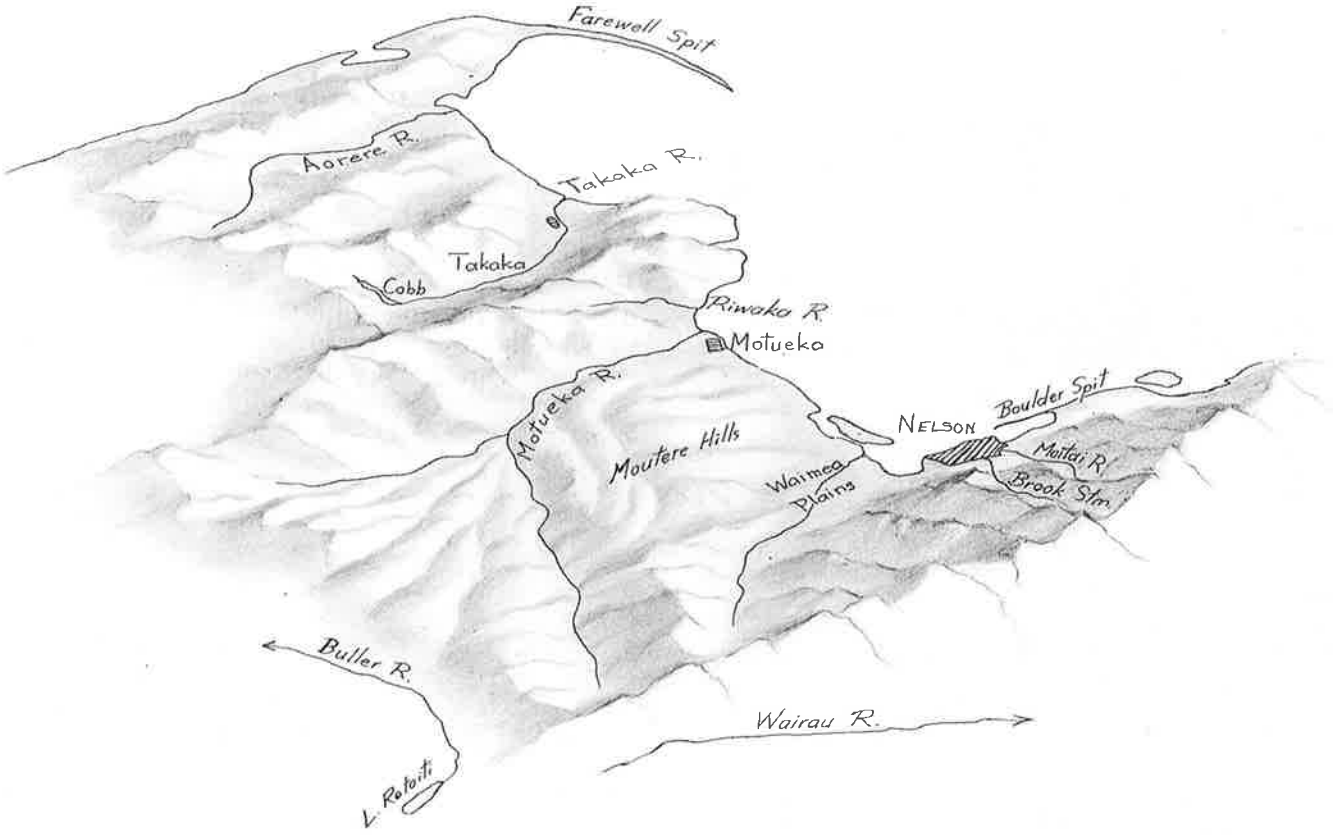
The Brook Stream Flood, 1970

Sunny Nelson! Boasting, often, more sunshine hours than any other place in the country, over 2400 per year. But the winter of 1970 was dull and rainy. The wettest period came at the end of August when the countryside was already saturated. Rain fell incessantly on the last two days of the month. In the city, tucked under high hills and mountains, all streams overflowed. One of them, Brook Stream, normally a quiet, innocent flow, rampaged down its bed and took off in new directions. One person was drowned and property was extensively damaged.

The rising flood waters showed up the defects of urban drainage designed, at first, for a small settlement, and then expanded to cope with ever greater flows of water concentrated from roof tops, paved streets and urbanised valley sides.

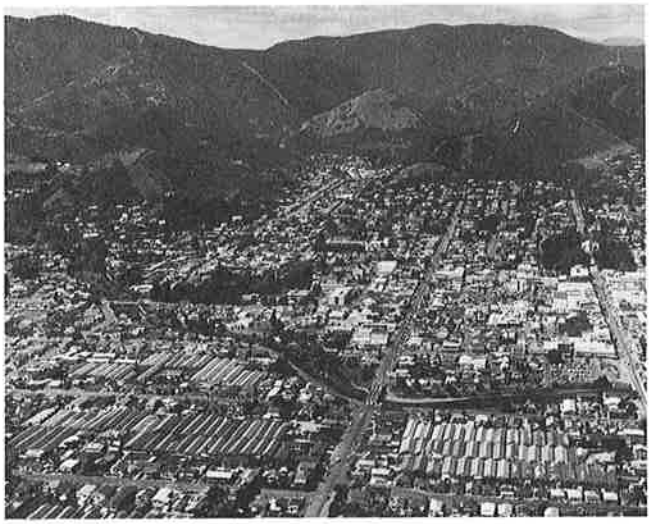
The watershed of the Brook catchment reaches several hundred metres up the mountains just a few kilometres outside the city boundary. In floods, which are frequent, it is a true mountain torrent. How was the city to cope with a flow that varied from much less than 1 to more than 100 cumecs? Other streams as well as a river, the Maitai, flow through the built-up areas. They also have steep catchments in the surrounding mountains.

It was inevitable that the Nelson Catchment Board, which was set up in 1943, should become involved in an urban flooding problem of such magnitude. No other organisation was equipped to design a control scheme that must be based on the whole catchment. It set to work in association with the city to do this. A model was built to refine the design and was used to demonstrate to the citizens how it would operate. After all, part of the costs were being met from city council rates.



161. Nelson Catchment District

A series of hills and mountains give rise to short, swift rivers flowing into Golden and Tasman Bays. They have small floodplains and long, narrow valleys. Because of the sunny climate and comparative lack of wind, some of the limited flat areas have been sought for the growing of horticultural crops. On the other hand, the hills have proved difficult to convert to farming, and, following initial failures, substantial areas have been established in exotic forests, mainly radiata pine. Native southern beech forest still occupies about 50 percent of the total region. (D W Lawrence)



162. Nelson was established on a restricted area of flat land on the shore of Nelson Haven with steep hills and mountains behind it. There have been problems of flooding by the streams that come from these mountains and flow through the city. The most dramatic was the Brook Stream flood in 1970. Brook Stream flows down the built-up valley to be seen on the left of the photograph. (Geoffrey C Wood)



163. The Brook Stream flood, August 1970. An attractive stream with a normal flow of less than one cumec was encroached upon by road works and buildings. Servicing pipes were installed in the fill. Bridges were erected at frequent intervals. During this storm the stream became a torrent. The flow increased by more than 100 times, sped down the steep gradient, ripped out the fill, exposing servicing pipes, and took loose obstructions with it. (Geoffrey C Wood)

Mountain Torrents and Narrow Valleys

The mountains around Nelson City are a small fraction of a series of ranges stretching from coast to coast at the northern end of the South Island where the Southern Alps fan out. The area is severed from the south by the mountains north of the Wairau and Buller Rivers. From the mountains north of the Buller a number of rivers flow to the Nelson coast. They are not large, but they are fast shingle rivers, flowing down steep gradients. They gather in precipitous valleys. In their lower reaches they have narrow plains which they flood frequently, changing course, eroding banks and depositing layers of silt and shingle.

In the centre of this wild terrain is the small Waimea Plain of less than 3000 hectares, formed partly by river shingle and silt and partly by glacial material filling a down-faulted valley. At one side of this plain the strongly dissected Moutere Hills, formed from deposits of semi-consolidated glacial gravels and sands and with a maximum elevation of about 600 metres, stretch to the sea in an area of about 120 000 hectares.

Pakeha Settlement and Hill Abuse

When Europeans first explored the region, fires had already burned the forest on the coastal Moutere Hills and the Waimea Plains. Otherwise the whole region was forested in beech and podocarps up to the timber line.

The site of Nelson was chosen by the New Zealand Company in 1841 after applications to purchase more favoured areas had been refused. The region had been examined for suitable flat land by travelling along the coast and proceeding up the rivers as far as possible. One surveyor sighted the Waimea Plains but thought them too small for settlement. Reports on other river flats and soils were generally not promising.

Nevertheless, the Company proceeded to survey land throughout the region for urban and rural purposes. By including steep hills and mountain sides, the survey covered areas far in excess of land really suitable for settlement. From the beginning there was great pressure on usable land and this has had distinctive effects on land use in the region. There was some compensation because the climate (especially the sunshine and lack of wind) and the soils favoured horticulture. Some of the earliest horticultural development in the country took place around Nelson. Tobacco, hops and a variety of fruit all thrived.

The Moutere Hills looked promising for farming. Fire had cleared the forest, and the scrub that had grown in its place could be readily burned. The

area, however, proved to be waterless, and the soils poor, impervious and subject to drought. Under such conditions English grasses and clovers would not establish.

Productive grasses would not grow in the poor soils which had been formed under beech forest either. What did grow without any aid were native *Danthonia* grasses which formed closely matted but unproductive swards. Regular burning of them was practised to produce some new growth edible to stock.

It was not long before one settler tried to increase stock feed by sowing gorse on the hills. This plant found a good home, and sowing of it became widespread. Seed could be purchased right up to the 1940s, even after it had been declared a noxious weed. Like *Danthonia*, its growth could only be kept young and palatable by burning.

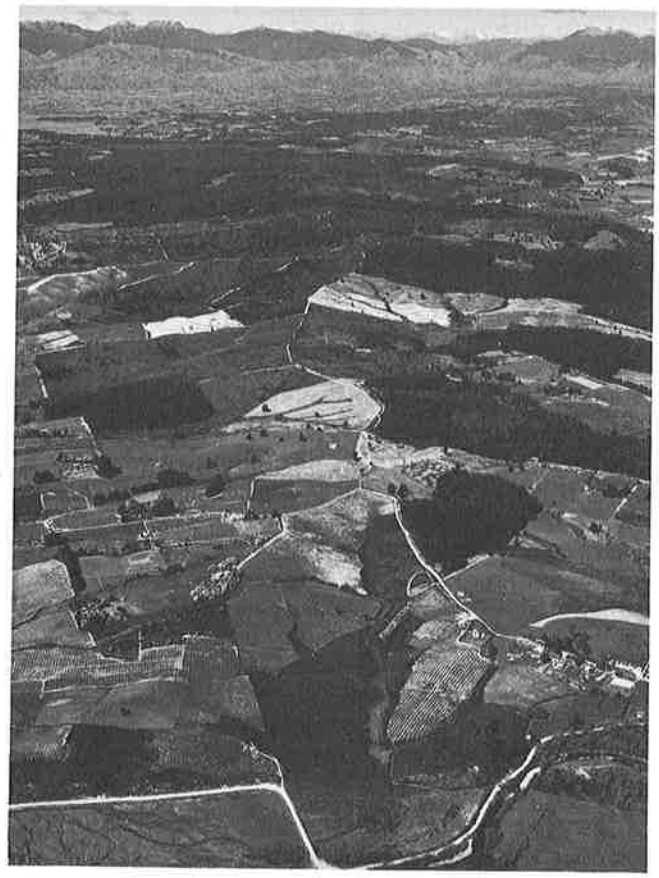
The spiral of degradation was thus introduced: burning beech forest which brought in *Danthonia* swards; sowing gorse; burning grass and gorse which led to the increase of gorse; deterioration of the soil through burning; erosion; abandonment of land. While all this was happening, many introduced forest trees were finding a particularly favourable home in the Nelson region. The most successful of them all was radiata pine and planting on abandoned agricultural land, particularly on the Moutere Hills, began. Here was a ray of hope for productive land use.

The Catchment Board

The array of river and land problems which had accumulated in the district by 1941 was formidable. Tobacco cropping used many of the river-flat soils, which were constantly flooded. River Boards had been unsuccessful in improving that situation to any great extent. Fruit orchards had extended from the flats on to the seaward end of the Moutere Hills where the climate was mild. Severe erosion was developing there because of poor cultivation practices on steepish slopes. Above all, farming use of the hill and mountain slopes was leading, through constant burning, to the growth of dense gorse cover. Nelson became noted for its yellow hills and for the pall of smoke that lay over the country when *Danthonia* and gorse were being burned.

Faced with these problems the Catchment Board developed methods of approach not tried by other Boards at the time. From the outset it paid considerable attention to land and conservation matters, and was bold in its policies. The first chairman was the city engineer, who placed great emphasis on an all-embracing approach to soil and river problems. The same influence undoubtedly came from Sir Theodore Rigg, the Director of the Cawthron Institute, who was a Board member and later became chairman. Quite early in the deliberations the Institute, a privately endowed research organisation working on soil surveys and the growing of crops in the region, was asked to prepare a bulletin on soil erosion in the Nelson district. In this and in other ways there was a close association between the Institute and the Board.

The Board also found itself involved in a multitude of small, 'fire brigade' jobs in streams and upper rivers. To finance these a general works rate was struck over a limited area. This led in 1956 to the introduction of a general rate over the whole district to provide funds for small river and conservation works. The Nelson Board is the only one that has



164. The Moutere Hills formed from gravels lie between the Waimea Plain and the Motueka River. They proved difficult to farm because of tight soils and lack of available water, but afforestation has proved successful. The plantations shown here are of radiata pine. Towards the seaward end of the Moutere Hills, where the climate is mild, orcharding has become established but cultivation practices need to guard against erosion. The catchment board has worked out safe methods to do this. Lack of water can only be overcome by constructing dams in the small valleys. (MWD)



165. The Waimea Plain looking from the Moutere Hills towards Nelson. The plain and Waimea River contribute importantly to the prosperity of Nelson. Orcharding and small cropping is carried out on the plain which is also the most suitable area near Nelson for urban development. The river once flooded surrounding land but is now controlled. Future development of the plain will depend largely on whether the river water can be harvested. (D L Homer, NZGS)

been able to do this, no doubt because residents throughout its district are aware of the peculiar nature of its problems; limited flat land resources, valuable for cropping, but much of it threatened by wild rivers. (Thoughts are now being turned to grouping these rates into districts).

The Motueka River

At an early meeting the Board received a petition from 20 tobacco growers for protection work on the Riwaka and Motueka Rivers. The small flood plains of these rivers were the centre of tobacco growing. An association of growers had been formed and research investigations were producing larger improved crops. Security of the land from flooding to protect these had become urgent.

A River Board, formed in the early 1930s, had undertaken initial control on both the Riwaka and the much larger Motueka but when the Catchment Board was set up the River Board passed the following resolution:

> "That the case for the abolition of the river board be placed before the Nelson Catchment Board at a meeting to be held on 2 August, as the Board is strongly of the opinion that the river board should never have been formed as the conditions were such that during its 14 years of existence, it has been impossible to carry out satisfactorily the work it was intended to do."

An unusually frank self-assessment, and a concise summing up of the inadequacies of the earlier river legislation. Could the Catchment Board operate more effectively?

By 1949 the Government had approved the Board's lower Motueka scheme for subsidy. Part of the local finance was advanced by the Tobacco Board which in turn levied the growers. The lower Motueka scheme was followed by channel clearing, river training and bank protection in the middle reaches and in the tributaries. The aim was to prevent bank erosion eating into arable land along the narrow valley floors and to reduce the frequency of flooding.

In the upper reaches of the river lies the Golden Downs State Forest planted on Moutere Hills country, and beyond that again is extensive beech protection forest. Interspersed with these forests was land containing areas of erosion, some of it severe; the result of forest clearing and burning. Protection planting by the Forest Service is now underway as well as river control work through the Golden Downs Forest.

The combined work means that the Motueka and its catchment are now being regarded and treated as an entity. It is not a large catchment but it is important in the region, with diverse land use, including protection and production forest, a limited area of hill pastures, cultivated river flats and urban communities. In addition, it provides the region's best potential water resource.

The Waimea River

The Waimea has a catchment area less than half that of the Motueka, but its flood peaks can be almost as high. Its head water tributaries gather in the hills and mountains rising abruptly from the Waimea Plains which are the key to the prosperity of the region. Because the Waimea River flooded parts of them frequently the Catchment Board designed a control scheme for its lower reaches. Ratepayers rejected the proposal, but shortly afterwards a severe flood in 1961 reversed that decision and the scheme got underway.

The Board also examined the upper catchment and came to the conclusion that "matchbox farming" was doing so much damage in the tributary catchments that much of the land should be behind a "conservation line". It introduced a plan to retire 15 000 hectares from farming. Since then exotic forest has gradually replaced farmland in this area.

Land Use and Conservation

Risking unpopularity and a direct confrontation with matchbox farmers, the Board decided in its early years to define the limits beyond which forest

clearing should cease, and to encourage the reafforestation of eroding and reverted land. The burning of gorse should also cease, because it led to soil deterioration and erosion, and escaped fires threatened plantations and orchards.

A proposed "conservation line", that at first came to be known as the "green line", was mapped. The area of upper catchment on one side of this line was defined as "the minimum area of headwater country requiring conservation". Within this area land "should be retired from farming and eventually brought into forest cover of some type". Moreover, it was recommended that properties inside the conservation area should be purchased and that "as much of the area outside of the conservation line is of very questionable value for farming . . . a land utilisation scheme be prepared . . . in order to frame a policy to deal intelligently with poor class lands". Imagine the effect on farmers bent on converting all country to pasture.





166. Moutere gravels washed out of the Moutere Hills because of poor farming practices, contrasted with the beginnings of erosion control. (Nelson Catchment Board)

The Board proposed that its technical officer draw up plans for conservation and afforestation, and examine the possibility of levying a flat rate to produce money for afforestation and forest conservation. By that time, however, both the Forest Service and private enterprise were undertaking afforestation on a reasonable scale so the Board was not allowed to proceed with its planting. It did continue to pursue a policy of encouraging afforestation in "conservation" areas.

The concept of broad land use areas so rigidly separated was later abandoned, but not before the measures and policies of the Catchment Board had ushered in an era of more rational land use. To be sure, hill farmers objected to having their methods questioned and changed. To this day they make strong accusations that forestry has taken over much land that is suited to agriculture. It was, however, their methods that paved the way for afforestation. The result now is a more sensible, balanced and profitable land use in the place of impoverished steep land.

A further effect of the conservation policy is that almost 50 percent of the region remains under natural forest. This is a substantial price to pay, but it is better than having rivers choked with erosion debris. There is no reason, however, why much of the beech forest should not be managed for production. Red deer have already severely eaten out the floor and working the forest could actually improve this condition.

Having curbed the farmer in his practices leading to erosion, the Board saw the need to control forest practices that might also induce erosion. Forest cover holds the soil in place but in forest management roads are required, logging disturbs the surface, and clear-felling of mature forest leaves areas bare until regeneration. It is also difficult to keep streams and waterways clear of logging debris.

The Board, therefore, used the legislation to introduce controls of forest operations to prevent erosion and the blocking of watercourses. These pioneering efforts paved the way for writing forest operation guidelines for application throughout the whole country.

The Takaka and Aorere Rivers

Leaving the Waimea Plains, the Moutere Hills and the Motueka Valley and travelling north-west, one rises 800 metres very quickly and drops even more



167. Valley of the Maruia River, tributary of the Buller River (in Westland catchment district). Half of the Nelson region remains in similar southern beech forest. (J H Johns, NZFS)

steeply into the Takaka Valley. The river in this long, narrow valley has its headwaters in the mountain mass of north-west Nelson. The area has always presented difficult problems to the Catchment Board.

Takaka was settled early, but the flat lands of the valley are limited to about 6000 hectares of which at least half used to be flooded. The river at peak flows could spread right across the valley in places. Of the remainder of the catchment, 90 percent is steep to very steep. Nevertheless, the usual attempts were made to farm the lower slopes. The result was, apart from the dairy pastures on the flat land, a desolate scene. More recently horticulture is gaining a foothold in this remote valley.

River control was the foremost requirement of the settlers. Taking this into account, the Board promoted a catchment scheme using a broad approach. Proposals covered the control of burning on the hills, promotion of farm conservation plans, recommendations to retire some land from farming and the promotion of more intensive animal pest control. As far as the river was concerned, all the Board could afford was to stabilise the channels and keep the floodway free of debris.

The vexed question of how much money should be spent on soil conservation and river control in such confined valleys was answered by the Soil Conservation and River Control Council. Reasonable farming country and townships occupied only 15 percent of the total Takaka catchment, but in its report on a control scheme the Council said this:

> "In such a highly developed country as New Zealand it is not unreasonable that river protection should make equal (if not greater) progress

with the development of motorways, state highways, aerodromes, universities, schools, television and other public amenities. Relief from flooding should be achieved as soon as possible, and the Council and Catchment Boards should spend their funds and energy installing planned protection schemes, rather than patching works in an emergency during or after floods."

This was a generous view. How far could it be extended to people seeking land and living in isolated valleys? The catchment of the next river westward, the Aorere, receives something like the high rainfalls of the West Coast. A normal flow of 15 cumecs could reach 3500 cumecs in flood. Apart from frequent flooding of the limited flats, bank erosion was severe.

In spite of these difficulties dairy farming became established. Rock protection of the river banks was undertaken even though the cost to farmers was high. Short-term economics were ignored. Rock protection was generally successful, though under the most severe conditions the Aorere River could move the largest pieces of rock placed on the banks. This spells continuing and expensive maintenance.

Water Resources

"Our Province has water enough for its purposes". (*Land of Streams*, by Kenneth Gregory). This might be so if it were in the place where it is wanted—the Waimea Plains and surrounding rolling country and centres of population. Greatly increased supplies of water for intensive irrigation and urban and industrial needs will largely decide the future prosperity of the Nelson area.

Where can this water come from? The Wairoa River and its tributaries, and underground water charged by them, have provided the main supplies up to now, but in dry seasons the demand over-taxes them. Some of the underground water is also showing signs of deterioration. There are excellent resources further out from Nelson and Waimea: to the south, the Buller River and Lakes Rotoiti and Rotoroa feeding it; to the north, the Motueka and Takaka Rivers. But these resources are all too remote at the present time.

The fan-shaped upper catchment of the Wairoa is a good collector of water. Although only 460 km² in extent, it provides peak flows of up to 1000 cumecs. The river leaves the hills abruptly, and about this point it could be dammed and sufficient water impounded to supply future demands for a long time. Such a scheme has the added attraction that it could be multi-purpose, supplying irrigation, urban and rural needs, and electricity.

The district can be thankful that, through the influence of the land use policies of the Catchment Board, the upper catchment of the Wairoa has remained in native forest or has been afforested; a good safeguard for the water resource.

The land use choice between radiata pine and grass which has long been a bone of contention throughout the district has now been followed by another: radiata pine or water. In the climate of Nelson, subject to droughts lasting a month or more, plantations use more moisture than pastures. Farmers maintain that creeks they have been dependent upon have been dried up by the new forests—they sometimes conveniently forget the creeks that disappear under the erosion debris filling the beds. "There should be no planting in the catchment of the Wairoa", they say.

A satisfactory land use pattern is now being achieved and an important part of it is exotic forests in place of reverted, eroded and uneconomic farmland. There could be no reversal of such a development that has evolved to meet the needs of all. Water supplies in areas of greatest need are so substantially insufficient that the choice of pines or pasture affects the situation very little. The solution lies in water harvesting and this is what the Catchment Board is helping to plan.

Pollution

Scallops or pollution? Are the estuaries, the Waimea inlet and the Nelson Haven, to be allowed to continue to deteriorate? These attractive parts of the Nelson coast are polluted from urban and industrial uses around them. The city sewer used to discharge into the midst of scallop beds. Taking contaminated fish was prevented by demarcation of the area where contamination might occur. Although fishing was supposedly excluded from this area, sly remarks were made as to the location of the largest scallops. The precaution also ignored the fact that the scallops as well as the fishermen move.

Sooner or later this sort of situation would have to be controlled through the issue of conditional water rights for the disposal of sewage, or the refusal of them altogether if the pollution became too severe. This was the task of the Regional Water Board. The Board did not simply adopt this restrictive attitude. It has actively encouraged local authorities to con sider planning a comprehensive sewage scheme. The rapidly growing recreational pursuits on the inlet can then proceed unhampered by pollution problems.

Flood Control

From raupo to vineyards; from a flooded valley floor to the Hutt cities; from swamp journeys to main highways: these achievements, brought about by flood control and land drainage in New Zealand, have been remarkable.

They are the result of progressive measures which commenced well before there was enough manpower, equipment, knowledge or money to implement them fully. Mistakes were made on the way, many of them because of our ignorance of the country's natural characteristics. Nature was often tested too severely.

The attraction and the need for water is so much part of us that we settled along the river and on the flood plains. Here lay the good soils and access to water was easy. Swampy land, great hardships caused by flooding of homesteads and townships, drownings and difficult communications did not deter us.

The formula for flood control and drainage on an effective scale was finally produced in the Soil Conservation and Rivers Control Act 1941. The speed with which Catchment Authorities came into being following its passage is proof of the urgent need and desire for the control measures it provided.

Scarcely more than 40 years later flood control schemes operate on most of our major rivers. A few are incomplete, amongst them those on rivers in Southland where drainage took priority over flood control in spite of repeated inundation of townships. And, on the West Coast, the construction of major schemes has not yet been attempted because of the difficulties posed by the area's rivers and the limited floodplains to be protected. Economically, the work would not be justified. Nevertheless, one effective way of assisting a difficult economy would be to give greater protection to these limited areas of good farmland and to extend drainage under the policies already established.

Once floods are no longer a threat they are soon forgotten. Forgotten too, is the memory that great benefits have flowed from flood control schemes. Throughout the country a total area of flood plain soils, well in excess of 600 000 hectares, has been freed from flooding and then upgraded. Intensive cropping has been made possible in South Canterbury and orcharding, cropping and vineyards on the Wairau Plains and the Heretaunga Plains. On the Poverty Bay flats there has been a remarkable transition from poor grass with a little maize to extensive maize, vineyards and horticulture. Horticulture has developed rapidly on the Rangitaiki Plains, cropping on the Manawatu Plains, and dairy farming in the Hauraki and on many other protected flood plains. So the story goes on. Intensification of production will continue far into the future and is a notable result of Catchment Authority works.

TABLE 5

Catchment Districts and Flood Control

	Area (ha)	Population	Controlled Flood Plains (ha)
Northland	1 260 000	108 000	40 985
Auckland	530 000	804 500	–
Hauraki	443 595	60 000	62 841
Waikato	1 865 587	251 300	31 666
Bay of Plenty	920 000	150 000	15 390
East Cape	1 040 064	52 600	16 769
Hawke's Bay	1 534 937	135 000	40 233
Taranaki	1 881 133	104 660	100
Rangitikei/Wanganui	1 483 500	112 460	4 031
Manawatu	1 943 319	165 000	48 074
Wairarapa	647 000	45 000	21 900
Wellington	137 600	323 162	1 464
Nelson	651 400	64 601	9 883
Marlborough	1 338 623	38 000	24 290
Westland	2 638 941	35 678	8 281
North Canterbury	1 905 130	336 846	84 149
South Canterbury	1 120 000	84 772	70 423
Waitaki	1 195 700	17 000	26 774
Otago	3 489 216	180 000	28 338
Southland	2 617 251	110 000	134 074

Occasionally, we are given a harsh reminder of the frequent happenings in the past. A stopbank fails and farmland is flooded. Or, more seriously, the Taieri Plains are flooded. Sometimes the collapse of a bridge or the washing out of a road once again cuts communications.

We are unable to prevent damage from high intensity rain storms. Their occurrence is too random and the standard of protection needed would be too costly to provide. So we have to bear with the disasters which occasionally hit populated areas. The 1981 Kerikeri flood and the 1976 Wellington flood were examples of events that have to be suffered from time to time. Damage can be reduced, however, by reservation of waterways and preventing encroachment on to them.

Are major failures of flood protection schemes a possibility in the future? Works have been designed for return periods of a stated number of years—sometimes as low as five, sometimes as high as 200, depending on the investment to be protected and the rating agreed upon. Flow data, upon which designs are based, have generally been collected for relatively short periods.

It seems inevitable that an unusual rain will, sooner or later, cause a major failure. "It couldn't happen to me" is a dangerous philosophy at the best of times and a disastrous one to adopt in matters of flood hazard.

Rains always come and rivers always flow and flood. Maintenance must be continuous and of the highest standard and schemes themselves must be constantly reviewed and upgraded as knowledge of rivers grows.

Erosion Control

Settlers took a gamble when they removed from hill and mountain nature's vegetative sponge. The hillsides looked so stable under the forests. Who could tell they were potential helter skelters? The first limited clearing for gardens, small crops and a few stock were successful. Good soils were uncovered and the forest humus fertilised the crops grown. Widespread clearing was soon underway. In most places the gamble paid off—the hard work spent chopping and burning down forest and sowing pastures. The provisions of the 1941 Act just headed off irreparable damage, in the form of soil loss and aggrading streams, occurring over wide areas of country.

If erosion control and prevention measures—including wild animal control—had not been put in train, the primary production of this country would be very much less than it is today. South Island mountains would be shedding detritus in unmanageable quantities and soils lost for good; loess hill soils would have eroded into grotesque valleys and shapes; the sheet, slip and slump erosion in the North Island would have made large areas unproductive. As it is, only a major change in land use coupled with intensive erosion control measures on pastoral land can halt deterioration of parts of the East Cape region.

We have seen how the strongest pressure to take action came from the South Island and Hawke's Bay and that the result was provision for erosion control measures in the 1941 Act. Successful development of erosion control techniques followed. Now, all but the most severe erosion can be cured, but it is still not possible to prevent unexpected erosion occurring during heavy rain storms.

In few parts of the world does intensive pastoral farming extend onto such steep slopes, which are subject to such high rainfalls, as it does in New Zealand. Farming methods used must prevent erosion and a watchful eye must always be kept for signs of it. Economic stresses can at times alter the management of this type of land so as to encourage erosion, as can incentives for increased production on vulnerable land. Or changes in climate—excessively dry or wet periods—can be too testing for the farming techniques used and lead to erosion.

Water Management

We are profligate in our use of water. Why worry? We have plenty. On both an area and a population basis we have the best supplies in the world. But in a world where water supplies are under increasing threat, having the best of a bad lot is no consolation. In some areas of New Zealand water is becoming scarce.

In recognition of this, and of pollution factors, water rights are now required for the use of natural water. During hearings for these rights unexpected claims come to light that often illustrate a widespread ignorance about the nature of water and the extent of our resources.

Many of the most favoured water resources have become over-taxed or over-polluted in use. The "open sewer", Lake Rotorua, has a catchment control scheme but, when it came to taking treated sewage effluent from Rotorua around the lake to the Kaituna River outlet, other issues appeared. Even though the effluent would be safely diluted and would have a long way to travel in a turbulent river, people in the lower river naturally objected.

One of the most important water needs will continue to be for expansion of the production of electricity. It is more than likely, however, that there will be the strongest opposition to manipulating water again on the vast scale that has been done on the Waikato, Waitaki, Clutha and Waiau—not that there

are many such bountiful resources remaining but there are a number of very good secondary resources. Could any Government now develop the Wanganui or the Buller, say, for hydro-electricity alone? Plans to do so for the Wanganui would certainly bring a protesting flotilla of rafts and canoes down the coast to Parliament.

Disputed water rights have become legal battlegrounds. Fish and waterfowl—or rather their catchers and observers—now have rights along with other claimants. Recreationists have rights. The Act states that all recreational uses of natural water must be taken into account. Indeed, recreationists can now lay claim to stretches of rivers or even complete rivers for their prized scenic and recreational values. All rivers or stretches of rivers possessing hydro-electric power potential are included in "a national inventory to establish the scenic, recreational and other features of rivers".

With the passing of the 1967 Act the administrative situation quickly became complex. Under it Catchment/Regional Water Boards were required to deal with total water resources but could find little information of help. Records of current uses were incomplete, if they existed at all. In the past Catchment Boards had studied high flows in order to design flood control schemes. Now, as Regional Water Boards, they had to study low flows so that they could apportion water when and where it was most needed. Permits issued in the past for withdrawals often added up to amounts in excess of mean low flows.

Demands for water rights made surveys of water resources urgent, but flowing water of changing volumes takes a long time to measure accurately. Regional Water Boards now have enough data to begin to look forward and plan to accommodate both current and possible future uses of some of their main resources, but a great deal more is required, so rapidly is the demand for water growing.

Regional Government and Planning

Can we make further progress in preventing damage by floods like that at Taieri, landslide calamities such as Abbotsford, disastrous coastal erosion as at Omaha, and pollution of water common throughout the country? We can, by bringing the water and soil organisation and local government closer together: in other words, co-ordinate the data and knowledge of one organisation with the planning procedures of the other.

At first, provincial governments grappled with river control and drainage because the progress of local communities depended on their efforts. Although the problems were large and the resources slender, enough was achieved to indicate that success could come in the long run.

The barrage of demands and deputations to which Central Government was later subjected was proof enough that the work was essential. Central Government also had its own motives. Trunk roads and railways had to be protected; and one quick way of increasing production to boost overseas earnings was by preventing flooding and by draining swamplands.

The Government used the Public Works Department for advice and execution. The department was at that time building up a body of knowledge of rivers in connection with the construction of roads, railways and bridges. In addition, the design of hydro-electric schemes had to be preceded by long periods of river studies. The department also undertook the construction of some river and drainage work on behalf of the Government itself.

When the time was ripe, the 1941 and 1967 Acts were passed. These provided, once again, for large regional units, Catchment Authorities and Regional Water Boards, substantially elected by local ratepayers, to undertake works at a local level. This was a wise development. Local communities live along rivers and occupy reclaimed swamps and have to contend with the problems these present. They must have regard to the whole river catchments and what is going on in them. They draw domestic, stock and industrial water supplies from the catchments, whether from a river, forested reservoir or underground supplies. They have to cure the erosion. The catchment is their homeland.

Planning authorities—planning committees of the united or regional councils set up under the Town and Country Planning Act 1977—are required to include representatives of Catchment Authorities and to have regard to the principles and objectives of the water and soil legislation. Thus, the means have been provided to develop co-ordination between the bodies that have to deal, in one way or another, with the two most basic resources involved in planning.

The two organisations have a number of complementary objectives. The co-ordination that is required will succeed through their ability to grasp one another's objectives. Whatever happens, Catchment Authorities should on no account have their position weakened. They have achieved a marked measure of success and built up strong staffs, especially in their technical departments, and have accumulated a substantial background of knowledge in the process.

Thoughts on the Future

The development of New Zealand along western lines has to a large extent been successful. Now concern and contention over land use is growing because we have almost run out of unoccupied land to expand onto. No longer can we carve farms out of forested hills. So we look more critically at the land we have already occupied. Intensity of production increases and changes in use are made. Catchment Authorities have a direct say on land use where erosion is threatened or rivers upset.

Land and soils yield crops which are the traditional measure of their usefulness and quality. But water is the most important yield of land; whether it is held as groundwater, percolates through to underground water, runs off into rivers and streams or is just evaporated.

We have exerted immeasurably more effort and spent a great deal more money in studying soils than we have in studying water. Now there are ever-increasing and urgent demands for information and knowledge about water. Its apparent that our over-abundance has led us into a sense of false values and now we know least about what is most precious. Water generates great wealth. A reasonable part of that should surely be used for its management and study.

We do not get our soil free; in fact we pay high prices for it. Why should we expect to get our natural water almost free? When we do, why should we continue to pollute it? We have good legislation to prevent this happening, but it seems very difficult to change our pioneering outlook on water as the easy means to cleanse everything.

The convergence of river control, soil erosion control and water management into the present water and soil organisation has been a long development. The present structure is an enviable one even if it appears complex to the outsider. Revised legislation should complete the convergence and do away with much of the seeming complexity.

Provincial governments performed necessary functions by taking some of the first steps in river control and drainage by coordinating individual efforts. Central Government was then needed to assist with and finally lay the basis for more comprehensive measures. Many major works, both river and soil conservation, have been completed and have enabled a tremendous input to the country's agricultural and other development.

Everybody now assumes the existence of river defence works and people are irked by the controlling actions of Catchment Authorities in the areas defended. Nevertheless, there is increasing responsibility in such areas as cultivation and development intensifies. The old threats are still there even if latent for the time being. Catchment Authorities are thrown more and more into direct contact—sometimes conflict—with the very people they are protecting. Even more annoying to both manager and user are the conflicts over water rights.

There is thus a changing role for Catchment Authorities in developing a closer association with local communities—a return to local and regional government. They should emerge much more from under the umbrella of the Central Government and increase their strength locally.

GLOSSARY

A.

Aggradation. The building up of a land surface by deposition; in the case of a river, building up the bed or flood plain with silt or shingle.

Alpine Fault. The geological fault along the western flank of the Southern Alps. Along it the Southern Alps have been raised and there has been a lateral displacement of 450 kilometres in parts.

Aquifer. A layer of rock or sediment permeable to water, either holding it or allowing percolation through it. It is confined when there is an impervious layer above, and unconfined when one is absent.

Artesian Water. Water accumulated underground in such a formation—e.g. a confined aquifer—that when released, usually by drilling a bore, it rises to the surface.

B.

Bar. An accumulation of material brought down by a river and deposited in the sea across the mouth. It thus forms a barrier—or bar—to shipping entering the river.

Basalt Cone. A cone-shaped hill formed by the falling of basic volcanic lava after it has been erupted and aerated in the process.

Basalt Lava Flow. A basic volcanic rock which when erupted in a molten state flows over the surface of the ground.

Beech Forest. Native (indigenous) forest dominated by southern beech (*Nothofagus*) trees. It can be contrasted with mixed podocarp—broadleaf forest. Beech forest now occupies more than half New Zealand's remaining forest cover.

Block Mountains. A mountain mass formed by the uplift of land between geological faults or the sinking of land outside them.

C.

Caldera. A large basin-shaped depression caused by the sinking of land when a volcanic eruption blows masses of material out of the ground.

Catchment. (See also watershed). The use of these two terms have become confused in technical writing. In New Zealand, catchment means the natural drainage area of a river system and this is also its legal meaning. Elsewhere the term watershed is frequently used in this sense but it is also used to mean the line separating waters flowing into different river systems. In this book catchments are the complete drainage areas of a river system and watersheds are the dividing lines between them.

Catchment Control Scheme. A co-ordinated plan of river and erosion control works and improved land use in a catchment in which erosion and flooding have created both individual and community problems.

Cirque. A steep-sided rounded hollow or head of a glaciated valley, formed through erosion by snow and ice.

Consequent. A stream or river that flows down the natural slope of the land; a consequence of the slope.

Cooling Water or Condensing Water. Water used for cooling in industrial processes in such a manner that it does not take up matter into solution or suspension.

Conservation. Literally the preservation from destructive uses. More loosely, permanent use without causing destruction.

Cumecs. (cubic metres per second, m^3/s) The amount of water passing a given point each second. See page 10 for fuller explanation.

D.

Danthonia Grasses. Grasses belonging to the genus *Danthonia.* The original New Zealand ones are now known by other names. The small native grasses, once known as Danthonias, growing on the dry hills of Nelson and Marlborough and elsewhere are *Notodanthonia* spp.

Demonstration Farm. A farm selected for demonstrating erosion control techniques which are usually applied by agreement between the farmer and Catchment Authority officials.

Down-faulted. A fault along which the movement on one side is vertical, or downwards, relative to the other.

Downland. Low altitude, hilly and undulating grassland.

Drainage District. An area constituted under the Land Drainage Act 1908, for which a Drainage Board is set up to administer drainage plans.

E.

Eutrophication. Nutrient enrichment of bodies of water, often accompanied by deoxygenation.

F.

Fan (Alluvial). Sediment laid down in the shape of a fan by a stream or river when the grade of the

flow is reduced. Alluvial fans can take many shapes from steep to almost imperceptible slopes depending upon the rate and change of flow and the sediment carried. They are very common in the New Zealand landscape because of the number of streams and rivers descending along steep gradients from the mountains and emerging on to flat lowland country. Streams frequently change their courses down the sides of fans they have built up.

Farm Plan. A plan of farm management embracing erosion control measures. The whole farm is included because of the need to cover the cost of erosion control and the prospects of increased production once it is cured. The plan is an agreed and binding document between the farmer and the Catchment Authority and involves subsidies.

Fault. A fracture in the earth's crust along which movement has taken place. Very common in New Zealand where there are a number of major faults and innumerable small ones in the mountains. Some large rivers, such as the Waitaki, flow along major fault lines.

Firebreak (Strategic). A cleared and graded track—usually negotiable by a "four-wheeled" vehicle—through tussock grassland giving quick access to fires. They are also useful in the management of South Island runs. In many tussock grassland areas a network of them has been built up in conjunction with Run Plans.

Floodgate. A gate or combination of gates which may be opened or closed to admit or exclude water, especially floodwater. In river control schemes floodgates are sometimes used to divert water down a specially constructed overflow or diversion channel because the river's main channel cannot carry the full flood flow.

Flood plain. A plain formed from the sediments of a river when they are carried over its banks during floods and dropped as the water ponds. The sediments can be silt or shingle depending upon what the river carries down during floods.

G.

Geothermal. The internal heat of the earth.

Glaciation. Country affected by the accumulations of ice and snow during the "Ice Age" period which generally extended from 2.5 million years to 10 000 years ago. During this period there were at least six separate glacial periods. Amongst the most notable legacies in New Zealand are the effects on some mountain and valley shapes and the amount of detritus left behind by glaciers as they melted.

Gneiss. Rock that has been altered by heat and pressure deep in the earth's crust.

Greywacke. The predominant rock of the New Zealand mountain chains. The word is derived from the German "grau-wacke", or "grey rock". It is a sandstone, containing many grades, laid down originally under the sea.

Groyne. A low, broad wall of rock built in a river to direct its current in a desired direction

H.

Hanging Valley. A tributary valley joining a main valley from a higher elevation. It is a common feature of glaciated country because a glacier has gouged the main valley out more deeply than have the glaciers in its tributaries.

High Velocity Channel. A channel with strong foundations and sides—usually built in concrete—formed to take the flow of a steeply graded stream without danger of erosion. It is a technique used to take the flood flows of streams in urban areas.

I.

Ice Polished. Hard rock worn smooth by a blanket of ice. Scratches on the rock give testimony to the movement of the ice. A common phenomenon in the hard rocks of Fiordland.

L.

Levee. The natural bank of a river formed during flooding. The heaviest material in suspension is dropped closest to the river bank and gradually builds it up.

Loess. Wind transported dust or silt, forming deposits sometimes of considerable thicknesses. In New Zealand deposits have been formed by strong winds blowing down mountain valleys and picking up material finely ground by glaciers.

M.

Matchbox Farming. When hill country was first cleared of native forest in New Zealand much of it reverted to second growth of native shrubs and introduced weeds. This was repeatedly burned in endeavours to encourage grass or other growth palatable to stock. However frequent burning encouraged prolific weeds such as gorse and caused deterioration of soils.

N.

Natural Water. The Water and Soil Conservation Act 1967 says natural water is " . . . all forms of water, including fresh water, ground water, artesian water,

sea water, geothermal steam, water vapour, ice, and snow that are within the outer limits of the territorial sea of New Zealand; but does not include water in any form while in any reservoir under the control of a public authority and used mainly for the water supply purposes of that public authority, or in any pipe, tank, or cistern."

New Zealand Company. Formed in England in 1839 to undertake the colonisation of New Zealand.

P.

Pakihi. Maori word for open space in forest. Usually a wet, badly-drained area covered with low-growing, acid-loving vegetation.

Petrochemicals. A range of numerous materials derived from petroleum or natural gas.

Podocarp. Literally meaning, "seed with a foot"—referring to the stalked seed. A family of coniferous trees and shrubs containing about 60 species and growing mainly in tropical and sub-tropical forest. In New Zealand rimu, totara, kahikatea and some other trees are podocarps.

Potable. Drinkable.

Pumice. A frothy, acidic volcanic rock formed by the sudden release of steam and gases as it solidifies after eruption.

R.

Rating District. A legally defined area over which rates are levied to help finance a river drainage or catchment control scheme.

Return Period. The lapse in time expressed in a regular period of years that is expected between floods of a given size. The figure is assessed from existing records of floods and a knowledge of the river's catchment. In nature floods occur randomly, but the longer the period of records and the more detailed the knowledge of the catchment, the more accurate the assessment of return periods.

Riparian. Situated on the banks of a river.

Riparian Right. A doctrine that governs the use of surface water and gives all owners of land contiguous to streams, lakes and ponds equal rights to water. A form of real property that is inherited with the land.

River Control Scheme. A plan of river training, with or without stopbanking, to prevent floods up to a certain level from inundating land and to prevent river bank erosion.

S.

Scree. A mass of detritus coming to rest as a steep stony slope on a mountain side. Screes are particularly common in New Zealand mountains following the last phase of glaciation and as a result of recent accelerated erosion.

Sedimentary Rocks. Rocks formed from sediments originally laid down under water. Because of the manner in which they have been laid down they contain distinct layers or strata.

Shingle. A collection of loose pebbles or small, rounded (water-worn) stones.

Sluice Gate. A gate constructed so that it can be opened or shut to let out or retain water. Most commonly built in drainage systems to regulate the level and flow of water.

Steroid. Complicated hydrocarbon chemicals occurring in plants and animals.

Stopbank. Artificial embankments built along streams or rivers or on flood plains to confine flood flows to a definite width for the protection of land outside the stopbank. Apart from protection, stopbanks have other effects such as raising the level of flood flows and increasing their speed. Construction to obtain the desired effect or combination of effects has to be carefully calculated and planned.

Stormwater. Water gathered in an urban area during rainstorms and carried away through the urban piped disposal system. The speed with which it gathers increases as the area of rooftops, sealed roads, footpaths, etc, grows.

T.

Tectonic Movements. Movements in the structure of the earth's crust.

Tidal. A body of water affected by the movements of the tide. The lower reaches of rivers in which there are flat gradients can be affected by the rise and fall of tides. When this happens high tide coinciding with a flood adds to the height of the flood.

Tussock Grassland. The common name applied to natural grassland of New Zealand that is dominated by bunched grasses growing individually, with other native plants in between. It can be contrasted with sward-forming introduced grasses used in agricultural areas.

V.

Volcanic Plateau. A plateau of rhyolitic rock known as ignimbrite, some 21 500 square kilometres in extent, lying between Ruapehu and the Bay of Plenty in the North Island. It was formed by eruptions in the early Pleistocene period. This plateau has since been warped, broken by great faults, and blanketed by ash showers. Large, high standing remnants of it survive as the Kaiangaroa, Patetere, Mamaku, and Kaharoa Plateaus. Volcanic cones and

domes have been built up above the ignimbrite, and depressions, formed by warping and explosions, have been occupied by lakes. At the southern end of the ignimbrite plateau are Mts Tongariro, Ngauruhoe and Ruapehu.

W.

Water Allocation Plan. Regional Water Boards investigate and record resources of natural water in their districts. Based upon this information they sometimes draw up tentative water allocation plans based on current and possible future uses. These serve as a guide to further investigations. The use of water, however, is only permitted through water rights except for the general legal right to water domestic stock and to fight fires with water.

Water Harvesting. Irrigation water stored in a dry catchment—by damming—during heavy rain or by diverting streams into it. The water is normally used for small scale horticulture or cropping associated with other farm activities. The term does not apply to large in-channel dams and reservoirs.

Watershed. See Catchment.

Water Right. The 1967 Water and Soil Conservation Act lays down that, with certain limited exceptions, "the sole right to dam any river or stream, or to divert or take natural water, or discharge natural water or waste into any natural water, or to use natural water, is hereby vested in the Crown . . ." Water rights must be obtained to do these things. Regional Water Boards handle the water right applications.

Water Table. The level below which the soil or the pores of a rock are saturated with water.

Wetlands. The IUCN (International Union for the Conservation of Nature) have defined wetlands as "areas of marsh, fen, peatland or water whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

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