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(E77-10235) SEISMOTECTONIC, STRUCTURAL, VOLCANOLOGIC, AND GEOMORPHIC STUDY OF NEW ZEALAND: INDIGENOUS FOREST ASSESSMENT IN NEW ZEALAND: MAPPING, LAND USE AND ENVIRONMENTAL (Department of Scientific and Industrial G3/43 N77-33566 Unclas 00235

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FINAL REPORT

LANDSAT II INVESTIGATION PROGRAMME

No. 28230 SRT

VOLUME III

Physics and Engineering Laboratory
Report No. 587 September 1977

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PART II

MAPPING, LAND USE AND ENVIRONMENTAL STUDIES IN NEW ZEALAND

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14.1 INTRODUCTION

14.1.1 As this is the final quarterly report on the LANDSAT II programme, it will cover the full range of our Department's involvement since the initial proposal submitted in January 1973 and will summarise the findings made during that time. Over this period we have regarded the investigation of the use of LANDSAT and airborne multispectral imagery primarily as research to evaluate their potential and acquire the necessary knowledge and expertise for continued involvement. Although some of the cartographic activities have proved productive, e.g., hydro lake shapes and relief shading assistance on small-scale mapping, the requirement for continued access to this information for these needs is not as essential as the monitoring and thematic mapping potential offered.

14.1.2 Over the period of this programme, several of our mapping, surveying, photogrammetric, and planning controllers have attended overseas conferences and establishments and have made first-hand observations of remote sensing activity and achievements. This contributed to the decision to appoint an investigator to evaluate the potential of remote sensing in general for the Department's activities. At the same time we have made great use of the knowledge and expertise of the principal investigators team at the Physics and Engineering Laboratory and their various overseas visitors. For instance, the advice and knowledge contributed by Dr Anthony J. Lewis from Louisiana State University were of particular value not only in remote sensing generally but particularly in the field of SLAR and SAR (Side Looking Airborne Radar and Synthetic Aperture Radar).

14.1.3 In retrospect, our initial expectations of the amount and frequency of available imagery have not been fulfilled; we have not yet received complete cloud-free imagery of the whole country. Our requirement for a mosaic of imagery covering the country has been deferred until complete coverage is achieved, although, as an interim measure, selected areas will be mosaiced and published.

14.1.4 Initial applications for use of the imagery were found in basic mapping production, but as our confidence and ability to utilise this data increased, concentration turned to other activities to produce results for evaluation.

14.2 OBJECTIVES

14.2.1 Our aims, submitted to NASA in early 1973, were the result of discussions with various discipline leaders within our Department. The potential benefits to these activities were unknown at that time, but the availability of some LANDSAT I images of New Zealand and the knowledge some people interested in remote sensing activity had developed enabled a statement of objectives to be formulated:

Topographic Mapping

The initial use proposed for the photographic images was in 1:250,000 scale mapping. Coinciding with the introduction of new metric mapping it was considered that satellite imagery could prove a valuable source of data for the revision of existing 1:250,000 mapping.

Photomap Series

As an interim alternative to the planned metric 1:250,000 series it was proposed that a 1:250,000 photo map series could be produced. Mosaiced LANDSAT images, suitably enlarged, could be produced covering the new metric sheet lines.

Environment Studies

It was proposed to utilise the monitoring potential of sequential LANDSAT coverage to:

1) Investigate conservation and pollution problems in New Zealand that have reached serious proportions overseas, e.g., lake weed proliferation.

2) Evaluate the progress and success of remedial practices applied in the management of high country pastoral lands. Extensive areas subject to serious soil erosion as the result of unwise depletion of vegetation cover and of overstocking are being restored to productive and recreational capability.

3) Provide input into the New Zealand Land Inventory series.

14.2.2 Data Handling

On receipt of data in the form of photographic products, examination and cataloguing would be performed before the production of quick-look prints. These prints would be made available to contributing users throughout New Zealand and to overseas investigators. Potential users of imagery would be informed of the acquisition of new images. Black and white prints of single-band images would be made available at up to seven times enlargement through our photographic library.

14.2.3 Reports

These would be prepared quarterly for NASA and monthly for departmental use. Liaison with the Department's cartographers, photogrammetrists, and planners would be maintained with informal discussion and workshops. Close contact with the principal investigators team at Physics and Engineering Laboratory would be arranged.

In the following sections, the results of these objectives will be presented together with other activity that has evolved throughout the programme.

14.3 DEPARTMENT'S REMOTE SENSING SECTION

14.3.1 With the acceptance of the Surveyor-General as a co-investigator, a section within our established photogrammetric branch was set up to evaluate the contribution LANDSAT could make to the Department's activities and to pursue the objectives in Section 14.2. The necessary expertise and knowledge to carry out this work would be acquired by study and liaison with other remote sensing activity in the country. Several workshops and discussion groups have been arranged to introduce to the Department's mapping, surveying, and planning groups the availability of remote sensing information and expertise. Although, so far, the prime use of this data has been in mapping, the anticipation of future improvements in quality of imagery has generated consideration of other activities, e.g., monitoring of National Park development and management, snow cover variations, vegetation damage by noxious animals, and the results of development programmes in retired high country pasture areas. (Although lake weed is a problem that is receiving some attention at present, airborne monitoring has proved of more practical use due to resolution limitations of satellite imagery.) It is in these fields particularly that evaluations of the potential of seasonal satellite coverage could be of great benefit. Over the period of the report the extent of cloud-free coverage received would indicate that monitoring of areas on an annual or bi-annual basis would be practical.

14.4 ACTIVITIES

14.4.1 Distribution of Imagery

Quick-look prints (see Fig. 14.4), have been produced for all the LANDSAT I and II imagery of New Zealand within the contractual area (see Fig. 14.5) up until April 1977. These prints are distributed to contributors and investigators on application to Photographic Library, Lands and Survey Department, Head Office, Wellington. Sets of prints are made available for reference throughout New Zealand in twelve main centres.

Up to seven times enlargements of individual bands can be provided in black and white print form. As most requests for false colour composites to date have been primarily for display purposes, it is proposed to make 35 mm slides available for sale. Slides of individual images as well as mosaics of specific areas will be made. These will have an "average" colour balance, and production of the prints for photography is now in hand. A mosaic of the whole of New Zealand for reproduction at 1.2 million scale is also being produced.

For interpretive analysis colour composites continue to be supplied by Physics and Engineering Laboratory, who have the only colour additive viewer in New Zealand.

14.4.2 Reflector Programme

The original requirement for a workable reflector programme was to mark triangulation points to facilitate geometric correction of imagery; we now realise that, owing to the increasing quality of imagery, this can be achieved as accurately by identification of selected topographic features on the LANDSAT imagery. The use of reflectors in New Zealand has limited cartographic application because of the relatively good mapping

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coverage of the country, but in Antarctica, for instance, there could be a real need for spot identification. It is also considered that the results of a successful reflector programme in New Zealand could, when compared with the results of similar projects overseas, produce information on relative atmospheric effects, satellite monitoring, and reflectance values. It is with these issues in mind that the reflector programme has continued. To date we have not been successful in locating the reflector on photographic products of the site, but we realise that a convex mirror as we are using may be difficult to identify. We are optimistic that positive identification will be achieved on the CCT of the scene. Once we have confirmation that the necessary calculation of azimuth and elevation can be carried out in setting up a reflector, then we plan to experiment with plane reflectors.

14.4.3 Photogrammetric Plotting of LANDSAT Data

As an evaluation of the cartographic accuracy of LANDSAT data on UTM-based maps, a short programme was carried out using a photogrammetric plotter to extract information from the photographic product. This experiment utilised black and white transparencies as well as colour composite transparencies. A variety of plotting scales within the capability of the instrument used for the study (the Zeiss Planicart E3) was produced, and the accuracy was found to be acceptable for ephemeral detail such as vegetation boundaries, for scales of 1:250,000 and smaller. Difficulty was experienced when plotting scales larger than 1:250,000 due to the area covered by the "floating mark" in the instrument (60 m diameter), although with an experienced photogrammetrist operating the plotter an agreement of ± 100 m was achieved with the map information. For scales of 1:250,000 and smaller the Bausch and Lomb zoom transfer scope was found to be adequate for extraction of the type of information that LANDSAT would be used to provide. This would be in the form of updating vegetation patterns on topographic maps. As indicated in paragraph 14.2 - Topographic Mapping - the most probable use LANDSAT data would have in this scale of mapping would be in a revisionary capacity, for which the zoom transfer scope would be adequate.

It was concluded on completion of this programme of photogrammetric applications of LANDSAT imagery that, as there is limited stereoscopic effect when overlapping images are viewed, the use of expensive photogrammetric plotters cannot be economically justified. Future analysis of imagery would be by zoom transfer scope, tracing, or by use of CCTs and a photowrite instrument.

14.4.4 Land Use Investigation

In 1973, when the initial LANDSAT II proposal was made, this Department's resource mapping activity was under review. We had been involved in the production of an inventory survey of New Zealand incorporating a variety of thematic maps on a common-scale topographic base. Because this work was of a lower priority and primary effort was being given to the completion of the country with basic (1:63360 1" = 1 mile) topographic mapping, it was decided that the initial programme was probably too ambitious and a review of the whole concept was instigated.

The basic requirement of the user of resource mapping (the planner) is that the information be collected and displayed visually in as short a time as possible to avoid being out of date too soon. With this concept in mind new specifications were designed to present categories that are "correct" at the time of compilation, and cartographic methods were adopted to reduce draughting time. Where previously our Land Use/Land Cover map had categorisation that indicated a productive/unproductive and developed/undeveloped basis, the new specifications adopted were similar to the USGS codes adapted for New Zealand conditions (see Fig. 14.1). Land use information is produced in a form that indicates the natural character and quality of the land from which interpretive evaluations can be made by the user. This map is produced in conjunction with other thematic maps all at the same scale and on the same land holding/topographic base, e.g., soils, geology, tenure, vegetation, and wildlife. Our sources of information for these maps, with the exception of tenure and use, are scientists in relevant disciplines employed by different Government departments.

For the Land Use and Land Tenure maps recourse to land title information, ground parties, and aerial photography has provided the material. It is in the land use field that LANDSAT data can make the most valuable contribution to our Department's activities. The convention that information for the land use map be provided for the cartographer to produce the map would in the case of LANDSAT analysis be improved if analysis of the imagery, ground truth checks, and map production have close liaison.

The initial area selected for study was Northland (see Fig. 14.2). This choice was based on a number of factors—it is a homogeneous region, an area of potential development, and one which is of interest to both regional and central government planners. It was also the first "region" to be the subject of central government's Regional Development programme. Unfortunately, for remote sensing purposes, we received only one LANDSAT II scene that covered part of the area.

The Northland study was superseded in priority by a requirement for data covering the King Country (see Fig. 14.2). Because of conflicting interests involved in the development of this area, a land use study was required by the Government as a basis for suitability evaluation and recommendation. The specifications for the Northland study were adopted with slight modifications. Although LANDSAT imagery of the area was available, the urgent need for the data, coupled with our relative inexperience in interpretation of the imagery, precluded its use in the survey, for the production of the land use map at least, and conventional ground survey methods were used. However, a retrospective study of part of this area, at a smaller scale (1:100,000) has been conducted using the LANDSAT image 2389-21172. The ground truth provided by the original parties for the conventionally produced map served as source data for this retrospective survey which also utilised airborne multispectral photography. Results indicate that LANDSAT could make a valuable contribution to studies of this nature in that the Land Use categories used for this study are closely related to vegetation patterns. If the specifications could be adapted to use vegetation patterns, then the use of LANDSAT would be assured. Consultation with the planners will ascertain the requirement of this type of information.

The Surveyor-General has indicated that, subject to the availability of suitable imagery in areas of departmental requirement, another Land Use study will be started. Possible areas are MacKenzie Basin, an area of high country management and hydro development, or Tongariro Region, an extension of the King Country (see Fig. 14.2). In this future study, use will be made of the 1^2S multispectral camera. This has recently been operationally tested over a variety of test targets, in order to evaluate suitable camera exposure settings for specific targets at differing times of the day and year. Although by no means comprehensive, a list of indicators for future use of the camera has been built up with the co-operation of the Physics and Engineering Laboratory.

The requirement for a "real time" ground receiving station has become evident for our resource mapping activity, but no cost benefit analysis has yet been made.

14.4.5 Topographic Mapping

Relief shading topographical maps has always been based on the contours and aerial photography for the basic 1:63,360 scale topographic series. For smaller scale relief shading, reference to the basic series covering the new map is made. The recent availability of LANDSAT imagery as an aid has enabled some evaluations to be carried out coincident with the introduction of a new metricated series. Difficulty has always existed, even with good, up-to-date source material, in relief shading areas of low profile or confusing, broken relief. This problem was obviously compounded in areas where the original surveys for the mapping were from less reliable methods than photogrammetry. Also, even where good survey information was available the relief is not always portrayed by contour intervals selected for the scale of the map. Generally, only in areas where the relief is not bold does the cartographer need to refer to information other than the contours. The new 1:250,000 map series is not suffering from a lack of reliable topographic source material, but the problem of low relief areas remains. The topography on this map series will not include contours, so the relief shading will need to be of a fairly high, detailed standard. LANDSAT's synoptic overview has contributed uniquely to the production of this mapping and to mapping of smaller scale maps. In New Zealand we are particularly fortunate that the "northern" illumination from the sun allows orientation of the imagery to coincide with the "north-at-the-top" convention of mapping. This avoids the pseudoscopic effects that seem to occur in northern hemisphere imagery. The convention of maintaining north at the "top" of the map could, of course, be broken, but in the southern hemisphere we can still maintain this conventional relationship and utilise the relief effects of the imagery. (This of course would make the production of a photomap series a reasonable proposition.

Band 7, black and white enlargements are used by relief shading cartographers for 1:250,000 mapping and smaller scales. The large coverage of the imagery helps keep a tonal balance between the high relief areas and the lower-lying areas. A comparison of summer and winter imagery indicates that the lower sun angle of the winter imagery tends to emphasise the low relief areas, a definite advantage to the relief shading draughtsman. Fortunately the effects of the low sun angle in high relief areas do not worry the cartographer, as these are the same areas that are easier shaded by reference to the contours.

The contribution to relief shading of 1:250,000 scale topographic maps (and smaller scales) is accepted, but less use has been made of the definition offered for cultural features. Scaled images have been used by the cartographer to edit the line drawings of the hydrography, particularly in areas where selection of detail is necessary due to scale changes. The imagery indicate which streams have made the most significant impact on the topography. The up-to-date shapes of low-lying lagoons, lakes, and hydro-electric storage lakes have been checked, and there is a growing awareness that this is a source of data that can be utilised to produce more accurate maps. A new edition of a 1:1,000,000 map of New Zealand is being considered, and LANDSAT will be utilised in its compilation.

14.4.6 Offshore Islands

As indicated in our initial proposal and with references to overseas applications, we hope that LANDSAT imagery will assist our mapping of numerous offshore islands, especially to orientate and position them in relation to the main islands. For example Cuvier Island (see Fig. 14.3) has been mapped photogrammetrically, but its orientation is uncertain because of the fact that there is only one co-ordinated triagulation point on the island. It is possible that good results could be achieved by utilising LANDSAT information of the area in the CCT form that can be geometrically corrected and the results output on a photowrite machine.

14.5 OTHER ACTIVITIES

14.5.1 Antarctic Mapping

Our Department has been involved with the mapping of parts of Antarctica. In recent discussion with R. H. Lyddan, Chief Topographic Division, U.S. Geological Survey, on the subject, it was agreed that co-ordinated mapping in the Ross Sea/Victoria Land area would be investigated and undertaken utilising LANDSAT imagery. An analysis of the work involved in updating the mapping in this region is being conducted. Although this activity is outside our contractual agreement, it is being reported on for interested readers.

14.6 CONCLUSIONS

14.6.1 As indicated in Section 5 "Objectives", the initial proposal indicated ways in which it was felt that LANDSAT data could be used in our Department's activities. The expectations at that time were that we would at least obtain complete coverage of the country, as within a year of operation of LANDSAT I the whole of the United States had been covered. Experience has now shown that to possibly achieve this would have required the setting of a higher figure for cloud cover acceptance than the 30% originally specified. The micro climate of New Zealand and perhaps the higher priority requirements of other areas militated against obtaining more comprehensive coverage. Complete cover of New Zealand is even more desirable now that we have found that the imagery is of a higher standard than initially indicated and continues to improve in quality. Over the period some aims have been achieved and new aims have been generated. With reference to Section 14.2 the following conclusions were reached:

14.6.2 Topographic Mapping

In this field the use of imagery for relief shading of 1:250,000 and smaller scale maps has been adopted without reservation. The use of scaled imagery for editing has been accepted, and as a compilation source for a new 1:1,000,000 and a 1:2,000,000 scale map the imagery is being supplied on production.

In this field, more use has been made of the imagery than was initially expected. Continual use should ensure its adoption as a standard source of compilation material.

14.6.3 Photomap Series

Investigation in this activity was deferred with the continual hope that cloud-free imagery would be obtained of the country. Although no progress was achieved in the production of a series, we have been conducting experimentation to combine line information, streams, roads, etc., with imagery. The success of this, as explained in the section by Physics and Engineering Laboratory, has led to a requirement for line/image base maps to be produced as an educational product for schools and as a base map for thematic overlays.

14.4.4 Environmental Studies

a. Little effort has been made to utilise imagery for monitoring pollution or conservation in our Department. Lake weed is a problem, but LANDSAT at present hasn't the resolution for this to be identified. Investigations are being conducted using colour and black and white aerial photography. Interest in the use of LANDSAT for snow monitoring has recently been expressed.

b. Again no progress has been made in the monitoring of high country management, but interest in this potential is still maintained. The recent receipt of an excellent scene in the central South Island has provided the potential to investigate this area.

c. The use of LANDSAT in the King Country has shown that in a variety of disciplines this imagery can contribute to

Inventory studies. Our Department's particular interest is in the production of Land Use maps, and the retrospective study in the King Country has indicated the potential of recent imagery for this type of map.

Data have been made available to all potential users, and display material has been produced to support the programme, particularly by Physics and Engineering Laboratory. Quarterly reports have been produced for NASA, and workshops, informal discussion, and direct liaison with users within the Department have been arranged. Throughout the programme the valuable co-operation and help of the Physics and Engineering Laboratory have been of benefit to our Department's development and results. Their co-ordinating of the varied and expanding spheres of interest in New Zealand's remote sensing field is appreciated. We look forward to continuing this joint involvement in future satellite programmes.

14.7 REFERENCES

1. A Land Use and Land Cover Classification for Use with Remote Sensing Data.

   USGS Professional Paper 964. J. ANDERSON, E. HARDY, J. ROACH, R. WITNER 1976

2. International Classification and Mapping of Vegetation. UNESCO Paris 1973

3. Positioning Offshore Features with the Aid of LANDSAT Imagery.

   E. A. FLEMING, Canada
   Photogrammetric Engineering and Remote Sensing
   Vol 143 No. 1

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NATURAL AREAS

Wildlands

s	Steeplands
u	Uplands
l	Lowlands
d	Downlands

Resource conservation areas

h	Water
p	Soil
v	Vegetation
w	Wildlife
r	Recreation
z	Special purpose

Wetlands and floodplains

f	Floodplains
a	Wetlands
m	Water, man-made
n	Water, natural
	Marsh

PRIMARY INDUSTRY

Farming

l	Specialists livestock
g	Market gardens and orchards
a	Arable farming
d	Dairying
	Grassland farming
s	sown / developed
i	undeveloped / improved
w	Farm woodlots
	Honey production
	spring
	summer

Forestry

	Plantation
p	cleared for planting
p (with + marks)	planted
	Timber
t	under $\frac{1}{3}$ removed
t	$\frac{1}{3}$ to $\frac{2}{3}$ removed
t	over $\frac{2}{3}$ removed
	Timber reserve
v	virgin
c	cutover

Extractive

q	Quarrying
u	Mining
e	Dredging and sluicing

OTHER AREAS

Rural institutional

h	Historical
a	Amenity
z	Special institutional

Urban

u	Built-up
p	Open space
f	Institutional functional

Idle Land

d	Waste
w	Derelict
i	Idle

SYMBOLS

For isolated features or areas less than 20 hectares

- Sawmill
- Quarry
- Dairy factory
- Isolated dredgings
- Isolated mine
- Airstrip
- Historical site
- Tourist site

NOTE:

Rural land is often used for multiple purposes and activities. These are shown by combining individual land use codes with important subsidiary uses shown in brackets.

s(aw)	Farming : predominantly grassland farming on sown pastures, with some arable land and woodlots.

Fig. 14.1—Example of Land Use Codes used for the King Country Land Use Study.

Recent Land Use Studies in New Zealand

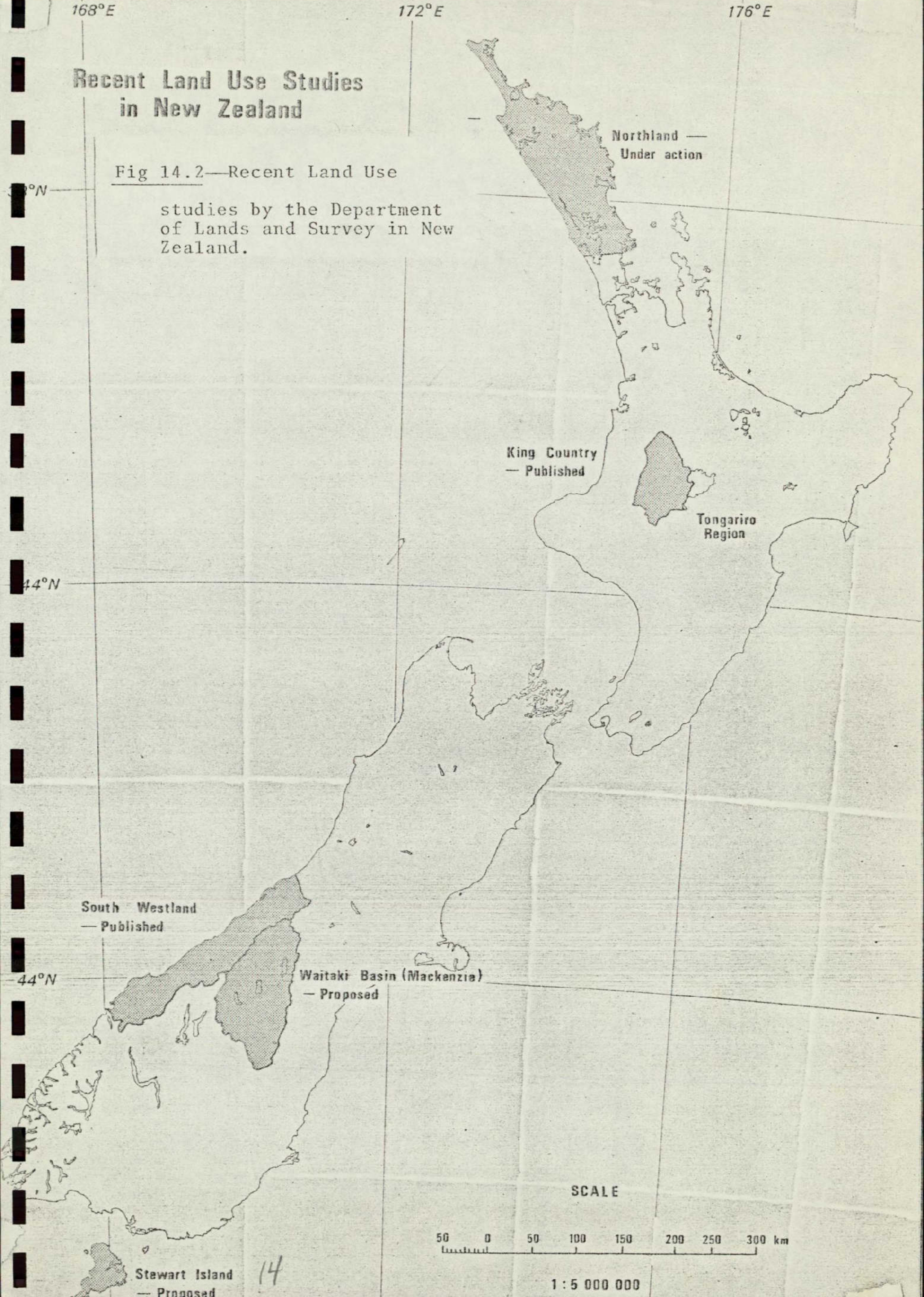


Fig 14.2—Recent Land Use studies by the Department of Lands and Survey in New Zealand.

Positioning of
Offshore Islands

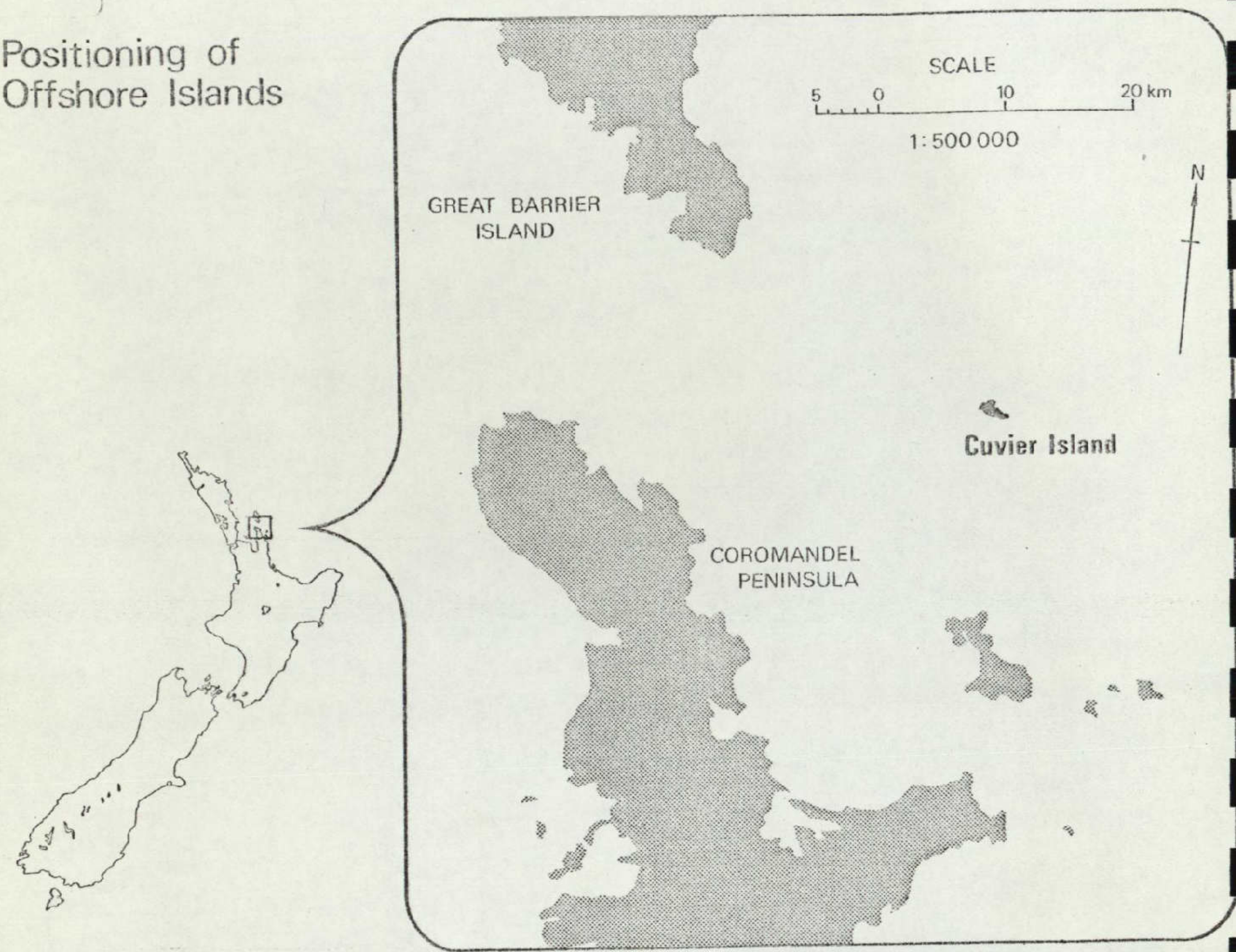


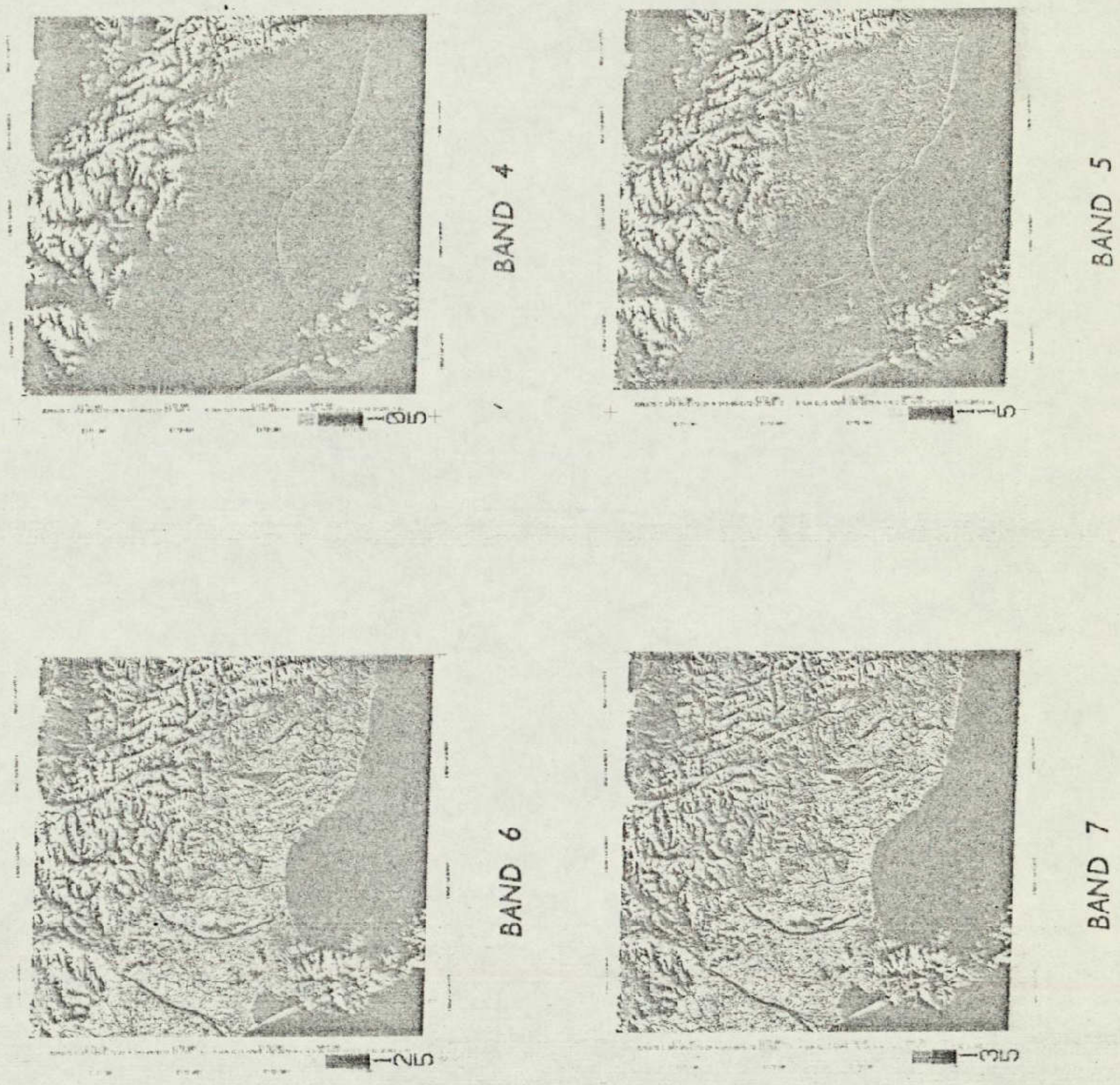
Fig. 14.3—Positioning of offshore islands

IDENTIFICATION NUMBERS

LANDSAT "QUICK—LOOK" PRINTS *E— 2192—21265 —4 (BAND)*
5 "
6 "
7 "

Photo. credit: NASA, U.S.A.

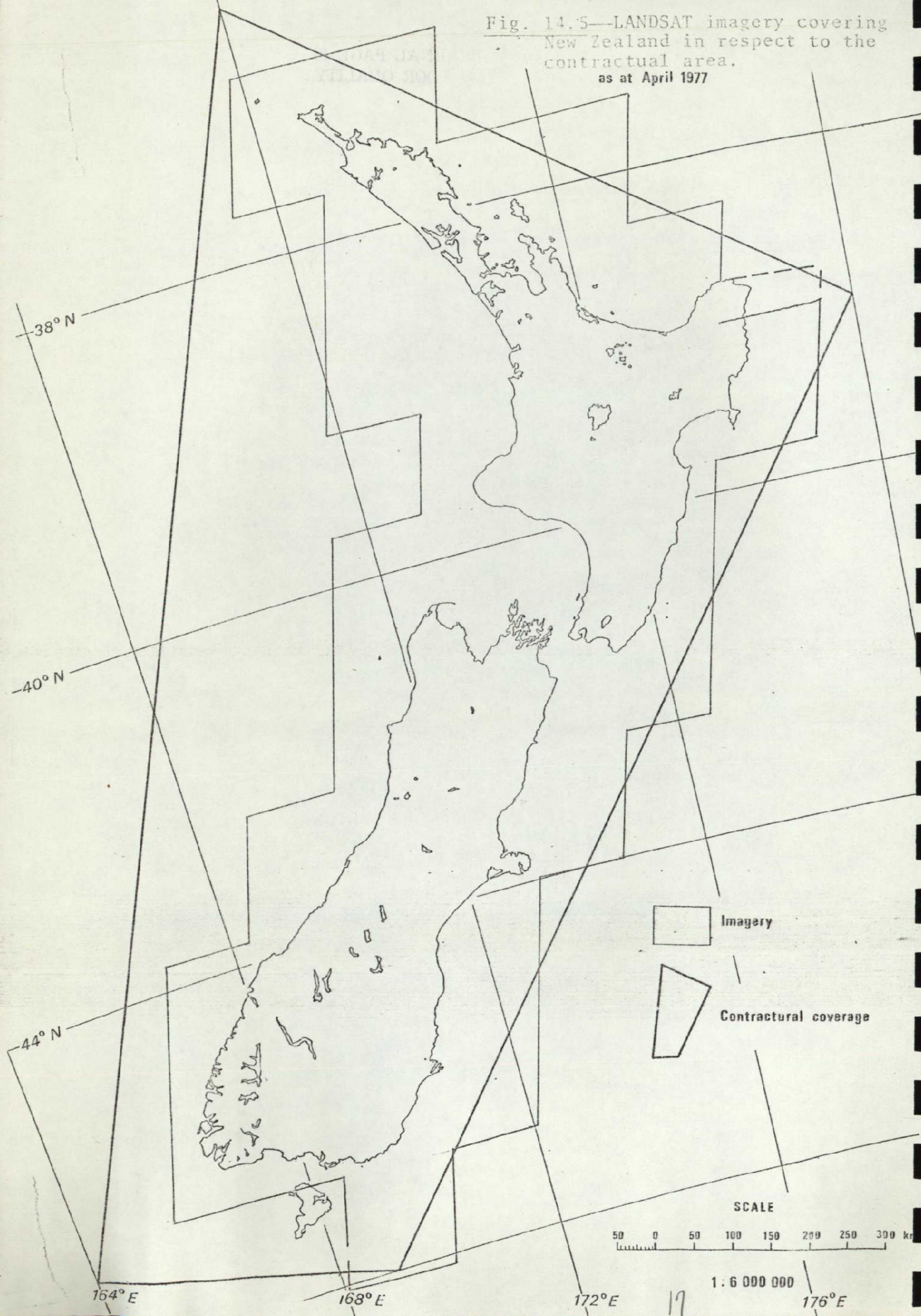
SCALE 1:3,369,000



Prints, or single enlargements of each band at 1:1,000,000, may be purchased from the Photo Library, Department of Lands and Survey, Private Bag, Wellington.

Fig. 14.4—Example of quick-look print

Fig. 14.5—LANDSAT imagery covering New Zealand in respect to the contractual area.
as at April 1977



PART III

SEISMOTECTONIC, STRUCTURAL, VOLCANOLOGIC AND GEOMORPHIC STUDY OF NEW ZEALAND

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CHAPTER 15

SEISMOTECTONIC, STRUCTURE, VOLCANOLOGIC, AND GEOMORPHIC STUDY OF NEW ZEALAND

P. J. OLIVER

WITH FOREWORD BY R. P. SUGGATE

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FOREWORD

Complete coverage of New Zealand by LANDSAT II has not been achieved. This, together with the variation in image quality, cloud cover, and variable sun angles, in the imagery that has been received has meant that a geologically useful complete mosaic of the imagery has not been possible. Geothermal and volcanologic mapping has also not been possible because no thermal band imagery was available from LANDSAT II. No new volcanic deposits were observed on the imagery received, although known volcanic centres, of all geological ages, were readily distinguished.

In general, geological features were most readily observed on black and white positive transparencies of MSS Bands 6 and 7. These were used, together with black and white prints and colour composite prints of all MSS Bands, to determine geological features.

The most positive use of the LANDSAT imagery has been for the mapping of lineaments. The lineaments are reflections of structural, seismotectonic, and geomorphic features. Lineaments related to active faulting could not be distinguished from other faults and fractures. Known major active faults could be seen on the LANDSAT imagery and could be enhanced by using colour composites of MSS Bands 4 and 7 to highlight the water contained in crush zones, but active fault traces in alluvium could not be detected.

Most of the lineaments observed are undoubtably related to the horizontal strain field that is a result of New Zealand's position on the boundary of two major crustal plates: the Pacific Plate and the Australian Plate. The regularity of the lineament directions confirms the regional nature of the faulting and fracture systems in both the North and South Islands.

The relation of lineaments to economic mineral deposits has only limited application over much of New Zealand. However, lineaments in the central Otago region have a positive correlation with known reefs in that area, and may prove to be of use in the location of additional economic deposits of gold, scheelite, and stibnite, in particular. Onshore petroleum exploration in New Zealand has been largely unproductive, but the lineaments from LANDSAT imagery in areas such as Gisborne will be useful as a guide to mapping of major structural features. Large décollement structures, already mapped in the field, can be identified on the imagery, and many sets of faults and probable faults observed on the imagery will prove a base for further field work.

In the Southern Alps of the South Island, where vegetation is sparse, lithologic units with distinct spectral signatures were observed in the higher country areas. However, snow, scree, loess, and glacial outwash deposits mask much of the lower country, and conceal the mapping of lithologies from LANDSAT imagery.

The geomorphological pattern of sedimentary rocks has been found to be sufficiently distinctive in some areas to warrant further study. In particular, known Jurassic rocks of the Canterbury - Marlborough region have a distinctly different erosion pattern and relief to known Triassic rocks of apparently similar lithology. In the Hawke's Bay-Gisborne area the Mesozoic rocks can be readily distinguished from the Tertiary rocks on the LANDSAT imagery. Further subdivision based on geomorphological studies seems possible, and extension of the work to include the Quaternary deposits is contemplated. The advantage of LANDSAT over conventional aerial photography is particularly evident in this area.

Several areas covered by LANDSAT imagery are described for the first time below. In general known geological features, such as major lithologic boundaries, can be identified by comparison with existing 1:63 360, 1:250 000, and 1:1000 000 geological maps produced by the New Zealand Geological Survey, but recognition of detailed geological features in LANDSAT imagery was often impossible. The only significant new geologically important data to be obtained from the images was that relating to lineament studies, and therefore only this aspect is discussed below.

It is hoped that with the better resolution and more frequent sequential cover provided by the proposed LANDSAT C project, together with the thermal (emissive) spectral band provided by that project, many of the present drawbacks of the LANDSAT II project may be overcome. In particular, geothermal mapping, which is of great importance to New Zealand, may then be possible.

The value of the LANDSAT imagery in the geological field has not been fully tested so far, but sufficient has been done to point the way to something of its uses and also to some of its limitations. It will be used in Geological Survey, in Universities, and by mining interests in an increasingly routine and detailed manner.

I should like to thank numerous individuals in Geological Survey, including D. L. Homer, K. R. Berryman, D. N. Williams, and most particularly P. J. Oliver, for their work in connection with this project.

R. P. Suggate
Principal Investigator

DETAILED STUDIES

P. J. Oliver

15.1 Otago

The 6 April 1977 LANDSAT image (E-2805-21165) of the Otago Province (Fig. 15.1) covers geological strata that have a south-east trending regional strike. The axial belt of Central Otago consists of Haast Schists, and the northern and southern margins consist of predominantly Triassic and Jurassic "greywacke"-type sandstone and siltstones. In the southern part of the LANDSAT image there are pronounced lineaments striking to the north-west (Fig. 15.2). These lineaments are a result of erosion al ong bedding planes in the Jurassic and Triassic sediments that make up the north-east limb of the Southland Syncline (McKellar 1966; Wood 1966). These prominent north-west striking lineaments are cut by a set of minor north to north-east striking lineaments.

In the central schist zone of the region there are also two prominent lineament trends with similar orientations to those observed in the Southland Syncline. However, the prominent lineaments in the central schist zone strike north and north-east, the minor lineaments generally having a north-west strike. The minor lineaments in this image are arbitrarily defined as those with lengths of 5 km or less (Fig. 15.3), and the major lineaments are those with lengths greater than 5 km (Fig. 15.4).

In the western part of the image both major and minor lineaments have a strong bias to a north-south orientation; few lineaments strike north-west.

There is a narrow belt along the coast of Otago in which there is a conspicuous absence of the minor north-west trending lineaments, but instead there are minor and major lineaments with strikes of north-east and east. South of Dunedin the coastal block has an apparent lateral displacement to the north. The change in lineament direction there may be related to this tectonic aspect of the coastal block.

The major north-east striking lineaments throughout Otago are parallel to mapped faults (Fig. 15.4) that control the "basin and range" topography of the region (McKellar 1966). These lineaments are probably erosional features formed along faults that resulted from the late Tertiary to Recent Kaikoura Orogeny.

The minor lineaments are generally parallel to the lineations in the schist, but not the schistosity. This is particularly evident in the area around Middlemarch and along the Taieri Ridge (No. 1 in Fig. 15.2). Many of the major lineaments that are not parallel to the main north-east trending faults are also parallel to the lineations in the schist, e.g., in the Lammerlaw Range where both lineaments and lineations strike approximately north (No. 2 in Fig. 15.2). A major arcuate lineament (No. 3 in Fig. 15.2), which is sub-parallel to other major lineaments in the Lammerlaw Range, extends from north of the Upper Manorburn Dam, through the western side of Lake Onslow, to the Clutha River -

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a distance of over 45 km. If this curved lineament is extended across the Clutha River, it is possible that it is continued as the lineament along the western side of the Blue Mountains (No. 4 in Fig. 15.2) which stand out in the LANDSAT image as a large block upthrown to the east of the lineament just described. This block transgresses the lithologic and metamorphic boundaries mapped in this region (McKellar 1966).

Lineaments (Nos 5 and 6 in Fig. 15.2) in the north-eastern corner of the LANDSAT image correspond to the known fault called Waihemo No. 1 and 2 (McKellar 1966). Existing maps show these faults as curving to the south near the coast. The lineaments on the LANDSAT image indicate that these faults extend in a straight line with branch faults curving to the south.

Economic mineral reefs (mainly gold, scheelite, and stibnite) occur in the schists of Otago. The lodes tend to be oriented parallel to the north-west striking lineaments and lineations within the schists, e.g., at Pukerangi (No. 7 in Fig. 15.2) located south-east of Middlemarch. Thus the lodes generally strike north-west, with a few striking north-east. They typically dip at steep angles (Williams 1965). The lodes are all similar structurally and consist of sheared rock and pug with quartz veins. Both pre- and post- mineralisation movement in the lodes has occurred (Williams 1965).

Most of the lodes were discovered last century as gossans at the surface. Generally the lodes are of limited length even where the faulted crush zone extends for a longer distance, and most of the crush zone contain no economic concentrations. However, LANDSAT images may be useful in prospecting, as there is a clear relationship among lineaments, lineations in the schist, faulted crush zones, and known lodes. The lineaments probably represent erosional depressions along crush zones parallel to the lineation of the schist. The erosional depressions forming the lineaments probably contain surface gravels that would mask any ore-bearing crush zones.

15.2 North Otago-South Canterbury

The LANDSAT image (E-2805-21163) of 6 April 1977 covers the area of North Otago and South Canterbury (Fig. 15.5).

Lineaments observed in the image are almost entirely confined to the pre-Tertiary geological strata. These are dominantly "greywacke"-type sandstone and siltstone of the Torlesse Supergroup in the north of the image, together with Haast Schist metamorphosed sediments in the south of the image.

In the south-east corner of the image (No. 1 in Fig. 15.6) the Waihemo No. 1 fault is visible in the Kakanui Mountains as a straight lineament with a north-west strike. The Kakanui Mountains are dominantly schistose rocks with the schistosity and structures striking north-west (Mutch 1963). From the LANDSAT image three lineament directions occur in these mountains. The dominant lineament trend is parallel to the known Waihemo Faults and lineation in the schist which, in this area, is

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generally parallel to the schistosity (i.e., striking north-west). The second set of lineaments strike approximately north-east, and the third, which are the least dominant, strike east. Faults mapped by Mutch (1963) between the Otekaieke and Maerewhenua Rivers strike in these three directions (No. 2 in Fig. 15.6) and it is probable that the three sets of lineaments represent erosion along fault crush zones.

In the Mt Ida region (Bishop 1976) the lineaments do not generally correspond to mapped faults or bedding structure (Bishop 1976). Exceptions are the lineament of Blue Duck Creek (No. 3 in Fig. 15.6) and those in the Otiake and Otekaieke Rivers (Nos 4 and 5 in Fig. 15.6) which correspond to mapped faults.

A major lineament occurs at Kurow (No. 6 in Fig. 15.6) where it can be traced on both sides of the Waitaki River, and strikes in an east-south-east direction. In places this lineament corresponds to known faults.

North of the Waitaki River the dominant strike trend in the lineaments is east (No. 7 in Fig. 15.6), with less common but quite clear north-striking lineaments, of which the two major ones in the Hunter Hills are the most conspicuous (No. 8 and 9 in Fig. 15.6). The east-striking lineaments are typically less than 5 km long and cut across topographic features. They are not therefore simple drainage features of tilted blocks. They also do not correspond to either bedding or schistosity directions.

North-north-east and north-east striking lineaments occur in the area west of Lake Tekapo. The most prominent of these is a lineament that follows the Jollie River (No. 10 in Fig. 15.6) with an adjacent parallel lineament across the Burnett Range (No. 11 in Fig. 15.6).

The effect of sun elevation and direction on the visibility of the lineaments can be demonstrated by a comparison of the images E-2265-21321, E-2805-21163, and E-2192-21272. The first of these, E-2265-21321, has a sun elevation of 38° and an azimuth of 058°. This image was recorded on 14 October 1975. Although there is some cloud cover, the areas that are free of cloud have very few lineaments. East-striking lineaments are conspicuously absent (Fig. 15.7).

The LANDSAT image E-2805-21163 has a mean sun elevation of 21° and an azimuth of 055°. This image was recorded on 6 April 1977, and the lineaments observed in it are described above. A much greater number of lineaments are visible than in E-2265-21321. In particular, east-striking lineaments show up more clearly (Fig. 15.6).

The image E-2192-21272 has a sun elevation of 14° and an azimuth of 046°. This image was recorded on 2 August 1975. Although it covers only the eastern part of the land area covered by the other two images, the relative number of lineaments is greatest in this 2 August image (Fig. 15.8). North-striking lineaments are the most notable addition in this image. A particularly clear north-striking set of lineaments are visible in the range of hills north of the Opuhi River near Geraldine (No. 1 in Fig. 15.8).

It is thus quite evident that for lineament studies in low to moderate relief terrain such as covered by these images, a mid-winter low sun angle is required to obtain shadow enhancement of the linear features.

15.3 Southern Alps

A LANDSAT image E-2409-21293 of the Southern Alps was recorded on 6 March 1976 (Fig. 15.9). The Southern Alps consist of Torlesse Supergroup sandstone and siltstone, grading into schist (Haast Schist) towards the Alpine Fault, along their north-west boundary. The late summer images of this area are geologically interesting because the high sun angle (elevation 32°, azimuth 063°) reduces the shadow effects to a minimum, and the snow cover is also at a minimum. Vegetation is sparse on the eastern side of the Alps, and concealment of the rocks by debris is not such a problem as elsewhere in New Zealand.

Fig. 15.10 gives the lineaments observed on positive transparencies of MSS Bands 6 and 7. Many other lineaments are suggested along erosion features, but many of these may be due to simple run-off channels on steep slopes. Many of the larger valleys also show up as lineaments, but, as many of these result from glacial erosion, they may not follow usual lines of weakness such as faults, fractures, or major lithologic boundaries. Most of the minor lineaments in Fig. 15.10 (generally those less than 5 km long) are contrasts between lithologic units and are traceable across ridges. Major lineaments (those greater than 5 km long) are almost certainly fault controlled.

Fig. 15.11 gives the lineaments observed on LANDSAT image E-2391-21300, covering the same area of the Southern Alps which was recorded on 17 February 1976. The sun angle (elevation 36°, azimuth 069°) is almost the same as in the 6 March image, but, because of different cloud and haze cover, different lineaments can be seen.

15.4 North Canterbury-South Marlborough

The LANDSAT images E-2192-21265 of the North Canterbury-South Marlborough region was taken on 2 August 1975 (Fig. 15.12). The Southern Alps, forming the high ranges to the west of the image, were snow covered, and lineaments seen in the Alps were mainly those controlled by large straight valleys (Fig. 15.13). Many of the major lineaments (over 5 km long) are known faults predominantly oriented in a north-east to south-west direction. A second set of major lineaments strike north.

Along the eastern margin of the Southern Alps a dense swarm of parallel minor (less than 5 km long) lineaments are predominantly sub-parallel to the major faults, and locally to the known strike of Torlesse sandstone and siltstone beds (Gregg 1964). In the area west of Hawarden the lineaments curve around to strike north (No. 1 in Fig. 15.13). This is consistent with the strike of the beds in this area as mapped by Bradshaw (1972).

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These minor lineaments could be useful as an indication of probable bedding strike in this region.

The area covered by the minor lineaments also corresponds to an erosion topography of lower relief than that of the Southern Alps. This distinct geomorphological pattern indicates that the Cavendish Hills (No. 1 in Fig. 15.13) and Okuku Range (No. 2 in Fig. 15.13) may be of the same rock type as the Jurassic rocks of the Lowry Peaks Range (No. 3 in Fig. 15.13). The Torlesse Supergroup rocks of the Oxford Hills (No. 4 in Fig. 15.13) and Malvern Hills (No. 5 in Fig. 15.13) also appear to have a similar degree of dissection to the Jurassic rocks to the north-east. Jurassic plant beds are known to exist in the Malvern Hills (Speight 1928).

The low sun angle (elevation 15°, azimuth 046°) in the LANDSAT images E-2192-21265 favoured the observation of lineaments in the low-relief terrain, but not in the high-relief terrain of the Southern Alps. Summer images of the Southern Alps (E-2409-21293), besides being snow-free over much of the ranges, showed up minor lineaments in that terrain better than the winter images, due to the reduction in shadowed area resulting from the high sun angle.

15.5 Central Marlborough

There have been six LANDSAT images of the Marlborough area (E-1520-21354, E-2281-21194, E-2282-21252, E-2292-21192, E-2335-21190, E-2390-21240) recorded from late October to mid February. Lineaments were taken from positive transparencies of MSS Bands 6 and 7 of these images. In addition a colour composite print using bands 4 and 7 was used to enhance crush zones associated with major active faults, e.g., Awatere, Wairau, Clarence, Fowlers, and Elliot Faults (Fig. 15.15). These major faults strike between east and north-east. A major lineament (No. 1 in Fig. 15.15) parallel to the faults was most readily observed on the colour composite. Many of the other lineaments observed are short (generally less than 10 km long) and have strikes that are not parallel to those of the major faults. From the images these shorter lineaments appear to be related to bedding in the Torlesse Supergroup sedimentary rocks that form the ranges in this area.

A pronounced plunging anticline or syncline with an axis striking north-north-east occurs in the Seaward Kaikoura Ranges (No. 2 in Fig. 15.15). A thick sequence of Upper Cretaceous basalts of the Gridiron Formation (Suggate 1958) occur in the Awatere Valley, and their oval form is conspicuous in the LANDSAT images. These basalts are crossed by several lineaments (No. 3 in Fig. 15.15) that were found to be faults cutting the flows. A lineament in the Clarence Valley (No. 4 in Fig. 15.15) has previously been mapped as the Fidget Fault (Lensen 1962), and includes an active fault trace.

15.6 North-west Nelson

A LANDSAT image E-2391-21291, covering the north-west Nelson area, was taken on 17 February 1976 (Fig. 15.16). The area is heavily vegetated and has rugged terrain. Most of the major lineaments are along eroded valleys, but many can be traced across valleys and over ranges.

Several lineaments can be seen across Cape Farewell where they occur in Upper Cretaceous Pakawau Group sediments (No. 1 in Fig. 15.17). Bishop (1971) has mapped several faults in the field and also probable faults from aerial photographs, many of which correspond to the lineaments on the LANDSAT images. In addition several north-east striking lineaments (No. 2 in Fig. 15.17) were observed, along the eastern side of the range, parallel to the Wakamarama Fault.

In the Wakamarama Range, north of Mt Stevens, there is a set of parallel lineaments that strike north (No. 3 in Fig. 15.17). These occur along the Aorangi Syncline (Grindley 1961) and are parallel to the strike of quartzite beds belonging to the Aorangi Mine Formation of Ordovician age. To the south, in the region of Mt White and Mt Percy, there is a similar north-striking set of lineaments (No. 4 in Fig. 15.17) also parallel to the strike of the Aorangi Mine Formation.

In the central region there are two major north-trending lineaments. These correspond to the Haupiri Thrust (No. 5 in Fig. 15.17) and the Devil River Thrust (No. 6 in Fig. 15.17) (Grindley 1971).

A lineament occurs along the length of the Cobb Reservoir (No. 7 in Fig. 15.17) and extends in a north-east direction to run along part of the Takaka River. This lineament is terminated at its southern extremity by a lineament (No. 8 in Fig. 15.17) that strikes north-west from Lake Cobb, along the Cobb River to the Arthur Range. These two lineaments are not faults (Grindley, pers.comm.).

15.7 Taupo-Hawke Bay

The LANDSAT image E-2334-21123, of the Taupo-Hawke Bay region, was taken on 22 December 1975 (Fig. 15.18). The area can be geologically divided into three parallel zones oriented in a north-east to south-west direction. The western zone consists of Quaternary to Recent volcanics which are separated from the eastern zone of Cenozoic sedimentary rocks by ranges of bush-clad Mesozoic "greywacke"-type sandstone and siltstone.

In the western volcanic zone of the image, the active volcanoes of Ruapehu and Ngauruhoe/Tongariro are clearly visible (Nos 1 and 2) respectively in Fig. 15.19). On the northern shores of Lake Taupo two lineaments can be clearly seen. One follows a recent fault trace (No. 3 in Fig. 15.19) and the other (No. 4 in Fig. 15.19) cuts across the recent Ngangiho Fault, and strikes more to the north-east. The Paeroa Fault is also visible as is lineament (No. 5 in Fig. 15.19).

There are many known faults that strike north-east between Rotorua and Taupo (Grindley 1960; Healy et al. 1964), but only those with large scarps can be seen clearly on the LANDSAT images.

The chasm that resulted from the 1886 AD eruption of Mt Tarawera can be seen as a lineament (No. 6 in Fig. 15.19) which

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can be extended across Lake Rotomahana to Waimangu.

In the central belt of Mesozoic rocks the lineaments dominantly strike north-east in the Kaimanawa Ranges (to the south of the zone), and swing around to strike in a dominantly northerly direction in the Urewera National Park region.

The lineaments in the Kaimanawa Ranges (No. 7 in Fig. 15.19) are approximately parallel to the regional strike of the schistosity and bedding.

Detailed mapping in part of this region by Spörli and Barter (1973) has shown that many faults and joint fractures have a north-east strike as also does the contact between schistose and non-schistose rocks in this area. Thus the lineaments are parallel to the main structural trend. A major lineament strikes east-north-east and extends 40 km, cutting across the north-east striking trend.

In the central and Urewera National Park regions of the ranges the lineaments are also parallel to both regional bedding and faulting as mapped by Grindley (1960) and Healy et al. (1964).

Three of the longest lineaments correspond to the Whakatane Fault (No. 8 in Fig. 15.19), the Waimana Fault (No. 9 in Fig. 15.19), and the Waikaremoana Fault (No. 10 in Fig. 15.19). A major lineament approximately 50 km long east of, and parallel to, the Whakatane Fault has not previously been recognised as a fault (No. 11 in Fig. 15.19).

A weak east-south-east lineament trend is recognisable in the Urewera National Park region. The largest of these lineaments (No. 12 in Fig. 15.19) cuts across the major north-striking lineaments.

The only lineaments in the eastern Cenozoic belt are in pre-Pliocene sedimentary rocks. These lineaments are slightly curved, concave to the south-east, and are parallel to the structural trend of the Tertiary rocks.

In the region of Lake Waikaremoana there is a conspicuous difference between the topography of the bush-covered Mesozoic rocks to the west and the bush-covered Tertiary rocks. The lower relief and the pronounced dissection pattern enable the less indurated Tertiary rocks to be readily distinguished from the deeply eroded Mesozoic rocks in the LANDSAT images.

15.8 Gisborne

The LANDSAT image E-2495-21025 covers the region of the Gisborne Province (Fig. 15.20). The image was taken on 31 May 1976. This area is heavily vegetated and has rugged terrain and complex geology. However, distinct lineament patterns can be seen on the images of MSS Bands 6 and 7.

At Cape Runaway a lineament occurs that strikes east and that separates the Matakaoa basalts from alluvium and Tertiary strata to the south (No. 1 in Fig. 15.21). No conclusive field evidence is known for a fault, but the lineament has been previously mapped as a fault by Ongley and MacPherson (1928), Moore (1957), Kingma (1965), and Chapman-Smith and Grant-Mackie (1971). Aerial photos also show an exceptionally straight scarp along much of the length of the basalt.

An extension of what Chapman-Smith and Grant-Mackie (1971) called the Waitewaka Fault can be traced inland on the LANDSAT image as a major lineament (No. 2 in Fig. 15.21). The western part of this lineament coincides with a boundary between two geological formations. Along its eastern part it is a steep gorge in which faulting has not been found, but an adjacent parallel fault scarp occurs to the north (I. Speden, pers. comm.), and the southern contact of the Matakaoa basalts in this area is probably faulted (Ongley and MacPherson 1928).

A set of north-east trending lineaments (No. 3 in Fig. 15.21) are also parallel to known faults (I. Speden, pers.comm.).

Along the west coast of the peninsula, in the Bay of Plenty, there are several east-trending lineaments. These correspond to faults mapped by Hoolihan (1977). In this area there are also a less well developed set of parallel lineaments that strike approximately north (No. 4 in Fig. 15.21). Towards the south the east-striking lineaments become less dominant and the north-striking lineaments become more dominant. A major lineament that can be traced for 40 km (No. 5 in Fig. 15.21) has been mapped as a fault for much of its length (I. Speden, pers. comm.). The southern extremity of this lineament terminates at Maungahaumi.

In the area around Maungahaumi there are slightly curved lineaments concave to the north-east (No. 6 in Fig. 15.21). These lineaments are related to the major lower Tertiary décollement thrust sheets mapped by Stoneley (1968). These décollement sheets separate an area of pre-Tertiary autochthonous rocks to the north and west from autochthonous Upper Tertiary rocks to the south and east (I. Speden, pers. comm.).

North of Gisborne the lineaments predominantly strike east, while west and south of Gisborne there are two well defined trends in the lineament directions, one striking north-north-west and one east-north-east.

15.9 South Waikato-King Country

The LANDSAT image E-2389-21172 was recorded on 15 February 1976 (Fig. 15.22). East of Kawhia Harbour there are east-north-east striking lineaments (No. 1 in Fig. 15.23), several of which cut andesite flows from nearby Mt Pirongia. These appear to be faults. An approximately north-striking set of lineaments (No. 2 in Fig. 15.23) in this region are parallel to the structural trend of the Jurassic and Triassic Sedimentary rocks (Kear 1960).

South of Kawhia Harbour the main structural trend in the Mesozoic rocks remains north-south (Hay 1967), but these are crossed by a conspicuous set of north-east striking lineaments

(No. 3 in Fig. 15.23). The largest of these (No. 4 in Fig. 15.23) extends almost to Otorohanga, and cuts mid-Tertiary strata.

A large curved lineament cuts Oligocene and Miocene sediments west of Taumarunui (No. 5 in Fig. 15.23). East of this lineament is a set of north-east striking minor lineaments. These minor linaments are parallel to the strike of the Tertiary beds, but faults mapped by Hay (1967) at this locality also have the same strike.

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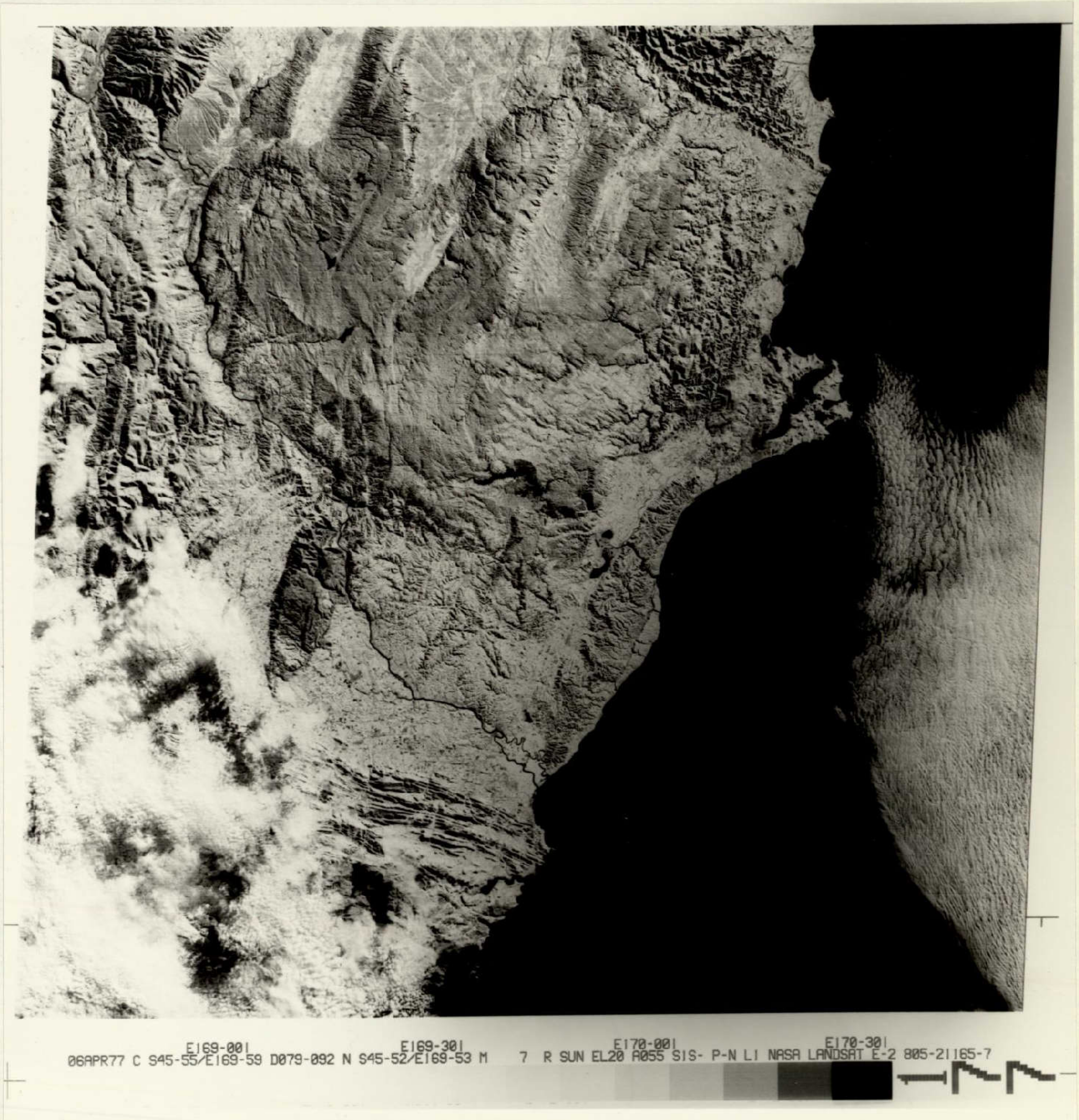

Fig. 15.1 LANDSAT image of Otago (E-2805-21165) MSS band 7

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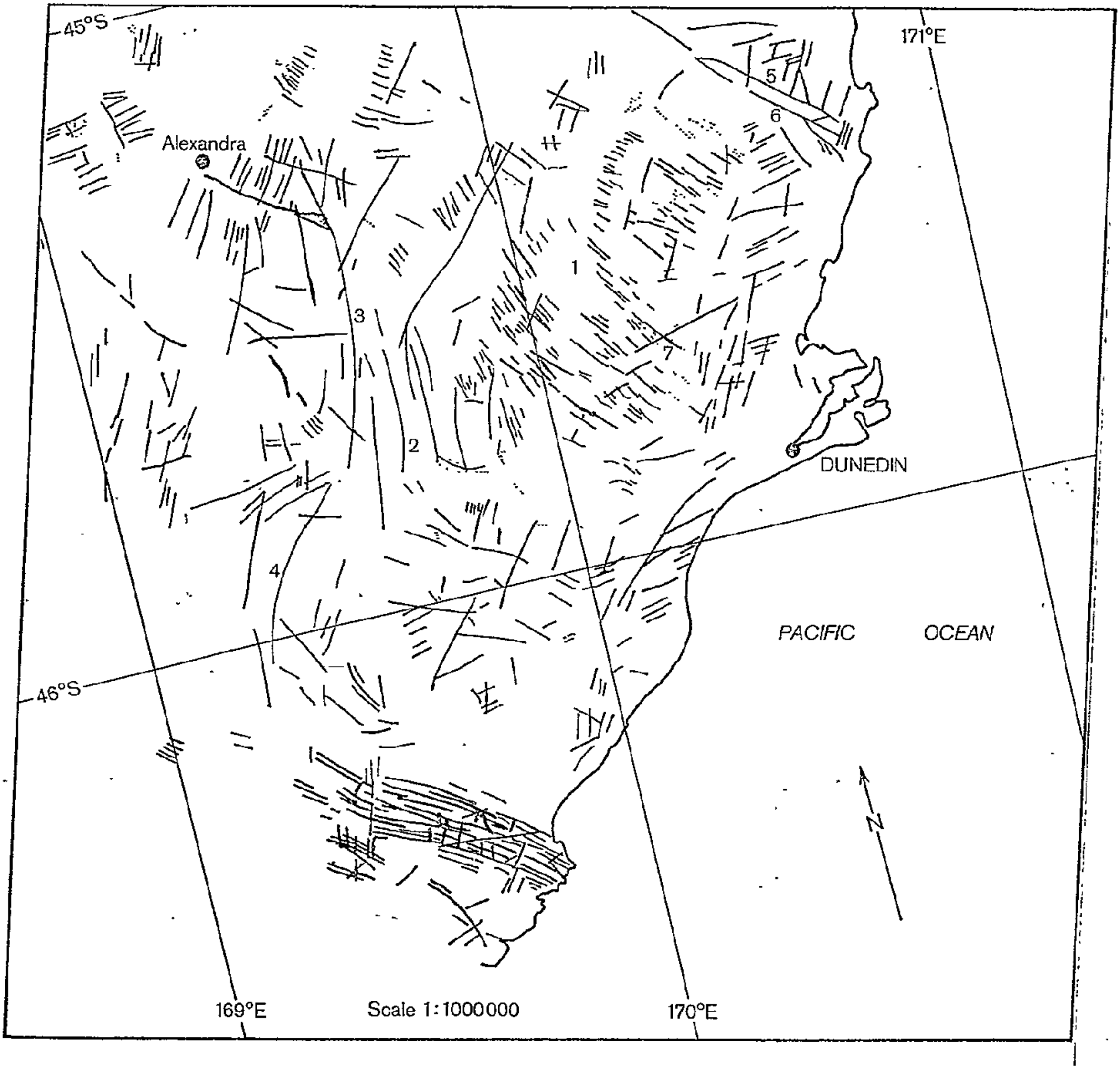

Fig.15.2 Lineaments observed from E-2805-21165. Dotted lines represent gold/scheelite and stibnite lodes.

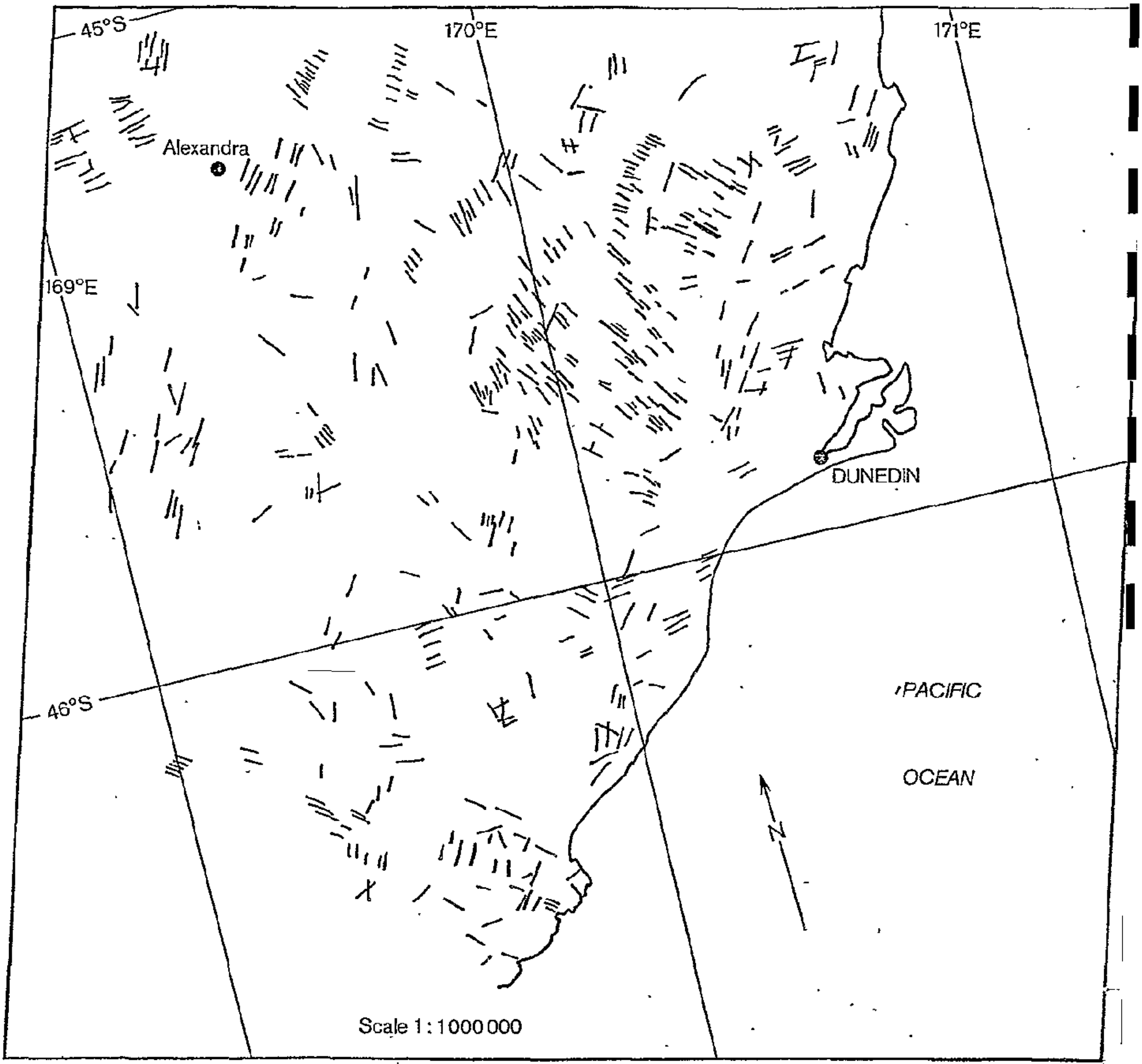

Fig. 15.3 Minor lineaments from E-2805-21165.

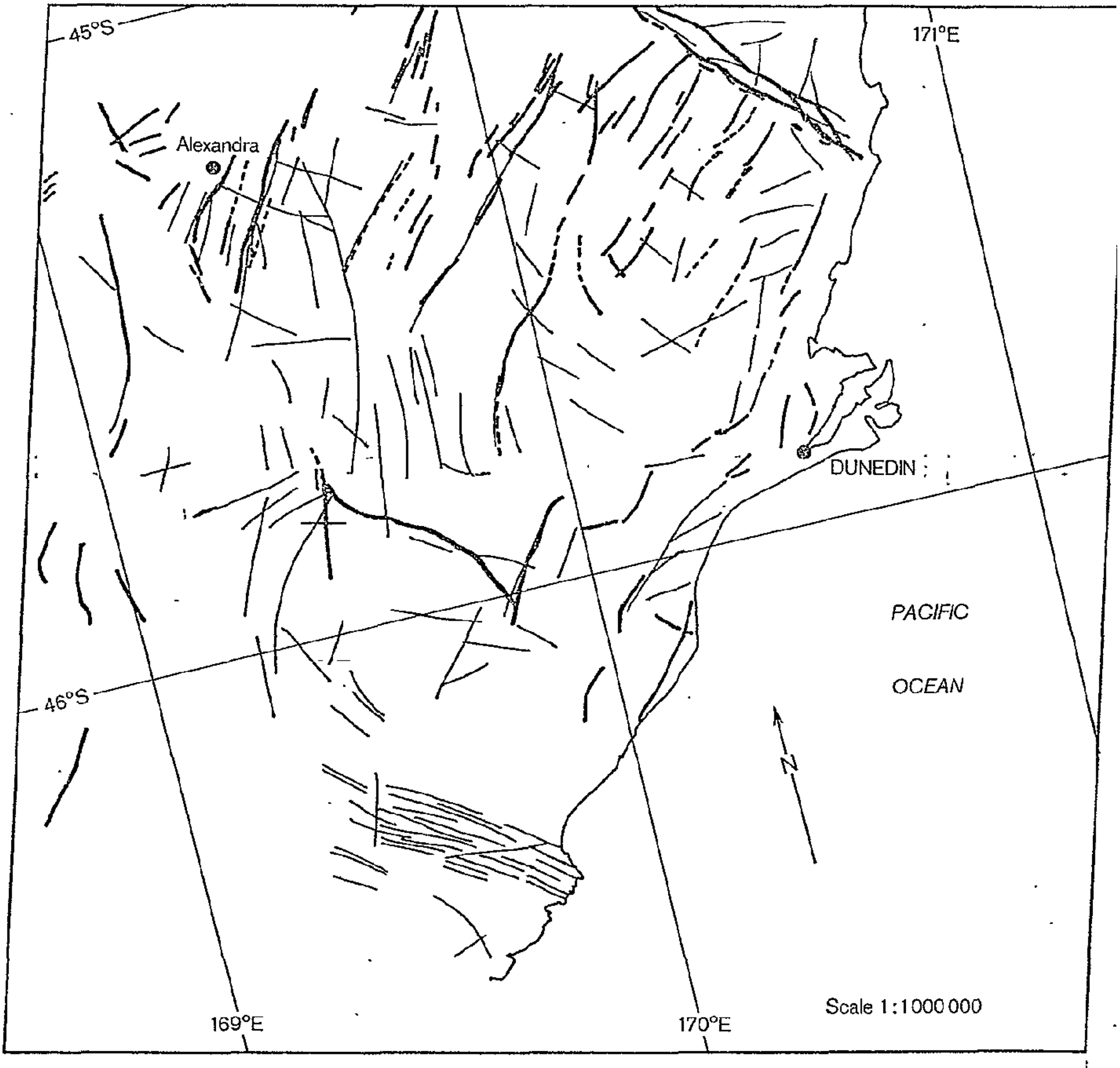

Fig. 15.4 Major lineaments from E-2805-21165, with previously mapped faults shown as thick lines.

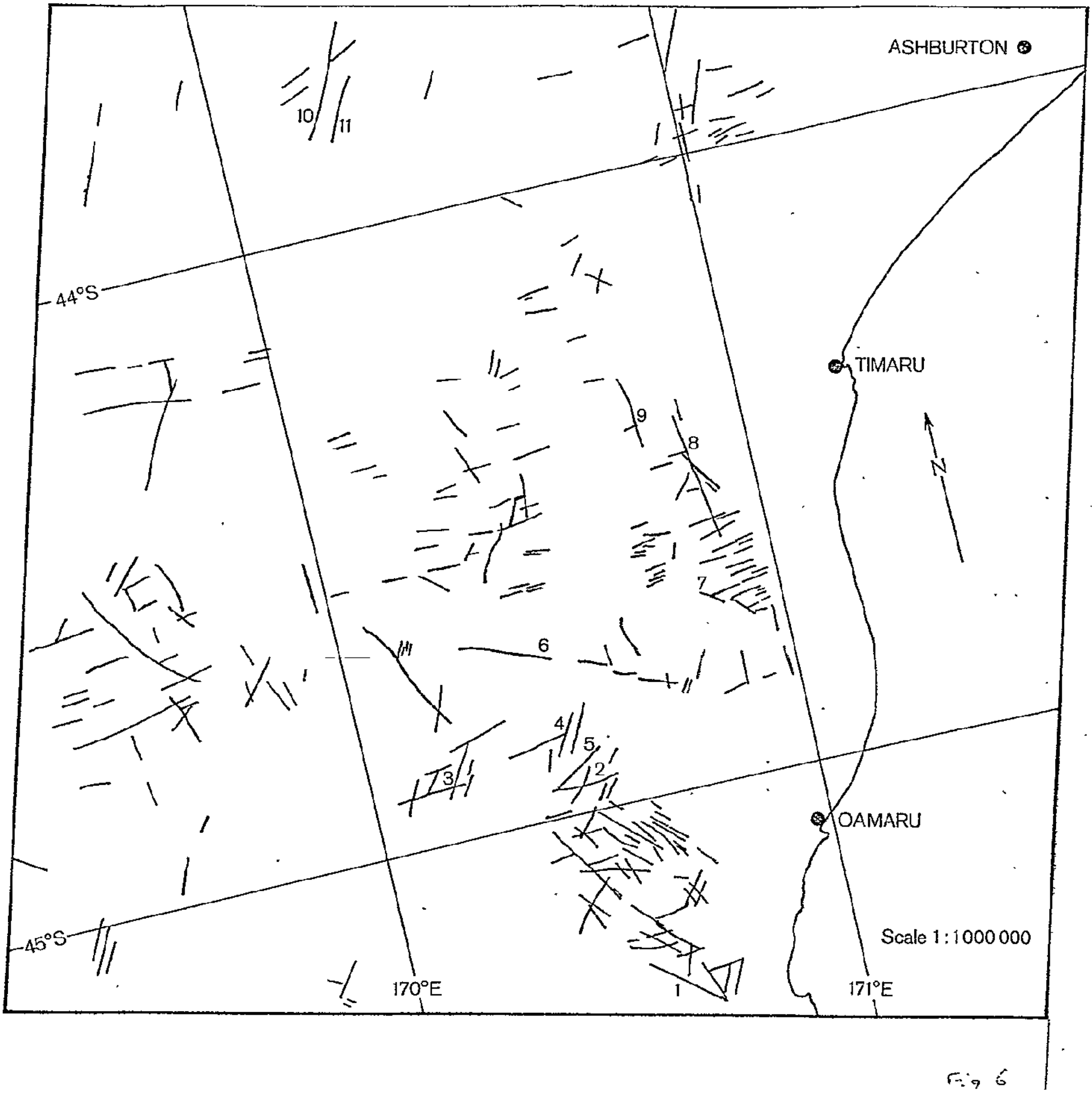

Fig 6

Fig. 15.6 Lineaments observed from E-2805-21163.

Fig. 15.5 LANDSAT image of North Otago-South Canterbury (E-2805-21163) MSS Band 7.

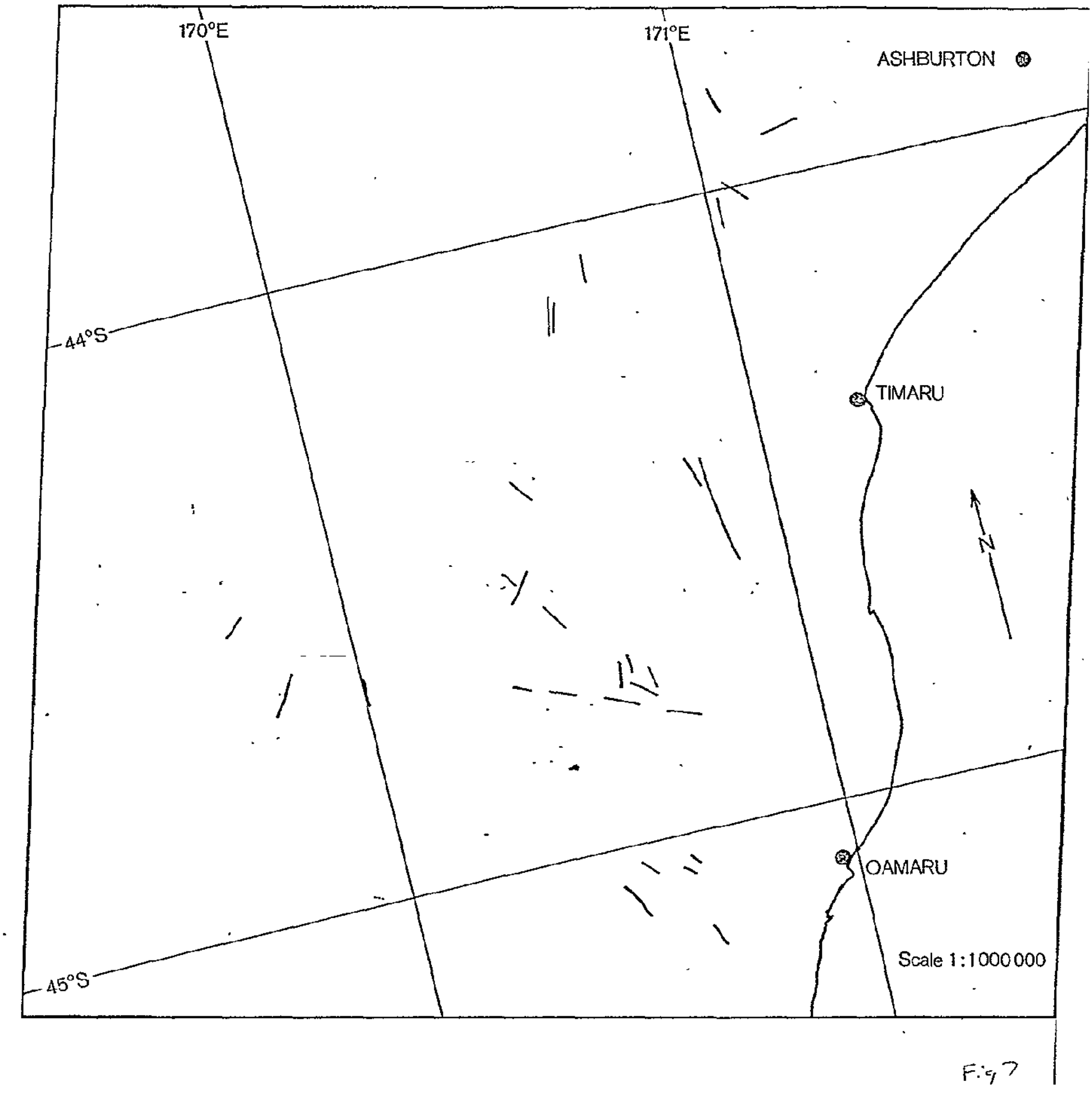

Fig. 15.7 Lineaments observed from E-2265-21321

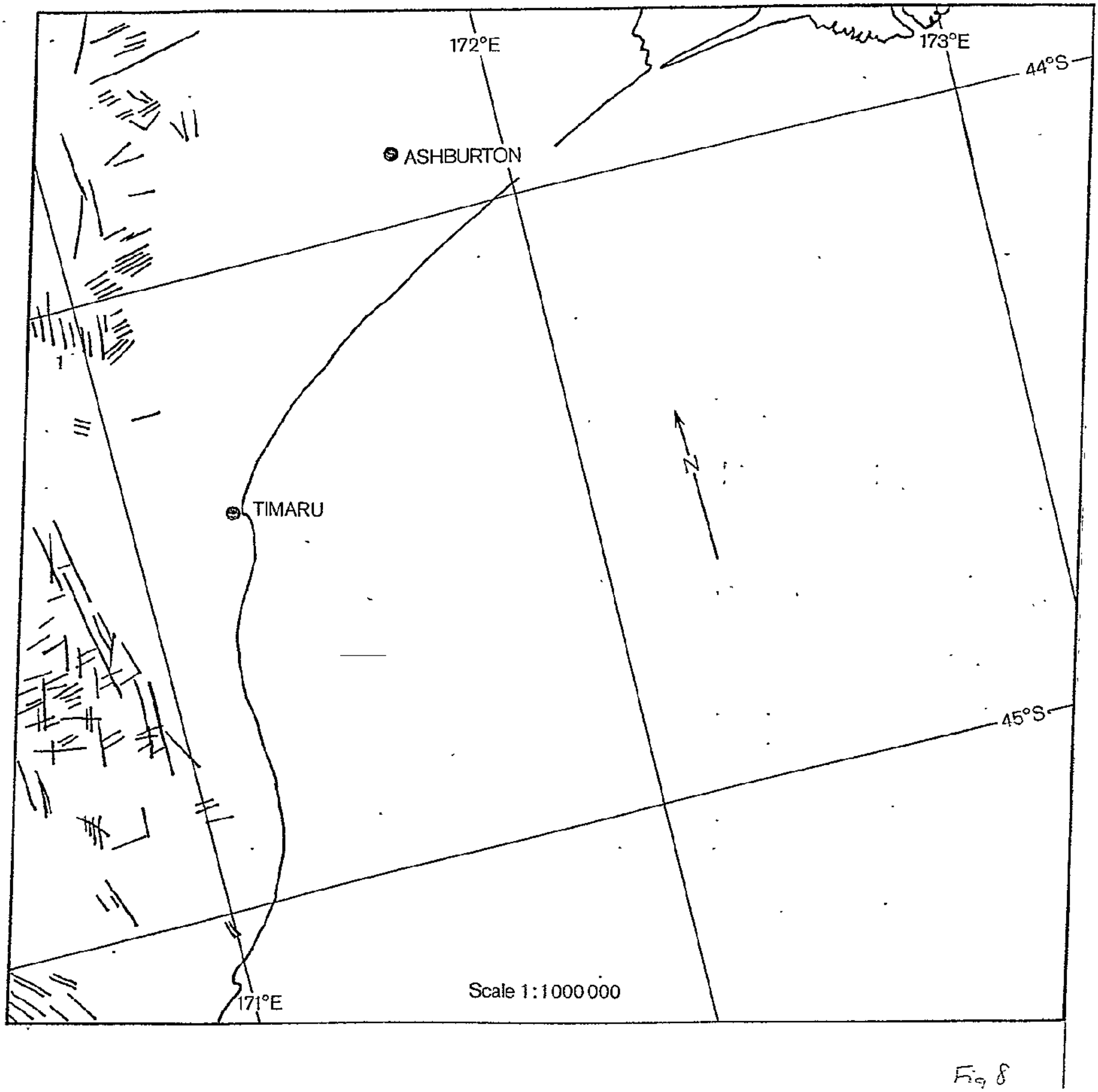

Fig. 15.8 Lineaments observed from E-2192-21272

Fig. 15.9 LANDSAT image of the Southern Alps (E-2409-21293)
MSS Band 7

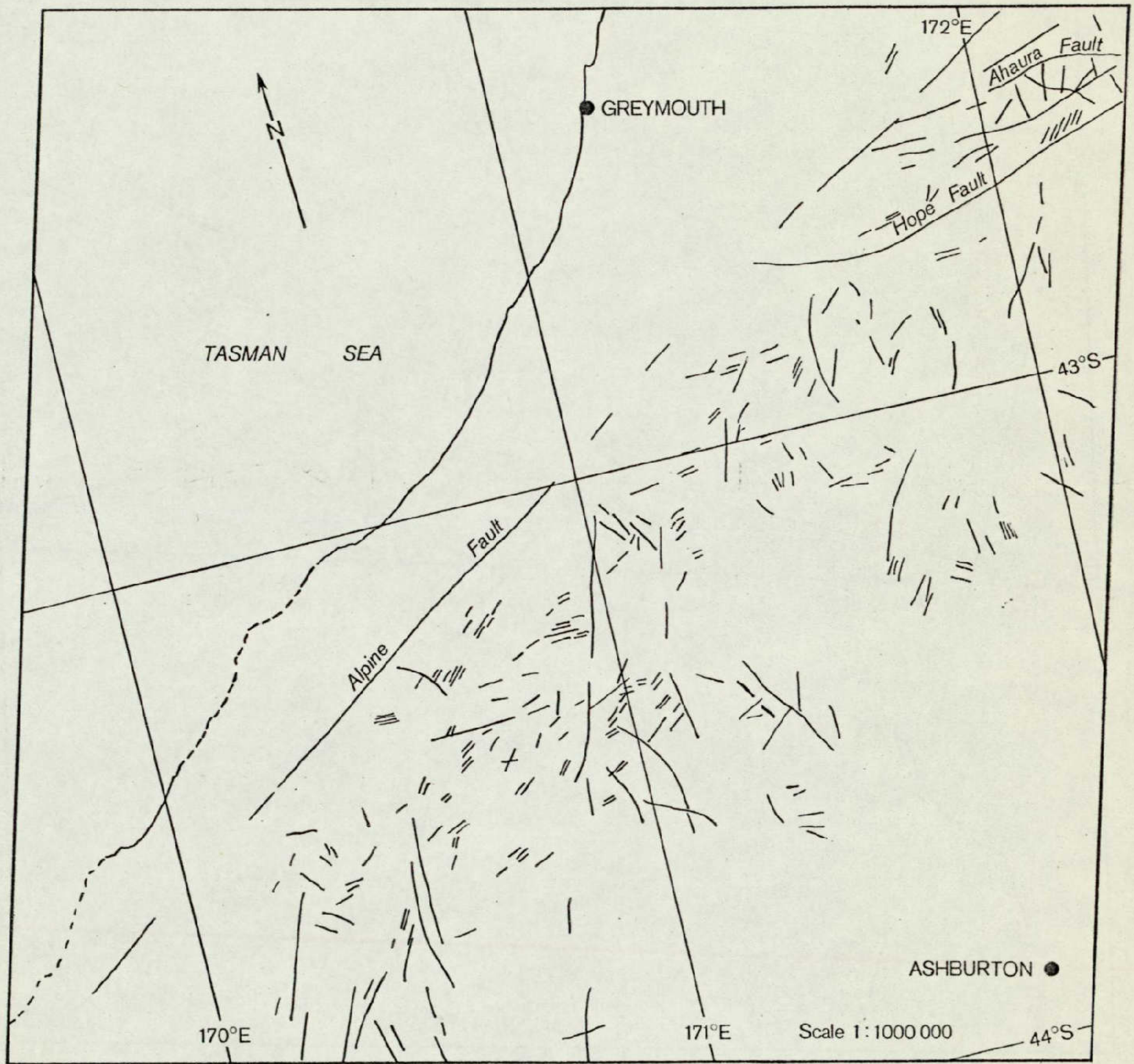

Fig. 15.10 Lineaments observed from E-2409-21293.

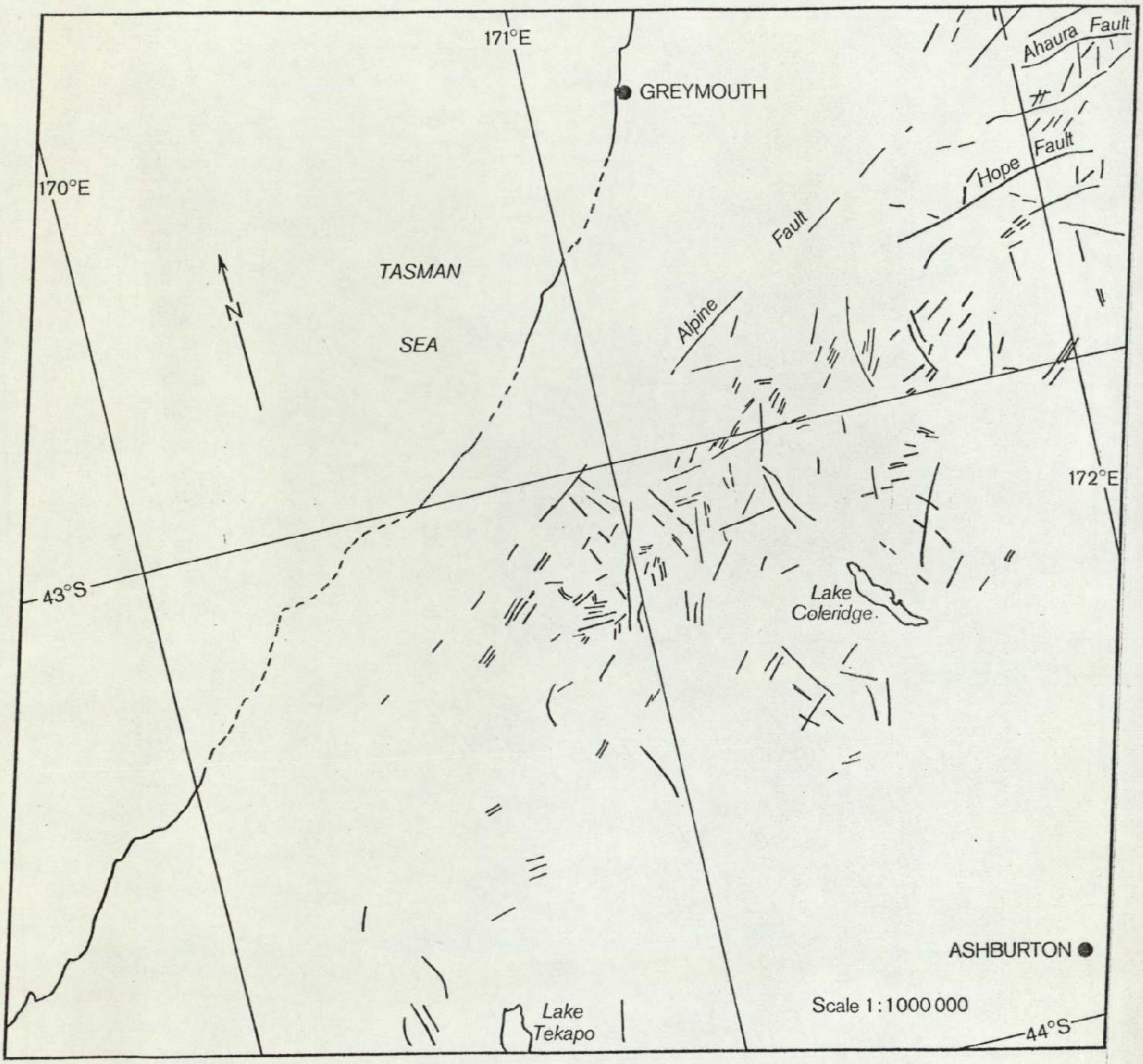

Fig. 15.11 Lineaments observed from E-2391-21300

Fig. 15.12 LANDSAT image of North Canterbury-South Marlborough (E-2192-21265) MSS Band 7.

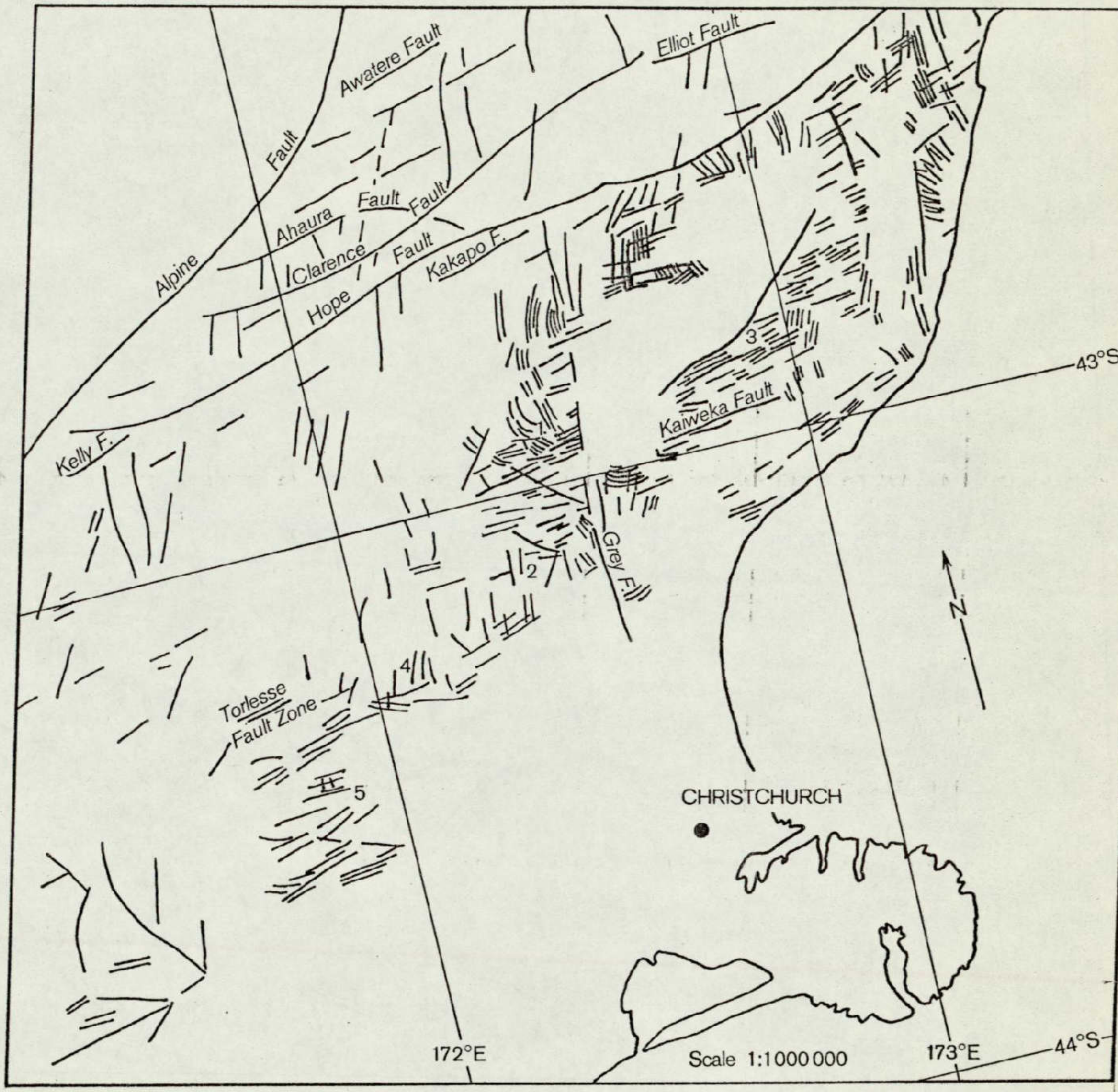

Fig. 15.13 Lineaments observed from E-2192-2165.

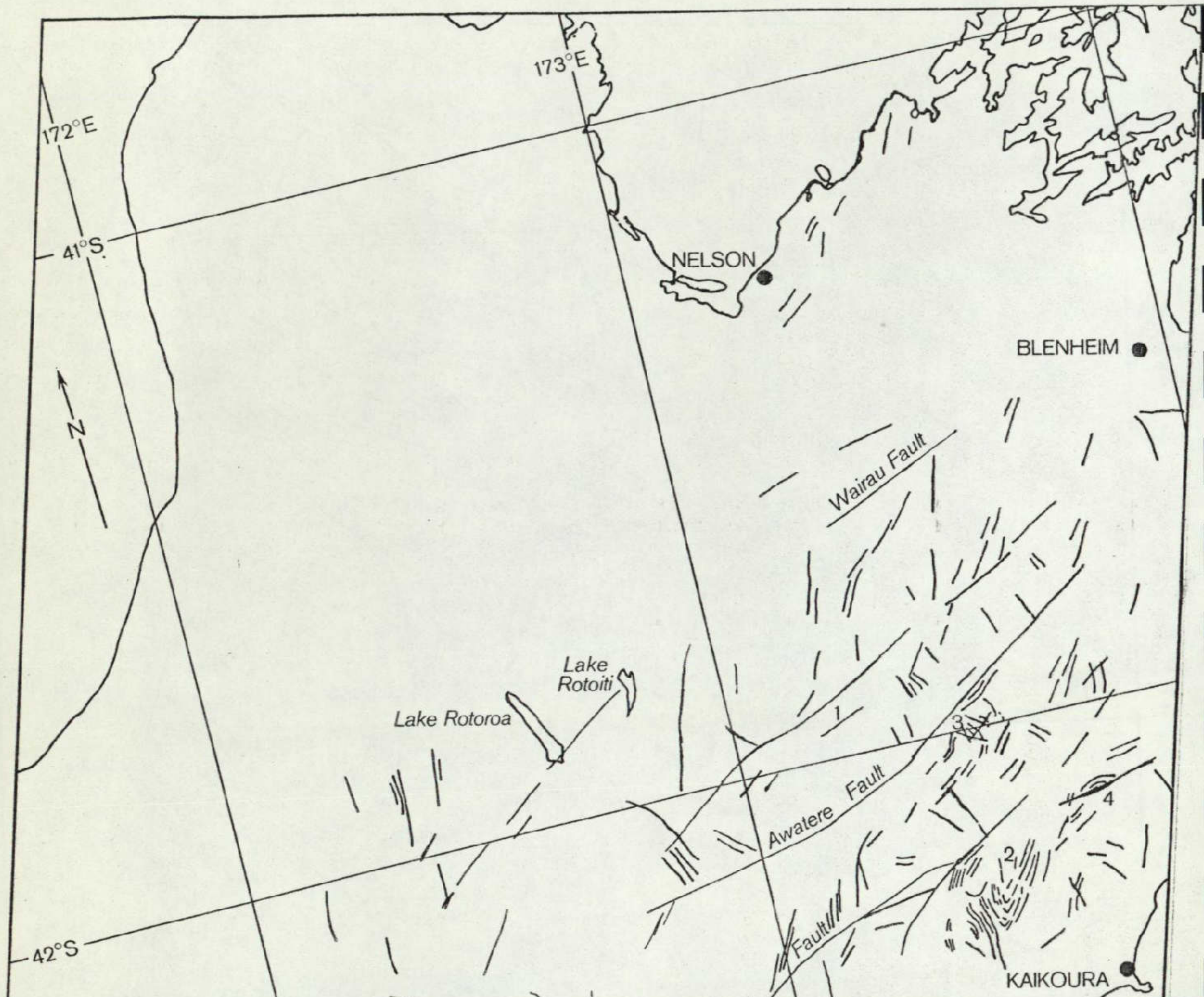

Fig. 15.15 Lineaments observed from E-1520-21354.

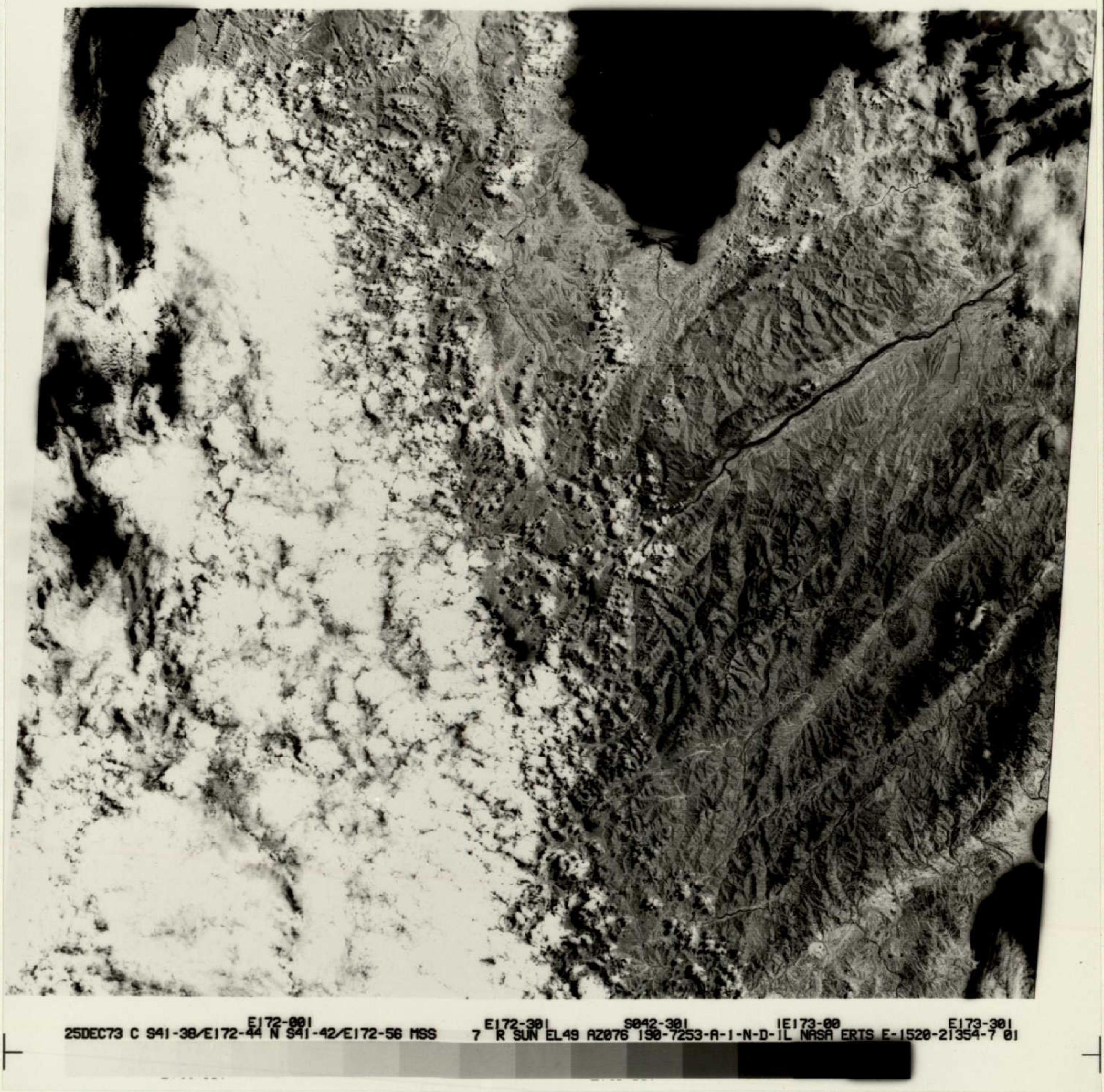

Fig. 15.14 LANDSAT image of central Marlborough (E-1520-21354) MSS Band 7.

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OF POOR QUALITY

Fig. 15.16 LANDSAT image of north-west Nelson (E-2391-21291) MSS Band 7.

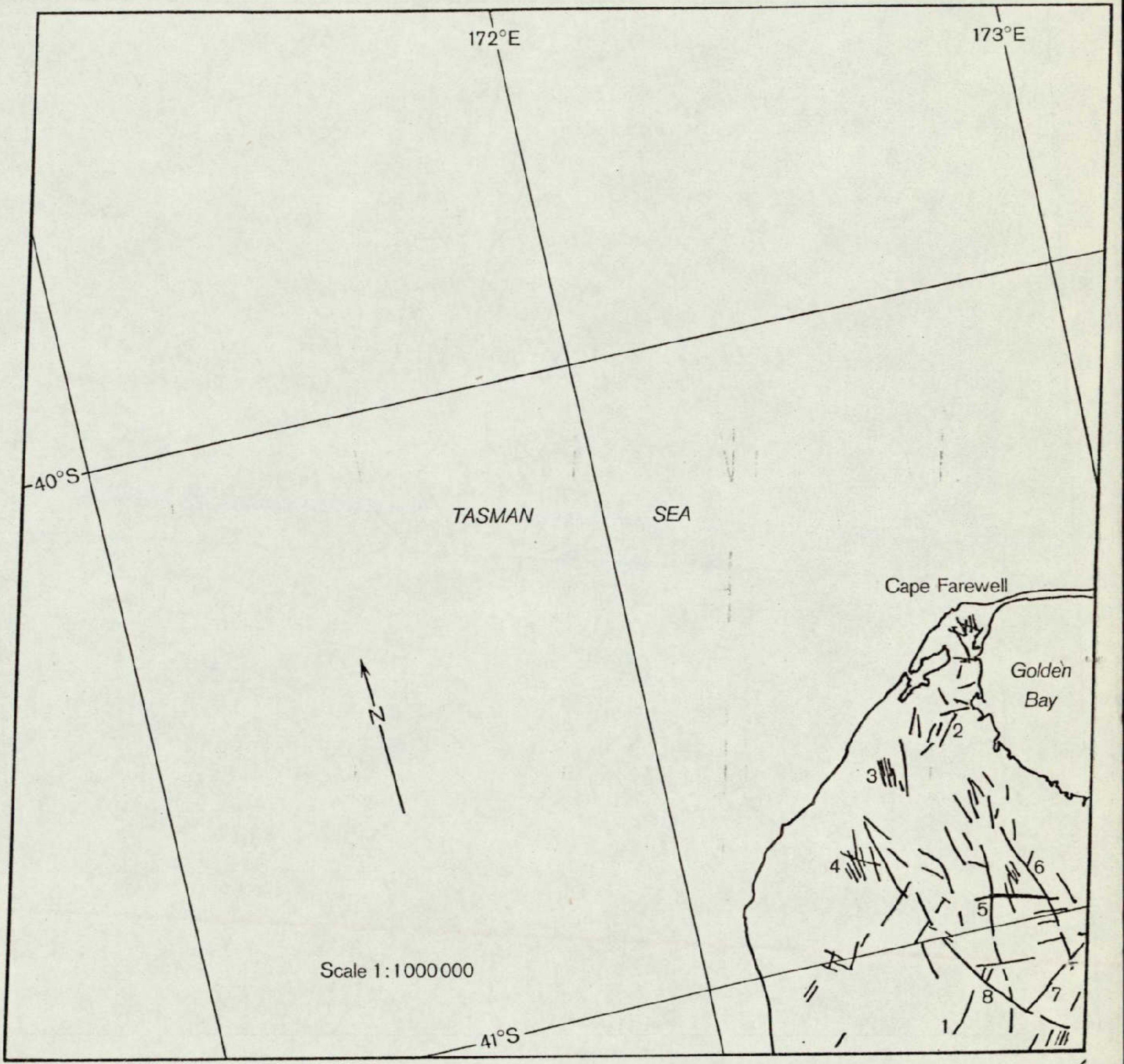

Fig. 15.17 Lineaments observed from E-2391-21291.

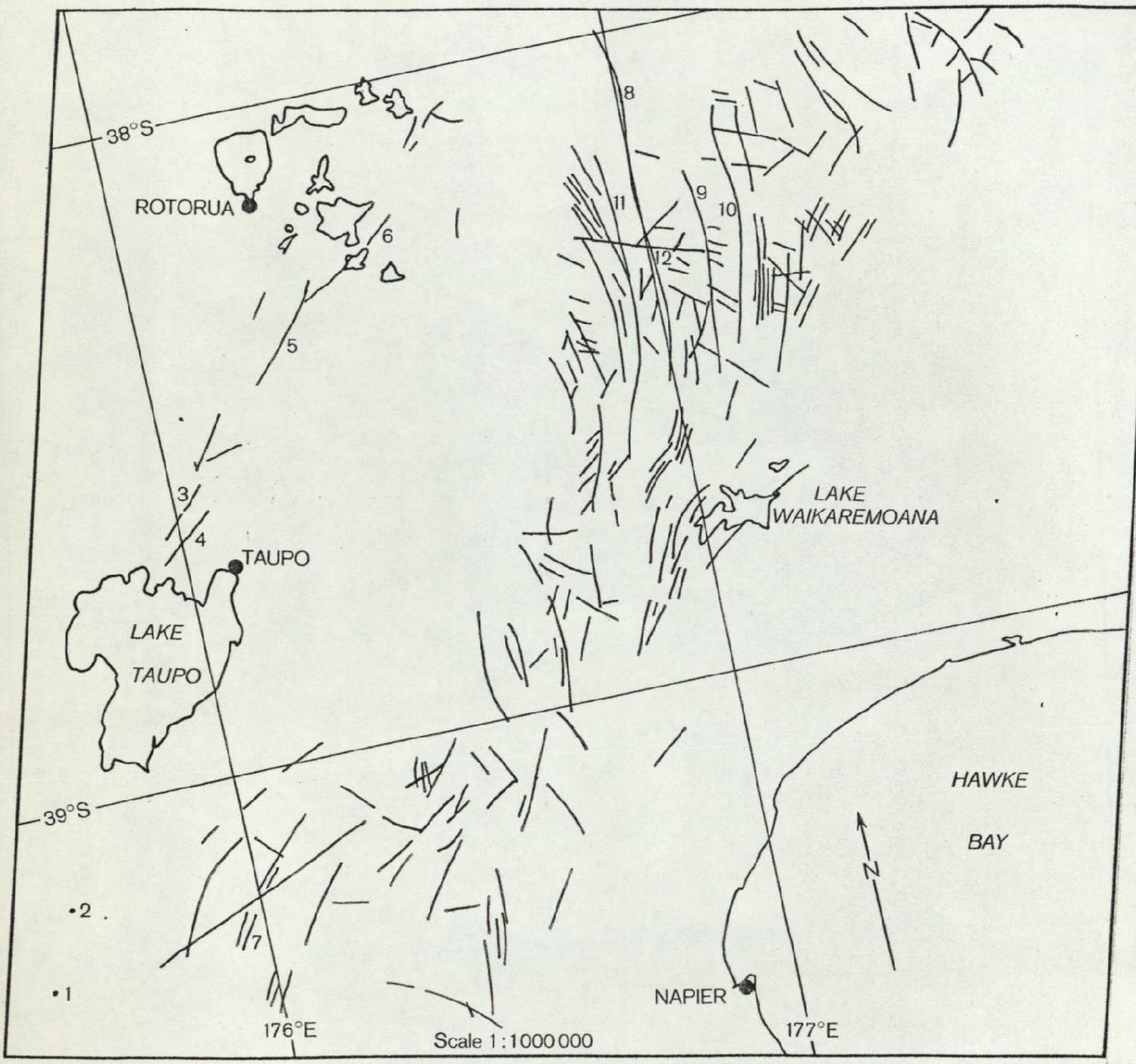

Fig. 15.19 Lineaments observed from E-2334-21123.

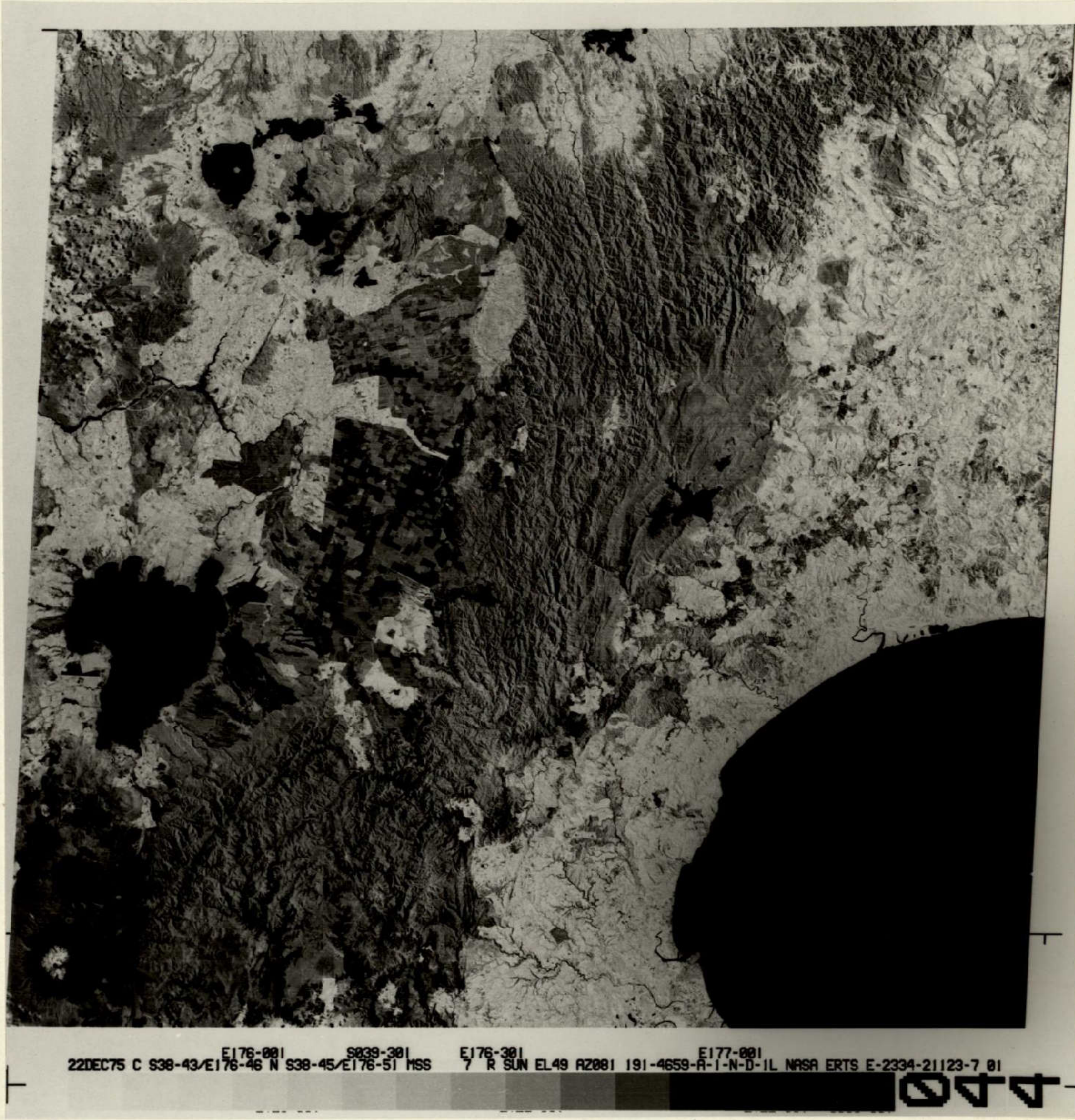

Fig. 15.18 LANDSAT image of Taupo-Hawke Bay (E-2334-21123) MSS Band 7.

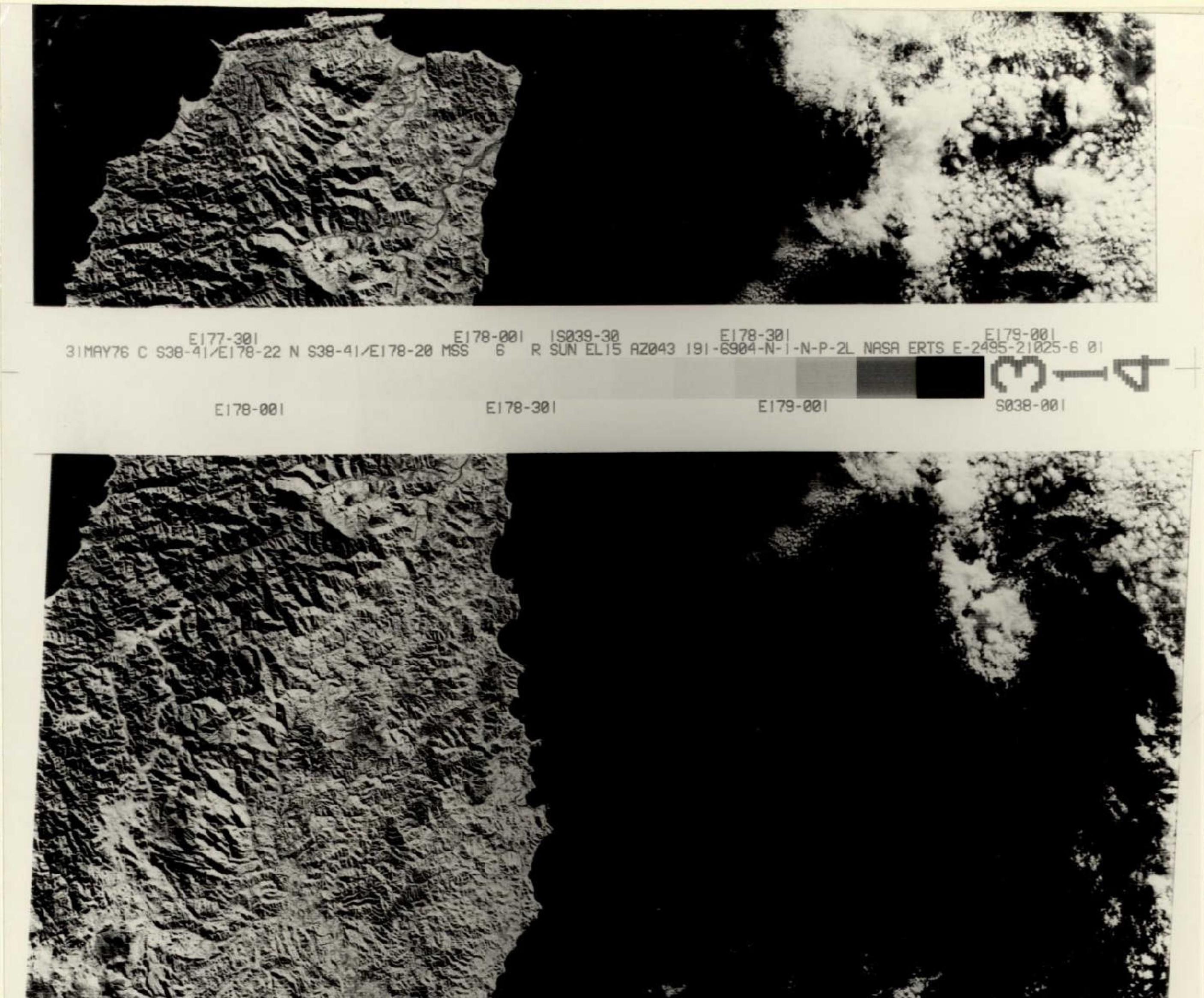

Fig. 15.20 LANDSAT image of Gisborne (E-2495-21025) MSS Band 7.

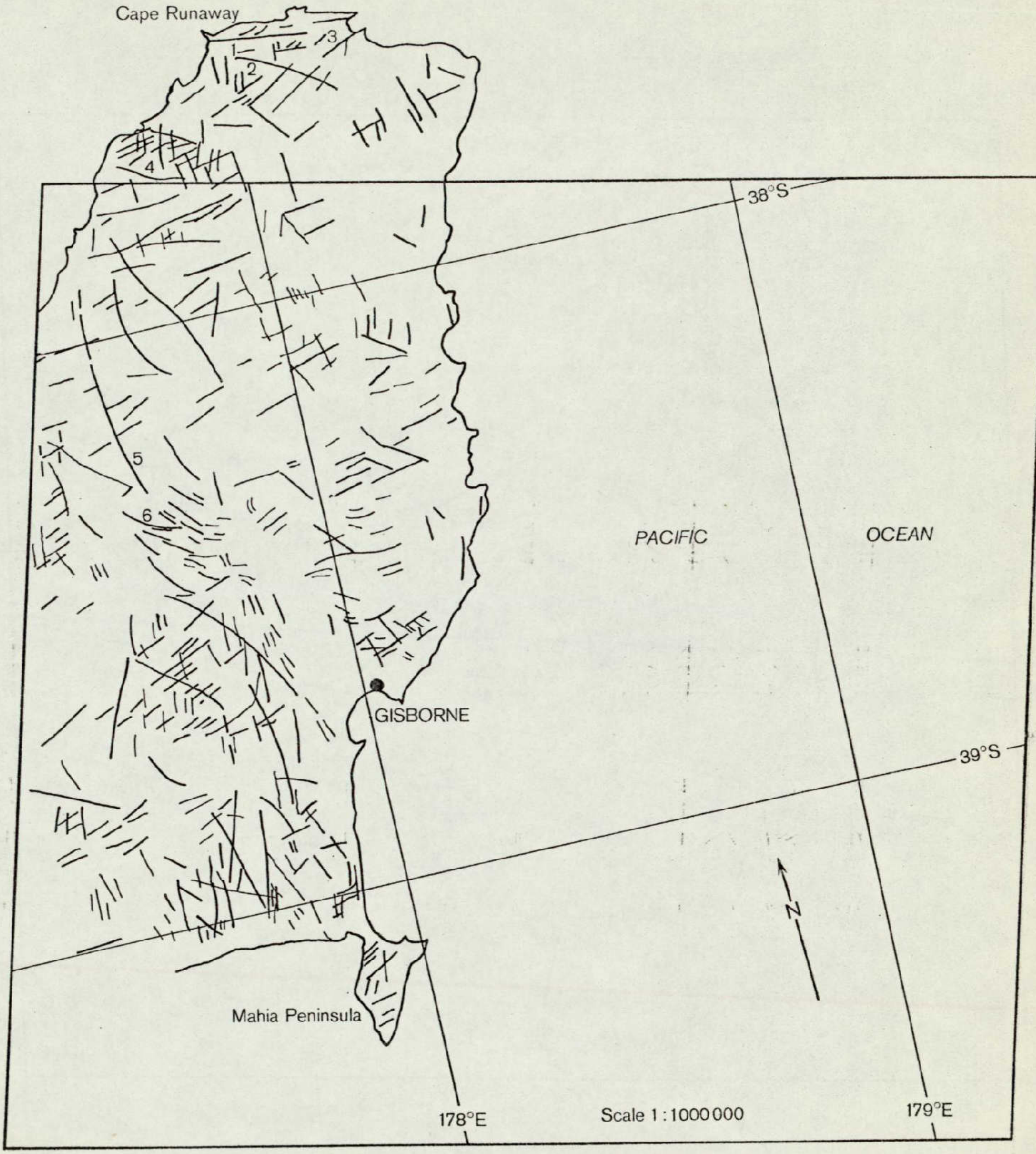

Fig. 15.21 Lineaments observed from E-2495-21025.

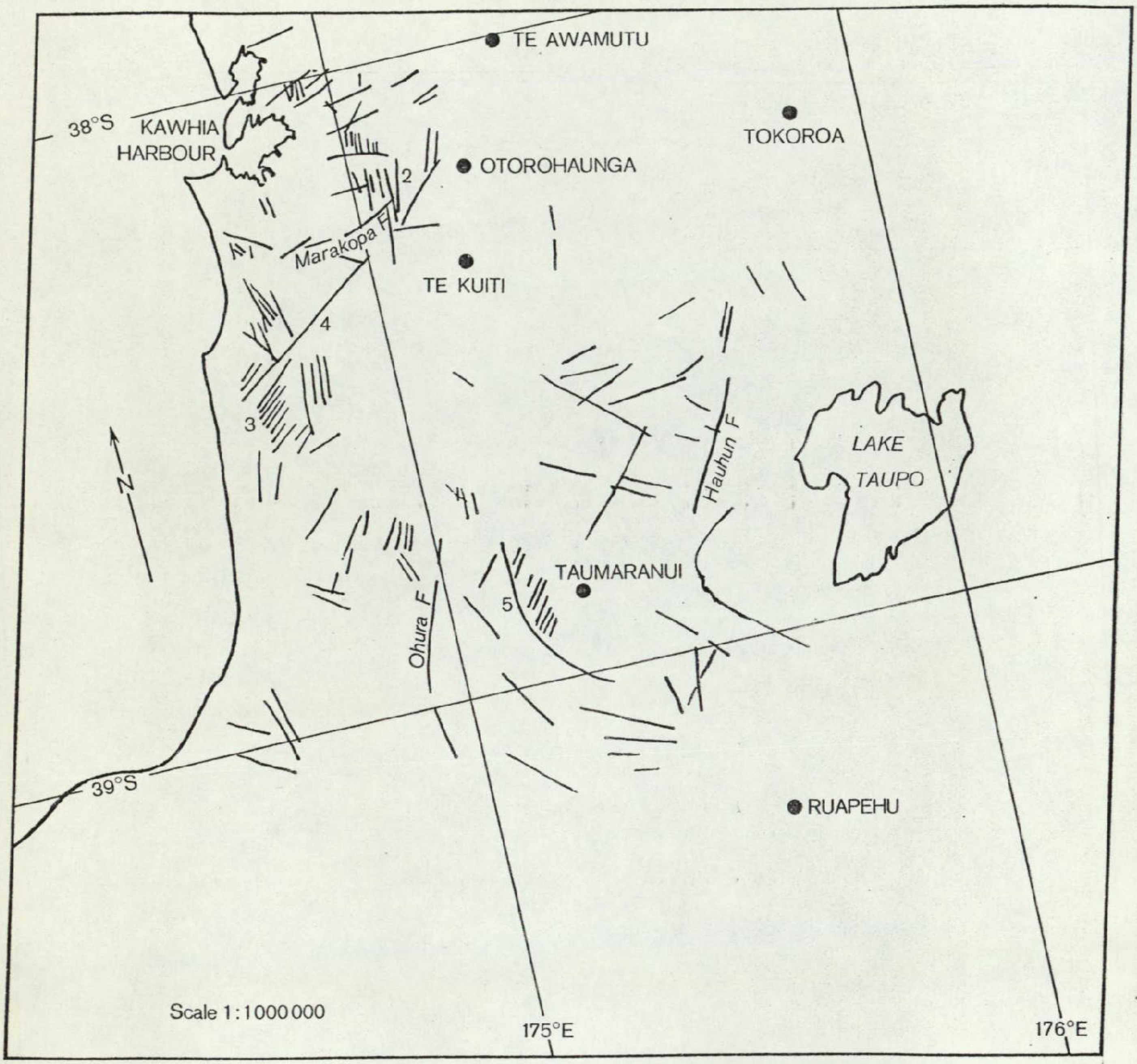

Fig. 15.23 Lineaments observed from E-2389-21172.

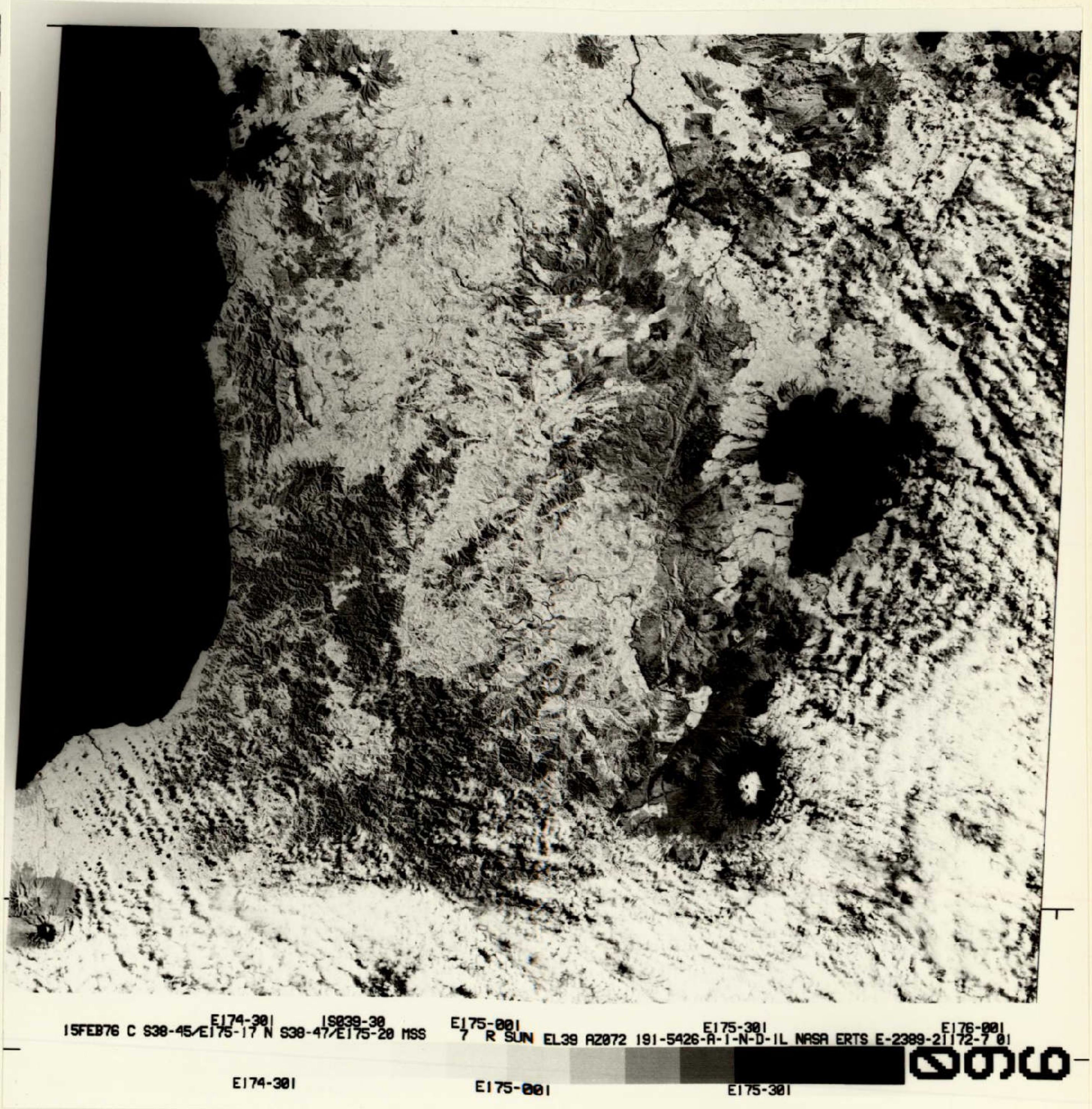

Fig. 15.22 LANDSAT image of south Waikato-King Country (E-2389-21172) MSS Band 7.

PART IV

INDIGENOUS FOREST ASSESSMENT

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CHAPTER 16

INDIGENOUS FOREST ASSESSMENT

M. G. McGreevy

INDIGENOUS FOREST ASSESSMENT

The extensive and often inaccessible nature of New Zealand's indigenous forest resource has made assessment of volume, vigour, and composition very difficult, as is indicated by a National Forest Survey 1955 (Masters, Hollaway, and McKelvey 1957) which was begun in 1946 and completed in 1955. It was hoped that multi-stage sampling using LANDSAT imagery as the initial stage would provide an efficient means of up-dating existing information. If the technique were successful it could be applied to special-purpose assessments when required.

The objectives of the initial study were:

(1) to define a 6-stage sample (including a first stage of LANDSAT imagery; three colour photographic stages at scales of 1:60 000, 1:9400, and 1:3000; a field plot sample; and finally individual tree measurements) where probability of selecting sample units was to have been defined in the preceding stage;

(2) to evaluate the suitability of each stage for indigenous forest assessment; and

(3) to refine ground sampling procedures for maximum efficiency.

Inherent in these objectives was the definition of spectral signatures of indigenous forest types. It was hoped that at least the following types could be identified:

(i) podocarp

(ii) hardwood

(iii) beech

(iv) hardwood-beech, and;

(v) podocarp-hardwood.

These species occupy a variety of geographic sites varying in slope, aspect, altitude, and latitude. In addition their spectral signatures vary from season to season, making the date of imaging critical.

The problems mentioned made it desirable to have image coverage of representative areas of each type at the extremes of its geography during all 4 seasons of the year. Ideally, all of the images would have the same solar azimuth and elevation. Realising the difficulty in achieving the desired coverage, it was hoped that at least one area containing the types required would be imaged during each of the 4 seasons of the year. This situation did not eventuate, making any seasonal variation in spectral signatures impossible to define. Without this seasonal definition of signature, any geographic variation discovered could be partially attributed to season.

The necessity for digital products was readily apparent after careful examination of forested areas on photographic products. Only a small fraction of the information collected within the forest boundaries is represented in the grey levels of the photographic products. Forest and non-forest land and even some forest types can be separated on isodensitometer scans and colour composites of photographic products, but precise and reliable information is required for defining the initial stage of the sample envisioned for this project. Until the species signatures can be defined precisely little advantage can be gained from the proposed 6-stage assessment. The sample also requires complete coverage of the country before initial probabilities are defined. Only 80 per cent has been received at the Forest Research Institute in the photographic form. An even lower percentage is available in required digital format.

While awaiting complete coverage of the indigenous forest resource, an attempt was made to correlate the level of the fungus Dothistroma pini (dothistroma) in the conifer Pinus radiata (radiata pine). The average spectral signature in each band was used as an independent variable in a least squares analysis of disease level. No significant correlation was found. This could have been due to the fact that the field assessment was completed in early October whereas the forest was imaged in mid-December. Earlier coverage during the following year was requested. In anticipation of this coverage an extensive field and photographic assessment was launched. When the imagery did not eventuate, the field assessment was discontinued.

Subjective evaluation of enhanced LANDSAT images used for forest typing were reported in the third quarterly report. However, no evaluation of their accuracy was given. Also, no mention was made of the degree of difficulty of translating these enhancement techniques from one set of images to another and the effect of this translation on the definition of types. A more objective appraisal of the reliability of the enhancement techniques and their resultant type maps must be made before they are useful for defining types in the multi-stage sample.

Evaluation of the 11 areas listed and illustrated in the fourth quarterly report is under way. Colour and black-and-white photography has been taken over each of the areas. Difficulty in orientating digital imagery listed on an ordinary line printer with the photography has made progress slow. Also, a member of the technical staff who was involved with this aspect of the project has left the Institute. A staff ceiling imposed some time ago has made his replacement impossible.

Evaluation of the possible utility of LANDSAT imagery in New Zealand forest conditions can be approximated from research conducted at the Laboratory for Applications of Remote Sensing, Purdue University. On test sites on steep terrain a Level I (differentiation of major forest types) analysis distinguished coniferous species correctly on 97.5 per cent of the test sites and deciduous species on 85.4 per cent of the test sites. However, a Level II (differentiation of major species groups within forest types) analysis distinguished ponderosa pine, spruce-fir, gambel oak, and aspen correctly in 81.4, 64.9, 61.7, and 78.4 per cent of the cases respectively (Hoffer, Fleming, and Krebs 1974). An analysis similar to a Level II analysis as described previously would be required to define the first stage in our sample. The nature and magnitude of the interpretation errors must be quantified before establishing sub-samples in the multi-stage sampling system to provide an estimate of the gross errors which may occur in the complete assessment.

To fully evaluate the potential of satellite imagery in New Zealand spectral signatures of plant communities must be defined with regard to seasonal, latitudinal, and topographical variation. Any canopy assessment, whether it be due to dothistroma in the exotic forests of radiata pine, tawa mortality, or kauri deterioration in indigenous forests, will rely on very specific time sequential imagery to evaluate the change in canopy during the time period in question. This implies that for imagery to be at all useful in New Zealand it must be readily available for specific dates during the year; also, certain knowledge that on overpasses when suitable weather exists imaging will take place. In short, this means more local influence on image acquisition.

Because a complete evaluation of the suitability of LANDSAT imagery for indigenous assessment and dothistroma assessment in exotic forests is impossible under the present circumstances, the following recommendations are made:

(1) Effort should be concentrated on LANDSAT images E2192-2165, E2334-21123, E2391-21294, and E2389-21170 covering the central North Island.

(2) The CCTs for these images should be rewritten photographically to enhance the forested areas.

(3) Colour composites of these enhancements should be made to allow subjective evaluation of their suitability for species type definition.

(4) The enhanced images should be digitised using a scanning microdensitometer and a statistical analysis carried out to specify the accuracy of type definition.

(5) The CCTs of these images should be sent to the Laboratory for Applications of Remote Sensing at Purdue University and to the Pacific Southwest Forest and Range Experiment Station at the University of California at Berkeley for evaluation. A ground truth map should accompany these CCTs to provide accurate test site information for these institutions.

If the above recommendations are carried out, a thorough, although incomplete, assessment of the imagery would allow a decision on the pursuit of a complete assessment to be made. Inadequate staff and computing facilities available at the Forest Research Institute make in-house processing of the CCTs impossible.

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PART V

MINISTRY OF WORKS AND DEVELOPMENT

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CHAPTER 17 MINISTRY OF WORKS AND DEVELOPMENT LANDSAT EVALUATIONS

17.1 ASSESSMENT OF LANDSAT II IMAGE 100 PRINTS FOR LAND RESOURCE SURVEYS

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Palmerston North.

ABSTRACT

In this paper an assessment of LANDSAT II Image 100 prints of the north-east King Country Region is made to determine their potential use for 1:63,360 Land Resource Surveys.

On these prints, broad vegetation associations are the most easily recognised factors. Although a number of other factors can be recognised, the main benefit of LANDSAT II Image 100 prints is their ability to record up-to-date vegetation patterns. This will be extremely useful in the regular updating planned for the New Zealand Land Resource Inventory Worksheets.

17.1.1 INTRODUCTION

The King Country Region (Fig.17.1.1) was covered by LANDSAT II scene E-2389-21172 of 15 February 1976. This was taken during a satellite overpass, which recurs every 18 days. Four Image 100 prints were prepared (by Dr P J Ellis* at the EROS Data Centre, USA) for a north-eastern portion of the region (Fig.17.1.1). These images which were initially displayed on a colour TV screen, were photographed using colour slide film in a 35 mm camera.

Prints at a scale of 1:134,000 were made from these and supplied to the authors for assessment of their potential use in 1:63,360 Land Resource Surveys. The prints supplied were:

Print A A colour composite made from positives of Bands 4, 5 and 7 (see Belon and Miller 1973 for a description of LANDSAT Bands and colour composites).

Print B A Colour composite produced from negatives of Bands 4, 5 and 7 with the radiance values of each Band 'stretched' to fill the available colour range on the Image 100 viewing screen.

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Print C A colour composite made up from negatives of Bands 4, 5 and 7 with the radiance values of Bands 4 and 5 squared.

Print D A colour composite produced from positives of Bands 4, 5 and 7 with the radiance values of Band 5 squared.

Print D (Fig.17.1.2) had the largest range of hues and showed differences between more features than the other prints. This print was the main one used in this study.

The Land Resource Survey Group of the Water and Soil Division, Ministry of Works and Development is engaged in the production of Land Resource Inventory Worksheets (worksheets). It is hoped that worksheets in this series will shortly be available for the whole of the country (Mitchell 1976). Regular updating of these worksheets is planned. Worksheets are at a scale of 1:63,360 (1 mile to 1 inch) and delineate units of land uniform for the following factors: lithology, soils, slope, erosion type and severity, and vegetation.

Worksheets of the King Country Region (Fig. 17.1.1) were completed during 1976. These were done as part of

(a) the Ministry of Works and Development national coverage and,

(b) an inter-departmental study on land use in the region involving seven government departments.

These worksheets provided the basis for assessing the value of Image 100 prints.

17.1.2 IMAGE 100 INTERACTIVE MULTISPECTRAL ANALYSER

The Image 100 system is one of the most developed hardware systems availabel for the interpretation of multispectral imagery (Nduaguba 1975; Cihlar and Thomson 1975). This system complements the photointerpretative powers of the user by employing a combination of hardware, software and human interpretation in an interactive fashion. The system accepts up to four Bands of multispectral scanner data recorded on computer compatible tape. Prior to final interpretation, several preprocessing functions can be used to manipulate the data. These include raw data mode, scaling of measured radiance values to various fractions of the dynamic range ('stretching'), and transformations of these values. The user can select a portion of the satellite image to be studied; this portion then becomes enlarged to fill the whole viewing screen. The preprocessing can then be further modified to highlight the information sought.

In assessing the classification accuracy of surveys conducted using the Image 100 system, Economay et al. (1974) and Nduaguba (1975) concluded that, on an area basis, average classification accuracies of 80% or higher can be obtained. They assessed the system accuracy for agriculture, forestry, urban and sedimentation classifications.

17.1.3 METHOD OF ASSESSMENT USED IN THIS STUDY

At the time of receiving the Image 100 prints the authors had detailed ground truth information. However some features that were highlighted on the prints could not be positively identified without further field examination. The main feature requiring examination was pasture areas that had been heavily grazed or recently mown for hay at the time of the satellite overpass. All hue and chroma changes on the prints were then assigned to features on the ground. All colour designations were determined using ICSS-NBS Centroid colour chips (Kelly and Judd 1968). Most changes were caused by vegetation differences; a few by severely eroding areas, recently constructed logging roads and bare ground (nil vegetation). Since most hue and chroma changes were due to vegetation differences, the potential of these prints was assessed mainly for vegetation mapping. Two maps were produced.

The first map was a vegetation map for the area covered by the Image 100 prints (Fig. 17.1.3). Information for this map was obtained from the King Country Region worksheets (Jessen 1976; Page and Noble 1976; Stephens 1976).

The second map (Fig. 17.1.4) was an interpretation of Image 100 print D which was the print showing the clearest distinctions between the largest number of features (this print is shown as Fig. 17.1.2). Boundaries were drawn around areas of consistent hue and chroma and classified according to the colour/feature relationship previously established. Severely eroding areas, recently established logging tracks and bare ground are shown on Fig. 17.1.4.

The Image 100 prints were assessed by:

(i) Comparing the vegetation map (Fig. 17.1.3) of the region with the interpretation map of Image 100 print D (Fig. 17.1.4). This comparison showed vegetation associations that could be consistently classified. Listed in Appendix I are the dominant species present in each vegetation association.

(ii) Comparing the erosion, lithology, slope and soil boundaries on the worksheets with those seen on Image 100 print D.

(iii) Comparing the relative merits of Image 100 prints A, B and C with print D with respect to the factors mapped in the preparation of the worksheets.

17.1.4 RESULTS AND DISCUSSION

17.1.41 Assessment of Image 100 Print D for Vegetation Mapping

Boundaries between pasture, scrub and forest were readily distinguishable. Further subdivisions within these three groupings were also apparent.

Within areas of pasture immediately adjacent to the western side of Lake Taupo (Fig.17.1.1), high producing pasture on undulating slopes (5^{o}) was readily distinguishable from low producing pasture on sheet eroding moderately steep slopes (22^{o}). It is not known whether this was due to the slope difference, difference in pasture composition or erosion. The difference can be seen as a colour difference on this Image 100 print (Fig. 17.1.2). High producing prasture appears as a very pale green hue, and low producing pasture as a light yellowish pink hue.

Scrub associations were identified by dark green and light bluish green hues. Low scrub types such as Dracophyllum, fern and blackberry, which could not be distinguished from one another, were a light bluish green hue. Manuka and kanuka were a dark green hue. These two species were not mapped separately on the worksheets because they form a very similar scrub vegetation type. The boundary between scrub and forest associations is clearly seen at the margin of the Pokaiora clearing. (Fig 17.1.1 and 17.1.2). Subalpine scrub appeared a medium green hue.

In forested areas there was a general trend of dark hues indicating podocarp and podocarp-hardwoods through to lighter hues indicating hardwoods and scrub hardwoods. Areas of podocarps were a black hue, while low and high altitude podocarp-hardwood and podocarp-tawa associations were a brownish black hue.

Areas of these associations which had been cutover (logged) were a dark reddish brown to dark red hue, the more intense the logging the redder the hue. High altitude podocarp-hardwoods when associated with subalpine scrub appeared a dark green hue.

The spectral signature of vegetation associations on steep sunlit (at time of satellite overpass) slopes were lighter in due. This was most apparent along the fault scarp in the Hauhungaroa Range where high and low altitude podocarp-hardwood forests appeared a medium red brown hue instead of brownish black.

Recently established exotic forests (mainly Radiata Pine) up to 4 years old appeared a light bluish green hue and were indistinguishable from low scrub associations. Areas of older exotic forests (about 20 years old) were a very deep red hue. Within the two recently established exotic forestry areas (Fig.17.1.1), the very purplish blue hue indicated bare ground prepared for planting (and some bare ground road formations).

Areas of deep reddish purple hue along the western side of Lake Taupo indicated paddocks with very short pastures. Consultation with land managers showed that these pastures were either heavily grazed by cattle at a stocking rate of 34 stock units/hectare for a considerable number of days prior to satellite overpass or recently mown for hay.

A number of vegetation associations were not distinguishable from one another. These were:

(a) lowland podocarp-hardwood forest from podocarp-tawa forest or highland podocarp-hardwood forest;

(b) hardwood forest from tawa forest;

(c) scrub hardwoods from scrub hardwoods with tree ferns;

(d) recently established exotic forest from fern or Dracophyllum

(e) fern from Dracophyllum;

(f) swamp associations from manuka/kanuka scrub.

Fortunately the vegetation associations that can be distinguished from one another include those that will be most important for the updating of worksheets. Recognition of colour changes, reflecting changes in the important vegetation associations, will indicate changes in land use. Recognisable vegetation association changes which indicate changes in land use are:

(a) from indigenous forest (podocarp, hardwood, podocarp-hardwood, podocarp-tawa, beech) or manuka/kanuka to pasture (the small light yellowish pink patches on print D, located by area Y on Fig.17.1.4, indicate recently established logging roads);

(b) from indigenous forest or manuka/kanuka to exotic forest;

(c) from pasture to exotic forest;

(d) from manuka/kanuka or fern to pasture;

(e) from pasture to crops or vice versa.

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17.1.4.2 Assessment of Image 100 Print D for Mapping Erosion, Lithology, Slope and Soils

(a) An area of severe localised debris avalanche erosion can be seen on Fig.17.1.2 (located by X on Fig 17.1.4) in the gorge of the Maramataha River.

Slight debris avalanche and soil slip erosion is common along the length of the gorge, but only in three small areas where the erosion is locally severe can this be detected on the print. These erosion scars appear on print D only on slopes which were sunlit at the time of satellite overpass. Similar scars on shaded slopes did not show up. The shaded slopes were dark on the prints with little detail apparent.

(b) Only one major lithological boundary was apparent. This was the contact between greywacke and ignimbrite along the north-east trending Hauhungaroa Fault in the Hauhungaroa Range.

(c) Gross topographical features, such as ridges, valleys and drainage patterns, could be identified on the print. The general ruggedness of the terrain was also apparent.

(d) No soil patterns were evident. In New South Wales, Australia, Emery (1975) recognised soil patterns based on differences in soil texture and moisture content. For the area studied here the soils of the pastoral areas are yellow-brown pumice soils (Vitric Andosols) derived from Taupo airfall and flow tephras hence there are no large differences in soil texture or moisture content and it is to be expected no soil patterns would be evident. The more podzolised yellow-brown pumice soils in the Hauhungaroa Range have a forest cover which masks any soil patterns.

17.1.4.3 Assessment of Image 100 Prints A, B and C

On print A no forest or scrub associations were observed which were not apparent on print D and boundaries between forest and scrub were less distinct than on print D. However certain areas of bare ground were highlighted. These were undulating to rolling slopes where mechanical land clearing operations had removed all vegetation and exposed underlying soil. The amount of detail in pastoral areas was poor, the boundary between pasture and other vegetation associations however was more distinct than in print D.

The amount of land resource information observable on prints B and C was inferior to that on prints A and D although print C did highlight areas cleared of vegetation (bare ground) and areas of short pasture.

17.1.5 CONCLUSIONS

Image 100 prints of satellite imagery provide a synoptic view of a large area. They show large-scale associations and inter-relationships, place the given area in its regional context, and have dramatic impact and credibility. To interpret them detailed ground truth is required

In the north-east King Country Region where 1:50,000 aerial photographs and medium to small scale geology, soil and vegetation maps already exist, little new data was discovered on the Image 100 prints. Print D showed differences between more factors than the other Image 100 prints assessed.

No soil boundaries could be seen on the prints but broad physiographic units and a few lithological boundaries were apparent. Debris avalanche erosion in the Hauhungaroa Range was detectable only where locally severe, and only on slopes that were sunlit at the time of satellite overpass. Sheet and gully erosion present on the pastoral areas were not seen on the prints. This was probably due to resolution limitations of the imagery. Areas of land bared preparatory to planting, very short pastures and recently established logging roads were easily seen on some of the prints.

Forest, scrub and pasture boundaries were visible on the Image 100 prints. These appeared as changes in hue and chroma. Some forest and scrub associations were able to be subdivided and delineated by more subtle differences in hue and chroma which were related to differences in vegetation structure and composition. Boundaries between low and high producing pasture were visible.

As these prints reveal broad vegetation patterns, they would be most useful to land resource surveyors in the preparation of small scale (1,100,000 to 1:250,000) maps. From observations made of colour composites of complete LANDSAT II images of New Zealand, regional inter-relationships between lithologies and soils are more clearly evident and would be of use at such scales of land resource mapping. Urban areas are clearly distinguishable from rural areas on these images.

It has been shown in this paper that the changes in vegetation which would indicate any of the likely significant changes in land use (forest to pasture etc) can be readily distinguished on some of the Image 100 prints. Aerial photographic coverages of New Zealand are infrequent; latest available photographs therefore often contain out-of-date vegetation information. However, since it is possible to get satellite images of an area every 18 days they provide up-to-date information on vegetation and land use changes. Because of this it is anticipated that Image 100 prints will prove to be extremely useful to staff of the Water and Soil Division, Ministry of Works and Development, New Zealand, in the regular (every few years) updating of the vegetation factor on the New Zealand Land Resource Inventory Worksheets.

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APPENDIX 17.1

The major species present in each vegetation association mapped and their colour on Image 100 print D are listed.

(a) High producing pasture (very pale green hue)

Perennial ryegrass	Lolium perenne
White clover	Trifolium repens
Lucerne	Medicago sativa
Yorkshire fog	Holcus lanatus
Cocksfoot	Dactylis glomerata

(b) Low producing pasture (light yellowish pink hue)

Perennial ryegrass	Lolium perenne
Brown top	Agrostis tenuis
White clover	Trifolium repens
Sweet vernal	Anthoxanthum odoratum
Plantain	Plantago spp
Ragwort	Senecio jacobaea

(c) Podocarp-hardwood forest (low altitude) (Brownish black hue)

Rimu	Dacrydium cupressinum
Matai	Podocarpus spicatus
Miro	Podocarpus ferrugineus
Totara	Podocarpus totara
Tanekaha	Phyllocladus trichomanoides
Kamahi	Weinmannia racemosa
Hinau	Elaeocarpus dentatus
Rewarewa	Knightia excelsa

(d) Podocarp forest (Black hue)

Rimu	Dacrydium cupressinum
Matai	Podocarpus spicatus
Miro	Podocarpus ferrugineus
Totara	Podocarpus totara
Tanekaha	Phyllocladus trichomanoides
Kahikatea	Podocarpus dacryioides

(e) Hardwood forest (Brownish black hue)

Kamahi	Weinmannia racemosa
Tawa	Beilschmiedea tawa
Rewarewa	Knightia excelsa
Hinau	Elaeocarpus dentatus

(f) Podocarp-tawa forest (Brownish black hue)

Rimu	Dacrydium cupressinum
Matai	Podocarpus spicatus
Tawa	Beilschmiedia tawa

(g) Podocarp-hardwood forest (high altitude) (Brownish black hue)

Hall's totara	Podocarpus hallii
Kamahi	Weinmannia racemosa
Broadleaf	Griselinia littoralis
Miro	Podocarpus ferrugineus

(h) Beech (Black hue)

Silver beech	Nothofagus menziesii

(i) Exotic forest (very deep red hue)

Radiata pine	Pinus radiata
Douglas fir	Pseudotsuga menzeisii
Eucalypts	Eucalyptus Spp.

(j) Manuka, kanuka scrub (Dark green hue)

Manuka	Leptospernum scoparium
Kanuka	Leptospermum ericoides

(k) Fern (Light bluish green hue)

Bracken	Pteridium aquilinum var. esculentum

(l) Scrub hardwoods (Dark red hue)

Five finger	Pseudopanax arboreum
Kamahi	Weinmannia recemosa
Rewarewa	Knightia excelsa
Tutu	Coriaria arborea
Rangiora	Brachyglottis repanda
Lemonwood	Pittosporum eugenioides
Lancewood	Pseudopanax crassifolium

(m) Scrub hardwoods and treeferns (Dark red hue) as for l plus

Treeferns	Cyathea spp.
	Dicksonia spp.

(n) Sub-alpine scrub (Medium green hue)

Mountain toatoa	Phyllocladus alpinus
Broadleaf	Griselinia littoralis
Pepper tree	Pseudowintera colorata
Bog pine	Dacrydium bidwillii

(o) Dracophyllum (Light bluish green hue)

Monoao	Dracophyllum subulatum

(p) Rushes (Dark green hue)

Rushes	Juncus spp.

(q) Swamp associations (Dark green hue)

Rushes	Juncus spp.
Flax	Phormium tenax

(r) Blackberry (Light bluish green hue)

Blackberry	Rubus fruticosus

Additional species, not mentioned in Ch. 17.1 but referred to in Ch. 17.2, are:

(b) Low-producing pasture

Timothy	Phleum pratense
Tall fescue	Festuca arundinacea
Danthonia	Notodanthonia spp.

(e) Hardwood forest

Rata	Metrosideros spp.

(g) Podocarp-hardwood forest (high altitude)

Kaikawaka	Libocedrus bidwillii

1) Scrub hardwoods

Mahoe	Melicytus ramifolius

(s) Tussock associations

Red Tussock	Chionochloa rubra

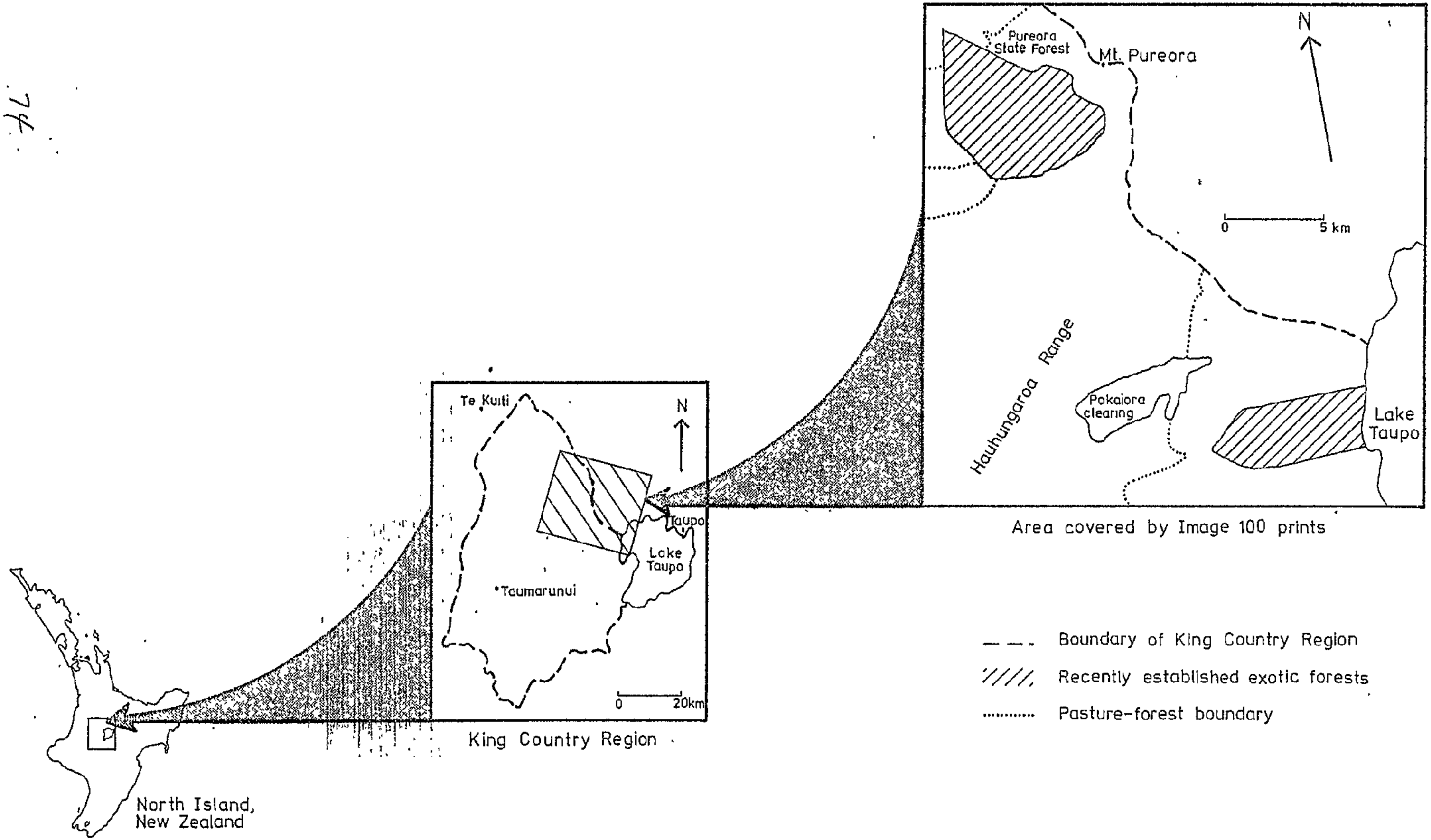

Fig. 17.1.1 LOCALITY MAP

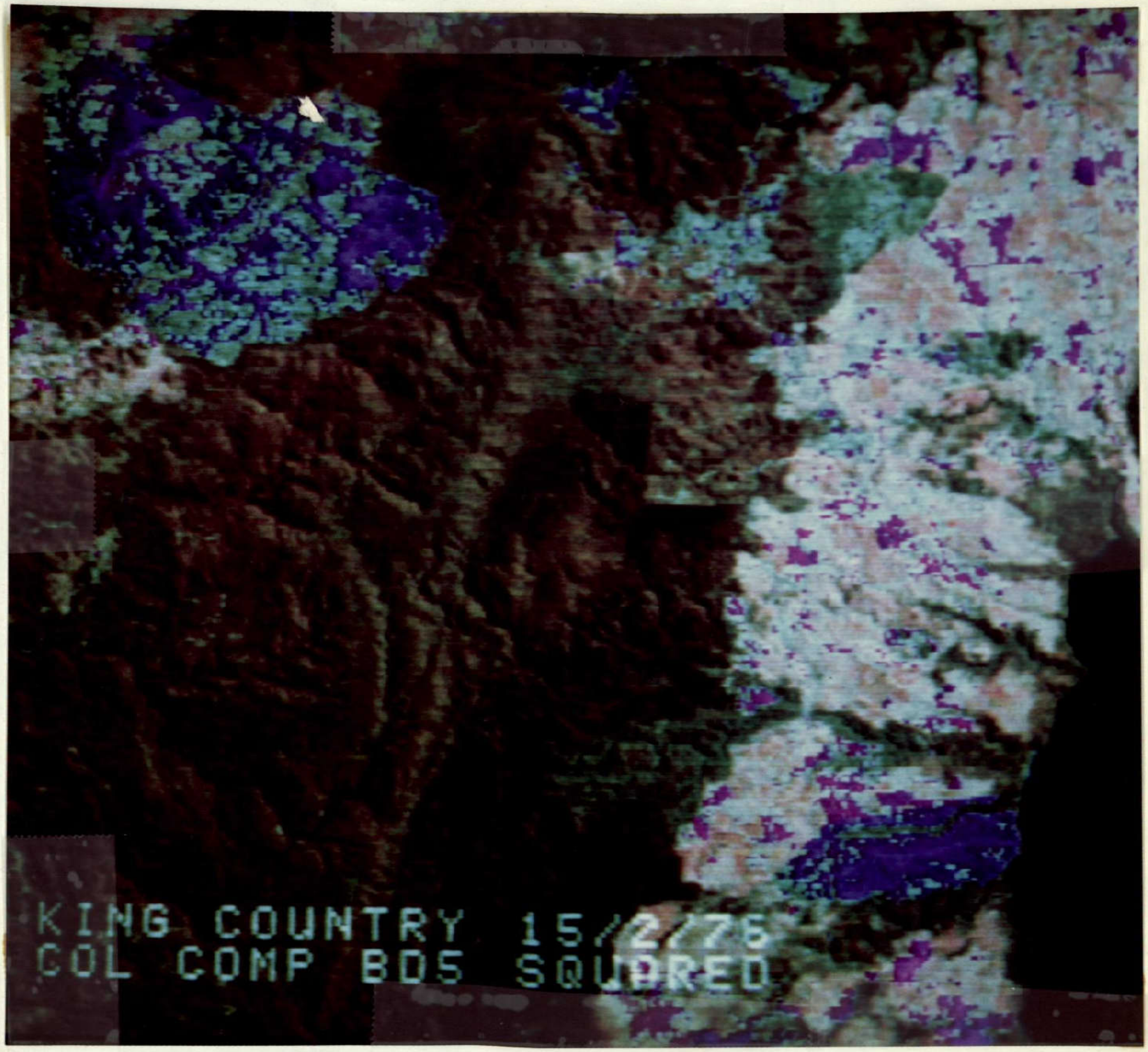

Fig.17.1.2

IMAGE 100 PRINT D
NORTH-EAST KING COUNTRY REGION

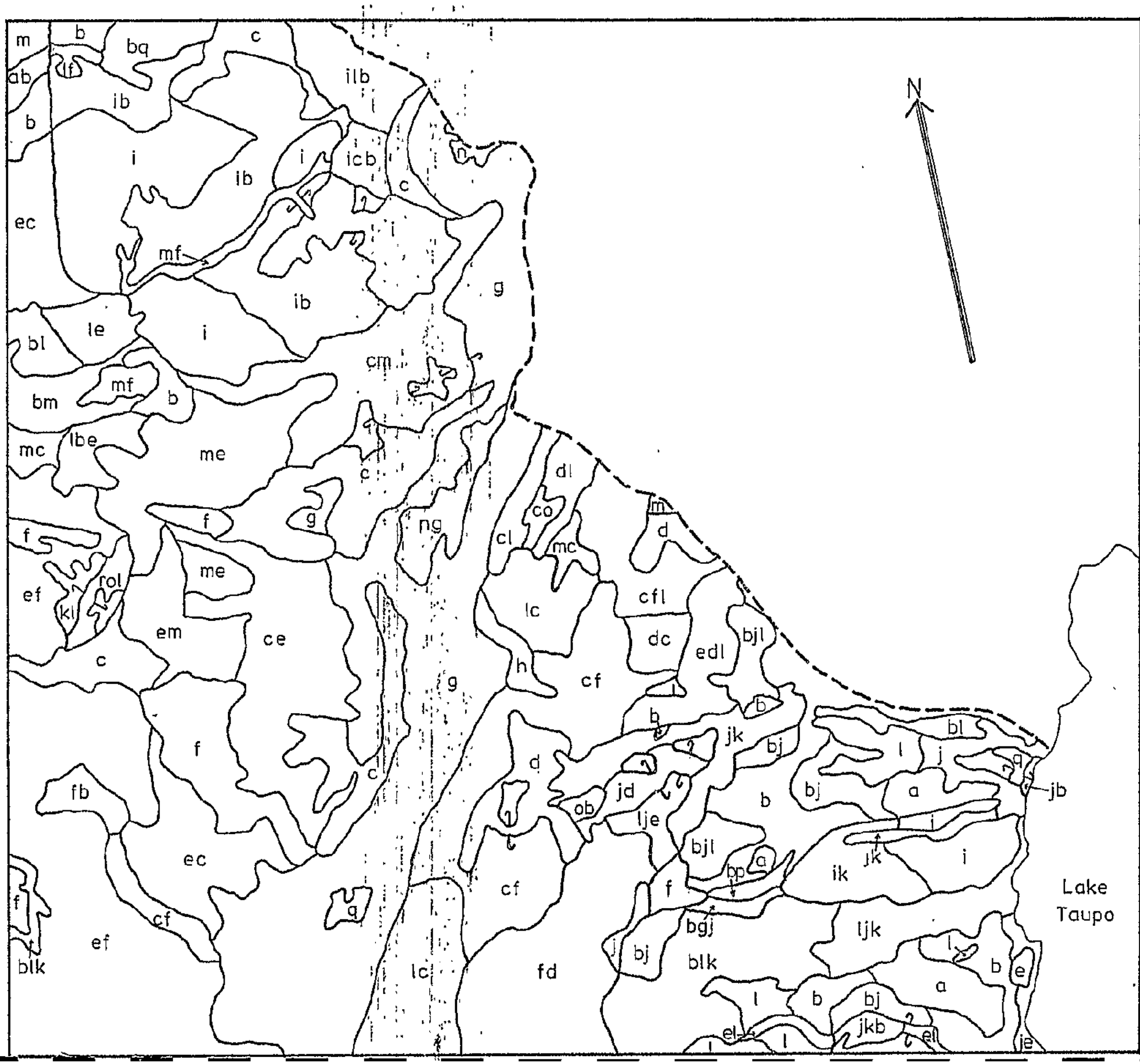

Fig. 17.1.3

VEGETATION MAP
NORTH-EAST KING COUNTRY REGION

LEGEND

a - High producing pasture
b - Low producing pasture
c - Podocarp-hardwood forest (low altitude)
d - Podocarp forest
e - Hardwood forest
f - Podocarp-tawa forest
g - Podocarp-hardwood forest (high altitude)
h - Beech forest
i - Exotic forest
j - Manuka, kanuka scrub
k - Fern
l - Scrub hardwood
m - Scrub hardwood and treeferns
n - Subalpine scrub
o - Dracophyllum
p - Rushes
q - Swamp associations
r - Blackberry

Scale

0 2 4 km

1:134,000

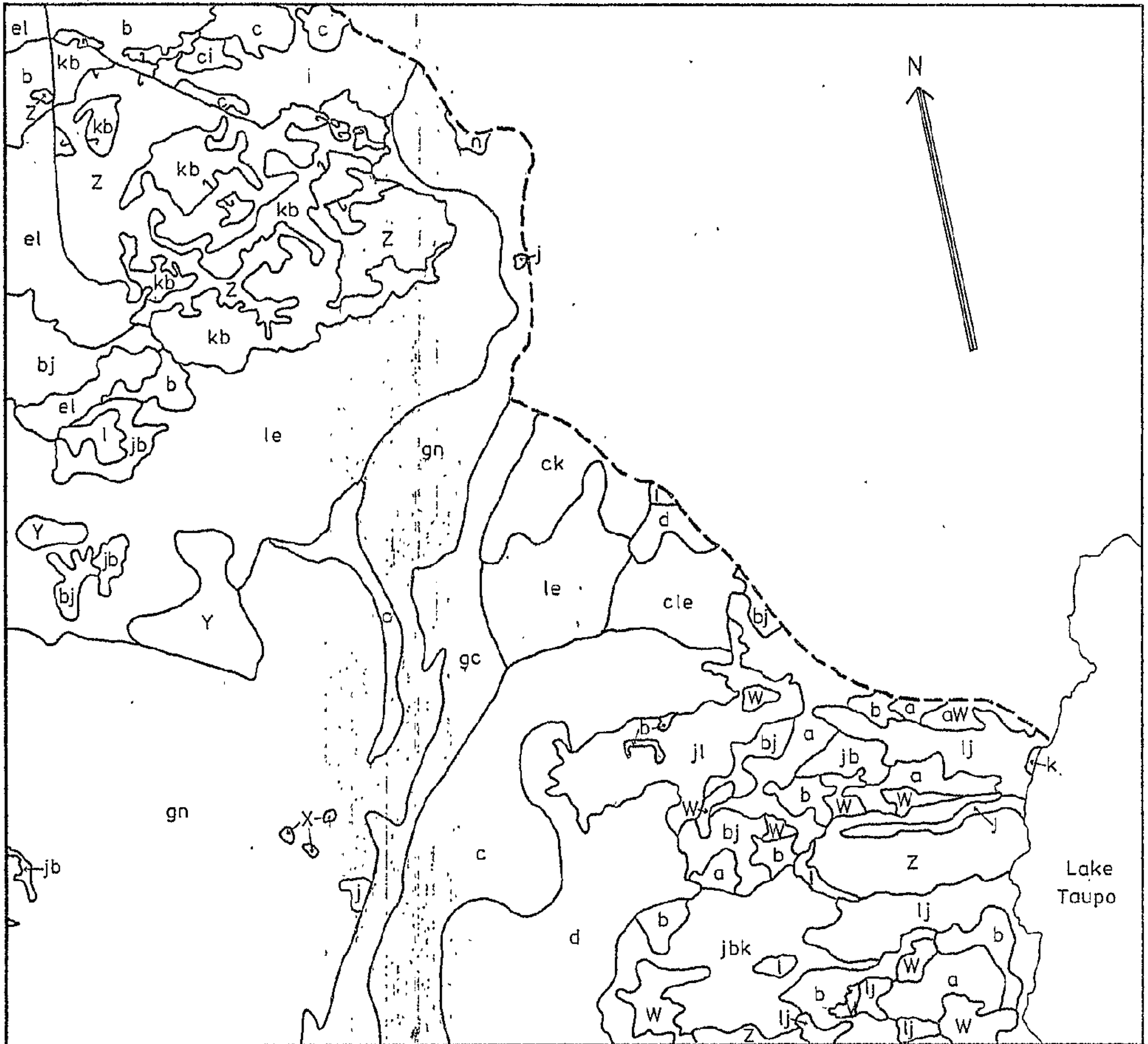

Fig.17.1.4

INTERPRETATION OF IMAGE 100
PRINT D
NORTH-EAST KING COUNTRY REGION

LEGEND

a- High producing pasture
b- Low producing pasture
c- Podocarp-hardwood (low altitude)/ podocarp-tawa forests
d- Podocarp forest
e- Hardwood forest
g- Podocarp-hardwood forest (high altitude)
i- Exotic forest
j- Manuka, kanuka scrub/swamp associations
k- Fern/dracophyllum/exotic forest (recently established)
l- Scrub hardwood/scrub hardwood and treeferns
n- Subalpine scrub

W- Very short pasture
X- Erosion scars
Y- Logging roads
Z- Bare ground

Scale

0 2 4 km

1:134,000

17.2 EVALUATION OF LANDSAT COMPUTER-COMPATIBLE TAPES AS AN AID FOR VEGETATION CLASSIFICATION ON LAND RESOURCE INVENTORY WORKSHEETS

Douglas L Hicks

ABSTRACT

This paper is a preliminary evaluation of LANDSAT Computer-Compatible Tapes (CCTs) as a source of data for vegetation mapping. An outline of land resource inventory worksheets, and their vegetation symbols, is followed by description of a computer mapping procedure which enables major categories of structurally similar vegetation to be differentiated. The direction which future evaluation may take, to enable a more detailed differentiation of vegetation types, is discussed.

17.2.1 Land Resource Inventory Worksheets and their vegetation symbols.

The land resource inventory worksheets (Worksheets) are being produced by Water and Soil Division, Ministry of Works and Development, as part of a national land resource survey for the National Water and Soil Conservation Organisation. The survey procedure is adapted from the U.S. Soil Conservation Service's eight-class standard land use capability classification. An inventory is made of rock type, soil unit, slope, erosion and vegetation, to delineate many distinct land inventory units. The units are assigned a I - VIII land use capability class, to indicate the capacity of the land for permanent, sustained production. Purpose, methods and uses of Land Resource Survey are fully described in the Land Use Capability Survey Handbook (Soil Conservation and Rivers Control Council, 1969, 1974). While the national survey, started in 1973, will soon be complete, two of the criteria - erosion status and vegetation cover/land use - are prone to rapid change, hence any technique which enables periodic up-dating of these criteria over wide areas of country in a short time is likely to be of considerable use to the Water and Soil Division.

Table 17.2.6 shows the vegetation classification used in preparation of Worksheets. Two points should be noted:

(i) There are five major categories: grassland, cropland, scrubland, forest, and miscellaneous herbland. These are divided into vegetation types, in part structural, in part floristic. Normally, a limited number of the types in the classification is present on any one Worksheet;

(ii) On the Worksheets, land resource inventory units are characterised by a code of the form

$$\frac{\text{Rock type - Soil Unit - Slope Grouping}}{\text{Erosion type/severity - Vegetation type}}$$

e.g.

$$\frac{\text{Kt/Mo} \; - \; \text{20e} \; - \; \text{A}}{\theta \; - \; \text{N3c}}$$

Where a vegetation type comprises more than 40% of the unit's area, its symbol (refer Table 17.2.6) is shown in large type; where less than 40% in small type. Any combination of symbols may be used, in descending order of importance from left to right, e.g.

P2
P2M6
P2M6m8
P2m6m8m9
p2m6m8m9

as the pattern of vegetation on a unit becomes increasingly complex.

17.2.2 Vegetation mapping procedure

P.E.L.'s coded picture print-out program RPCTAL (Thomas 1977) was used to obtain CCT print-outs for four areas in the eastern King Country, on LANDSAT II image E-2389-21172 (15.2.76). Figure 17.2.1 and Table 17.2.1 show an example of RPCTAL print-out, with its corresponding radiance key.

Inventory units characterised by a single, upper-case, vegetation type symbol were located on the print-outs. Spectral signatures for the vegetation types were defined by listing the complete radiance range of the print-out characters occupying the area of the Inventory 'target unit'. The spectral signatures in each band are listed in Table 17.2.2. In any one hand, the spectral signatures of most vegetation types overlap. This is not surprising, because:

(i) several different plant species, often markedly different in physiognomy and colour, comprise some vegetation types, e.g. hardwood forest (N5) and broadleaf scrub (M6);

(ii) some vegetation types are similar in physiognomy and colour e.g. high producing pasture (P1) and low producing or native grassland (P2);

(iii) small areas of other vegetation types may be present in the unit, even though it is designated by a single symbol;

(iv) variations in reflected radiation, due to aspect and slope, may have affected the signatures of some units although variations in incident radiation or due to atmospheric transmission are less likely, since all the target units are on the same CCT.

Table 17.2.3 summarises the signatures in Table 17.2.2. It indicates that while some vegetation types cannot be separated in any band, distinct spectral signatures in at least one band can be defined for three physiognomic groupings:

(i) P1 and P2: short grass sown pastures, dominated by ryegrass, cocksfoot and clover (P1) or by sundry low-producing grasses e.g., timothy, tall fescue, browntop and danthonia (P2).

(ii) N4 + N7: mature forest with a dense closed canopy of uniform dark colour, either southern beeches (N4) or the podocarp species rimu, miro, matai, kahikatea, totara and kaikawaka (N7).

(iii) M3 + M4 + M6 + M6a: either natural successions and disclimaxes, or induced successions on abandoned farmland, or the exposed under-storey of logged forest. Dominated by Dracophyllum heath (M3) bracken fern (M4), numerous broadleaved shrubs e.g., Pittosporum, Coprosma, five-finger, mahoe (M6), or by tree ferns (M6a).

(Refer to Appendix 17.1. in the paper by Stephens and Page, for generic names of species.)

Distinct spectral signatures in at least one band can be defined for three single vegetation types:

(i) P5: red tussock grassland, with tall, bunched growth form (single species + hybrids).

(ii) H2: sedge and rush associations, with tall, bunched growth form (several species).

(iii) N5: mature forest composed of numerous hardwood species, principally tawa, kamahi and rata: the mature equivalent of M6 scrub. The canopy is tall and closed, but is less uniform than either N4 or N7.

(Refer to Table 17.I. in the paper by Stephens and Page, for generic names of species.)

Figure 17.2.3 is part of a vegetation map, prepared from a THEMAPP print-out corresponding to the north-eastern part of Worksheet N111 (Waimarino). PEL's new thematic mapping program THEMAPP, a considerable advance on RPCTAL, differentiates up to 13 different targets by testing each pixel against 13 sets of 'parallelipiped radiance gates'. For instance, target 1, sown pasture (P1 + P2) has the following gates:

Band	Lower limit of gate	Upper limit of gate
1	10	16
2	10	16
3	49	67
4	30	40

(These limits were defined from RPCTAL print-outs of the eastern King Country on E-2389-21172, taken on 15.2.76, sun elevation 39°, solar azimuth 79°E. Units are LANDSAT MSS radiance levels.)

If a pixel's radiance values are within these limits, it will be identified as sown pasture by the symbol '1' on THEMAPP's output. If its radiance value in even one band is outside the 'gate', the program tests the pixel against the 'gates' for target 2, mixed scrub (M3 + M4 + M6), and so on for all 13 targets until the pixel is identified, or finally printed out as a blank, unidentified area. If a pixel has four radiance values which are within the 'gates' of two targets, say 5 and 6, the pixel will be identified as whatever target it is tested against first, i.e. as 5. The list of targets used to produce Figure 17.2.3 is given in Table 17.2.5. Targets 5, 6 and 9, which do not have distinct spectral signatures, were inserted to see if THEMAPP could isolate these vegetation types. The gates for targets 11, 12 and 13, which were fixed in the original version of THEMAPP, were made alterable and re-defined to correspond with the test area. The RPCTAL spectral signatures for targets 1-10 were adjusted to approximate a normal frequency distribution, on the basis of frequency distributions produced for each target by a dummy run of THEMAPP. The adjusted spectral signatures were used for the production of Figure 17.2.3, and are listed in Table 17.2.4. Figure 17.2.2 gives examples of initial and amended spectral signature frequency distributions.

The THEMAPP print-out was compared with the vegetation classification for the Worksheet units in the test area (Figure 17.2.4) and with Lands and Survey Department 1:25,000 aerial photographs taken on 20.1.76. This showed:

(i) There is a fairly good correspondence of boundaries for the major vegetation categories - scrub (M), forest (N) and grassland (P) - although some discrepancies occur.

(ii) Areas of hardwood forest (N5) have been printed out as areas of podocarp forest (N7). Areas identified as hardwood forest (N5) correspond, on the aerial photographs, with isolated patches of scrub (M6) and sedge (H2), disseminated through units P2m6 and P2h2. This indicates that the spectral signature of hardwood

81

forest, even when corrected on the basis of the THEMAPP frequency distribution for target 3, has not been isolated. In Figure 17.2.3 all areas printed out as hardwood forest (3) were therefore grouped with pasture (1).

(iii) Some areas of sedge (H2) and tussock (P5) have been correctly identified, while others have been incorrectly identified as mixed scrub (M3 + M4 + M6), or left as blank, unidentified areas. This, once again, indicates that spectral signatures for sedge and tussock overlap with the spectral signature for mixed scrub.

(iv) Areas of beech forest (N4) and mixed forest (N3c + N3d) have been identified as podocarp forest (N7). This is due to over-lapping spectral signatures for beech forest and podocarp forest, and the allocation of higher priority to target 5 (podocarp forest) in the classification procedure. Small areas of mixed forest, which would otherwise have been unidentified, have been printed out due to the insertion of target 7. In Figure 17.2.3 all areas printed out as podocarp forest (5), beech forest (6) and mixed forest (7), have therefore been grouped together as one forest category (which also includes hardwood forest; see (ii) above).

(v) Unidentified areas correspond with grasslands (P2, P5, H2) in the south of the print-out, and with mixed scrub (M6), or mixed scrub - hardwood forests (M6n5, N6n7) in the north. This is probably due to the spectral signatures of the unidentified areas lying slightly outside the ranges defined for these targets.

(vi) Steep east-facing slopes under scrub (M6) and mixed forest (N3a) in the north of the print-out have been erroneously identified as pasture (P1 + P2). This has probably been caused by higher reflected radiance from these slopes due to low sun angle (39°) at the time of satellite overpass. The surrounding terrain, which has gentle, west-facing slopes, has been correctly identified.

(vii) In mixed units (e.g. M6n5, N5m6), the pattern of scrub and forest corresponds closely to the actual pattern on the aerial photographs although the forest has been identified as podocarp (N7) instead of hardwood (N5) (see (ii) above).

(viii) The revised interpretation of THEMAPP, after comparison with the Worksheet and aerial photographs, is given below. Figure 17.2.3 has been colour-coded to correspond with this revision.

(viii) cont.

Identified by THEMAPP as:		Shown on Worksheet and air photos as:	Revised interpretation of THEMAPP
1.	Sown pasture	Sown pasture; small areas scrub and forest.	Grouped and colour-coded as grassland (P)
3.	Hardwood forest	Scrub and sedge in sown pasture	
8.	Sedge	Sedge and tussock	
10.	Tussock	Sedge and tussock	
2.	Mixed scrub	Mixed scrub; small areas sedge	Colour-coded as scrub (M)
5.	Podocarp forest	Podocarp, beech and hardwood forest	Grouped and colour-coded as forest (N)
6.	Beech forest	Beech forest	
7.	Mixed podocarp-beech	Mixed podocarp-beech	
9.	Manuka (Nil)	-	Not colour-coded
11.	Water (Negligible)	Water	
12.	Urban (Negligible)	Sedge and tussock	
13.	Pine Forest (Nil)	-	
	Unidentified	Pasture, mixed scrub, hardwood forest	

Figure 17.2.4 has also been colour-coded according to the principal vegetation type in each unit. When comparing the two figures it should be noted that most units have secondary vegetation types (< 40% of the unit's area) which are not shown by the colour-coding. These can be identified from the symbol key in table 17.2.6.

(ix) Residual errors in the colour-coded, revised interpretation of THEMAPP are areas of scrub and forest colour-coded as pasture on steep east-facing slopes, small areas of sedge colour-coded as scrub, and unidentified areas.

17.2.3 CONCLUSIONS

Three major Worksheet vegetation categories - grassland (P), scrub (M) and forest (N) - have been differentiated with P.E.L.'s program THEMAPP. When the THEMAPP targets are grouped the boundaries correspond closely to the scrub-forest-grassland boundaries on the corresponding Worksheet, and on aerial photographs taken one month before satellite overpass.

Worksheet vegetation types, e.g. N5 as opposed to N4 or N7, have not been successfully differentiated. The attempt to do so produced erroneous identifications, unidentified areas, and displaced boundaries. Most discrepancies disappeared when the vegetation type - targets were grouped to the category level. The failure to differentiate Worksheet vegetation types is due to a greater degree of overlap between spectral signatures than was apparent from either the 'target units' identified on RPCTAL print-outs, or the THEMAPP frequency distributions. This highlights the need to define spectral signatures from something other than the complete range of radiance values in single 'target units'. It also indicates that overlap in spectral signatures will prevent identification of Worksheet vegetation types even when a 4 band filter algorithm of the THEMAPP type is used.

LANDSAT computer tapes could be used to identify areas where major changes in land use e.g. logging of forest, farm development, afforestation, have altered the Worksheet vegetation category e.g. from forest (N) to scrub (M). The tapes cannot be used to map changes in Worksheet vegetation type e.g. from N3a to M6n5, until procedures for isolating and classifying the spectral signatures of vegetation become more refined. The procedure described in this paper could be used during revision of Worksheets to identify areas where re-mapping of vegetation on the ground is necessary, as opposed to areas where it is not, and could save field parties from the unnecessary investigation of areas where no changes have occurred.

The paper by Stephens and Page in this report shows that some individual vegetation types can be mapped from multi-band photographic products, of the type produced by combination and manipulation of single band image densities in colour additive viewers and electronic image processors. The relative ease with which this has been done suggests an analogous approach to vegetation mapping from computer tapes: application of the classification algorithm to a summary radiance statistic for each pixel e.g. a summation, product or ratio of two or more bands, instead of application to four single band radiances in turn. P.E.L.'s computer mapping programs are currently moving in this direction e.g. the insertion of a band ratio option in THEMAPP, and the batch of programs being developed by McDonnell (1976a, b).

While multi-band photographic products from LANDSAT imagery are easier to interpret than computer tape print-outs, the latter possess characteristics which warrant their continued evaluation as a tool for Worksheet revision. The tapes enable the direct use of radiance data, by-passing the photographic process. Areas of vegetation as small as 0.4 ha are discernible to the eye as individual pixels hence line boundaries can be drawn to a theoretical accuracy of ±78m. The scales of the IBM 370 line printer are 1:21,232 in the W-E, and 1:10,425 in the N-S direction; inherent distortions in the scale could be rectified when the print-out is photographed prior to printing. While it will be some time before LANDSAT tapes can be used for practical, as opposed to experimental map revision, they contain a large amount of potential information on vegetation, which will be released when better means of spectral signature definition and classification are developed.

References

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TABLE 17.2.1 <u>RPCTAL Output Radiance Key</u>

(a) 47 - level print-out

?				=	0.00
?	>	0.00	to	< =	2.70
%	>	2.70	to	< =	5.40
@	>	5.40	to	< =	8.11
$	>	8.11	to	< =	10.81
&	>	10.81	to	< =	13.51
*	>	13.51	to	< =	16.21
>	>	16.21	to	< =	18.91
<	>	18.91	to	< =	21.62
(	>	21.62	to	< =	24.32
)	>	24.32	to	< =	27.02
A	>	27.02	to	< =	29.72
B	>	29.72	to	< =	32.43
C	>	32.43	to	< =	35.13
D	>	35.13	to	< =	37.83
E	>	37.83	to	< =	40.53
F	>	40.53	to	< =	43.23
G	>	43.23	to	< =	45.94
H	>	45.94	to	< =	48.64
I	>	48.64	to	< =	51.34
J	>	51.34	to	< =	54.04
K	>	54.04	to	< =	56.74
L	>	56.74	to	< =	59.45
M	>	59.45	to	< =	62.15
N	>	62.15	to	< =	64.85
O	>	64.85	to	< =	67.55
P	>	67.55	to	< =	70.26
Q	>	70.26	to	< =	72.79
R	>	72.79	to	< =	75.66
S	>	75.66	to	< =	78.36
T	>	78.36	to	< =	81.06
U	>	81.06	to	< =	83.77
V	>	83.77	to	< =	86.47
W	>	86.47	to	< =	89.17
X	>	89.17	to	< =	91.87
Y	>	91.87	to	< =	94.57
Z	>	94.57	to	< =	97.28
|	>	97.28	to	< =	99.98
/	>	99.98	to	< =	102.68
-	>	102.68	to	< =	105.38
-.	>	105.38	to	< =	108.08
+	>	108.08	to	< =	110.79
=	>	110.79	to	< =	113.49
:	>	113.49	to	< =	116.19
;	>	116.19	to	< =	118.89
,	>	118.89	to	< =	121.60
"	>	121.60	to	< =	124.30
.	>	124.30	to	< =	127.00

(b) 10 - level numerical code substitution

Selected Radiance Interval for Band 3

9	>	16.21	to	<=	17.83
8	>	17.83	to	<=	19.45
7	>	19.45	to	<=	21.08
6	>	21.08	to	<=	22.70
5	>	22.70	to	<=	24.32
4	>	24.32	to	<=	25.94
3	>	25.94	to	<=	27.56
2	>	27.56	to	<=	29.19
1	>	29.19	to	<=	30.81
0	>	30.81	to	<=	32.43

1. Radiance is expressed in units of the 0-127 LANDSAT MSS radiance scale.

2. Pixel radiance values are stored as integer values on CCTs. The values in the key should therefore be rounded to the nearest integer.

3. Figure 17.2.1 (b) is an example of the 10-level numerical code print-out option. The 10-level code can be substituted for part or all of the 47-level range in Figure 17.2.1 (a).

FIGURE 17.2.1 RPCTAL - OUTPUT

a 47 level

```
BB)>*<&*>>)AA))()(>)CEFFHHLMIJFSCBA)))((()>>()A(()))(((<>)))((A
A>)B)*<))ABAABA)))(>ADFECCFHHKLIC))))))>()>&<>)))A)>(()>>))A()A
EA<*)))>(ABCDEFA)DB<>BDDEGFEEDDFHFDB)()))(()><)()(>>A)(()>(()(((
BDAA>(AAAB?DEDCBAF)*)ADGFGIKLKGGDBACA>(()()>>>()AA)())>>>>)))((
>(>>>AABBC?EECBA>A>&A(>BCEFGIJLGCBA((B((>>>>>>>((()AAB)<>(((((
>><>()BBDEEEEEB>>))><))*(ABBBEGIIB()B))A)A)<>(>(>>()((AA())))))(
>>>><>)CFIIEFEC()<>()(<)(CJEEIFCA>>>()))))**((<>(>)(>>AB(()BCEA
>>>(AABCCEFEFIIFD))AG)*)(<CKKJHDCAA)>>(()BA<*<<>(>)))(>(>))BABC
<((()))AACDFFHIFJMLJHE)))((CHFCAA))))()))AA(**<*((()()))()))()
<>>>>())A)ACEFFDEHJKLMLHGE)>BGDCBA)AAA>(()()A)&**>>)AA(>)BA)AAA
>>(()((A(>))BCCCCDEHJLLLJLE>BB)(ABA)>)(>>>>)ABA>>**<>>(>()>BCBB
)))()))))ABB)BCCBBBCCCEIJII(H)>AC>>AAAA)(>(()(())BBA<)()>>ABAABBB
)))))><)AB()EEC)A)CE)(EHHIHA&AE>&>))>A)))>()(<>))A)><)))AABABCE
)))))))()AC()EHJHBCAHEBCFHFEC*(CA<*(C(<B)>())A>>B(A)))AABABCDCD
))((AB)<CEA>CDDFJFADFCACDDDB*<)CB*<))<)(*<(()(<)((()ADDB)))CDDD
>AA)ACB>)EGC>DECDGIGCDB>)A(BE)&<AC(<))*>>*<>>)>>A)))BDDEDA()BBD
(B><)FB*>BGBAEEECDGIEB)<(()<>CC**AA*>(>>()><>()BBCBCDBCBEE)>(BB
AB<<)DGCBBBDAEFEDA)CECB>)>()&<BDA)AA)(><<)CB)&*)))BBBBBBDBBB>)A
CF)>)CFEBE)E)CECC(()AAA)><)(<<<)CB)BCC((>*&>AB>>()A))B)BCABBCCB
KJF(>CFHBABDCCCCC<*(BCB))AA**)>)BBA)ACD)*(<<**)>())A))()CCCCCCD
JILKB<AFHE)CA()))>(<&>()>(B*&<*)))(>>(AB*<A)))(<A))CCBA)(ABDDBC
EGHKLG((DFC>AA(BB)>>*>())>>>)><*>AAA(**>)A**BAAB(>(>)DDCA))ABDEA
FIIIIJGACB()C><>AA>*<>)()><(<&&<>>AC>>>>><*>>(BB)>>>(BCCBBBBCBE
DHJIFGIG)A(()A>>)>)**>>(AA)(**>>>>)CA>>&*(>>>>>AA)AA)AABCABBCDD
```

b 10 level numerical code

```
0037*9&*873223454574CEFFHHLMIJF0C02344555477542554345558843455 2
28414*843212212433572DFECCFHHKLIC3443447548&874342475547744254 2
E28*337520CDEF2300870DDEGFEEDDFHFD035333553783535772355775535 55
0D2262220 0DEDC02F4*42DGFGIKLKGGD02C276646488864224644788744466
757772200CDEEC02728&2570CEFGIJLGC025505578787775553220387555555
7898641 1DEEEEE17837934*62111EGII163144232497676776466226434444 6
7777873CFIIEFEC549754593 5CJEEIFC2777544333**55085745772055 40CE2
777522 1CCEFEFIIF0342C4*358CKKJHDC2248755312 8*988573435757431 21C
955533322CDFFHIFJMLJHE33355CHFC2233335333225**9*55533533353335 3
88777644242CEFFDEHJKLMLHGE470GDC024222766464248**7842267402422 2
77553552573 30CCCCDEHJLLLJLE7C03520237358777320277**87758537 0C00
443643342 1141CC100CCCEIJIIH482C78222246766466331129464782122011
444447842053EEC323CF35EHHIH262E78734823447535884324783432 2020CE
4344335420 54EHJH1C2HE1CFHFEC*5C28*5C58138543277715234322121CDCD
33552038CE27CDDFJF2DFC2CDDD0*83C0*933935*85535935553 2DD0333CDDD
72242C074EGC7DECDGIGCD084260E4882C6844*88*8984782444000ED264000
50783F0*70G02EEECDGIE038553 88CC**22*858853887530 0C0CD0C0EE38500
21994DGC111D2EFED23CEC18376 3&91D24224 68994C038*441111001D010732
CF484CFE0E3E3CECC5532223894588 93C030CC558*&8208754243030C200CC0
KJF57CFH121DCCCCC8*51C13322**47311232C03*558**48533233 53CCCCCD
JILK082FHE3C2533375 9&753750*89*333577520*92333592 33CC023520DD0C
EGHKLG66DFC722600777*764788488*82226**842**022068684 0DC24420DE7
FIIIIJ32C053C788227*8735378 58&88772C777788*785003578 50CC0000C09
DHJIFGIC3266427847 3**7762236**88784C277&*688888223224221C210CDI
```

Target unit for spectral signature definition

Refer to Table 17.1 for symbol key

TABLE 17.2.2 Spectral Signatures for Land Resource Inventory Vegetation Types

Symbol and Type	'Spectral Signature' (Radiance range on 0-127 LANDSAT MSS radiance scale)			
	Band 1	Band 2	Band 3	Band 4
P1 High producing pasture	10-16	10-16	49-64	30-40
P2 Low producing or natively grassland	10-16	10-16	49-67	30-40
P5 Red tussock assns.	14-16	17-21	38-48	25-29
M1 Manuka, kanuka	11-16	11-16	38-48	36-48
M3 Dracophyllum	11-13	11-13	30-43	17-21
M4 Fern	11-13	11-13	30-43	17-21
M6 Broadleaved scrub	11-13	11-13	30-43	17-21
M6a Broadleaved scrub with tree ferns	11-13	11-13	30-43	17-21
N4 Beech forest	9-10	6-10	22-32	11-16
N5 Hardwood forest	9-13	6-13	38-48	22-27
N7 Podocarp forest	6-10	6-10	17-32	9-16
H2 Rushes, sedges	14-16	22-27	38-48	25-29

Note:

1. Types P, P3, P4, P6, L, L1-4, M, M2, M7-12, N1, N2, N6, N8-10, H, H1, and H3-7 occupy insignificant areas of Worksheet N111.

2. Types N3a-N3e are amalgams of N4, N5, N7 and M6.

TABLE 17.2.3 Vegetation types with distinct spectral signatures in at least one band

Type	Band	Range of radiance values (units of 0-127 LANDSAT MSS radiance scale)
(a) Grouped		
(P1+P2) Sown pasture	3	49-67
(M3+M4+M6+M6a) Mixed scrub	4	17-21
(N4+N7) Beech and podocarp forest	4	9-16
(b) Single		
P5 Red tussock assns.	2	17-21
H2 Rush - sedge assns.	2	22-27
N5 Hardwood forest	4	22-27

TABLE 17.2.4 Original and revised spectral signature of THEMAPP targets

Target No.	Vegetation Type		'Spectral Signature' (Radiance range on 0-127 LANDSAT MSS radiance scale) Band 1	Band 2	Band 3	Band 4
1	P1+P2 Sown Pasture	(a)	10-16	10-16	49-67	30-40
		(b)	9-18	9-18	49-67	23-40
2	M3+M4+ M6+M6a Mixed scrub	(a)	11-13	11-13	30-43	17-21
		(b)	8-15	8-15	28-43	14-26
3	N5 Hardwood Forest	(a)	9-13	6-13	38-48	22-27
		(b)	9-15	6-16	26-50	18-29
5	N7 Podocarp Forest	(a)	6-10	6-10	17-32	9-16
		(b)	8-13	7-13	15-32	7-19
6	N4 Beech Forest	(a)	9-10	6-10	22-32	11-16
		(b)	9-10	6-10	22-32	11-16
7	N4+N7 Beech and Podocarp Forest	(a)	6-10	6-10	17-32	9-16
		(b)	6-10	6-10	17-32	9-16
8	H2 Sedges, rushes	(a)	14-16	22-27	38-48	25-29
		(b)	15-16	20-25	45-51	25-28
9	M1 Manuka, kanuka	(a)	11-16	11-16	38-48	36-48
		(b)	11-16	11-16	36-48	38-48
10	P5 Red tussock assns.	(a)	14-16	17-21	38-48	25-29
		(b)	14-18	15-21	41-47	22-28
11	W Water	(a)	0-40	0-30	0-20	0-10
		(b)	0-31	0-30	0-22	0-5
12	U Urban Areas	(a)	16-28	12-28	47-55	25-37
		(b)	19-22	20-27	49-54	23-28
13	Pine Forest	(a)	10-19	8-18	25-45	13-25
		(b)	14-17	13-18	20-27	15-21

(a) = Original spectral signature, defined from RPCTAL print-outs.

(b) = Revised spectral signature, from target's frequency distribution in dummy run of THEMAPP.

FIGURE 17.2.2 THEMAPP FREQUENCY DISTRIBUTIONS

(a) Initial Spectral Signature for Pasture (defined from RPCTAL)

BAND 4		BAND 5		BAND 6		BAND 7	
11.00:	60	11.00:	83	49.00:	28	30.00:	361
12.00:	494	12.00:	610	50.00:	85	31.00:	504 X
13.00:	1025	13.00:	699	51.00:	161 >	32.00:	346
14.00:	208	14.00:	724	52.00:	75	33.00:	357
15.00:	683	15.00:	405	53.00:	272 >	34.00:	291
16.00:	268	16.00:	217	54.00:	225	35.00:	287
0.00:	0	0.00:	0	55.00:	256	36.00:	218
0.00:	0	0.00:	0	56.00:	211	37.00:	165
0.00:	0	0.00:	0	57.00:	269	38.00:	93
0.00:	0	0.00:	0	58.00:	152	39.00:	83
0.00:	0	0.00:	0	59.00:	193 >	40.00:	33
0.00:	0	0.00:	0	60.00:	149	0.00:	0
0.00:	0	0.00:	0	61.00:	94	0.00:	0
0.00:	0	0.00:	0	62.00:	251 >	0.00:	0
0.00:	0	0.00:	0	63.00:	45	0.00:	0
0.00:	0	0.00:	0	64.00:	95	0.00:	0
0.00:	0	0.00:	0	65.00:	81	0.00:	0
0.00:	0	0.00:	0	66.00:	22	0.00:	0
0.00:	0	0.00:	0	67.00:	74	0.00:	0

(b) Revised Spectral Signature for Pasture

BAND 4		BAND 5		BAND 6		BAND 7	
9.00:	0	9.00:	0	49.00:	280	23.00:	1
10.00:	0	10.00:	29	50.00:	416	24.00:	3
11.00:	119	11.00:	154	51.00:	422	25.00:	14
12.00:	755	12.00:	863	52.00:	145	26.00:	61
13.00:	1392	13.00:	870	53.00:	463	27.00:	228
14.00:	281	14.00:	961	54.00:	282	28.00:	406
15.00:	1045	15.00:	584	55.00:	334	29.00:	450
16.00:	509	16.00:	384	56.00:	243	30.00:	390
17.00:	131	17.00:	161	57.00:	316	31.00:	568
18.00:	11	18.00:	237	58.00:	184	32.00:	409
0.00:	0	0.00:	0	59.00:	216	33.00:	414
0.00:	0	0.00:	0	60.00:	179	34.00:	341
0.00:	0	0.00:	0	61.00:	101	35.00:	328
0.00:	0	0.00:	0	62.00:	308	36.00:	240
0.00:	0	0.00:	0	63.00:	47	37.00:	175
0.00:	0	0.00:	0	64.00:	109	38.00:	97
0.00:	0	0.00:	0	65.00:	92	39.00:	84
0.00:	0	0.00:	0	66.00:	22	40.00:	34
0.00:	0	0.00:	0	67.00:	84	0.00:	0

TABLE 17.2.5 THEMAPP Targets

(i) THEMAPP print-out (Figure 17.2.3)

Target	Vegetation Type	Equivalent LRI Symbols
1	Sown Pasture	(P1+P2)
2	Mixed Scrub	(M3+M4+M6+M6a)
3	Hardwood Forest	N5
4	No target defined	-
5	Podocarp Forest	N7
6	Beech Forest	N4
7	Mixed Beech - Podocarp Forest	(N4+N7)
8	Sedge - Rush Association	H2
9	Manuka	M1
10	Red Tussock Association	P5
11	Water	-
12	Urban Areas	-
13	Pine Forest	N6

(ii) Revised, colour-coded interpretation

Target	Vegetation Category.	Equivalent LRI Symbols
1,3,8,10	Grassland	P
2	Scrub	M
5,6,7	Forest	N
9,11,12,13	Negligible areas not colour-coded	

Blank areas of Figure 17.2.3, unidentified by THEMAPP, were not colour-coded.

Figure 17.2.3 PORTION OF THEMAPP VEGETATION MAP

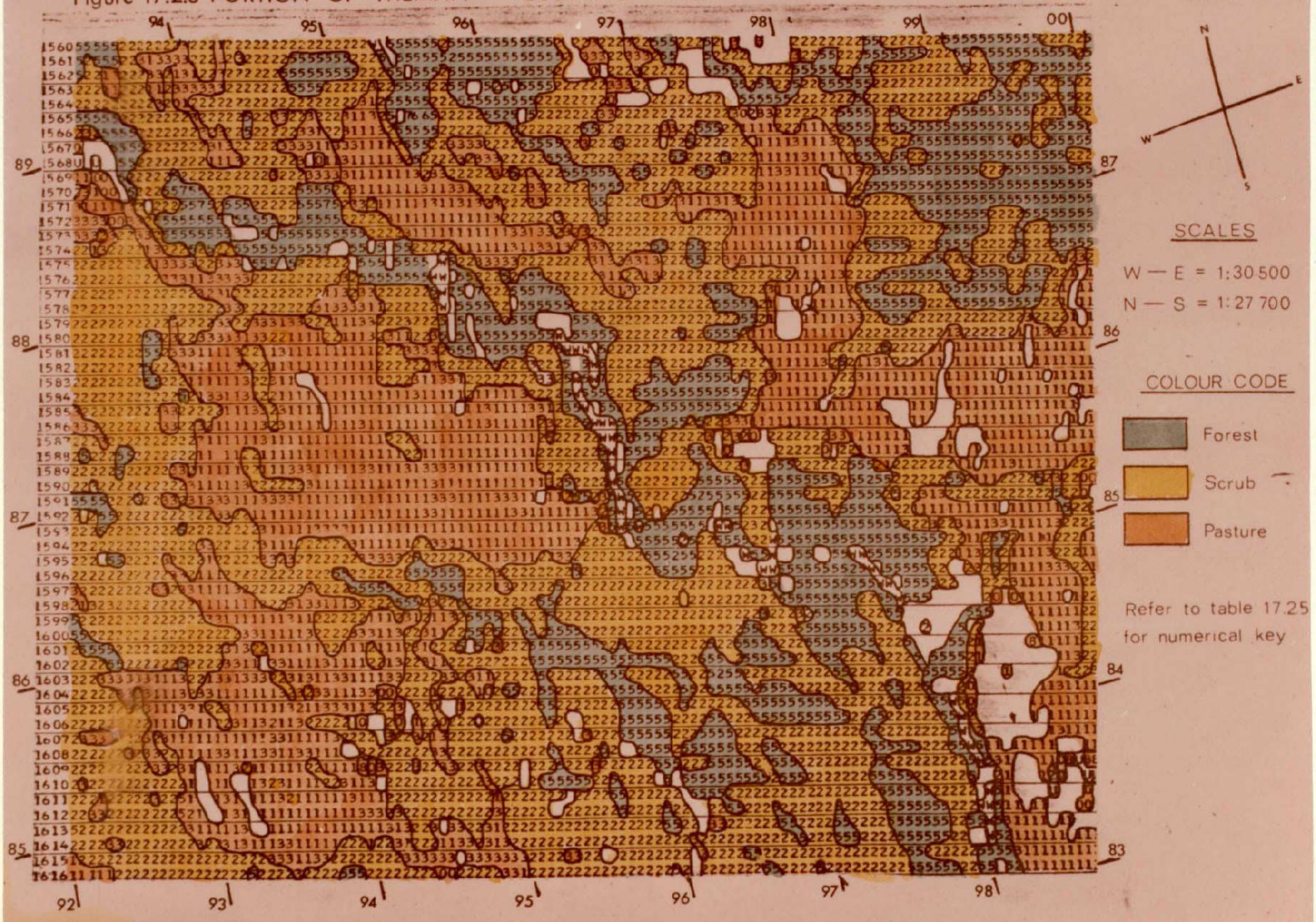


TABLE 17.2.6 Land Resource Inventory Vegetation Types

GRASSLAND

- P Unspecified grassland
- P1 High producing pasture
- P2 Low producing or native grassland
- P3 Short tussock assns. mainly silver and hard
- P4 Snow tussock assns.
- P5 Red tussock assns.
- P6 Sand dune assns.

CROPLAND

- L Unspecified crops
- L1 Cereals
- L2 Orchards and vineyards
- L3 Root and green fodder crops
- L4 Horticulture

SCRUBLAND

- M Unspecified scrub assns
- M1 Manuka, kanuka
- M2 Tauhinu
- M3 Dracophyllum
- M3a Heath
- M4 Fern
- M5 Sub-alpine scrub assns.
- M6 Broadleaved scrub
- M6a Broadleaved scrub with tree ferns
- M7 Broom
- M8 Gorse
- M9 Blackberry
- M10 Sweet briar
- M11 Matagouri
- M12 Mangroves

FOREST

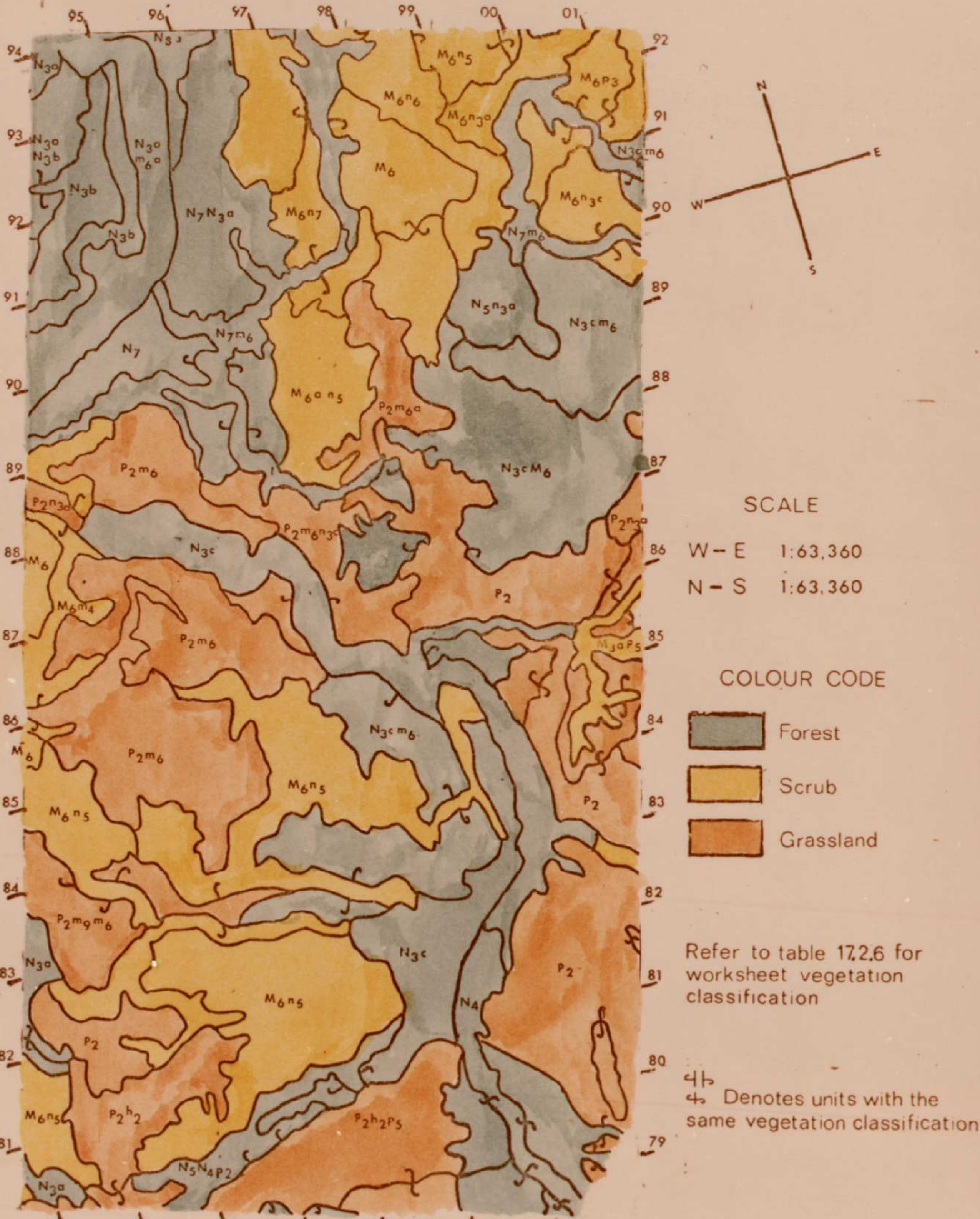
- N1 Coastal forest
- N2 Kauri
- N3a Podocarp-hardwood (low altitude)
- N3b Podocarp-hardwood (high altitude)
- N3c Podocarp-hardwood-beech
- N3d Podocarp-tawa
- N3e Podocarp-tawa-beech
- N4 Beech
- N5 Hardwood
- N6 Exotic forest
- N7 Podocarps
- N8 Poplars and willows
- N9 Exotic hardwoods other than poplars and willows
- N10 Exotic softwoods other than Pinus spp.

WEEDS, HERBS, ETC

- H Unspecified herbaceous plant assns.
- H1 Swamp assns.
- H2 Rushes, sedges
- H3 Sand dune assns.
- H4 Sub alpine herb assns.
- H5 Salt tolerant assns.
- H6 Pakihi
- H7 Semi-arid herbfield assns.

Initial capital letter indicates that vegetation type comprises >40% of unit's area; initial small letter <40%. Second small letter, e.g. a in N3a, indicates a sub-type.

Figure 17.2.4 VEGETATION OF LAND RESOURCE INVENTORY UNITS ON PART OF WORK SHEET N111 (WAIMARINO)



PART VI

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CHAPTER 18 : AUCKLAND UNIVERSITY LANDSAT PROJECTS

18.1 THEMATIC MAPPING: LAND USE AND VEGETATION MAPPING OF THE AUPOURI PENINSULA, NORTHLAND, NEW ZEALAND, FROM LANDSAT

G. Ross Cochrane and J. Batty

18.1.1 Introduction

The northern extremities of New Zealand have a reputation for morning cloud cover. The name given to this country by its first settlers, the Maori, was Aotearoa, 'Land of the Long White Cloud'. Between 16 December, 1976 and 1 February, 1977, only three suitable days for remote sensing from space were recorded. Not surprisingly then, there are only two images of the Aupouri Peninsula, one from each LANDSAT satellite (E-1648-21420 of 2 May, 1974, and E-2391-21273 of 17 February, 1976) relatively free from cloud cover. The land area on image E-1648-21420 is 95% cloud-free. A colour composite print at a scale of 1:1 000 000 of this scene is currently under examination to evaluate its potential as a tool for land use, land cover and vegetation mapping.

18.1.2 Methods

One difficulty arising during the analysis of the land use and land cover of LANDSAT E-1648-21420 colour composite image is the small size of the land area (80 mm x 20 mm) on the 1:1 000 000 scale image. This imposes limitations for the accurate delineation of boundaries (Waddell & Waddell 1969, Rosenberg 1971, Simonett & Coiner 1971, and Colvocoresses 1976). In an attempt to overcome this problem the colour composite was viewed using a wide field magnifier (a) in natural light, and (b) on a Zeiss viewing table with excellent uniform lighting. Thus, the entire area could be viewed simultaneously for comparison of tonal contrasts present.

Investigations carried out by the senior author of other LANDSAT images, have shown that a colour composite positive transparency viewed on an overhead projector and on a Zeiss viewing table with a wide field magnifier provide more information about subtle tonal contrasts and resolution detail than is possible from colour composite prints or from black and white prints of individual bands. Invariably, reproduction to a colour print results in some degradation of both resolution and colour fidelity. Surveys of SKYLAB photographic imagery by Welsch (1974, 1976) and Colvocoresses (1976) recognise this same problem. It is hoped that a colour positive transparency, as well as colour composite print enlargements of this LANDSAT scene, will be received from PEL so that further comparative analyses may be carried out.

Alternative additive viewer combinations to the simulated colour infrared colour composite used as a basis foı mapping, as well as colour isodensitometer images of the Aupoı Peninsula were analysed as supporting evidence for verifying the subtle tonal contrasts recognised during mapping.

A three-tiered sampling model was used during the mapping. This involved:

1. the LANDSAT imagery;

2. vertical and oblique aerial photographs, plus the LANDSAT image in hand for point-by-point comparisons during low altitude aircraft survey; and

3. detailed ground inspection of representative areas and of the boundaries recognised.

Any boundaries drawn by photo interpreters are subjec judgments. Thus, there is likely to be variability in the mapping of boundaries and in the delineation of categories. Depending upon their individual philosophies, photo interprete are normally "splitters" or "lumpers". The authors recognis this problem. In an attempt to overcome variability between interpretations four procedural steps were adopted. (1) Eac author analysed the area separately and subsequently results compared. (2) The three-tiered sampling model previously mentioned was used to verify the delineated boundaries and th entities recorded. (3) Additional colour composite combinat were used to verify or more clearly differentiated areas. (4) Alternative analytical procedures, using colour isodensit images, were employed for comparison with tonal contrasts map from the initial colour composite interpretations. Surveys Simonett et al. (1969), Colwell et al. (1974), Anderson R. et (1975), Bale et al. (1975), Colwell (1975), Poulton et al. (1 Rohde & Simonett (1975), Williams & Coiner (1975), Everett & Simonett (1976), Hajic & Simonett (1976), Simonett (1976), an Story et al. (1976) have demonstrated that the most accurate results and least variability between interpreters are achiev

1. when interpreters are experienced, and

2. when they have familiarity with the area being analysed.

Both the authors have detailed knowledge of the Aupou Peninsula. The senior author has long experience in both ph interpretation teaching and research.

C-2

18.1.3 Results

Seven broad classes of land use - land cover, grouped from 27 detailed categories mapped, are shown in Figure 18.1.1, mapped according to the classification presented by Anderson J. et al. (1976) for mapping from LANDSAT images. Comparison of Figs. 18.1.1 & 18.1.2 illustrate that subdivisions within Anderson's broad categories can be mapped from LANDSAT imagery of this area of Northland even at the 1:1 000 000 scale.

Detailed mapping from the LANDSAT colour composite produced 27 categories of land use - land cover delineated on the basis of tonal contrasts and subsequently verified as meaningful categories from field analysis. Some of these are included in Fig. 18.1.2, of the vegetation of Aupouri Peninsula. The main interpretation results are presented in the following summary.

1. Clear contrasts between east and west coast sands are recognised. Parengarenga sand, with a high proportion of pure quartz resulting in very high albedo values, produces an almost total reflectance, and differs from the darker western sands with a higher iron content.

2. An indication of the relative relief of sand dune areas through cyan tonal contrasts.

3. Easily distinguishable, successive plantings of *Pinus radiata* in the Aupouri State Forest. The central western area, mapped as a single category (E) on Fig. 18.1.1 is made up of five easily distinguished different tonal areas corresponding to young exotic pine plantations of different ages. These include areas of pine of undifferentiated age and of 1971, 1972, 1973 and 1974 plantings.

4. Sand dune areas which are undergoing stabilisation with marram grass planting.

5. Areas which will in the future be added to the Aupouri State Forest. (Lupin plantings are usually carried out four years prior to *Pinus radiata* plantings.)

6. Accurate delineation of the various sand dune vegetation associations.

7. The relative success of various areas of farm development by the Lands and Survey Department can be evaluated in terms of areas of grassland reclaimed from the surrounding scrub. At the date of the LANDSAT image Te Paki Block has over 30 percent developed into pasture, Parengarenga 35 percent, Cape View 80 percent and Rarawa over 90 percent, while Onepu has about 70 percent developed in either pasture or pine.

8. Alluvial valleys can be distinguished from surrounding rolling hill country.

9. The effect of soil and drought on the growth of pasture species is shown by variations in signature in areas of different soils.

10. Patterns and size, shape and extent of sand dune formation, and direction of dune migration, can be determined.

11. Grass-topped hills in the northern sector contrast with the scrub-covered valleys, enabling their orientation and relative relief to be easily detected.

It is anticipated that mapping from enlarged images wil provide a more accurate map of land use. Evaluation of indivi dual MSS bands is being undertaken to determine the effective contribution of each band in mapping land use and land cover classes.

18.1.4 Vegetation of the Aupouri Peninsula

Examples of the vegetation of the Aupouri Peninsula follow. The type, symbol, and Munsell colour code are shown in Table 18.1.1. This should be consulted in conjunction with Figure 18.1.2 showing categories and distribution of vegetation as mapped from the LANDSAT colour composite. The Munsell colo codes recorded in this survey are appropriate only to the particular colour composite image used. They are not standardised values that can be applied to all areas for a particular vegetation class, land use or land cover category, nor, indeed, to the same area at different times because of differences in foliage radiance and variations in sun angle.

Vegetation of the fore dune is usually exotic marram grass (Ammophila arenaria) on the seaward slope with three different associations on the lee slopes and valleys. The mos frequent is the marram association (A) containing marram grass and the two indigenous sandbinding plants, the pilvery grass, Spinifex hirsutus, and the golden sedge, pingaeo (Desmochoenus spiralis) as well as Calystegia soldanella, introduced Kikuyu grass (Pennisetum clandestinum) and the succulent, Carpobrotus australe.

Two areas of sedge, Scirpus assocation (B) were located on the colour composite. Locally within this association extensive mats of dark-coloured scrambling pohuehue occur with the sedges, Leptocarpus simplex and Scirpus nodusus in the valleys, with Calystegia soldanella intertwining around plants on the higher portions of the dunes.

Usually further inland flax or Phormium tenax grows amo sedge, Carex pumila, shrubbery, Cassinia retorta, large clumps toetoe (Cortaderia conspicua), pohuehue (Muehlenbeckia complexa and stunted Coprosma species. Recent plantings of Pinus radia have occurred in some of these associations.

Afforestation areas are first planted with marram grass then Californian tree lupin, Lupinus arboreus (D) three to four years before Pinus radiata is planted. Natural colonisers in this association include toetoe, flax and pohuehue, but lupin is a vigorous dominant.

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The 1971, 1972, 1973 and 1974 pine plantings can be differentiated but are mapped collectively here under symbol E for both unconsolidated and stabilised dunes.

Marram grass on consolidated dunes (F) records a slightly different tonal value to marram on foredunes (A). A remnant of stabilised dunes has a tree covering of coastal forest (G) dominated by pohutukawa (Metrosideros excelsa) and kohekohe (Dysoxylum spectabile). Pastures on these stabilised dunes (T) have the same tonal value as pastures on upland areas of sedimentary soils (V) but are separated in this map on the basis of pasture-soil differences rather than purely on plant properties alone. Differences between pasture areas mapped as U and V are primarily based on tonal differences derived from the integrated radiance of pasture and soils (Table 18.1.2).

Although there is considerable variation between pastures in the Aupouri Peninsula not all these can be readily recognised from the colour composite. Important seasonal variations in dominance and relative vigour of pasture sward species could probably facilitate mapping of pastures if relatively frequent sequential imagery were available. Three categories of sown pasture for grazing (T, U & V) have been delimited on Figure 18.1.2. Most areas of V are former sand dunes with pockets of alluvial flats supporting high quality pastures of rye (Lolium perenne), cocksfoot (Dactylis glomerata) and clovers. Drought resistant, subtropical Kikuyu grass and paspalum (Paspalum dilatatum) as well as Festuca arundinacea flourish during the summer, whereas introduced European grasses increase in dominance during the rainier late autumn and winter months. Poorer quality pastures of fescue and Notodanthonia racemosa are typical of hill country areas.

Small areas of scrub, of swamp, of deteriorating pastures and fields surrounded by shelter belts can be recognised within this class but are too small to be separated out at the scale of the vegetation map.

Shrubland (scrub) communities are variable within the Aupouri Peninsula with quite minor differences in species composition, density and structural characteristics being recognisable as subtle tonal changes on the colour composite. Seven categories are mapped in Fig. 18.1.2. The vegetation class symbol, location of the association, dominant species present, and subsidiary species are listed on Table 18.1.2.

TABLE 18.1.1: VEGETATION, MUNSELL COLOUR CODE AND MAP CLASS FOR VEGETATION MAP OF AUPOURI PENINSULA

	Munsell Colour Code Hue, Value, Chroma			Map Class
SAND DUNE COMMUNITIES				
Fore dune:				
Marram	2.5	YR	4/8	A
Scirpus	10	R	2/2	B
Flax, pines sub-dominant	10	R	5/8	C
Lupin	5	Y	6/4	D
Pinus	10	R	4/6	
Pine planting 1971	2.5	YR	6/8	E
1973	7.5	GY	7/2	E
1972	5	R	4/10	E
1974	2.5	Y	7/2	E
Partially stabilised and Stabilised dunes:				
Marram only	2.5	GY	8/4	F
Pohutukawa	5	R	3/6	G
Grasses	10	R	5/8	T
Pinus	5	R	3/8	E
ESTUARINE				
Mangroves	10	YR	2/4	I
SCRUB				
North Cape	10	R	4/6	L
Gumland	10	R	5/3	M
East Coast Mt Camel	7.5	YR	3/2	N
Ngataki				O
Parengarenga	2.5	YR	4/3	P
West Coast Highland	5	R	3/2	O
Lowland	2.5	YR	3/4	R
PASTURE				
On volcanic soils	5	R	5/10	U
On other soils (Complex patterns of old dunes, alluvials & peats)	10	R	5/8 crests	V
	10	R	7/6 valleys	V
SWAMP				
Wiwi	2.5	YR	2/0	J
Raupo	2.5	YR	3/6	J
North Cape swamp-scrub	7.5	YR	2/4	K

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TABLE 18.1.2: SCRUB ASSOCIATIONS PRESENT ON THE AUPOURI PENINSULA

Vegetation map classes	Location of the Association	Dominant Species	Other Distinguishable Species
L	North Cape	(Manuka) Leptospermum scoparium and (Kumarahoe) Pomaderis elliptica	Cyathodes spp. (mingimingi) Cassinia amoena
M	Gumland	Schoenus brevifolius	Hakea sericea, L. scoparium Cassinia retorta, Pomaderis kumeraho Cyathodes juniperina
N	Henderson Bay	Cyathodes juniperina Hakea acicularis and L. scoparium	Acacia longifolia Ulex europaeus L. ericoides
O	Ngataki	Acacia longifolia	Pinus radiata Eucalyptus spp.
P	Parengarenga	Hakea acicularis and L. scoparium	L. ericoides (kanuka) Ulex europaceus (gorse)
Q	West Coast Highland	L. ericiodes and L. scoparium	Cassytha paniculata Pteridium aquilinium var. esculentum (bracken fern)
R	West Coast Lowland	Pteridium and L. ericiodes	L. scoparium Cassytha paniculata

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Wiwi sedge swamps are clearly recognisable on the image, and are mapped as J on Fig. 18.1.2. The sedges Schoenus tendo, S. brevifolius and Cladium terretifolium are the dominant species, with harsh umbrella fern Gleichenia circinata on drier margins. Raupo (Typha angustifolia) swamps, located on relatively sand-free, poorly drained, freshwater peat areas, are not readily distinguishable from the wiwi swamp areas on the space imagery.

18.1.5 Summary

1) This investigation has shown that land use, land cover, and vegetation data can be obtained efficiently over large areas from LANDSAT colour composite imagery, even at scales as small as 1:1 000 000. Category II Land Cover classes equivalent to those outlined by Anderson J. et al. (1976) have been recognised throughout the Aupouri Peninsula. LANDSAT colour composite imagery is, therefore, useful for updating and correcting land use and land cover information.

2) Extension of agricultural land and afforestation can be rapidly obtained from LANDSAT imagery for map revision purposes. The identification, location and use of prime agricultural land can be accomplished rapidly and efficiently. Subsequent progress can be monitored if sequential imagery is available. Similarly, LANDSAT imagery provides a useful tool for recording and monitoring forest development and use in wildland areas.

3) Mapping from LANDSAT prints is a relatively inexpensive technique that is highly flexible in application. Because changes in land use and land cover occur at highly variable rates throughout an area, the intervals between updating various categories would also vary. Once a substantial initial survey is carried out, subsequent updating would be a relatively simple and flexible procedure.

4) Particularly if larger scale colour composite imagery were more readily available, this would facilitate land use/land cover and vegetation mapping at scales of 1:250 000 and 1:100 000. Colour composite positive transparencies would be the most useful, but enlarged colour composite prints would make mapping easier and increase substantially the detail that could be recorded.

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LAND USE - LAND COVER OF AUPOURI PENINSULA

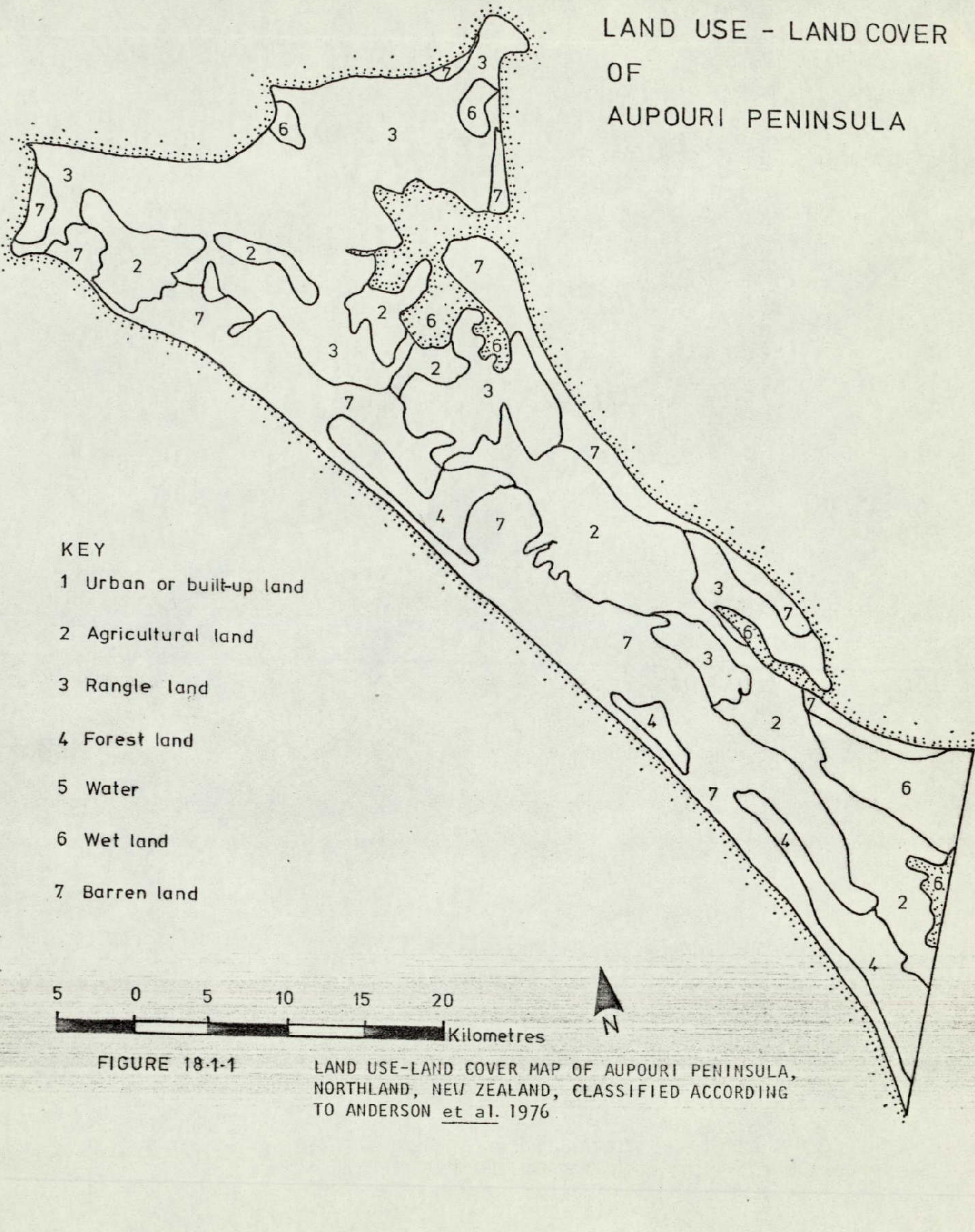

FIGURE 18·1·1 LAND USE-LAND COVER MAP OF AUPOURI PENINSULA, NORTHLAND, NEW ZEALAND, CLASSIFIED ACCORDING TO ANDERSON <u>et al</u>. 1976

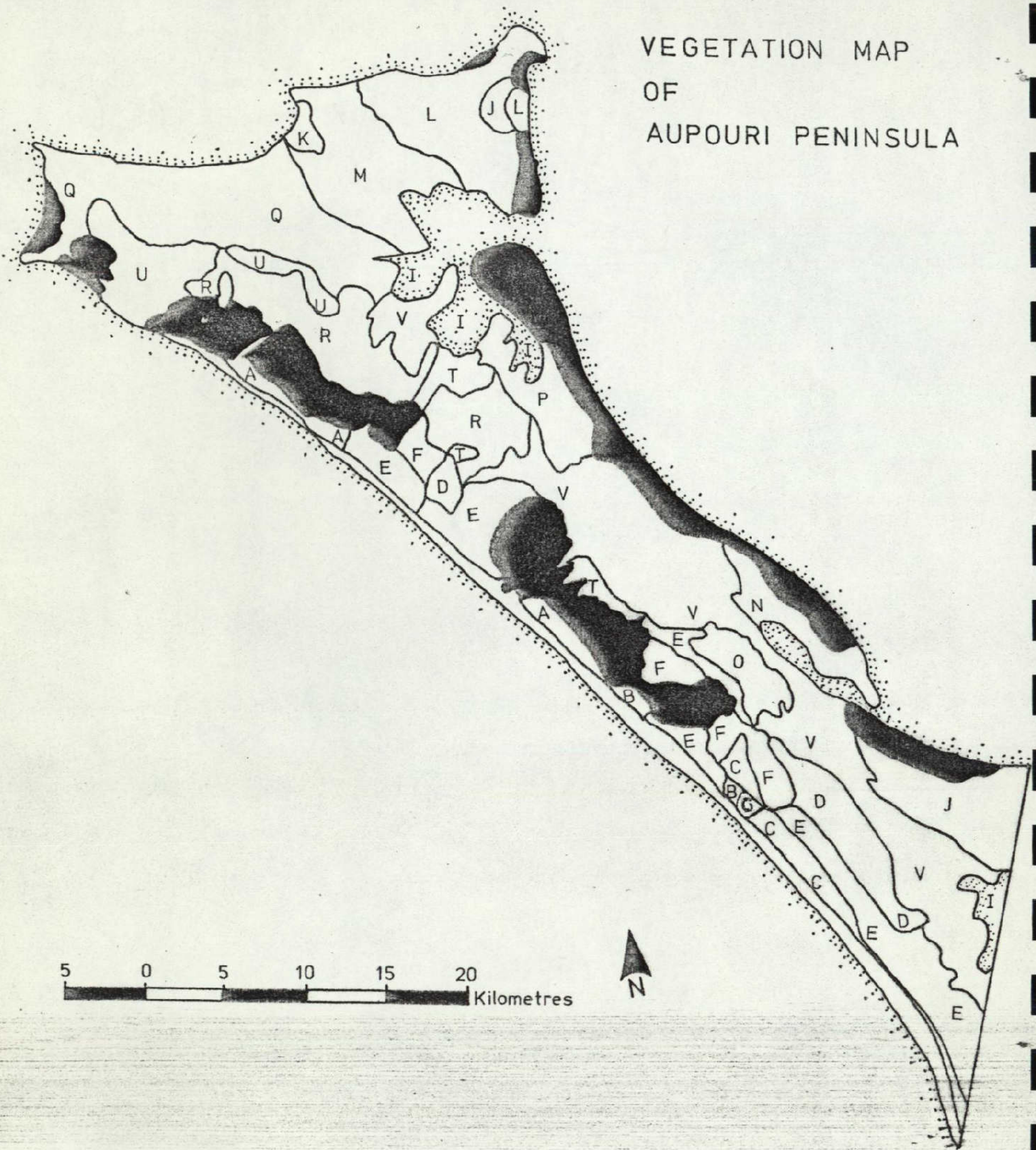

FIGURE 18·1·2 VEGETATION MAP OF AUPOURI PENINSULA, NORTHLAND, NEW ZEALAND, DERIVED FROM LANDSAT COLOUR COMPOSITES

18.2 LARGE-SCALE MAPPING OF VEGETATION FROM A LANDSAT-II IMAGE OF EAST TAUPO: A PRELIMINARY SURVEY

Caroline Strachan and G. Ross Cochrane

18.2.1 Introduction

A brief resume was presented in the third Quarterly Report (September 1976) of vegetation cover mapping in a small area in East Taupo. This outlined a method of producing a vegetation map in which six cover types were distinguished by inspection of a colour isodensitometer image of LANDSAT image E-2334-21123. The map produced was simple though somewhat confusing due to poor resolution of the slide when enlarged. Since the September report was compiled the Department of Geography at the University of Auckland has acquired both 'Photowrite' images (bands 4, 5 and 7) and pixel-by-pixel line prints of the area. A detailed field check of part of the area was undertaken in November 1976. This report will present a larger-scale, more precise and more useful vegetation map of the East Taupo area.

The area studied is presently being developed for commercial forestry but previously has been covered by dense native forest and scrub and still remains, for a large part, inaccessible. Vegetation mapping by field survey under such conditions is difficult and time-consuming. Medium to low-level aerial photography (for example at a scale of 1:60 000 to 1:20 000) would involve a great deal more photography to cover the same area.

Field observations were made primarily from access roads and from vantage points within easy distance from the road. It must be realised that although the distance across the area is not great, access is such that to cover the distance to Te Whakao. (about fifteen kilometres) takes an hour or so because of the poor condition of roads, and from Lake Taupo to the eastern part of the area involves a trip of some hundred kilometres as, at present, no connecting road crosses the catchment. It is under these conditions that vegetation mapping using Landsat imagery is most applicable.

18.2.2 Vegetation Maps (Figs. 18.2.1, 18.2.2 and 18.2.3)

Three maps have been included which show vegetation classes as mapped from: field observations and vertical aerial photographs; from a Band 5, black and white 'Photowrite' image; and from a computer line print (original at a scale of about 1:20 000).

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18.2.3 Field Map (Fig. 18.2.1)

Seven broad categories have been mapped. The central part of the map (following the road) has been most accurately mapped and the remaining sections mapped from 1:15 840 scale aerial photographs (1971 photographs were borrowed from New Zealand Forest Service, East Taupo Forest headquarters for the purpose).

18.2.4 Photowrite (Fig. 18.2.2)

Because the scale of the available 'Photowrite' image is small this has less use for mapping of vegetation except on a broad field. Enlargement of the 'Photowrite' image increases its usefulness for classification (for example a colour composite image included in the September 1976 report of the Kaingaroa State Forest (Part 1, Figure 2) shows part of the same area as Fig. 18.2.2).

18.2.5 Printout (Fig. 18.2.3)

As the 'Photowrite' imagery is a pixel-by-pixel photographic print, an enlargement to a scale of 1:20 000 will give much the same image as Fig. 18.2.4 produced by computer enhancement. This image is composed of fifteen distinct symbols, each for a reflectance value range in MSS band 4. Light tones are represented by small symbols and increasingly darker tones by correspondingly larger and darker symbols so that, when the printout is viewed from a distance patterns become clear.

In some instances it is feasible to map patterns using reflectance values from one or other band. In this case, however, the variation, due to variation in species, shadowing, etc., is so great that values from individual pixels vary such that no pattern is discernable in most instances (Fig. 18.2.5). Averaging of similar signals is necessary and has been carried out in production of the composite printout in Fig. 18.2.4.

The patterns have been further simplified to ten classes to represent distinct vegetation types. These are as follows:

18.2.6 Grasslands

1. Pasture or Grassed Ground, such as along roads (the Southern Boundary Road) although some roads have grown over with tussock and shrub vegetation, (Opawa Road). Grassed areas also appear bordering river channels (Te Arero stream). These areas appear blank on Figs. 18.2.3 and 18.2.4. One of the best examples of this is at Te Whakao station where the small area of pasture set among exotic forest plantations is quite distinct.

2. Tussock inhabits flatland, for example on the river flood plain and on the plateau, often in association with Monoao (*Dracophyllum subulatum*) a low shrub species. Depending on the relative proportions of the dominant species this category is represented in Fig. 18.2.4. as (-) or (=).

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18.2.7 Exotic Forests

3. Recently Planted Stands of exotic forest have recently been planted at Te Whakao station, in the East Taupo Forest (the most northerly part of which appears in the south-eastern corner of Fig. 18.2.3) and south of the Southern Boundary Road of the Kaingaroa Forest. This category is represented on Fig. 18.2.3 as (.) and (,) although where they are associated with darker symbols, they represent tussock. However, when they are adjacent to areas cleared for planting, these symbols are assumed to be forest.

4. Immature Exotic Forest. The triangle between Southern Boundary Road and Te Arero Stream has been established in exotics longer than East Taupo Forest or Te Whakao. The area has a darker tone and is represented on the printout (not shown in Fig. 18.2.4) by the sumbols (=) and (*).

5. Mature Exotic Forest. The Kaingaroa Forest, north of Southern Boundary Road, has been established for some time and is represented by darker tones (for example on the 'Photowrite' image in the September report) and symbols. Whereas the native forest and scrubland (see later) show a variety of tone, the more uniform species distribution in the plantations has the effect of a more uniform symbol occurring over this area. There is some variation due to species but this does not show up well in this example. Three categories have been mapped in the Kaingaroa Forest but it is taken to be a reflection of tree age rather than of different species.

18.2.8 Scrublands

Scrub originally covered most of the tablelands. Part of the area is now occupied by the Kaingaroa and East Taupo Forests though a large area in the north-west corner of Fig. 18.2.3 remains under scrub. This can be divided into two categories.

6. Kanuka (*Leptospermum ericoides*), *Hebe stricta* and other soft-leafed species such as fivefinger (*Neopanax arboreum*). The latter are bright green in colour and have a lighter signature on the Landsat image than manuka (category 7).

7. Manuka (*Leptospermum scoparium*) and Monoao (which also occurs in association with tussock grasses on the river flats) are hard-leafed and red-brown coloured. These species tend to be located on ridges and steep slopes. This is represented by a darker symbol in Fig. 18.2.4.

The kanuka association occurs extensively on the tablelands south of Hinemaiaia Stream with manuka more common on the northern side.

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Kanuka can reach tree height (fifteen metres) and may occur with silver beech (Nothofagus menziesii) in incised valleys, for example between the two lakes on Hinemaiaia Stream. Although this vegetation type is easily distinguishable in the field, in the composite printout it is not possible to recognise a symbol for the beech/kanuka stands and these probably merge into the kanuka shrub association.

8. Native Forest. The Kaimanawa State Forest Park is largely beech forest. The spectral signature differs from both the exotic plantations of Kaingaroa and the shrublands to the west. It has a dark signal with a few scattered lighter patches which suggest perhaps less dense forest or cleared areas which have regenerated (especially around the margins of the forest). Although the vegetation is all evergreen some differences probably do occur, depending upon the species, between seasons due to changes in the physiological state of the trees, e.g. when beech is flowering or seeding heavily the spectral signature will be altered. Nevertheless, seasonal contrasts in spectral radiance from such forest is minimal compared to changes that occur in temperate deciduous forests.

18.2.9 Advantages of Computer Data

Comparison of the three maps shows primarily the far greater detail obtainable from the printout because of the larger scale.

Although ultimately field mapping of vegetation is most accurate, in cases such as this the time involved to construct an accurate map in remote areas with limited access and out-of-date base data, is far in excess of that required to present a reasonable map from the Landsat data. Random checks of the categories differentiated from the printout provide the optimum means for checking imagery interpretation. A compromise used was to check representative areas that were relatively easy to access from roads. Thus field checking of selected samples need take only a relatively short time.

Mapping from Landsat data also allows for a present day map to be produced. For example, the area planted in exotics in 1975 is far more extensive than that suggested in Fig. 18.2.1 in 1971. Availability of Landsat imagery poses limitations for the regular monitoring of forestry.

Some disadvantages occur in the nature of the printout itself. The scan lines are noticeable in some instances (especially in the forested area) and it becomes difficult to determine whether or not a difference in vegetation exists or if the variation is due to noise from the scan lines.

Although the map obtained from the averaged data can be analysed to give ten classes it is difficult to determine whether the variation is due to species, to stand age, or shading effect. Accurate location of individual species is also not possible within the scrub and native forest communities. However, the map is useful for distinguishing associations and would be valuable, therefore, for estimating the area of different vegetation types for forest or land use planning.

Further investigations are obviously necessary to isolate the effects of dominant species, understory species' contributions to canopy radiance values, season and solar angle, age of vegetation, and the topography on the total spectral signature.

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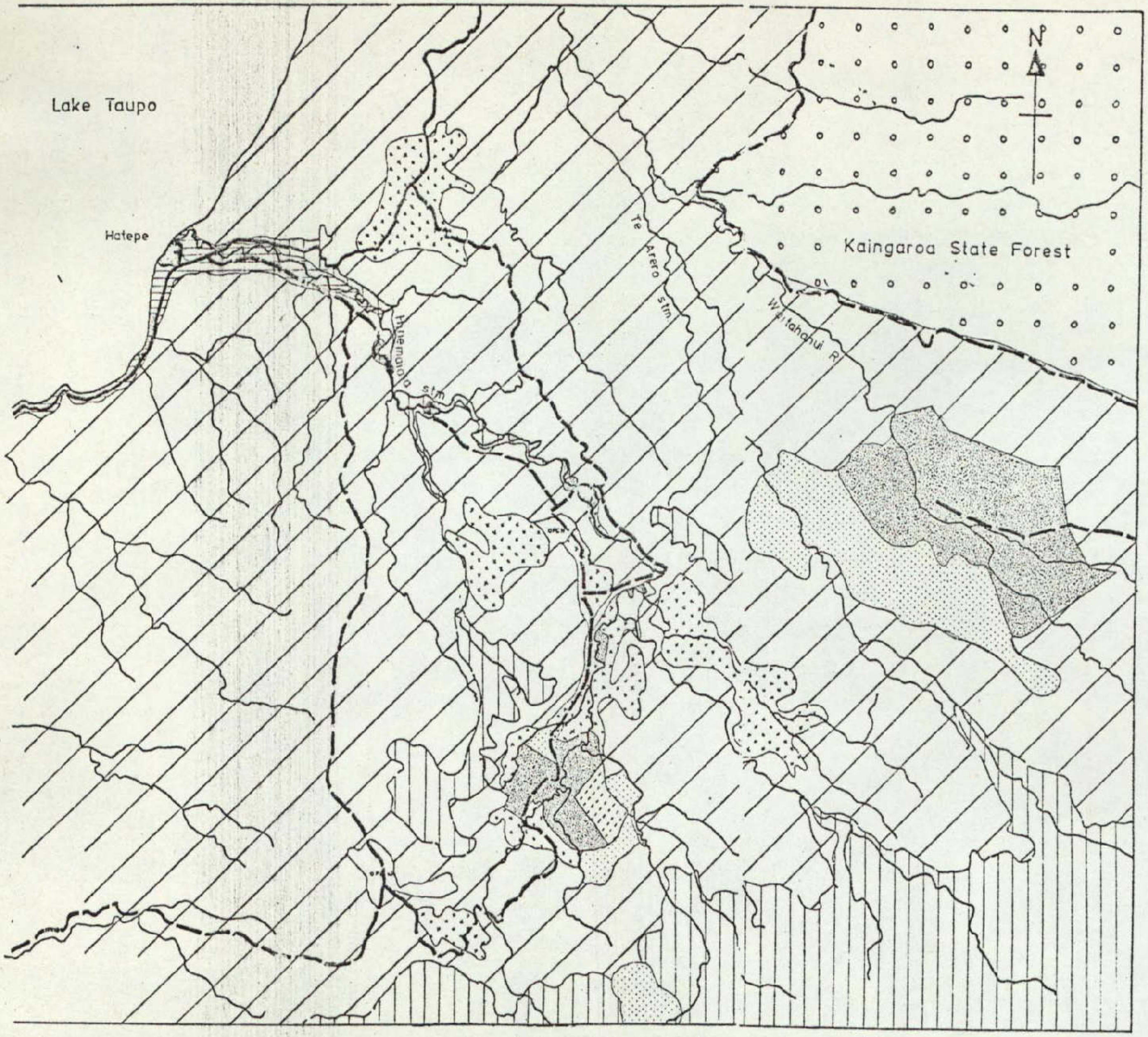
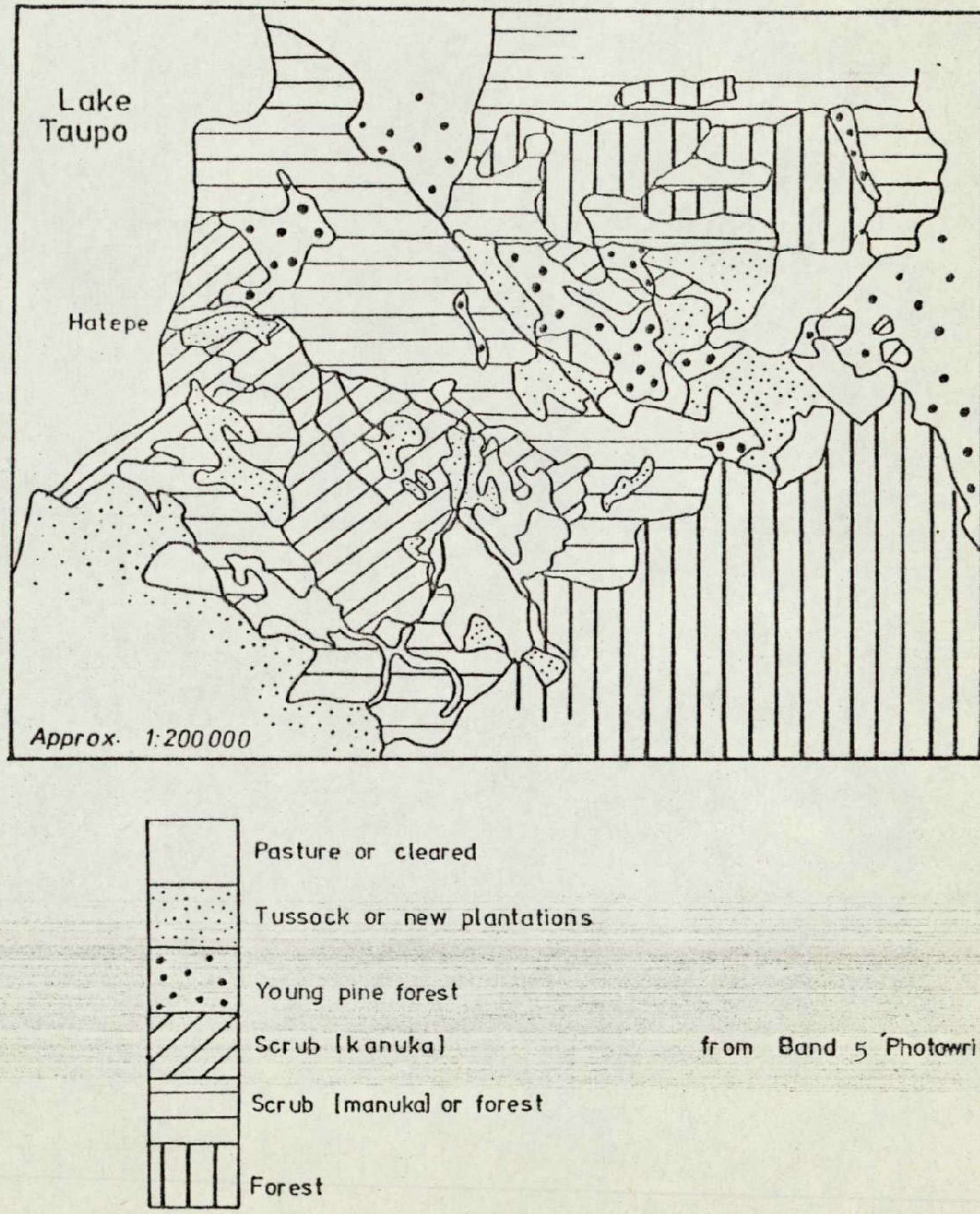


Fig. 18.2.1
HINEMAIAIA / WAITAHANUI
VEGETATION COVER, 1976

From FIELD OBSERVATION

EAST TAUPO VEGETATION

Fig. 18.2.2



from Band 5 'Photowrite'

Fig. 18.2.3 EAST TAUPO:

VEGETATION

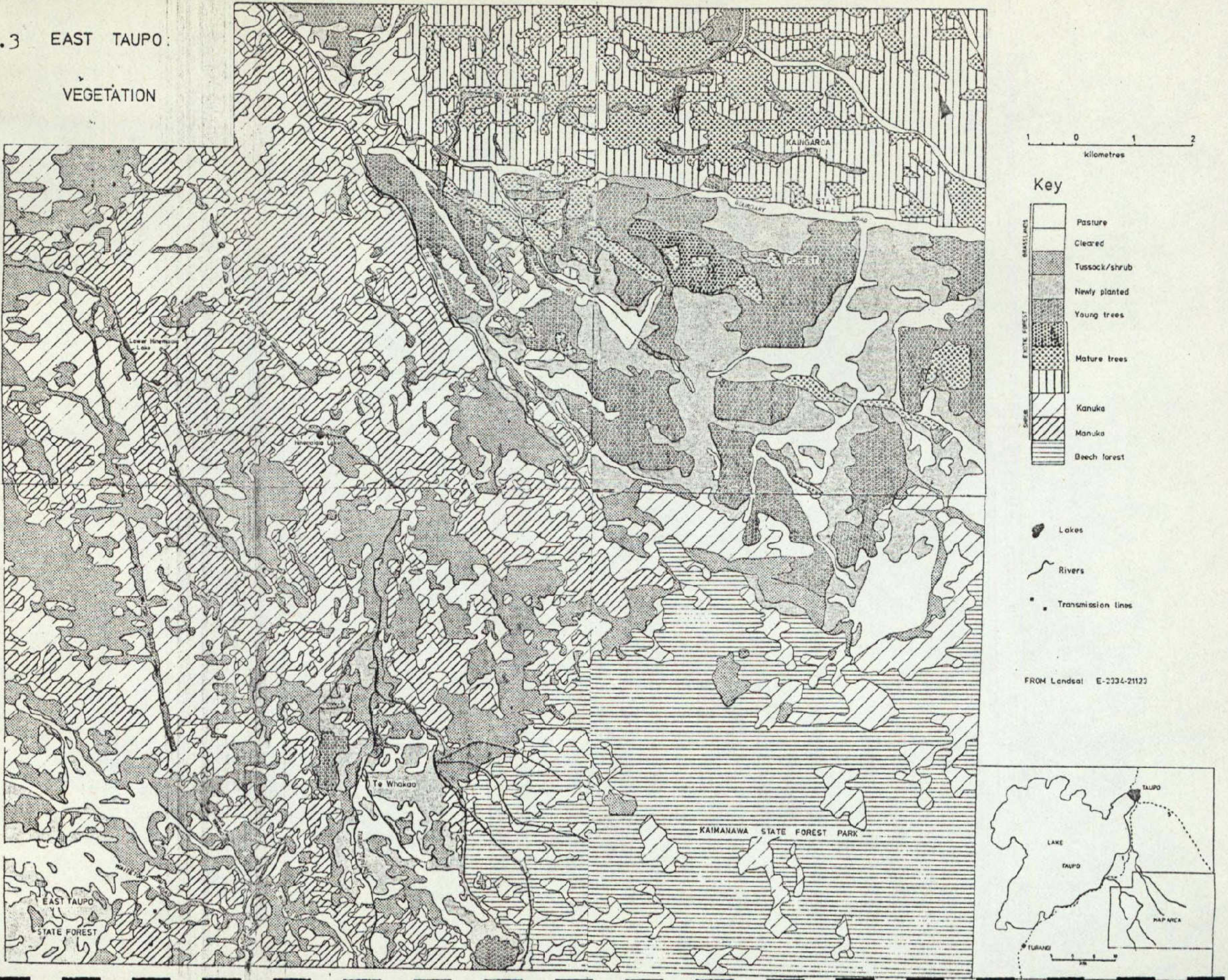


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Fig. 18.2.4 Band 4

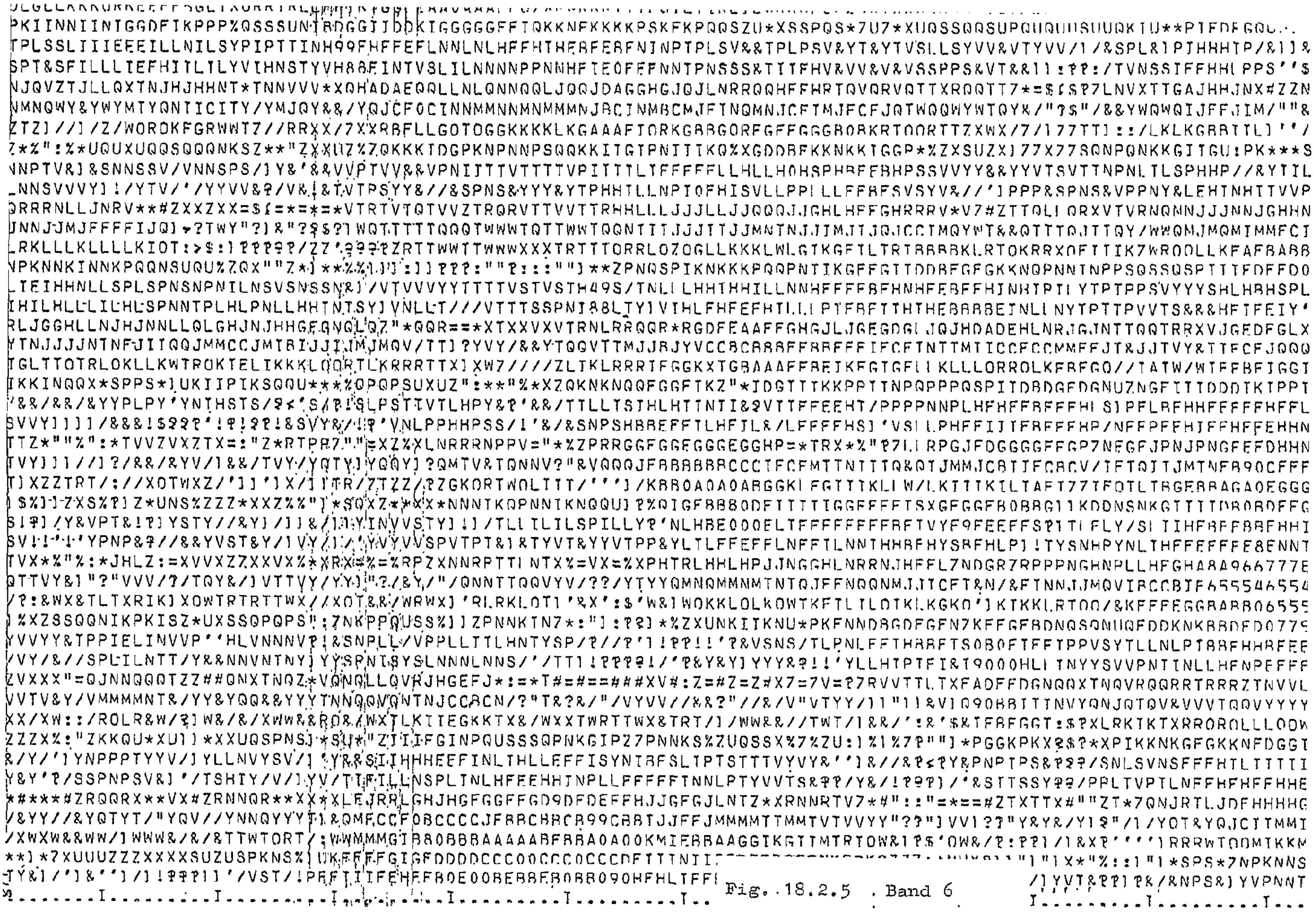


Fig. 18.2.5 . Band 6

18.3 THEMATIC VEGETATION MAPPING IN WESTLAND, SOUTH ISLAND, NEW ZEALAND, FROM LANDSAT COLOUR COMPOSITES: A PRELIMINARY SURVEY

J. Batty and G. Ross Cochrane

Williams & Coiner (1975) found LANDSAT colour composite imagery useful for mapping the vegetations of New Guinea on the 1:1 million scale. Westland, on the South Island of New Zealand, is a valuable test area as it has a complex range of vegetation, including economically important indigenous timber trees, as well as being physiographically varied and difficult of access.

Two colour composites of the December 1973 LANDSAT image (E-1503-21421) of Westland, South Island, New Zealand, at a scale of 1:1 000 000 were examined for the purpose of evaluating their use for small scale vegetation mapping. Colour composites used were (a) bands 4, 5 and 7 and (b) bands 5, 6 and 7. A map (Fig. 18.3.1) of forested areas was drawn using standard photo interpretation techniques. The bands 4, 5 and 7 colour composite was preferred although the other colour composite was used to help in delineating boundaries.

Beech (Nothofagus) and mixed beech forests were delineated by their red-brown tones. Within these areas, the obvious and distinct light-coloured snowline tussock vegetation and bare mountain tops were subsequently mapped.

Fig. 18.3.2 shows coastal areas subdivided on the basis of distinctive tonal differences, namely pale pink alluvial valleys supporting pastures; fawn tones of gravel outwash areas with scrub; and deep browns of dense scrubland.

Bands 4, 5 and 7 colour composite enlargements were made to a scale of 1:310 000 showing area A. These were compared with projected colour slides made from colour isodensitometer images derived from a LANDSAT MSS band 7 positive transparency of this area.

Although a larger area was mapped an area surrounding Lakes Hochstetter and Brunner was selected for detailed analysis of spectral signatures because of its physical complexity and the variety of vegetation that was present. Fifteen regions with distinct tonal-density differences were delineated using these complementary techniques.

A subsequent procedural step employed two levels of substage sampling. Vertical aerial panchromatic photographs flown for the West Coast Beech Scheme in 1974 (SN 3777) at a scale of 1:66 666 and SN 2647 at a scale of 1:15 000 (Fig. 18.3.3) were used as a form of comparative intermediate ground truth data to verify or modify the divisions recorded.

Results from these comparative evaluations showed that using LANDSAT data, more categories were able to be mapped and with greater ease than was the case with photographic interpretation of the medium to moderately large scale vertical aerial photographs. A number of subtle differences recognised on the LANDSAT multiband enlargements could not be distinguished from the panchromatic aerial photographs. In some cases subsequent field investigations revealed that these differences were strongly related to geologic and geomorphic features rather than primarily vegetation change. For example, dense podocarp-hardwood lowland forest on granite parent material at the Turiwhate Range was mapped as a different category from podocarp-hardwood lowland type growing on greywacke rocks at Constitution Hill. Similarly, because of tonal signature contrasts, numerous terminal moraines covered with low shrub vegetation (scrub) produced spectral signatures that differed from those from the same type of vegetation growing on outwash till deposits.

Subsequently, some classes were amalgamated to produce a more accurate map of the vegetation distribution. Fig. 18.3.4 shows the vegetation classes found on lower altitude and ground truthed from coloured slides and photographs. An improved map would doubtless be achieved if more field checking could have been carried out in this sample area of complex vegetation. Difficulty was experienced in confidently discriminating some areas mapped as scrubland (by tonal signature) but believed to be forest to the west of Lake Brunner. Fig. 18.3.5 depicts the forested section of the sample area..

Having established the existence and identification of distinct vegetation classes for the sample area a vegetation map, Fig. 18.3.6, was compiled at a scale of 1:310 000. With experience gained from these investigations, a map at a scale of 1:1 000 000 was produced by superposition of Figs. 18.3.1 and 18.3.2. Fig. 18.3.7, a preliminary map of the region, was subsequently modified from ground truth data. The final product (Fig. 18.3.8) is a vegetation map of Westland at a scale of 1:1 000 000 produced from LANDSAT colour composite positive prints. Shortcomings are recognised but useful small scale thematic maps from LANDSAT imagery provide an additional mapping tool for foresters and planners.

It would be desirable to carry out more detailed and wider field sampling than has been done for this preliminary mapping exercise to establish how consistenly communities were correctly typed and the percentage accuracy achieved. For example, the authors experienced difficulty in categorising much of the area between the Waitaha River and the Hokitika River. This was typed as highland-podocarp forest but contains much lowland podocarp-hardwood forest. Similarly, in the area east of Lake Hochstetter tonal contrasts are too subtle to readily differentiate between beech and mixed beech-podocarp forest. Refinement of sampling procedures or possibly the use of different colour composite combinations to the two used may facilitate differentiation of such vegetation.

The authors firmly believe that a substantial increase in accuracy would be achieved using a colour composite positive transparency rather than the colour composite positive prints used. There is up to 70% resolution degradation with each generation photographic product.

For future mapping from LANDSAT-C the use of MSS colour composite positive transparencies augmented by the improved resolution (40m) panchromatic photographs should provide a valuable tool for small scale mapping. Resolution of 40m is closely approaching the resolution threshold level where a great increase in ability to discriminate entities is achieved.

Successive prints of colour composite photographs vary in tonal properties due to a range of factors, so a comparison or standardisation of colours for vegetation signatures is difficult. Table 18.3.1 indicates the variation in colour of the same object on the colour composite used at scales of 1:1 000 000 and 1:310 000.

TABLE 18.3.1 Colour Values for Vegetation Types

	Standard Colour Composite Print (Bands 4, 5 and 7)	Colour Enlargement (Bands 4, 5 and 7)
Scale	1:1 000 000	1:310 000
Tussock	5 Y R 7/4	5 Y 8/4
Pasture	2.5 R 7/8	5 Y R 7/10
Southern Rata	7.5 R 4/10	10 R 5/10

Colour classification based on Munsell (1963) "Munsell Colour Charts from Plant Tissues", Munsell Colour Company. Symbols in sequence: hue, value, and chroma.

Allowance for this variation must be made while comparing the remainder of the report with other prints. In preparing colour composite prints, standardisation of tonal values between imagery is difficult but desirable.

The sample area vegetation provided an interesting test of the usefulness of LANDSAT photographic imagery for vegetation mapping. The area straddles the vegetation boundaries of the West Coast Beech forests and the Podocarp-Hardwood forests. Additionally, a range of terrain irregularities produces variations in the signatures of numerous plant communities and species, increasing the classification difficulties. Geologically, major influences have been glaciation and subsequent glacio-fluvial processes, producing gravel outwashes and terraces. Rugged limestone terrain flanks the Paparoa Range, while alluvial flats and low terraces occur in the Grey and other river valleys.

A brief discussion follows of plant communities, locations and characteristic spectral signatures recognised from the LANDSAT colour composite imagery.

Nothofagus Forests

Red beech, Nothofagus fusca (usually 7.5 Y R 4/10 colour code) and silver beech, Nothofagus menziesii (2.5 Y R 6/8) forests are found on most of the northern and eastern mountainous sector. N. fusca occurs from 300 metres above sea level east of the Brunner Range to its altitudinal limit 1100-1200 m.a.s.l. Above this are belts of either N. menziesii which appears on the photograph to be usually confined to gullies and moderate slopes or mountain beech, N. solandri var. cliffortioides with occasional mixed stands found on the tree line - 1100 m.a.s.l. in the middle reaches of the Ahaura River, 1300 m.a.s.l. in the Paparoa Range, and 1500 m.a.s.l. at the spurs of the Southern Alps.

At lower altitudes N. fusca dominates over N. menziesii especially on valley floors where reflectance is at a maximum for obtaining accurate radiance values for spectral signatures. N. menziesii increases in importance with altitude (seen as a stronger orange tone on the colour composite imagery) and is the major tree-line species on the Paparoa Range, the western side of Victoria and Brunner Ranges, and the upper reaches of the Ahaura River. Stunted mountain beech forms the uppermost forest along the Southern Alps. Windthrow or felled areas show in these forests as a cyan tone, 4 B G 4/6. Alluvial flats and low terraces in the Grey Valley and north of Lake Ahaura have pure stands of beech which have generated after selective logging of the original Dacrydium cupressinum - Dacrycarpus dacrydioides - N. fusca - N. menziesii forest.

Podocarp Forests

Rimu, Dacrydium cupressinum, with a colour tone of 7.5 G Y 5/6, is abundant in the sample region below its altitudinal limit of 600 m.a.s.l. Most of the terrace country from Greymouth, eastward to Lake Brunner, north and east to Lakes Hochstetter and Haupiri contain areas of heavily logged, formerly dense rimu forest shown as 7.5 G 3/4 and 5 B G 3/6. Between the Ahaura and Taramakau River abundant rimu is found in association with miro, Podocarpus ferrugineus, P. hallii and kahikatea (Dacrycarpus dacrydioides) on the morainic terraces. Where these terraces are strongly gullied, on steep lower slopes to the south and east of Lake Brunner and on the south-eastern sector of Paparoa Range, large rimu, P. hallii and miro emerge above the canopy of southern rata (Metrosideros umbellata), kamahi (Weinmannia racemosa) and Quintinia acutifolia. These three broadleaf hardwoods of the secondary canopy are responsible for the 5 Y R 5/8 flecks on the colour composite enlargement in this area in contrast to the greenish tones (7.5 G Y 5/6) of forest dominated by rimu.

On older dissected terraces in the Grey Valley and north of Ahaura River, podocarp associations are mixed with hard beech, N. truncata. Red beech replaces hard beech on the lower valley sides of Paparoa. Hard beech, with an altitudinal limit of 700 m.a.s.l., is replaced at higher altitudes by a mixed rimu-red and silver beech association. To the west of Paparoa, on the rugged limestone terraces, mixed podocarp-beech forests are present where hard beech replaces the red beech of the former community.

The podocarps, rimu, kahikatea and P. spicatus dominate on outwash limestone fans. Of these two communities present on limestone the former mixed podocarp-beech community shows as Munsell colour code 2.4 G Y 4/6, whereas the latter, of podocarps only, shows as 2.5 G 2/2.

Ribbon development of a rimu-kahikatea-red and silver beech association borders the larger streams in the Paparoa Range. It is also present on alluvial flats and low terraces in the middle reaches of both the Grey and Ahaura Rivers. The colour code for this association ranges around 2.5 G 3/4 depending on altitude and slope.

Moderately podzolised to infertile water logged soils have developed on glacial outwash terraces in the mid-reaches of the Grey River and surrounds of Lake Ahaura. These areas, characterised by a 5 G Y 3/4 tone on the colour composites, support a vegetation of small rimu as well as Phyllocladus colensoi, D. colensoi, D. intermedium, mountain beech and other species. Adjacent, drier, higher areas, for example, to the east of Lake Hochstetter contain rimu, miro, P. hallii, Phyllocladus colensoi, D. intermedium and kahikatea. The edges, where orange tints appear on the colour composite print, are caused by spectral reflectance from kamahi, Quintinnia acutifolia, red and silver beech.

A distinctive colour signature, 10 R 5/10, is associated with low forests on steep, windswept, unstable slopes on the mountain ranges south of Lake Brunner and in the narrow valleys of the eastern side of the Southern Alps. Hardwood broadleaf species of Southern rata, kamahi and Quintinnia acutifolia are responsible for this colour tone on the colour composite print.

It was found difficult to find distinctive tonal signatures for swamp areas as species composition and site conditions were highly variable giving consequently a highly variable range of tones. Swamps and bogs contain the sedges, Typha angustrifolia, Carex secta and in drier stretches flax (Phormium tenax) as dominant species. Dominant D. colensoi with subdominants kamahi and Phyllocladus alpinus surround some bogs and beyond these are found rimu and kahikatea. Coprosma tenuicaulis, Dicksonnia squarrosa and P. spicatus may often occur in swamp forests but their contribution to the tonal signature is small.

The utility of enlarged LANDSAT colour composite imagery for vegetation mapping in the Westland region has been encouraging. Many major plant associations can be recognised by their distinctive tonal signatures. Important variations are also recognisable where geomorphological features contribute strongly to the composite spectral reflectances.

Currently, computer printout data of this region (courtesy of PEL), is being analysed to evaluate its usefulness for vegetation mapping:

(a) as a separate mapping tool;

(b) in conjunction with photographic and isodensitometer imagery to verify patterns; and

(c) to augment analysis and to help subdivide areas and define boundaries about which some doubt persists from the imagery analyses (Gialdini et al. 1975).

Table 18.3.2 shows the characteristic colour tones recognised on the colour composite used and the vegetation associations associated with these spectral signatures.

TABLE 18.3.2 Colour Tones and Vegetation Types Westland Standard Colour Composite Print (Bands 4, 5 and 7)

Munsell Colour Tone Value/Hue/Chroma	Vegetation
5 Y R 7/4	Indigenous Tussock grass
2.5 R 7/8	Exotic pasture grass
	BROADLEAF FOREST
7.5 R 4/10	Southern Rata
7.5 Y R 4/10	Red Beech (Nothofagus)
2.5 Y R 6/8	Silver Beech
5 Y R 5/8	Rata/Kamahi/Quintinia
5 B G 4/6	Windthrow Beech areas
10 R 5/10	Rata-Kamahi-Eastern Sides of Southern Alps
	PODOCARP FOREST
7.5 G Y 5/6	Rimu
5 B G 3/6	Logged Rimu areas
7.5 G 3/4	Logged and regenerating Rimu
2.5 G 2/2	Rimu-Kahikatea-Totara
	MIXED PODOCARP-BEECH
2.5 G Y 4/6	Rimu-hard beech-silver beech
2.5 G 3/4	Rimu-kahikatea-red beech-silver beech
2.5 G Y 3/4	Low podocarps and mountain beech on waterlogged glacial outwash areas

Summary

Williams & Coiner (1975) found LANDSAT colour composite imagery useful for small scale mapping of the vegetation of New Guinea. Similarly, this investigation of Westland vegetation, employing a sequence of preliminary vegetation typing through to confirmed typing using LANDSAT colour composite imagery in combination with intermediate scale vertical aerial photographs along with ground truth data, is a useful method for small scale thematic mapping in complex areas of relatively difficult access.

Major difficulties experienced in category identification and boundary delineation are present where tonal contrasts are complex or subtle. The use of colour composite positive transparencies, enhancement procedures, and additional field checking, should partially overcome these difficulties. Economies of survey time can be achieved as large areas can be successfully typed with a moderately high degree of accuracy. Thus, more detailed sampling can be focused on areas where forest typing is least confidently mapped from analysis of LANDSAT imagery.

Although specific spectral signatures of vegetation associations will vary with topography, season and various other factors, distinctive tonal signatures ranging a little from a representative Munsell colour code can be associated with categories of vegetation for a particular region.

Variations in tonal signatures, if and when sequential LANDSAT imagery becomes available, will aid rather than confuse detailed vegetation typing.

References

Gialdini, M. J., Titus, S., Nicholls, J. and Thomas, R.W. 1975
The integration of manual and automatic image analysis techniques with supporting ground data in a multistage sampling framework for timber resource inventories: three examples. Proceedings NASA Earth Resources Survey Symposium, Houston, Texas, June 1975, Vol. 1A: 1377-1388

Williams, D. L. and Coiner, J. C. 1975
Utilization of LANDSAT imagery for mapping vegetation on the millionth scale. Proceedings NASA ERSS, Houston, Texas, June 1975, Vol. 1A: 53-59.

FIG. 18·3·1

FORESTED
AREAS
of
WESTLAND

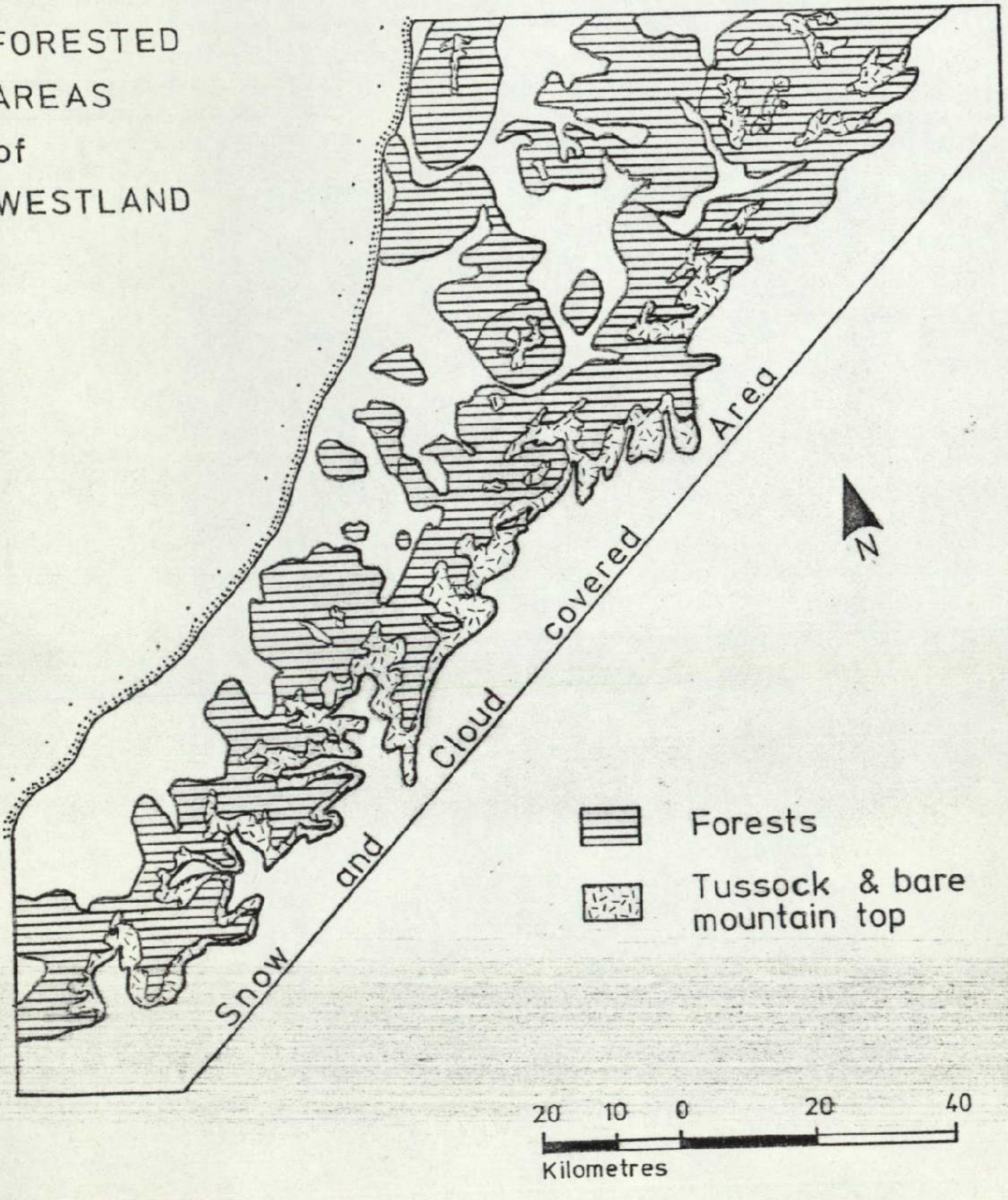


FIG. 18·3·2

COASTAL VEGETATION WESTLAND

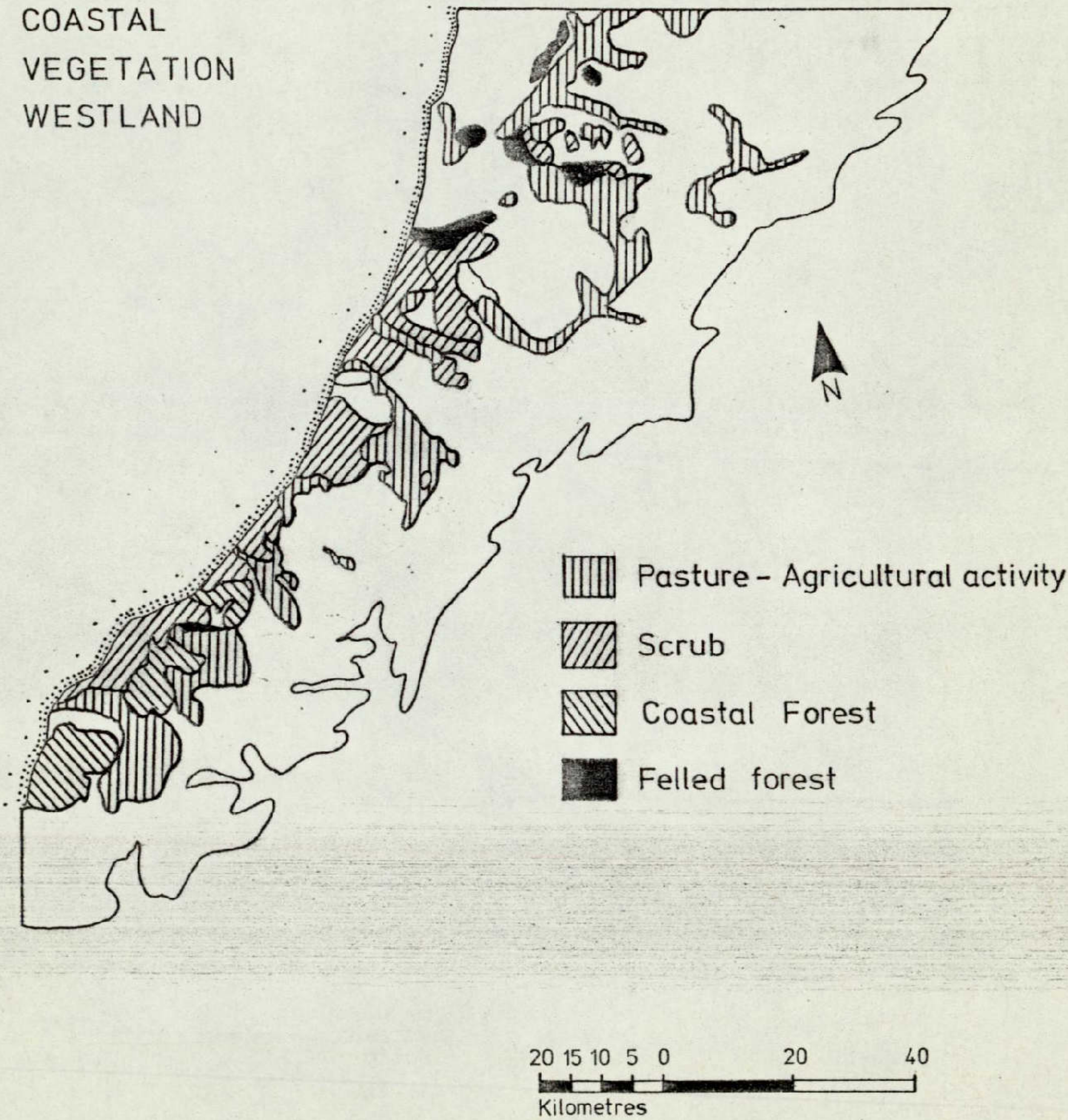
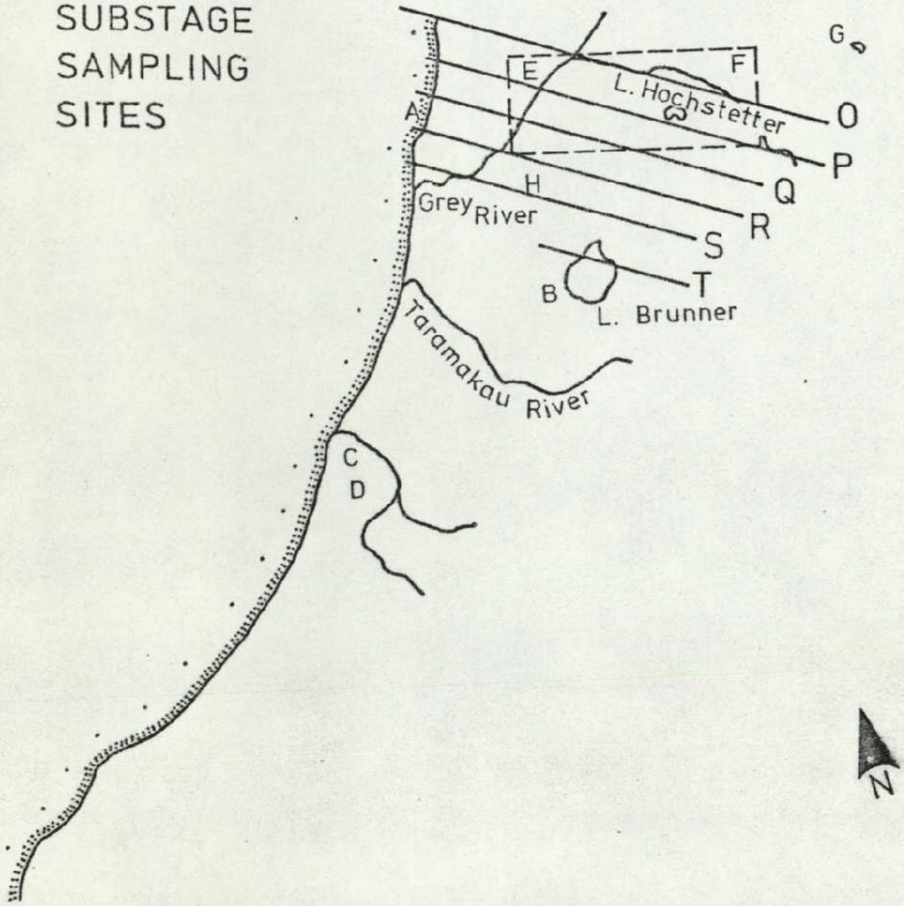


FIG. 18·3·3

SUBSTAGE
SAMPLING
SITES



—— O S.N. 3777 1:66,666
---- S.N. 2647 1:15,000
A Colour Photographs

20 15 10 5 0 20 40
Kilometres

Fig. 18.3.4

LOW ALTITUDE VEGETATION MAP of SAMPLE AREA

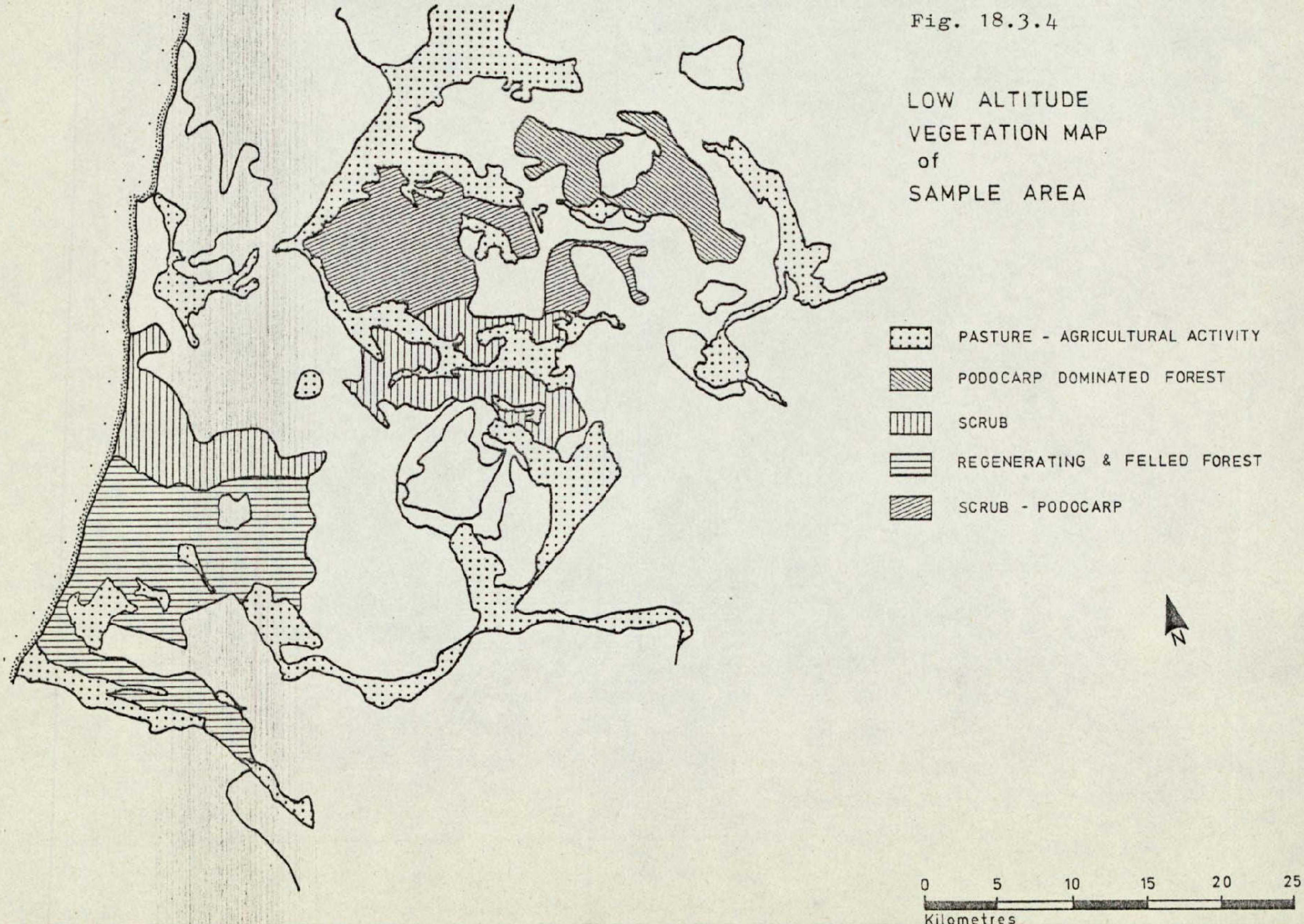


Fig. 18.3.5

FOREST VEGETATION of SAMPLE AREA

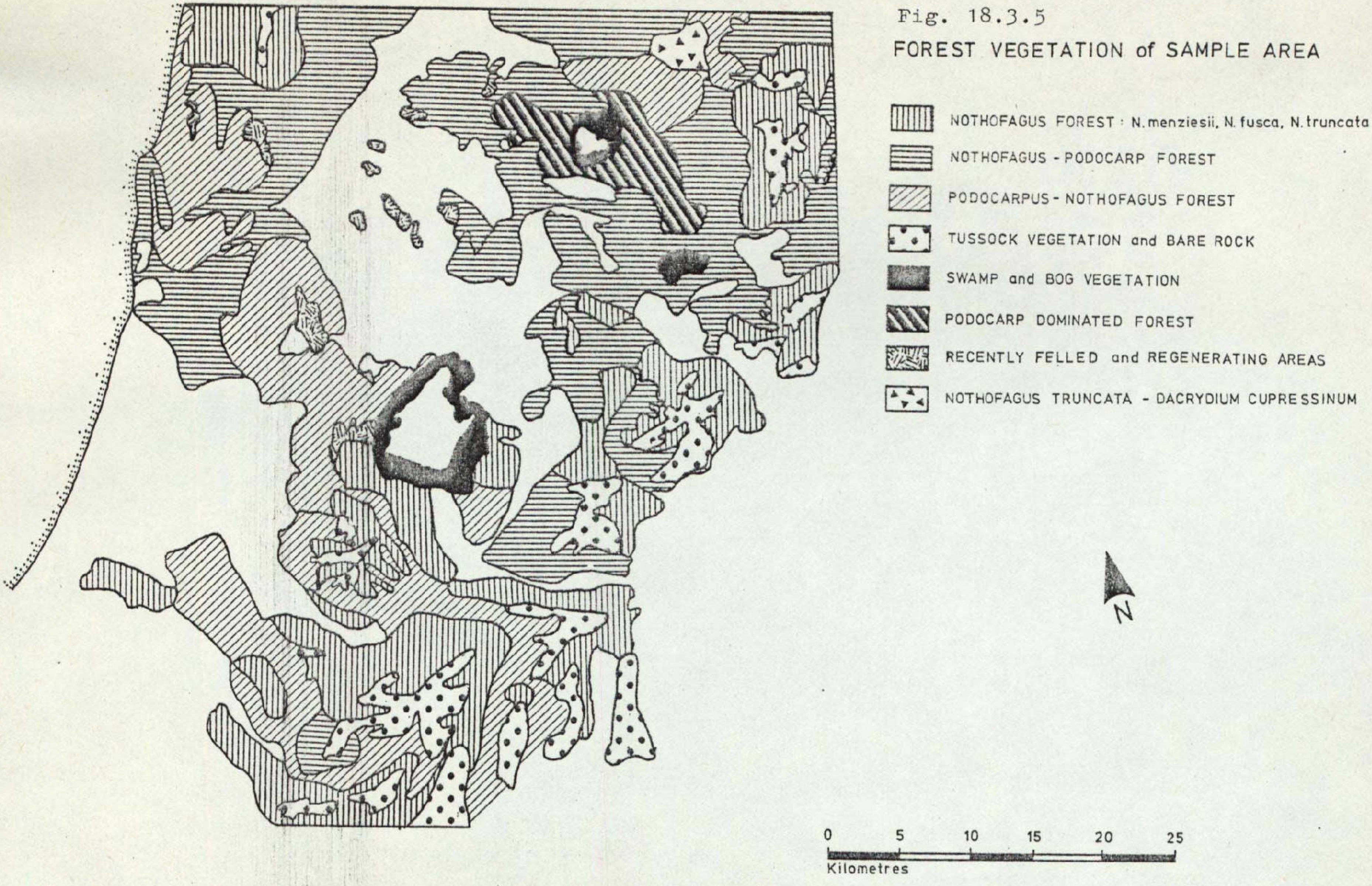


Fig. 18.3.6

VEGETATION MAP of SAMPLE AREA

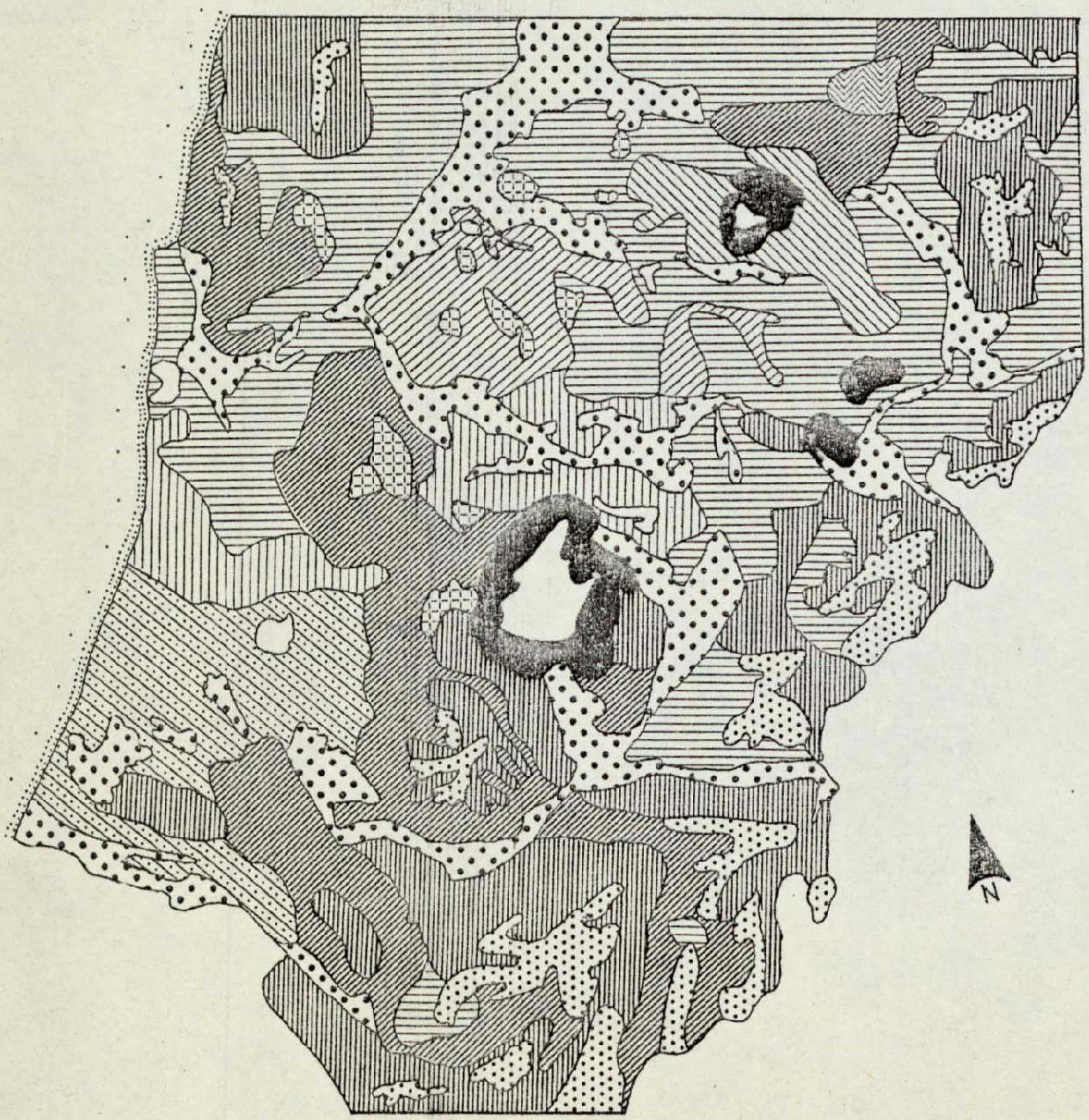


FIG. 18·3·7

TENTATIVE VEGETATION MAP of WESTLAND

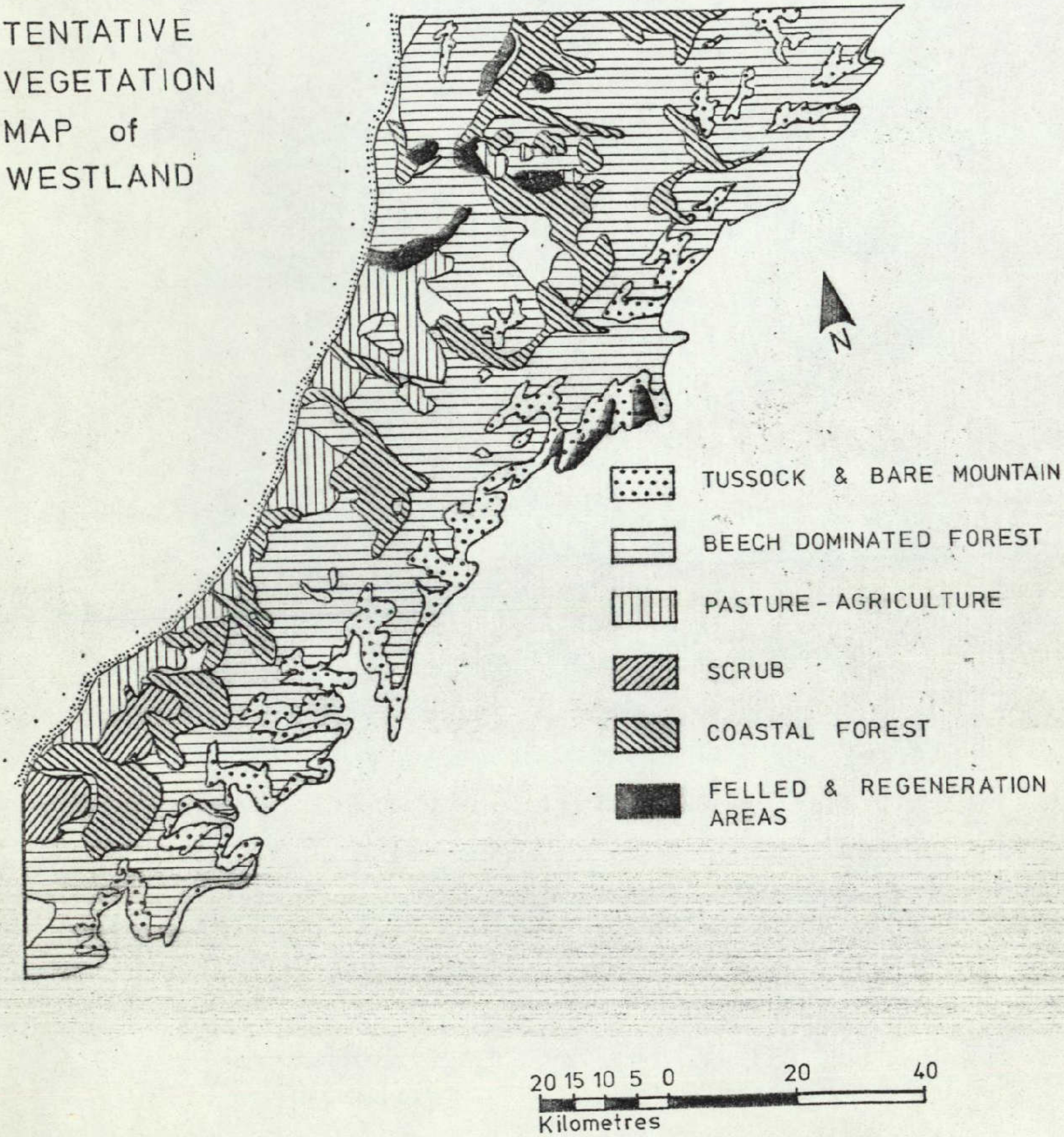
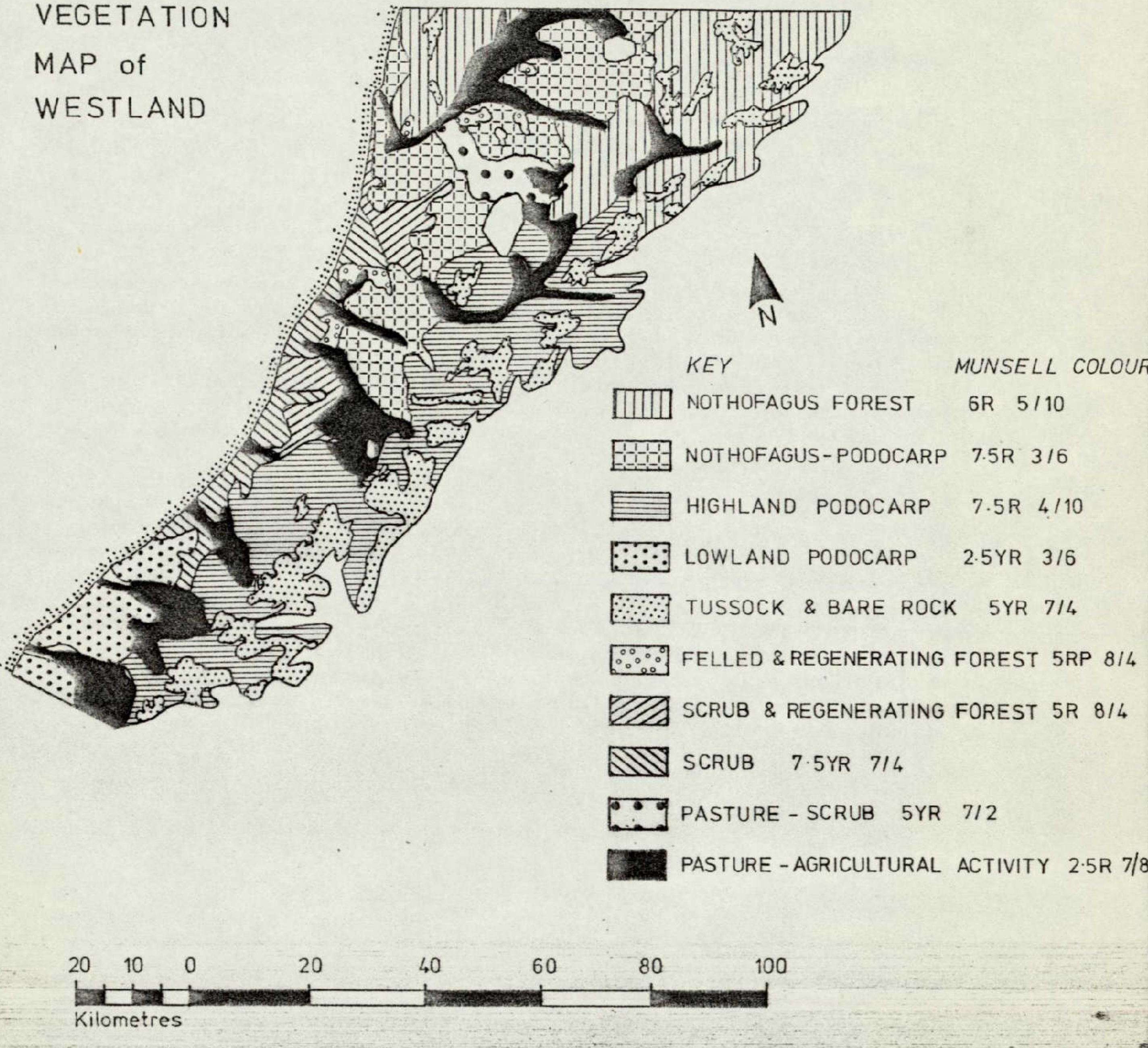


FIG.18·3·8

VEGETATION MAP of WESTLAND



18.4 COASTAL GEOMORPHOLOGY

ANALYSIS OF SAND DUNES OF AOTEA HARBOUR, WEST COAST, NORTH ISLAND, NEW ZEALAND, FROM LANDSAT

G. Ross Cochrane and M. Bellingham

The New Zealand coastline has extensive areas of coastal dunes. In recent years, there has been an increasing demand on these areas for general recreation, for coastal resort development and various economic developments, e.g., forestry, pasture extension, and iron-sand mining. LANDSAT imagery can be used for analysing such areas for potential development, and subsequently to provide an assessment of the environmental impact of such development.

The sand dune area on the north head of Aotea Harbour is a suitable area for study as the dunes are sparsely vegetated, occupied by a small population of feral goats (which keep the vegetation browsed), and are not subject to disturbance or other effects of any vehicular traffic. It is located on the west coast of the North Island which is subject to stormier weather than areas on the east coasts. Consequently, dynamic geomorphic processes and effects of human modification are likely to be more marked. Thus, changes in dune movement and pattern are likely to be rapid, and can be observed on LANDSAT sequential coverage.

Mapping of the dunes was carried out using a projected coloured 35 mm positive transparency which had been photographed from a density-sliced, colour-enhanced isodensitometer LANDSAT image (E-2389-21170-7). Although there is a loss of detailed resolution when using a colour isodensitometer there are other advantages. Tonal patterns are more easily recognised. It is possible to selectively enlarge portions of a LANDSAT image to ten times and more than the maximum possible by photographic processes without loss of the image tonal properties. Thus the area of the Aotea Harbour covered only 1 cm^2 on the 1:1 000 000 LANDSAT image, but this was effectively enlarged more than fifteen times on the colour isodensitometer. Figure 18.4.1 shows a smaller enlargement. When the patterns mapped were checked in the field it was found that the dune and interdune areas could be readily distinguished from each other and from the littoral sands. The lupin/Leptospermum and Leptospermum scrub adjacent to the dunes were also clearly distinguishable (Fig. 18.4.2). Thus, different types of sand, as well as two colonising vegetation communities, that could not be detected by conventional photo interpretation methods were differentiated from the colour isodensitometer image.

The subtle tonal contrasts of these features present on the LANDSAT imagery that cannot be recognised by the unaided human eye can be detected using a colour isodensitometer. This shows that analysis of a colour isodensitometer LANDSAT image can be very useful for studying coastal sand dunes. The technique would be applicable to other areas of New Zealand. It is hoped that forthcoming analysis of line printouts from LANDSAT MSS CCTs will provide further information about the sand dunes.

Alternative analytical methods have been employed in Northland. Comparative analysis of LANDSAT I and II separate band black-and-white prints and enlargements to 1:1 000 000 scale in conjunction with a colour composite of the sand dune areas of the Aupouri Peninsula, North Auckland, have also been carried out. Preliminary interpretation has indicated that as well as dune morphology, successive stages in dune evolution can be recognised. Differences in the strand composition such as areas of sand, old shells, beds of growing molluscs (e.g. tuatua) can be differentiated on very large scale enlargements on one image taken at low tide. Colour isodensitometer studies have not yet been carried out with this imagery.

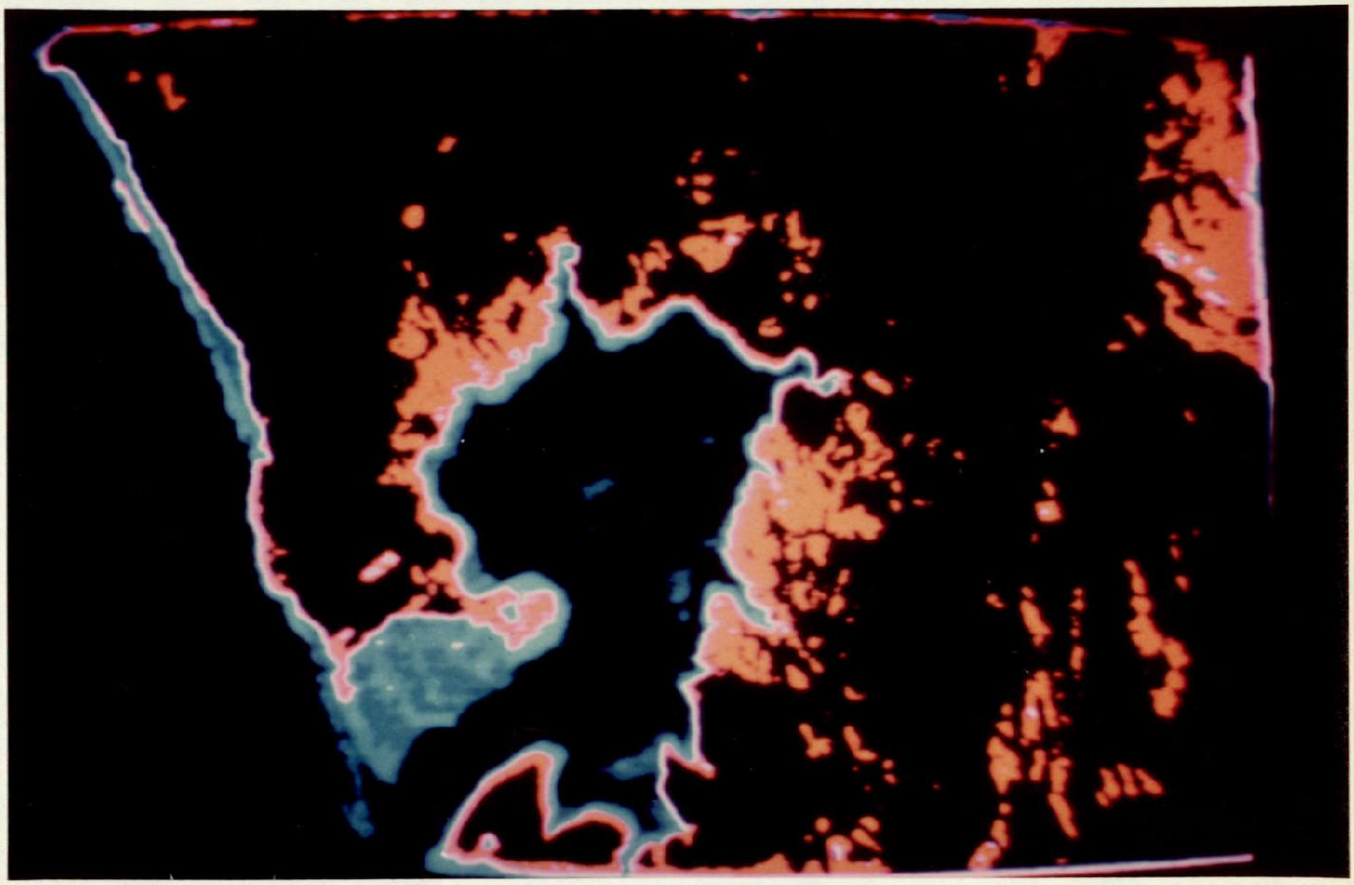


Fig. 18.4.1 Aotea Harbour. Colour enhanced image from colour isodensitometer analysis of E-2389-21170-7. Scale 1:123,000.

Fig. 18.4.2

NORTH HEAD, AOTEA HARBOUR.

From colour isodensitometer analysis of E-2389-21170-7

Scale: 1:24,500

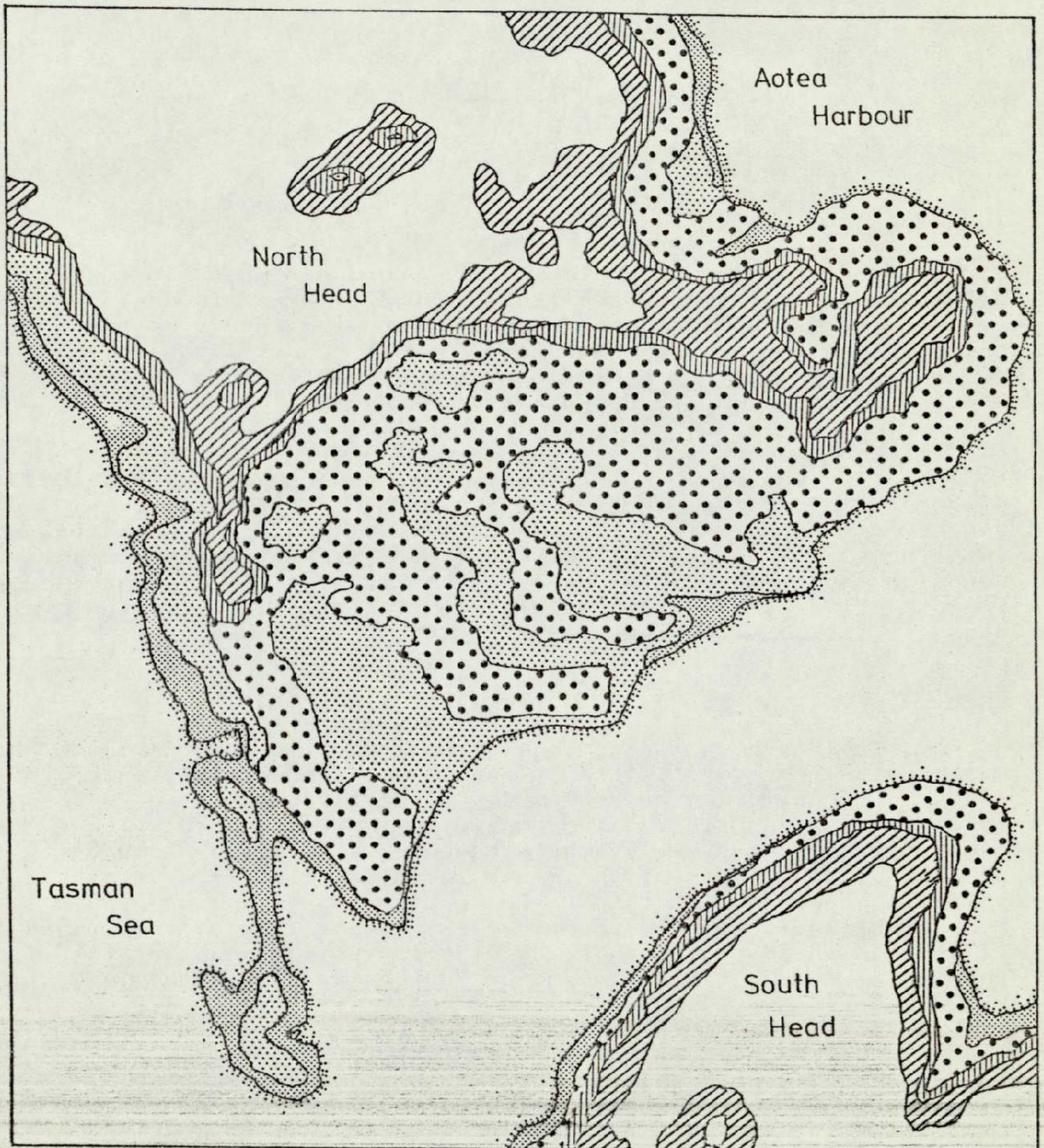


Fig. 18.4.1 Key	Fig. 18.4.2 Key	
Dark blue		Littoral sand
Medium blue		Interdune and open beach sand
Light blue		Elevated dune ridges
Pink		Lupin / Leptospermum vegetation
Orange		Leptospermum vegetation

18.5 ANALYSIS OF SUSPENDED SEDIMENT PATTERNS IN THE FIRTH OF THAMES

A. G. R. Male and G. Ross Cochrane

Introduction

A continuing programme of suspended sediment mapping is being conducted from the available LANDSAT imagery in an attempt to prepare maps of the seasonal and regional offshore movement of sediments on the New Zealand coast. This report is to give a general outline of the preliminary work undertaken in the Firth of Thames, North Island, New Zealand.

A colour composite of Bands 4, 5 and 7 of image E-2281-21182 was used in the analysis in conjunction with slides of colour isodensitometer images of the Band 4 positive transparency of the same image. At the moment a field work programme is being pursued which will give further information about (a) deposited beach materials; (b) the sediment matrix discharged from the rivers; (c) the circulation patterns; and (d) the mixing characteristics of the waters in the Firth of Thames.

Results

The Firth of Thames is a structural graben bordered on the west and east by parallel faultlines. The Coromandel Peninsula is an upthrust mountainous block or horst of volcanic rocks that forms its eastern side. The rugged, but more subdued, block-faulted greywacke rocks of the Hunua Ranges form the western boundary. The mouth of the Firth is in a northerly direction, while the southern limit is formed by the low-lying, prograding Hauraki Plains formed by the progressive infilling of the graben. It is from these plains that the majority of the sediment is supplied to the Firth. The major sources are the Waihou and Piako Rivers.

The sediment pattern on the LANDSAT image has two components: (1) a well developed plume on the eastern side of the Firth, and (2) a less well developed secondary sediment deposition pattern on the western side. These patterns may be the result of a number of interacting factors such as position of sediment source, wind direction, and tidal currents.

The largest and major sediment sources in the Firth are the Waihou and Piako rivers which discharge in close proximity to each other in the south-easterly corner of the almost rectangular Firth. This, therefore, would favour the development of the most obvious plume in this area (Fig. 18.5.1). This appears to be the case as depicted on the LANDSAT image and from preliminary sediment sampling carried out at various places within the Thames estuary, although the pattern has been accentuated by the other factors.

The wind direction appears to have been from a south to south-westerly direction with the result that the plume will have been confined to the eastern side of the Firth rather than dispersing in a more even manner over the whole Firth. The wind direction would also have resulted in the maximum northward movement of the plume by wind generated surface currents.

The tide also appears to affect the plume development in this area. The image time corresponds to approximately one hour after low tide. Thus, the plume would have reached this maximum development as a result of the ebb tide. There is little tidal movement half-an-hour each side of both low and high tide within the Firth. Later tidal movement increases to a rate of 1 to 1.5 knots.

The smaller plume development on the western side is the result of a much lower supply of sediment which is affected by a predominantly southerly movement along the shoreline by the current. This results in a retarded plume development. However, the western side displays an interesting pattern of sediment beyond the mouth of the Firth. It appears that the incoming tide may have interrupted the dispersal of sediment resulting in the development of a relect plume.

The sediment pattern on the image was compared with a Hydrographic Chart of the area (Chart NZ533 Hydrographic Office 1968) to test the possibility that the shape and depth of the bottom was affecting the image as a result of bottom reflection. It was found that the shape of the plume had minimal correlation with submarine morphology. This, therefore, confirmed that the pattern observed was actually suspended sediment and not the result of bottom reflection.

Preliminary measurements with a Secci dish of water clarity also supports this as water turbidity is very high. Although Band 4 can "penetrate" clear water to depths of several fathoms to show bottom features this is not the case in the Firth of Thames.

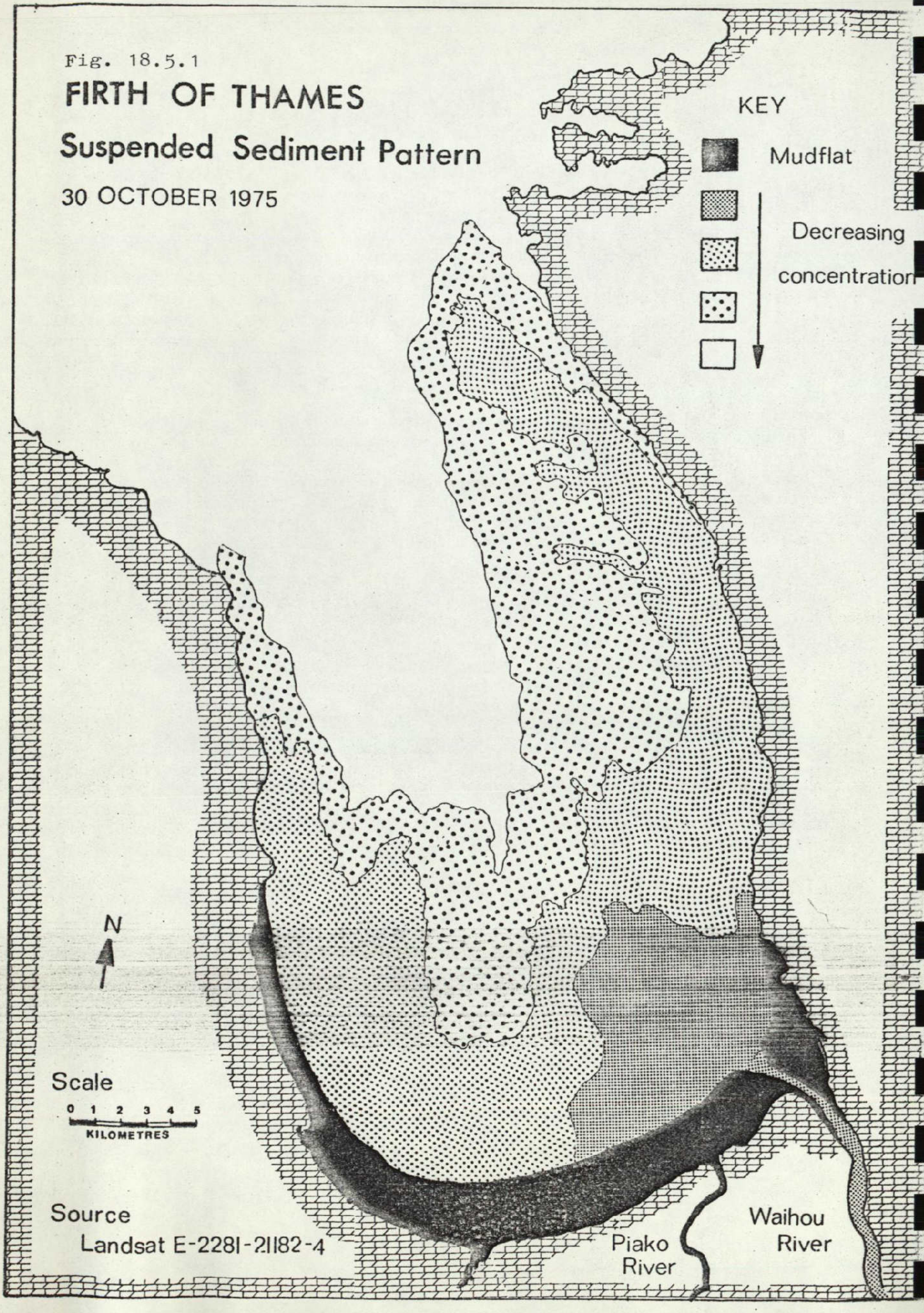


Fig. 18.5.1
FIRTH OF THAMES
Suspended Sediment Pattern
30 OCTOBER 1975
KEY
Mudflat
Decreasing
concentration
N
Scale
0 1 2 3 4 5
KILOMETRES
Source
Landsat E-2281-21182-4
Piako
River
Waihou
River

140

18.6 SUSPENDED SEDIMENT PATTERNS ON THE WEST COAST OF THE NORTH ISLAND

A. G. R. Male

Introduction

LANDSAT images E-2281-21185-4 and E-2389-21172-4 were used in the study of suspended sediment on the West Coast of the North Island between Albatross Point and Urenui. These images are the only images available of this coastal area, and as several months elapsed between the two images they do not show the successive development and dispersal of a single plume, nor do they show the development of plumes under similar conditions. A comparative study was conducted within these limitations to examine any general similarities between the sediment patterns shown on the two images.

The sediment patterns were mapped by slides made from colour isodensitometer images which were projected on a base map drawn from New Zealand topographic maps. This resulted in a standard scale which improved the comparative study. These are shown as Figs. 18.6.1 and 18.6.2.

Results

Both images are useful in determining the relative importance of the various rivers as sources of sediment. In both images the Awakino and Mokau Rivers appear to be discharging the most sediment. This is reflected by the high optical densities in close proximity to the mouths of these rivers. The Tongaporutu River is also a substantial source of sediment but of rather less importance than the other two rivers. Smaller secondary streams north of the Awakino River also produce small plumes which can be seen on both images as localised high concentrations.

The pattern of dispersal of the sediment also displays certain similarities between the two images. Firstly, the sediment is swept considerable distances off the shore (30+ km) and this enables the effects of coastal currents to be seen. Secondly, it can be seen that the sediment moves towards the south after it has left the coastal zone and is then swept north again at distances of 15-20 km from the shore. The southward movement of the sediment was entirely unexpected as the West Coast North Island has a marked northward drift of beach materials and the predominant coastal current is also the northward-moving Westland Current. The evidence derived from these images seems to suggest that the effect of the Westland Current is only substantial at considerable distances from the shoreline while northward movement of beach materials only occurs in the littoral drift zone as a result of wave orientation.

The influence of tidal set was investigated but further imagery is needed to study this effect as image E-2281-21185 shows the outgoing tide while E-2389-21172 is a full tide situation. Therefore the tidal effects on the development of sediment plumes in this area cannot be studied from available imagery.

Attempts to determine the effect of river discharge were also restricted due to the lack of adequate data. Discharge measurements of these rivers are very infrequent and thus do not supply helpful information. However, it is hoped that information from climate stations in the area can be used to allow a more detailed study to be attempted in the future.

Fig. 18.6.1

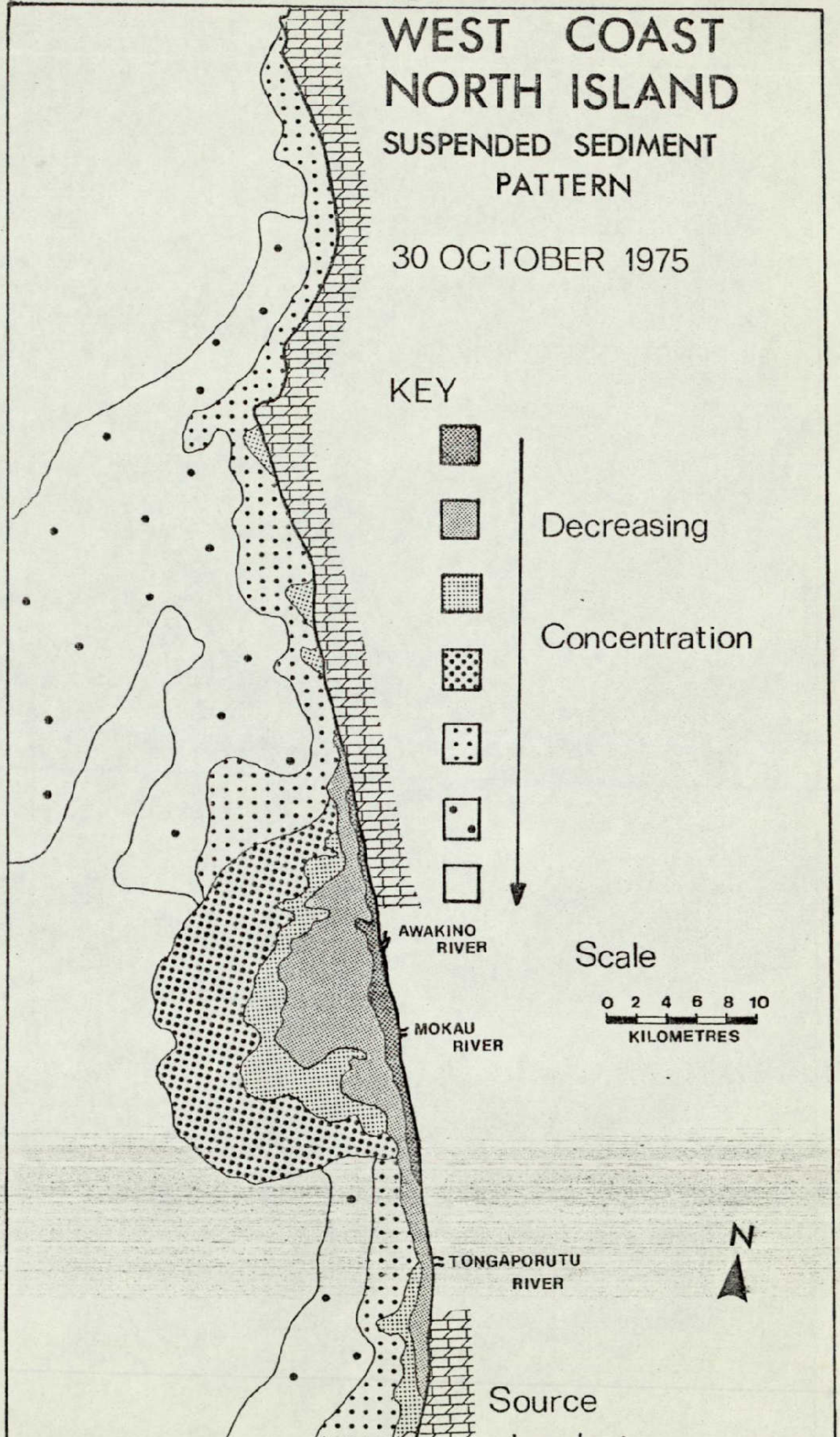
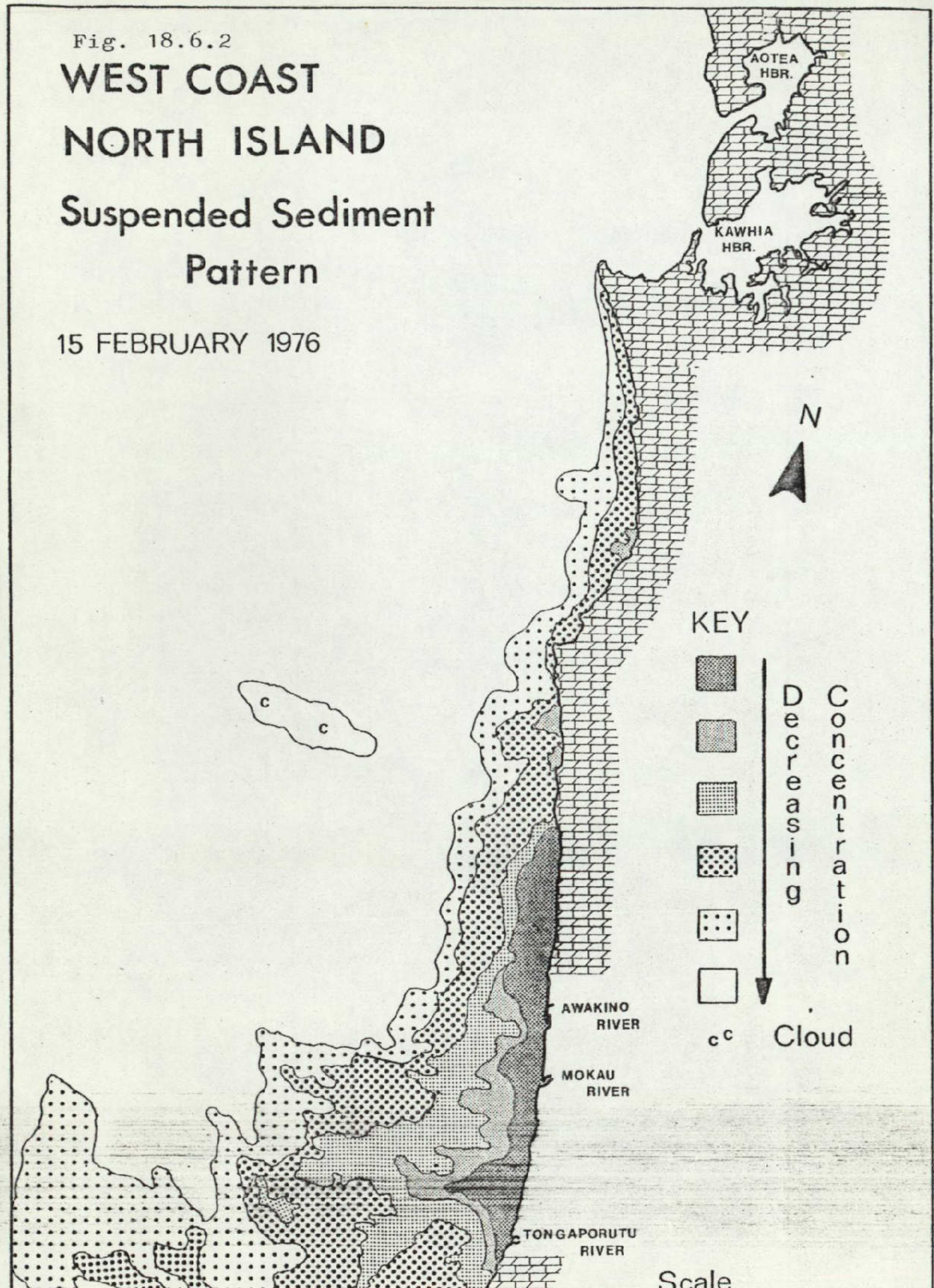

WEST COAST
NORTH ISLAND
SUSPENDED SEDIMENT
PATTERN
30 OCTOBER 1975
KEY
Decreasing
Concentration
AWAKINO RIVER
MOKAU RIVER
TONGAPORUTU RIVER
Scale
0 2 4 6 8 10
KILOMETRES
N
Source
Landsat
E-2281-21185-4

Fig. 18.6.2


WEST COAST
NORTH ISLAND
Suspended Sediment
Pattern
15 FEBRUARY 1976
AOTEA HBR.
KAWHIA HBR.
N
KEY
Decreasing Concentration
c c Cloud
AWAKINO RIVER
MOKAU RIVER
TONGAPORUTU RIVER
Scale
0 2 4 6 8 10
KILOMETRES
Source
Landsat E-2389-21172-4

18.7 LAKE TAUPO SUSPENDED SEDIMENT STUDY: A PRELIMINARY STATEMENT

G. H. Campbell and G. Ross Cochrane

LANDSAT II imagery provides an ideal vehicle for the study of sedimentation processes and patterns in Lake Taupo. Such study is of value, even at a general level, because it provides indicators of water movement within the lake whilst identifying sources of sediment load and providing a quick and easy mode of comparison among source areas. Sediment deposition areas are also readily identifiable.

Lake Taupo is situated near the geographic centre of the North Island of New Zealand. It has a total area of 606 km^2 within a catchment area of 3289 km^2, and is 357 m above sea level. The depression occupied by the lake is of Pleistocene volcanic and tectonic origin and is characterised by a narrow shoreline falling away steeply to a depth of about 100 m.

Band 4 of the LANDSAT image 22 Dec 75 (E-2334-21123) shows clear sediment traces in Lake Taupo, the most distinctive characteristic being a broad zone of suspended sediment running from the south-west of the lake towards the north-eastern corner of the lake. There are areas largely clear of suspended sediment in the south-east and north of the lake.

Fig. 18.7.1 was prepared using an enlargement (approximately 1:300 000) produced in U.S.A. from a Photowrite negative of Band 4 that had been computer enhanced by PEL, DSIR. For conventional photo interpretation it was a considerable improvement over the standard Band 4 photographic product. Four zones of suspended sediment density were visually identified and traced from the photo. This technique, though crude, shows the general patterns and serves a useful purpose without the need of sophisticated facilities.

Fig. 18.7.1 shows that the most significant plumes of suspended sediment were originating in the Kuratau and Waitahanui Rivers and the Whareroa stream (Fig. 18.7.2). Lesser flows of suspended sediment came from the Tongariro River and the Hinemaiaia stream and from the streams flowing into Western Bay. It is significant that there is little or no sediment trace from the Tauranga-Taupo, Waimarino and Waiotaka Rivers on the lake's south-eastern shoreline, nor from the Waihaha River into Western Bay.

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The densest suspended sediment zone runs in a belt southwest-northeast across the lake. Its plume-like nature suggests a considerable flow rate. It is apparent, however, that rather than passing out of the lake down the Waikato River, the sediment (on this day at least) tends to settle out in the deepest parts of the lake. There is a clearer area (Fig. 18.7.1, zone 2) in the north-east of the lake, roughly corresponding to the 140 m isobath of the Whangamata Basin and a small clear area with no suspended sediment evident over the deepest part of the lake, the Waitahanui Basin (155+ m).

Dense zones of sediment are also evident in the plumes from the mouths of the Hinemaiaia stream and Waitahanui River. These plumes move both northward and towards the centre of the lake.

It is possible that in the densest areas around stream mouths there has been a combination of lake floor and sediment recorded by the LANDSAT MSS sensors. However, the absence of dense patches near other shallow stream mouths and the very steep bathymetric contours tend to discount this.[1]

The evidence suggests that the subaqueous Kuratau, Whangamata and Waitahanui Basins act as sumps in the lake. Suspended sediments flow towards them and sink to the bottom beyond the range of LANDSAT sensors.

As a second step in the study an analysis was made of an HP 2100 computer tape printout of Bands 4, 5, 6 and 7 radiance values and an enhanced shaded printout obtained by character overprinting on a line printer of all bands, obtained from PEL, DSIR, Wellington. Both the coded radiance data and the printout provided detailed imagery at a scale of approximately 1:20 000. A reduction of part of the enhanced shaded printout is shown in Fig. 18.7.3.

A detailed map of suspended sediment was prepared for the south-western corner of the lake in three stages. The first step involved hand-shading the individual pixel symbols on the printout and generalising the resultant patterns to remove some of the six-line striping. This map served as a workable practical guide for the second stage which involved checking these patterns against the individual coded radiance data. Preliminary sampling indicated that all pixel units did not require verification and only those close to boundaries recognised on the intial hand-shaded map were checked.

The third stage involved some generalisation of data for cartographic drafting purposes. Fig. 18.7.4, a map with five classes of suspended sediment densities portrayed, is the final result.

As described above, there is a broad band of suspended sediment extending from the Tongariro River delta north-westwards to meet the western shore of Lake Taupo just north of Pukawa and then flowing northwards along this coast as far as Pokuru Pa before turning abruptly north-eastwards towards the centre of the lake.

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1 Bathymetry from: IRWIN, J., 1972 Lake Taupo Bathymetry 1:50 000 N.Z. Oceanogr. Inst. Chart. Lake Series.

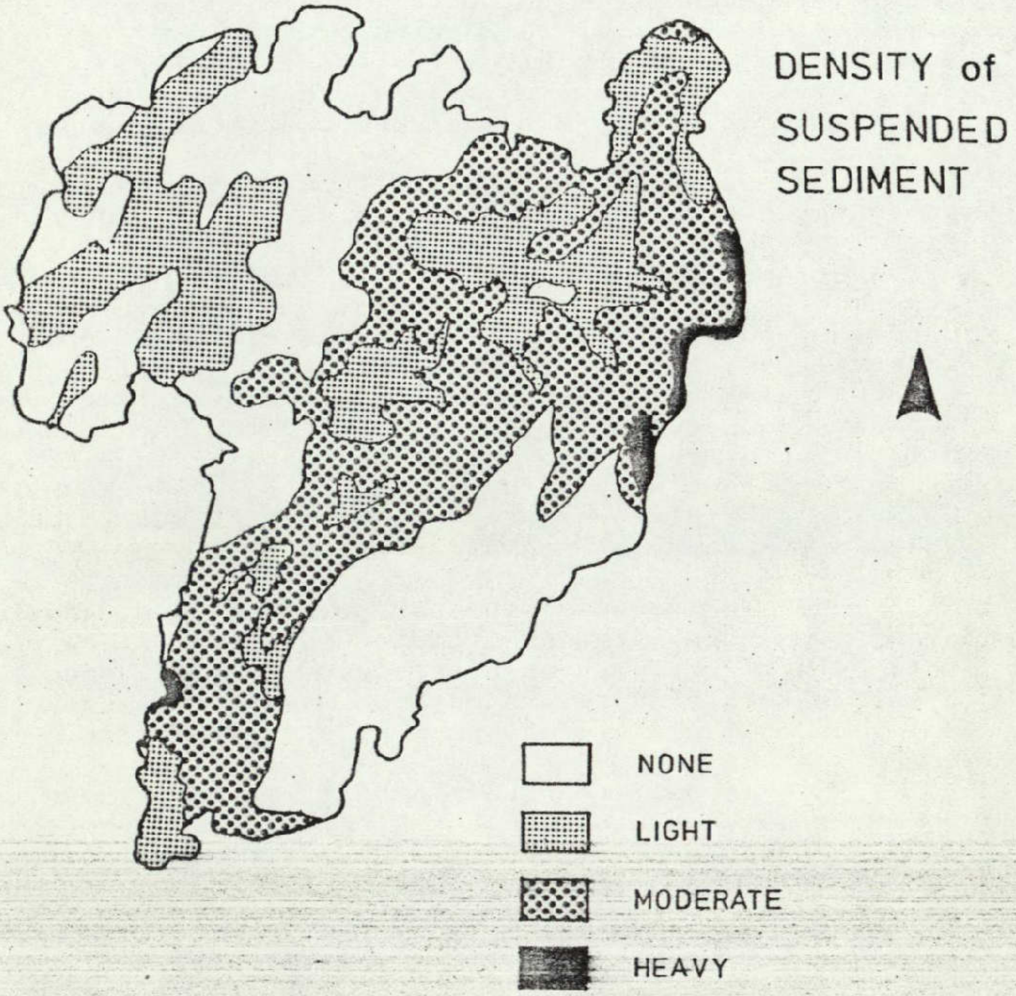
Only two areas of this part of the lake are in the densest category - the waters off the mouths of the Kuratau River and Whangaroa stream. In both these places the lake is less than 10 m deep over most (not all) of the area. These areas are, however, clearly sources of sediment and are surrounded by extensive isopleths of the second densest category waters, indicating only moderate settlement or dispersion some distance from the river mouths.

The clear evidence of this map is that the Kuratau and Whareroa catchments were the most significant contributors of sediment into south-western Lake Taupo on this day, their suspended sediments remained markedly dense (class 2) at a distance of up to three kilometres from the lake edge at a depth of over 105 m. Even at this point the density of the suspended sediment still matched that of the densest recordings at the mouths of the much larger Tongariro River (see Fig. 18.7.4). It is also evident that beyond the influence of these heavy load-bearing streams the lake is largely clear of suspended sediment.

The preparation of this report has demonstrated difficulties encountered with the imagery used. It would be helpful to redraw Fig. 18.7.1 using imagery from an isodensitometer. The printout of Lake Taupo measures some 2 x 2 m and is difficult to reduce to a workable size. Furthermore, on the enhanced shaded printout used to produce the first map the character overprinting class intervals changed across the strips, as symbols were appropriate within a single strip but were not necessarily comparable between the five adjacent strips studied. This made lake-wide comparisons difficult for the preparation of a working map. The usefulness of the printout was further compromised by marked six-line striping. Nevertheless this provided a useful short cut to analysis of the coded radiance printout values.

Given access to further printout data, and tape manipulation, along with access to densitometer data it will be possible to refine the material presented above. It is hoped that it will be possible to extend this study to imagery from all seasons to build up an overall picture of sediment processes within the lake.

It is believed that LANDSAT II imagery analysis can make an important contribution to this study, and complement field studies which are at present under way.



Scale: Approx. 1:300,000

Fig. 18.7.1 DISTRIBUTION PATTERN OF SUSPENDED SEDIMENT ZONES MAPPED FROM PHOTOWRITE BAND 4 ENLARGEMENT OF LANDSAT E-2334-21123 OF 22 DECEMBER 1975

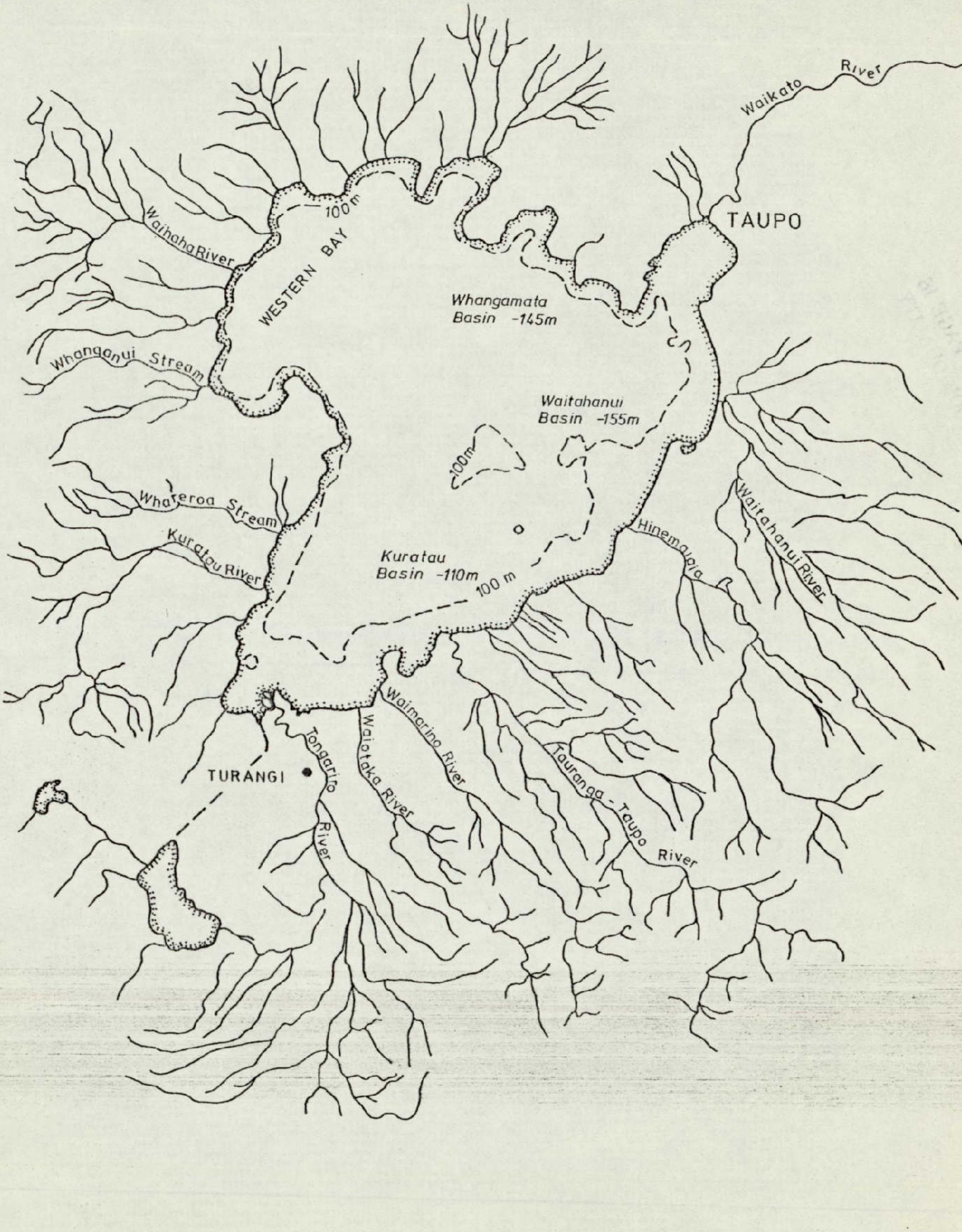


Fig. 18.7.2 LAKE TAUPO AND TRIBUTARY STREAMS

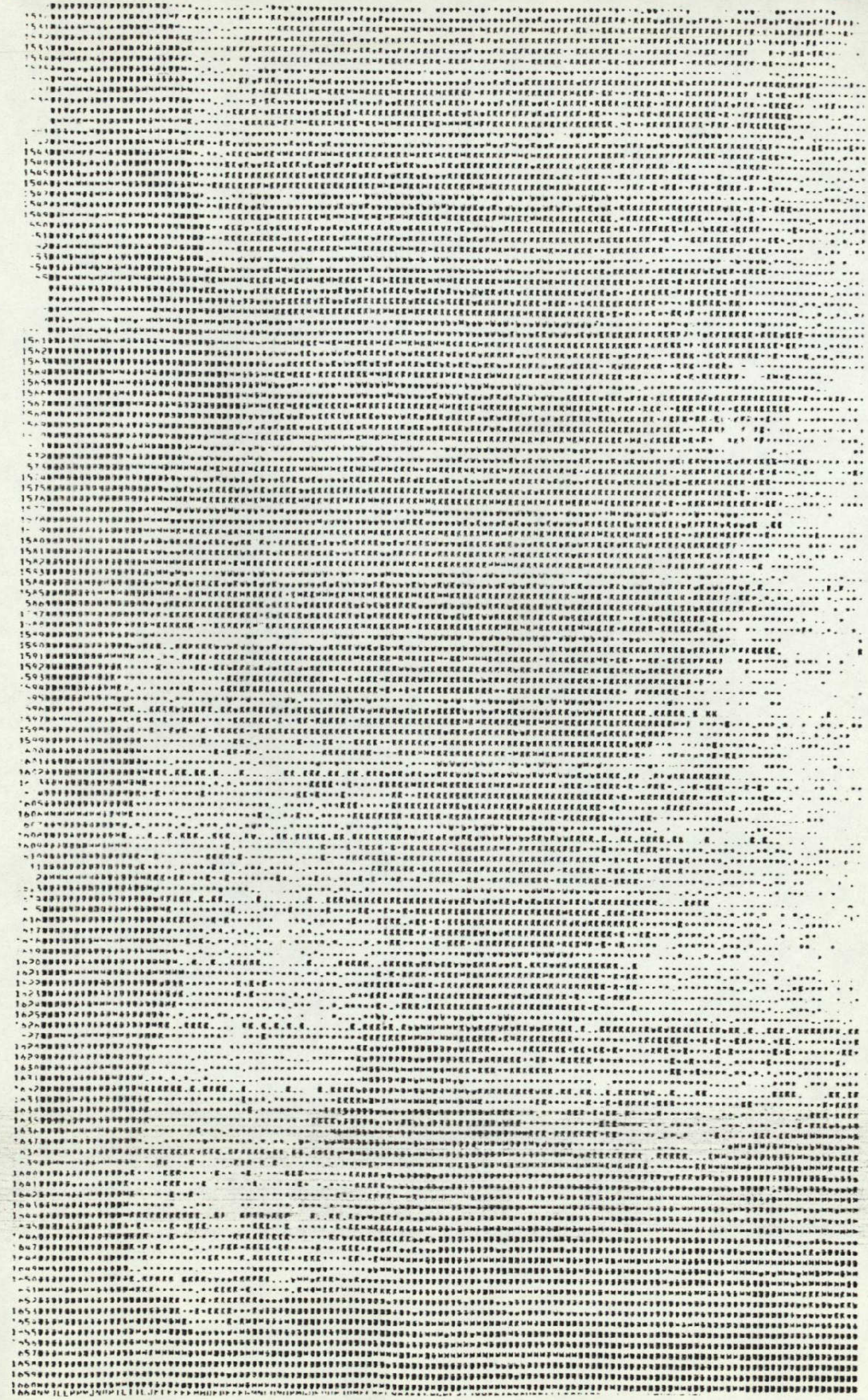


Fig. 18.7.3 REPRODUCTION AT A REDUCED SCALE OF A COMPUTER PRINTOUT FROM LANDSAT CCTs OF PART OF SOUTHWESTERN LAKE TAUPO

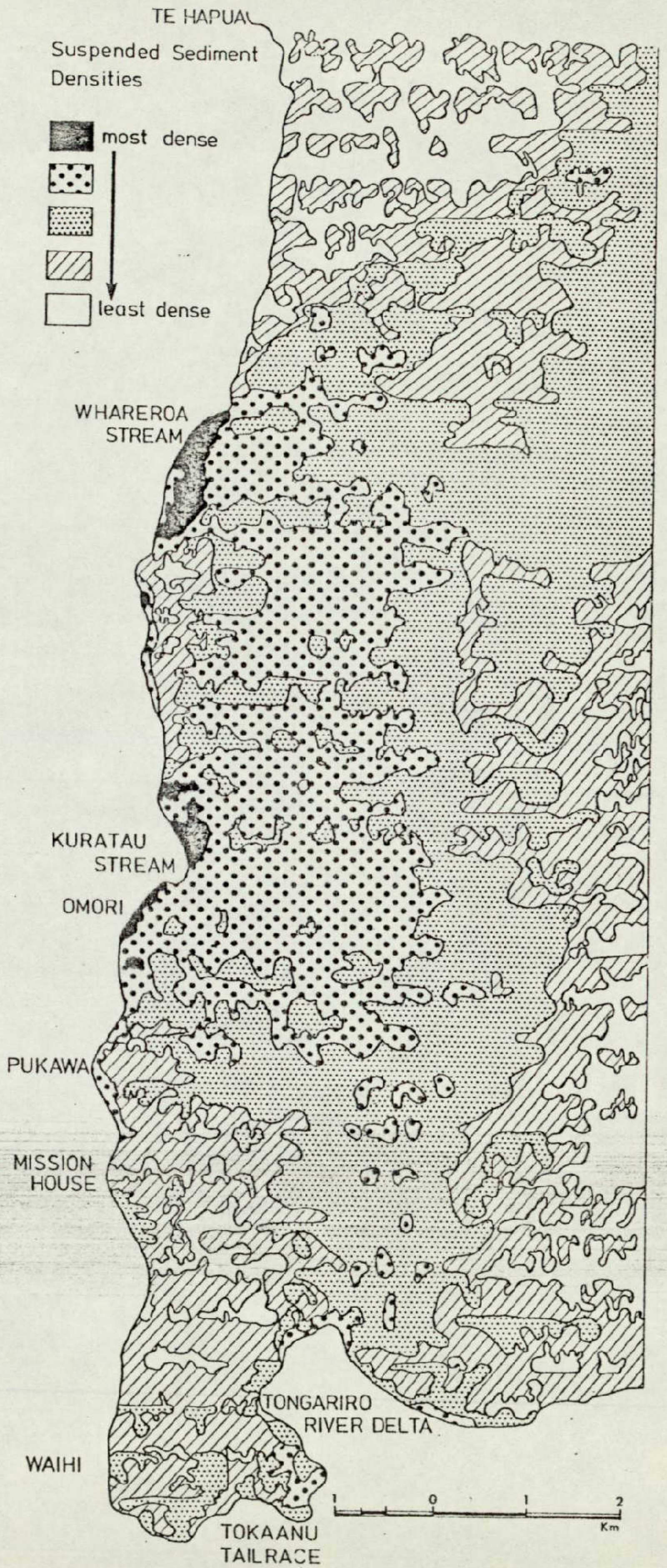


Fig. 18.7.4 Computer map of suspended sediments, southwestern Lake Taupo

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PART VII

LANDSAT IMAGERY AS APPLIED TO FOREST MANAGEMENT

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CHAPTER 19

LANDSAT IMAGERY AS APPLIED TO FOREST MANAGEMENT

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FIGURE CAPTIONS

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19.1 INTRODUCTION

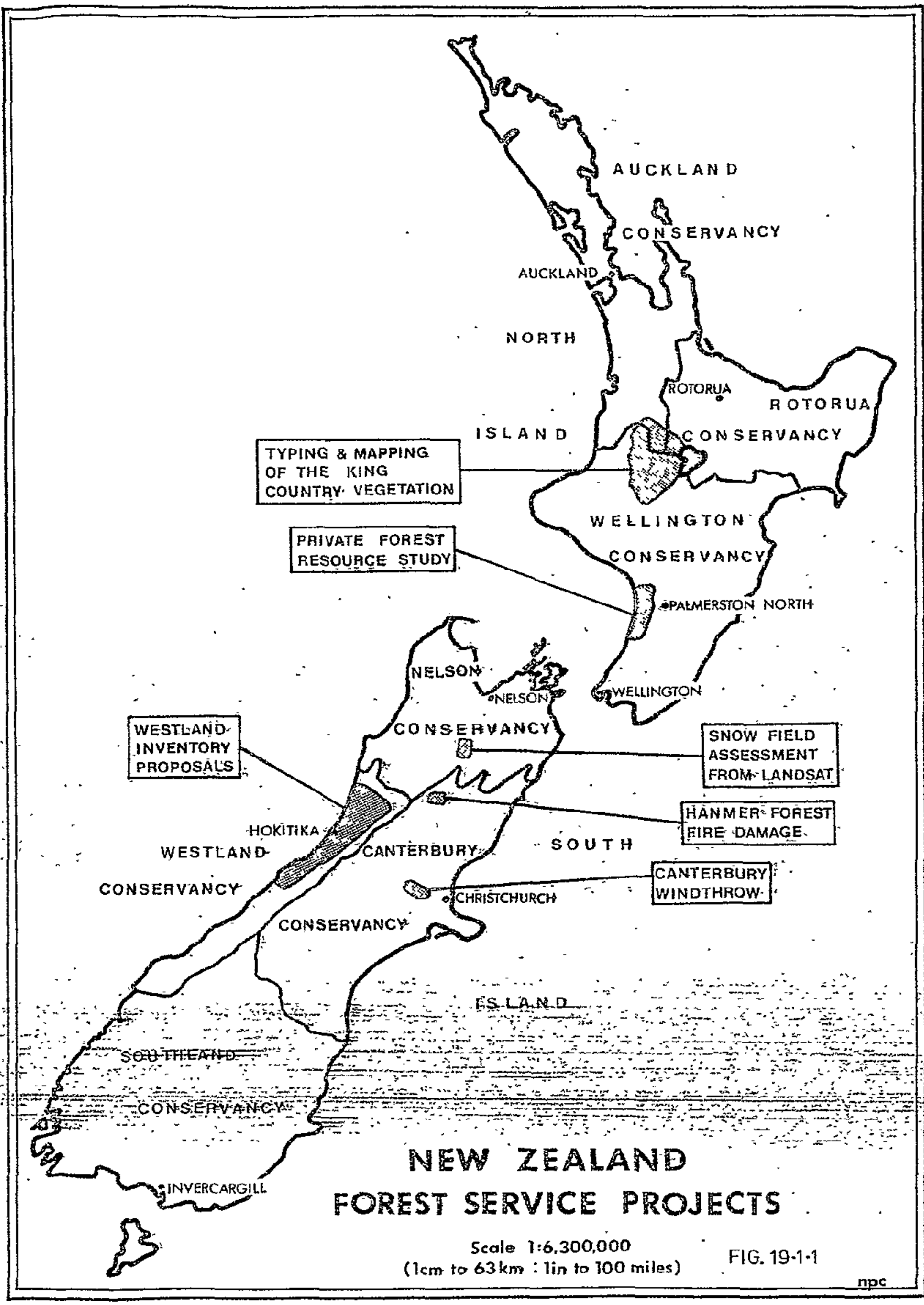
Early in 1976 the New Zealand Forest Service began assessing the potential of LANDSAT for forest management purposes. Our only previous experience was the investigatory work by Mr M. McGreevy, NASA co-investigator, of the Forest Research Institute, Rotorua. The time seemed opportune to use LANDSAT for its operational value.

As projects came forward from our conservancies (regional forest administrative offices), the Remote Sensing Section of DSIR gave valuable assistance in training our staff in the use of equipment, such as the isodensitometer and the colour additive viewer, and in applying their research to our particular projects.

Lack of sequential imagery over study areas has been disappointing, and as a consequence monitoring of such projects as the Hanmer Forest fire windthrow in Canterbury forests, and snowfield assessment has suffered. Hopefully this will become a disappearing factor as more satellites become available.

In the forest management field, the results to date have shown that LANDSAT has considerable application to our requirements. This is especially so for indigenous forest inventories where extent and inaccessibility make collection of field data difficult and expensive, and for our private exotic forest inventories which include large numbers of small woodlots.

N. P. Ching



NEW ZEALAND
FOREST SERVICE PROJECTS

Scale 1:6,300,000
(1cm to 63km : 1in to 100 miles)

FIG. 19-1-1

19.2 CANTERBURY WINDTHROW

FOREST CONDITIONS AND WINDSTORM DAMAGE IN EYREWELL STATE FOREST INTERPRETED FROM LANDSAT II IMAGERY

B. M. Lean

ABSTRACT

Colour-enhanced composite prints generated by computer from LANDSAT data were produced to emphasise the varying reflectances from forested areas. With the aid of conventional aerial photography, various forestry operations and forest conditions (damage and growth) were recognised.

19.2.1 INTRODUCTION

In North Canterbury and 30 km NW from Christchurch lies the pine plantation known as Eyrewell State Forest. On 1 August 1975 a windstorm caused 22% of the plantation to be windthrown. When LANDSAT II data of 31 October 1975 became available an experiment was initiated through Mr N. Ching (Head Office, N.Z. Forest Service) to locate the areas of windthrow on LANDSAT imagery. From any subsequent satellite data it was hoped to measure, if possible, the rate of desiccation.

During the 1976-77 summer unfavourable weather prevented any further LANDSAT data becoming available. During one satellite overflight in February 1977 an underflight to take multi-spectral photography was attempted unsuccessfully in cloudy conditions.

This present study is therefore mainly confined to a visual or optical interpretation of the colour composite prints derived from the October 1975 LANDSAT scene.

19.2.2 METHODS

From the LANDSAT II data of scene 2282-21254 composite colour prints derived from bands 4 (0.5 to 0.6 μm), 5 (0.6 to 0.7 μm), and 7 (0.8 to 1.1 μm) were produced on the STATOS and ANAC line printers. These prints were supplied by the Remote Sensing Section, PEL, of DSIR at a scale of 1:38,000. Subsequently the ANAC print (Fig. 19.2.2) was found to be easier to interpret.

The portion of the Eyrewell pine plantation being studied was also covered by 1:10,000 panchromatic aerial photography taken a day later than the satellite imagery (1 November 1976).

During comparative analysis of the airborne and satellite imagery it became apparent that the LANDSAT scene was more influenced by the reflectances from such objects as vigour of grasses, density of tree coverage over land surfaces, logged areas, areas of forest thinned during silviculture operations, windthrow damage, and varying soil disturbances such as site preparation. On this basis a ground truth map with categories chosen to promimate the variations indicated in the colour composite LANDSAT imagery was compiled (Fig. 19.2.3).

19.2.3 RESULTS AND DISCUSSION

Almost all of the forest depicted in the study area is Pinus radiata planted since 1965. The forest crown density variations reflected the growth of the forest, thinning operations, and windthrow.

In the thematic interpretation based on the LANDSAT II data (see Fig. 19.2.4) low crown density cover, thinned areas, and windthrow could be confused. Any subsequent LANDSAT data would also have shown up recent second thinnings. Increased crown density of the younger tree crops and recent logging would also have been recorded.

The moisture content of the windthrown but rooted trees has remained constant, and the uprooted or wind-broken trees have deteriorated over the last two years (obtained from ground sampling within the forest). These variations would be difficult to pick up on the satellite data. Fig. 19.2.1 illustrates the varied pattern and density of windthrown trees as against the land surface, foliage abundance (pruned or unpruned trees), and tree trunks, all of which would have varying reflectance values.

Familiarity with the apparent radiances or spectral patterns of the scene objects in the various LANDSAT bands and more selective computer print-outs of chosen signatures, including proportion estimated, in the wavebands would be needed for refined classification.

Of the windthrow-damaged areas in the forest covered in the study, 64% was clearly identified; 24% was recognised with uncertainty or confused with low tree crown coverage; and 11% was not picked up. Failure to identify was often because damage was scattered, confined to small areas, or affected mixed tree species.

19.2.4 CONCLUSIONS

The LANDSAT II imagery shows up the general pattern of forest growth and changing conditions resulting from such abiotic agents as wind storm and logging and thinning operations. If readily obtainable and regular sequential satellite data were available, they could, with further development in interpretation techniques, be used as a monitoring and survey tool to identity the areas of forest operations and changing conditions.

Readily obtainable large-scale 70 mm colour or colour infra-red photography would seem to be best for identifying small changes in foliage of the often isolated areas in windthrown trees.

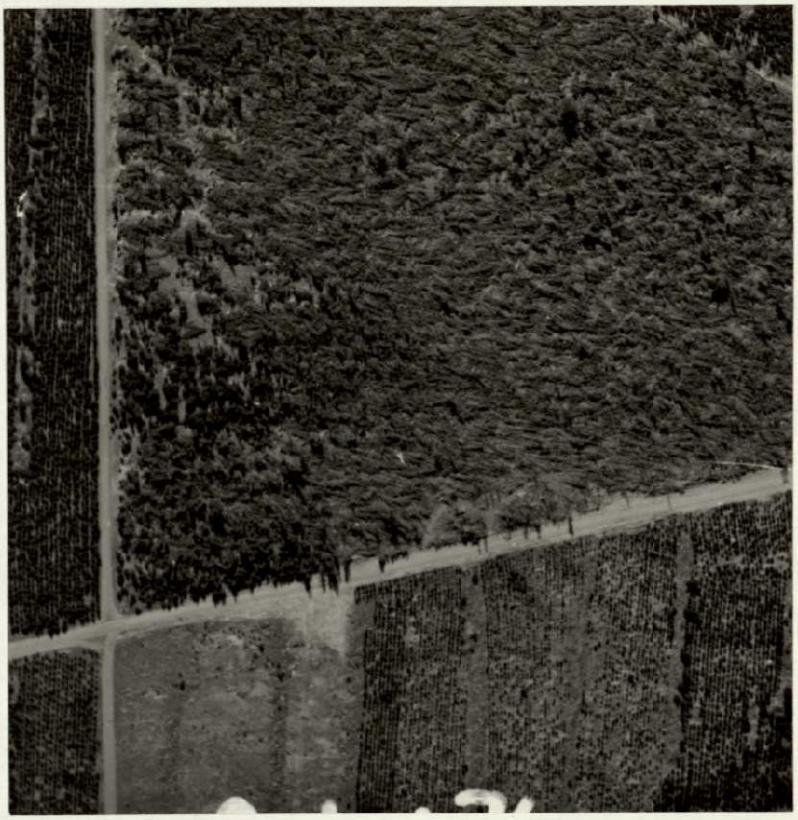
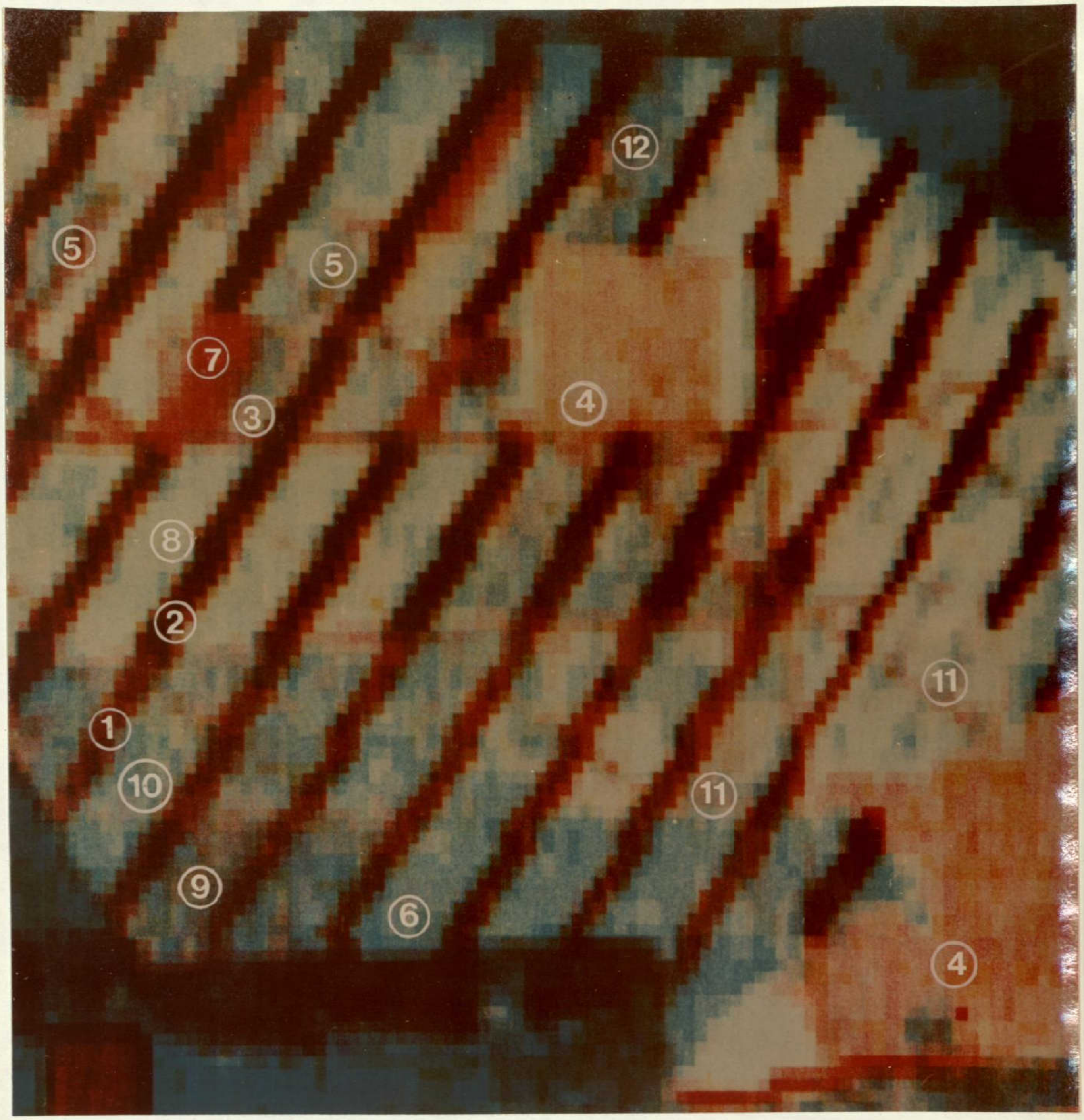


Fig. 19.2.1 An example of the varied forest cover and windstorm damage in Eyrewell State Forest



Scale 1:28 000

Fig. 19.2.2 A colour enhanced composite from scene 2282-21254

The numbered sample areas were interpreted from aerial photography.

1 Windthrown site
2 Recent planting
3 Mostly windthrown
4 Completely windthrown
5 Thinned stand, (approx 40% cover)
6 6-year stand, (approx 60% cover)
7 Logged area
8 7-year stand, (approx 70% cover)
9 5-year stand, (approx 35% cover)
10 6-year stand
11 Scattered windthrow
12 Windthrow and varying crown density areas.

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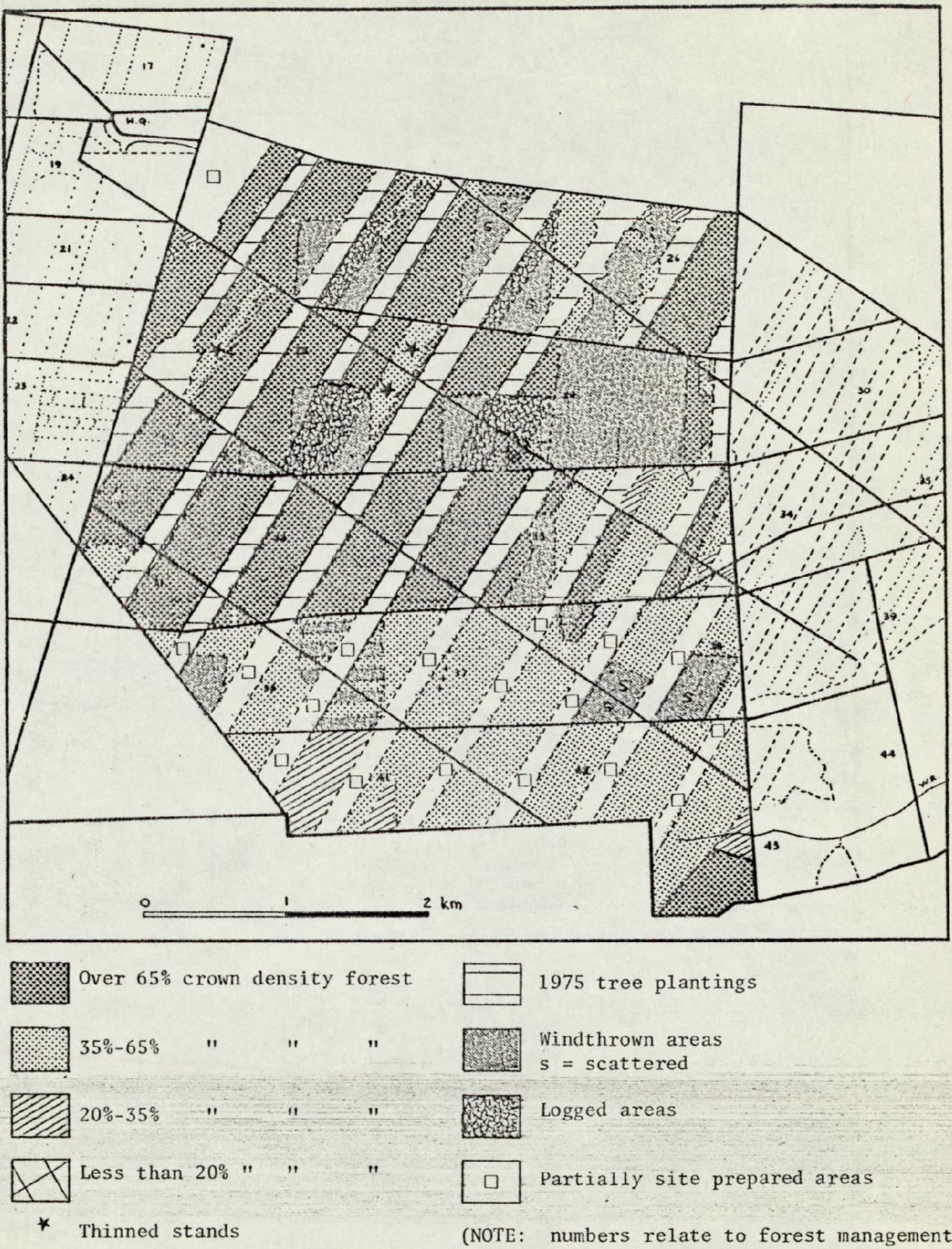
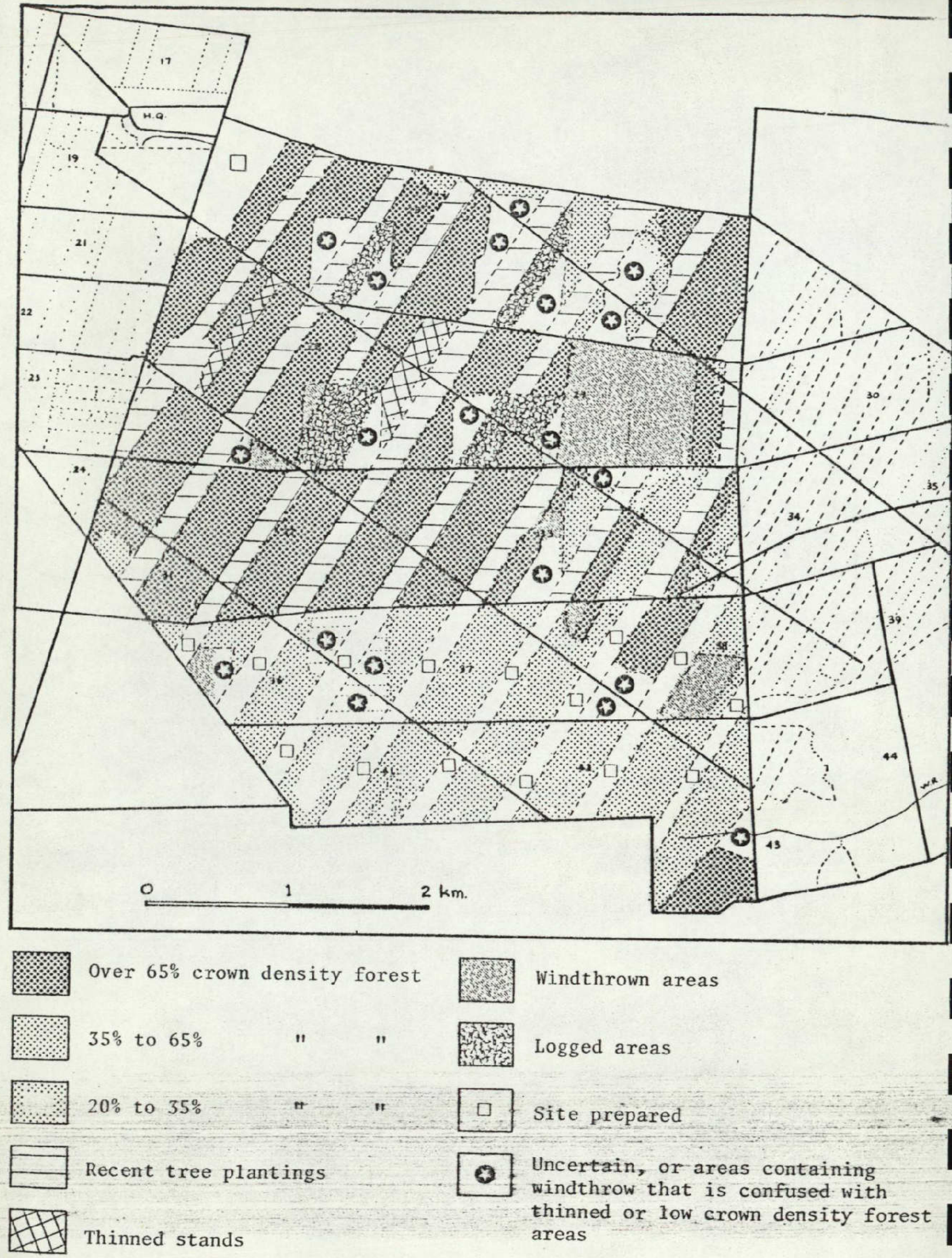


Fig. 19.2.3—Ground truth map of the study area in Eyrewell State Forest as at 1 November 1975.



—(Note: Numbers refer to forest management units, known as Compartments)

Fig. 19.2.4—A thermatic map based on the LANDSAT imagery.

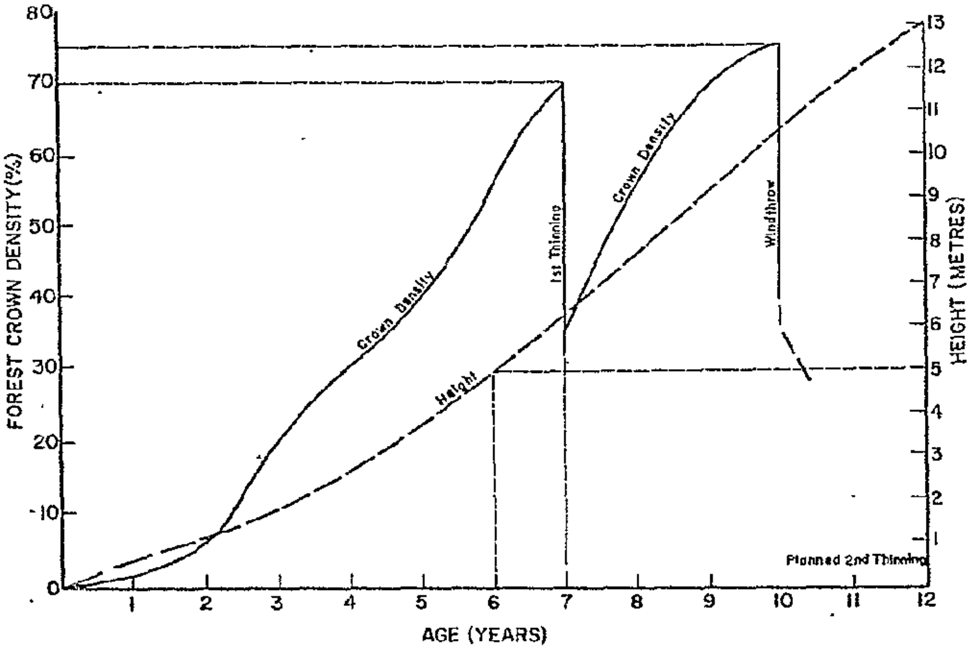


Fig. 19.2.5—Crown density of the Pinus radiata planted in the study area related to age, forest operations, or damage.

19.3 TYPING AND MAPPING OF THE KING COUNTRY VEGETATION

R W DALE

SYNOPSIS

The use of LANDSAT II imagery for the typing and mapping of forest and scrubland vegetation in the King Country region of the North Island of New Zealand was investigated during October 1976 to 1977. Density enhancement and colour composite techniques were evaluated for the typing and mapping of vegetation as part of an interdisciplinary land use investigation in the King Country. Results of the investigation were compared to vegetation type maps prepared from conventional aerial photography and field sampling.

19.3.1 INTRODUCTION

In 1975, New Zealand Forest Products Limited released details of a 60,000 ha afforestation scheme for an area lying between Taumarunui and Te Kuiti and east of the North Island Main Trunk Railway line (N.Z. Forest Products Ltd 1975). The area (Fig. 19.3.1) comprises farmland, reverting farmland, scrub, and indigenous forest, and includes Maori land, freehold land, State Forest, and other Crown land. Following submissions from various organisations, including conservation organisations, sporting groups, Government Departments, and local authorities, the Commissioner of the Environment's audit, while noting the lack of data available on the region, supported the company's plans in principle and recommended that the company proceed with more detailed planning and investigation (Commission for Environment Audit 1975).

Subsequent investigations of State Forests, which the company had hoped would provide a substantial proportion of the 60,000 ha required, indicated that much of the logged forest was not derelict as earlier assumed and was regenerating vigorously in many areas. In accord with the Indigenous Forests Policy for State Forests (New Zealand Forest Service 1977) which was being prepared at that time, a relatively small area was zoned as being available for conversions to exotic forest.

Fears expressed by the farming industry that the non-availability of State Forest for conversion would place greater pressure on existing farmland for afforestation, and by the local community at the social and economic effects of a large afforestation, and by the local community at the social and economic effects of a large afforestation scheme in the region, resulted in the Government calling for a full multi-disciplinary investigation of land use in the King Country, considering not only the potential use of land but the social, economic, and environment implications of various land use options available.

As a result of an inter-department investigation including the New Zealand Forest Service, Ministry of Agriculture & Fisheries, Ministry of Works & Development, Department of Scientific and Industrial Research, and the Department of Lands & Survey (who were charged with the co-ordination of the investigation) was initiated in early 1976.

To consider land use within the King Country region and its implications for regional social and economic development, the study area was enlarged considerably from the earlier area considered by N.Z. Forest Products Ltd, to extend from Rangitoto in the north to Erua in the south, west to the Wanganui River and east to Lake Taupo and Turangi, comprising a total of approximately 400,000 ha. This enlarged study area is also shown on Fig. 19.3.1

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19.3.2 THE ROLE OF THE NEW ZEALAND FOREST SERVICE IN THE LAND USE STUDY

The Land Use Study is a three-phase investigation:

Phase 1 collection and mapping of basic data such as vegetation, soils, geology, present land use, and land tenure.

Phase 2 assessment of land use potential for each discipline, e.g., pastoral farming, exotic forestry.

Phase 3 synthesis of phase 2 data to prepare a series of land use options for social, economic, and environmental scrutiny.

The major role of the New Zealand Forest Service in this inter-disciplinary study was:

(i) To type and map the existing forest and scrub pattern of the study area.

(ii) To evaluate and rank forest and scrub within the study area in terms of potential indigenous production forest management. Criteria used were forest condition, timber volume, species regenerating, abundance of regeneration and topography.

(iii) To assess the exotic afforestation potential of the study area. Criteria used were soil productivity, stability, slope, vegetation cover, and pathological risk.

19.3.3 APPLICATION OF REMOTE SENSING TO VEGETATION TYPING

The forests of the King Country were first typed in 1955 during the National Forest Survey (Masters, Holloway, McKelvey 1955). This assessment of the indigenous timber resource was undertaken during 1943-45 aerial photography, and was followed by a subsequent investigation (McKelvey 1963) that concentrated largely on the ecology of the forests and their development. Forest type maps at a scale of 1" : 1 mile, based again on 1943-45 aerial photography, were again produced.

However, during the intervening decades, extensive forest modification has taken place, large areas being logged, converted to pasture, burnt and left to revert to scrub, or, more recently, converted to exotic forest. Aerial photography of the region was at varying scales, quality, and age, some up to 10 years old. As good quality recent LANDSAT II imagery was available for the entire study area (Fig. 15.22), the potential of LANDSAT multispectral imagery for identifying and typing forest and scrub was investigated.

19.3.4 TECHNIQUES USED

LANDSAT II imagery, scene number 2389-21172 taken on 15 February 1976, was used for the investigation

Two basic techniques were evaluated at the Remote Sensing Section's Laboratory at Lower Hutt:

Colour Additive Viewer

Three colour composites were prepared on the colour additive viewer. The original transparencies were enlarged and photographically enhanced by the PEL Photographic section and colour combined using the usual additive balances of Band 4 Blue, Band 5 Green, and Band 7 Red in the following exposures:

		Band		
Composite	4 Blue	5 Green	7 Red	Exposure
1	0.5 neg	0.6 neg	1.0 neg	18 secs
2	2.0 neg	1.0 pos	2.0 pos	3 secs
3	2.0 neg		2.0 pos	6 secs

Colour prints were prepared for each composite at the above exposures. Colour composite number 1, with the dominant red component, proved the most satisfactory for distinguishing between vegetation types; grassland, scrub, and several forest types were easily identified. Greatest resolution of topography and other features was also obtained with this composite (see Fig. 19.3.2).

The vegetation types identified on the colour composite number 1 were correlated to a vegetation map prepared from conventional photographic interpretation and field sample for a test area near Pureora, north-west of Lake Taupo. The correlation is tabulated below:

Photograph Colour	Code	Vegetation Type
Light Red/Pink	1	Pasture
Blue	2	Urban or indigenous forest recently logged or converted to pasture or exotics
Even textured Red/Orange	3	High altitude hardwood forest
Even textured Red/Blue	4	Exotic forest. Blue component is reduced as exotic canopy closure occurs.
Dense Black	5	Dense podocarp forest
Red & Black	6	Cut-over forest, generally a well structured tawa forest remaining
Lighter Red - Less Black	7	Heavily cut-over podocarp-hardwood forest with a low mosaic of kamahi and other scrub hardwood species
Light textured Red/Black	8	Scrub Areas

The western shore of Lake Taupo appears on the right hand side of the photograph, the township of Taumarunui being clearly visible as blue on the Wanganui River. Te Kuiti shows clearly in the top left hand corner of the photograph as blue also. The high altitude hardwood forest along the main crest of the Rangitoto and Hauhungaroa Ranges shows clearly, and the dense virgin podocarp forest of Pureora and Waihaha State Forests north-west and west of Lake Taupo respectively are clearly shown. Most obvious on the photograph are the blue areas recently cleared of forest or scrub cover and converted to pasture or exotic forest. The most obvious is a 5,550 ha block recently converted by New Zealand Forest Products Ltd at Pureora, and a similar area west of Lake Taupo. Older exotic stands at Pureora, Waituhi, and Tihoi State Forests appear as an even textured red.

19.3.5 SCALE ENLARGEMENTS

All maps for the Land Use Study are being produced at a scale of 1:63,360, whereas the scale of colour composites was 1:500,000. Interpretation for mapping at a greater scale was difficult.

To enlarge the photographs to a working scale the composites were photographed and enlarged by the National Publicity Studios to scales of 1:100,000 and 1:63,360.

A portion of the Pureora test area is shown at a scale of 1:100,000 in Fig. 19.3.3. The vegetation typing of the test area produced by conventional means is shown in Fig. 19.3.4.

19.3.6 ISODENSITOMETER

(1) Positive transparencies of a single MSS band were viewed on the colour-enhancing densitometer and the image viewed on the colour cathode screen. The video camera was adjusted to maximum magnification producing a screen image at a scale of approximately 1:80,000.

(2) A Pentax 35 mm camera was mounted on a tripod 1.5 m from the camera and the entire King Country Land Use Study area was photographed on 15 colour transparencies. A grid was later superimposed to facilitate identification of each slide.

(3) Various MSS bands were used in the isodensitometer in an endeavour to distinguish between various vegetation types in a test area near Pureora. The red band, 6, provided the greatest range of densities and allowed identification of various vegetation categories.

(4) It was intended to project the colour slides on to a screen containing topographical base data. However, distortion from curvature of the colour cathode screen, incorrect alignment of the camera, and the lack of recognisable control points prevented close registration and mapping of vegetation types using this technique.

(5) A mosaic was prepared from colour photographic prints reproduced from the colour transparencies of the isodensitometer image for an area covering the Hauhungaroa Range, Hurakia, Waihaha, Waituhi, and Taringamoutu State Forests, south to Tongariro National Park. The mosaic, reproduced in Fig. 19.3.5, shows the type of species differentiation possible using density enhancement. In this mosaic, the colours correspond to vegetation types as follows:

Dark Blue/Black	Dense podocarp forest comprising rimu, matai, totara, kahikatea, and miro.
Deep Blue	Moderate-dense canopy of larger hardwood species, particularly tawa, hinau, kamahi, and maire.
Lighter Blue	Open-less dense canopy of above species.
Yellow shades	Scrub areas including bracken, heath, gorse, manuka, kanuka, and scrub hardwoods remaining following intensive logging of podocarp forest.
Clear areas	Areas of grass, very light scrub, and areas recently converted to grass or exotic species. Older exotic species appear as a blue/green/yellow haze in Pureora Forest in the mosaic.

A fine transparent overlay of road and stream patterns on the 1:1,000,000 transparency would provide more accurate registration for mapping.

Conclusion on use of LANDSAT MSS Imagery for Typing of Indigenous Forests in the King Country

1. Tight deadlines were imposed for the completion of the King Country Land Use Study, so it was not possible to develop and test the necessary techniques for a full-scale vegetation typing exercise. Minimum area recognition of 15-20 ha was specified for the Land Use Study at the 1:63,360 mapping scale; to apply LANDSAT imagery to such intensive mapping was considered somewhat optimistic at such an early stage in the investigation.

2. Only the colour additive viewer and density enhancement techniques were evaluated. Using these techniques it was possible to identify and map broad categories of vegetation, although the difficulty of producing images at a scale suitable for mapping and registration with topographical features was a limitation.

3. However, spectral signatures on MSS imagery are affected by both solar elevation and topographic relief patterns, which cannot be compensated for using colour additive and density

enhancement techniques. Variation in slope and aspect can cause significant variation within an individual spectrum signature for a specific forest type, and can also cause overlap of spectral signatures between several forest types. Solar elevation would also vary spectral signatures for a specific forest type, and atmospheric effects during imagery could also affect the signature recorded.

4. The use of digital enhancement techniques using digital information on computer tapes can minimise the effect of solar elevation and topographic variation. The use of digital information could also increase resolution and allow delineation of smaller areas of vegetation.

5. Limited access to the necessary digital tapes and delays in processing digital imagery for this particular study meant that the full potential of MSS imagery was not utilised for this study.

6. Special signatures also vary with seasonal changes in the physiological state of vegetation species. The effect of seasonal variation could be determined from a series of imagery covering a range of seasons.

7. For national studies such as monitoring changes in the indigenous forest resource on a year-to-year basis, particularly within the private forest sector, LANDSAT imagery would be a valuable management aid.

8. The information gained from the initial study of the application of MSS imagery in vegetation typing shows that for future regional studies LANDSAT imagery can be considered a valuable management aid to the forest manager and planner.

ACKNOWLEDGEMENTS

The assistance of Mr N. P. Ching, N.Z. Forest Service, Wellington, and the staff at PEL is gratefully acknowledged. Also to Mrs J. R. Sims, N.Z. Forest Service, Auckland, for draughting and preparation of the maps.

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Masters, S. E.; Holloway, S. T.; McKelvey, P. J. 1955: The Indigenous Forest Resources of New Zealand.

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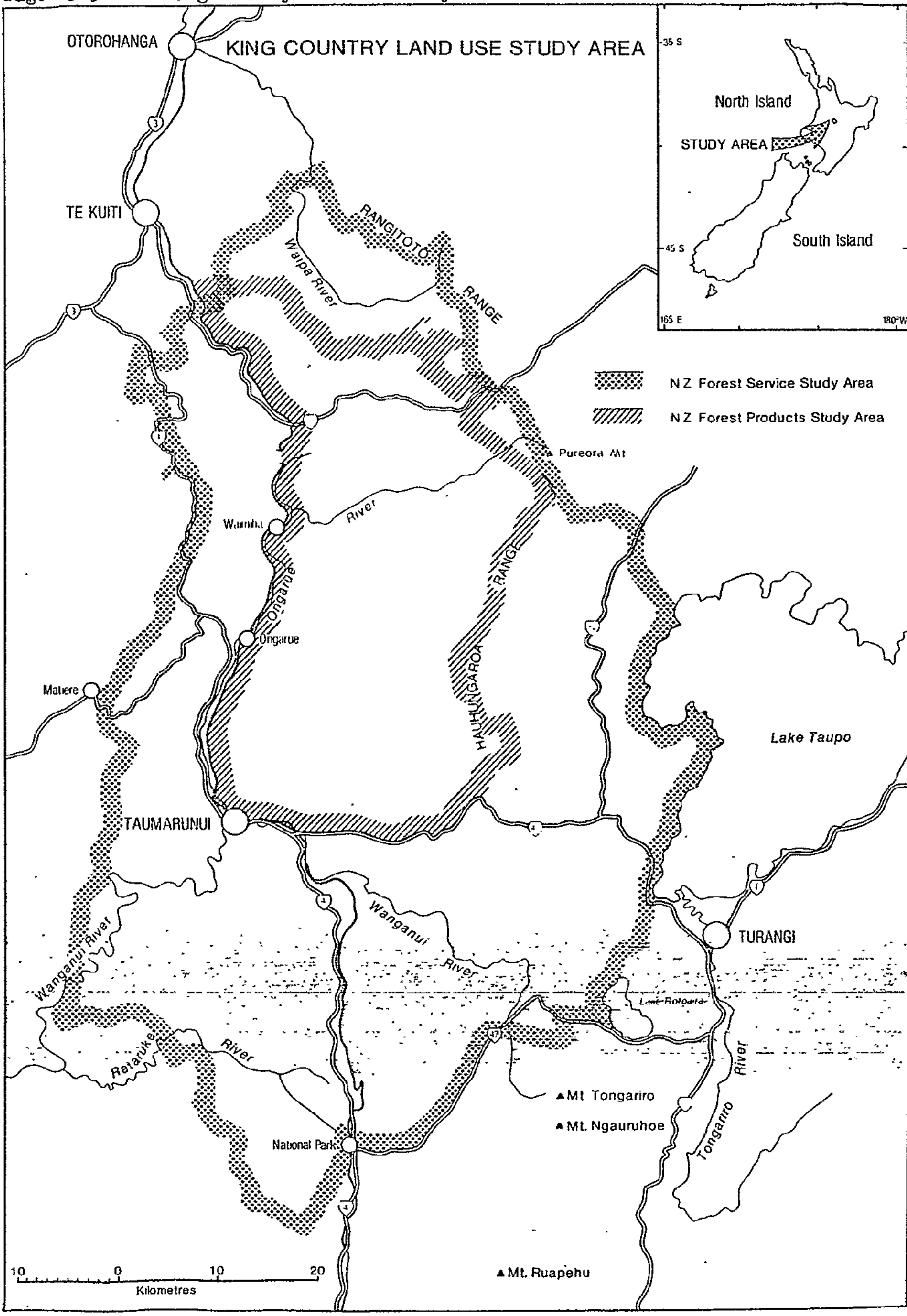
New Zealand Forest Products Ltd 1975: Environmental Impact Report Re-afforestation Proposals in the King Country.

New Zealand Forest Service 1977: Management Policy for New Zealand's Indigenous State Forests.

Fig. 19.3.1 - King Country Land Use Study Location



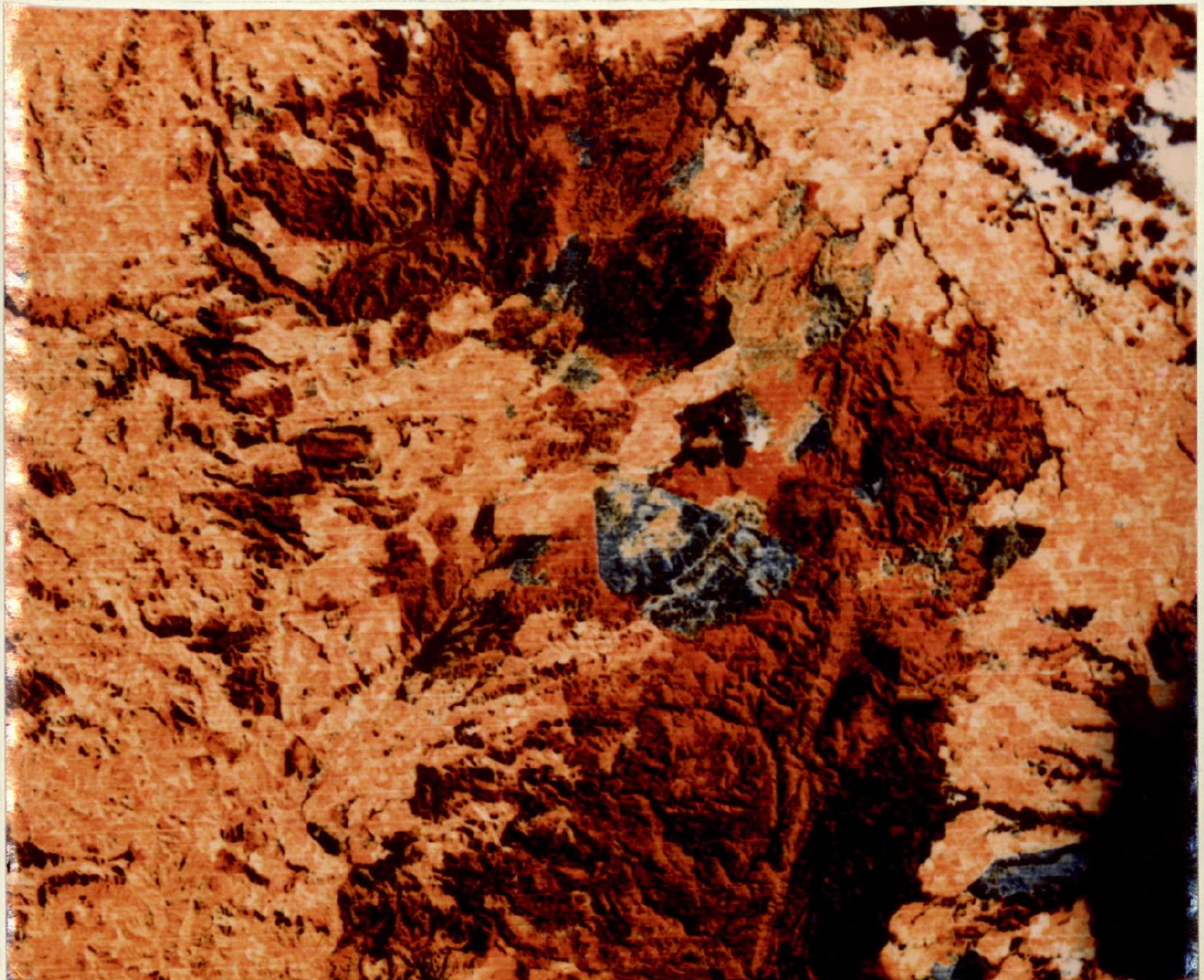


Fig. 19.3.2 An enlargement to 1:500 000 of the 15 February 1976 LANDSAT II image 2389-21172, of the King Country area, produced on the colour additive viewer.

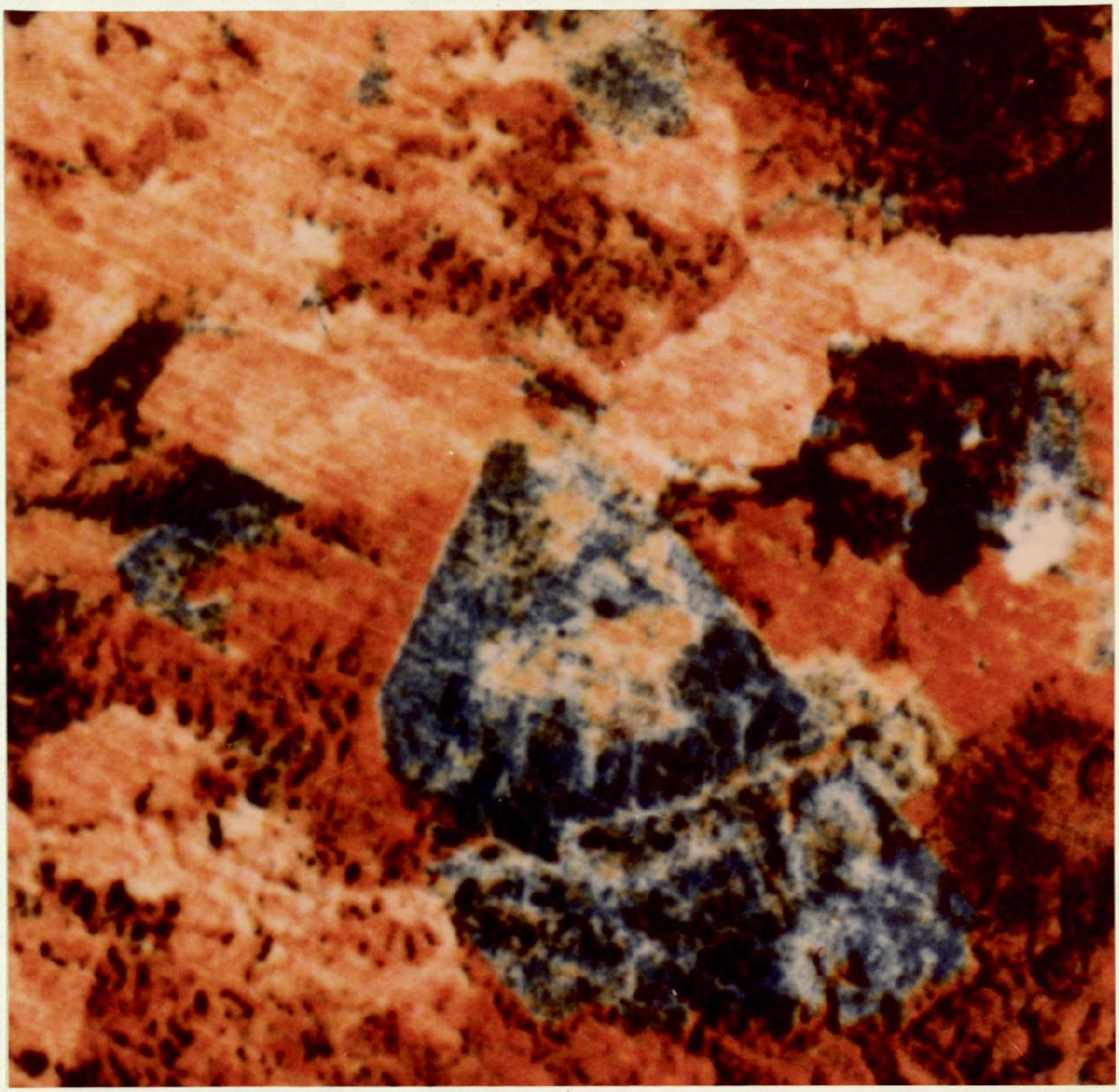


Fig. 19.3.3 An enlargement of Fig. 19.3.2 to 1:100,000 showing a portion of the Pureora test area.

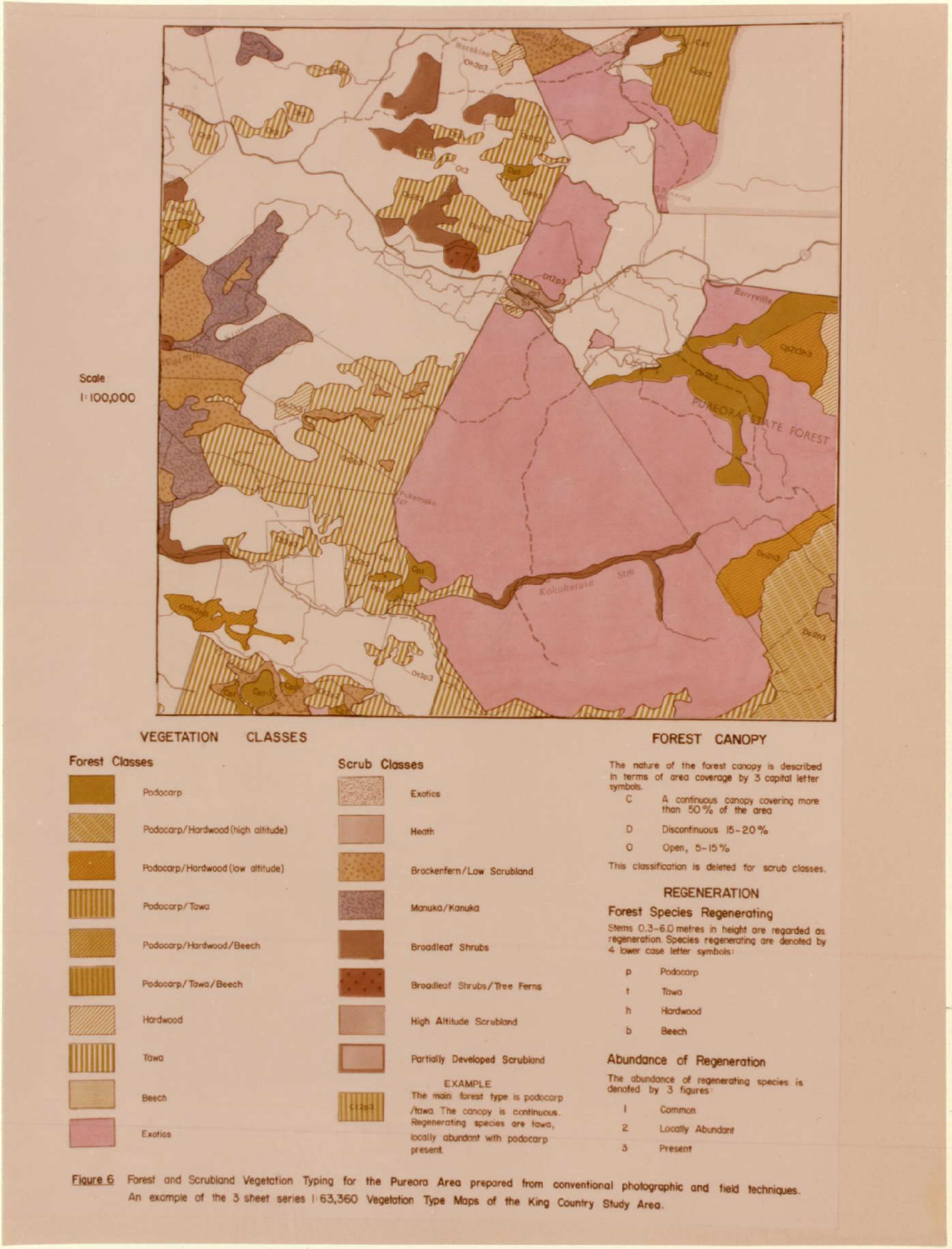


Figure 6 Forest and Scrubland Vegetation Typing for the Pureora Area prepared from conventional photographic and field techniques. An example of the 3 sheet series 1:63,360 Vegetation Type Maps of the King Country Study Area.

Fig. 19.3.4 The same area as Fig. 19.3.3 compiled from field surveys and conventional aerial photography.

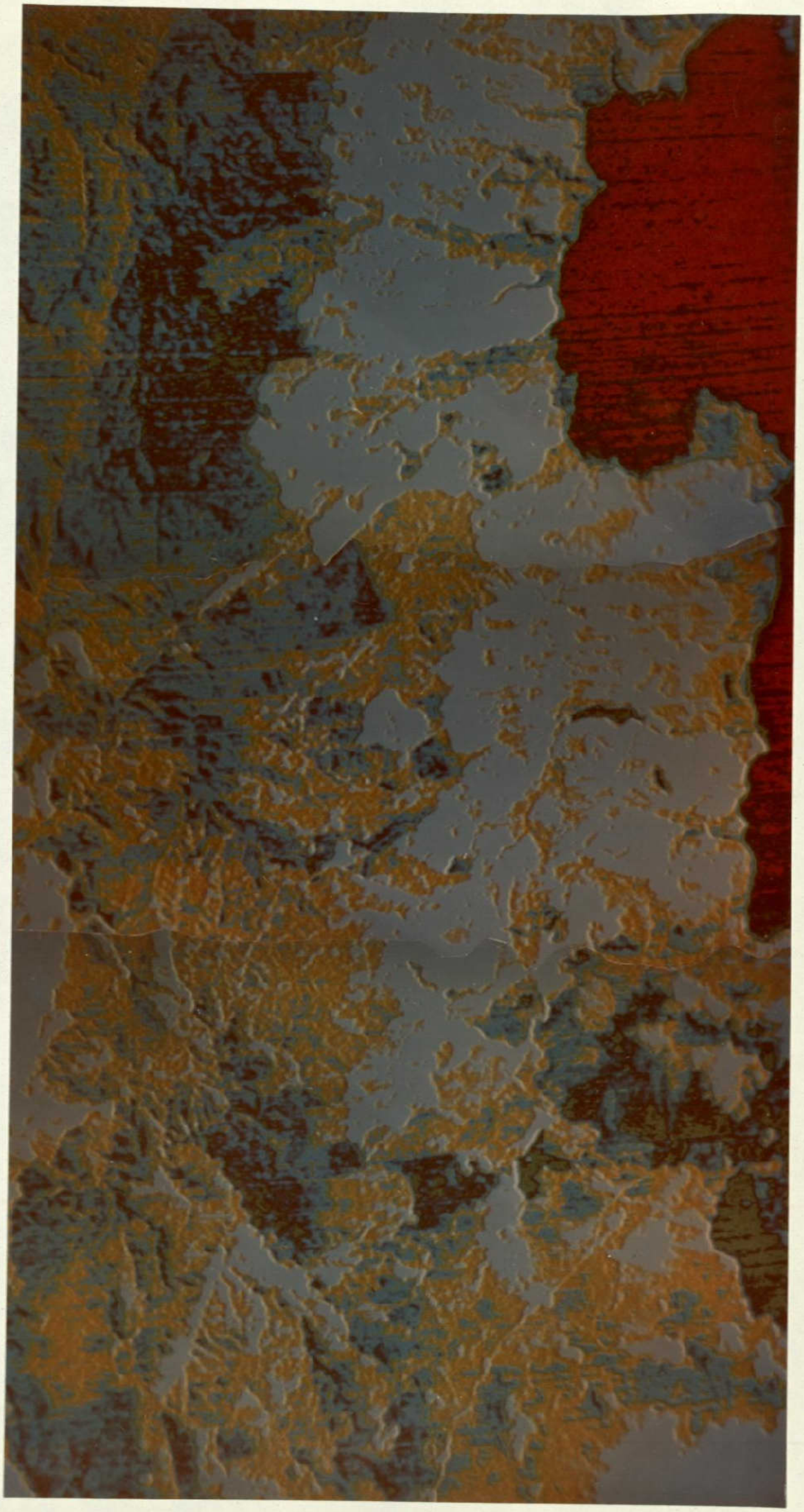


Fig. 19.3.5 Colour isodensitometer coding of density levels from MSS band 6 of the 2389-21172 scene recorded 15 February 1976.

19.4 SNOWFIELD ASSESSMENT FROM LANDSAT

I. L. Thomas
A. J. Lewis
N. P. Ching

Investigations were initiated by the National Parks Authority to study the possibility of setting up an alternative to the present Mount Robert Skifield in the Nelson Lakes National Park. LANDSAT imagery was proposed as a means of mapping to obtaining a record of snow conditions and cover on the St Arnaud Range and to provide a comparison to that of the Mt Robert Skifield. The St Arnaud Range is the highest and most easily accessible snowfield in the region. Of the several basins in this range the "Six Mile Creek" headwaters appeared to have the most potential because of its size, altitude, aspect, topography, and physical accessibility.

The only existing Winter LANDSAT scene, 2282-21252, was used, first of all, to locate suitable ground truth sites and secondly to study whether measurements of snow type and snow cover could be made.

Based on the 31 October 1975 image, a transect line was established across the basin. (See Fig. 11. 1, Chapter 11) Data on snow depth was collected on two occasions which coincided with LANDSAT overpasses. Unfortunately no imagery was recorded.

Successful investigations were made using the imagery as well as the CCT data, and these are reported fully under Chapter 11 of this report. Below is a copy of the abstract.

ABSTRACT

The potential use of LANDSAT MSS data for routine monitoring of the area and condition (type/depth) of a snowfield is explored. Area measurements are readily possible from the photographic product and the CCT data. The CCT data may also reveal variations in snow density and/or moisture content. This study demonstrates that LANDSAT MSS data have the potential for contributing to rapid assessment and management of snowfield resources, especially if repetitive satellite coverage is obtained.

Although further work relating actual snow conditions to the recorded radiances is necessary, the importance of using absolute radiance values from CCT data and of considering the effect of topography on recorded snow reflectance is demonstrated.

Due to failing data tape recorders on LANDSAT II, aircraft multispectral imagery has been requested and is hoped to be available from a flight during September 1977. Every effort will be made to coincide this flight with a LANDSAT II overpass in the hope that spacecraft imagery will be obtained. Ground truth data will be collected during this survey. By the 1978 skiing season it is hoped that LANDSAT C will be operational so our study of the skifields can be continued using spacecraft imagery.

19.5 HANMER FOREST FIRE-DAMAGED TREES

B. Lean
P. Hay

ABSTRACT

Underflight mltispectral photography was viewed on a colour additive viewer and clearly depicted the dead and living foliage and defoliated trees of the burnt forest.

19.5.1 INTRODUCTION

In March 1976 a fire burnt 537 ha of pine plantation in Hanmer State Forest. It was proposed to see what detail of foliage change could be detected on LANDSAT data.

19.5.2 DATA COLLECTION

Both colour and panchromatic and infrared 70 mm photography have been taken over the area. Weather conditions precluded any LANDSAT data being taken. During February 1977 an underflight was successfully made by DSIR staff and multispectral photography obtained.

At Physics and Engineering Laboratory of DSIR the colour additive viewer was used with the negatives of bands 5 (0.6 to 0.7 μm), 6 (0.7 to 0.8 μm), and 7 (0.8 to 1.1 μm). Red light was projected through band 5, green through band 6, and blue through band 7. An example of the composite imagery is shown in Fig. 19.5.1.

19.5.3 RESULTS

The black and white infrared photography showed up in sharp contrast the living and dead trees. Colour photography depicted the scorched (brown) and green foliage of the burnt trees. Small changes were interpreted with difficulty when photography taken in different seasons was compared because of the shadow and colour saturation variations.

Multispectral imagery showed up very clearly the living foliage. For example, in Fig 19.5.1, the trees with live foliage show up as red. The green areas contain defoliated trees and trees with dead foliage. In this scene the defoliated and dead foliage area is 106 ha. This is 1% less than the areas that were mapped a year ago as scorched or defoliated. Small areas of partially scorched foliage (3 ha) have shown up more definitely without sign of recovery, and some areas of scattered scorched trees (7 ha) show up as living.

Fig. 19.5.1 Hanmer State Forest, colour additive, multispectral scene M.S.H. 12/A/8. The live foleage is red and the defoliated trees or dead foliage green.

19.6 POTENTIAL FOR THE USE OF LANDSAT IMAGERY IN WESTLAND INVENTORY PROPOSALS

A. D. Reid

A preliminary investigation into the use of LANDSAT II imagery has been carried out in Westland Conservancy. Its undoubted potential has yet to be applied as a management tool in the region, and these notes briefly discuss its potential as an interpretive medium. The accompanying photographs were prepared from colour slides of scenes displayed by the colour additive viewer located at the Remote Sensing Section, Physics and Engineering Laboratory, DSIR, Gracefield, and cover areas in the central portions of Westland.

LANDSAT would appear to provide a great deal of scope for typing broad land use and indigenous forest in Westland. In addition its resolution and multispectral attributes may provide information on the vigour and stocking of exotic stands in the conservancy. Its role is seen to complement the more detailed planning facility afforded by lower-level aerial photography. Its specific assets include continuous up-dating of information, the provision of infrared scenes, and broad coverage of the area. These assets could prove particularly valuable in the extensive indigenous forest areas of South Westland where aerial photograph coverage has not been up-dated recently.

Figs 19.6.1 and 19.6.2 illustrate broad zones of interest. These include geographical features such as steepland and lowland areas, lakes, waterways, and drainage patterns. Information on the extent of forested land, protection forest zones, and lowland production areas may be readily provided by the highlighting and quantifying of specific interest. This would involve the use of interpretative apparatus, viz, the colour additive viewer and isodensitometer located at the Physics and Engineering Laboratory. This would complement existing zone area data at present used by Westland Conservancy.

Figs 19.6.1 and 19.6.2 illustrate more detailed features including land cover. Broad indigenous forest types (important units in indigenous forest management), scrub, cleared land, and exotic plantation areas may be discerned. Of particular interest is the strip-felled area (alternating bands of virgin and cut-over indigenous forest) to the north of Lake Kaniere. Wetland areas areas are also highlighted. Area information on these land cover types and forest types could be provided by the apparatus mentioned above.

Yet to be investigated is whether the resolution capabilities of LANDSAT will enable exotic stocking and stand health to be assessed. Fig. 19.6.3 illustrates some of the exotic stands in the region. Of particular note are those in Mahiaipua State Forest to the south of Hokitika township and Kaniere and Omoto State Forests to the east of Hokitika and Greymouth respectively (the stands appear as red zones in the predominantly green shades of indigenous forest and farm land. Areas of turbid water also appear as red).

It is felt that LANDSAT will provide valuable information in subsequent work carried out in this conservancy.

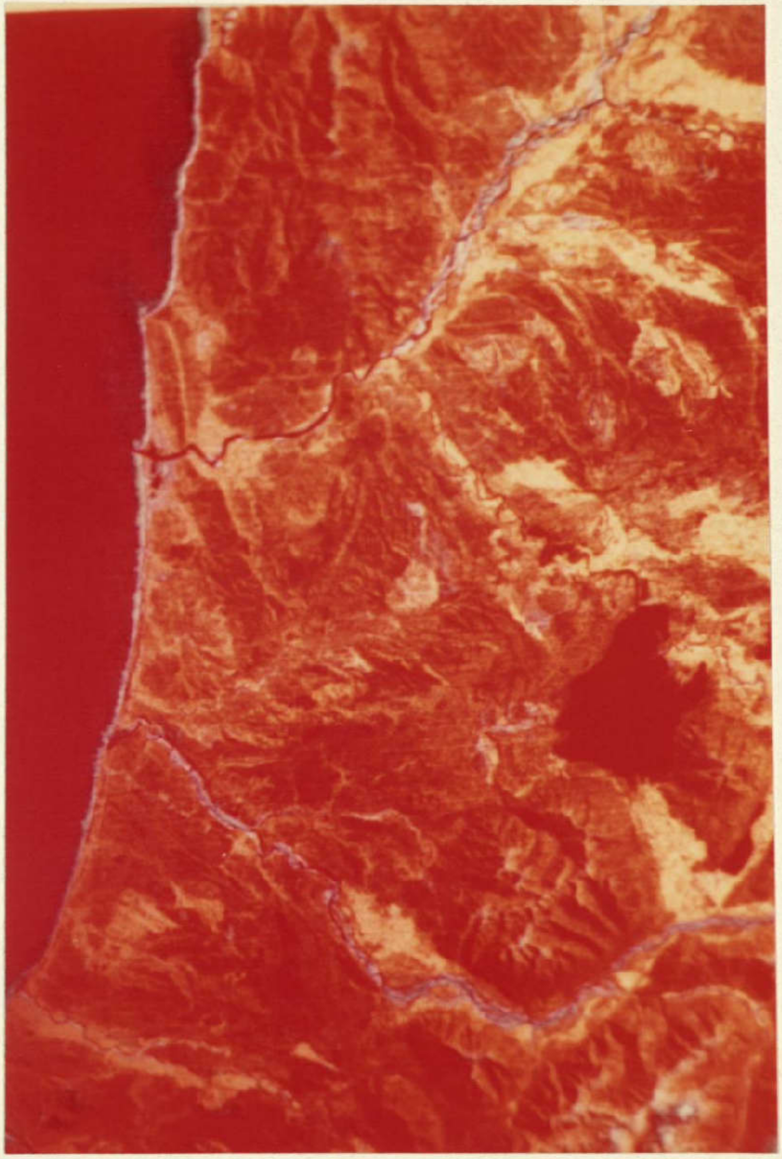


Fig. 19.6.1 General geographical features.
Greymouth - Taramakau Rivers.

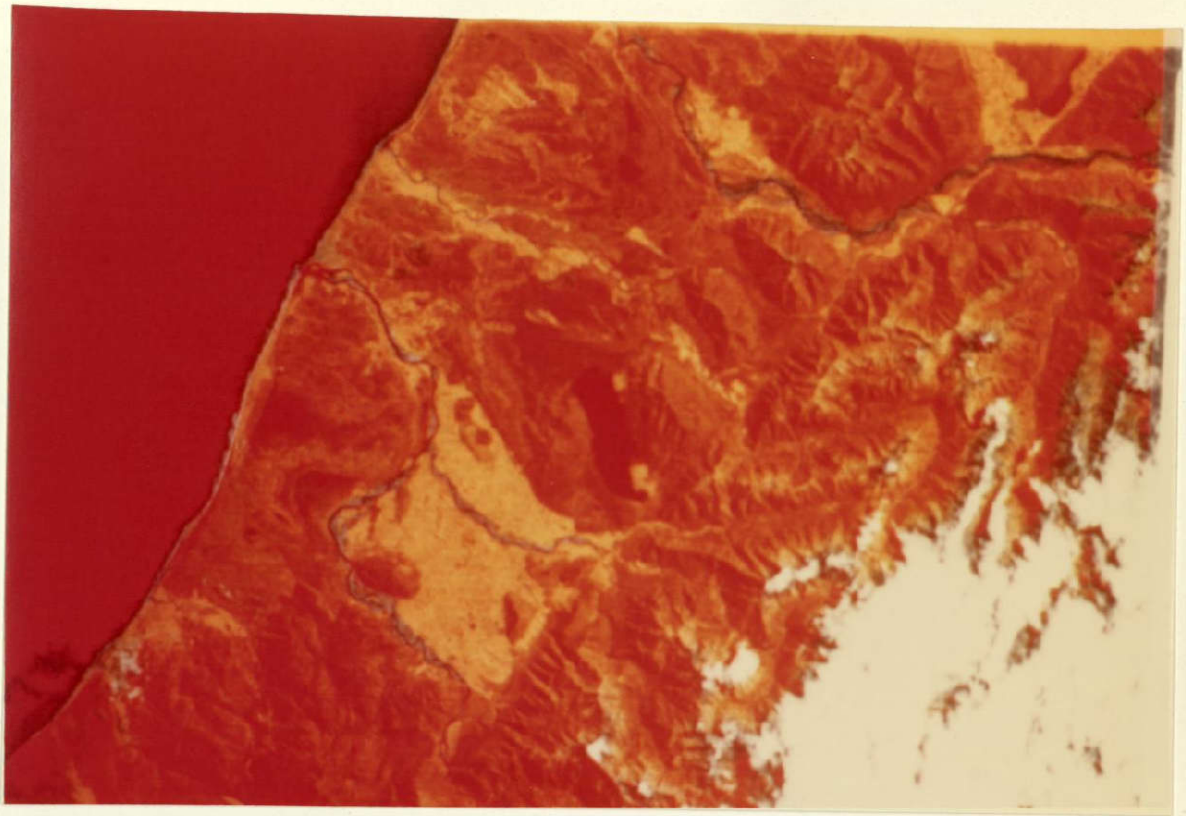


Fig. 19.6.2 Land cover east of Hokitika. Some exotic stands visible.

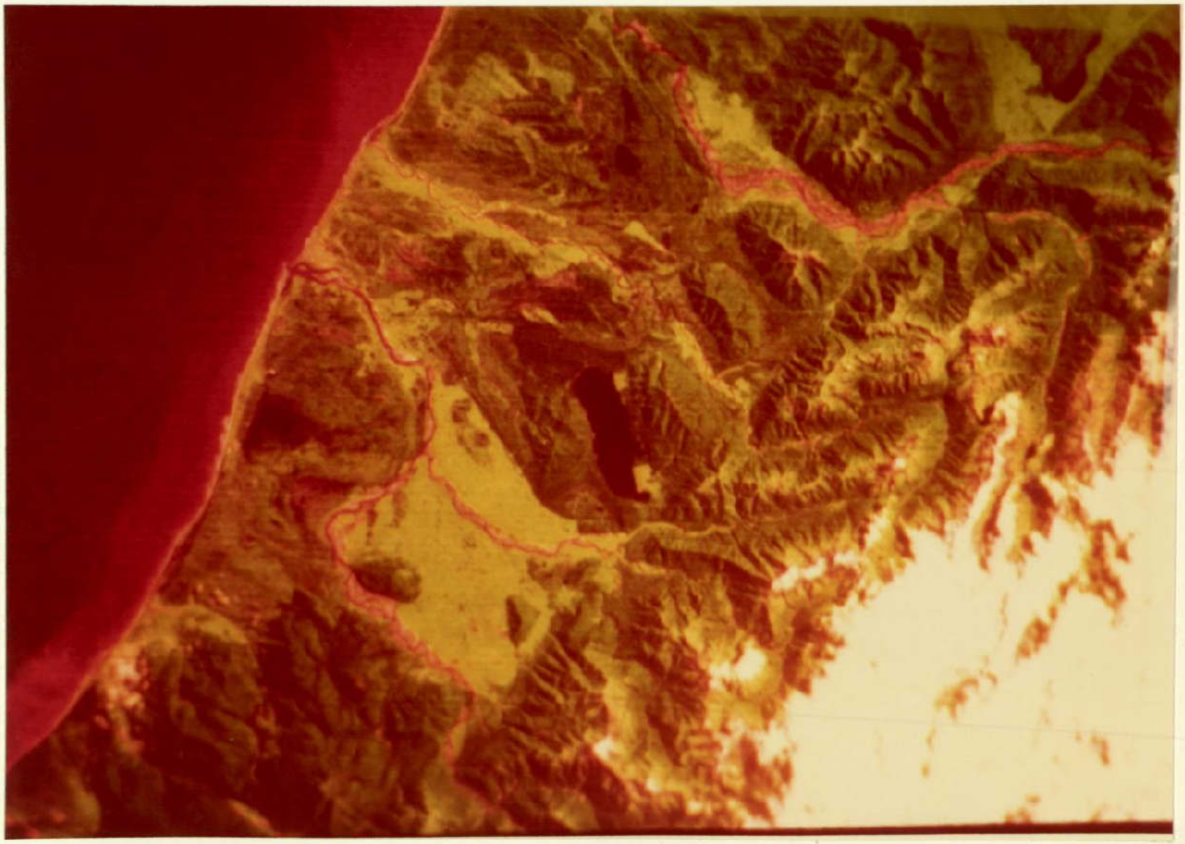


Fig. 19.6.3 Land cover. New exotic stands - red.

19.7 PRIVATE FOREST RESOURCE STUDY

I R Hunter

19.7.1 INTRODUCTION

This study with LANDSAT imagery is occasioned by the need to estimate the location, area, species, and age class distribution of private forests in the Wellington conservancy of the N.Z. Forest Service.

The problems associated with this estimation are:

1. The size of the land area involved. Wellington conservancy covers the whole southern half of the North Island of New Zealand (south of 38' 30" and has an area in excess of 5 million ha. Much of the land area will have some forests.

2. The preponderance of small units. Approximately 25% of the total volume resource is distributed in woodlots smaller than 4 ha. For the conservancy as a whole 3000 of the estimated 3600 woodlots are smaller than 4 ha. These small woodlots contain the bulk of the mature timber and are of great importance in the short term.

3. The general shortness of rotation lengths. Generally the clearfelling age of the main exotic species, Monterey pine (*Pinus radiata* D. Don) is less than 35 years. In any 10 year period therefore up to a third of the total area may be expected to change at least in age class and possibly in land use.

4. No complete reporting procedure. Apart from the forests established under grant from the government which have accurate information recorded about them, reporting on other private forests is incomplete.

Possible methods of obtaining this data are:

1. By returns to Forest Service or other Government department. This approach may in future have more value than it has had, but may always be weakened by non-compliance and by poor definition. Some small forest owners grossly under- or over-estimate the value and area of their woodlot.

2. By aerial survey. Such an approach has great value for the large private woodlots where the area covered justifies the cost of photography. Scattered smaller woodlots would be prohibitively expensive to photograph specially. General-purpose photography done by other departments has value only when very recent.

3. By ground survey. Apart from the fact that in hilly country woodlots are not always readily visible from road access and hence may be missed, this is the most expensive option. Generally the cost precludes more than a very infrequent survey which then rapidly becomes out of date.

The expected role of LANDSAT imagery is therefore to provide a relatively cheap way of updating our data base on the private forest resource.

19.7.2 LANDSAT INVESTIGATIONS : METHODS AND RESULTS

19.7.2.1 Isodensitometer

Using one band (generally band 6) of scene 2299-2119000 taken on 17 November 1975 of the Manawatu agricultural area which has coastal State Forests and inland farm woodlots against a background of permanent pasture, a calibration could be achieved which highlighted large areas (greater than 10 ha) of pine forest known from a ground truth study. However, there was considerable interference from areas of scrub and native forest which it proved impossible to exclude on this one-band approach.

19.7.2.2 Lineprinter pictures

Tapes from the above scene were available to PEL and they used a multiple-gate program to screen the pixel values for pine forest. In the first series of runs the values were:

Band	Radiance values From	To
4	8	18
5	6	14
6	27	36
7	15	22

In the area covered (scan lines 931-1428 and pixels 380 to 854) there was poor separation of pine forest from other agricultural uses of bands 4 and 5. Most of the area under pasture passed tests in these bands. Separation improved markedly in band 6.

Areas passing all 4 tests and identified as pine forest were then checked for ground truth. It was found that closed-canopy pine forest was identified with considerable accuracy. There was little consistent differentiation into species, however, in Waitarere State Forest test area which included Monterey cypress (Cupressus macrocarpa Hartw.) and maritime pine (Pinus pinaster Ait.) as well as Monterey pine.

This result was a trifle disappointing in view of the excellent species separation achieved in Kaingaroa State Forest (see Fig. 5.2), and is of importance to our study where the many areas of Monterey cypress represent a less merchantable resource.

Young pines or stands that had been recently thinned were not located by the scanning. Known locations of such areas failed the test in Band 6. The listing of radiance values was studied, and it was found that these areas were considerably brighter in Bands 6 and 7.

There was some interference from areas which were not pine forest. These, checked on the ground, proved to be manuka scrub (Leptospermum scoparium J. R. & G. Forst.), native bush (podocarp and hardwood species mixed), or yellow lupin (Lupinus arboreus Sims). In most cases the radiance values for these areas proved central to the pine forest range in this scene. The native bush, however, is darker on Bands 4, 5, and 7 than the pine forest, and it is probable that by increasing the lower limit of the gates as follows

	Band No.			
	4	5	6	7
Lower limit	10.00	8.00	29.00	17.00

much of the interference from native bush can be excluded while retaining over 95% of the pine forest pixels.

19.7.2.3 Lineprinter pictures with revised program

Experience with the first series of runs indicated that:

a) Since there is considerable scale distortion in the line-printer picture (east-west skew and north-south stretch), landmarks such as towns and rivers would aid location.

b) Young pine forest might be located by a change in the radiance spread.

PEL therefore revised their programme to search for several targets at once.

Radiance Values

Band	Old Crop From	Old Crop To	Young Crop From	Young Crop To
4	10	15	15	21
5	8	16	17	25
6	29	41	45	57
7	17	24	24	33

On a printout from scene 2299-2119000 (scan lines 847 to 1557 and pixels 420 to 754) the following results were achieved:

a) Areas of water such as estuaries, lakes, and sea are clearly defined and are of great help in location of forest areas.

b) Urban areas are adequately defined and are of further assistance.

c) Areas of old crop pine forest larger than 2 ha were located with fair accuracy. There was a low level of misidentification in the known ground truth areas.

d) Young crop pine or thinned pine identification suffered from more failures to locate known areas and from much more random 'noise'.

19.7.2.4 Evaluation in terms of objectives

a) With some uncertainty due to misidentification the presence of woodlots of closed-canopy pine type with areas greater than 2 ha can be located from line printer pictures.

b) Areas of woodlots less than 20 ha cannot be accurately defined in this generation of satellite picture due to the large pixel size.

c) Species cannot be separated, and only an indirect indication of age class can be achieved by the radiance values.

d) The line printer pictures can therefore be used as a method of indicating changes in stocked area, which can be checked by a directed ground search.

19.7.2.5 Further work

a) It is thought that a spring scene, the only one available to us, is not as good as an autumn scene in discriminating between vegetational types. One December 1973 scene gave much better separation on the isodensitometer than the November 1975 scene. Tapes of this scene are being acquired.

b) Initial analysis of spectral frequency distribution for young pine and for different species provides no simpler answer to problems encountered here. This aspect will have to be developed further and perhaps spectral signatures of various phases of plantation pine studied separately.