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AN APPROACH TO MANAGEMENT OF
THE MOKAU COAL RESOURCE

A project
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of the requirements for the Degree
of
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Frontispiece: Mokau Coalfield, view N.E. across Awakau Valley area towards centre of coalfield. Manga-awakino Valley on left, Mokau River flows from right.

ABSTRACT

The Mokau Coalfield, North Taranaki, New Zealand contains about 73 million tonnes of mineable coal which may be required to fire a 1000 MW thermal power station. Planning for development of the coalfield is at an early stage and current investigations are oriented towards coal resource measurement and infrastructure requirements.

The predominantly rural environment of the Mokau Coalfield region will suffer a number of impacts if coal development is to proceed at the proposed scale. Early recognition of these impacts, together with recognition of possible constraints on development, is desirable so that development planning may maximise environmental benefits. Traditionally coal development does not incorporate environmental information until the late feasibility stage of planning. It is however desirable to initiate environmental management planning at an early stage of coal resource development planning. Early inclusion of environmental aspects is possible and an approach to environmentally aware management of the Mokau coal resource is illustrated. The approach relies on development of a materials balance for both mining and use sectors of the development.

The materials balance details inputs to the development (i.e. resource requirements) and identifies all outputs as primary product, increased inventory or residuals. A planning framework is described whereby environmental factors are incorporated into mainstream planning at the pre-feasibility stage.

A number of potential impacts and constraints are identified in this largely indicative study. Before all impacts and constraints can be identified a more detailed study, using the methods developed here, is warranted.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

The Mokau Coalfield is located in an area of dense bush and reverted farmland in the area between South Auckland and North Taranaki, about 80 km north-east of New Plymouth (Fig.1.1, 1.2). The coalfield has had an intermittent history of mining since the middle of last century and about 120,000 tonnes of coal have been extracted. The Mokau coal resource has been the subject of much interest in recent years. Maori owners of a large portion of the coal initiated investigations with the aim of private development of the resource. Mines Division of the Ministry of Energy has become involved in investigations since 1980 and exploration work is continuing. This work indicates that reserves of at least 75 million tonnes of sub-bituminous coal are mineable by opencast and underground methods. This tonnage represents about 10% of the nation's recoverable bituminous and sub-bituminous coal reserves (Ministry of Energy, 1983).

At present, there are no definite plans for use of the coal, however the coalfield is recognised in the 1983 Energy Plan (Ministry of Energy, 1983) as a possible contributor to national electricity supplies. The Ministry of Energy (1983) believe that a further coal-fired thermal power station of 500MW will be required in the North Island, to provide for predicted demand, by 1995. This proposed 'North Island Thermal No.1' is hopefully to be supplied with coal from the Maramarua coalfield, in Waikato. However, that field may not be able to supply the subsequent development of North Island Thermal No.2 (500MW). The major alternative supply of coal for that station (as yet unsited) would be the Mokau Coalfield



FIG.1.1: Mokau Coalfield; part of southern opencast area.



FIG.1.2: Mokau Coalfield; region of Kaipaku Stream, Manga-awakino stream junction.

(Ministry of Energy, 1983). In view of possible shortages of coal in the Waikato, Ministry of Energy (1983) stated that

"Investigations on coal supply for North Island Thermal No. 1 should be extended to cover other deposits as well as those of the Maramarua field, specifically the Mokau field."

First commissioning dates for the power stations, assuming maximum electricity demand, are 1995 (North Island Thermal No. 1) and 1997 (North Island Thermal No. 2).

Therefore, although no definite plans have been formulated for the Mokau coal resource it is being regarded as a source of 'contingency' coal for supply of either or both of the proposed stations. There is, then, a distinct possibility that the Mokau coal will be used in a 500MW power station and it could be required to supply a 1000MW station. There is at least 10 years before the likely commissioning of a power station, however some studies have been carried out on the coalfield. These have investigated the size, extent and quality of the coal reserves (Phelps, 1982), possible mining methods and costs (Longworth et.al.,1982), and some infrastructure requirements and costs (Ministry of Works and Development, 1983a). As yet, no specific environmental studies have been carried out.

The coalfield is largely unexploited and the region is predominantly rural with no existing infrastructure at a scale sufficient to support a major development such as a mine and power station. Thus initiation of coal mining at a rate sufficient to supply a large thermal power station (2 Mt y^{-1} for a 1000MW facility), and location of the power station in the area would be expected to have a number of impacts on present land users and on the environment.

Environmental studies are carried out as a matter of course in coal development. However, these studies are generally intuitive in character and there is a lack of formal interplay between environmental and other planning investigations until late in the planning process.

Environmental impacts must occur with coal resource development. However with early prediction of impacts and recognition of constraints related to the proposed development it is believed that environmental factors can be incorporated into coal resource planning.

This present study represents the first detailed statement on environmental aspects associated with the Mokau coal development. However this study is not an environmental impact report, Rather, it aims to describe and illustrate a method whereby environmental factors related to coal development can be rationally and simply predicted at an early stage of planning. In addition, the study identifies a framework within which environmentally aware coal resource management could proceed.

1.2 THE STUDY APPROACH

The approach demonstrated in this study involves the development of a materials balance for mining and use of the coal.

The materials balance provides a framework for the identification of resource needs and operational outputs and is particularly suitable for early prediction of environmental impacts and constraints related to coal development.

In order to carry out a materials balance study, formal information is required on the likely nature and scale of the proposed development. Environmental information is also required. The mining pre-feasibility

study (Longworth et.al., 1982) provided a good basis for definition of operational aspects, and environmental information has largely been collected from Government agencies. The approach taken here not only facilitates prediction of impacts and constraints but it also indicates areas where more definite information is required.

In view of the early stage of planning of the Mokau coal development, some assumptions have been necessary. These relate primarily to the method and scale of coal use. A major feature of a materials balance approach is that such assumptions are easily accommodated and in no way invalidate the model. Variations on the assumptions made here may change the scale or nature of specific impacts but the methodology will remain valid.

Significant time constraints have been imposed on this study. This has two major implications for the scope of the study. It was decided that rather than provide a specific solution to environmental management of the Mokau coal resource, it may be more instructive to provide the methodology which may be developed to provide required details for coal resource management. Secondly, this study is necessarily regional in its approach. Therefore national implications of utilising Mokau coal are not considered in any detail. Similarly, impacts and constraints related to transport of coal from the mine to a power station have not been considered here.

CHAPTER 2

THE MOKAU COALFIELD

2.1 INTRODUCTION

This chapter discusses the geological setting of the Mokau Coalfield and the distribution, character, reserve status and possible uses of the coal resource. Chapter 3 discusses the other resources of the coalfield region and present resource users.

The coalfield is located north-east of New Plymouth, about 20 km inland from the west coast at Mokau (Fig.2.1). The field spans the boundary between Auckland and Taranaki provinces (the Mokau River); the majority of the field however lies within the Auckland Province. The coalfield boundaries were described by Phelps (1982) and are as follows: to the north the field is approximately bounded by S.H.3 between Awakino and Mahoenui, to the west by the Awakau Road and to the east by the Mokau River. The southern boundary lies south of the Mokau River. The boundaries of the coalfield are shown in Fig.2.2 and they coincide roughly with geological boundaries (Phelps, 1982). The field covers at least 150 km² and is subdivided into three sectors identified on Fig.2.2 and discussed below.

2.2 GEOLOGICAL SETTING

Various geological studies have been carried out in the region of the Mokau Coalfield. Henderson and Ongley (1923), produced a bulletin on the geology of the Mokau Subdivision and Hay (1967) published a 1:250,000 scale map of the Taranaki region. Happy (1971) and Fried (1979) have investigated aspects of the regional Tertiary geology. Chappell (1964) discussed Quaternary geology and Nelson et.al.(1977) discussed the North

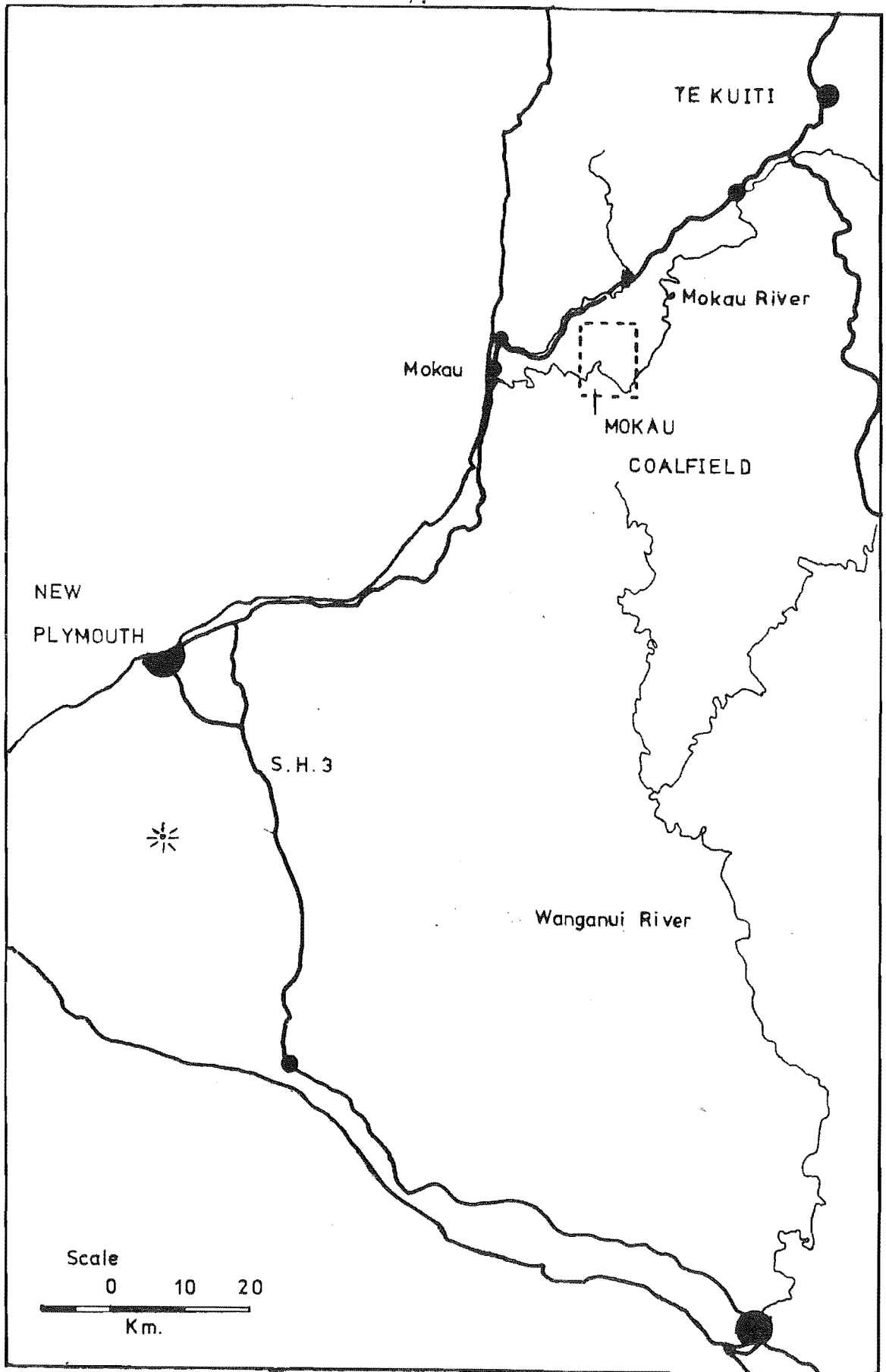


FIG.2.1; Coalfield location map.

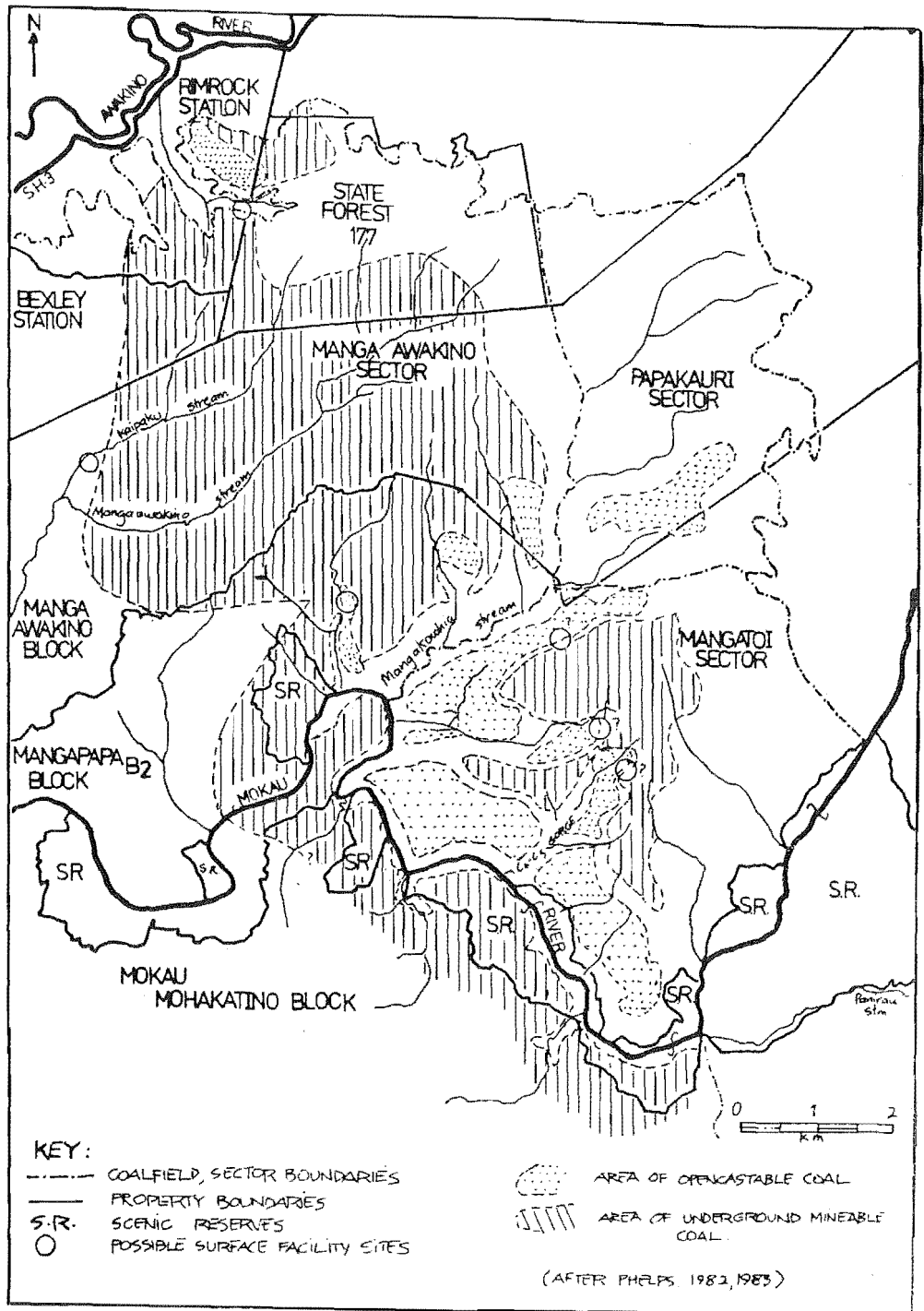


FIG.2.2: Prime features, Mokau Coalfield.

Wanganui Basin in the context of tectonic regimes. Phelps (1982) reported on coalfield exploration. Brown (1982) and Miller et.al. (1982) have discussed engineering geological aspects of the coalfield.

The Mokau Coalfield is located within the North Wanganui sedimentary basin which extends from about Kawhia Harbour to Stratford (Nelson et.al.1977). The basin contains up to 7,500 m. of Tertiary sediments of Oligocene to Pliocene age. The oldest Tertiary sediments are the Oligocene Te Kuiti Group (coal measures, siltstones, sandstones and limestones). These are overlaid by the Mahoenui Group (Taumatamaire Formation; limestones and mudstones). These sediments are generally typical of deep marine origin (Phelps, 1982).

The Lower Miocene Mokau Group was probably deposited in a sheltered harbour with a major source area to the east (Fried, 1979). The Mokau Group is subdivided into three formations, including the Maryville Coal Measures. The youngest Tertiary sediments in the area (the Mohakatino Group; siltstones, sandstones, mudstones), overlie the Mokau Group. Quaternary sediments include the Tauranga Group which unconformably overlies the Maryville Coal Measures in the Mangatōi sector. This Group comprises alluvial sand, clay and silt with peat beds and lenses.

The Tertiary sediments have a regional dip of less than 10° to the southwest and the coalseams within the Maryville Coal Measures generally dip at between 4° and 5° (Phelps, 1982). There are two major fault patterns. These strike between 000° - 020° and 025° - 080° . (Happy, 1971; Nelson et.al.1977).

The Mokau Group has been discussed in detail by Happy (1971), Fried (1979), and Phelps (1982). The Lower Mokau Sandstone is up to 100 m. thick and comprises grey, massive, fine to medium grained, generally muddy sandstone. Two thin, dirty coal seams may be present.

The Maryville Coal Measures contain significant economic coal reserves and are restricted in extent to the Mokau Coalfield and areas to the south. There are usually five coal seams present, although in the southern areas the topmost seam has been eroded from the sequence. The base of the formation is regarded by Phelps (1982) to be marked by the base of the lowest coal seam and the top is some metres above the topmost seam.

Sandstones within the coal measures may be very clean (grey, well sorted, occasionally carbonaceous, occasionally calcite cemented) or muddy, poorly sorted sandstones. Mudstones are often streaked with carbonaceous material and Fried (1979) reported that "... fine grained pyrite is dispersed throughout the mudstone with occasional larger crystals within the carbonaceous streaks". Phelps (1982) stated that the coal seams were deposited in a paralic situation within which there has been alteration from peat swamp to lagoonal to coastal shelf environment. Fried (1979) considered that the coal basin was bounded to the west by deeper water. The five seams vary in thickness from less than one metre to over 2.6 metres, with interseam thicknesses between 5 and 25 metres. Three typical stratigraphic summary logs for the coalfield are shown in Fig.2.3.

Engineering geological studies were carried out on cores from the Maryville Coal Measures (Miller and Wintour, 1982). The rocks generally have low strength although well cemented sandstones may be much stronger. The sandstones are generally more slake-resistant than mudstones which deteriorate rapidly in exposed sections. The Upper Mokau Sandstone is

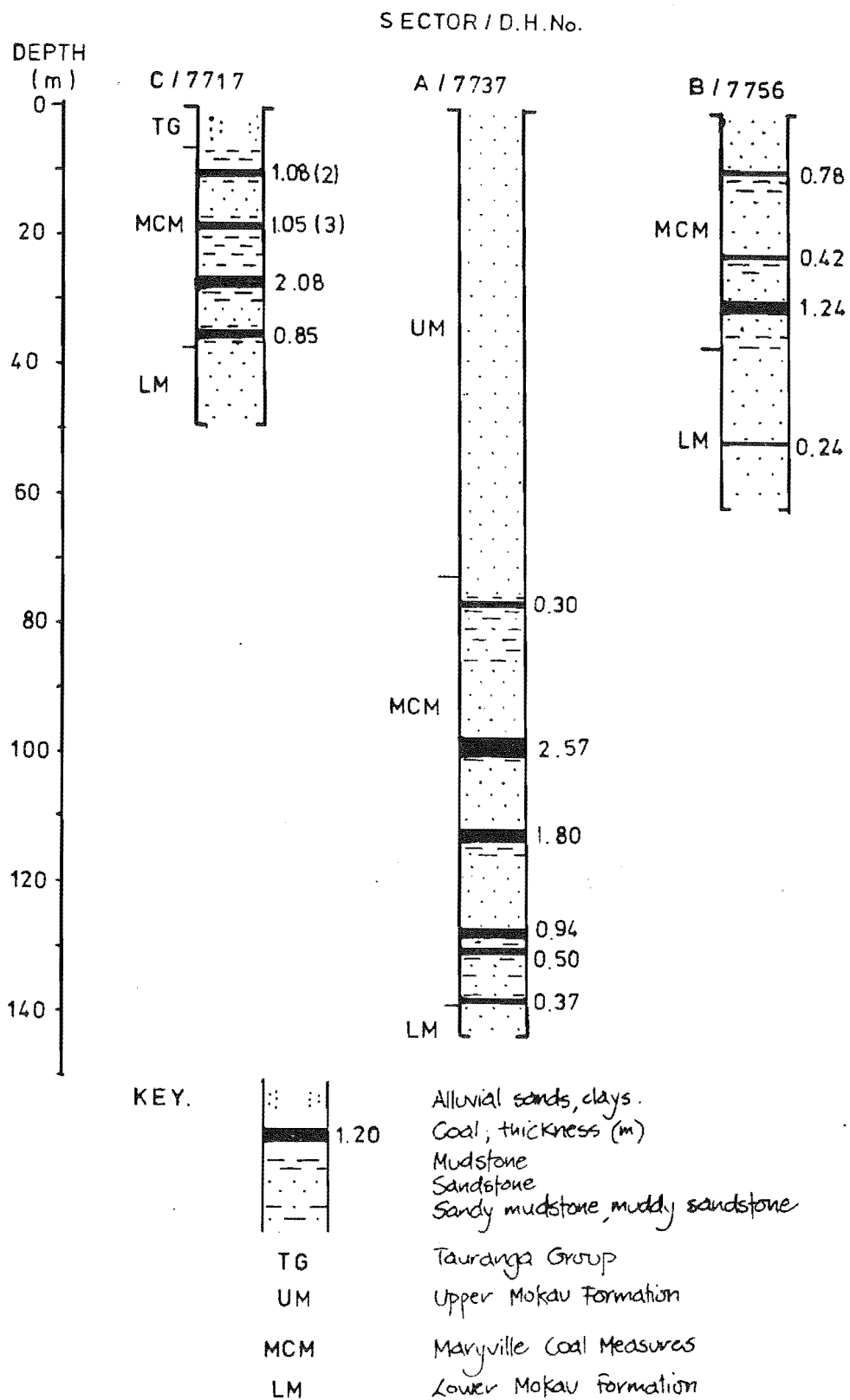


FIG.2.3: Summary stratigraphic logs, Mokau Coalfield.

composed of light grey, fossiliferous, argillaceous sandstone and interbedded mudstone and siltstone. Maximum thickness is about 100 m. in the coalfield. The sediments are commonly ferrous cemented and occasionally calcite cemented. Pyrite is present (Fried, 1979).

2.3 DISTRIBUTION OF COAL

The coalfield is subdivided into three sectors on both geological and geographical grounds. The sectors are:

Sector A: Manga-awakino

Sector B: Papakauri

Sector C: Mangatoī.

Sector A: This sector is in excess of 50 km² and is bounded by coal seam outcrop in the north and east and by coal thinning in the west and south. The coal measures are overlaid by at least 50 m of Upper Mokau Sandstone except in opencast areas in the south and north. Five seams are usually present. The first, second, third and fourth seams having economic interest over parts of the sector for underground mining. The fifth seam is only of interest in opencastable areas.

Sector B: The Papakauri sector is bounded to the west by the Mangakawhia stream, to the north and east by ridges and to the south by a 070°-striking fault, seams 2-5 are present, the maximum thickness is 1.4 m., and the greatest thickness of coal in the four seams is 3.90 m. The overburden to coal ratio is at least 9.5:1 and there is limited opencast potential in the south (Longworth et.al., 1982).

Sector C: The Mangatoī sector is bounded to the west, south and east by the Mokau River and to the northwest and north by the Mangakawhia stream and the fault boundary with the Papakauri sector. Seam one has for the most part been eroded from this sector; the reserves are thus

composed of four seams varying in thickness between 0.3 m. and 2.6 m. The total coal thickness ranges between 3.1 m. and 6.2 m. with overburden to coal ratios always below 14.5:1 and generally below 10:1. The third seam in the sequence is always the thickest, and opencastable coal is found over most of the sector.

2.4 COAL QUALITY, RANK AND TYPE

While coal-forming vegetation can occur in widely different environments, there are three fundamental requirements for the deposition of sufficient quantities of peat to form coal. These are

- (i) water: the water table should restrict oxygen so that vegetation is preserved. The water table should also be gradually rising so that a substantial thickness of vegetation can accumulate
- (ii) protection: inorganic particles must be excluded from the depositional environment so to restrict ash content.
- (iii) environment: the climate and other ecological factors must be suitable for plant growth. The type of coal formed will be governed by variations in these factors and by the type of depositional environment. There are seven factors which determine the primary character of coal seams (Stach, 1982). They are:
 - (i) deposition type (allocthonous/autochthonous)
 - (ii) peat vegetation type
 - (iii) depositional milieu
 - (iv) nutrient supply
 - (v) pH, bacterial activity, sulphur
 - (vi) peat temperature
 - (vii) redox potential.

Coal quality may be assessed by numerous tests determining various parameters. The following tests have been carried out on Mokau coal.

- a) proximate analysis (moisture, ash, fixed carbon, volatile matter, sulphur, specific energy)
- b) ultimate analysis
- c) ash analysis
- d) forms of sulphur (pyritic, organic, sulphate)
- e) trace element analysis
- f) ash fusion temperature
- g) hardgrove grindability.

Analysis results are detailed elsewhere (Black, 1981; Phelps, 1982; Gray, 1983). Summary results only are provided here.

Proximate analyses for the Mangatoui sector (opencast areas) show the following results (Gray, 1983).

| | <u>Seam 2</u> | <u>Seam 3</u> | <u>Seam 4</u> | <u>Seam 5</u> | <u>'Average'</u> <u>(2-5)</u> |
|-------------------------|---------------|---------------|---------------|---------------|----------------------------------|
| Moisture % | 16.8 | 16.7 | 15.4 | 15.0 | 16.0 |
| Ash % | 7.6 | 6.6 | 8.3 | 8.2 | 7.7 |
| Volatiles % | 35.2 | 35.3 | 37.1 | 36.4 | 36.0 |
| Fixed carbon % | 38.6 | 39.6 | 36.9 | 35.9 | 37.8 |
| Sulphur % | 1.76 | 1.83 | 2.36 | 4.01 | 2.49 |
| Specific energy (MJ/kg) | 22.78 | 23.11 | 23.26 | 23.52 | 23.20 |

(Note: all figures for 'coal-in-ground')

Within the underground areas, seams 1-4 are of importance. Published proximate analyses for this area are not available at the time of writing and it is assumed for planning purposes that properties will be similar to those quoted above.

Ultimate analysis determinations provided by Phelps (1982) are as follows (all d.m.m.f.):

| Carbon % | Hydrogen % | Nitrogen % | Sulphur % | Oxygen % |
|----------|------------|------------|-----------|----------|
| 74.73 | 5.48 | 1.1 | 3.14 | 15.95 |

Forms of sulphur analyses indicate that sulphur occurs as: organic 68%; pyritic 26%; and sulphate 5.6% (Gray, 1983).

Ash analyses have been carried out by Gray (1983) on 209 samples from the Mangatoui sector. His results (averaged for seams 2-5) are as follows (all weight %):

| | | | | | | | |
|------|-------------------------------|------------------|--------------------------------|--------------------------------|-------------------|------------------|------------------|
| CaO | MgO | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | Na ₂ O | K ₂ O | TiO ₂ |
| 16.5 | 4.4 | 28.6 | 13.0 | 12.1 | 3.6 | 0.5 | 0.7 |
| MnO | P ₂ O ₅ | Cl | SO ₃ | | | | |
| 0.1 | 0.5 | 0.009 | 18.7 | | | | |

In addition, Black (1981) found up to 2% B₂O₃ in some samples.

Trace element analysis has been carried out by Black (1981) on 41 samples from the coalfield. Her results (averaged) are as follows (all p.p.m.):

| | | | | | | | | | |
|----|-----|-----|------|-----|-----|-----|-----|-----|-----|
| V. | Cr. | Ni. | Cu. | Pb. | Zn. | As. | Se. | Th. | Bc. |
| 6 | 7 | 4 | 14.5 | <5 | 17 | 1 | <1 | <5 | 11 |

Ash fusion temperature is moderately high and little variation is found across the coalfield. Temperature varies between 1160°C (softening) and 1300+°C (flow) in both reducing and oxidising atmospheres. Hardgrove grindability index ranges between 39 and 55 (Gray, 1983).

The coal is ranked as sub-bituminous A-B (Black, 1981; Phelps, 1982; Gray, 1983).

Coal type is controlled by the relative abundance of maceral groups and coal texture. In brown coal, the maceral groups are huminite, exinite

and inertinite. Black (1981) assessed the petrographic character of Mokau coal. She found that the coal is inertinite-poor and huminite-rich (in excess of 50%). In addition, the petrographic analysis indicated that pyrite is common in the coal as framboids.

2.5 COAL RESERVES

Resources are usually classified according to the level of certainty as to their existence and to the ability to remove them. Thus a resource will contain reserves (resources which are feasibly recoverable using available technology) for which there may be varying levels of probability regarding their presence. With regard to coal, Bowen (1978) subdivided resources on the grounds of decreasing geological probability of existence into measured, indicated, inferred, hypothetical and speculative.

Coal technically capable of being won is termed 'coal-in-ground' and then 'extractable coal' using an appropriate extraction percentage. Coal beyond these limits is classed as inaccessible. (Bowen, 1978).

Coalfields are generally divided into sectors and estimate areas for calculation of quantities of coal-in-ground.

Coal exploration has been progressing within the Mokau coalfield since 1980. Phelps (1982) estimated coal reserves using information available at that time and drilling is continuing. Currently (Dec.1983) about 130 drillholes have been completed in the field. The reserves and estimate areas quoted in this report are those provided by Phelps (1982) and modified by Longworth et.al.(1982). The current drilling programme has changed the extent and tonnage in some estimate areas however the limitations in using 1982 figures are believed to be insignificant for planning.

(i) Opencast reserves

Opencastable coal is located within the Manga-awakino, Papakauri and Mangatoī sectors. Longworth et.al. (1982) applied a coal recovery percentage of about 83% and a dilution factor of 10% to obtain extractable coal reserve figures. The opencastable coal areas are shown on Fig.2.2 and tabulated below.

| <u>Sector</u> | <u>Estimate Area</u> | <u>Coal-in-ground (Mt)</u> | <u>Extractable Coal (Mt)</u> | <u>Status</u> |
|---------------|----------------------|----------------------------|------------------------------|------------------------------|
| A | A ₁₋₄ | 3.4 | 3 | Indicated |
| B | B ₁ | 3.5 | 3 | Indicated |
| C | C ₁₋₆ | 32.8 | 30.3 | Good indicated - measured |

(Note: The reader is referred to Phelps (1982), Longworth et.al. (1982) for detail on coal reserves in opencast areas).

Total available mineable reserves are about 36.3 million tonnes.

(ii) Underground reserves

Underground mineable coal is located within the Manga-awakino and Mangatoī sectors. Mining recovery averages 65% (Longworth et.al. 1982). Areas underlaid by underground mineable reserves are shown on Fig.2.2 and summarised below.

| <u>Sector</u> | <u>Estimate Area</u> | <u>Coal-in-ground (Mt)</u> | <u>Extractable Coal (Mt)</u> | <u>Seam</u> | <u>Status</u> |
|---------------|----------------------|----------------------------|------------------------------|-------------|---------------|
| A | A ₅₋₇ | 42 | 33 | 1-4 | Indicated |
| C | C ₇ | 5 | 4 | 4 | Indicated |

(Note: These figures are indications only; refer to Phelps (1982) or Longworth et.al. (1982) for detail.)

The total underground mineable reserves are thus about 37 million tonnes.

2.6 POTENTIAL USES OF MOKAU COAL

The most suitable use for a coal depends primarily upon its quality and secondly upon its quantity. Sub-bituminous coals may be used for char production, steam raising, domestic combustion, liquefaction (e.g. pyrolysis) or sundry other uses such as lime, cement or carbide manufacture.

Of these uses, two have been seriously considered with regard to Mokau coal. They are

- (i) pyrolysis and
- (ii) steam raising for a thermal power station.

Black (1981) stated that Mokau coal could possibly be suitable for liquefaction, particularly by the pyrolysis process. This process enhances the liquid yield from coal by appropriate measures, e.g. by heating pulverised coal very rapidly with production of char, gas and tar (Diessel, 1981). The high volatile, exinite-rich nature of Mokau coal appeared suitable for this process but as results from recent tests were not promising (Phelps, 1983) this use is most unlikely.

Longworth et.al., (1982), directed their mining pre-feasibility study towards production of coal for a 1000 MW thermal power station. The 1983 Energy Plan discussed the use of Mokau coal for thermal power generation and this study is directed to such a use. Numerous systems have been designed for generation of electricity from coal and some are currently available for commercial use, others are still at the design or pilot plant stage. Conventional generation uses a steam cycle with steam generated through heat produced by coal combustion. This system is apparently nearing the limits of its efficiency (Shires et.al., 1981).

The conventional firing system uses a pulverised fuel boiler although there is an increasing interest in fluidised bed boilers which have environmental advantages and are less stringent with regard to fuel quality.

Research into advanced alternative cycles for electricity generation from coal is being carried out world-wide in an attempt to increase thermal efficiency and reduce power supply costs. All alternative systems are at an early development stage with the exception of the combined cycle system, in commercial operation in Germany (Shires et.al., 1981).

Both Huntley and Meremere power stations use pulverised fuel systems to burn coal and it is likely that any future system will use the same process (Toynbee, 1982). It was assumed by New Zealand Electricity (1981), as no other suitable system was currently available, that a pulverised fuel-fired power station would be built as the North Island Thermal No.1. For the purposes of this study, a 1000 MW pulverised fuel system is also assumed. The consequences of choosing such a plant are dealt with later in this study.

Coal properties can vary widely for such a system, although for any one station, design and specifications will demand only a limited range in fuel properties. Moisture content should be below 15% and most stations use low or medium rank coal with volatile matter content in excess of 20% (d.a.f.). Ash content can be up to 30% without significant problems; higher ash content may carry cost penalties. Beneficiation processes should generally be avoided with this type of coal as they may reduce the specific energy yield (Diessel, 1981). Ash type is important and

fusibility should be above 1200°C (deformation) in an oxidising atmosphere. Sulphur content of the coal should preferably be low as environmental and corrosive problems may accrue with high sulphur fuel. The function of a pulverised fuel plant is discussed in detail by St Baker (1981). Briefly, the function is as follows. Coal is received, stockpiled, blended and delivered to boiler bunkers. The coal is dried by mixing with preheated primary combustion air as it passes into the pulveriser. A constant stream of dry fine coal is then delivered to the burners. Heat of combustion is transferred to water in boiler-wall tubes, producing steam. Heat exchangers aid in achievement of maximum heat recovery, with most combustion heat being used in superheating and reheating steam. Furnace-exit temperature is about 1200°C and flue gas is ejected at about 130°C (St Baker, 1981). Steam passes through a turbine producing mechanical energy which turns a generator, producing electrical energy. Steam is then discharged at low temperature and pressure to a condensor. Waste heat must be ejected (to maintain efficiency of the system) prior to water returning to the boiler. This is done by transfer to a body of water. Cooling methods are either

- (i) open cycle, or
- (ii) closed cycle.

Open cycle cooling involves drawing water from an adjacent body, passing it through the plant and returning it to the original system. An open cycle cooling system can use a river, estuary, sea or lake as a water source.

Closed cycle systems include wet or dry cycle cooling towers. Wet-cycle towers cycle water continuously from the condensor to a tower where water is sprayed downward through a draught of cool air. The draught may be naturally or mechanically derived. Makeup water is required for the

system to replace loss by evaporation, drift and blowdown. "Blowdown" is the amount of water constantly removed and replaced to maintain an acceptable impurity level in the cooling water.

Dry cooling towers are similar but do not spray water, rather they pass hot water through radiators. Open-cycle systems require high withdrawal levels of water (38 cumecs at Huntley) and low consumption levels, whereas closed-cycle systems consume more water (i.e. 1 cumec) but withdraw less. The choice of cooling systems will have two major effects. Operating temperature differs between options resulting in power output differences (higher operating temperature results in lower gross output). In addition auxiliary power required for pumps or fans will vary with net energy output consequently varying. Of the six cooling types assessed for the North Island Thermal No. 1, the cheapest was open cycle river cooling. Pond, estuary, natural and mechanical draught towers systems are progressively more expensive with open-cycle offshore cooling the most expensive at about twice the cost of open-cycle river cooling (New Zealand Electricity, 1981b). The major features of the Huntley Power Station and the planning parameters derived for North Island Thermal No. 1 have been used in this study to determine prime features of a station using Mokau coal.

2.7 EXTRACTION METHODS

Assuming a 75% availability and 50% average load factor, a 1000 MW thermal power station requires about 1.80 Mt y^{-1} of coal (Longworth et.al., 1982). Additional "dry year" usage may be in the order of 0.14 Mt ann^{-1} , thus about 2 Mt y^{-1} would be mined. Longworth et.al. (1982) undertook a mining pre-feasibility study and decided that to balance resource use, coal would be produced from both opencast (0.95 Mt y^{-1}) and underground (1.05 Mt y^{-1}) methods.

(i) Opencast mining

A single opencast mine could progressively work the reserves with productions centring on the Mangatoui sector. Mining would begin in the C4-north area with over- and interburden from the initial opening being dumped in the gorge between C4 and C5. Once room is available within the pit, burden could be back cast. The operation would mine C4, then C5, C6, C2, C3 and C1. Timing and overburden and coal production levels are shown on Table 2.1. The mine would progress up-dip where possible and would comprise a multi bench (4-5 benches) operation, each being about 30 m. wide. Batter angles could probably be 25° in Tauranga Group and 60° in Maryville Coal Measures (Longworth et.al., 1982). Spoil material would be selectively placed, with overburden being replaced over interburden and topsoil respread on the surface. Spoil-pile angles could be about 25° with adequate drainage (Longworth et.al., 1982). Topsoil removal and replacement could be carried out by motor scrapers. Power shovels are considered to be the most suitable earth-moving machinery using trucks to carry overburden to a dump site; blasting should not be required (Longworth et.al., 1982). Coal would be removed by backhoe excavators and trucks. Mining recovery should be between 77-87% and should average 83% (Longworth et.al., 1982). One hundred and sixty five persons would be required at full production (reached after five years' build-up). Working a three-shift (8-hr each) day, operator hours would total $4,200 \text{ y}^{-1}$. Overburden machinery would be used for $3,225 \text{ hr y}^{-1}$ and coal removal machinery, $21-2200 \text{ hr y}^{-1}$ (Longworth et.al., 1982).

(ii) Underground mining

Access to underground mines will probably be by seam in four areas, e.g. 'North', 'West', 'South' and 'Highwall' entries (Longworth et. al., 1982). Approximate positions of these entries are shown on Fig. 2.2.

Production could build up to a maximum by year six. Seams would be worked in descending order, the method of working varying with depth of cover. Depth-of-cover zones, and associated winning methods are (Longworth et.al. 1982):

- a) 0-50m.: these areas will most probably be worked by bord and pillar methods with a continuous miner. Roof support of bolts and straps will be required.
- b) 50-150 m.: two alternative working methods could be used. Bord and pillar mining with continuous miners would be suitable, using some 'Alpine' miners in difficult conditions. Alternatively, a longwall extraction system could be used in some areas, using 'Alpine' miners for main heading and face development.
- c) 150 m. + : a change in work method would be required as depth increases. Narrow roadways supported by steel archways will be driven by 'Alpine' miners and longwall extraction will be used, apart from small blocks where bord and pillar methods would be used. Production levels would vary with mining and cover depth. Working on 2-4 shifts, at an overall extraction rate of 65% with 11% dilution, annual production from all underground mines would total 1,049,000 tonnes. Production levels, scheduling, and manpower are shown on Table 4.2.

Underground mining uses electrical energy and this will be provided from a substation at each mine. Manpower requirements would increase from 60 in year 0 to 539 in year four and thereafter.

Numerous sundry requirements for mining include the construction of an access road, coal handling facilities, bathhouse, workshop and administration buildings for each mine. Construction of coal and overburden haulroads is required within the opencast areas and diversion of some streams would be necessary to reduce water inflow into pits.

A district workshop (c.5000 m²) is required for major overhauls and repairs as the area is remote from such facilities. A central office for mine administration (700 m²) will also be necessary as will electricity reticulation (Longworth et.al., 1982).

Access to the mines could be by one of at least three routes (Longworth et.al., 1982). These are the river (following the Mokau River), the ridge (along the central ridge) and the Kaipaku stream routes. These routes are discussed in detail by Longworth et.al. (1982) who for reasons of conservatism chose the ridge route and associated intra-coalfield roads in costing. This choice necessitates approximately 20 km of road being constructed.

TABLE 2.1 COAL AND OVERBURDEN PRODUCTION SCHEDULE: OPEN CAST MINES
(From Longworth et.al., 1982).

| Year | Estimate Area | Coal Production (Mt) | Overburden MM ³ |
|-------|---------------|----------------------|----------------------------|
| 1 | C4 | 0.2 | 1.38 |
| 2-3 | C4 | 0.32 | 2.21 |
| 4 | C4 | 0.52 | 3.59 |
| 5 | C4 | 0.85 | 5.87 |
| 6-13 | C4 | 0.95 | 6.55 |
| 14 | C4/C6 | 0.95 | 5.96 |
| 15-17 | C6 | 0.95 | 5.70 |
| 18 | C6/C5 | 0.95 | 5.73 |
| 19-22 | C5 | 0.95 | 5.89 |
| 23-29 | C2/C3 | 0.95 | 6.46 |
| 30 | C3/C1 | 0.95 | 8.37 |
| 31-34 | C1 | 0.95 | 8.68 |
| 35-41 | C1/B1/A1-4 | 0.95 | 10.30 |

TABLE 2.2 PRODUCTION, SCHEDULING, MANPOWER: UNDERGROUND MINES
(From Longworth et.al., 1982).

| Year | Mines | Manpower | Total Output Mt. |
|-------|-----------------------|----------|-------------------|
| 0 | South, West | 60 | - |
| 1 | " " | 150-240 | 119,000 |
| 2 | " " | 325 | 224,000 |
| 3 | " " | 400 | 595,000 |
| 4 | South, West, North | 539 | 886,000 |
| 5 | " " " | 539 | 990,000 |
| 6-16 | " " " | 539 | 1,049,000 |
| 16-17 | All | 539 | 1,049,000 |
| 18-23 | South, West, Highwall | 539 | 1,049,000 |
| 23-27 | " " " | 539 | 1,049,000 |
| 27-29 | " " " | 539 | 1,049,000 |
| 29-34 | South | 539 | 1,049,000 |
| 34-36 | " | 539 | 1,049,000-669,000 |
| 36-40 | " | 539 | 669,000 |

CHAPTER 3

THE NATURAL ENVIRONMENT AND RESOURCE USERS

3.1 NATURAL ENVIRONMENT

This section of Chapter 3 summarises the major features of the environment of the Mokau Coalfield and surrounding areas. A more detailed discussion of the natural environment is included in this report as Appendix 1.

3.1.1 Topography

The topography of the study area is extremely varied, with three broad physiographic regions being apparent. They are:

- (i) coastal terraces
- (ii) river flats
- (iii) uplands.

The coalfield is located within the upland region and its topography is dominated by a high central ridge. Generally the coalfield is in rugged broken country although extensive dip slopes have formed in some areas, particularly in the area of Mangatoī Station.

Flat land is restricted to river flats, coastal terraces, plateaus and dip slopes.

3.1.2 Climate

Climatic variations occur between the coastal and upland regions. Annual precipitation ranges from 1600 mm at the coast to over 2000 mm inland, with most falling during May, June and July (N.Z. Meteorological Service, 1973). Winds are dominantly from the west or south and temperatures may rise to over 35°C in the summer. Frosts are rare on the coast but increase in frequency inland.

3.1.3 Hydrology

The Mokau and Awakino Rivers are the only major rivers in the study area. The Awakino has a mean annual flow of about 12 cumecs (at the Awakino Gorge gauging station: Ministry of Works and Development, (1983b)), is 75 km long and flows through varied country with its characteristics changing accordingly.

The Mokau River is 174 km long, and drains 1420 km² of catchment flowing from the south Waikato region. The river carries a significant sediment load appearing dirty in the lower reaches. The lower 25 km is tidal and easily navigable by small craft. No reliable gauging records are available for the lower section of river which flows through the study region. A gauge at Totoro Gorge (c. 78 km from the mouth) indicates a mean annual flow of about 37 cumecs (Ministry of Works and Development, 1983b).

Numerous tributaries flow into the Mokau River in the study area. These include the Panirau, Mangatoti, Mangakawhia and Mangaawakino. Some of the streams cross or lie adjacent to opencast coal areas.

Both the Mokau and Awakino rivers experience severe flooding at times and the effects of floods may be heightened in the lower reaches by tidal fluctuations. Flood levels in the opencast areas of the Mokau River were taken by Longworth et.al. (1982) to be 10m a.s.l.

The rivers have some areas of high scenic and recreational value and the Mokau River is flanked by scenic reserves for much of its length (Fig.3.1).



FIG.3.1 Mokau River c.25 km above the mouth.

Little is known of the groundwater resource in the region although Hay (1967) evaluated aquifer potential in Tertiary sediments in the area, and the Tauranga Group sediments almost certainly constitute water-bearing strata (Longworth et.al., 1982).

3.1.4 Active earth processes

Active processes within the study region include both erosion and faulting. The sediments of the coalfield region are "soft" rocks being of generally low strength (Miller et.al., 1982). Such rocks generally have as dominant defects, bedding planes, faults, joints, crush zones and thin clay layers. Failure may occur along such defects, within the mass, or at the rock surface by slaking or exfoliation. Soils vary within the region and different types are susceptible to different modes of erosion (see section 3.1.5). Of the 13 erosion types identified in the N.W.S.C.O. Land Resource Inventory, eight are recorded in the study region (Reid et.al., 1979). These are wind, soil slip, sheet, streambank, debris avalanche, earthflow, tunnel-gully and scree slip. None are extreme in effect. Within the coalfield, soil slip, earthflow,

debris avalanche and sheet erosion are identified by Reid et.al.(1979).

Priest (1977) noted that erosion on Mangatōi is not serious under present vegetation, but observed that the sandstones weather deeply producing a clay-rich regolith which may slip, 'gully' or flow. Failures within the Maryville Coal Measures include isolated slide-flow events, and the sediments slake very quickly in cores. Slabbing failures of Upper Mokau rocks may occur as do toppling failures. Chandler (1978) observed and discussed regolith failures in Mahoenui Group mudstones. These rapidly slake and often fail in the subsoil zone by sliding, and mudstones and sandstones in the coalfield rocks can be expected to fail in a similar fashion.

Brown (1982) stated that Tauranga group sediments "... judged on the hummocky topography, ... are slowly creeping downslope". Such failure is also observed to the north on Rimrock Station.

Only a few of the numerous fault traces in the study area show recent movement. The Blacks fault was thought to have moved in Pliocene times (Happy, 1971), and at least one active fault is present in the Mangatōi region (Brown, 1982).

3.1.5 Soils

Information on soils in the Mokau Coalfield region was obtained from Taylor et.al.(1954) and Reid et.al.(1979). The following discussion derives from those sources.

Twenty-one soil units in five major groups were identified in the region by Reid et.al.(1979). The major groups are:

- (i) Recent soils (silt and clay loam). These form on flat alluvial material and are high to very highly fertile. They are susceptible to stream scour and flooding.
- (ii) Secondary podzolic soils. These soils form over a long period on silica-rich sediments (Taylor et.al., 1954). Sand based soils have low to medium fertility, are often droughty and are susceptible to wind erosion. Sedimentary rock-based soils (young and immature stages) form on undulating to moderately steep sandstone, mudstone and Mairoa ash. They are generally moderately fertile and prone to slips.
- (iii) Yellow-brown loams. These derive from volcanic ash, generally of the Mairoa suite. They are of only moderate fertility, having free drainage and may suffer a continual loss of nutrients. They are easily worked and grow excellent pasture when fertilised. Skeletal variants may form on eroded hills.
- (iv) Saline soils. These occur on the Mokau River tidal flats. Natural fertility is very high when salt is removed.
- (v) Skeletal steepland soils. These soils are relatively unstable and periodically rejuvenate by erosion. Forest clearing in some areas results in loss of topsoil, those soils with fertile subsoil respond to farming, the infertile soils revert to scrub cover. All are prone to slips but scars heal readily.

3.1.6 Ecology

Vegetation. Present vegetation in the study region can be divided into seven types:

- (i) Native forest: covers a significant area of the Mokau Coalfield and surroundings. Dominant forest types are podocarp and hardwood (rimu, rata, tawa, totara) and some beech is present on exposed faces and ridges. All of the forests have undergone some modification by grazing, logging or burning.

- (ii) Exotic forests: these comprise less than 100 ha.
- (iii) Swamps, wetlands: these are found along some streams and on flood plains but are never abundant, many having been drained.
- (iv) Scrub: areas from which forest has been cleared have in part reverted to Manuka, punga, Mahoe, marbleleaf and supplejack scrub.
- (v) Pasture: covers much of the region with introduced grasses dominant. Vegetation quality varies with soil, aspect and management.
- (vi) Weeds: introduced weed species (gorse, blackberry, ragwort) have invaded many areas, particularly blackberry on Mangatoi Station.
- (vii) Coastal vegetation: comprises lupins, flax, dune grass, and of particular importance, the Tainui tree (Pomaderris apetala).

Wildlife. A variety of habitats are available for wildlife in the region. These include coastal, fluvial, and forest areas. The large tracts of native forest in and around the Mokau Coalfield have regional significance as wildlife habitat, and in part, national significance. River and wetland habitats attract various birds and fish species of which whitebait (Galaxias spp.) are the best known. Details of habitats are discussed in Appendix 1.

3.1.7 Social aspects

The closest centres to the Mokau Coalfield are the coastal villages of Mokau and Awakino. These are both on S.H.3 which links New Plymouth and Te Kuiti, the two closest large towns. There are tunnels at Mount Messenger and at the top of the Awakino Gorge and the area between these tunnels is known locally as the Tainui district.

Access to the coalfield from S.H.3 is presently difficult. Rough tracks exist up the north bank of the Mokau River to Mangatoi Station, and

through Bexley and Rimrock Stations to the north. The Maui gas pipeline passes to the west of the coalfield and this track provides useful access to and around the coalfield. Mokau and Awakino are 5 km apart, and in many respects may be treated as one town as their proximity facilitates mixing of communities in many activities.

Awakino (pop.c.100) is located along the Awakino River on S.H.3. The village contains a school (28 pupils, 2 teachers), 2 garages, a hotel, saleyards, council depot and a number of private dwellings. Mokau, 5 km south is both a service centre for the surrounding farms and a holiday resort. Some development has progressed along the coastal strip between Mokau and Awakino with a motor camp, store and scattered baches being present.

Mokau has a permanent population of about 100 and this may treble during holiday periods. The town contains a two-teacher school (with about 45 pupils), two tearooms/stores, a general store, Post Office, police station, ambulance station, butcher and Ministry of Works and Development depot.

Both water supply and sewage disposal are currently satisfactory for Mokau and Awakino but would be pressured by increased population. Primary school children are well served for schools in the area but the closest high school is at Waitara and a bus service takes children there daily. Current employment opportunities in the region include M.O.W.D., council, agriculture, tourism and service industries.

Apart from various public reserves and associated facilities, most land in the region is in private ownership. The coalfield, as defined in Ch.2. is largely under Maori ownership, in two blocks. The Mangapapa B2 block (4,674.5 ha.) covers the south part of the coalfield to the

Mokau River, and has been farmed under lease as Mangatoi Station. This land is controlled by an incorporation representing the 92 owners. The Mangaawakino Block lies north of Mangapapa in the centre of the coalfield. North of this block, coalfield land is held by D.Salmon (Rimrock Station), P.Gibbons (Bexley Station) and the N.Z.F.S. (S.F.177). Numerous scenic reserves flank the Mokau River and to the south of the river is the Mokau-Mohakatino Block (10,870 ha.).

3.1.8 Summary

It has become obvious while reviewing literature on resources of the Mokau Coalfield and its environs that there is great variation in the quantity and quality of information available.

The current coal exploration programme and associated research has produced extremely detailed data on coal quantity and quality but at present environmental data is generally sparse and of low detail.

Orbell (1983) noted that there is a lack of detailed knowledge on soils in the Mokau area, yet information on soils is fundamental to planning as soil is an essential component of land. Climatic data is also sparse for the coalfield and while hydrological data is available for some parts of the region's watersheds more detail will be required in the coalfield area. Information on ecological and social aspects is also largely of a reconnaissance nature.

3.2 LAND USE

3.2.1 Historical view

The Mokau River apparently derives its name from the name of a very early settler who drowned there. He was believed to be one of the crew of the

Tainui canoe which arrived in New Zealand in the 14th century and landed along this coast. The supposed anchor stone of the canoe is stored at the Maniaroa Pa between Mokau and Awakino. The Mokau region was well known to pre-European Maoris and numerous archaeological sites are recorded in the area (Ministry of Works and Development, 1982).

The pattern of land use and resource exploitation in the Mokau area is similar to that throughout most of New Zealand. Perhaps the greatest difference between this and other regions was the fact that no significant resource development took place until late in the 19th century. This was due to the then Maori King (King Tawhiao) closing off the region to white exploitation during the 1860s and the early 1870s.

Barr (1979) provided a useful summary of the history of the area in his discussion of the Mokau mines. Much of this review derives from that source.

The earliest record of white settlers in the area dates back to the beginning of the 19th century. A trader, Thomas Ralph, exploited the flax resource for which the area was famous. However he was kidnapped by Waikato Maoris and, when rescued, escaped to the East Coast. Reverend J. Whitely came to Mokau in 1840 and set up a mission station at Te Mahoe near the river mouth. There was a small settlement at Mokau during these relatively peaceful times, but when war broke out in the 1860s, Europeans left. A boundary line was declared by King Tawhiao at the Mokau River, beyond which whites could not cross. The closed area was looked at with envy and Barr (1979) records a statement by a Minister of the Crown (in 1879), Mr Frederick Whitacker, who was moved to state:

" ... any man who gets land out of the hands of the natives and cultivates it is a public benefactor".

In the late 1870s the Maori King let whites into the area and large numbers of 'public benefactors' began buying land. Subsequently timber milling and cultivation took over and numerous attempts were made to win coal from the Mokau Coalfield.

Since the first white invasion in the 1880s, much the same land use patterns have prevailed with farming, forestry and fishing being dominant. Perhaps the major land use change to date has been the increase in recreational use of the area. Current land uses are shown in Fig.3.2. and discussed below.

3.2.2 Mining

The presence of coal along the Mokau River was well known to the Maoris, and from at least 1841, to whites. Captain Moore of the 'Jewess' ventured up the river by canoe in this year and was thus the first white person to see the coal. As early as 1859, recognising the need to develop minerals, the government undertook a geological reconnaissance using Mr Hochstetter (Barr, 1979). Prior to the Maori Wars, no development was carried out but after the war, exploitation attempts began. Hector, in 1878, extracted five tons of coal for trial. In all, eleven mines were opened in the field. An Australian entrepreneur was the first to initiate an operation. As he was plagued with money problems and land title disputes he did not remove significant amounts of coal.

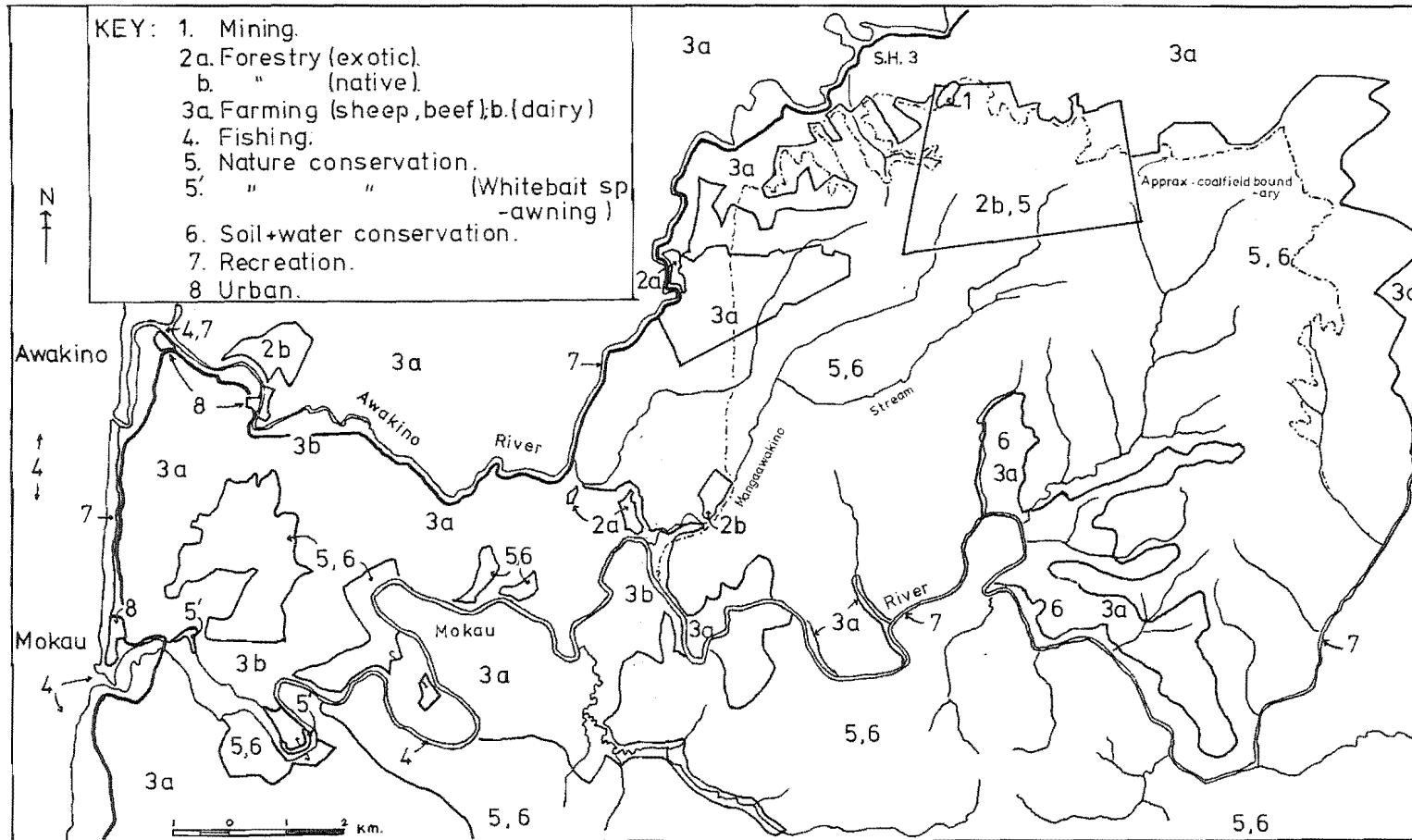


FIG.3.2: Sketch map, present land uses, Mokau Coalfield region.

The 'Mokau Coal Company' run by George Stockman and Taranaki businessmen began mining up the Mokau River in 1855. Coal was carried down-river from the Maryville Mine in small steamers and taken to Waitara. Production reached a peak in 1891 (2773 tons); the total for the 10 years of operation between 1855-1895 was 8,500 tons. Further attempts were made to win coal from up the river but constant money and transport problems (six ships were lost and 20 accidents occurred between the Mokau River and Waitara) dictated that only small amounts of coal were worked. The 'Stockman' mine was the last in operation on the river. It closed in 1952 after yielding 20,498 tons of coal in 32 years of mining.

A mine was built up the Manga-awakino Valley in 1931 and access was by narrow gauge railway. The remnants of the embankments are still visible and various pieces of mine machinery are still in place. The mine only lasted one year, producing 4,000 tons of coal. 'Valley Collieries' was opened on the north side of the coalfield in 1953 and production continues with a small operation.

Other mining operations in the region (or potential operations) include extraction of limestone from the Awakino and Upper Mokau areas, and the quarrying of grey-wacke for road metal. Hay (1967) noted that titaniferous magnetite is found on the 30 m. terrace at Mokau and on the beaches between Mohakatino and Awakino.

3.2.3 Forestry

Forestry was at one time a dominant land use in the study area. The target forests were both podocarp and hardwood and the aim of forest removal was twofold:

- (i) to clear the land for farming, and
- (ii) to utilise the timber resource.

The forest in the Manga-awakino region has been selectively logged in the recent past and clearfelling is occurring on some land in the lower valley. Small scale utilisation of Kahikatea is in progress in this area, with removal of young trees for use as posts (Fig.3.3).



FIG.3.3: Forestry in the Lower Manga-awakino Valley.

The major indigenous timber resource is contained within the state controlled Mahoenui Forest. However, other sizeable pieces of millable forest still exist on Mangatoi Station and are recognised by the owners as being a possible source of income. Local official opinion with regard to the fate of native forests is stated in Harris (1981):

"... the land and its forest are seen as a resource to be either developed in the best productive interests of the district, region and nation, or to be preserved only when some specific feature ... occurs. The wholesale preservation of remnant areas of forest, often not regenerating, and with no supportive features, is seen as grossly wasteful of a vital land resource" (p.59).

Exotic forestry is a minor land use in the area although potential for this use is considered to be sufficient to warrant further discussion. This aspect is dealt with in section 3.2.9.

3.2.4 Farming

Sheep and beef farms comprise 90% of farms in Waitomo county, with dairying on 8% of farms and 2% of farms devoted to 'other' types (Harris, 1981). Sheep and beef country varies in character from hard hill country to hill country with some scattered areas of intensive fattening land. The majority of the farms in the Mokau region fall within the category of hard hill or hill country as defined by N.Z. Meat and Wool Boards' Economic Service (1980).

Since land clearance began in the late 19th century, farming has been an important land use in the region. There are two dominant farming types in the area at present. They reflect the county pattern and are

- (i) sheep and beef, and
- (ii) dairying.

(i) Sheep and cattle farming. This is by far the dominant land use in the area. Full time farms (those where at least one person is kept employed all year) range in size from 160 ha. to 4654 ha. Many are fairly large, i.e. greater than 600 ha. but much land on these is non-productive. A similar mixture of land is found on most farms, ranging from river flats, terraces, and plateaus, to steep or medium hill country.

Stock numbers vary with farm size, and carrying capacities vary from 18 s.u.ha⁻¹ on good land to 8 s.u.ha⁻¹ on poorer quality ground. Lambing averages 100% and may reach 107%. Calving is generally lower at between 70-85%. Management varies from extensive grazing on large blocks (e.g.

Mangatoai Station) to intensive rotational grazing. This variation generally reflects the state of development of the property.

Development potential is seen as good by most of the land owners even though the country is regarded as poorer quality than that further east. Diversification plans vary widely. One farmer plans to build up a large goat herd (partly for weed control). There is little interest in horticulture but some in forestry. The Waikato Valley Authority play a role in farm development with construction of soil and water conservation plans.

Mangatoai Station, in the south of the Mokau Coalfield, has been leased by the Maori owners since early this century. It was once a progressive sheep and cattle run and contained a small village for workers. Now only a 12-stand woolshed, two cottages and a shed remain. The station is currently run by way of an annual grazing lease carrying 3000 sheep. Much of the once-cleared land on the station has reverted to punga and Manuka and there may be as little as 350 ha. of grazing land available at present. Much of this land is badly infested with blackberry and fences are in very poor condition.

(ii) Dairy farming. There are only a few dairy farms in the Mokau region and all have small herds (50-170 cows), although the largest unit has a capacity of 300. This herd is also the newest in the district and is run in the Awakau Valley on a 2400 ha. property of which 200 ha. is in good grass with a further 120 ha. in rough pasture. Other dairy units are well established and vary in size from 100- to 140 ha. Country is generally flat or plateau land with dominant soil types being recent, or yellow brown loams. Production is good on the established farms; one in the Awakino Valley produces 22,000 kg of butterfat per annum (from 130 cows). Produce is sent to Moanui Dairy Company near Inglewood with

collection every two days. Development on dairy farms includes drainage and land clearing to increase subdivision. Major problems with dairying are transport oriented.

Generally the farmland in the Mokau region is well supplied with water from both dams and creeks. Weeds are only a problem in some areas. Of major importance is the problem of reversion of land on poor soils to scrub. In general the region appears to be experiencing a growth period with a new flux of farmers since the 1960s who are actively attempting to return the land to full production.

3.2.5 Fishing

The Mokau coast forms part of a larger trawling zone extending from New Plymouth to Albatross Point, with fishing concentrated between six and 35 fathoms (Lincoln, 1983). The area is regularly worked by six trawlers from New Plymouth and during October-November 1982, 82,807 kg of snapper were landed. From October to January up to twenty trawlers from Auckland, Raglan, Nelson and New Plymouth also work here. The snapper fishery is seasonal however other species caught throughout the year include those listed elsewhere (Appendix 1) with gillnetting and longlining carried out by about 10 local boats. Amateur fishing pressure is low in this offshore area.

Onshore the Mohakatino mussel reef is an attraction for people from as far as Taumaranui and Te Kuiti. This reef is subject to seasonal silting which increases pressure on the resource. Lincoln (1983) noted that on one weekend, over 5,000 mussels were legally taken from the reef.

The Mokau and Awakino rivers are the target for flounder, kahawai, eel and whitebait fishermen. Surfcasting is popular for kahawai and snapper

at the mouths of these rivers, however the whitebait fishery is by far the largest of the river oriented fisheries. The season begins in August and continues until the end of November. Use on the Mokau River is heavy with up to 180 nets being counted along the 35 km stretch of river fished (McKenna, 1981). A whitebaiting survey of Taranaki was carried out in 1980 to examine preferences and activities of fishermen in the area. Before 1950, there was a prosperous whitebait fishery at Mokau but its present status is difficult to assess. The number of fishermen has doubled in the last 10 years and many take annual holidays during the season. Production from the river (est. annual average) is 16.5 kg per person and up to 90% of people sell some or all of their catch. Twenty-seven percent of fishermen who use North Taranaki rivers prefer the Mokau as the quantity of catch is generally good. However the river is not as intensively used as the Waitara, which is closer to the main population centres (McKenna, 1981).

3.2.6 Nature conservation

Much of the land in the region of the Mokau Coalfield has use as wildlife habitat and as an area within which native vegetation remains relatively unaltered. Moynihan (1983) noted that the Mokau vicinity "... seems to be a sort of boundary for wildlife in the region, perhaps because the forests south of the river are less fragmented and disturbed than those to the north".

New Zealand's endemic fauna is dwindling, largely through destruction of suitable habitat. Even though almost all native species are protected under the Wildlife Act, their protection is not guaranteed unless suitable environments are maintained. Of the many faunal species found in the Mokau Coalfield region, a number are classed as rare and endangered while others may be regarded as endangered but not yet rare.

Williams et.al.(1981) noted some species, which are probably or definitely present in the Mokau forests, which are regarded as rare. The short-tailed bat (northern subspecies) inhabits lowland podocarp-broadleaf forest and is declining through forest habitat destruction, rodent predators and human interference.

The kokako (Callaeas cinerea) is vulnerable and, although not officially recorded in the Mokau area it has been recorded in forests to the south. Its decline is due largely to habitat destruction, only a few hundred may be left. The striped skink (Leiolopisma striatum) has been recorded through central and western parts of the North Island. Numbers are not known but are estimated to be low.

Two galaxid species, G. argenteus and G.postvectis are of indeterminate status (Williams et.al., 1981) but swamp drainage, forest clearing and competition are causal in decline of these fish. Faunal species less at risk yet still only found in low numbers in New Zealand include the kiwi, rifleman, robin, falcon, Paradise duck, kaka and whitehead (Cusa et.al., 1980).

The forest in the region has outstanding value as habitat. Moynihan (1983) stated that the size of a forest will play a major role in its capacity to retain faunal diversity. He noted that modification of part of a forest block detracts from the value of the whole block, regardless of the quality of the part removed. The native vegetation in the region is of value not only as a harbour for wildlife but also as an entity in itself.

3.2.7 Soil and water conservation

Erosion of soil and rock from land leads to aggradation of streams and consequent flooding of downstream areas. In addition, the removal of soil by erosion is becoming a major problem (Eyles, 1983), and one towards which much attention should be directed.

The Mokau area falls within the responsibility of the Waikato Valley Authority, who identify areas where soil conservation measures should be carried out as

- (i) management techniques
- (ii) landuse restrictions
- (iii) rehabilitation programmes, or
- (iv) total preservation of the land and its vegetation. (Harris, 1981).

Soil and water conservation as a land-use is obviously interactive with other uses such as good farm management and vegetation preservation.

3.2.8 Recreation

Recreational pursuits centre on the aquatic resources, notably the two main rivers. Whitebaiters, as noted earlier, have both a recreational and commercial interest as do other fishermen. Camping grounds and motels cater for tourists and there are a number of holiday houses at the mouth of the Mokau River. Egarr et.al. (1981) discussed, in detail, the recreational use of the Mokau and the Awakino Rivers. The upper Awakino River is navigable by jet boat for 38 km in high water and may provide some of the best jet-boating in Taranaki. Drift boats, canoes and swimming are other uses for which conditions are excellent. The lower Awakino River is used by fishermen, motor boats, and swimmers. The upper Mokau is beyond the region of this study, in any case its recreational value is low (Egarr et.al., 1981). The Totoro Gorge,

has high recreational value with high grade drift boat or canoe water (Egarr et.al., 1981). The lower Mokau is used by boaters for access to other recreational pursuits and also for aquatic pleasure. Use is high, and the recreational value is also high.

Other recreational pursuits include passive scenic appreciation. The scenic value of the region is greatly enhanced by numerous scenic reserves and excellent views towards Mt Egmont are obtained along the coast. Hunting of pigs and goats is enjoyed by some in the forest areas behind Bexley and Mangatoi Stations. The archaeological and historic sites around Mokau and Awakino provide some attraction for tourists. More 'social' recreational facilities such as a rugby club, bowls, badminton, and library service are oriented towards locals rather than the visitor and much use is made of such facilities.

In general the region provides a blend of coastal and inland wilderness of high scenic value which is utilised by both group and private recreational interests.

3.2.9 Future land uses

Future land uses in the Mokau area are expected to be broadly similar to present patterns. It is likely that most farms will develop further with intensification of operations. Recreational uses will most likely become more important with increasing pressure on available amenities.

A detailed discussion of future land uses is not warranted in this study. It is likely, however, that major land use changes are only likely to occur within the immediate coalfield region, particularly the opencast areas, and in areas chosen for any power station and associated infrastructure.

Any proposed resource development in the Mokau region must consider future land uses both in the context of possible impact of the new development upon patterns and with regard to possible alternatives to the proposed development. In addition, if the currently proposed mining and power generation is to go ahead, post-mining land uses must be clearly determined prior to commencement of operations to enable appropriate planning of infrastructure and reclamation. Passive land uses such as nature conservation and soil and water conservation must be recognised as legitimate uses. The Mangapapa B2 block, which contains the majority of opencastable coal in the Mokau field is largely reverted farmland. Its potential for development has been recognised by a number of workers. The Maori owners of the Block are aware of the potential as regards timber and coal development and feel that the coal resource should be exploited to provide funds for agricultural or forestry development of the land (Carter, 1983).

Priest (1977) investigated the potential for forestry and agricultural development, making various recommendations in that regard. Watson (1978) investigated the economic viability of afforestation programmes in the area. With the probability of coal development, further studies are required, investigating possible integration of post mining land uses and determining appropriate reclamation techniques.

CHAPTER 4

A METHOD FOR IDENTIFYING IMPACTS AND CONSTRAINTS
RELATED TO RESOURCE DEVELOPMENT

4.1 APPROACH

Sound environmental management requires the early identification of resource requirements and impacts (or constraints) of a proposed development. This section of the study discusses a method for early impact definition which is both simple and practical in application.

A framework is required to aid in identification of resource needs and residuals. Traditionally impact definition has been intuitive without a sound rational basis. In view of the complexity of the proposed Mokau operation, a 'materials balance' approach is considered to provide a suitable framework.

The materials balance principle has been developed by a number of authors including Ayres et al.(1969), Kneese et al. (1971), Noll et al.(1971) and Ayres (1978). Ayres et al.(1969) stated that although most earlier authors who discussed welfare economics had regarded externalities as exceptional cases, there was at least one class of externalities which are a normal and inevitable part of consumption and production processes. These residuals increase in significance as the ability of the natural environment to absorb them decreases.

Ayres et al.(1969) noted that '... the means of disposal of unwanted residuals which maximises the internal return of decentralised decision units is by discharge to the environment, principally watercourses and the atmosphere.'

Water and air have traditionally been regarded as free goods in economic theory but it must be recognised that they are common property resources of increasing value. The first law of thermodynamics states that matter can neither be created nor destroyed but can be transformed, thus residuals will continue to exist once removed from the production process. It was noted by Ayres et.al.(1969) that many processes for treatment of residuals do not destroy them but only change their form. They therefore advocated that residuals problems be seen in a regional context.

Their approach was to view pollution and pollution control within the context of a materials balance for the economy with inputs of fuel, food and raw materials, and outputs of final goods and residuals. They developed a model for tracing residual flows and for quantifying these flows.

Noll et.al.(1971) reviewed the Ayres et.al.(1969) model and made a number of modifications. They believed that Ayres et.al.(1969) had implicitly equated mass of residuals with mass of pollutants and noted that the environment has a very large natural assimilative capacity for some residuals and they cannot cause significant pollution. They therefore advocated a vector approach through which '... one can account for the fact that nature has varying assimilative capacities for different residuals' (Noll et.al., 1971).

Noll et.al.(1971) also observed that elements of residuals often interact to form a new pollutant and this interaction should be incorporated into any model. These changes would increase the generality of the model and would admit wider scope in searching for pollution abatement methods than just advocating decreasing total residual mass by recycling or increasing total assimilative capacity through public investment as was done by

Ayres et al.(1969). The materials balance principle remains, however, and was clearly stated by Ayres (1978).

'... the sum total of materials and energy extracted from the natural environment as raw materials must exactly balance the sum total of materials and energy returned to the environment as waste flows, less any accumulations in the form of capital stocks and products inventories.'

The principle obviously has as its basis the laws of thermodynamics. The first law was stated earlier, and the second law, important in consideration of energy flows, states that for any transformation of energy, some will be lost as heat.

The materials balance principle has a number of uses. It will identify residuals and pollutants from conversion processes and while the principle should ideally quantify the flow of materials this is not always reliable at an early stage of planning. The Joint Centre for Environmental Science (1982) used the principle to determine coal requirements for liquefaction from various coal regions. They noted that 'This principle must be a dominant feature of any research method that purports to examine the environmental implications of increased materials transformation.' Their model was a partial materials balance which did not consider all of the material flows associated with lignite development but which was useful in determining the natural resources required for, and the residuals directly associated with, coal liquefaction.

Hide et al.(1983) used the principle to provide

- (i) a crude estimate of capital material requirements; and
- (ii) a quantification of inputs and outputs for calculation of annual production and consumption of materials.

As was noted earlier the principle is used in this study to provide a rational analytical framework within which identification of resource requirements and residuals can proceed. Quantification of all material flows is not possible for all aspects of the Mokau coal development, however the level of detail available at this early planning stage does allow some quantification of important aspects.

4.2 APPLICATION

The materials balance approach to identification of residuals for environmental management requires information on inputs to the system and an appreciation of the scale of operations. Given the information on inputs, it is a simple task to determine the nature and quantity of outputs which are either 'principle product', increased inventory, or residuals. The method is as accurate as the available information on inputs and operational scale, both of which are fairly well documented for the Mokau development.

The scale of mining operations discussed in the pre-feasibility study undertaken by Longworth et al.(1982) is used here to provide the basis of the mining materials balance. Some resource requirements for mining two million tonnes of coal were discussed in that report and these requirements together with data on the resource and ambient environment provide inputs to the balance. Other inputs have been calculated using available data.

Inputs to the mining balance include the ambient environment, coal-in-ground, labour, land, energy, machinery, potable water, construction materials and sundry operational requirements. Outputs comprise:

- (i) principle product; coal
- (ii) increased inventory; labour, machinery, buildings, sundry equipment
(note: this category shall revert to category (iii) below at completion of mining);
- (iii) residuals; land, water, operation emissions, ambient environment
(with modifications).

Information on the utilisation phase (a 1000 MW thermal power station) has been derived from a number of reports (N.Z. Electricity, 1981a; St Baker, 1981; Hill, 1975; Lewthwaite et al. 1983; among others).

Inputs to utilisation include the ambient environment, mined coal, land, labour, construction materials, energy, air and various sundries. Outputs comprise:

- (i) principle product: electricity;
- (ii) increased inventory: labour, buildings, equipment (this category shall revert to residuals at the cessation of operations);
- (iii) residuals: land, water, gas, ash, waste heat, operational emissions and the ambient environment with modifications.

The materials balance for mining and use of Mokau coal (fully detailed in Appendix 2) aids in identification of environmental impacts by indicating the nature and scale of inputs and outputs. The nature of environmental impacts which may be relevant to environmental management at Mokau are discussed in Chapter 5.

CHAPTER 5

IMPACTS AND CONSTRAINTS RELATED TO MINING
AND USE OF COAL FROM THE MOKAU COALFIELD

5.1 INTRODUCTION

Environmental impacts and constraints will derive from both inputs and outputs of mining and use sectors. It should be noted prior to discussion of impacts that no negative connotation is implied by the word. The Penguin English Dictionary (1979) defined 'impact' as '... strong impression or effect...' and there may be both positive and negative effects. Gehrs et al.(1981), in discussing implications of coal utilisation (mining and use) subdivided important factors into areas of 'system', 'site' and 'controls'.

The system has various resource requirements (inputs) and outputs. These may create impacts which are in part controlled by the ambient environment (site). Thus such features as local population, existing levels of pollution, present infrastructure etc. are all relevant.

Discussion of impacts related to coal mining and use has traditionally focussed on a number of features, some of which are inter-related and fall into five general categories:

- (i) Lithospheric impacts
- (ii) Hydrospheric impacts
- (iii) Atmospheric impacts
- (iv) Biosphere impacts
- (v) Social impacts.

Lithospheric, hydrospheric and atmospheric impacts are discussed here in relation to each sector. Biospheric impacts are discussed within the context of the related primary impact. The materials balance facilitates identification of primary impacts but these may have secondary effects. Where significant, secondary impacts are discussed in relation to the primary impacts.

Although a sectorial approach is used in discussion of most aspects of the resource development, such an approach is not appropriate for discussion of social impacts. These will be similar in many respects for both mining and use and are discussed in Chapter 5.4.

5.2 IMPACTS AND CONSTRAINTS RELATED TO COAL MINING

5.2.1 Lithospheric impacts and constraints

The geology of the opencast mine area will control mine design and may form a constraint to some operations. Instabilities of both cut batter and spoil pile slopes could produce safety, economic and ecological impacts. Small scale failures may be dealt with relatively cheaply and may be readily incorporated into the mine plan. Large scale instabilities, however, will have potentially disastrous consequences. In-pit failures would have predominantly economic and safety consequences while the failure of spoil piles such as in the C4-C5 gorge could have massive environmental impacts. Lithospheric constraints on underground mining, and requirements for further study were discussed by Longworth et.al. (1982) and need not be restated here.

Mining will produce impacts on soils, underlying strata and on surface ecology. Gross disturbance of about 14 ha. y^{-1} of opencast mine land, and underground mine working will remove much of the existing geological structure and any aquifers within the Maryville Coal Measures and Tauranga Group will be modified.

The lack of available flat land not underlain by opencastable coal forms a constraint on siting of initial overburden heaps; thus it may be necessary to dump this material (c. 5.0 Mm^3) into the C4-C5 gorge with possible ecological and water quality impacts. Flat land for surface facilities is also limited particularly in the West Entry area where a significant wetland occupies the only flat area and could suffer great degradation.

When soil is replaced it may take a number of years to recompact, creating a constraint on construction of any major engineering structures.

Differential settlement may occur forming cracks hazardous to livestock and machinery.

Insufficient information is currently available to enable valid statements to be made on all impacts to soils. However some general predictions are valid. Soil is a major resource in New Zealand and any disturbance of this resource should be fully justified or countered by suitable protection or treatment to reduce losses of quantity and quality. Soil would be stripped and replaced in one operation, thus disturbance by weathering will not be great, but physical attributes are likely to change.

With disruption of the soil, soil-forming processes will be disrupted and soil characteristics will change. The Tauranga Group materials may form hard surfaces during replacement. If soil is replaced directly upon this surface, drainage and root penetration will be inhibited. Reworking can alter soil texture by mixing horizons. Bulk density may increase through compaction particularly in fine grained soils such as are present in the coalfield. This increase will generally have an adverse effect, as water holding capacity is reduced and oxygen diffusion is inhibited. A decrease of infiltration into compacted soils would increase surface erosion.

Landscape changes may occur as a result of mining. As there will be dumping of initial overburden into the gorge, there will be a deficit of about 5 Mm^3 of spoil to fill the final void. Bulking of overburden should compensate for coal loss and there should not be a significant depression of the land surface. The most notable impact on land resultant from underground mining is derived from subsidence. The high extraction rates in underground mines will result in some subsidence. It is not possible at this early stage to predict subsidence levels or effects to any detail.

These aspects are adequately discussed in general terms by Brauner (1973), Thomas (1973) and Peng et.al. (1981). Lithospheric effects will derive from subsidence and will include possible generation of instability in steep areas. The lithospheric impacts related to mine access will be varied. Some land will be taken up, with ecological destruction. Increased runoff from sealed surfaces may increase erosion rates and there may be slope stability problems with road construction. Materials excavated from roadway cuttings must be disposed of, if rock and soil is merely pushed aside siltation problems could result. Visual and ecological degradation may also occur with spoil dumping.

5.2.2 Hydrospheric impacts and constraints

The existing hydrological regime in the opencast mine areas may impose constraints upon mining, and mining may have impacts upon water quantity and quality.

Groundwater within the Tauranga Group and Maryville Coal Measures may reduced batter stability and any water entering the pit would cause adverse working conditions, or localised pit flooding. Pumping of ground and pit water may cause water quantity and quality problems within the receiving water body. Surface water will also impose a constraint upon the operation as some streams will have to be diverted to avoid pit flooding. The c.2000 mm y^{-1} rainfall in the region will lead to collection of water in open pits. The hydrological balance of soils may change as a result of mining. Soil permeability and infiltration capacity may alter through changes in soil structure and by surface compaction. Reduced infiltration would increase flood levels in streams and reduce base flows; the opposite would happen if infiltration rates were increased. Vegetation changes after mining may affect the hydrological balance by changing evapotranspiration rates and some vegetation species may be inhibited in growth by different hydrological characteristics.

The gorge between Estimate Areas C4 and C5 within which dumping of initial overburden is proposed has a sizeable catchment area (180 ha.) and permanent changes to the hydrology of this gorge may be difficult to achieve.

Water quantity impacts will derive from the abstraction of water for mining, from the introduction of increased runoff into existing waterways, and possibly from introduction of pumped ground and pit water into streams.

The quality of both surface and ground water may be reduced through mining by contamination with suspended sediments and chemicals. Runoff from haulroads and spoil banks will be sediment laden. These sediments will mostly be clays, sands and silts although some coal fragments will be found in the mine spoil and these could also enter waterways. The high rainfall in the region may suppress dust but the dust will then become a water pollutant. The Mokau River will receive all of the water from the south opencast areas and if due care is not taken to control sediment-laden runoff gross degradation of water quality could occur with resultant ecological impacts.

Chemical water pollution resulting from coal mining has been discussed by numerous authors both in New Zealand and overseas, and can arise from trace and macro-elements found within the coal and surrounding strata.

Acid drainage produced during and after mining has caused great ecological damage in many coal regions. Pyrite (Fe S_2), present within carbonaceous mudstones and coal at Mokau can oxidise to produce sulphuric acid (H_2SO_4) and lower pH of surrounding water. Sulphate sulphur, an oxidation product, is water soluble and could add to production of acid drainage. The form of pyrite within the rock controls its rate of oxidation and Caruccio (1979) noted that small particles of framboidal pyrite are generally more reactive than coarse grained pyrite due to their higher surface area to volume ratio.

Detailed accounts of acid drainage formation are available in El Ashry (1979), Caruccio (1979), and Swaine (1981). If acid drainage is produced the solubility of various elements will increase with additional aquatic pollution resulting. Acid drainage pollution would increase water treatment costs, destroy much aquatic life, inhibit recreational use of the river and lower aesthetic values.

It is noted (El Ashry, 1979) that calcium, magnesium and nitrate pollution of water have occurred in surface coal mining in the U.S.A., and trace elements in Mokau coal may cause pollution if concentrations exceed environmental assimilative capacity. These elements include arsenic, boron, chromium, copper, lead, manganese, nickel, phosphorus, selenium and zinc.

Water is required in underground mines primarily for dust suppression. This water will be discharged together with water produced by the mine. This water will collect coal dust and may be toxic, containing dissolved trace elements. Acid drainage was discussed earlier and El Ashry (1979) studied in detail the potential for acid drainage from underground mines. Expulsion of mine water will have impacts for the receiving body if treatment is not carried out. Longworth et.al. (1982) allowed for protection pillars under main streams. However there could be some hydrological modification through mining subsidence. Subsidence could cause swampy areas to form, alter catchment areas and cracks in the ground could lead to increased infiltration of surface water. Such infiltration into underground mines was attributed by El Ashry (1979) as a major cause of acid drainage in Appalachian mines. Mularz (1979) noted that subsidence can lead to soil dehydration.

There is considerable difficulty experienced in maintaining open access on any of the exploration tracks constructed to date. This difficulty

generally arises from stream crossing washouts. The numerous streams along the Mokau River route contain large amounts of debris which could cause major problems with crossings over these streams. It was noted by Priest (1977) that culverts may be inappropriate along the Mokau River as the tidal fluctuations could cause water backup, and fill saturation. This would probably lead to piping failure of fill. The route along the Kaipaku stream would cross an area of wetland near the Kaipaku/Manga-awakino stream junctions. Any access development here would have extreme negative effects on this aquatic system.

The bath-house, workshops and office buildings will require clean potable water. The facilities will discharge an equal amount of dirty water including sewage, and stormwater runoff will also arise from sealed areas.

5.2.3 Atmospheric impacts and constraints

Air pollution associated with mining will arise through dust, noise, and diesel emissions,

Dust will be produced from numerous sources including haulroads, unvegetated areas and overburden and coal removal operations. While particulate emissions could be high near the mine, effects would generally be localised. Dust may, however, have a detrimental effect on vegetation in the region. This could include any vegetation used in reclamation and may affect the palatability and growth of stock feed. Haynes et.al. (1979) noted that dust from rock and coal may have health effects for workers and may cause some loss of machinery efficiency. Dust on haulroads could constitute a safety hazard, and visual quality of the landscape may be reduced by dust coatings on vegetation. Fugitive dust may also enter waterways.

Within the underground mine, significant amounts of dust will be produced. Simeons (1978) noted that modern equipment increases dust levels and it may constitute a health hazard. The 24-hour operation of the mines will produce much higher noise levels than exist in the area at present. Noise pollution in the mining environment is discussed in detail by Brdanovic (1982). Methane, CO₂ and diesel emissions may create some impact with possible safety hazards.

5.2.4 Other impacts and constraints

Direct energy inputs to the coal mine operations are discussed in Appendix 2. "Order of magnitude" calculations indicate that these inputs constitute about 1% of the energy entrained in mined coal. U.S. Department of the Interior (1981) stated that in a typical mine in U.S.A., between 1% and 2% of energy produced will be required as an input, with coal transport requiring about 60% of total energy input.

Thus there is an energy efficiency of about 99% for mining if only direct energy inputs are considered. A full energy balance would also consider indirect inputs (e.g. requirements for machinery manufacture) and the coal left in ground after mining (1.6×10^{10} MJ: c. 38% of output energy). Therefore true energy efficiency of mining may be lower than the indicated 99%. This aspect has, however, not been pursued in detail in this study.

Provision of direct energy requirements has two major implications:

- (i) there may be an impact to other energy users; and
- (ii) there must be some energy reticulation system.

Energy reticulation will create lithospheric, hydrospheric and ecological impacts with corridor destruction of vegetation.

The numerous material inputs required for construction and operation of the mines have been discussed in preceding sections. It is expected that with the exception of aggregate which is obtainable locally, all of the materials must be imported to the district. Continued heavy traffic along S.H.3, adding to already heavy use could lead to physical degradation of the road and may also lead to social problems.

It is unlikely that many of the material requirements will constrain other users by their use at Mokau, or cause environmental problems in their extraction. Aggregate, sand and gravel may be the exception.

Most of the material input becomes an increase in inventory. The materials will however continue to exist after the mine is closed and must then be considered as residuals with potential for impacting land, water and air.

5.3 IMPACTS AND CONSTRAINTS RELATED TO USE OF MOKAU COAL

5.3.1 Lithospheric impacts and constraints

Lithospheric constraints upon use of Mokau coal in thermal power generation relate primarily to

- (i) availability of flat land for the station; and
- (ii) foundation conditions at otherwise suitable sites.

No detailed siting study has yet been carried out, however it is obvious that there is little available flat land in the Mokau region suitable for a power station. Most of the large areas of flat land cover coal at opencastable depths and many other flat areas are prone to flooding. Siting of the facility is extremely important as it is a fundamental factor in controlling the extent of impacts (Gehrs et.al. 1981).

Power station siting has been discussed in detail by New Zealand Electricity (1981a-c) and by New Zealand Electricity (1976). The reader is referred to these reports for detail on site requirements. Although no decision has been made with regard to siting of a station, lithospheric impacts may still be predicted with some confidence.

During construction, earthmoving will be required to prepare foundations. Thus wholesale ecological damage to land-based communities will result. Good access to the site will be required and this will probably necessitate construction of a major road with attendant lithospheric impacts as discussed earlier (section 5.2).

During plant operation, the major lithospheric impacts will relate to disposal of power station wastes (ash, coal dust). Both have potentially major impacts on land. Ash will mostly be collected within the station and disposed of elsewhere. Dependent upon toxicity of the ash, secondary post-depositional impacts may occur. Ash released to the environment ($c. 5700 \text{ t y}^{-1}$) will fall on adjacent land and may constitute a pollutant. Ambient trace element levels in soils are not available to determine the likely effects of this ash.

If scrubbers are used to remove sulphur from flue gas, large amounts of limestone-based sludge will be produced. This resists solidification and requires special land disposal (Ramsay, 1979). This material would thus create a need for more land.

The final major land-related impact is secondary in nature and relates to landscape modification. It was noted by the Commission for the Environment (1976) with regard to Huntley Power Station that "The hope ... that the station will be able to be visually integrated with its natural surroundings is a forlorn one."

5.3.2 Hydrospheric impacts and constraints

Water-related impacts and constraints are concerned with both its supply and discharge. Provision of sufficient cooling water may impose a major constraint on siting of the plant. Neither the Mokau nor Awakino River are large enough to provide sufficient cooling water for open cycle cooling. Therefore if the coal is to be used in the region (coal transport costs may dictate that this is so) cooling options are reduced to "once-through oceanic" or cooling towers. The lack of suitable flat land adjacent to the coast, together with the high cost of ocean cooling (New Zealand Electricity, 1981b) indicates that this may be an unattractive option. Thus cooling towers are assumed to be used in the remainder of this discussion. Only about 1.17 cumecs of cooling and potable water would be needed and the Mokau River could supply this volume. It is doubtful that the Awakino River could be used as the minimum recorded flow is only 1.14 cumecs.

Using cooling towers, thermal pollution of waterways is largely eliminated. Boiler and cooling water blowdown (0.26 cumecs) would be added to the river water at about 10°C above ambient temperature (New Zealand Electricity, 1981b). Thermal pollution is discussed in some detail by Hill (1975) and Moore et.al. (1976) among others. In brief, organisms may be killed by thermal shock and oxygen concentration will drop at high temperatures. The release of boiler and cooling system water (and boiler cleaning water) will result in some addition of chemicals to the receiving waterbody. Blowdown from the cooling system will contain rust inhibitors, corrosion products, and an increased concentration in natural elements caused by water evaporation losses. Boiler blowdown contains similar elements together with S_1O_2 from water treatment.

Sewage effluent from the station will further strain a river's assimilative capacity for pollutants and the station stormwater runoff may be quite

significant. This runoff may be sediment laden during construction and may be of very low quality during operation if runoff from coal stockpiles and coal handling areas is untreated.

If it is decided to use land in the Awakau region, near Mokau, for the station, the tidal nature of the Mokau River in that area may have some effects on pollutant dispersal.

The final major area of hydrospheric impact is in the ash disposal sector. Runoff from ash disposal sites could be high in pH (Gehrs et.al. 1981). Settling ponds may not be very efficient at fly ash removal, and elements within ash that are most likely to reach the aquatic environment are those contained in fly ash (Gehrs et.al, 1981). The environmental effects of fly ash constituents must be assessed against background levels.

Toxic elements in ash could leach from disposal sites by runoff and seepage, polluting ground and surface water. However Gehrs et.al. (1981) noted that most of the elements will become fixed and remain in the soil with minimum migration to groundwater.

Ash pond supernatant (c, 8700 day^{-1}) must be disposed of. It will contain various suspended or dissolved elements from the ash. Disposal would not be difficult with opencycle cooling but with use of cooling towers a major disposal problem could develop.

5.3.3 Atmospheric impacts and constraints

Atmospheric impacts and constraints related to combustion identified in the materials balance derive from the following areas:

- (i) stack emissions
- (ii) cooling tower emissions
- (iii) ash disposal
- (iv) coal handling
- (v) noise.

Stack emissions include gases, particulates and heat. These emissions may recombine in the atmosphere and may also act synergistically on targets. Atmospheric residuals have a four-way fate, and may change their chemical state while airborne. Aerial transport leads to soil, water, land and humans. There are numerous routes from these receptors for both transport and transformation.

Gases and particulates may reach the ground by dry or wet deposition with resultant nutrient status changes in soil or aquatic systems.

Gases may travel many thousands of kilometers and their effects will change with distance (Clarke, 1980). Short range effects of emissions (c.10 km range) are dominated by sulphur dioxide (SO₂), nitrogen oxides (NO_x) and particulates. SO₂ can irritate the bronchial tract and plants are more sensitive to this gas than are animals (Holdgate, 1980). SO₂, nitrogen oxides and particulates enter or block plant cell stomata causing cell collapse, modifying plant surface properties (Holdgate, 1980). Particulates have their major impact at short range, however Clarke (1980) noted that modern arrestor equipment may reduce dust to almost indiscernible levels. Dust composition rather than quantity is however probably more environmentally significant. It was noted earlier that Mokau coal ash can have a high boron content. This level is similar to that of Waikato coal (Black, 1981).

The effects of boron emissions on land adjacent to a power station were discussed by the Commission for the Environment (1976), who noted that about 2% B₂O₃ in ash could result in topdressing of 0.54 kg ha⁻¹ y⁻¹.

Regional atmospheric effects (c.100 km) are characterised by partial conversion of SO₂ to sulphates which can affect visibility, and enhance corrosion of stone and metal. Nitrogen oxides (usually NO₂ at mid ranges) contribute a photochemical smog and these pollutants can affect forest and fish yields (Holdgate, 1980).

Long range effects (c.1000 km) primarily constitute acid rain. SO₂ and NO₂ have been implicated in this regard (Holdgate, 1980). Carbon dioxide (CO₂) may also create a negative impact on a long range or global level. CO₂ concentration in the atmosphere has increased by about 15% during the 20th century, rising at about 1/3% per annum; an increase due largely to fossil fuel combustion (Mason, 1980). The implications of this "greenhouse effect" are discussed by numerous authors (Moore, et.al. 1976; Mason, 1980, among others) and it was noted by Mason (1980) that prediction of a 2-3°K rise in global annual average temperature is widely agreed upon. Salinger (1982) discussed the possible changes to the New Zealand climate in a warm, high CO₂ world.

Emission from cooling towers will comprise a column of warm moist air. This may create a visual impact and may increase precipitation rates. Hill (1975) noted that moisture droplets from the plume could mingle with SO₂ forming sulphuric acid droplets.

Coal dust will be produced from various points and will impact visual quality and land and water quality. Ash disposal will create problems

if non-water disposal is used. Resuspension of ash could have secondary soil and water quality impacts. The final atmospheric impact is noise. The background noise level of the region will increase, detracting from local rural values in most possible site areas.

5.3.4 Other impacts and constraints

During coal combustion there is a great loss of heat energy to water and air. Only 35%-38% of input coal energy can be expected to be delivered to the power transmission system. There may be further energy losses if a cooling tower system is used for heat removal. This energy loss may be in the order of 2% (New Zealand Electricity, 1981b). Further energy loss will occur during power transmission. Thus the total energy efficiency of electricity generation may be much lower than the often quoted 35%-38% efficiency of a pulverised fuel generation plant.

The use of coal in a thermal power station will obviously render it unavailable to other users. This constitutes a major impact which should be carefully investigated prior to commitment of such a significant proportion of known indigenous fossil fuel reserves.

Construction materials are unlikely to create any major impact in their provision other than through quarrying of aggregate. However, as "increased inventory" they will become residuals after the plant is decommissioned and could create an ongoing impact.

A power transmission system will be required from the station to users. Environmental impacts of such a system are discussed elsewhere (e.g. New Zealand Electricity, 1976) and not considered in this study.

5.4 SOCIAL IMPACTS OF COAL RESOURCE DEVELOPMENT

In order to mine and use coal from the Mokau Coalfield, a large labour force will be required to construct and operate the power station and operate the mine. This labour force must be imported to the area and there will be an associated influx of families and service sector employees. Thus it is anticipated that a major social change will occur in the region with this population increase. Ministry of Works and Development (1983a) noted that a new town will probably be required to support coal development. Their study on town infrastructure investigated parameters and costing of towns associated with the mine and a power station at a site between New Plymouth and Lower Waikato.

Social impacts will accrue in a variety of areas both as a result of increased population and as a result of changes brought about in the local environment.

Wisniewski et.al. (1981) studied socio-economic effects of coal fired electric generating plants in the U.S.A. They noted that when large developments occur in rural areas, socio-economic changes will most likely be significant and disruptive of orderly growth. This influx is the driving force behind social consequences of development (J.C.E.S., 1982), and the change in population will increase demand upon services and resources and create a burden on local authorities.

Ward (1982) noted that social impacts commence from the time proposals are advanced until after the development is completed. The size of the impact will depend upon the nature and extent of existing infrastructure.

Social concerns related to a sudden influx of people into a relatively under-populated area include the introduction of a distorted age/sex structure, mental health problems, crime increase, and social conflict through distorted class compositions (Ward, 1982). In addition, impacts may occur to existing employment patterns with local workers attracted to higher wages.

After the construction phase is completed, the construction workers will become residuals, and similarly after decommissioning of the station and mine closure operators and dependent service sector workers will also become residuals. This potential "boom town" phenomenon has been discussed in detail by Taylor et.al. (1983).

There will be impacts on land, water and air and energy resultant from construction of a new town. It is however not possible to detail these impacts until a definite site decision is made.

The sphere of social impacts is worthy of more detailed discussion than possible in this study. The reader is referred to Taylor et.al. (1983); J.C.E.S. (1982); Wisniewski et.al. (1981); and New Zealand Electricity (1981c), for further discussion on social impacts of major resource developments.

5.5 ENVIRONMENTAL SIGNIFICANCE OF IDENTIFIED IMPACTS AND CONSTRAINTS

The materials balance has identified primary outputs, increased inventory, residuals and resource requirements associated with Mokau coal development. Potential environmental impacts and constraints have then been easily identified within this framework.

The impacts could have many significant implications for current land and water users in the Mokau region (and in the power station area if not sited near Mokau). Soil and water conservation land uses could suffer severe negative impacts. Water oriented uses could be seriously impacted by both mining and use of coal. In particular, the following areas may be at risk:

- (i) the whitebait hatchery areas
- (ii) the Mohakatino mussel reef
- (iii) the Mokau River downstream from the mine.

Nature conservation is becoming an increasingly important land use as more habitats are removed, and this use is under threat from all impacts discussed earlier. Farming may be impacted by flat land alienation with possible downstream effects such as developing poorer quality land.

The impacts and constraints vary in importance and some of the negative impacts may be largely avoided by careful design. Geological constraints upon mine layout and design and power station siting may be assessed by site investigation which should determine site characteristics, provide indications of spoil heap stability and identify potentially unstable areas.

Gross land disturbances are highly significant and may form ongoing impacts to water and land uses if reclamation of a stable landscape is not attained. Neither opencast nor underground mines need derelict land and may actually turn waste land into productive land. Such an improvement may be perceived for Mangatōi Station but it is only in the area of agricultural production that this is a wasteland. The impact of land disturbances could largely be controlled by good site reclamation. The degree to which reclamation is carried out will largely determine post-mining land use although there is an increasing tendency to reclaim with definite uses in mind.

Although there is variation in terminology used to describe post-mining land treatment (e.g. "reclamation", "restoration", or "rehabilitation") philosophies are similar. Fortune (1975) stated that reclamation means the elimination of offsite damage and return of land to productive use. Powell et.al.(1981) believed that the common initial objective of stabilising land is to prevent erosion. Their second objective would be to consider the steps necessary to return the land to production. The Joint Centre for Environmental Science (1982) stated that reclamation involves the restoration of a stable landform and the restoration of a stable and productive soil. They recognised the need for site specificity in reclamation planning and demanded that reclamation can only be considered complete when vegetation cover is self-perpetuating and landforms are stable. Miller (1981) has noted that to only reclaim land to its pre-mining state is to lose the opportunity for lasting improvements. In this regard, the impacts, advantages and possible integration of post-mining land uses must be assessed. Atkinson (1980) noted that the most effective reclamation requires soil and overburden being early inputs into mine planning. Ramani (1978) also noted that good pre-mine planning can greatly help reclamation of the land to a decided use; a decision which should be made in advance of mining for optimal planning.

Subsidence may not be a major constraint upon mining of Mokau coal. There are few engineering structures that could be damaged and the possibility of subsidence prediction should aid in the identification of any problematic areas.

Power station ash disposal impacts may be ameliorated if some commercial uses can be found. Ward (1982) noted that the ash may be used as landfill, or in industry. Ash may also be reinjected to underground mines. Manz (1979) discussed in detail the economics of re-use of ash.

Although mine and power station water requirements are not likely to create major constraints for other users, hydrological modifications and impacts are potentially extreme. The presence of pyrite and other potentially toxic material in coal and rocks does not necessarily result in a loss of water quality. The ultimate drainage quality will depend on natural water quality and upon materials handling procedures (Groenwold, 1979). Rechar (1975) noted that surface mining without undue hydrological impact is possible; the key to success being investigation, planning, environmental awareness and mine planning flexibility. Dorling (1978) discussed water control at the Centralia opencast mine in Washington where water, after treatment, enters natural streams only when it is at least as clean as the stream water. Lawrence (1982) discussed water and soil guidelines for mining and noted that "The overriding philosophy behind the guideline is to integrate water and soil considerations into mine planning at all stages rather than to mitigate problems after they have occurred."

Of atmospheric impacts, the most environmentally significant will probably be those derived from the power station. However, there is potential for removal of much of the toxic material from flue gases using techniques such as removal during combustion (e.g. Fluidised Bed Combustion) or wet scrubbing. These methods are discussed in detail by Morrison (1982) and Gehrs et.al.(1981). It should be noted that these methods do not eliminate the residual but only convert it to another (easier handled) form.

Social impacts may prove to be extremely significant problems during and after the project life. Wisniewski et.al.(1981) noted that accurate

predictions of changes incurred by energy developments may allow preventative or control measures to be taken to minimise undesirable social impacts.

It was noted in Chapter 4 that before a residual can be called a pollutant, the environmental assimilative capacity for that residual must be known. Thus at this stage it is not possible to absolutely determine how much pollution will occur. However as the residuals are known, site studies could rapidly assess which residuals are likely to be problematic, and efforts to devise controls would follow. Thus there is potential for amelioration of many impacts that may arise with Mokau coal development. Some of the impacts may be unavoidable if coal is to be mined and used at the rate and in the manner assumed here. These impacts will then be the final environmental costs of the project.

CHAPTER 6

IMPLICATIONS OF THIS STUDY FOR COAL MANAGEMENT PLANNING

In Chapter 5 it was shown that a number of impacts and constraints related to mining and use of Mokau coal may occur. It was also shown that further environmental information is required in some areas before all environmental impacts and constraints can be fully assessed.

The potential for amelioration of negative environmental impacts and the incorporation of environmental constraints into mine planning can only be realised if the necessary information on environmental factors is available. This information gathering will require ongoing studies in numerous areas, some are yet to be fully identified. While resource development without environmental impacts is not possible, some impacts are more significant than others. Planning requires identification of environmental components that may be most affected and design of strategies that will confine the impacts within acceptable limits (Hayward et.al., 1982). Thus planning should recognise that ecosystems are capable of adaptation to some limited changes in environmental quality.

The assessment of potential for impact amelioration and incorporation of constraints in planning will indicate those impacts which cannot be controlled using current technology. These 'environmental costs' of the project must then be carefully assessed against the benefits of coal utilisation at the proposed scale. Dependent upon their nature, these costs could create severe constraints upon the development. The planners may then be required to investigate alternative strategies to obtain electrical energy.

Early recognition of environmental aspects related to development and their incorporation into management planning was advocated by some authors discussed in Chapter 5 (i.e. Atkinson, 1980; Ramani, 1978; Lawrence, 1982; Wisniewski et.al. 1981).

The benefits of early environmental assessment for resource planning have also been discussed by Ward (undated) and Hayward et.al. (1982).

Ward (undated) stated that

"Mine planning can be assisted by early identification of physical and ecological constraints which have the potential to cause monetary losses resulting from sterilisation of reserves, lost production, unscheduled construction activity and compensation."

He also noted that environmental assessment should be started early in the exploration programme, when environmental studies are able to be carried out most cheaply, and should continue until mining begins (when environmental monitoring takes over).

Hayward et.al. (1982) stated that

"... if we are to minimise the environmental problems caused by development, environmental issues must be considered early in the planning process."

They also noted that if development is framed within environmental constraints identified early in planning stages, long run efficiencies of resource use are achieved. Furthermore, if other land and resource users are ignored until late in planning, " ... we often inhibit other equally legitimate ... enterprises, frequently violate important environmental constraints and invariably fail to address the central question of wise or appropriate resource use" (Hayward et.al. 1982).

The position of such a study as this in mine planning is therefore regarded as critical. Coal resource development planning follows a framework outlined by Major Projects Advisory Group (1983). While this framework (Fig. 6.1) incorporates environmental factors, they are apparently not regarded as a major factor and there is no input from environmental studies into the mainstream of mine planning until late in the 'Feasibility Study' stage. Coal management planning is thus dominated in the early stages by technical and physical fact finding.

It is obvious therefore that there is a requirement to substantially change coal management planning procedure in order to bring environmental assessment forward into the early planning stages. A strategy that would suitably incorporate investigation requirements for the Mokau coal development is summarised in Fig.6.2. This strategy brings environmental factors into the planning mainstream at the pre-feasibility stage incorporating a study similar to this 'environmental pre-feasibility' study.

Thus mine planning would be aware of potential environmental problems from an early stage. While feasibility study investigations would continue with drilling, mining feasibility and geotechnical work, environmental investigations would be incorporated into the work programme. Ongoing interplay between investigation sectors (as currently occurs between exploration, mine engineering and geotechnical sectors) would then be possible.

A preliminary mine plan would still be produced at the end of the feasibility study and this plan having had the benefit of good environmental input would

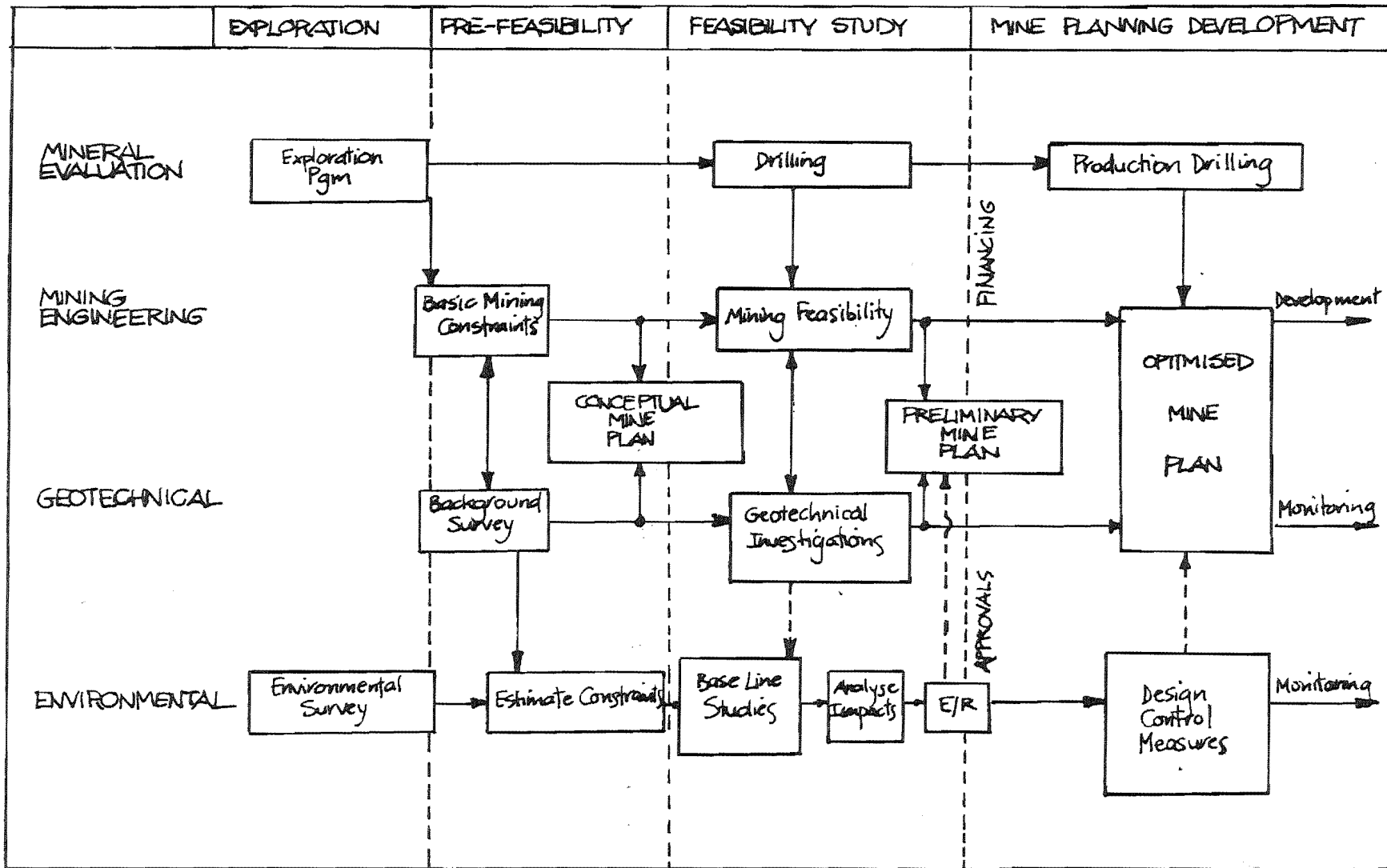


FIG 6-1 STAGES OF MINE DEVELOPMENT INTEGRATION OF ENVIRONMENTAL PLANNING - after M.P.A.G. (1983)

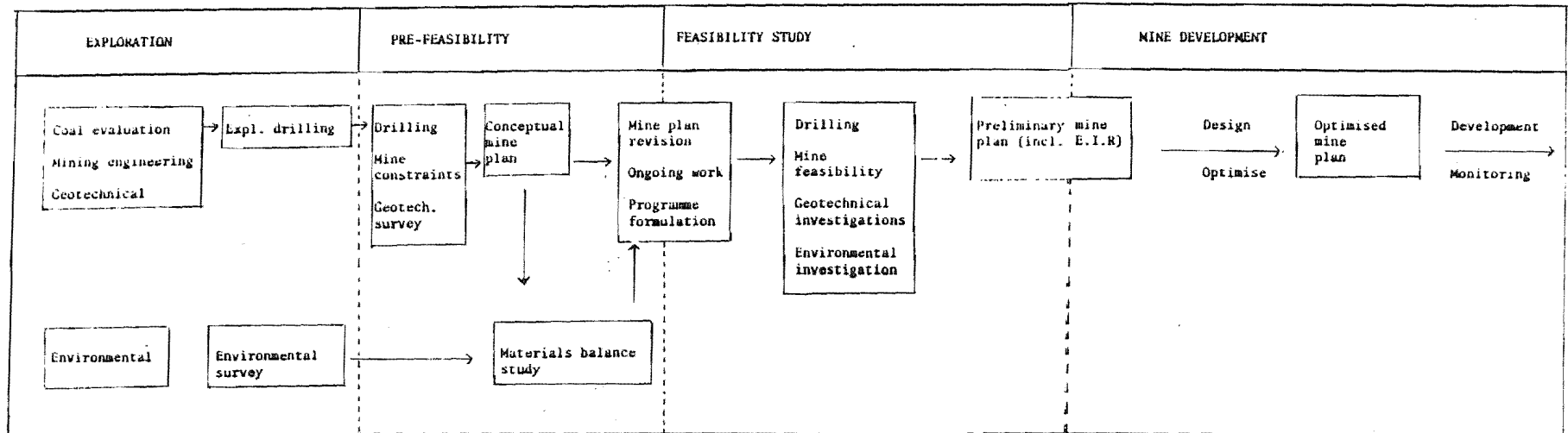


FIG. 6.2: 'Environmentally aware coal resource management planning framework'.

thus incorporate full environmental information and provide detail on expected impacts together with plans for their amelioration or avoidance. In addition the preliminary mine plan would incorporate strategies for development recognising and incorporating environmental constraints.

The goal of this current study has not been to provide details on the future management strategy for the coalfield. Rather, given the constraints on the scope of this study it was considered more appropriate to describe and demonstrate a suitable methodology for early inclusion of environmental factors into coal resource planning.

However, some investigation requirements for future management planning of the Mokau coal resource are made obvious as a result of this largely indicative study. In brief, the future investigations for Mokau coal development planning must include the following:

- (i) Geological studies - coal proving, overburden, interburden
geochemical analysis
- (ii) Geotechnical studies - largely as discussed by Longworth et.al.
(1982), also power station site investigations
- (iii) Hydrology studies - regional water quality, quantity
- (iv) Subsidence prediction - assuming mining methods discussed in this
study
- (v) Reclamation studies - detailed alternative land use studies and
potential for reclamation
- (vi) Environmental studies - numerous, particularly in areas where
assimilative capacity of residuals needs to be known for
impact definition
- (vii) Alternative coal use - include alternative coal combustion methods
particularly Fluidised Bed systems

(viii) Social impact assessment

(ix) Climatic studies - both in the coalfield and possible power station site areas.

(Note: It must be stressed that this list is by no means exhaustive.)

Only when a more detailed analysis than was possible in this study is carried out, and necessary investigations are recognised and executed will sound environmental management of the Mokau coal resource be possible.

CHAPTER 7

CONCLUSION

Significant environmental impacts and constraints related to development of the Mokau Coal resource may be predicted at an early stage of planning using the method illustrated in this study. This early identification of impacts allows project planning and design to proceed in such a way that these impacts can be managed within acceptable limits.

The approach used is an adaptation of the materials balance principle of Ayres et.al. (1969) and others. The materials balance has a rational base and provides a sound framework for prediction of environmental impacts and constraints. Using the management approach advocated in this study, it would be possible to incorporate environmental factors at the pre-feasibility stage of coal resource planning.

It has not been possible given the constraints on the size of this study, to identify all important environmental factors or to quantify all of those identified. However, this does not invalidate the method. Problems unresolved in this study will be solved by some detailed environmental investigations and by extension of the materials balance model to cover all areas of the proposed coal development.

An obvious comment regarding the materials balance approach is that the identified impacts and constraints could have been identified using a "common sense" (intuitive) approach. This may be true; however the materials balance approach ensures that all aspects are considered and also provides a clear framework of the nature and scale of development for analysis by both professionals and planners. Hayward et.al. (1982) believed that there are three sets of issues necessary for inclusion in environmental management and resource development planning.

They are thermodynamics, ecology and socio-economics. The materials balance approach allows easy incorporation of all three sets of issues into coal resource planning.

GLOSSARY

| | | |
|-----------------|---|---|
| "Alpine" miner | : | a "continuous" mining machine suitable for use in difficult ground. Cuts an arched roadway. |
| Dilution factor | : | the percentage of "stone" which becomes mixed with coal during mining. |
| D.a.f. | : | dry, ash free. |
| D.m.m.f. | : | dry, mineral matter free |
| Highwall | : | the cut slope of the advancing face of an opencast mine pit. |
| M.a.s.l. | : | metres above sea level |
| M.W. | : | mega watt = 1MJ/sec. |
| Mt | : | million tonnes. |
| Mm ³ | : | million cubic metres. |

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APPENDIX 1

NATURAL ENVIRONMENTA1.1 Topography

From the Tasman Sea in the west to the highest point (500 m.a.s.l.) in the centre of the coalfield, there is great topographic variation in the study area.

The region is on the western edge of the old and extensive North Taranaki surface which formed on Upper Miocene sediments and is now highly dissected by tributaries of large rivers. Three broad physiographic divisions are apparent. They are:

- (i) coastal terraces
- (ii) river flats
- (iii) uplands.

Chappell (1964) recognised five Pleistocene terraces on the coast around Mokau. The lowermost of these terraces forms the narrow coastal plain upon which Mokau is situated. River flats are locally extensive along the Mokau and Awakino Rivers, particularly in the lower reaches and in the Mahoenui region of the Awakino River Valley. The upland region is a mixture of steeply dissected land, plateaus and shallow dip slopes formed on Mokau Group sediments. These dip slopes are particularly important on both Bexley and Mangatoi Stations as grazing land. The topography of the coalfield is dominated by a high central ridge with broken country, plateaus and dip slopes extending to the North and South. The often steep (35°) slopes in the area terminate either in "knife-edge" ridges or in broad undulating plateaus. Lithologies in this area are generally soft and easily erodible however occasional resistant beds, including coal seams, cause waterfalls to develop in many streams. Phelps (1982) noted that tributary streams may follow fault traces for considerable distances.

Relatively flat land in the area is thus restricted to river flats, coastal terraces, plateaus and dip slopes.

A1.2 CLIMATE AND HYDROLOGY

A1.2.1 Climate

The study region exhibits both coastal upland climatic types. The climate station at Mohakatino provides data for the coastal area but only limited data are available for the upland region. Rainfall stations are scattered throughout both climatic regions.

Rainfall records are shown on Table A1.1 for both coastal and upland areas. Rainfall distribution is shown on Fig. A1.1. Generally rainfall is about 1600mm y^{-1} at the coast, increasing to over 2000mm y^{-1} inland. The maximum one-day rainfall at Mohakatino was 149mm, the maximum two day rainfall was 257mm. The average number of days with more than 1.0mm is 142.3, with more than 10mm is 50.7 and with more than 20mm is 22.1 days. May, June and July are the wettest months although heavy rainfalls may occur during spring. The driest month is January or February and in most of Taranaki rainfree spells average about 18-20 days in length about once a year, in summer.

Potential evaporation only exceeds precipitation in January to March and no farmers in the area report drought problems.

Rainfall increases with elevation into the upland region. Rainfall stations were established at Mangatoi, Te Matai, and Mokau River (Fig. A1.1). Unofficial rainfall information was obtained from two farmers in the upland region. P. Gibbons at Bexley Station estimates annual precipitation to be in the order of 2200-2400mm y^{-1} and D. Salmon at Rimrock Station provided information for the period June 1977 - June 1982.

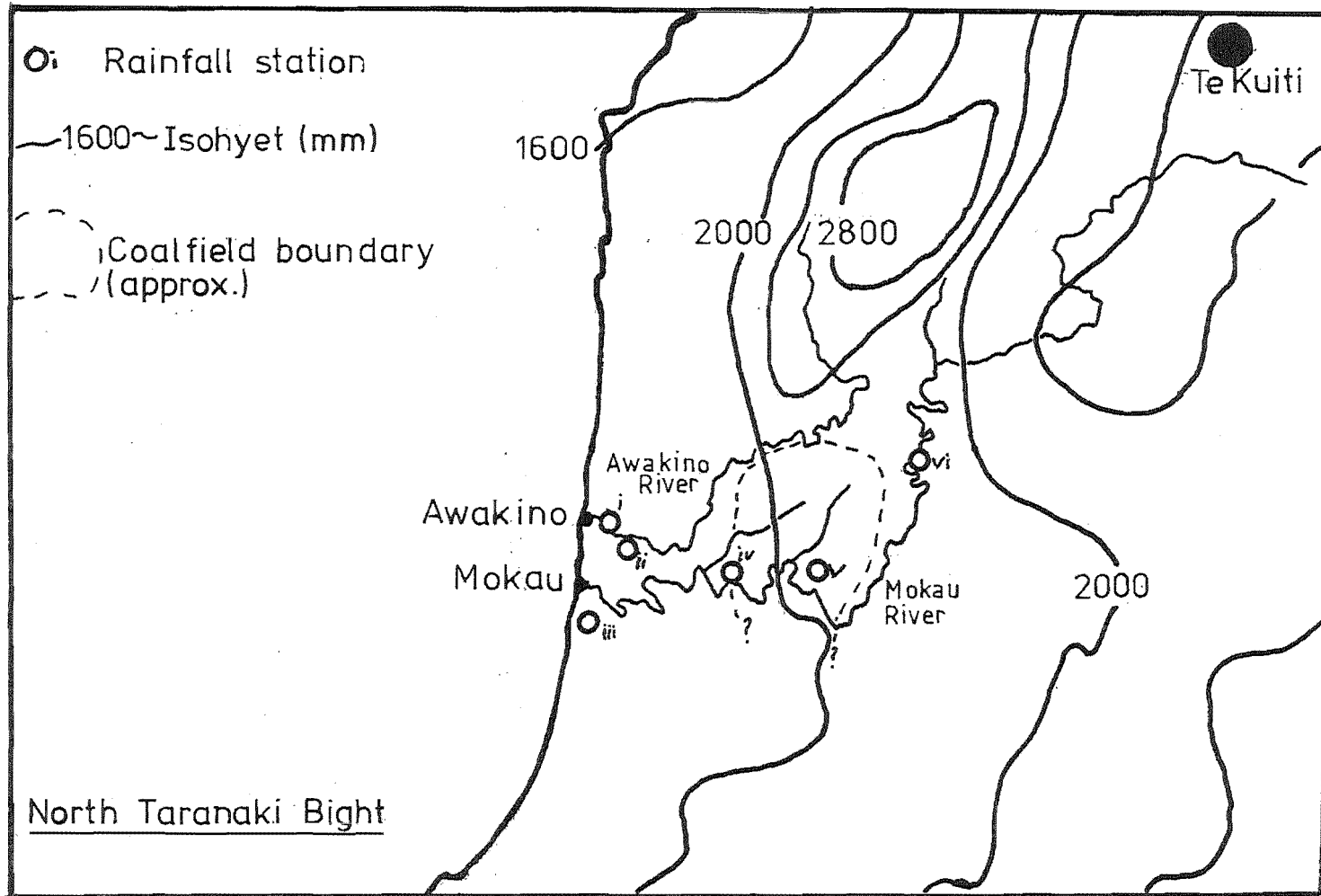


FIG.A1.1: Rainfall distribution, Mokau Coalfield region.
 (Note nos. i-vi. ref. to Table A1.1.)

TABLE A1.1 RAINFALL RECORDS
 (From New Zealand Met. Service, 1973; 1982).

| Station | RAINFALL (mm) | | | | | | | | | | | | |
|--------------------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann. |
| Awakino (i) | 100 | 120 | 110 | 140 | 170 | 200 | 180 | 160 | 130 | 160 | 140 | 140 | 1750 |
| Awakino School (ii) | 110 | 130 | 120 | 150 | 190 | 210 | 200 | 170 | 140 | 170 | 160 | 170 | 1920 |
| Mohakatino Station (iii) | 103 | 117 | 95 | 133 | 162 | 168 | 160 | 145 | 126 | 143 | 137 | 127 | 1616 |
| Mokau River (iv) | 120 | 120 | 120 | 150 | 200 | 210 | 200 | 170 | 140 | 170 | 150 | 160 | 1910 |
| Mangatoai (v) | 132 | 150 | 180 | 165 | 201 | 231 | 203 | 188 | 178 | 208 | 191 | 196 | 2173 |
| Te Matai Aria (vi) | 127 | 142 | 122 | 157 | 191 | 221 | 193 | 180 | 170 | 198 | 180 | 188 | 2069 |
| Rimrock | | | | | | | | | | | | | 2064 |

The most common wind directions are from the west and the south but local details are unavailable. Records at New Plymouth indicate that winds blow from these directions for more than half of the year (Tomlinson, 1976). Gale force winds are expected on 1.8 days per year at Mohakatino.

Temperature variations are more marked in the upland region as the proximity of ocean ameliorates the coastal climate. Ground frosts are only expected on 17 days per year at Mohakatino but severe frosts are common inland (Tomlinson, 1976). Summer temperatures rise to over 25^o at the coast and probably exceed this inland. Mean daily temperatures at Mokahatino range from 18.2^oC in summer to 9.7^oC in winter. The average daily range is about 6-7^oC.

Sunshine hours are lower than for much of Taranaki, ranging between 1800 and 2000 hrs y⁻¹. Hail is expected on average on 3.7 days per annum at Mohakatino and thunder on 13 days. Snow is not expected on the coast but has been recorded inland.

A1.3 HYDROLOGY

A1.3.1 The Awakino River

The Awakino River flows to the west from the Herangi Range into the Tasman Sea at Awakino. The 75 km river is generally of slight to nil gradient. It is clear in the upper reaches, becoming increasingly discoloured downstream. Egarr et.al. (1981) noted that the river is suspected of being polluted. The upper section of the Awakino above the Mahoenui Bridge (S.H.3) is in hill country and the river is clear.

TABLE A1.2.FLOW AND SEDIMENT YIELD DATA: MOKAU AND AWAKINO RIVERS (Data from Ministry of Works and Development, 1983b.)

a) Minimum, mean, maximum flows (l sec^{-1} , ave. 1979-82)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Extremes | Ann. Mean |
|------|-------|-------|-------|-------|--------|-------|--------|--------|-------|--------|-------|--------|----------------|-----------|
| Min | 9949 | 6430 | 7518 | 15315 | 12479 | 14864 | 19579 | 28066 | 27373 | 16000 | 12709 | 12477 | 2670 (2/82) | |
| Mean | 26579 | 11920 | 15955 | 31538 | 37094 | 38739 | 48368 | 52396 | 50056 | 42391 | 24719 | 36245 | | 34700 |
| Max | 69113 | 30515 | 47735 | 75193 | 103614 | 90421 | 117348 | 120943 | 94904 | 148892 | 61247 | 144521 | 267057 (10/79) | |

| AWAKINO | | | | | | | | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------------|-----------|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Extremes | Ann. Mean |
| Min | 2660 | 2029 | 2506 | 3015 | 4028 | 3988 | 4875 | 7642 | 7445 | 5119 | 4315 | 3770 | 1139 (2/82) | |
| Mean | 8528 | 4207 | 7051 | 11886 | 15011 | 15552 | 14485 | 17734 | 17975 | 14932 | 10575 | 11835 | | 12481 |
| Max | 31734 | 15146 | 29704 | 47359 | 49073 | 37229 | 41957 | 57476 | 45643 | 72074 | 36928 | 63978 | 13084 (10/79) | |

b) Sediment gaugings (mg l^{-1})

| MOKAU | Date | Flow (l s^{-1}) | sed (mg l^{-1}) | AWAKINO | Date | Flow (l s^{-1}) | sed (mg l^{-1}) |
|-------|----------|----------------------------|----------------------------|---------|----------|----------------------------|----------------------------|
| | 15.10.79 | 270900 | 396 | | 15.11.79 | 8447 | 33 |
| | 16.10.79 | 195900 | 130 | | 6.12.79 | 4482 | 14 |
| | 15.11.79 | 43813 | 75 | | 22.5.80 | 50856 | 238 |
| | 4.9.80 | 44290 | 62 | | | | |
| | 22.5.80 | 102471 | 226 | | | | |
| | 26.8.80 | 32565 | 18 | | | | |
| | 20.11.80 | 16152 | 14 | | | | |

Below the main road, velocity drops and the river flows through farmland until the Awakino Gorge is reached. This 15 km section is dominated by steep bushclad hillsides on either side and is navigable by jet boats at high flows (Egarr et.al, 1981). The lower reaches of the river are tidal and pass through farmland. The river here is navigable and the banks are muddy. Adjacent flats are prone to floods which are often heightened by high tides. A N.W.S.C.O. gauging station is located in the Awakino Gorge at N91:269452. The station gauges 226 km² of catchment and records are available for 1979-1982, for both water and sediments. Results are summarised on Table A1.2.

A1.3.2 The Mokau River

The Mokau River has been divided into three sections (Egarr et.al. 1981). The upper Mokau River (from its source to the Wairere Falls Power Station) has low velocities. The central 13 km section of river is located about the Totoro Gorge. This stretch of water is described as "wild" (Egarr et.al. 1981). The 78 km lower section of river includes all that part from the Totoro Gorge to the mouth. The river flows from farmland into rugged bush near the eastern edge of the Mokau Coalfield and the scenic value is impressive. The lower 25 km of the river is tidal and a wide estuary is present at the mouth.

There is a considerable sand and silt deposit in the river and Moyes (1977) noted that there is no doubt a large bed load, particularly during floods. The river contains many snags, most the result of great floods in 1915, but is navigable by small craft. The numerous tributaries flowing into the Mokau in the study area drain bush and scrub country and are often swampy.

As on the Awakino River, the combination of high flood flows with high tides can cause serious inundation of farmland in the lower reaches, particularly in the Awakau area. A gauging station is maintained at the Totoro Gorge Bridge (N91: 431547) and results of both water and sediment gaugings are given on Table A1.2.

A1.3.3 Groundwater

The extent of the groundwater resource is not well known at present. Hay (1967) believed that useable water may be found in Mokau and Te Kuiti sediments, and the water bearing nature of Tauranga Group sediments is well documented (McInally, 1982). Groundwater is present in places in sufficient quantities to provide household supplies and most farmers rely on spring-fed streams for stock water.

A1.4 ECOLOGY

A1.4.1 Vegetation

Vegetation was retained largely in its natural state until European occupation began. Forest covered most of the area inland from the coast but is now restricted in extent and much is replaced by pasture grasses. In some areas reversion to forest is obvious with punga and manuka flourishing on hillsides that have been cleared up to four times in European history. The present vegetation distribution in the region reflects both historic and contemporary efforts by exploiters to change the environment and also the adaptability and resilience of the native vegetation.

Native forest is found in State Forest 177 (Mahoenui State Forest), Awakino State Forest, most of the Manga-awakino River valley, the large area to the south and east of the Mokau River, and in scenic reserves

and isolated pockets remnant after forest clearing. The area of forest to the south and east of the Mokau extends in a largely unbroken tract to the Wanganui River.

The Mahoenui State Forest was gazetted in 1954 and covers 1075 ha., with a resource of 14-15000m³ of podocarps and 13500m³ of hard woods (Guest, 1983). Moynihan (1983) noted that the forest, in a virgin state and at a climax stage, is a mosaic of forest types. The forest contains both podocarp and hardwood species. Rimu is the most frequent podocarp and tawa the most frequent hardwood. Other species present include rata, rewarewa, miro, hinau, kamahi, pigeonwood, Hall's totora and hard beech. Browsing animals have depleted the forest understorey in some areas.

The block of forest to the south of Mahoenui State forest in the Manga-awakino valley is depleted and modified. Much of the area has been selectively logged for podocarps. The forest remnant is made up of tawa, old rata and occasional hard beech trees.

The region contains many scenic reserves. These were gazetted as early as 1915 and they contain kahikatea, kanuka, tawa, rimu, karaka, totora and nikau. Willows, gorse and blackberry infest some of these reserves and the native understorey is generally depleted by browsing. The isolated pockets of forest in the region (e.g. Mackford Bush, Awakino State Forest) contain diverse vegetation. Milling and burning have depleted these stands.

The largest area of native forest is found to the south of the Mokau River and is moderately diverse in character, comprising hardwoods, occasional podocarps and some hard beech on higher ridges.

Wetland vegetation is found along some of the creeks and on flood-plains but is never very common. The Manga-awakino valley contains a number of small often interconnected areas in a relatively undisturbed state.

A1.4.2 Wildlife

Much of the vegetation in the area has value as wildlife habitat. The large areas of native forest have regional, and in part national, significance in this regard (Moynihan, 1983). Being in a coastal situation, the region offers a variety of habitats. Table A1.3 lists faunal species found in the region during a national survey by Wildlife Service (Moynihan, 1983).

The Mokau River mouth area of tidal flats, bluffs and black sand beaches has high to moderate habitat value. There is a lack of such habitats along this coast (Moynihan, 1983). Although the sedge and rush margins of the Awakino estuary were not given special status by that survey, the estuary is an important habitat for aquatic fauna and waterfowl.

Inland from the coast, forest habitats are dominant. Awakino State Forest and surrounding bush is regarded as being of moderate value as a habitat and has moderate bird species diversity. The most outstanding forest habitat in the region is the large area extending south to the Wanganui River. Of note among forest avifauna within this forest are kiwis, falcons, and a few robins (Moynihan, 1983). The

TABLE A1.3 SOME WILDLIFE SPECIES RECORDED IN THE MOKAU COALFIELD REGION (from Moynihan, 1983).

| <u>SPECIES</u> | <u>AREAS RECORDED</u> |
|---------------------|---|
| Paradise Duck | River mouths, Mokau River |
| Mallard Duck | " " " " |
| Grey Duck | " " " " |
| Black Shag | " " " " |
| Little Shag | " " " " |
| Gulls | River mouths |
| White Fronted Heron | River mouths, Mokau River |
| Reef Heron | River mouths |
| Oyster Catcher | " " |
| Pied Stilt | " " |
| Caspian Tern | " " |
| Bittern | " " |
| Kingfisher | River mouths, various bush areas |
| Pukeko | Widespread river areas, farmland |
| Kaka | Mahoenui State Forest, bush to south of Mokau River |
| N.I. Kiwi | " " " " " " |
| N.I. Robin | " " " " " " |
| Falcon | " " " " " " |
| Rifleman | " " " " " " |
| Long Tailed Cuckoo | " " " " " " |
| Bellbird | " " " " " " |
| Pied Tit | " " " " " " |
| Grey Warbler | Various bush, scrub areas |
| Whitehead | " " " |
| Tomtit | " " " |
| Silvereye | " " " |
| Woodpigeon | " " " |
| Shining Cuckoo | " " " |
| Tui | " " " |
| Fantail | " " " |
| Harrier | " " " |

numerous small areas of bush inland have potentially good or moderate habitat value.

The large section of (partly depleted) forest in the centre of the coalfield and north to the ridges above Mahoenui is regarded as having high habitat value with a high diversity of native avifauna. Moynihan (1983) noted that Kokako could be present (the situation is ideal) and bats, robins, kiwis and kaka have been recorded here.

The river and wetland habitats attract various birds. These include mallard, grey and paradise ducks, occasional Canadian geese and bitterns. Herons and shags are fairly common. The aquatic habitats also host other fauna. Possibly the best known aquatic fauna are the "whitebait". These are an attraction for many people. Whitebait are found up to 35 km upstream in the Mokau River and comprise the juveniles of the following species:

Galaxius maculatus (major contribution)

Galaxius brevipinnis (secondary contribution)

Galaxius fasciatus (small contribution)

Galaxius postvectis (minor contribution)

Galaxius argenteus (minor contribution)

Whitebait are believed to move into rivers in response to reduced salinity (Mckenna, 1981) and the Mokau River is the source of good catch quantities. Of importance to the maintenance of good whitebait reserves is the availability of a breeding population and a breeding habitat. The most common species, Galaxius maculatus, breed in their first year, moving down from freshwater to estuaries. During high spring tides, water floods rushes and grasses on estuary banks and the fish swim and spawn amongst the vegetation at its base (Mckenna, 1981). There are two

potentially excellent spawning sites on the Mokau. These are identified on Fig.3.2. McDowell (1980) stated that adult galaxid habitat varies between overgrown small creeks, deep holes in streams, lakes, lagoon margins (G. maculatus, argenteus). Small rocky streams in forested areas and forest swamp (G. fasciatus, postvectis) and in rapidly flowing bouldery streams especially in forests (G. brevippinis).

Freshwater crayfish, eels and trout (in the Awakino River) make up the majority of faunal species in freshwater. Fish found in the estuaries include trout, eels, galaxids and also smelt, flounder and kahawai. On the coast, mussels are found in abundance on the Mohakatiro Reef just south (c.500m) of the Mokau River mouth. Mussels, pauas and crayfish are found on coastal reefs north of Awakino.

Offshore, snapper, dogfish, warehou, trevally, flatfish and gurnard are present in commercial quantities.

MATERIALS BALANCE FOR MOKAU COAL MINING AND USE

A2.1 MINING

A2.1.1 Introduction

As was noted in the main text of this report, the Mokau mine development is assumed to be orientated towards the supply of a 1000 MW thermal power station. Coal must therefore be mined at a rate of two million tonnes per annum from both opencast and underground mines.

The essential features of such a system have been incorporated into a materials balance to provide a qualitative and partially quantitative assessment of both inputs and outputs related to mining. Figure A2.1 summarises inputs and outputs of the system and, in this assessment, outputs are divided into:

- (i) principle product;
- (ii) increased inventory; and
- (iii) residuals.

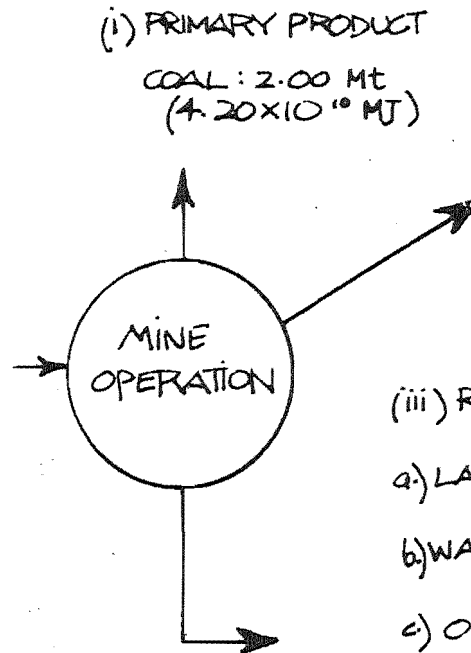
The components of the balance are listed below (with numbers relating to those on Figure A2.1), together with notes on information sources, assumptions and data manipulation. All figures are given on a per annum basis at full production where applicable.

A2.1.2 Inputs and outputs

1. Ambient environment: the environment of the Mokau region is regarded as an input to the mining operation. The environment has been discussed elsewhere in this report and includes climatic, hydrological, geological, ecological and social aspects. As a generally passive input, the environment would be modified by mining. For example, about 0.16

INPUTS

1. AMBIENT ENVIRONMENT
2. COAL - 2.77 Mt
3. LAND - 155 HA
4. ENERGY (i) DIESEL : 1.72×10^8 MJ
(ii) ELECTRICITY : 17.68 MVA
5. MACHINERY
6. WATER - 7.3×10^6 M³
7. CONSTRUCTION MATERIALS
8. LABOUR (704)



OUTPUTS

(i) PRIMARY PRODUCT
COAL : 2.00 Mt
(4.20×10^{10} MJ)

(ii) INCREASED INVENTORY

- a.) LABOUR : 704 persons
- b.) MACHINERY : VARIOUS
- c.) BUILDING MATERIALS
- d.) SUNDRIES.

(iii) RESIDUALS

- a.) LAND : 155 HA
- b.) WATER : 7.3×10^6 M³ plus environmental input.
- c.) OPERATION EMISSIONS - noise, dust, fumes.
- d.) AMBIENT ENVIRONMENT - alterations, manipulations.
- e.) ENERGY LOSSES - coal left in ground (0.77 Mt ; 1.6×10^{10} MJ), Diesel, electricity.

FIG A 2.1 - MINING MATERIALS BALANCE (All data per annum where applicable)

million m³ of soil and 6.62 million m³ of overburden would be moved per annum to enable coal removal from opencast areas. Other effects on the environment are discussed in Chapter 5 of this report. It is noted that the environment can also constitute an active input to the operation as in hydrological and climatic processes.

2. Coal: If opencast coal is extracted at an average efficiency of 83%, 1.145 million tonnes must be available in-ground to mine 0.95 million tonnes. At 65% underground mining recovery, 1.62 million tonnes must be available to extract 1.05 million tonnes. Thus a total of 0.77 million tonnes would be left in the ground and would be counted as an energy cost of mining.

The mining operations would result in dilution of the coal with rock. This would occur at a rate of 10% in opencast mining and 11% in underground mining, thus increasing ash content of coal (Longworth et al. 1982). Adjusting average coal proximate analyses (Chapter 2.7) for seams 2-5 opencast and 2-4 underground for new ash levels, the proximate analyses would be as follows:

| | M% | A% | VM% | FC% | S% | S.E(MJ/kg) |
|-----------------|------|------|------|------|------|------------|
| a) opencast : | 14.5 | 17.7 | 32.7 | 34.4 | 2.3 | 21.1 |
| b) underground: | 14.7 | 18.5 | 32.2 | 34.6 | 1.78 | 20.8 |

The tonnage of each constituent can then be calculated. These calculations indicate that the two million tonnes of mined coal may be composed of:

| | |
|-----------------|------------------------------|
| Moisture: | : 0.29 million tonnes |
| Ash | : 0.36 million tonnes |
| Volatiles | : 0.65 million tonnes |
| Fixed carbon | : 0.70 million tonnes |
| Sulphur | : 0.04 million tonnes |
| Specific energy | : 4.20 x 10 ¹⁰ MJ |

(Note that rounding errors in calculation of tonnage may indicate slightly different levels than those actually mined.)

Similarly ash constituent and trace element tonnages mined per annum may be calculated. However, this has not been carried out for this study.

3. Land: 155 ha of land would be used per annum. Some would remain in use throughout the life of the mine. Other land would 'flow' in and out of use.

40 ha (4 x 10 ha) has been assumed for surface facilities and administration. Access routes chosen by Longworth et al. (1982) would total 18.5 km. At 20 m wide, this will require 35 ha of land. Opencast mine haulroads (12.2 km x 20 m) would require 24.4 ha. The largest land area would be used in opencast mining. Stripping ratios, overburden thicknesses and production rates from opencast areas (quoted in Longworth et al. 1982) indicate that about 14 ha would be used per annum. In addition, 14 ha (one year's requirement) in front of, and two years behind (to allow for soil stripping and reclamation) is assumed to be out of production. Thus 56 ha in total would be used by the mine each year. 14 ha would be restored to production each year.

4. Energy: Energy requirements were derived as follows:

- (i) diesel requirements were assumed given the opencast mining machinery required and machinery availability hours (Longworth et al. 1982). Manufacturers' average fuel usage figures for such machinery indicate that about 703,500 l of diesel would be consumed per annum;
- (ii) electricity requirements (7.00 MVA opencast, 10.68 MVA underground) were provided by Longworth et al. (1982).

Energy produces work but as this is ultimately lost as heat, it is thus treated as an energy cost in the balance.

5. Machinery: Machinery requirements for mining were discussed in detail by Longworth et al (1982) and need not be relisted here. All machinery is treated as an increase in inventory in the output of the balance until the end of the design life. Machinery then becomes a residual.

6. Water: This input category includes all that water required for mining but not inputs from the ambient environment. Water would be required for dust suppression, personal use, and for fire fighting. Lewthwaite et al.(1983) noted that water requirements for mining may be in the vicinity of 100 l per man-day plus 50 l per tonne of coal produced. Using this formula, about $7.3 \times 10^{11} \text{ m}^3$ of water would be required per annum. This water should flow through the system collecting sewage, dust and other wastes. As an output it is included with ambient-environment water which intersects the mining operation.

7. Construction materials: No detailed inventory of construction materials has been made in this study. However they would comprise wood, steel, aggregate, cement and sundries for offices, workshops, coal handling facilities etc,. These should all comprise an increase in inventory until their design life is over; they would then be residuals.

8. Labour: 704 persons would be required. These were discussed in Chapter 2.7. Labour is treated as an increase in inventory, being static through the mine life. At the completion of mining, the 704 people become residuals.

A2.2 UTILISATION

A2.2.1 Introduction

At present, there has been no firm proposals for siting of a power station or a coal transport system. Thus a materials balance study of the transport phase is not warranted at this stage. This section deals with the major inputs and outputs related to the use of coal in a 1000 MW thermal power station. The sources discussed in Chapter 4.2 provide planning parameters for such a station and form the basis of the materials balance data in this chapter.

A2.2.2 Inputs and outputs

1. Ambient Environment: The environment of the power station would constitute an active and passive input. The inputs would include site geology, climate, hydrology, ecology and social aspects. Environment is regarded as a residual 'output' of the operation with modifications resulting from construction and operation of a power station.
2. Coal: The principle product of the coal mine (2 million tonnes per annum) is the major input to the power station. The proximate analysis constituents of this amount of coal was given in A2.1.2 and in order to calculate outputs from coal combustion, the coal ultimate analysis is required (St Baker, 1981). Ultimate analyses were given in Chapter 2.4 and the weight constituents can be calculated. As ultimate analyses are conducted on a dry mineral-matter free basis, the analyses must be readjusted to incorporate moisture, ash and mineral matter which will be present when the coal is burnt.

Using average moisture and ash values of M: 14.6%, A: 18.1% and assuming that total ash and mineral matter is 1.1 ash (i.e. 19.91%), the following percentages and weights are derived.

| | <u>%</u> | <u>wt (million tonnes)</u> |
|---|----------|----------------------------|
| C | 55.56 | 1.1 |
| H | 4.07 | 0.08 |
| N | 0.82 | 0.02 |
| O | 11.86 | 0.24 |
| S | 2.30 | 0.05 |
| M | 14.60 | 0.29 |
| A | 18.1 | 0.36 |

These figures must be regarded as being indicative as 'rounding' errors have been incorporated, and the sample size is very small.

Outputs of coal combustion are discussed later in this section.

3. Land: The Huntley thermal power station is located on 40 ha., but this is considered to be restrictive (N.Z. Electricity, 1981a). Therefore 60 ha is allocated for that purpose, with 40 ha being required for construction purposes. A coal storage area would be required and 50 ha is considered adequate (N.Z. Electricity, 1981a). Ash disposal land would total 100 ha for the life of the station. Sundry other land areas may be required depending upon design criteria (e.g. cooling towers would probably be used). Thus the total requirements could be for at least 250 ha. The areas of land would not have to be adjacent to each other although plant, construction and stockpile land would be in the same area. Sequential use of some land may be possible. It should be noted that were cooling ponds to be considered for heat removal, between 400 and 800 ha may be required (Hill, 1975). Land required for coal utilisation would be lost to other uses and is regarded as a static residual.

4. Labour: A labour force will be required in two phases, i.e. construction and operation. The size of the construction force would depend upon the time period available to build the plant. Based on Huntley experience (N.Z. Electricity, 1981a) it is shown that a workforce of about 1500 would be necessary. Construction to full production would then take 8-11 years. Construction workforces would largely be residual after the station is built.

The operating workforce would total about 425 persons (Lewthwaite et al., 1983). These would build up over five years as machines are commissioned. The operating workforce is regarded as an increase in inventory until the design life of the station is over.

5. Construction materials: Construction materials are a major input to the station. Lewthwaite et al. (1983) provided a list of materials required for such a station as planned for Mokau. The list is as follows:

| | |
|--------------------------|------------------------|
| (i) chip and base course | 625,000 t |
| (ii) concrete | 217,000 m ³ |
| (iii) metal | 305,000 t |
| (iv) cement | 65,000 t |
| (v) steel | 30,000 t |
| (vi) timber | 6,850 t |

The materials required for cooling towers have not been added to the balance. It is noted (N.Z. Electricity, 1981b) that natural (concrete hyperbola) draught towers are about 115 m high with a 85 m high with a 85 m diameter base. Two would be required.

6. Water: Water requirements during construction (not included in the balance) will peak at 2000 m³ per day for the Waikato Thermal No.1 (N.Z. Electricity, 1981a) and a similar quantity is likely to be required at Mokau.

During operation, potable water would be required for station services and domestic use. N.Z. Electricity (1981a) allowed 30 l per person per day ($13 \text{ m}^3/\text{day}$) plus about 5 m^3 for process water, totalling $18 \text{ m}^3/\text{day}$ or $6,570 \text{ m}^3 \text{ y}^{-1}$. Firefighting water must always be available and $23,600 \text{ m}^3 \text{ day}^{-1}$ is allowed for this purpose (N.Z. Electricity, 1981a). If water is used in bottom ash disposal at least $1.6 \times 10^6 \text{ m}^3$ per annum would be required (based on Huntley experience). Water is also required for boiler makeup to replace water lost through leakage and blowdown. About $72,000 \text{ m}^3 \text{ y}^{-1}$ would be required (N.Z. Electricity, 1981a).

By far the major water requirement will be in cooling water. The amount of water required for condensor cooling is determined by allowable heat release in the cooling water. There are two temperature differences of importance in cooling water. The difference in temperature at the outlet and inlet (Temperature Range) is important for all systems. The temperature difference between ambient air wet bulb temperature and intake cooling water temperature (Approach Temperature Difference) is important in cooling towers.

The temperature range of open-cycle river cooling is 8°C at Huntley, corresponding to a through-flow of 38 cumecs of water. If ocean cooling was used, a large Temperature Range would be accommodated and 20.2 cumecs of water would be required. Cooling towers have an important design temperature range of $11\text{-}17^\circ\text{C}$, and 'approach temperature difference' of $8\text{-}14^\circ\text{C}$. N.Z. Electricity (1981a) quoted design temperatures for cooling towers as 15°C Temperature Range and 10°C Approach Temperature Difference. This would correspond to a cooling water flow rate of 20.2 cumecs (N.Z. Electricity, 1981a).

If a cooling tower system is used, these 20.2 cumecs will cycle through the system. 0.53 cumecs would be lost as evaporation and mist and 0.26 cumecs returned to the river as blowdown. Thus there would be a constant draw of 0.79 cumecs.

Water is also required for cleaning boilers. At Huntley, the maximum requirement is 280 tonnes per test.

7. Energy: Energy inputs are required during plant construction and operation. Construction-energy demand would peak at 2.0 MW (Lewthwaite et al., 1983) and operational inputs may be in the order of 3% of input coal energy (St Baker, 1981). If cooling towers are used, they too will require energy.

8. Air: Air is required for coal combustion and the requirements can be calculated. Total air (including moisture per unit fuel) is calculated using the following formula (St Baker, 1981).

$$\text{Air} = (13.619C + 40.574H_2 + 5.102S - 5.112O_2) \times 1.013$$

This represents the amount of air for combustion of coal with an 18.6% excess to ensure that no carbon monoxide is released in flue gas.

Thus air requirement per annum would be 1.214×10^6 million tonnes.

9. Sundries: Various sundry inputs are required for power station operation. These include boiler treatment materials. Prior to commissioning of a plant, the boilers must be cleaned using acid and alkali. Operational cleaning is also required. Boiler water has various chemicals added to maintain pH. All boiler and boiler-water treatments are discussed in detail by N.Z. Electricity (1981a).

10. Outputs: Outputs from the electricity generation process are dominated by electricity produced. A Pulverised Fuel plant has a maximum second-law efficiency of 38%; when Huntley is operating at full load, the efficiency is 37.5%. At lower loading, efficiency reduces to about 35.5% (N.Z. Electricity, 1981a). Using this figure an output of 4.20×10^{10} MJ \times 0.355 = 1.49×10^{10} MJ would be obtained as potentially useable energy per annum. Of the coal entering the plant, about 88% of the entrained energy is delivered to steam with 12% boiler loss. This loss is made up of latent heat of evaporation of water vapour in combustion products, loss of unburnt carbon (0.5% wt of coal, 2-3% of ash - St Baker, 1981) radiation and other unaccounted losses. About 49.2% of input energy is lost in cooling water (N.Z. Electricity, 1981a) and after accounting for auxiliary energy inputs useable energy is between 35.5% and 38% of input energy.

Construction materials and labour (operational) constitute an increase in inventory for the life of the power station. They will then become residuals and possibly pollutants.

Residuals arising from operation of the plant are numerous. Some (e.g. land) have already been mentioned, others include ash, gas, water and other operation emissions (dust, noise). Ash may be subdivided into bottom or fly ash depending upon its route from the furnace. Bottom ash includes about 20% of total ash at Huntley; with about 0.36 Mt y^{-1} of ash at Mokau, about 72,000 tonnes of bottom ash would be produced. Fly ash comprises the remaining 80% ($288,000 \text{ t y}^{-1}$) and, of this, 12% would be collected in the air heater and economiser, 86% would be collected in electro-static precipitators and 2% (5760 t) would be released with flue gases.

St Baker (1981) provided formulae for obtaining a rough indication of flue gas composition. The weights of combustion flue gases per unit weight of coal (2 million tonnes per annum) can be calculated using the following formulae:

$$\text{CO}_2 = 3.664\text{C}$$

$$\text{H}_2\text{O} = 8.937\text{H}_2 + \text{H}_2\text{O} + 0.13 \text{ TDA}$$

$$\text{SO}_2 = 1.998\text{S}$$

$$\text{N}_2 = 10.459\text{C} + 31.161 \text{H}_2 + 3.918\text{S} - 3.926\text{O}_2 + \text{N}_2$$

$$\text{O}_2 = 0.496\text{C} + 1.476\text{H}_2 + 0.186\text{S} - 0.186\text{O}_2$$

Note: TDA (total dry air) is calculated by:

$$(11.483\text{C} + 34.211 \text{H}_2 + 4.3025 - 4.310 \text{O}_2) \times 1.186$$

Using these formulae, the following gas weights have been calculated:

$$\text{CO}_2 : 4.03 \text{ million tonnes}$$

$$\text{H}_2\text{O} : 3.96 \text{ million tonnes}$$

$$\text{SO}_2 : 0.10 \text{ million tonnes}$$

$$\text{N}_2 : 13.25 \text{ million tonnes}$$

$$\text{O}_2 : 0.63 \text{ million tonnes}$$

Thus the gaseous emissions would comprise CO_2 , H_2O , SO_2 , N_2 and O_2 in varying amounts at a flow rate of about $1.2 \times 10^6 \text{ kgh}^{-1}$ for each boiler (N.Z. Electricity, 1981a). These tonnages are only approximations and adjustments should be made to SO_2 emissions recognising that some sulphur will be bound to calcium in coal during combustion. In addition some N_2 will be released as nitrogen oxides. Water would be released from a number of sources including cooling water as described earlier. The chemicals routinely added to cooling water would also be expelled. Potable water would be released as sewage ($20 \text{ m}^3/\text{day}$). Storm water runoff from a 250 ha site could be up to 16 cumecs (20 year return period) at Huntley but this figure may vary widely with climatic variations.

Supernatant from ash pond settlement would need to be disposed of. This will contain trace elements from coal. Other site outputs include coal pulveriser rejects (12 t per day) and dust from station vacuum cleaners (c.24 t per day). Sundry emissions would include fuel emissions (diesel exhaust etc.), dust and noise from coal handling and various operational activities. Figure A2.2 summarises inputs and outputs of the power station materials balance.

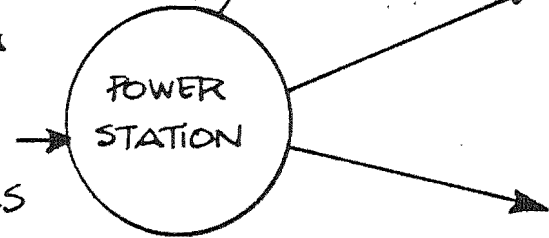
A2.3 DISCUSSION

Inputs and outputs discussed in this section have been derived using available data. Manipulation of coal analyses have been carried out using standard formulae such as provided by Suggate (1959). It must be stressed that no exhaustive study has been made to derive absolute values for either inputs or outputs. That is not the aim of this study. Rather, this study emphasises a method using rough estimates, which can be checked quickly or altered without altering the structure of the materials balance.

However, figures are provided with reasonable confidence. They are either derived from sources dealing directly with the Mokau Coalfield, or with similar proposed or operating ventures. They are regarded as providing reasonable guidelines for planning.

INPUTS

1. AMBIENT ENVIRONMENT
2. COAL 2 Mt (4.2×10^{10} MJ)
3. LAND - 250 HA
4. LABOUR - 1500 CONSTRUCTION
425 OPERATION
5. CONSTRUCTION MATERIALS
6. WATER
7. ENERGY
8. AIR - 1.214×10^6 Mt y^{-1}
9. SUNDRIES



OUTPUTS

- (i) PRIMARY PRODUCT:
ELECTRICITY:
 1.49×10^{10} MJ
- (ii) INCREASED INVENTORY
 - a. LABOUR
 - b. CONSTRUCTION MATERIALS
- (iii) RESIDUALS
 - a. LAND
 - b. ASH
 - c. FLUE GASES
 - d. WATER
 - e. SUNDRY EMISSIONS
 - f. AMBIENT ENVIRONMENT ALTERED.
 - g. WASTE HEAT.

FIG A 2.2 POWER STATION MATERIALS BALANCE