

AN ASSESSMENT OF THE EFFECTS ON HORTICULTURAL PRODUCTION
OF FUGITIVE DUST AND ASH FROM THE PROPOSED WAIKATO COAL-FIRED
POWER STATION ACTIVITIES

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PREFACE

This Research Report presents a continuation of the work carried out by the AERU on the effect of dust on horticultural and agricultural activities. The analysis presented is an example of the way possible effects of dust from major construction and industrial operations can be evaluated. The level of possible dust related costs identified in this Report indicates that studies of this type are important in the evaluation of proposed construction activities. The Ministry of Energy commissioned the study and the Ministry is to be commended for its recognition of the potential effect of dust and their action in having a public report prepared.

J.G. Prdye
Director

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SUMMARY

As part of the site selection process for the proposed Waikato coal-fired power station, it is important to conduct an economic analysis for each site option, with respect to the surrounding environment.

The aim of this study was to assess the possible impact of dust, ash and chemical pollutant emissions from the proposed power station activities, on horticultural production systems surrounding the station complex and to identify suitable methods of controlling the various forms of fugitive dust emission.

Because of time and resource constraints and a lack of relevant data regarding coal-fired power station dust and ash emissions, this study was based largely on a number of previous studies related to dust emissions from a number of other source types; and in consultation with a wide range of technical experts. Consequently, there is much uncertainty surrounding the magnitude of many of the findings.

Four major potential sources of dust or ash emission from power station activities were identified. These include:

- (1) Construction activities;
- (2) Dry ash disposal;
- (3) Coal stockpiles; and
- (4) Chimney emissions.

However each of these source types differ with regard to their respective distributive mechanisms, timing, order of magnitude and types of possible effect.

Chapter three outlines possible physical effects of dust and ash emissions on horticultural production. The most significant of these include:

- (1) reduced photosynthesis leading to loss of plant yield;
- (2) increased pest and disease incidence causing yield losses and downgrading of produce;
- (3) hindered pollination, especially in small seeded fruits;
- (4) toxic effects and burning of leaves due to the high boron and PH levels contained in Waikato coal; and
- (5) yield losses due to sulphur dioxide pollution.

Chapters 5, 6 and 7 are involved with calculating the quantity and distribution of dust and ash emissions from each source type, for each site option. Chapter 7, somewhat subjectively, quantifies the various costs to horticultural production associated with each emission type.

A menu of possible emission control measures is set out in Chapter 8.

The report concludes that the potential for horticultural production losses due to the dust and ash emissions from the proposed power station, will depend largely on the choice of locations and operational procedures for the various power station activities and also, upon the amount of land purchased by the Ministry of Energy. In addition, the types and efficiencies of emission control procedures carried out on the power station site will have a considerable influence on the magnitude of dry dust problems.

CHAPTER 1

INTRODUCTION

1.1 General

The construction and subsequent operation of a proposed coal fired power station in the Waikato will have a considerable effect on the district surrounding the station complex. Consequently, analyses of possible effects caused by the power station, for both of the preferred sites (i.e. Rangiriri and Clune Road), are an important part of the site selection process.

Several previous reports (e.g. PD 20, 1984; PD 21, 1984; PD 24, 1984; and the Environmental Impact Report, 1984) have mentioned the problems the effect of particulate emissions from the power station site and its associated facilities, on the surrounding environment.

A study conducted in Waikato County by McCrea (1984), showed that the costs from road dust emissions to horticultural enterprises bordering unsealed roads, may be quite high. It was largely the result of the road dust study, plus the concern expressed about particulate emissions from the proposed power station activities onto horticultural land, which prompted this study.

1.2 Sources of Power Station Dust Emissions

The quantity of dust¹ emitted from the power station, and its resultant effects on horticultural returns in the region, depend largely on the methods chosen for various station activities and on which site is chosen. However, depending upon the final outcome of the location choice, there are five major potential sources of dust emission from power station activities, which can be identified. These include:

- (1) Construction activities - the construction phase of the power station project will continue for approximately eight years. However it is anticipated that dust emissions will only be a problem during the first three of these, whilst initial major construction activities are being undertaken (Willis, pers.comm., 1985). The principle causes of dust are expected to be from the large scale earthworks required and from associated road haulage activities over unsealed roads;

1 The term 'dust' is used in this report to include all particulate matter less than 75 μm in diameter, which may be emitted from power station activities (i.e. coal dust, ash and soil dust).

- (2) Ash disposal - if a method of dry ash disposal being considered is adopted, then there may be dust emissions caused by;
 - (i) soil stripping and land reclamation;
 - (ii) spreading and compacting the ash;
 - (iii) the exposure of bare ash piles to the elements; and
 - (iv) transport to the ash dump site.
- (3) Coal stockpiles - stockpiles of crushed coal will occupy a total area of 34 hectares. It is likely that there will be some wind generated dust emissions from these piles even when dormant. However the problem will be further accentuated by on site coal movement and by stockpile construction and reclamation;
- (4) Coal transport to power station site - coal dust generated during the loading, transport and unloading of coal may be a further source of dust nuisance. This may be accentuated if a road transport method is chosen, as some additional road dust will be generated; and
- (5) Chimney emissions - firing of the coal burners during the operation of the power station will create discharges into the atmosphere of fly ash and toxic gases. However any adverse effects of these emissions to horticulture are most likely to occur well away to the north and east of the station sites.

1.3 Project Objectives

- (1) To estimate the levels of dust emission and to calculate the deposition distribution away from the source points, for each of the above-mentioned dust sources;
- (2) To assess the possible effects of dust emissions from power station activities, on horticultural production in the vicinity of both the proposed Clune Road and Rangiriri sites;
- (3) To provide an approximation of the cost to horticulture from the power station dust emissions; and
- (4) To suggest suitable techniques of dust abatement.

CHAPTER 2

POSSIBLE EFFECTS OF DUST FROM POWER STATION ACTIVITIES

Dust deposition on horticultural production areas is believed to be related to a number of factors affecting both the yield and/or marketability of affected produce. An extensive list of possible effects of dust on production are listed below. Some of these relationships appear to be more realistic than others and whenever possible, some conclusion is drawn regarding the likelihood of significant effects of dust.

2.1 The Effect of Dust on Leaf Surfaces with Regard to Plant Photosynthesis, Transpiration and Respiration Rates

Dust cover on leaf surfaces may affect yield in a variety of ways, with the yield reduction depending upon the thickness of cover and to an extent, the type of plant. The effects are likely to be greater on plants with pubescent leaves as these retain a greater amount of dust, even after a moderate rainfall.

2.1.1 Photosynthesis

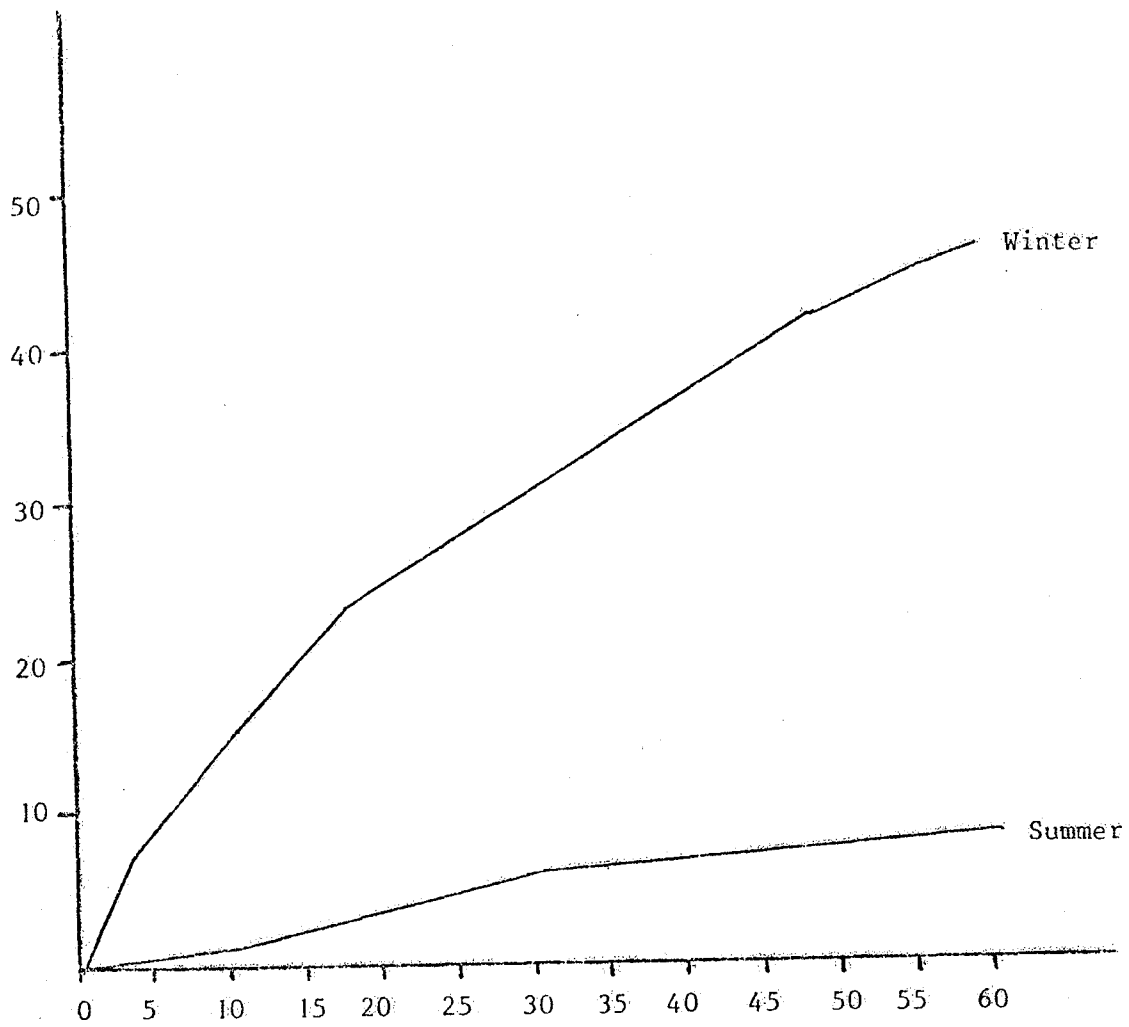
Photosynthesis is the process by which the energy of sunlight is absorbed through the leaf surfaces of green plants and used to build up complex substances from carbon dioxide and water. This process provides the fuel for plant growth; any reduction in photosynthesis is accompanied by an approximate corresponding percentage loss of plant growth and yield.

Cook et al. (1980), investigating the impact of the Mt. St. Helens eruption on agricultural production, found that a coating of ash 1mm thick on a leaf surface reduced photosynthesis by 90 per cent and that a lighter coating reduced it by 25-33 per cent. In addition, it is likely that coal dust would have a greater sun block effect than ash or soil dust, and hence would reduce photosynthesis by more than the other dust types.

Exactly how plant growth and yield are affected appears to differ, depending on plant type and circumstances. Storey (1983, pers. comm.) predicted that a probable major effect would be a cumulative retardation of plant growth and maturity time, thus diminishing expected crop yields each year. Cook et al. (1980) hypothesised that reduced photosynthesis may also be responsible for the early senescence of leaves, thus further retarding plant growth.

FIGURE 1
Photosynthetic Response to Road Dust Cover
on Leaf Surfaces

% Reduction of
Photosynthesis



Average Daily Deposition
Density on Leaf Surfaces g/m²

Jackson (pers. comm., 1983) noted that in the presence of adequate water and nutrients, a reduced photosynthesis rate could directly affect fruit production in three ways:

- (1) by a reduction in the number of buds formed, resulting in lower flower initiation and hence, lower fruit setting;
- (2) by reducing fruit size due to an inadequate supply of carbohydrates. This is important in fruits (e.g. apples and kiwifruit) which are graded for size. However, low bud formation may offset this effect; and
- (3) by lowering the sugar content of fruits. Some fruits (e.g. grapes and kiwifruit) are harvested according to sugar levels and low readings will delay harvesting. This may be a crucial factor in marginal areas which are susceptible to frosts.

However it is not possible at this stage to isolate and quantify each effect caused by reduced photosynthesis; rather to recognise that there is an overall loss.

An approximation of this loss was estimated by McCrea (1984), by relating measurements of light reduction to plant surfaces from road dust cover, to a function developed by Goudriaan and Van Larr (1978) for the photosynthetic rates of temperate plants. The resultant estimates of photosynthetic yield loss caused by road dust cover are illustrated in Figure 1.

2.1.2 Stomatal interference

Dust particles of a size range less than 5 μm in diameter can interfere with the mechanism of stomatal pores. These small openings are largely responsible for the basic respiration and transpiration functions of plants.

Work by Ricks and Williams (1971) and Eller (1977) indicate that plugging of stomatal pores by small particles may lower the rate of respiration and also the maximal stomatal diffusion resistance at night. However Gallagher (1983 pers. comm.) held that these effects would be very small and likely to be of little significance to yield.

Further, Stanhill et al. (1975) found that Kaolin dust applied to crop foliage during a drought period in Israel, actually increased crop yield by 7-20 per cent over a three year period. The dust had the effect of increasing the reflectivity of plants and reducing their transpiration heat load, thus increasing transpiration resistance. It is possible that if sufficient construction dust or fugitive ash (assuming a dry ash disposal method) was deposited onto horticultural land that this could have a similar effect and actually aid yield by:

- (1) alleviating drought damage to plants at critical growth stages; and
- (2) reducing the potential water demand from the atmosphere.

However, given the relatively high rainfall of the Waikato region, any such effect is likely to be extremely small and almost non-measurable.

2.2 Increased Incidence of Plant Pests and Disease

Although there is little hard evidence on the subject of dust as a predisposing cause of plant disease and increased pest infestation, opinions and observations of several growers and scientists tend to support a relationship. The effects vary according to plant type and in some cases the type of fruit produced. However some of the major problems include the following.

2.2.1 Establishment of conditions conducive to disease initiation

Dust accumulation in the rooks and crevices of fruit and plant surfaces aids moisture retention, thus providing, in the right conditions, a medium for the growth of bacteria and fungi.

2.2.2 Pest-beneficial insect population balances

Studies by Alexandrakis et al. (1979), Fleschner (1958) and Bartlett (1982) prove that generally, dust inhibits the activity of beneficial insects and consequently increases the damage from pests. The reason stems chiefly from the habits and structures of the respective types of insects and the mode of action of dust.

Beneficial insects, primarily the predators and parasites of insect pests, are particularly susceptible to three modes of action of dust on their systems, which can be lethal:

- (1) Dessication may be facilitated by dust by abrading the epicutular waxes, thereby increasing the permeability of the cuticle, by exposing the permeable intersegmental membranes, and by increasing the evaporative area of the body;
- (2) Starvation may be caused by the formation of a mechanical barrier to the insects food supply, by impeding their movement or by clogging their digestive systems; and
- (3) Respiration may be hindered where spiracles are clogged by dust particles.

The reasons for the vulnerability of beneficial insects to these effects, compared to the pest insects, stems from a number of factors:

2 For convenience, the term 'insect' is used loosely to include all mites, etc.

- (1) Whereas most pests are relatively immobile, parasites and predators must search over the leaves and fruit of plants if they are to control the pest species satisfactorily. The more efficient the beneficial insect is in this respect, the lower will be the host (pest) population and the greater will be the surface area of the plant over which the beneficial insect must travel. Hence, on dust covered plants, as the amount of travel required over dusty surfaces by beneficial insects begins to increase, so too does the death rate of beneficial insects, thus moving the population balance back in favour of the pest community.
- (2) Some pests, are well protected from dust deposits by wax covers or by hard, thick body walls. Conversely, few beneficial insects have any special protective covers to shield them from dust.
- (3) In contrast to pest species, which are in constant contact with a food supply of living plant material which is high in moisture content, beneficial insects do not have a constant supply of food and water available. Adult parasites generally depend upon the chance supply of natural sugars (honeydew and nectar) as their main source of food and water, while predators supplement this by feeding off their host.

Thus (as in their search for hosts) beneficial insects must travel almost continuously over the surface of the plants in the search for food and water. This constant contact with dust becomes especially critical when the dust has a desiccating effect on the insect, as there is little opportunity for them to replenish vitally needed water.
- (4) Most pest species have piercing mouthparts which penetrate the plant cuticle, so that these pests feed on clean, dust free plant sap. On the other hand the honeydew and nectar which parasites, and to a lesser extent predators, depend on for their food source, are found exposed on plant surfaces. These foods could be so covered by dust deposits that they are unavailable to beneficial insects, or they may be so contaminated with dust particles that digestion is impaired; both can result in death by starvation.
- (5) Dust adhering to the beneficial insects delicate sensory organs, used to locate and recognise food and host insects, may dull the insects' senses, agitate them and cause them to depart the area, or may slow down their rate of travel, so that their searching capacity is reduced. Each can ultimately lead to starvation.

These factors tend to support the findings of Alexandrakis et al. (1979) that the beneficial population increased and the pest population decreased further away from dust source.

2.2.3 Spray effectiveness

Closely aligned with the problems already mentioned, is the detrimental effect which dust has on the effectiveness of many agricultural sprays.

A basic aim when spraying plants is to gain maximum retention of spray droplets on the leaf surfaces. Dust may affect this retention ability and also reduce plant uptake of chemicals where applicable. Although producers would usually spray after rain when leaf surfaces are clean, lengthy dry spells during summer may necessitate spraying at sub-optimum times in terms of spraying efficiency.

(1) Herbicides

All except those which are soil applied must be absorbed by the leaf; thus a dust cover will impede this movement. Also, some herbicides (e.g. Roundup) are known to be deactivated on contact with the soil surface, due largely to the effect of soil micro-organisms. Although it has not been conclusively proven that dust will produce this effect, producer observations and work by Dunn (pers. comm., 1983) at the Sariab Agricultural Research Station, Pakistan, support the view that spray effectiveness is severely reduced when dust is present.

Dunn found that when Paraquat was applied to broad-leafed weeds at both single and double strength following dust storms, that the spray had little effect and further, that wetting agents did not improve the effectiveness.

Field (pers. comm., 1983) suggests that where no weed control is achieved in low growing crops (e.g. cereals and berryfruit) then production loss could be as high as 100 per cent for the affected area, due to either increased weed competition or to reduced harvesting efficiency. However he feels that a more realistic loss may be in the vicinity of 20 per cent.

(2) Pesticides and fungicides

Only the systemic and eradicant action sprays may be affected, with their uptake by plants possibly being impeded by a dust layer. Resultant increases in pest or disease incidence can hinder plant growth, affect fruit set, or damage fruit appearance.

2.3 Reduced Light Intensity on Fruit

Highly coloured fruits (e.g. red apples, nectarines and peaches) require high light and low temperature to achieve full colour. Coal dust especially, present on fruit surfaces may reduce the light intensity reaching fruit so that expected colour levels are not achieved.

The Apple and Pear Marketing Board's grading schedule requires that coloured varieties of apples contain a minimum colour percentage

for each grade. Standards for nectarines and peaches are not specified, but under-coloured fruit would probably be down-graded, at least from export designation to local market.

2.4 Pollination

Well pollinated flowers are a basic requirement for the development of large and well formed fruit. Although there have been no scientific investigations conducted into the effects of dust on pollination, many growers and several Ministry of Agriculture and Fisheries Advisors, have strong suspicions that dust on the flowers of small seeded fruit plants (e.g. kiwifruit, strawberries, blueberries and raspberries) can cause substantial losses in affected areas.

Of particular significance is the kiwifruit which, even without a dust coating, has a fairly unattractive flower to insects. It is suspected that a dust coating on flowers may dissuade bees from pollinating them effectively, leading to either:

- (1) total flower abortion; or
- (2) the development of 'scrub' fruit not suitable for export.

2.5 Rejection and Down-Grading of Horticultural Produce Due to Road Dust Contamination

According to the horticultural marketing trade, little produce is rejected or downgraded because of dust contamination. However many growers, either trying to establish or to protect a good name, grade out any contaminated produce so that it does not reach the market.

Dust contamination affects different produce in different ways and to varying degrees. Pubescent fruits (e.g. peaches), berryfruit and leafy vegetables are perhaps the worst affected as dust particles cannot be removed effectively.

Kiwifruit for export undergoes a dehairing operation which would rid it of much dust but in many cases, enough may remain on the fruit to cause downgrading. This effect could be accentuated when the fruit has been wet, as a combination of dust and moisture could produce a stain on the fruit. Likewise, export apples are subjected to a waterdumping and polishing process. However, where dust has accumulated in the stem cavity at the end, this method may not be sufficient to pass the fruit for export.

Dust causes citrus fruit to lose its lustre, a problem which graders do not entirely solve. This impairment of the fruits attractiveness tends to lower its market price.

Unless very badly contaminated by dust, wine grapes are probably not badly affected since impurities would be removed during the winemaking process. However, asparagus could be affected when grit gets down into the spears and cannot be removed. In addition, if a packing shed is sited within range of the power station dust then problems of dust contamination during a wet packing procedure may arise.

Also as mentioned before, small, deformed or diseased fruit could necessitate quite large amounts of down-grading or even dumping. However because much of the grading is conducted informally, only rough estimates can be made of how much produce could actually be down-graded or dumped due to dust.

Government regulations state that all produce for export, and its packaging, must be clean and free of disease and dirt. In addition, marketing authorities require that most produce meets set standards regarding, for example, size, shape, and colour. Hence much of the dust contaminated produce would not even be submitted for export.

Depending upon the extent of contamination, there are a number of ways of dealing with sub-export standard produce. These are given below.

2.5.1 Place in local auction market

For many fruits (e.g. kiwifruit, avocados and strawberries), withholding fruit from export consignments alone represents a substantial cost to growers. However in addition, all contaminated produce submitted to the local market would on average receive only about 66 per cent of that gained by premium produce on the local market (Russel, pers. comm., 1983).

Further, if a grower were submitting a percentage of sub-standard fruit, this may have the effect of dragging down the price of even his best quality produce, as buyers often make decisions on the basis of grower reputation.

2.5.2 Gate sales

Several growers agreed that gate sales of poorer quality produce, in general, are about 30-40 per cent below prices received for good quality produce in the market. Selling by this method has the advantage of protecting the growers name in the marketplace but unless conducted from a reasonably accessible location, it is not really a serious alternative.

2.5.3 Sell as process grade

This involves a much reduced price but has the advantage of being quick, convenient and often a least cost method of clearing substandard fruit. There are several drawbacks however. Firstly, it is only a feasible alternative for produce types which have a processing plant in reasonable proximity (e.g. boysenberries) and secondly, processors often require that contracts be signed before the produce is harvested. Hence any shortfalls must be met with high quality produce.

2.5.4 Dumping

The final solution would be simply to dump produce. This method of disposal has been conducted by a number of mainly market gardeners and berryfruit growers, where they have incurred problems with other forms of dust.

2.6 Nutrient-Toxicity Effects of Dust on Plants

Coal dust and ash are considerably more chemically active than normal construction or road dust and are assessed separately below.

2.6.1 Road and Construction Dusts

Although soil dusts³ are considered to be relatively inert, in some instances they may contain quantities of nutrients which can be taken up by plants through their leaf surfaces.

Dusts from glacial and recent soils have many primary minerals (e.g. phosphate and potash), which are relatively unweathered and available to plants, and these are likely to provide some benefit to plant growth. However most of the soils around the proposed power station sites are of intermediate age (yellow brown loams) and have weathered to form allophane clays which are fairly low in primary minerals. Hence, it would be fair to assume that any fertiliser effects from these types of dust source would be negligible.

2.6.2 Coal Dust and Ash

All Waikato coals are highly alkaline due to their inclusion of relatively large proportions of calcium in their ash. In addition, the Waikato coal ashes as compared to soil generally, contain greater quantities of all essential plant nutrients except nitrogen (Prasad, 1975).

In a study of the potential agronomic value of flyash from the Meremere power station (which should be fairly relevant to the proposed power station's ash), Toxopsus (1977) concluded that the "flyash was essentially a low grade liming material, with a magnesium content that increases its agronomic value comparably with limestone and a boron level somewhat in excess of that required agronomically".

Lucerne trials by Toxopsus during 1975 showed that flyash has about one third the 'liming' value as ground lime. However it is the level of boron contained in the ashes which are of most concern to horticultural production, due to its toxicity from over-exposure to

3 The term 'soil dusts' is used here to include all dusts from construction and earthmoving activities, and those originating from unsealed roads.

many horticultural crops. Boron, as with many other elements and trace elements contained in coal, becomes more highly concentrated after burning (i.e. in the ashes) and is contained at an especially high level in most Waikato coals.

The exact effects of Boron on plant growth at different levels of plant availability are not fully understood but it is known that Boron is essential in small quantities for plant growth but that at higher rates, causes tip dieback and eventually plant death.

The finding of studies conducted into the levels of Boron in Waikato coals and ashes (shown in Table 1) have varied considerably, but all have concluded that the levels are substantially higher than the arable soil limit for Boron of 3.25 parts per million (ppm), set in the United Kingdom.

TABLE 1

Findings of Studies into the Boron Content
of Waikato Coals and Ashes

Study	Main Area of Study	Boron Content (ppm)	
		Coal	Ash
Kennerly (1973)	Meremere flyash		5000
Toxopsus (1977)	Meremere flyash		5000
Gainsford (Chem Div, DSIR)	Huntly flyash		15000-20000
Coal Research Assn (1983)	Properties of Maramara Coal	191-333	
Coal Research Assn (1983)	Summary of 5 Waikato Coals	320-420	
Coal Research Assn (1984)	Huntly coal and flyash	10000-15000	15000-20000
Chem Div, DSIR and Soil Bureau	Huntly ashes		5600-9300

Hence very high dilution factors would be required to bring the levels of boron deposits on horticultural land to within an acceptable limit. In addition, trials by Percival (1984) in which different concentrations of flyash were mixed with various soil types, showed that toxic levels of boron were present at 1 percent ash concentrations.

An example of the detrimental effects of high boron levels to horticultural production has already occurred in Waikato County, when a mix of fertiliser was sold to growers and applied at equivalent rates of up to 10 kilograms of boron per hectare. These applications resulted in the death of blueberry and kiwifruit plants and severely retarded apple trees, causing streaky leaves. Also, boron toxicity of radiata pine has been linked to the dumping of boiler ash in New Zealand (Smidt and Whitten, 1975).

Preliminary results of growth trials by Widowsen (pers. comm., 1984) in which pasture species were grown in ash-soil mixes tend to support these field observations. These trials showed that plant growth was severely restricted at a one percent ash content level and was almost non-existent at a 10 percent level. It is likely that boron was the major contributor to these results.

An indication of the tolerance of various horticultural crops to boron levels has been provided by Williams (1972), who looked at the effect of boron levels in irrigation water. Table 2 presents his list of some crop types according to their boron tolerance level.

TABLE 2

Relative Tolerance of Various Crop Types to Boron

Tolerant Crops	Semi-tolerant Crops	Sensitive Crops
Asparagus	Potatoes	Plums
Beet and Mangolds	Tomatoes	Pears
Lucerne	Raddish	Apples
Beans	Peas	Cherries
Onions	Barley	Strawberries
Turnips	Maize	Raspberries
Cabbage		
Lettuce		
Carrots		

Also, until further information is available, it would be wise to categorise crops such as kiwifruit, blueberries, avocados and boysenberries in the sensitive grouping.

A further problem exists with boron in that if a soil becomes contaminated with it, then it is difficult to reclaim the land. Excess boron in soils is not readily removeable as an equilibrium exists between dissolved and adsorbed boron. Adsorbed boron acts as a buffer which impedes the removal of toxic levels of soluble boron with leaching.

Toxopsus (1977) has suggested that flyash is a useful soil amendment and fertiliser and that application rates of up to five tonnes per hectare once every five years should be safe in respect to

boron levels in the soil. However this relates to an application rate of boron, of approximately 75 kilograms per hectare, which is well above the level of boron applied in the Waikato fertiliser incidents. In addition a further problem may exist if the ashes increase the alkalinity of the soil too much. This has the effect of 'tying up' certain elements to plants and causing trace element deficiencies.

Thus it would seem that the benefit/costs of ash deposits on horticultural land will depend on the rates of deposition. Certainly, if they are too high, then boron accumulation will prove toxic to plants. In most instances however, the levels of ash and coal dust deposition onto productive land are likely to be relatively low and thus the effect of elements being leached through to root systems for plant uptake, is likely to be fairly small and possibly of benefit to horticultural production.

The nutrient-toxicity effect of the ash and coal dust depositions onto plant leaf surfaces may be more significant but at this stage, what the effects would be are rather uncertain. It is known that the high alkalinity of ash can burn leaves, similar in effect to burnt lime. It is also possible that boron, magnesium and potash, etc. may be taken up through the leaf surfaces in reasonably concentrated forms, but this would depend on the plant availability of the elements. Although there is a lack of hard evidence to support it, various indicators tend to suggest that the continuous subjection of plant leaves to ash and coal dust depositions could have an over-all negative effect on crop production; although this again would depend on the level of deposition.

2.7 Sulphur Dioxide

The flue gas, sulphur dioxide at high levels of concentration can directly cause visible effects (acute damage) e.g. chlorosis (loss of green colouring in leaves) and necrosis (death of cells within leaves) with plant death ensuing as exposure is increased. At lower concentrations there may be reductions in growth without visible injury (chronic injury).

Indirect effects of sulphur dioxide include acidification of soils and beneficial effects of sulphur as a soil nutrient and possibly in pest control, synergisms between sulphur compounds and other pollutants and the interaction between sulphur dioxide and carbon dioxide in pollutant plumes. However insufficient data exist for any estimation of these facets.

Species differ in their relative tolerance to concentrations causing acute and chronic damage and in addition, injury resulting in depression of plant yield is very dependent on the timing of exposure with respect to the plant cycle. Bud formation and flower setting periods are the most sensitive parts of the life cycle. Injury to plants is affected by numerous factors including temperature, relative humidity, soil moisture, light intensity, nutrient supply and age of plant tissue. Hence, for the reasons outlined above the basis of any calculations relating sulphur dioxide contamination to plant yield must be very uncertain.

However, Jeffree (OECD, 1981) has established a dose-yield relationship linking yield losses for *Lolium perenne* (rye grass) to sulphur dioxide concentrations. This relationship is shown in Table 3 and may be used as a very tentative general guideline, for expected losses to crops sensitive to sulphur dioxide contamination. Until further information is available regarding the sensitivity of blueberries, avocados, kiwifruit, grapes, etc. to sulphur dioxide, it should be assumed that they are in the 'sensitive' category.

TABLE 3

Sulphur Dioxide Dose - Crop Yield Relationship

The dose-yield relationship used in the calculation of damage to crops predicts the following reductions in yield at annual mean SO₂ concentrations between 0 and 100 g/m².

SO ₂ conc. g/m ²	Yield loss %	SO ₂ conc. g/m ²	Yield loss %	SO ₂ conc. g/m ²	Yield loss %
0.5	0.004	6.0	0.20	30.0	2.7
0.7	0.006	7.0	0.26	35.0	3.4
0.9	0.01	8.0	0.32	40.0	4.2
1.0	0.01	9.0	0.38	45.0	5.0
1.5	0.02	10.0	0.46	50.0	5.9
2.0	0.03	12.0	0.61	55.0	6.8
2.5	0.05	14.0	0.79	60.0	7.8
3.0	0.06	16.0	1.0	65.0	8.8
3.5	0.08	18.0	1.2	70.0	9.8
4.0	0.10	20.0	1.4	80.0	11.9
4.5	0.13	22.0	1.6	90.0	14.1
5.0	0.15	25.0	2.0	100.0	16.3

2.8 Nitrogen Dioxide

Symptoms of vegetation damage from exposure to another major flue gas pollutant, nitrogen dioxide, are similar to those for sulphur dioxide, however much higher levels of nitrogen dioxide can be tolerated without damage.

2.9 Psychological Effects

A further potential problem from the power station, is the psychological effect on overseas buyers who see the location of a huge coal fired power station, with its resultant dust and ash emissions, centred in an area of intensive horticultural production. Burton (pers. comm., 1984) expressed the opinion that regardless of whether the power station emissions do have a significant detrimental effect on horticultural produce or not, overseas buyers may reject the produce

for export, solely on the grounds of potential industrial contamination. Certainly, considering some of the past cases of produce rejection by recipient countries, and especially Japan, this is a problem which should not be disregarded.

CHAPTER 3

FACTORS INFLUENCING THE EFFECTS OF PARTICULATE EMISSIONS ON HORTICULTURE

A number of factors influence the actual effect of the total particulate emissions from any source point. A distribution model of stack emissions has been fairly comprehensively outlined in Report No. PD24 (August 1984) and so the factors influencing the effects of these emissions will not be expanded upon in this section. However, ground source emissions are more difficult to predict and are influenced largely by a range of local climatic and topographic features. Some of these influencing factors are explained below.

3.1 Rainfall

Rain reduces the amount of dust which is present on leaf surfaces with the double effect of both laying the dust from most sources and also of cleaning plant surfaces covered in dust.

Storey (pers. comm., 1983) indicated that it would take approximately 4mm of rain on any one day to remove dust already present on plant surfaces, since it takes 6-12mm to remove agricultural sprays.

Rain will suppress dust from all open emission sites at the power station (e.g. construction, roads, etc.) and where no new material is brought in (e.g. dry ash for dumping) it is assumed that two days for an arbitrary winter period (April to October) and one day for an arbitrary summer period, are required for the particles to dry out and revert to being a source of dust. However where new dry matter is constantly being exposed to the elements (e.g. from dry ash disposal) then it must be assumed that these sources will become dust sources almost as soon as any period of rain is finished.

Given these assumptions and the rainfall patterns for Waikato County from 1973-1982, on average, approximately 57 percent of all annual days can be considered as dusty, for permanently exposed dust sources, and a significantly higher percentage, for dust source areas which are being constantly replenished with dry material.

A further effect of rainfall would be to facilitate the leaching of nutrients and trace elements contained in particulate matter deposited on the ground around horticultural plants, for uptake by their root systems. However the nature of this effect is uncertain and in any event, is likely to be of little consequence.

3.2 Irrigation

The proposed Te Kauwhata irrigation scheme will be constructed in the vicinity of the Rangiriri site. The most probable method of on farm water application will be by micro-sprayer which will have no effect on the amounts of dust present on plants.

However, if spray irrigation is used by some growers then this can have a marked effect on the amounts of dust on plant surfaces. Basically, the effects are the same as for rain. That is:

- (1) washing dust off leaves;
- (2) washing dust into nooks and crevices; and
- (3) dirt splash;

but there can be complications. Because the source areas of dust are still dry while plant surfaces are made wet, dust deposited immediately after irrigation tends to adhere more readily to surfaces, and becomes more difficult to remove.

3.3 Time of Year

Agricultural and horticultural production and marketing cycles are directly controlled by the season (time of year). Thus the effects of dust will be of greater economic significance at certain periods than at others.

Deciduous trees are dormant over the winter months and so are not affected by dust during this time. However, during the dustiest months over the summer, plants are generally experiencing rapid growth, crops are ready for harvest and pest and disease incidence is often at its height.

Hence, when assessing the effects of dust on different enterprise types, it is necessary to consider these time related factors.

3.4 Wind

Wind speed is an important determinant in the emission of fugitive dust from dormant areas of exposed ground and stockpiles. However, it is not such an important factor in the dispersion of dust plumes once the dust is airborne. Dispersion is much more dependent on the direction of the prevailing wind.

Work by Handy et al. (1975), Ward et al. (1979) and Hoover et al. (1981) show that dust levels on either side of a metal road can be almost identical for up to the first 20 metres. However, further away from the road the prevailing downwind side appears to receive roughly twice the amount of dust deposition as the prevailing upwind side, depending upon conditions. These findings are assumed to hold for the power station dust emissions.

Data on wind speed near the ground for sites at Huntly West and Kopuku indicate that the major prevailing wind for both the Clune Road and Rangiriri sites is from the south west and that approximately 55-60 percent of the expected winds will blow dust onto productive land to the east of the sites.

Wind speed as a determinant of dust plume dispersion and distribution is highly dependent on a number of other factors, especially surface roughness⁴ and an advection component. Becker (1978) found that except over smooth surfaces, such as clear pasture land, wind speed has little influence on the distance which a dust plume may travel. Dust deposition is largely a result of the amount of interaction a plume has with the deposition surface.

Hence over rough surfaces, when a light wind is blowing, the advection effect is stronger, thereby lifting the dust higher and giving it more time to interact with the deposition surface. Conversely, with a strong wind the advection is greatly restricted and the surface interaction time is decreased. Thus an inverse relationship exists between wind speed and the advection component over rough surfaces, and this results in an insensitivity of dust deposition to wind speed.

Where smooth surfaces (e.g. pasture land) border the dust source areas however, wind speed has a direct influence on the distance and distribution of dust plume deposition. Thus the stronger the wind, the greater the deposition will be at locations away from source areas.

3.5 Roughness Height

The height of vegetation on land adjacent to dust sources has a significant influence on the rate of dust deposition. Deposition close to the sources is always greater over rough surfaces than smooth surfaces.

Becker (1978) showed that deposition differences due to the different roughness heights may be very large. This can be explained by the fact that surface roughness causes a larger friction velocity which in turn, enhances the deposition velocity resulting in more deposition. Hence, it follows that dust effects would be confined to a much smaller area where horticultural production systems border the power station site, than if it were all pasture land. Similarly, the deposition rates for this area could be expected to be greater than if the dust were spread over a greater area.

3.6 Shelterbelts

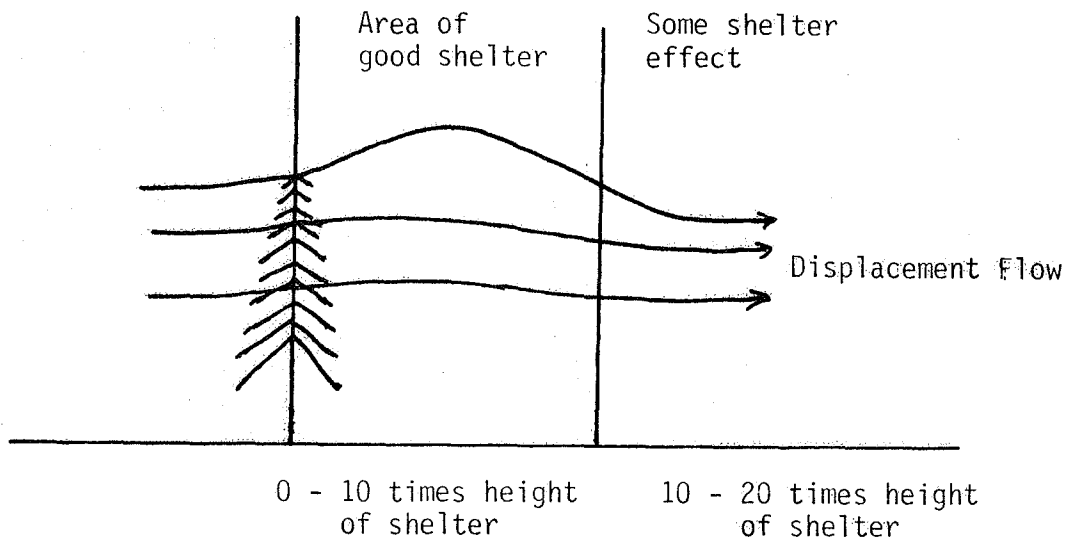
The effect of shelterbelts on road dust deposition is virtually just an exaggeration of the concept of surface roughness. That is, they increase the surface friction velocity but to a larger degree than most rough surfaces, due to their greater height and continuous line.

Shelterbelts are designed to be 50 per cent permeable to wind (Batt, 1979) so that a smooth airstream is retained rather than pockets of turbulence.

4 Surface roughness is determined by the height of vegetation, prevalence of buildings, etc. situated alongside dust source areas.

FIGURE 2

Distance of Effect of a 50 Per Cent Permeable Shelterbelt
on Flat Ground



It would seem reasonable to assume then, that a shelterbelt may reduce the amount of dust which reaches a paddock by up to 50 per cent. However, taking into account the displacement flow (Figure 2) which would cause some dust to be transported over the shelterbelt a realistic figure for the amount of dust retained by the shelterbelt may be 40 per cent.

Considering that wind speed has little effect on dust plume deposition except over smooth surfaces it is assumed that the remaining 60 per cent of dust, which gets past a shelterbelt, is deposited at a proportionally similar rate away from the dust source, as dust when there is no shelterbelt present.

Another matter related to shelterbelts requires a brief mention. Although dust is often a factor in poor plant growth and fruit production in the rows nearest to a dust source, two other possible factors should also be considered under different situations.

- (1) When shelterbelts are present, they provide competition to fruit trees for sunlight, water and soil nutrients.
- (2) Where there are no shelterbelts, the outside rows of trees may be stunted by wind stress.

Hence, caution is needed to ensure that the magnitude of the effects of dust on plant growth and crop yield are not overstated and that all possible influencing factors are examined.

3.7 Size of Dust Particles

For this report, dust is defined as all particles less than 75 μm in diameter. The smaller the particles, the greater is the distance of deposition distribution away from the sources of dust. Of all the power station dusts, in general, fly ash is the smallest followed by bottom ash, coal dust and construction dust.

In addition, smaller particles are more likely to hinder plant physiological functions (e.g. clogging of stomatal pores) and the functioning of beneficial insects, and are often more difficult to remove from plant surfaces.

3.8 Topography

Undulating countryside will affect the distribution of dust deposition. The mechanics which apply to surface roughness also have an application here and there will also be areas of turbulence and wind funnelling of dust up gullies. However it is not practical to include allowances for the topography of the region around the power station site, in this report.

3.9 Operational Procedures

The emission of dust from the proposed power site will depend to a large extent on the operational procedures used for both the construction and operation of the power station.

The types, speeds and numbers of vehicles using unsealed haul roads around the power station site are one obvious critical factor determining the quantity of dust emitted. Others include the procedures followed for the watering of roads, stockpiles and construction areas during dry periods, methods of ash disposal, coal transport, etc.

3.10 Conclusions

The large number of factors influencing the emission and distribution of dust away from the various power station sources, mean that it is virtually impossible to accurately predict the impact of the dust on horticulture. Many studies have been conducted into the emission, distribution and effects of dust from mining, industrial plants, unsealed roads, etc., but still, at best only an approximation of what can be expected to happen, may be given.

CHAPTER 4

POWER STATION EMISSIONS OF DUST AND ASH

The potential sources of dust emission from the proposed power station activities were outlined in Chapter 1. The costs of each source type on horticultural production will vary with respect to the:

- (1) source emission strength;
- (2) composition of dust emitted;
- (3) location of source area; and
- (4) the duration and timing of emissions

In some instances, the effects of dust emitted from different sources will be additive, whilst in others they will be isolated.

The purpose of this chapter is to provide an approximate estimate of the likely effect and extent of each dust emission source on horticultural production. Given that very little conclusive and detailed data pertaining to dust distribution mechanisms, the effects of dust on horticulture, nor to many power station activities, is available; the results of these analyses must be regarded with a great deal of caution and used as a guideline only.

4.1 Earthworks and Construction Dust

The construction phase of the proposed power project is due to begin in mid 1987 and will continue for 8 years. However it is assumed that the greatest problems from dust emissions will be during the first year of major earthworks and to a lesser extent, during the following 2 years of major construction activities. The remaining 5 years of construction are not predicted to be a significant source of dust emission (Willis 1985). The methods of construction and quantities of dust emitted during this phase are assumed to be similar for whichever site location is chosen; only the distribution onto productive land will differ.

4.1.1 Sources of Dust

The chief sources of dust emission during this phase are expected to be:

- (1) the operation of earthmoving machinery;
- (2) windage losses on haul trucks;
- (3) windage losses from areas of bare soil;
- (4) windage losses from truck dumping of soil and aggregate; and
- (5) the movement of trucks and vehicles along unsealed haul roads.

The first four sources identified above will probably only be a significant problem during the major earthwork phase while the fifth, road dust emissions from unsealed roads, will continue to be a problem throughout the life of the station; except in the unlikely event that all roads within the station complex are sealed.

4.1.2 Emission Estimates for Major Earthworks Phase

The major earthworks phase will involve the movement of approximately 4 million tonnes of soil over an expected period of 200 days (one long summer). The estimation of the dust emissions during this phase are based on a number of assumptions concerning the logistics of the construction processes. These were provided by Tetley (pers. comm., 1984) of the Ministry of Works and Development, and are as follows:

- (1) The earthworks phase will involve a period of 200 12 hour days; or a total of 2,400 hours worked;
- (2) The construction fleet consists of the following vehicles;
 - (i) 2 x D9 dozers,
 - (ii) 8 x 40m scrapers,
 - (iii) 4 x 40m dump trucks with a laden weight of 80 tonnes and an unladen weight of 40 tonnes,
 - (iv) 2 x 10m loaders,
 - (v) 1 x grader, and
 - (vi) 2 x water trucks.
- (3) The length of unsealed road on the site is 10 kilometres;
- (4) The length of each haul for dump trucks is 1 kilometre each way with the average time of 1 cycle equal to 15 minutes. This represents 36 cycles per day or 72 kilometres travelled per truck;
- (5) The area of bare ground uncovered at any one time will be 100 hectares;
- (6) The length of on-site unsealed haul roads will be 10 kilometres.

In addition, a number of other general assumptions have been used including:

- (1) Only 66 percent or 132 days of the 200 day earthworks phase will be sufficiently dry for dust emissions to occur (McCrea, 1984);
- (2) The silt content of roading material on haul roads is 6 per cent (McCrea, 1984);
- (3) The reduction of dust emissions when water control is practised will be 65 per cent (Dyck and Stuckel, 1976). This seems reasonable since the effect of water applications is very short due to evaporation, especially when vehicles are moving over and drying out the road surface; and

- (4) Water control during earthworks is only practised on haul roads and bare areas of land which are causing a dust problem and are not presently being worked. It is assumed that water control is not practised where earthmoving machinery is working.

The emission of dust from earthwork operations can be extremely variable (PEDCO⁵, 1980). The dust losses from this operation vary with the composition, texture and moisture content of the earth being moved, excavation procedures, equipment employed, etc. Hence a number of assumptions and generalisations drawn from previous studies have necessarily been used in the estimates of dust emission set out below. Note however, that these estimates relate to emissions for any day sufficiently dry for dust to be present.

(1) Scraper operation

PEDCO (1976) estimated that the operation of scrapers stripping the topsoil and subsoil of a lignite surface mine in North Dakota each produced dust emissions of seven kilograms per hour of operation. If this figure is assumed to be reasonably representative for scraper operations at the Waikato site, then daily scraper uncontrolled emissions will be:

$$\begin{aligned} &8 \text{ scrapers} \times 12 \text{ hours} \times 7 \text{ kilograms/hour} \\ &= 672 \text{ kilograms per day} \end{aligned}$$

(2) Dozer operation

No emission factor was available for dozer operation, so for the purposes of this study, it is assumed to be the same as for scrapers; i.e. seven kilograms per hour of operation. With two dozers working, this produces a daily emission level of 168 kilograms.

(3) Grader operation

A grader will be used mainly for the purpose of maintaining the unsealed roads and storage areas around the construction area. The uncontrolled emission factor for graders is assumed to be 15 kilograms per hour of operation (PEDCO, 1980) which yields a daily emission level of 180 kilograms. However, it is assumed that the operation of the two on-site water carts would reduce this level to approximately 63 kilograms of dust per day.

5 The term 'PEDCO' refers to a large American environmental consultancy firm called PEDCO-Environmental Specialists, Inc.

(4) Windage losses from soil and aggregate transport and handling

The movement of soil and aggregate by haul truck involves three possible sources of dust emission:

- (1) loading by front end loader;
- (2) windage losses during transit; and
- (3) dumping.

Estimates of emission factors for these activities are based on the quantity of material handled. Thus, assuming that each of the four dump trucks completes four trips of 40 tonne loads per hour, the total quantity of material moved per day is 7,680 tonnes.

The best available estimate of emissions during truck loading was developed by the Midwest Research Institute (MRI) who sampled the loading of crushed rock by front end loaders and determined an average emission rate of 0.025 kilograms per tonne of rock (EPA, 1974). This rate has also been applied by PEDCO (1975) to the loading of copper ore. However it is likely that the material being moved during the power station construction would have a slightly higher moisture content level and larger particle size than the above mentioned sources, and so an emission rate estimate of 0.02 kilograms per tonne of material loaded has been adopted for this study.

Although in some conditions, windage losses during transit may be a minor problem, both Hittman (1974) and PEDCO (1976) concluded that these losses are negligible. Hence for this study they are assumed to be nil.

Dust is generated by truck dumping as soil and aggregate tumbles from the truck and strikes the ground. An emission rate for truck dumping developed by PEDCO (1975) and used in a number of studies since, of 0.01 kilograms per tonne, has been chosen as most applicable to this study.

Thus the total emission rate for windage losses during transit is 0.03 kilograms per tonne of material carted. This yields a daily emission rate for during the power station earthworks phase of 230 kilograms per day.

(5) Haul roads

It is assumed that most access roads to the power station site will be upgraded before commencement of the construction phase and that they will be negligible sources of dust emission. However the site area will contain approximately 10 kilometres of temporary⁶ on-site unsealed road⁶ for access during construction and these could be a major source of dust emissions.

⁶ Just how temporary these unsealed roads will actually be is rather uncertain, especially as the Huntly power station still has a considerable amount of unsealed roading on site.

The first obvious cause of haul road dust emissions are the dump trucks which will be travelling on average, a total of 384 vehicle kilometres per day. However, in addition to the dump trucks, other vehicles will be using the haul roads regularly; water trucks, fuel and service trucks, materials delivery trucks, pick up trucks and a host of other administrative cars and vehicles. In the absence of any data regarding vehicle movement on site, for the purposes of this study, it is assumed that the average daily vehicle kilometres travelled by heavy vehicles, other than dump trucks, total 350, and a further similar figure for light vehicles (i.e. cars and pick-up trucks).

A crude estimate of the haul road emissions can be made by assigning road emission factors, which are experimentally derived empirical factors representing the mass of dust generated per length of road on which a vehicle travels. The crudeness of such parameters are apparent since they mask many of the effects of:

- (1) the speed, weight, shape, number of tyres and type of vehicle;
- (2) the physical characteristics of the road surface;
- (3) meteorological conditions that affect the transport of dust; and
- (4) the size, distribution and density of dust particles.

A number of equations have been developed to estimate the dust emission from light vehicles on unsealed roads. One that appears to be a better fit to most experimental data than any others developed to date was developed by McCaldin and Heide1 (1979)⁷. This equation shows that the rate of dust emission from unsealed roads varies as a square of speed rather than directly with speed as had been earlier thought. It is expressed as:

$$e = 0.38 (S) (V^2)$$

where e = emission factor per vehicle kilometre expressed in kilograms (kg)

s = silt content of the roading material expressed as a decimal fraction

v = average speed expressed in kilometres per hour (km/hr)

If the average speed of light vehicles on the haul roads is assumed to be 40 km/hr, which is likely given the close proximity of the roads around the construction area, then the predicted emissions are:

7 Converted to metric units in McCrea (1985)

$$e = 0.0038 (.06) (40^2)$$

$$= 0.36 \text{ kg/km travelled}$$

Using the assumptions regarding the daily distances travelled on the haul roads, the daily emission level from light vehicles travelling on haul roads is 126 kg/day.

This figure of 0.36 kg/km dust emission, approximates very closely to a figure of 0.4 kg/km which was estimated by PEDCO (1980) to be the level of dust emission by light vehicles using haul roads at an open-pit copper mine.

Considering the compatability of PEDCO's findings to McCaldin and Heidels, and also the lack of suitable data concerning emissions from heavy vehicles on haul roads, a corresponding estimate for emissions from heavy trucks on haul roads, developed by PEDCO (1980), is used in this study. This emission estimate is 1.1 kg/km travelled and gives a total daily emission level for heavy trucks of 807 kg/day.

Hence the total uncontrolled daily emissions from vehicles using haul roads during the construction phase may be around 933 kg/day. However if control is practised on the roads then this level can be expected to decrease by 65 percent to 326 kg/day. In addition, because the haul roads are a line source of dust emission, running around different parts of the power station site, the emission depositions will be spread over a wide area. Thus it is necessary to calculate the expected daily emission for each kilometre of the roading complex. By assuming that each of the 10 kilometres of haul road receives equal use then the expected daily emissions for each kilometre of road in the complex is approximately 33 kg/km/dry day.

(6) Exposed ground

During the period of major earth works, an average of approximately 100 hectares of bare ground area will be exposed at any one time. Wind erosion of the topsoil layer of this land will be a further source of dust emission during this period. A wind erosion equation which was originally developed by the United States Department of Agriculture (USDA) to estimate soil losses from cropland, but which has been adapted to predict the suspended particulate fraction of total soil losses and has been applied in a number of studies to evaluate exposed soil surfaces other than cropland (EPA, 1974), appears to provide the best available estimate of emissions.

The modified wind erosion equation is as follows:

$$e = aIKCLV$$

8 A rather broad generalisation but sufficient for the purposes of this study

where e = emission factor, t/ha/yr

a = portion of total wind erosion losses that would be measured as suspended particulate

I = soil erodibility, t/ha/yr

C = climatic factor

K = surface roughness factor

L = unsheltered field width factor

V = vegetative cover factor

In this equation C , K , L and V are all dimensionless.

Studies (PEDCO, 1976) have indicated that the variables ' a ' and ' I ;' are related to soil type and for the predominantly clay and silt soils around the proposed power station site options, the values that may be applied are:

(1) $a = 0.025$; and

(2) $I = 113$ t/ha/yr

Values of ' K ' can vary between 0.5 and 1.0, with 0.5 a surface with deep furrows and ridges, which protect against soil erosion, and 1.0 denoting a smooth erodible surface. Hence for this study, it is assumed that a value of 1.0 for ' K ' should be used.

Since the width of the exposed ground area at the site will in most cases be greater than 600 metres, the value of ' L ' should be 1.0. (For lesser widths, the ' L ' value should be around 0.7). In addition, because the bare surfaces will have no vegetative cover, the value of ' V ' is 1.0.

The USDA has determined climatic factors (C) for most parts of the United States but an estimation of a ' C ' value for this study has necessarily involved a large degree of subjective judgement. With reference to Waikato's wind and rainfall patterns, a ' C ' value of 0.7 has been chosen.

Given the above parameter values, the predicted emission for exposed ground is:

$$e = .025 (113) (1.0) (0.7) (1.0) (1.0)$$

$$= 1.98 \text{ t/ha/yr}$$

Further calculations show that the average daily rate of dust emission for exposed ground areas is 9.25 kg/ha/day⁹ with a total daily emission for the 100 hectares of exposed ground, of 925 kg/day. However if water control methods were used on this area then the emission rate would be 23 kg/ha/day and the total level of daily emissions 323 kg/day.

9 Adaption of the annual emission to a daily estimate was made using the figure for the average number of dry days per year in Waikato County (McCrea, 1984).

(7) Summary of earthworks emissions

A summary of all major expected dust emissions during the earthworks phase is set out in Table 4.

TABLE 4

Summary of Earthworks Emissions

Emission Source	Daily Emission Levels (kg/day)	
	Total Uncontrolled	Total With Water Control ¹⁰
Scrapers	672	NA
Dozer	168	NA
Grader	180	63
Windage losses in transit	230	NA
Haul roads	933	326
Exposed ground	925	323
TOTAL EMISSIONS	3108	1782

This shows that given the intended use of water control methods for dust suppression during the earthworks phase, that:

- (1) scraper emissions are likely to be the largest single cause of dust emission; and
- (2) the use of water control can be expected to reduce total emissions by almost a half.

¹⁰ Note that water control for dust emission will only be used for some sources of dust.

4.1.3 Emission Estimates for Dust Generation During Major Construction Phase

Following the completion of major earthworks, there will be approximately two years of major construction activity during which dust generation may still be reasonably high. It is difficult to place any specific estimates on likely emissions during this period since little information is available on the nature of the activities which will be occurring. However, it is likely that some minor earthworks will be undertaken during the period and thus, an estimate of daily emissions has been calculated, based on some rather arbitrary assumptions, that:

- (1) the daily traffic volumes on haul roads for light vehicles and heavy vehicles other than dump trucks is the same as during the earthworks phase;
- (2) grader operations are reduced by 20 percent;
- (3) all other earthwork operations are reduced by 90 percent; and
- (4) there are no other significant sources of dust emission during this period.

The resultant daily emission levels are set out in Table 5. This shows that estimated emissions during this period are 70-80 percent lower than during the period of major earthworks¹¹.

4.2 Dust from Power Station Operation

4.2.1 General

The proposal for the power station is for a conventional coal-fired steam cycle power station, ultimately with 4 generators of 250 MW each. It is presently programmed for development in two stages with two generators of 500 MW total capacity being commissioned first, with the other two following some time within the ensuing 10 years; the timing depending largely on energy requirement forecasts.

However this study will look only at the emissions from the fully commissioned station generating at 1000 MW. The reasons for this are:

- (1) the station will be generating at this capacity for most of its planned life;
- (2) this provides a 'worst' estimate; and
- (3) emissions for the station generating at 500 MW could be assumed to be about 55 percent of those when generating at 1000 MW (55 percent is used and not 50 percent because it is assumed that some dust generating activities would not change much with output).

¹¹ In fact the emissions for this period may be even lower still, since a correction factor for the larger number of wet days during the winter periods was not included. However given the subjectivity of these estimates, this should not matter too much.

TABLE 5

Summary of Emissions for Remainder of Construction Phase

Emission Source	Daily Emission Levels kg/day	
	Total Uncontrolled	Total With Water Control
Haul roads	553	193
Grader	144	50
Scrapers	67	67
Dozer	17	17
Windage losses in transit	23	23
Exposed ground	93	32
TOTAL EMISSIONS	897	382

There are 3 major source areas of emissions each of which will be assessed separately. These are:

- (1) On site emissions which may affect horticultural land around the perimeter of the power station site;
- (2) Off site coal transport emissions which may have effects on production along the transport routes; and
- (3) Chimney emissions which may effect horticultural areas well away from the power station site.

4.2.2 On-site Emissions

There are three major potential source types of on site emissions which may be of consequence:

- (1) coal stockpiles and associated coal handling activities;
- (2) unsealed roads; and
- (3) if a dry ash disposal method is chosen then there will be emissions from the activities involved in that process.

Emissions for each of these will be assessed separately and distinctions made between the toxic and non-toxic emissions from each source.

(1) Coal stockpiles and handling activities

The on-site handling and storage of coal for the power station will include a number of activities which may generate dust emissions. The general handling and storage processes and parameters for the station are outlined below.

Coal supplied to the power station from the mine(s) will be stockpiled on-site and subsequently fed to the stations boilers as required to supply the demand for electricity. The average daily fuel requirement is expected to be approximately 6000 tonnes. On-site coal storage will occupy a substantial area of land, comprised of three stockpile facilities:

- (1) a short-term store with a 40,000 tonne capacity, covering an area of Approximately 2 hectares;
- (2) a medium-term store with an 80,000 tonne capacity covering an area of 4 hectares; and
- (3) an on-site strategic stockpile with a 1,000,000 tonne capacity covering an area of 30 hectares.

The coal in these stockpiles will be rotated to a preset plan.

The coal received will be crushed and screened to size before being transferred by conveyor to bunkers which can store one day's supply of coal. From the bunkers, the coal will be fed to the coal mill which grinds or pulverizes the coal to a fine powder from where it will be carried in an air stream to the furnace for firing. On-site coal movement will be generally by conveyors, with stockpile construction and reclamation by mobile earthmoving plant.

The estimates of dust emissions for these activities are set out below.

(a) Screening and crushing coal.

The United States Environmental Protection Agency's (EPA) (1975) published compilation of emission factors for coal crushing does not include a quantitative estimate, but states that "the crushing, screening, or sizing of coal are minor sources of dust". This report on coal crushing also indicates that 95 percent control can be achieved by use of water sprays and 99 (plus) percent control is possible with sprays followed by mechanical dust collectors.

However where no form of dust control is used, PEDCO (1976) have estimated the following emission rates:

- (1) Crushing 0.02 kg/t crushed; and
- (2) Screening 0.05 kg/t crushed.

All screening and crushing at the Waikato power station will be conducted within enclosed towers where anti-dust sprays, comprising of water plus a suppressant additive, will be applied to the coal. Hence using the EPA's (1975) estimates for the effectiveness of the dust control processes, the total daily emissions should only be about:

$$e = 6000 (0.02 + 0.05) (0.01)$$

$$= 4 \text{ kg/day}$$

where: e = total daily emissions.

Hence, even if the emissions were 10 times larger than this, the amount will still be of little significance. This finding is supported by Norris (pers. comm., 1985) who concurred that emissions from this activity will be negligible.

In addition, Norris stated that emissions from the coal pulverising before it is burnt, will be zero since the process will be carried out in a sealed vacuum.

(b) Coal stockpile emissions

In order to avoid combustion dangers, all coal will be crushed and then compacted into stockpiles. The compacting process has the effect of crushing the particles finer, thus contributing to the emission of dust.

No estimates are available for dust emissions from crushed coal storage areas. However, for the purposes of this study, an emission estimate for crushed rock storage developed by the Midwest Research Institute (MRI) (EPA, 1974), should be sufficient.

The MRI study identified four major emission producing activities in crushed rock storage and these are listed along with their relative percentage contributions:

- (1) Loading onto piles - 12 percent
- (2) Equipment and vehicle movement in storage area - 40 percent
- (3) Wind erosion - 33 percent
- (4) Loadout from piles - 15 percent

It is likely that these same activities are the major dust sources in all types of open storage.

The resultant emission factors estimated during the MRI study are presented in Table 6.

TABLE 6
Emission Factors for Crushed Rock Storage Piles

Activity rating	Emission Factor kg/hectare of storage/day
Active ^a	14.8
Inactive (wind erosion only)	3.9
Normal mix ^b	11.6

a Eight to 12 hours of activity per 24 hour period

b Five active days per week

Source: EPA (1974)

Assuming that the bulk of storage handling activities would be conducted during a normal five day week and that no emission control procedures would be used (Norris, pers. comm., 1985), the relevant emission factor is 11.6 kg/ha of stockpile area. Calculations show that the average daily emission rate from stockpiles would be around 418 kg/day.

(c) On-site coal conveying

Most of the on-site coal movement will be by belt conveyor. Loss of material from the conveyors will primarily be at the feeding, transfer and discharge points and may occur due to spillage or windage. Because the conveyors will be relatively short (i.e. less than 300 metres) the dust emitted from them is assumed to be from a single area close to the power station.

A report by Hittman and Associates Inc. (1974), stated that coal conveyor systems "are either covered or operated at such a speed that dusting does not occur to any great extent. However the same report used a value of 0.4 kg/tonne, loss through spillage at conveyor transfer points.

Hence, if it is assumed that say 10,000 tonnes of coal are moved on-site by conveyor daily, and that only five percent of the spillages are in the form of dust, then the daily emissions from on-site coal conveying will be 200 kg/day. This should serve as a fair estimate for this study.

(2) Unsealed roads

It is assumed that a number of on-site roads will remain, and continue to be unsealed after the construction phase is completed. These will probably be used for general access around the site and to station facilities (e.g. ash dump sites^{1,2}, dust monitoring equipment, etc.).

The worst case for dust emissions from this source will be if both dry ash and truck haulage methods are used for on-site ash disposal. This process would require approximately 25 round trips per day of roughly 4 kilometres each, by 24 tonne dump trucks; or a total of around 100 vehicle kilometres per day.

If it is assumed that the total kilometres travelled by all heavy vehicles is double this amount (200 km/day) and that the total distance travelled by light vehicles on the station's unsealed roads is 100 km/day then the uncontrolled daily emissions would be 220 kg/day from heavy vehicles and 36 kg/day from light vehicles, giving a total emission level of 256 kg/day.

However with water control on roads, this would be reduced to around 90 kg/day.

(3) Dry ash disposal

Evaluations to date have shown that a method of dry ash disposal has a number of advantages over wet disposal methods. However, dry ash disposal will be a source of dust emission.

The process of dry disposal essentially entails the land-filling of ash, moistened with a certain amount of water for dust control and adequate compaction. Bottom ash, which will be hydraulically transported from the bottom of the boiler to a dewatering bin, will probably be transported separately from fly ash to the disposal area in trucks. Conversely, the fly ash will probably be transported pneumatically from the air heater and hoppers to storage silos, from where it will be transported to the disposal area either by pneumatic trucks, open trucks, rail or pneumatic conveyor.

As ash arrives at the site, it will be dumped in piles and spread and compacted in layers by conventional earthmoving machinery to achieve a fill of high density.

Essentially then, there are two potential sources of dust emission during this operation; these are set out below.

(a) Windage losses from open truck or rail transport

Although the flyash component of the ash, which will comprise around 700 tonnes of the expected 1000 tonnes total daily ash production is of extremely fine and similar composition to Portland cement, there is likely to be negligible dust emission caused by a

12 The assumption is made that if a method of truck hauling for on-site ash disposal is chosen, that unsealed roads will be retained.

possible open truck or rail transport procedure. Any ash which is transported by this method will be humidified or water conditioned which should eliminate any dust problem.

(b) Exposed ash disposal areas and related handling activities

The area exposed at the ash disposal sites at any one time is predicted to be up to 10 hectares. It is expected that although the humidifying process used on the ash before dumping will aid the conglomeration of ash particles and hence help to reduce the dust nuisance, there will still be a large capacity for dust emissions via wind erosion and vehicle disturbances etc.

In the absence of any data relating to the emission of dry ash from disposal sites, an arbitrary assumption is made that emissions for ash, are greater than similar emissions for earthworks and coal stockpiles by a factor of 1.5. This would seem to be reasonable in the circumstances, especially given the sizing of the ash particles. In addition, it is assumed that where dust is perceived to be a nuisance at the disposal site, that water carts will be used to suppress the dust. These will have a similar level of dust to those stated earlier (i.e. 65 percent).

Hence the following emissions could result from disposal sites:

(i) Dumping of ash at site (PEDCO, 1975)

$$\begin{aligned} e &= 0.015 (1000) \\ &= 15 \text{ kg/day (uncontrolled);} \end{aligned}$$

and assuming water conditioning reduces this amount, emissions are approximately only 5 kg/day; and

(ii) Exposed ash disposal area

$$\begin{aligned} e &= 10 (14.8)(1.5) \\ &= 222 \text{ kg/day (uncontrolled)} \end{aligned}$$

With water control this emission level will be reduced to 78 kg/day.

(4) Summary of On-Site Operational Emissions

The total potential on-site emissions for major activities during the operational phase of the station are set out in Table 7.

TABLE 7

Summary of On-Site Operational Emissions

Emission Source	Daily Emission Levels (kg/day)	
	Total Uncontrolled	Total with water control
Coal crushing and screening	NA	4
Coal stockpiles	418	NA
Coal conveyance	NA	200
Unsealed roads	256	90
Ash transport	NA	Negligible
Ash dumping	15	5
Exposed ash disposal areas	222	78
TOTAL EMISSIONS	1109	793

This shows that the highest levels of on-site emission are likely to be from the coal stockpiles, with the ash disposal areas, coal conveyancing and unsealed roads, also causing fairly high emissions.

4.2.3 Transport of Coal and Dry Ash to and from Power Station

It is not envisaged that the transport of coal from mines to the power station, nor the possible backloading of dry ash to the Maramarua mine will be major sources of dust emission whatever method of transportation is chosen, and subject to reasonable dust control measures. Several of the transport options have limited potential for windage losses (i.e. rail, road haulage, conveyor and ropeway) and road haulage could cause some minor road dust emissions. Emissions from coal handling and loading at the mines are not considered in this report, since it is assumed that any such emissions would occur without the power station anyway, with the coal being diverted to other uses.

A brief outline of the possible emissions from coal and ash transport are set out below:

(1) Windage losses¹³

Windage losses during transit by either of the methods of ropeway, rail or road haulage are likely to be fairly similar. To some extent they will depend on a number of operational factors, viz;

- (1) how high wagons are filled;
- (2) whether or not water spray is used to wet the coal or ash; and
- (3) speed of vehicles travelling.

However both Hittman (1974) and PEDCO (1976) found that such losses during transit are generally negligible. This assumption will be retained for this study.

Hittman (1974) found that emissions from conveyors used for coal transport may be quite high, but this method of transport will almost certainly not be used for either site option and so will not be considered any further.

(2) Road dust emissions

These are not likely to be a problem, since if a road haulage method of transport is chosen, either existing sealed roads and/or especially constructed sealed roads, will be used for the transport route.

It would appear then, that dust emissions from coal and ash transport systems will not be of any significance to horticultural production.

4.2.4 Chimney Emissions

Chimney emissions will be of interest mainly for the emission of the toxic chemicals sulphur dioxide and to a lesser extent, nitrogen dioxide. Estimates of the chimney emissions from the proposed power station, based on the parameters of the Huntly power station, have already been conducted. These are shown in Table 8. Some are elements in the air which pass through the boiler, while the remainder are products of coal combustion.

13 Emissions through windage loss during coal transit have been discussed in greater detail earlier in this chapter (6.1.2 and 6.2.2).

TABLE 8

Anticipated Chimney Emissions from 1000 MW Station

Discharge	Approximate Discharge Rate t/day
Particulates*	16.8
Sulphur Dioxide*	48
Nitrogen Oxides*	48
Carbon Dioxide	21,600
Nitrogen	79,200
Oxygen	6,000
Water	7,200

* Signifies of interest to this study

However, emissions will probably generally be lower than the levels stated, since it is likely that the power station may often be running at less than full capacity, especially in the summer period when emissions will have the greatest effects on horticultural production.

4.3 Conclusions

There will be a number of dust and ash emission sources at the proposed power station, irrespective of which site is finally chosen. These potential emissions can be categorised both by time and location of the emission source. Table 9 sets out these relevant categories which can be used for determining the likely effects of emissions on horticultural production.

TABLE 9

Emission Categories by Time and Location of Source

Emission Type	Time	General Location	Daily Emission Levels (kg/day)	
			Uncontrolled	Controlled
Major earthworks	First 200 days	Mainly area of main facilities	3108	1782
Major construction	2.5 years	Mainly area of main facilities	897	384
On-site coal handling and storage	Continuous* after construction period	Mainly area of main facilities	878	712
On-site dry ash disposal	Continuous* after construction period	Defined disposal areas	231	81
Coal Transport	Continuous after construction period	Off-site	Negligible	Negligible
Chimney Discharge	Continuous after construction period	Area of main facilities	Particulate SO NO	16,800 48,000 48,000

* The levels for all these emission types would actually be about half the stated levels until the second 500 MW part of the station is completed.

The following chapter calculates the general deposition distributions for each emission type, away from their respective source areas.

CHAPTER 5

DEPOSITION DISTRIBUTION AWAY FROM POWER STATION

EMISSION SOURCES

The distribution of dust and ash emissions onto the area surrounding the proposed power station will depend largely on a number of influencing factors (e.g. wind, rainfall, etc.) which will vary both in intensity and timing. Hence it is difficult to establish a comprehensive definition of the area of productive land which will be adversely affected by dust and ash deposition.

The distribution of chimney emissions has been modelled by Brasell et al (P.D. 24, 1984) and the results of that study are used in this report. Little information is available regarding the distribution of ground source emissions. However, by stating a number of broad generalisations and assumptions regarding the distributive mechanisms of these emission types, it is possible to estimate a range of generalised distances from the source areas, within which the dust and ash deposits may be of economic significance.

5.1 Chimney Emissions

Gas dispersion modelling has been carried out for an area of 120,000 hectares surrounding the proposed power station site options, to predict the ground level concentrations of sulphur dioxide as a result of the new power station. Figure 3 illustrates the annual average sulphur dioxide levels predicted by the computer model studies, for a 1,000 MW power station operating at the Rangiriri site.

A rough approximation of the areas within the modelling boundaries affected by different levels of ground level sulphur dioxide concentration can be gained by physical summation of the grids shown on figure 3. The results of these calculations are set out on Table 10. This shows that approximately 20 percent, or 21,040 hectares of the area modelled may be affected by chimney emissions.

FIGURE 3

Predicted Annual Average Sulphur Dioxide Levels from Rangiriri Site

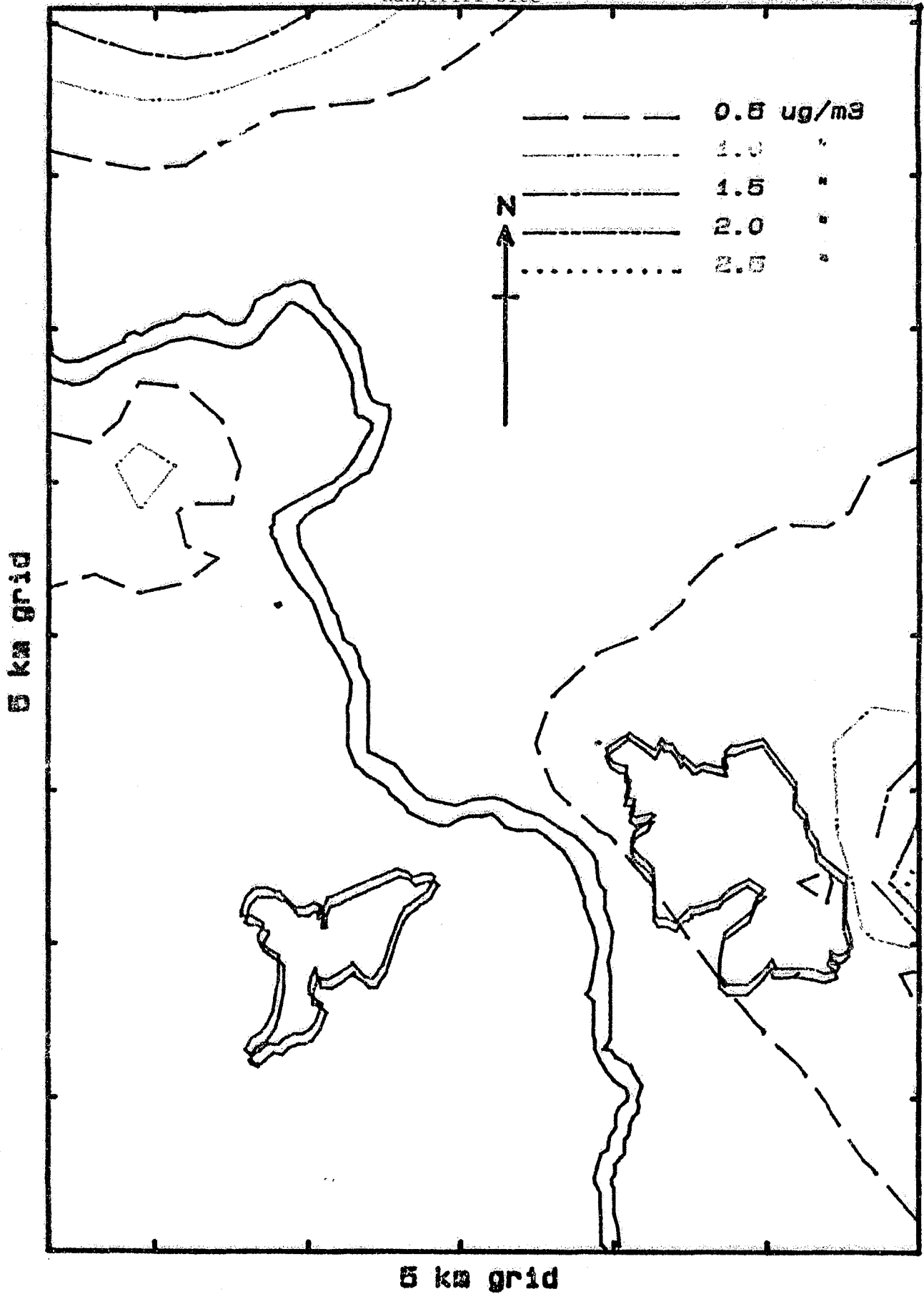


TABLE 10

Approximate Areas Affected by Sulphur DioxideRangiriri Site

Range of Concentration Levels (g/m ³)	Mean Concentration Level (g/m ³)	Area Affected (hectares)
0.5-1.0	0.75	17,400
1.0-1.5	1.25	2,750
1.5-2.0	1.75	750
2.0-2.5	2.25	125
2.5-3.0	2.75	15
TOTAL AREA AFFECTED		21,040

In addition, Brasell (pers. comm., 1984) stated that these levels would not vary greatly for a power station sited at the Clune Road location.

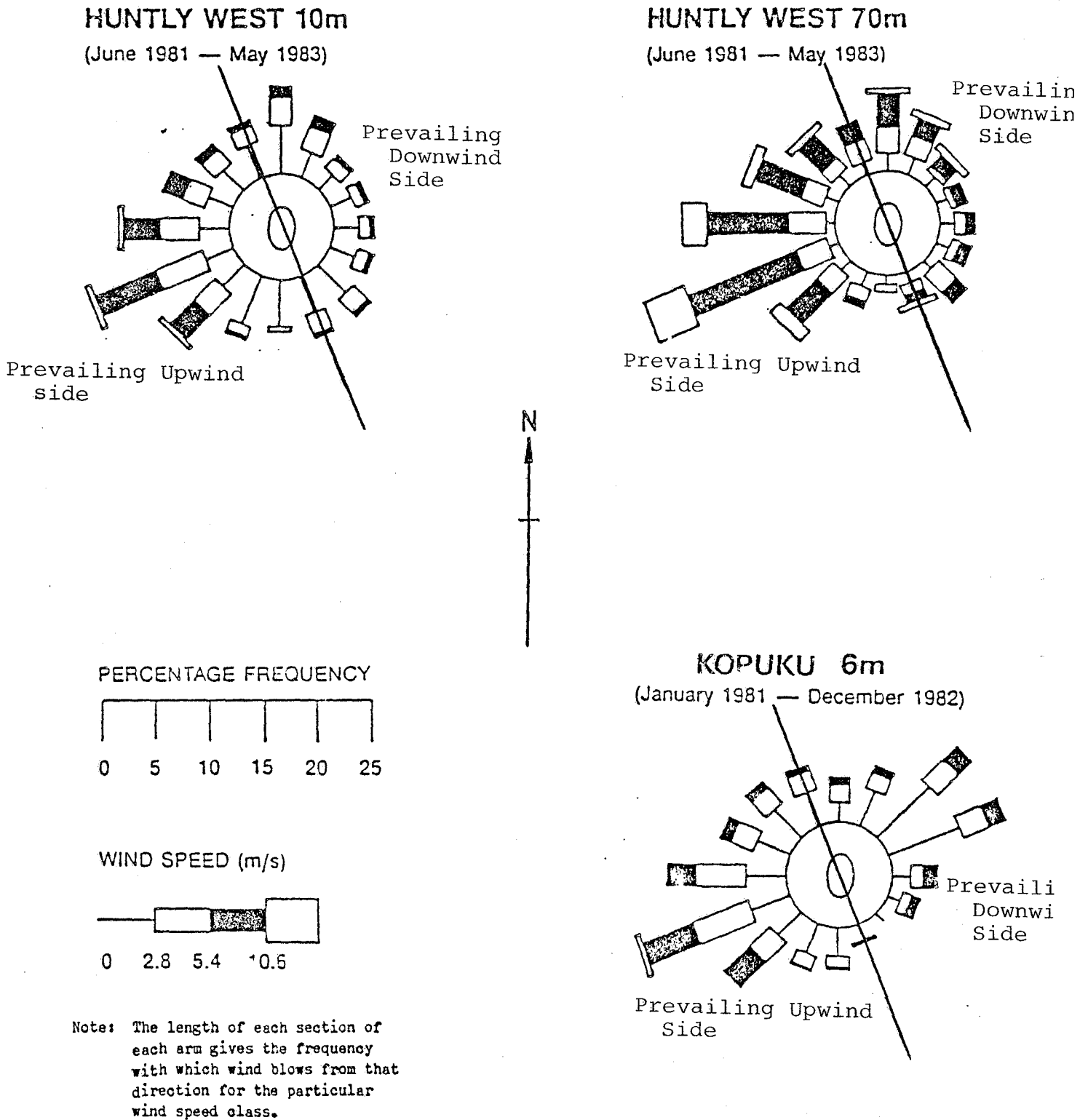
5.2 Ground Source Emissions

Wind direction is probably the single most important determining factor in the distribution of dust and ash deposition. The wind-rose information for two Waikato meteorological stations, shown on Figure 4, illustrates that winds in Waikato are quite variable in direction. However unfortunately, it is not possible at this stage to account for this variability in estimating deposition distribution. Instead, a fairly crude method used by McCrea (1984) is adopted, which provides an approximate estimate of deposition distribution for land on the prevailing upwind and downwind sides of the emission source.

The recordings for both stations on Figure 4 show that the stronger winds are predominantly from the west to south west and, while at Kopuku, there are a high proportion of light winds from the north east and east-north-east, these occur largely at night when ground source emissions should be fairly low. Hence, for the purposes of this study, the south-west side of emission sources shall be termed the 'upwind side' and the north-east side, the 'prevailing downwind side'. These are indicated on Figure 4.

FIGURE 4

Wind Rose Information for Waikato Meteorological Stations



Source: NZED Report no. PD-24 (1984)

McCrea (1984) combined and adapted data found by Handy et al (1976), Becker (1978), Ward et al (1979) and Hoover et al (1980) in previous studies, and estimated the deposition distribution of dust emissions away from unsealed roads. The resultant deposition figures are shown on Table 11, and reveal that:

- (1) 71 percent of all depositions fall on the prevailing downwind side of the emission source and that approximately;
 - 50 percent of these emissions are deposited within 70 metres of the source;
 - 90 percent within 400 metres of the source; and
 - 99 percent within 550 metres of the source.
- (2) Only 29 percent of total depositions fall on the prevailing upwind side of the emission source and that;
 - 50 percent are deposited within 30 metres of the source;
 - 90 percent within 200 metres of the source; and
 - 99 percent within 400 metres of the source.

TABLE 11

Percentage and Cumulative Percentage Depositions
of Road Dust Away from an Unsealed Road

Distance from Road (Metres)	T O T A L		D E P O S I T I O N	
	Downward Percentage	Upwind Percentage	Cumulative Downwind Percentage	Cumulative Upwind Percentage
0 - 10	13.4	9.1	13.4	9.1
10 - 20	7	3.5	20.4	12.6
20 - 30	4.9	2.7	25.3	15.3
30 - 40	3.7	1.7	29.0	17.0
40 - 50	3.3	1.5	32.3	18.5
50 - 60	2.6	1.0	34.9	19.5
60 - 70	2.2	0.8	37.1	20.3
70 - 80	1.8	0.7	38.9	21.0
80 - 90	1.7	0.6	40.6	21.6
90 - 100	1.5	0.6	42.7	22.2
100 - 150	6.5	2.0	48.6	24.2
150 - 200	5.0		50.6	
200 - 250	4.1		57.7	
250 - 300	3.1		60.8	
300 - 350	2.4		63.2	
350 - 400	2.4		65.6	
400 - 450	2.1		67.7	
450 - 500	1.8		69.5	
500 - 550	1.3		70.8	29
TOTAL	71%	29%	71%	29%

Source: McCrea (1984)

Although these distribution figures relate to emissions from a moving point source (i.e. an unsealed road) it is assumed that the distributive mechanisms away from the source point would be similar for a fixed point source (e.g. a coal stockpile).

In the road dust study, McCrea (1984) somewhat subjectively, chose the distances of 150 metres and 40 metres away from the emission source, as the average distances of significant effect to horticultural production, for the prevailing downwind and upwind sides respectively. However, for this study, these figures are increased by a factor of 2, in order to account for a number of related factors which may have some bearing on the deposition distribution. These include the factors that;

- (1) the source emission areas of the proposed power station are not as clearly defined as for single roadway emission sources;

- (2) the figures used by McCrea (1984), were based largely on American studies. However, during the construction of the Tongariro Power Station at Turangi, problems were experienced with pumice dust up to a kilometre away from the construction area. Hence it is wise to include an allowance for possible differences with New Zealand conditions; and
- (3) the areas surrounding the source areas at the power station, are likely to be more exposed than the area around unsealed roads, which would usually be bordered by fences and shelterbelts, especially in horticultural areas.

Hence, it is assumed that all significant depositions from ground source power station emissions will occur within 300 metres on the prevailing downwind side, and within 80 metres on the prevailing upwind side, of each source area. In addition, the prevailing downwind side of the proposed power station is defined as all those boundary areas excluding the Waikato River boundary. Conversely, the prevailing upwind side of station is taken to include only the area along the Waikato River boundary.

These definitions involve some broad simplifications and may cause some over-estimation of costs along some boundaries, but it is felt justified since;

- (1) there is so much uncertainty surrounding the distribution of dust and ash emissions;
- (2) the productive areas affected by dust and ash are likely to only be small anyway; and
- (3) it provides a 'worst case' scenario of possible costs.

Given these definitions, a further assumption is made that there will be no significant depositions of dust or ash on the prevailing upwind side of the power station (i.e. west of the Waikato River). This assumption is based largely on the fact that the majority of productive land on that side of the river will be further than 80 metres away from emission sources and in addition, the land in this area is generally of poor land use capability.

CHAPTER 6

POWER STATION SITE OPTION SCENARIO'S

6.1 Introduction

Both of the preferred site options for the proposed power station are situated amongst productive rural land, which is fairly variable in terms of land use capability¹⁴. Traditionally, farming in both areas has been predominantly dairying with intensive sheep, mixed livestock and beef cattle being of lesser importance. Horticulture is of some importance with the main concentrated area consisting of 280 hectares to the north-east of the Rangiriri site, around Te Kauwhata, with other individual horticultural properties scattered around the proximity of the two site options.

The impact of the proposed power station on horticultural production will depend largely on the site selected, the development of horticulture in the area and also on the methods chosen for coal transport, ash disposal and dust abatement.

Any problems encountered from dust emissions from the proposed power station activities will likely be mainly to the north and east of the sites since the prevailing wind in the area is from the west to south-west and further, the south-west boundaries of both sites are predominantly bounded by the Waikato River.

6.2 Rangiriri Site

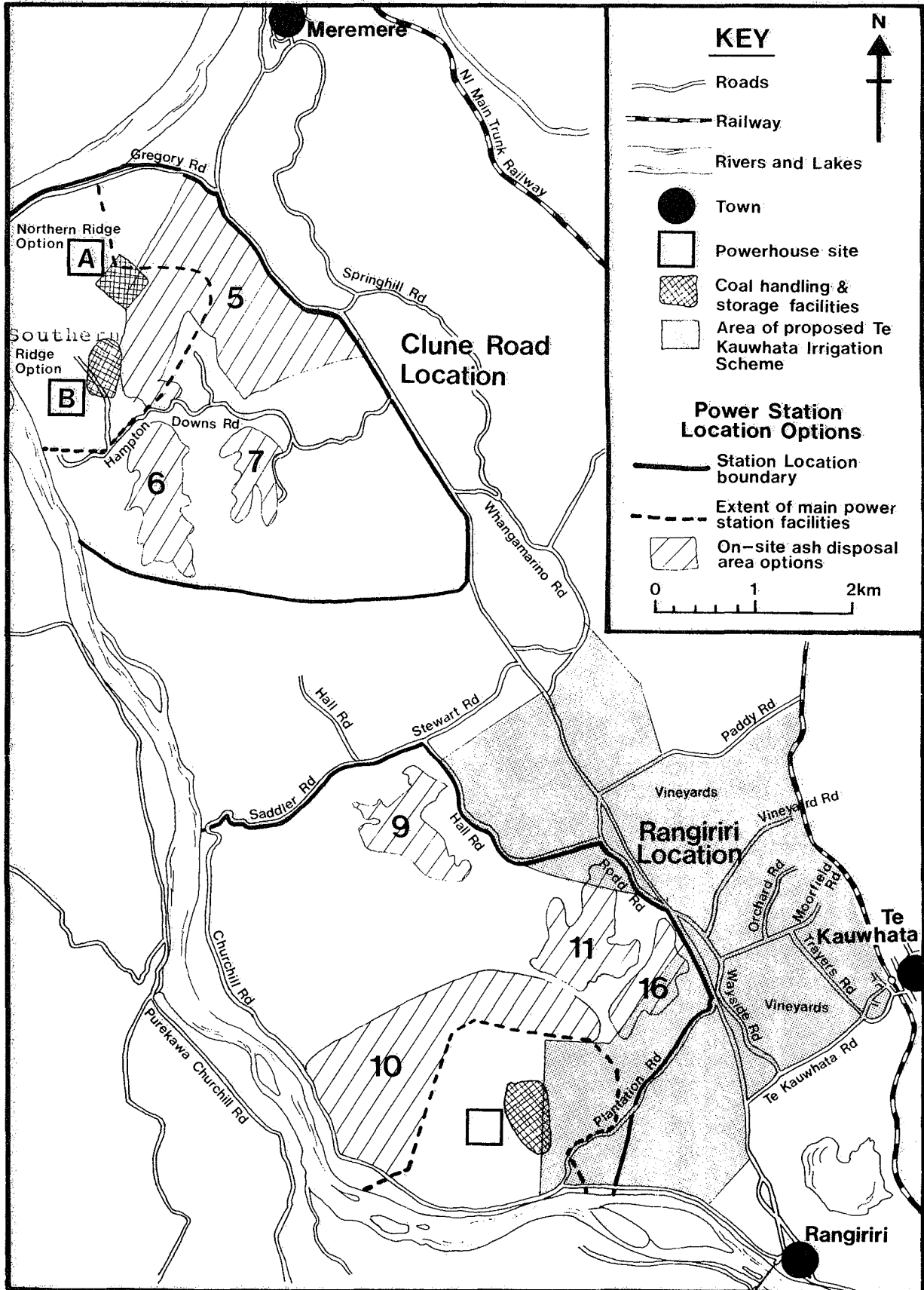
The site layout for the Rangiriri site option presented in Figure 5 shows the area of main facilities, the locations of proposed ash dump sites and also the extent of the proposed Te Kauwhata irrigation scheme. There is presently quite a lot of horticultural production around the eastern surrounds of the site and the proposed Te Kauwhata irrigation scheme will undoubtedly enhance further development of horticulture in this locality.

The Te Kauwhata irrigation scheme consists of 694 irrigable hectares of which 271 hectares are currently being used for horticulture and a further 180 hectares are expected to shift into horticulture over the next 10 years (Wilson, 1983). Thus the total expected area of irrigable land represents 65 per cent of the total irrigable land.

14 The term 'land use capability' is used to define an assessment of the land's present capacity to sustain productive use. Limitations to use increase from Class I through to a maximum in Class VIII. The classifications used do not represent land use, either present, potential or recommended; just the general limitations for pastoral, cropping and forestry use.

FIGURE 5

Power Station Location Options



A map of land use capability classes for the area (Figure 6) indicated that much of the land to the north of main power facilities and ash disposal site number 10 is comprised of Class II land which is quite good for horticultural production and similarly, for much of the land to the south east of the main facilities area. The land to the north east of ash disposal site numbers 9, 11 and 16 is predominantly of Class III and IV land which has a number of limitations, but is capable of supporting some horticultural production.

6.3 Clune Road Site

The layout of the area of main facilities and the proposed ash disposal site options are presented on Figure 5, with the land use capability classes for the locality shown on Figure 6. Overall, the land around the Clune Road location is not a suitable for horticulture as that around the Rangiriri location; nor does it have the imminence of an irrigation scheme.

However, there is one large belt of Class II land which adjoins the area of main facilities, ash disposal site number 5 and is in close proximity to ash disposal site number 7. There has been some horticultural development on this land already, with the potential for a substantial further amount. Apart from this belt, virtually all of the remainder of the land around the site is Class III, IV and VI which would be largely unsuitable for horticulture without irrigation.

6.4 Estimates of Future Horticultural Production

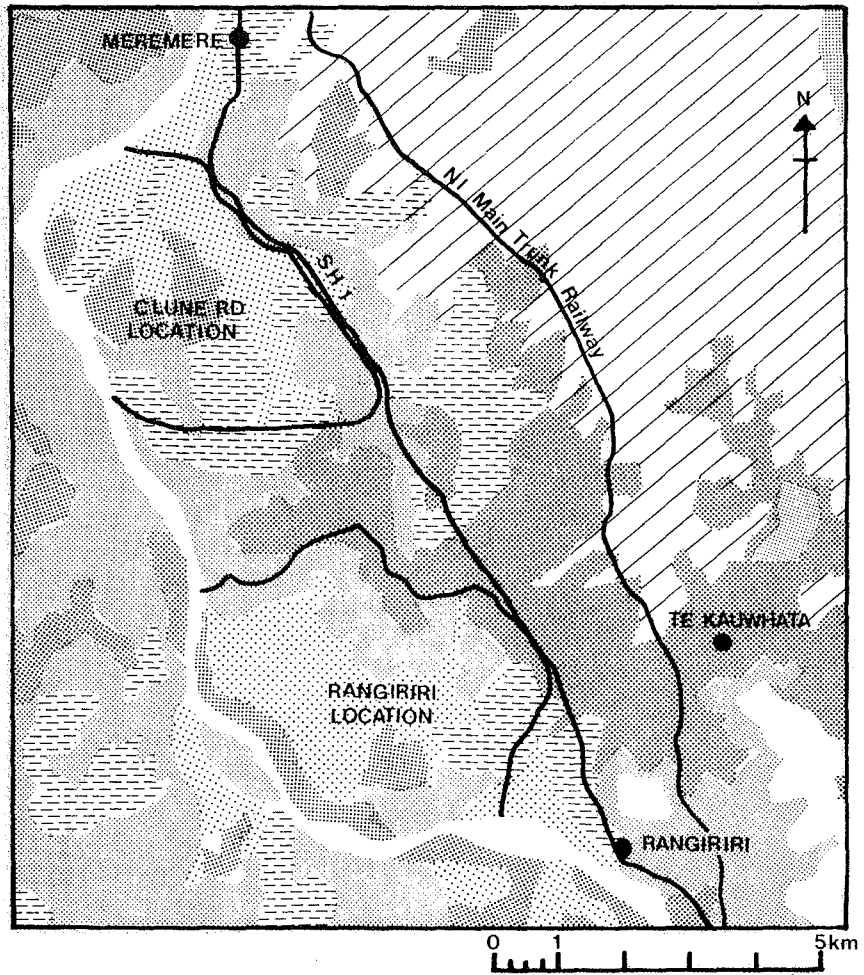
Some approximate estimates of the likely percentage areas which may become involved in horticulture production were calculated with respect to present horticultural development patterns, the location of the proposed Te Kauwhata irrigation scheme and also, the land use capability of the areas around both the site location options. In addition, an allowance was made for the fact that approximately 20 percent of land on horticultural enterprises is non-productive due to space required for buildings, access tracks, shelterbelts, etc. Based on these premises, the following assumptions of productive horticultural land use were derived;

- i) that 52 percent of the land within the bounds of the proposed Te Kauwhata irrigation scheme will involve horticultural production;
- ii) that 40 percent of non-irrigated Class II land will involve horticultural production;
- iii) that 16 percent of non-irrigated Class III land will involve horticultural production; and
- iv) that negligible horticultural production will occur on all lower classes of non-irrigated land.

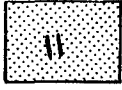
The results of these estimates are illustrated on Figure 7 and are necessarily very subjective, since the development of horticulture in the area will depend on a large number of external factors which cannot easily be predicted. However they do serve to allow some quantitative estimate of the potential costs to horticultural production from various power station activities. These estimates are outlined in the following chapter.

FIGURE 6

Land Use Capability Classes



Legend to Accompany Figure 6
Land Use Capability Classes



Slight limitations to arable use (usually wetness; unsuitable soil texture and/or depth). Generally alluvial soil on flat or undulating land. Erosion risk may be slight to moderate.



Moderate limitations to arable use may restrict choice of crops (limitations include erosion; slope; low soil fertility; shallowness and poor drainage of soils; salinity; climatic factors). Undulating to rolling land. Moderate to high erosion risk under certain circumstances.



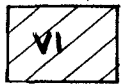
Severe limitations to arable use (commonly erosion; shallow, stony or low fertility soils; wetness; climatic factors associated with altitude). Undulating to strongly rolling country. High susceptibility to erosion.



Generally restricted to pastoral use or productive forestry. Only slight erosion hazard under those uses. Includes land too steep for cultivation and flat to gently undulating land with limitations such as stoniness, rockiness and/or wetness.

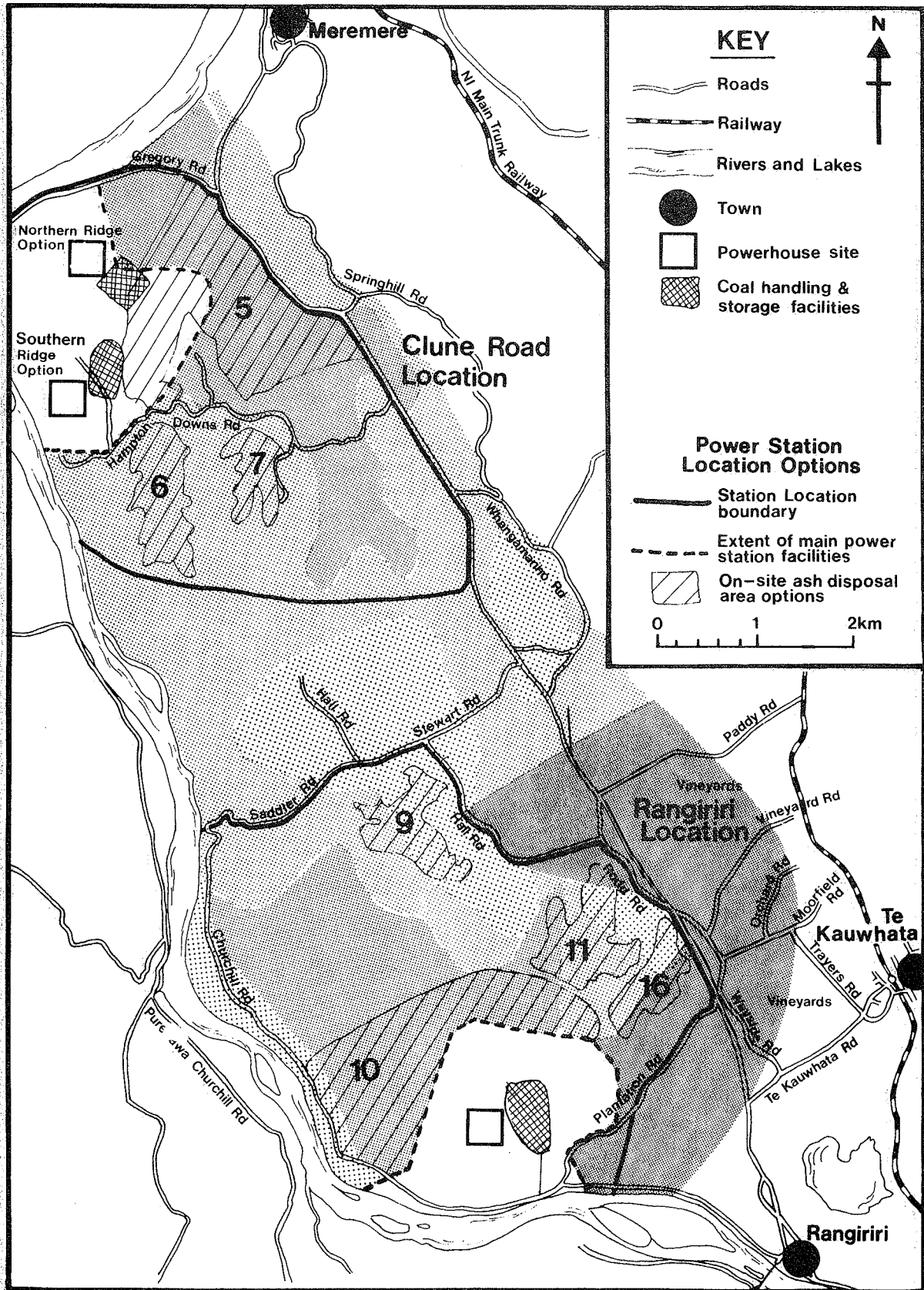


Non-arable land with moderate limitations under a perennial vegetation cover (mainly erosion and soil limitations other than wetness and climate). Stable, hill country; also stony and shallow soil on fans and terraces.



Non-arable land with severe limitations under a perennial vegetation (mainly erosion; soils; wetness; climatic factors). Steep, erodible hill country; also some stony, shallow, low fertility soils on fans and terraces.

ESTIMATES OF PERCENTAGE AREAS
 OF LAND SURROUNDING THE POWER STATION SITE OPTIONS WHICH
 MAY BE INVOLVED IN HORTICULTURAL PRODUCTION



52%
 40%
 16%
 Negligible

CHAPTER 7

ESTIMATION OF HORTICULTURAL PRODUCTION LOSSES AND COSTS DUE TO POWER STATION EMISSIONS

Economic losses may be incurred by horticulturalists situated in the vicinity of the proposed power station, due to both yield depression and downgrading of crops caused by dust and ash depositions.

The losses caused by chimney emissions are likely to comprise very small percentage yield losses spread over a wide area, whereas the ground source emissions will probably cause higher percentage levels of loss, but only over very small areas of productive land.

Because these two emission types vary so greatly, both in their levels of effect and methods of estimation, they are treated separately in this analysis.

7.1 Chimney Emission Losses

The major pollutant contained in chimney emissions which may cause yield depression to horticultural crops is sulphur dioxide. Nitrogen dioxide may cause some additional problems but it is likely that the significance of these levels will be so low that production effects will be negligible.

The expected areas and levels of ground concentrations of sulphur dioxide on areas surrounding the power station locations were stated in Chapter 6, and the predicted percentage yield losses due to varying levels of sulphur dioxide concentration were tabled in Chapter 2. A summary of the relevant parts of these sections to the estimation of costs to horticultural production from chimney discharges, are contained in Table 12.

TABLE 12
Estimates of Sulphur Dioxide Effects
from Chimney Emissions

Mean SO ₂ Concentration Level (ug/m ³)	Total Area of Land Affected (ha)	% Yield Loss
0.75	17400	0.007
1.25	2750	0.015
1.75	750	0.025
2.25	125	0.040
2.75	15	0.055

The estimation of costs due to sulphur dioxide emissions from the power station chimney can only be a very illustrative guide at this stage, since it was not practicable, nor economically desirable to collect detailed data related to horticultural production in the region. Instead a number of broad assumptions are used to provide at least a 'ballpark' estimate of cost. These assumptions include;

- (1) that only 20 percent of the total area of land affected by sulphur dioxide would be involved in horticultural production (in reality, it would probably be much less than this, but this figure partly allows for the fact that the area modelled does not include the total area affected);
- (2) the average level of gross income for all horticultural production in the region is \$20,000.00 per hectare; and
- (3) all estimates of percentage yield loss due to sulphur dioxide pollution are calculated directly from the gross income figure.

Using these assumptions and applying the expected levels of yield loss to the figures for gross income and the estimated area of horticultural land affected by sulphur dioxide, the total cost to horticulture from chimney emissions was calculated. This was estimated to be around \$7,500.00 per annum and, assuming a 30 year life span for the power station, this figure shows a net present value cost of \$77,772.00, using the Treasury discount rate of 10 percent. Hence, in terms of both the overall costs involved in the power station decision making process, and also the large area over which the sulphur dioxide costs are spread, these cost figures appear to be relatively low.

7.2 Ground Source Emission Losses

It is impossible to predict exactly what horticultural crops will be grown in the areas surrounding the two power station site location options in the future. However, there is already a considerable quantity of grapes being grown by Cooks New Zealand Limited around Te Kauwhata and a large number of kiwifruit vines being planted in the region. Also, Wilson (1983) has assumed that all future horticultural developments within the bounds of the proposed Te Kauwhata irrigation scheme will be in kiwifruit.

Thus, for the calculations used in this report, it is assumed that;

- (1) all horticultural production in the affected localities, except for the Te Kauwhata area (on the north-eastern boundary of the Rangiriri site), comprises totally of kiwifruit orchards; and
- (2) that around Te Kauwhata, half of the horticultural area is planted in grapes and half in kiwifruit.

In addition, it is assumed that kiwifruit will be susceptible to costs from both yield losses and downgrading, whereas grapes being grown for wine will suffer only yield loss costs.

7.2.1. Identification of Major Causes of Costs

The severity of different types of causes of loss varies for different crop types, depending largely upon the types of leaf and fruit surface, the pollination method and the product end use. However generally, the major causes of revenue loss for inert dusts as identified by McCrea (1984), include;

- (1) photosynthetic yield loss;
- (2) downgrading due to dust on fruit;
- (3) poor pollination; and
- (4) increased incidence of pests, disease and weeds.

In addition, for coal and ash depositions there may be further losses caused by toxicity through plant leaf surfaces.

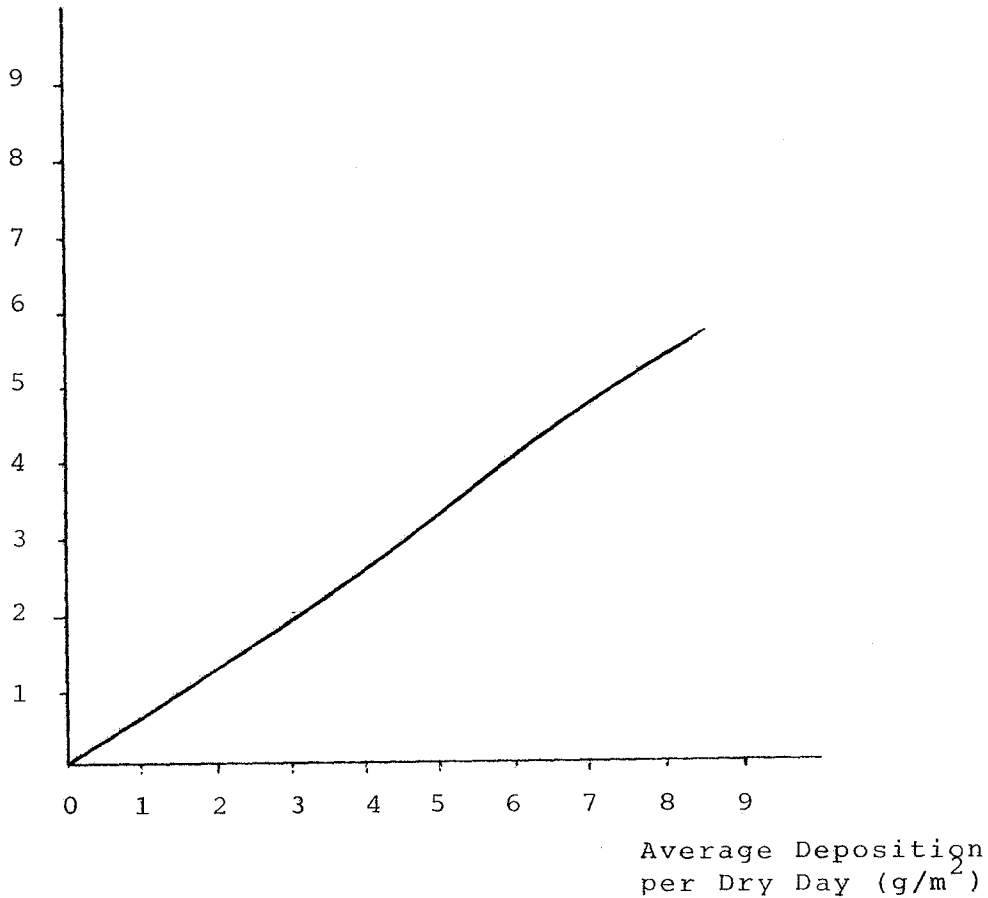
Unfortunately, apart from photosynthetic yield loss, there is no available data relating production losses to the relatively low levels of dust and ash cover, which will probably be experienced around the vicinity of the power station. Manipulation of McCrea's (1984)

findings on the effect of road dust cover on plant leaf surfaces, on plant photosynthesis levels in Waikato County, shows that there is a linear relationship between the average dry daily level of dust deposition onto plant leaf surfaces and the annual percentage level of photosynthetic yield loss. This is illustrated on Figure 8.

FIGURE 8

Average Annual Percentage Photosynthetic Yield
Loss Due to Dust and Ash Cover

Average Annual
Percentage Loss



Source: McCrea (1984)

In the absence of any relevant data, McCrea (1984) used arbitrary estimates of 1.0 and 0.5 annual percentage loss, for high and low estimates of all other types of predicted loss due to road dust.

However, it is probable that any ground source emissions from the Waikato power station will be very localised and possibly more intense than the emissions from unsealed public roads. Thus for this

study, for all emission sources other than major earthworks the figures of 2.0 and 1.0 annual percentage loss are used as the arbitrary estimates for high and low levels of loss. For major earthworks, where emission levels are expected to be much higher than for other activities, the figures of 3.0 and 1.5 percent (annually) are used as estimates of loss. In view of the fact that the overall costs to horticultural production are not likely to be very high, especially in terms of other economic factors related to power station siting considerations, these estimates seem reasonable, since they provide a 'worst case' scenario of costs.

In addition, because it is almost impossible to isolate the direction, distribution and intensity of dust and ash emissions from the power station, the same annual loss levels chosen for all other causes of economic cost to growers, are used for photosynthetic yield loss. The use of these figures, simplifies the assumptions needed, brings the estimates for these losses 'into line' with the other identified causes of production losses and in any case, they appear to be at least in the 'ballpark' of what the author would expect the losses to be (ie. relating to an average dry daily deposition level of from 1.0 - 3.0 g/m - Figure 8).

Given the arbitrary estimates of percentage loss for each major type of effect, viz;

(1) For earthwork activities

- High = 3.0 percent annual loss
- Low = 1.5 percent annual loss
- Nil = 0.0 percent annual loss; and

(2) For all other ground-source emission activities

- High = 2.0 percent annual loss
- Low = 1.0 percent annual loss
- Nil = 0.0 percent annual loss,

the expected levels of loss can be estimated for both kiwifruit and grapes, with respect to their relevant growth, production and end-use characteristics. These are set out in Table 13.

TABLE 13
Estimates of Intensity of Dust and Ash Related
Effects Influencing Production Returns

Effect	Kiwifruit		Grapes	
	Coal/Ash	Inert Dust	Coal/Ash	Inert Dust
Photosynthetic Yield Loss	High	High	High	High
Dust on fruit	High	High	Nil	Nil
Poor Pollination	High	High	Nil	Nil
Pest and Disease	Low	Low	Low	Low
Toxicity through leaves	High	Nil	High	Nil

7.2.2. Production and Price Parameters

All calculations conducted in this study are based on the figures for mature orchards and vineyards, since it is not feasible to predict the age structure of plants for any one time or location. This method may overstate costs to some extent but should not be too bad since some production effects are likely to be cumulative from year to year (eg. toxicity, pest and disease and photosynthetic loss effects). Also, it provides an estimate of what the highest levels of cost may be.

All costs and prices used are averages for the 1983-84 production season, stated from the national point of view. The resultant production and price parameters for kiwifruit and grapes are set out in Table 14.

TABLE 14
Production and Price Parameters for
Kiwifruit and Grape Production

=====

(1) Kiwifruit

Yield -	-	21 tonnes/ha
Average weighted price*	-	\$1634/tonne (all grades)
Price - export grade	-	\$1890/tonne
Price - process grade	-	\$ 523/tonne
Average weighted costs (that vary with yield)	-	\$ 879/tonne
Costs - export grade	-	\$1018/tonne
Costs - process grade	-	\$ 303/tonne

(2) Grapes

Yield -	-	16 tonnes/ha
Average price	-	\$ 430/tonne
Average costs	-	\$ 65/tonne

* Average weighted price reflects the overall average price for all grades of Kiwifruit.

=====

Source: Ministry of Agriculture and Fisheries

Given the above production and price parameters and the estimates of dust effect, it is simple enough to calculate the per hectare costs to both kiwifruit and grape production from dust or ash cover¹⁵. These are;

15 Yield loss costs are calculated in the following manner;

$$\text{Yield loss} = (\text{Average wted} - \text{Average wted}) * (\text{Yield/ha}) * (\text{Percentage})$$

$$\text{Costs } (\$/\text{ha}) \quad (\text{Price } (\$/\text{t}) \quad \text{Costs } (\$/\text{t})) \quad (\text{Loss})$$

Downgrading costs are found by the equation;

$$\text{Downgrading} = (\text{Price Premium} - \text{Price Low}) * (\text{Costs Premium} - \text{Costs Low})$$

$$\text{Costs } (\$/\text{ha}) \quad (\text{grade } (\$/\text{t}) \quad \text{grade } (\$/\text{t})) \quad (\text{grade } (\$/\text{t}) \quad \text{grade } (\$/\text{t}))$$

* (Yield/ha) * (percentage downgraded)

(1) Kiwifruit

a) For coal dust or ash deposits

i) Earthwork activities
Costs = \$2073.00/ha/annum

ii) All other activities
Costs = \$1382.00/ha/annum.

b) i) For inert dust deposits
Costs = \$1598.00/ha/annum

ii) All other activities
Costs = \$1065.00/ha/annum

(2) Grapes

a) For coal dust and ash deposits

i) Earthworks activities
Costs = \$438.00/ha/annum

ii) All other activities
Costs = \$292.00/ha/annum

b) For inert dust deposits

i) Earthworks activities
Costs = \$262.00/ha/annum

ii) All other activities
Costs = \$175.00/ha/annum.

7.2.3. Total Costs to Horticultural Production From Each Ground Source of Dust and Ash

The total level of costs from dust and ash emissions will depend largely on the methods and sites chosen for power station activities and also upon the amount of surrounding productive land which is acquired by the Ministry of Energy for use as a buffer zone. Hence, since these options have not yet been finally decided, the accurate prediction of costs to production from future power station operations is made even more difficult. To partly overcome this problem, the costs of emissions from each potential source are assessed here separately, so that the figures can be manipulated to find the level of total costs, for different combinations of power station operation.

The areas of productive land which may be affected by ground source dust or ash emissions, have been calculated for each potential source area by using the assumptions of 300 metre and 80 metre distances of effect for the prevailing downward and upwind sides respectively; and by incorporating some tentative Ministry of Energy predictions for areas of land purchase, for each site activity option¹⁶. In order to calculate the costs to production from each dust source, the estimated percentage areas of land which may be involved in horticultural production (shown on Figure 7) were used to estimate the total area of horticultural production likely to be affected by any particular dust source; these were then multiplied by the relevant per hectare costs calculated in the previous section.

The relevant predicted areas of effect and the resultant costs to production for each dust source are outlined below. These costs are provided both as an annual amount, and also as a net present value cost, discounted to the date of station commissioning; and expressed in terms of 1985 dollars.

(A) Clune Road Site

1) Major Earthworks and Construction

If it is assumed that most major earthworks and construction activities at the power station will occur within the area of main facilities and further, that ash disposal site number 5 is not selected, then approximately 20 hectares of productive horticultural land could be affected by these emissions. Applying the levels of effect due to dust deposition stated earlier, the following annual costs could result during the first three years of the construction phase;

- (i) a cost of \$31,960 for the first year in which most major earthworks would occur; and
- (ii) a cost of \$21,300 per annum for the following two years, when it is predicted (Willis, pers. comm., 1985) that most major dust causing construction activities would have occurred.

16

Because the areas of land purchase are still very much uncertain, the Ministry of Energy have requested that these remain confidential for the time being and hence, are not explicitly included in this report.

17

The Environmental Impact Report for the proposed power station (MOE, 1984) reports unfavourably on the use of ash disposal site area number 5 for a variety of reasons.

Compounding these costs forward at the Treasury discount rate of 10 percent to the year of station commissioning, yields a total net present value cost of \$144,350.

In the unlikely event that ash disposal site number 5 is selected, then the production cost caused by construction dust would be eliminated, since virtually all of the dust would be deposited on the land purchased for the ash disposal area.

2) Ash Disposal Site Numbers 5 or 7

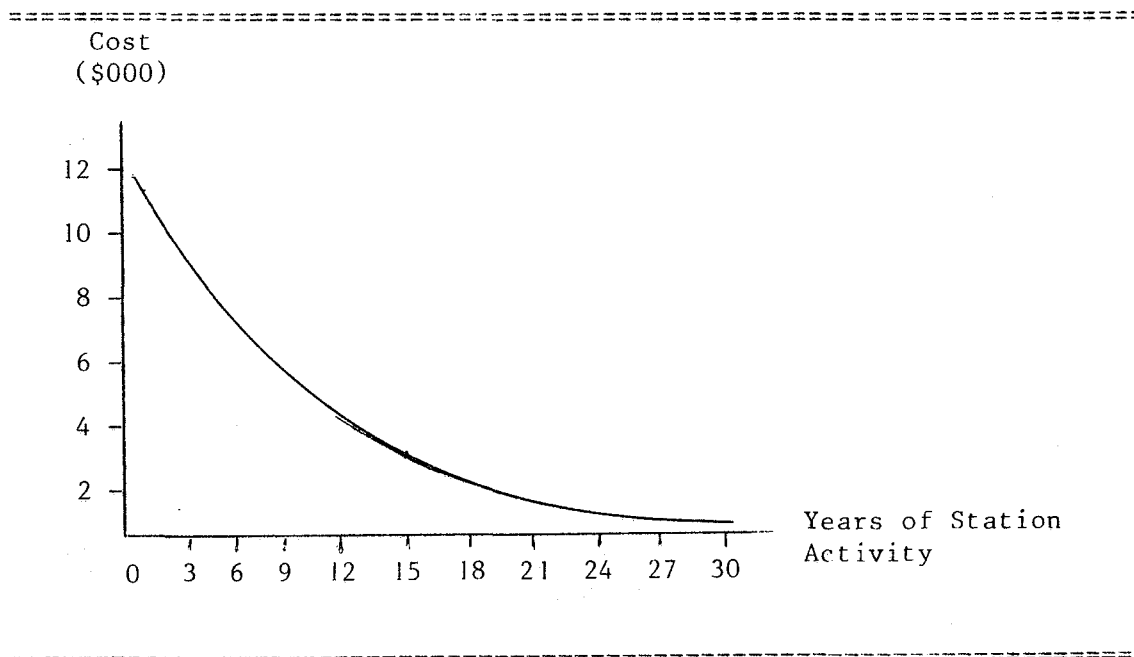
The choice of either ash disposal site number 5 or number 7 could possibly cause problems of ash deposition on about three hectares of productive horticultural land. However, only about 10 hectares of a dry ash disposal site will be uncovered at any one time and hence, the horticultural land will probably only be affected by ash emissions for a maximum period of around three years.

If it is assumed that the total three hectares are affected during each year of these problem emissions, and the earlier assumptions for price, yield and level of effect are used, then the costs to horticultural production from either of these dry ash sites are estimated to be around \$4,146 per annum. Applying the Treasury discount rate, this would represent a net present value cost to production from as high as \$11,341, if the problem area of the dump site was used during the first three years of station operation, down to a net present value cost of \$864, if the area is used during the final three years of station operation. These net present value costs are illustrated on Figure 9.

FIGURE 9

Possible Net Present Value Costs for Emissions

From Either of Dry Ash Disposal Site Numbers 5 or 7



3) Ash Disposal Site Number 6

It is anticipated that ash emissions from an ash dump at site number 6 would cause no problems to horticultural production since it is surrounded by non-horticultural land.

4) Coal Handling and Storage

If the northern ridge option for the power station site at Clune Road is chosen, then around three hectares of productive land may be affected by coal dust emissions caused by operations at the proposed coal stockpile area; and only if ash disposal site number 5 is not chosen. These emissions could cause a cost to production of approximately \$4,146 per annum, with a net present value cost of \$42,992.

Conversely, if the southern ridge site option is chosen then the coal stockpile emissions should cause no problems to horticultural production.

(B) Rangiriri Site

1) Major Earthworks and Construction

The magnitude of costs to production from dust causing activities during the earthworks and construction phase of a power station sited at the Rangiriri location, is highly dependent on which ash disposal site is chosen, since the land purchased for either of site numbers 10, 11 and 16 will be directly adjacent to the area of main power station facilities. For this reason, the costs relative to each ash site option are calculated separately below:

- a) Site numbers 9 or 11 selected. Approximately 18 hectares of horticultural land could be affected by dust from construction activities if either of dust disposal site numbers 9 or 11 are selected. Either of these could result in the following annual costs;

- (i) \$26,092 for the first year of major earthworks;
and
- (ii) \$17,390 for the following two years of major
construction activities.

Compounding these costs to the station commissioning date yields a total net present value cost of \$120,650

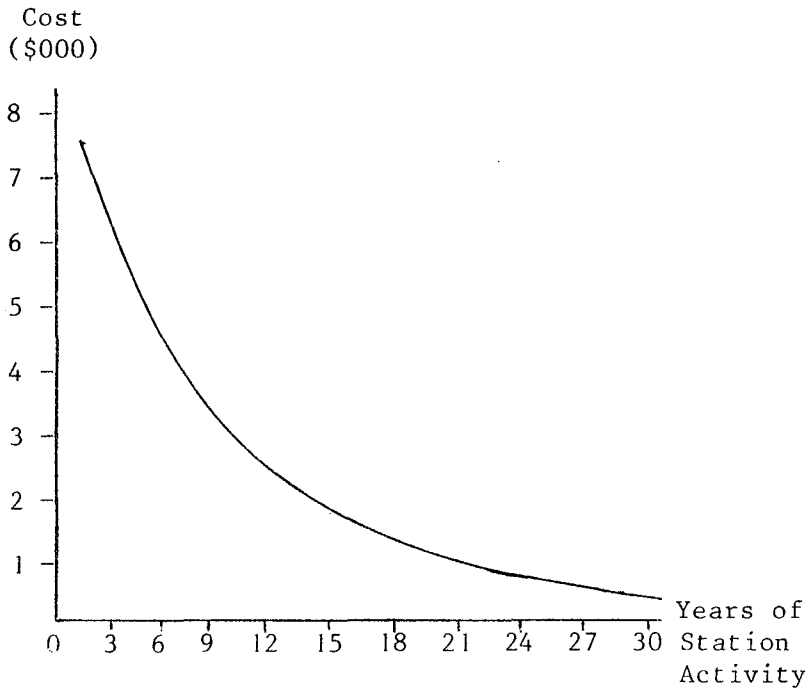
- b) Site number 10 selected. Only about four hectares of productive land are likely to be affected by the construction dust emissions if ash disposal site number 10 is chosen. This may result in the following annual costs;
 - (i) \$3,720 for the first year; and
 - (ii) \$2,480 for each of the following two years. These costs would result in a net present value cost of \$17,203.
- c) Site number 16 selected. Approximately 14 hectares of productive horticultural land are likely to be affected if disposal site number 16 is selected. This may result in the following costs;
 - (i) \$22,372 for the first year of major earthworks;
and
 - (ii) \$14,910 for each of the following two years of major construction. These costs would result in a net present value cost of \$103,445.

2) Ash Deposit Site Numbers 9 or 11

Any ash dumping at either of site numbers 9 or 11, is likely to affect a maximum of only about two hectares of productive land, over a total period of approximately three years. The annual cost of this would be about \$2764 for each of the three years with a net present value cost ranging from \$7,561 is used in the first three years of the power station's estimated 30 years of operation, to \$577 if used in the the final three years of operation. These net present value costs are illustrated on Figure 10.

FIGURE 10

Possible Net Present Value Costs for Emissions From Either Of
Dry Ash Disposal Site Numbers 9 or 11



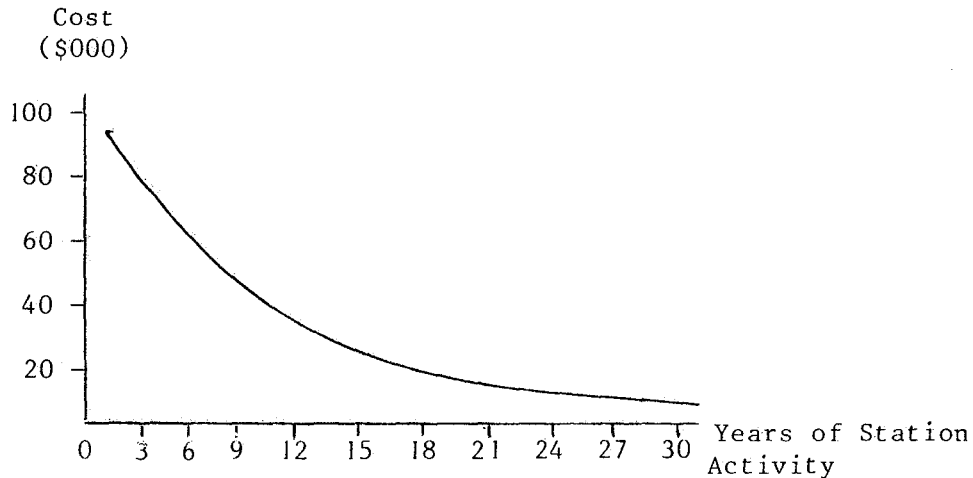
3) Ash Disposal Site Number 10

Approximately 25 hectares of productive land may be affected by dust if disposal site number 10 is selected.

This would result in an annual cost for an estimated three years of effect of \$34,550 per annum, with a net present value cost ranging from \$94,913 to \$7,209. These net present value costs are illustrated on Figure 11.

FIGURE 11

Possible Net Present Value Costs for Emissions From
Dry Ash Disposal at Site Number 10



4) Ash Disposal Site Number 16

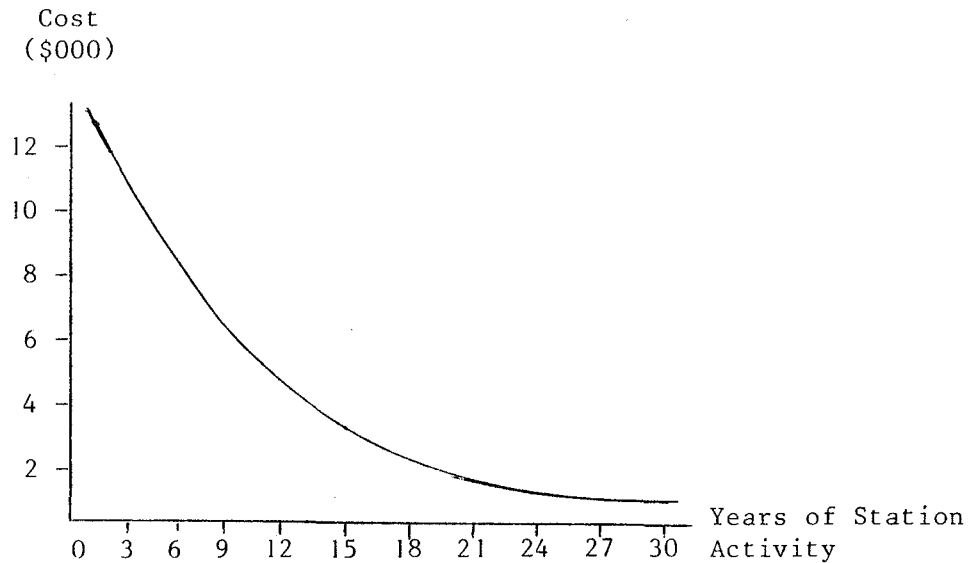
Ash dumping activities at disposal site number 16 are likely to affect about four hectares of productive land at an annual cost of \$4,610 for each of the three years of effect. The resultant net present value costs (shown on Figure 12) range from \$12,610 to \$962.

5) Coal Handling and Storage

It is estimated that all emissions from the handling and storage of coal at the coal stockpile site at Rangiriri, will be deposited well within the site boundary; hence dust from this source will not be a cause of production cost.

FIGURE 12

Possible Net Present Value Costs for Emissions From
Dry Ash Disposal at Site Number 16



7.2.4. Conclusions

Although the actual level of fugitive emissions from activities related to the proposed power station may be high at times, it is likely that there will only be limited effects from the emissions on horticultural production in the area. Theoretically, there may be some yield depression caused by chimney emissions but in practice, the levels of sulphur dioxide will be so low, and there will be so many other variables acting upon crops that it will be almost impossible to directly attribute any yield losses to the sulphur dioxide emissions from the Waikato Power Station.

The various sources of ground level emissions will probably cause some problems at isolated areas around the station, but these will depend largely on the efficiency of control techniques and a number of climatic factors (ie wind and rain).

TABLE 15

Costs to Horticulture from Power Station Emission

Source	Annual Cost (\$)	No. Years of Emissions	TOTAL N.P.V. COSTS (\$)		
			High Estimate	Mean Estimate	Low Estimate
(1) CLUNE ROAD SITE					
Earthworks and Major Construction (Only if ash site No. 5 is not selected)	31960 21300	1) 2)	-	144350	-
Ash Site No 5 or 7	4146	3	11341	2986	864
Ash Site No 6	Nil	3	-	Nil	-
Coal Handling & Storage (Only if northern ridge is selected and ash site no 5 is not)	4146	30	-	42992	-
Chimney	7500	30	-	77772	-
(2) RANGIRIRI SITE					
Earthworks and Major Construction					
a) Ash Site No's 9 or 11 selected)E 26092)C 17392	1) 2)	-	120650	-
b) Ash Site No. 10 selected)E 3720)C 2480	1) 2)	-	17203	-
c) Ash Site No. 16 selected)E 22373)C 14910	1) 2)	-	103445	-
Ash Site No's 9 or 11	2764	3	7561	1991	576
Ash Site No. 10	34550	3	94913	24888	7209
Ash Site No. 16	4610	3	12610	3321	962
Coal Handling & Storage	Nil	30	-	Nil	-
Chimney	7500	30	-	77772	-

KEY: E = Earthworks
C = Major Construction

The costs assessed in this chapter have necessarily been calculated rather subjectively, and are based on a number of arbitrary assumptions. However, in view of the difficulty and benefit-cost of gaining any more reliable data, they can be used as a 'best estimate' of cost for the purposes of site appraisal; especially since similar assumptions have been retained for each site option. Hence, although the estimates may not be particularly accurate, they are fairly unbiased and should give at least an idea of the possible magnitude of costs to horticultural production from the power station emissions.

A breakdown of the possible costs to horticultural production, which may be incurred from different activities and site options at the proposed power station is presented in Table 15. In addition, the average total net present value costs which may occur due to dust generating activities, with respect to the dry ash disposal site selected, are set out on Table 16.

TABLE 16

Costs From All Dust Generating Activities Given Ash

Disposal Site Selected

Ash Disposal Site No.	Total Average Net Cost Present Value (\$)
<u>Clune Road</u>	
5	80758
6	265114
7	268100
<u>Rangiriri</u>	
9	200413
10	119863
11	200413
16	184538

-
- 18 No sensitivity ranging has been conducted on the costs estimated in this report, since most calculations have been based on such subjective and arbitrary assumptions that it would be very difficult to provide a confident estimate of the range of sensitivity of costs, resulting from the lack of suitable data and measurement errors. Instead, the author suggests that rather crude 'back of the envelope' methods, of doubling and halving the costs estimated, may serve as the best possible indicator of cost sensitivity.

Table 16 implies that by considering only the costs of horticultural losses due to dust emissions, that the Clune Road location option using;

- 1) dry ash disposal site number 5; and
- 2) dry ash disposal site number 7

would provide the overall most optimal and least optimal site choices respectively. However these factors need to be balanced against other factors (eg. land use, capacity etc) which are probably of greater economic consequence in the site selection process.

CHAPTER 8

EMISSION CONTROL METHODS

A number of control methods for dust and ash emissions are planned for the proposed power station. These include the use of;

- (1) precipitators and a 150 metre high chimney for the control of chimney emissions;
- (2) water carts for suppressing dust on haul roads and some areas of exposed ground;
- (3) water conditioning of dry ash for disposal; and
- (4) enclosing conveyors and crushers and the use of anti-dust sprays within the crusher enclosures.

However, even with these measures, there may still be problems encountered with ground source dust emissions drifting onto horticultural land. This chapter briefly explains some of the methods of control which are available and their applicability to the various operations which may be conducted at the power station.

8.1 Major Dust Control Techniques

(The information contained in this section is drawn largely from the findings of PEDCO (1980)).

Almost all of the dust control methods which have been identified are applications of one or a combination of three basic techniques; watering, chemical stabilization, and reduction of surface wind speed across exposed sources. An outline of these techniques is set out below.

8.1.1. Watering

Watering generally requires a low first cost, but it also provides the most temporary dust control. Depending on the nature of the dust-producing activity, water may be an effective dust suppressant for only a few hours or for several days. In addition to the direct cohesive force of a film of moisture in holding surface particles together, watering is also effective in forming a thin surface crust that is more compact and mechanically stable than the material below and is less subject to dusting even after drying. However, this crust and its dust-reducing capability are easily destroyed by movement over the surface or by abrasion from loose particles blown across the surface. Therefore, watering must be repeated frequently to reform the moisture film or surface crust.

8.1.2. Chemical Stabilisation

Several types of chemicals have been found effective in reducing dust emissions when applied on fugitive dust sources. These chemicals utilize different properties for dust suppression and are generally categorized by their composition; bituminous, polymer, latex, resin, enzymatic, emulsion, surface-active agent, ligninsulfonate, etc. Many of these are by-products or wastes from the production of other materials.

Available commercial products offer a wide range of characteristics making it possible to select a chemical stabilizer with maximum efficiency for each dust control application. Some of the materials "heal" if the treated surface is disturbed, but many do not reform. The life of the treated surface under natural weathering also varies widely with different chemicals. Selection of the appropriate material may require that several other criteria be checked for compatibility, including effect on vegetative germination and growth, method of application, possible contamination of material being protected from dusting, and correct chemical for the texture of a specific soil or material.

Unfortunately, no single comprehensive summary of dust suppressant chemicals and their properties is available, although several evaluations have been prepared for different chemicals on a single type of fugitive dust source (eg. Hoover et. al. (1981)).

8.1.3. Reduction of Wind Speed

Wind can contribute significantly to all of the ground sources of dust, both by the erosion of the exposed surfaces of storage areas and bare ground, and by direct transport of the dust generated by other power station operations. Therefore, reduction of wind surface speed across the source is a logical means of reducing emissions. This takes such diverse forms as windbreaks, enclosures or coverings for the sources, furrowing of smooth surfaces, and planting of tall grasses or grains on or adjacent to exposed surfaces. The vegetative techniques all need a soil that supports growth; one containing nutrients, moisture, proper texture and no phytotoxicants. These requirements often cannot be met around coal-fired power station areas; therefore natural protection against wind erosion is not always achievable.

8.2 Control Methods for Unsealed Roads

There are a number of methods available for the control of emissions from unsealed roads at the site. These include:

8.2.1. Watering

Spraying of unsealed roads by water cart is the proposed method of dust control for the station's haul roads. Obviously the effectiveness of this method will depend on the frequency and quantity of water applications, the traffic volume and the climate.

Previous studies have shown that on average, water control is about 65 percent effective in reducing dust emissions (Dyck and Stuckel, 1976), but if applications are rigorously applied during dry periods, then much more effective levels of control should be achievable.

An alternative method of water application for unsealed roads which are envisaged to be relatively permanent, is by a fixed pipeline spray system. This would have a higher initial cost than the water cart method but would have the advantages of reduced on-going costs and ease of operation.

8.2.2 Chemical Stabilisation

Various chemicals may be added to the water or applied separately to the haul road surface to improve binding and reduce dusting. Application of a surface chemical treatment to suppress dust from haul roads is a relatively inexpensive control method. However, tests on public roads (conducted in the United States) have failed to uncover any commercial material that retains its effectiveness over a reasonable period of time, ie, two months under traffic conditions. Most of the treated surfaces abrade badly to the depth of penetration of the chemical (an important factor when considering the combined weight of the vehicles and loads trucking over the power station roads); others maintain a stabilized surface with traffic but are water-soluble and lose their effectiveness after rain. Several surface-treatment chemicals are presently under development or are being tested and technology for this method is likely to increase greatly within the next few years.

A few successful special applications of surface treatment have been found. On non-traffic surfaces such as roadway shoulders, chemical soil stabilization has proven highly effective in reducing the dust produced by air turbulence from passing vehicles; however, this type of control would not be very effective for haul road berm stabilization because these berms are continuously disturbed by the passing trucks.

Another chemical dust suppressant method involves working the stabilization chemical into the roadbed to a depth of 5 to 15 cm. This construction technique has been used extensively on rural unsealed roads in parts of the United States where locally available petroleum by-products provide a cheap material for oiled earth roads.

Considering the likely semi-permanence of the haul roads around the power station site, and also the relative proximity of the station to the Taranaki gas and oil fields, there may be some potential for the use of chemical stabilization of the power station's haul roads for emission control. If a suitable method could be found, this would have the effect of reducing on-going operational costs.

8.2.3. Road Carpet

A relatively new method of emission control on unsealed roads involves the use of a civil engineering fabric, which is synthetic,

stable, water permeable, rot-resistant, and usually employed in road stabilization. Laid below the haul road overburden, this tough fabric, termed 'road carpet', separates the fine soil particles from the coarse aggregate. This action prevents the fine material from reaching the road surface so that dust emissions are reduced (Blackwood and Drehmel, 1981).

The major advantages of this control method are that;

- (1) it avoids environmental problems (eg. oil leaching into streams);
- (2) it does not involve constant maintenance; and
- (3) for semi-permanent roads, the method has been shown to be more cost effective for emission control than either watering or oiling of road surfaces.

8.2.4. Sealing

Due to the high initial capital costs and the subsequent maintenance costs required for sealed, haul roads, this option is not really feasible for 'temporary' power station haul roads, and thus, should be restricted to permanent roads only.

8.3 Control Methods for Coal Stockpiles

Coal storage piles are expected to contribute the largest quantities of ground - source dust emissions during the operational phase of the power station. The proposed method of controlling these emissions, if any, is by watering. However, it is unlikely that this method, at least by itself, will be a sufficient nor a suitable method of controlling the coal dust emissions. The various methods available are set out below.

8.3.1. Watering

There are a number of reasons which preclude the reliance on water spraying as the major method of controlling dust from the coal stockpiles. These include reasons that;

- (1) because the stockpiles will contain fine crushed coal, the stockpile surface will dry very quickly after watering, and will rapidly become susceptible to the effects of wind erosion. Hence the logistics of constantly applying water to an area approaching 40 hectares would be immense;
- (2) the temporary effect of the watering would be further heightened in many instances, since the continuous turnover of at least some of the stockpile area would expose new surfaces to wind erosion;
- (3) excessive watering may have some detrimental effect on the quality of the stockpiled coal and may make the coal more difficult to handle; and
- (4) there may be problems associated with run off.

It is envisaged though, that although watering should not be used as the on-going principle method of controlling stockpile emissions, it should be used as a temporary measure for specific dust problems.

8.3.2. Chemical Stabilisation

Chemical stabilizers react with dry inactive coal piles to form a wind-resistant crust or surface layer. Of 65 chemicals for which test results have been recorded, the resinous, polymer, ligninsulfonate, bituminous base, wax, tar and pitch products have proven most successful in stabilizing stockpile areas (Dean and Havens, 1971) and in addition, a latex spray has been used successfully at the Huntly Power Station (Norris; pers. comm., 1985). Most of the above chemicals have demonstrated a long-term effectiveness in this application, although on stockpile areas being constantly worked, water is probably a more viable option. The chemicals may be applied either by truck or piping spray systems.

8.3.3. Chemical Suppression

An effective, long lasting method of controlling dust from stockpiles is the addition of dust suppressant chemicals to the water sprays. Rather than acting as chemical soil stabilizers to increase cohesion between particles, most of these chemicals work as wetting agents to provide better wetting of fines and longer retention of the moisture film. Some of these chemicals remain effective without rewatering on stockpiles for weeks or months.

8.3.4. Hydra-seeding

For the strategic stockpile at least, emissions may be successfully controlled by using a form of hydra-seeding which involves a combined chemical-vegetative technique. The chemical stabilizers alleviate the problems of sandblasting and highly reflective surfaces and hold more water near the surface of the otherwise porous coal piles. Chemicals that do not have an inhibitory effect on plant growth must be selected for this purpose.

8.3.5. Furrowing or Ridging of Stockpile Surfaces

A large smooth surfaced area on the top of stockpiles allows ground-level wind speed to build up and thus, enhances the rate of wind erosion of the stockpile surface. Painter (1977), studying the effects of wind erosion on exposed cultivated paddocks, discovered that deep furrowing of the ground surface at right angles to the prevailing wind direction, can reduce wind erosion by a large amount. In addition, he also found that reducing paddock lengths along the prevailing wind erosiveness direction can further reduce dust emissions.

The application of these findings to the design of the coal stockpiles would involve little cost and would be a useful measure in emission control.

8.3.6. Shelterbelts

Single row shelterbelts bordering unsealed roads are estimated to be about 40 percent efficient in controlling fugitive dust emissions (McCrea, 1984). Hence, the planting of substantially denser rows of shelter, both on the prevailing upwind and downwind sides of the major coal stockpile area, should have a considerably greater impact on the control of coal-dust emissions. Trees planted upwind of the stockpile would have the effect of reducing the wind speed over the stockpile surface, while downwind plantings would intercept much of the wind-borne dust emissions.

As an alternative to vegetative shelterbelts, or while trees are at an immature stage of growth, artificial windbreaks could be used to provide shelter.

8.4 Control Methods for On-Site Dry Ash Disposal Areas

Although the 'dry' ash arriving at the disposal areas will have been water conditioned, it is anticipated that there will still be problems with wind erosion of the ash as it dries out. The major viable alternatives for control of these emissions are set out below.

8.4.1. Water Control

Since the disposal area will be being constantly worked and reclaimed, and because it involves a maximum area of only 10 hectares, water spraying will probably be the best direct method of emission control. It is unlikely in the ash disposal operations, that additional chemical control will be feasible due to the nature of the operations.

8.4.2. Shelterbelts

For the ash disposal site options situated in valleys, there is likely to be a wind funnelling effect which could heighten the level of wind erosion from the exposed ash area. Hence, where ash emissions are likely to cause problems, the provision of shelter around the ash disposal area would aid in the reduction of emissions. Due to the limited useable life-span of each disposal site, artificial shelter is probably the most practical type to use.

8.5 Control Methods for Earthmoving Operations and Exposed Ground during Earthworks Phase

A conscientious programme of water spraying of exposed areas of earth is really the only feasible direct form of dust control which can be followed during the earthworks phase. As the area will be worked intensively by heavy machinery for a single, relatively short period, complete control will be difficult to achieve.

However, apart from water spraying, the problem may be minimised by;

- (1) ensuring that all exposed ground areas are reclaimed as quickly as possible after each particular earthworks operation; and
- (2) providing artificial windbreaks alongside areas which are perceived will cause dust problems to adjacent horticultural enterprises.

8.6 Control Methods for Windage Losses during Transit

Windage losses of dust and/or ash during transit are not predicted to be a major source of dust emission. However, should problems occur, then there are a number of measures available to help alleviate them. These include:

- (1) not filling trucks or wagons too full;
- (2) covering loads with tarpaulins or spraying the load surfaces with water and/or chemical stabilizers; and
- (3) reducing vehicle speeds.

8.7 Control Methods for On-Site Coal Conveyance

Emissions caused by coal conveyance are relatively easy to control since the emission source is clearly defined. The best method of control is to enclose the conveyance system and to have the transfer points hooded and vented to a dust collector. Both the enclosure and the hooding will greatly reduce fugitive dust emissions from this operation.

8.8 Conclusions

This chapter has outlined a number of measures available for controlling dust emissions from the Waikato Power Station. These are summarised on Table 17. However, until all the site options and operational procedures for the new power station have been finally decided, it is not possible to specify exactly what methods will be needed to optimize emission control nor indeed, to establish if controls will be required for each emission type.

It is likely that the proposed predominant use of water spraying to control emissions at the power station will be adequate in terms of horticultural protection; so long as it is conducted conscientiously. However, the greater permanence and cost effectiveness of other forms of emission control should not be overlooked.

In addition, for some emission types, a combination of a number of emission control procedures may provide the most cost-effective form of dust control.

TABLE 17

Summary of Control Efficiencies for Power
Station Dust Sources

Source	Control Method	Estimated* Efficiency(%)	Comments
Haul Roads	Watering	65	Most temporary, but flexible.
	Chemical Stabilization	65	Often more cost-effective than watering.
	Road Carpet	65	Special cost advantages over very soft terrain.
	Sealing	95	Not suitable for temporary roads.
Coal Stock-piles	Watering	65	Most temporary, possibly detrimental effects.
	Chemical Stabilization	75	Binds particles.
	Chemical Suppression	65	Increases permanence of watering.
	Hydra-seeding	75	Combines vegetative and chemical techniques.
	Furrowing and Ridging	50	Very low cost procedure.
	Windbreaks	40 plus	Vegetative or artificial
Dry Ash Disposal Areas	Watering	65	Only feasible direct method
	Windbreaks	40 plus	
Earthmoving Operations	Watering	Variable	Often difficult to maintain watering
	Windbreaks	40 plus	Limited application
Windage During Transit	Reduce vehicle loads and/or speed	NA	Difficult to regulate
	Cover loads or spray	NA	Often too costly or impractical.
Coal Conveyance	Cover total operation	95	Only feasible method

* Estimates based on findings of various previous studies (eg. Dyck and Stuckel, 1976; McCrea, 1984; Hittman, 1974; EPA, 1980).

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