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Coal Company, Carter Mining Company, Sunoco Energy Development Company, Mobil Oil Corporation, and Atlantic Richfield Company, Denver, CO, July 1981.

COAL MINING EMISSION FACTOR DEVELOPMENT AND MODELING STUDY

TRC ENVIRONMENTAL CONSULTANTS, INC.

PREPARED BY:

DONALD L. SHEARER
RAE ANN DOUGHERTY
CALVIN C. EASTERBROOK

TRC PROJECT #0908-D10-05
JULY 1981

8775 EAST ORCHARD ROAD
SUITE 816
ENGLEWOOD
COLORADO 80111
(303) 779-4940

OVERVIEW

This report is the result of a detailed study to develop emission factors for the major elements of the surface coal mining activity in the Powder River Basin of Wyoming. Referred to as the Emission Factor Development Study or EDS, the work has been undertaken for the purpose of developing actual emission factors utilizing real conditions resulting from the surface mining activities in the Powder River Basin. Both private industry and applicable regulatory authorities may opt to use these factors as they represent the latest state-of-the-art in air pollution measurement and control.

The EDS Study centers on field measurements collected specifically for use in development of emission factors and employs the developed factors in a concentration prediction model to estimate the impacts of the regional mining activities for future years.

A group of five companies with operating or permitted surface coal mines in the region southeast of Gillette, Wyoming commissioned TRC ENVIRONMENTAL CONSULTANTS, INC. to conduct the EDS program. Participants include AMAX COAL COMPANY, CARTER MINING COMPANY, SUNOCO ENERGY DEVELOPMENT COMPANY, MOBIL OIL CORPORATION, and ATLANTIC RICHFIELD COMPANY.

The EDS Study began in Autumn 1978 with the collection of field data at two operating mines (AMAX's Belle Ayr and SUNEDCO's Cordero) in the Gillette Corridor during each of the four seasons of the year. Field measurements continued through the 1979 Summer season. Evaluation of the field data, development of emission factors, and application of the findings to modeling have been carried out since completion of the field portion of the study.

Extensive field measurements were made to document the particulate emissions during actual mining operations. The principal measurements consisted of total suspended particulates (TSP) at multiple downwind and crosswind ranges from several different sources--each documented separately, documentation of particle size distributions at multiple ranges, amounts of particulate settling/dry deposition at multiple ranges, and documentation of

meteorological variables. Atmospheric tracers were employed to assist in separating particulate contributions from more than one source in the cases when the mine operations being tested was in close proximity to other sources.

Emission factors representative of each of the major sources of airborne particulates were developed from the collected field data. The emission factors were also corrected so as to represent the total amount of particulates emitted at the source as opposed to the apparent amount emitted at some finite distance from the source. The developed emission factors represent both the individual elements of the mining operations as well as the surface mine as a whole. The individual factors are used in this study to determine the impact in the near distance field surrounding each mine. A "whole mine" emission factor was derived as a cross-check to enable evaluation of the representativeness of the individual factors when viewed collectively, and to assess the real impact of emissions made in the pit. In addition, a method for determining emissions from in-pit operations was developed which allows a simulation of material transport from the pit as it really occurs. This approach has been verified by independent measurements to show that a significant portion of particulates emitted from pit operations does not escape from the confines of the pit.

After the emission factors were developed they were employed in two steps of modeling. Step one was to accomplish a model verification and step two was to calculate the expected impact of the mining activity in the Gillette Corridor at a future date. The model used in both steps is the EPA's recently released Industrial Source Complex (ISC) Dispersion Model which is considered to be a state-of-the-art model (EPA, 1980). In carrying out model verification, calculations for both short-term periods (6 hours) and a long-term period (one year) were compared against measured concentrations that were observed independently from the data used to develop the emission factors. The results of model verification showed that the ISC Model employing site specific emission factors was verified at a level of comparison generally accepted to be very good. For the second step of modeling, calculating the expected impact of the surface coal mining activity in the Gillette Corridor for a future date, the year 1988 was utilized. The year 1988 represents a peak level of mining activity and production as well as the

year selected by the Wyoming Department of Environmental Quality (WDEQ) as the basis for predicting the annual region-wide particulate concentrations from the total mining activity in the Gillette Corridor. WDEQ has employed a model called CDMW (Dailey, 1980) (which includes modifications to make it applicable for rural environments) to make its calculations of region-wide TSP concentrations. Using this approach TRC was able to make a direct comparison of the expected annual total suspended particulates calculated by different models using different emission factors for a common future period. As an integral part of this study the ISC Model with EDS factors has been verified against independent field measurements.

The highest annual TSP concentration predicted for the year 1988, by the ISC Model used in this study is 46 $\mu g/m^3$. That value is 14 $\mu g/m^3$ lower than the Wyoming standard of 60 $\mu g/m^3$ and is 12 $\mu g/m^3$ lower than the comparable value predicted by WDEQ with the CDMW model. Explanation for the significant difference in the TSP levels predicted by the ISC Model and the CDMW model is seen in several technical findings of the EDS Study as are described below.

First the EDS Study revealed that a large portion of the particulate material that is generated as an airborne emission is comprised of very large particles. These particles, due to their large size and mass, settle to the ground very quickly thus removing them from the atmosphere. Since a large portion of the mass of material introduced to the atmosphere by surface coal mining activities is of a large size (above 20 μm) that the process of settling/dry deposition is a predominant physical process reducing mass transport downwind. TRC believes that the process is so critical and fundamental that any model which omits or does not simulate the physical process of settling and removal by dry deposition cannot adequately predict downwind concentrations of TSP. The ISC Model satisfies this requirement.

The second major finding is that emissions from the pit are mainly of large particle size, and, therefore, are largely confined below grade where they fall out before they can escape to the ambient atmosphere.

Another significant finding is that particles from haul roads are by far the largest single source of emissions from surface coal mining activities in the Gillette Corridor. Haul road emissions can be significantly controlled by watering. Control efficiencies were determined from field measurements to be as high as 78 percent, i.e., controlled to a factor of 0.22 of what would be emitted without control.

TRC concludes, therefore, that use of the ISC Model with site specific emission factors enables prediction of mine emission impact on the regional air quality with a degree of precision that represents a significant advancement of the state-of-the-art.

This study has developed an approach for modeling the impact of open pit mines which utilizes a realistic simulation of material containment within the pit and predicts reduced downwind impacts from the pit which compare well with actual measurements. It has been found that deposition is a significant process for containing material within the pit and should be treated in any realistic modeling study. Likewise, emission factors for above grade operations must address material deposition. The modeling approach developed in this study also provides for a realistic treatment of this physical process. Results of individual mine modeling studies based on this modeling approach verify well with independent measurements to demonstrate the physical reasonableness of the study findings.

STATEMENT BY PARTICIPANTS

The Participants have provided financial support to the Emission Factor Development Study (EDS) for the expressed purpose of developing accurate, scientifically valid particulate emission factors which will allow accurate projection, through modeling, of the impact of surface coal mining upon particulate ambient air quality in a portion of Campbell County, Wyoming. The approach taken in the study and the findings made are those of TRC ENVIRONMENTAL CONSULTANTS, INC. (TRC), not the Participants. TRC believes it has made a significant finding which advances the state-of-the-science regarding gravitational settling/dry deposition. Using this finding, TRC projects, through modeling, an ambient particulate concentration in the study area in 1988, on an annual geometric mean, approximately 20 percent lower than that being projected by the Wyoming Department of Environmental Quality. The validity of the modeling is dependent upon both the accuracy of the emission factors developed in the study and how realistically particle deposition is simulated. The Participants also believe the study advances the state-of-the-science; however, the state-of-the-science in emission factor development, deposition, and air quality modeling is imprecise. For example, as is apparently inherent in this type of work the standard deviations for the emission factors developed in the study are large.

Although the Participants presently support the findings of the study, for the reasons set forth above, the Participants reserve the right at any time in the future to disagree with, or question, any portion of the study, or its findings and projections, if new information becomes available or for any other reason any of them considers appropriate.

GLOSSARY

AMAX - Amax Coal Company

Ambient - The environment about an object but undisturbed or unaffected by it, as in ambient air or ambient temperature.

Apparent Emission Rate - Emission rate calculated from a concentration measured at a receptor some distance from the source. The apparent emission rate is lower than the actual emission rate when dry deposition and gravitational settling of large particles occur in the distance between the source and the receptor.

ARCO - Atlantic Richfield Company

Atmospheric Dispersion Model - A mathematical expression which accounts for the concentration of emitted air pollutants as those pollutants disperse in the atmosphere. The expression includes effects of advection, dispersion, along with considerations of plume rise, complex terrain, dry deposition, and gravitational settling.

Atmospheric Stability - A measure of the atmosphere's natural suppression of turbulent dispersion.

Back Calculation - A method used with atmospheric dispersion models to compute the actual emission rate from input-output ratios and chosen input emission rates.

Background Concentration - Value representing that part of the regional pollutant concentration not attributable to the sources within the region.

Boundary Layer - The layer of air near the ground where dispersion processes are significantly influenced by the nature of the ground surface. This layer extends to the mixing height (usually four or five hundred meters above the ground).

Buoyant Force - The upward force exerted upon a parcel of air attributed directly to a local increase of temperature.

CARTER - Carter Mining Company

CDM - Climatological Dispersion Model--one model of the EPA UNAMAP series. It is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual) geometric mean pollutant concentration at any ground level receptor.

Confidence Levels - The limits of a range of values determined from a sample by definite rules so chosen that in repeated random samples from the hypothesized population, an arbitrarily fixed proportion of that range will include the true value of an estimated parameter.

Corridor - An area south of Gillette, Wyoming in the Powder River Basin encompassing a region approximately 12 miles wide and 37 miles long wherein six coal mines modeled in this study are located.

Deposition Velocity - Ratio of the deposition rate to the immediate ground-level air concentration. (Chamberlain, 1953)

$$\omega = V_d \ \bar{X}(x,y,0)$$

Discrete Receptors - Nongrid point receptor locations within a Cartesian coordinate system.

Dry Deposition - The process by which small particles are deposited onto the ground via nongravitational and nonprecipitation mechanisms, such as surface impaction, electrostatic attraction, adsorption, and chemical interaction.

Dustfall - Total settleable particulates measured by a standard container of uniform cross-section as described by Designation D1739, latest revision, American Society for Testing and Materials, or by an equivalent method.

EDS - Emission Factor Development Study

EPA - Environmental Protection Agency

Flux Measurement Method - A field measurement method employing a vertical array of sampling devices placed such that all the pollutants emitted from a given source can be measured as the wind carries those emitted pollutants away from the source.

Fugitive Dust - Dust material that is introduced to atmospheric suspension by wind or (in this case) mining activities and is not emitted through ducts or stacks, etc.

Gaussian Plume - Most popular algorithm used to describe the diffusion of material emitted from a continuous point source. Based on the statistical theory of turbulence, it is assumed that the probability density function for pollutants dispersing in the atmosphere is Gaussian--both immediately after the pollutant release and after a long time has elapsed.

Gravitational Settling - Removal of large particles suspended in the atmosphere resulting from gravitational forces.

Gravitational Settling Velocity - The rate of descent of a particle, determined by the amount the gravitational force exerted by the earth exceeds the aerodynamic drag force on the suspended particulate.

Hi-vol - High volume air sampler--the EPA-recommended instrument used to measure the mass concentration of suspended particulates in ambient air.

ISC - Industrial Source Complex Dispersion Model--an EPA approved model designed to estimate the short-term and/or long-term air quality impact from large industrial source complexes.

ISCST: short-term program of the ISC Model
ISCLT: long-term program of the ISC Model

Long-term Modeling - Application of a dispersion algorithm to estimate the impact of atmospheric pollutants emitted from various source configurations--time averaging period on the order of months to a year.

Mean Fractional Error - The mean difference between the observed (O_i) and predicted (P_i) divided by the average of the observed and predicted.

$$\frac{2}{N}\left[\sum_{i=1}^{N}\left(\frac{O_i - P_i}{O_i + P_i}\right)\right]$$

MOBIL - Mobil Oil Corporation

Model Verification - The process of establishing the accuracy of an atmospheric dispersion model--achieved by comparing measured air quality with modeled estimates for the same locations, the same times, and for the same conditions.

Millipore Filters - Membrane filters with a 0.45 .m pore size used to sample particulate matter to determine particle size distributions.

Mixing Height - The height above the ground surface through which relatively vigorous vertical mixing occurs.

NAAQS - National Ambient Air Quality Standards

NCC - National Climatic Center

Particulate Matter - Any material, except water, in uncombined form that is or has been airborne and exists as a liquid or solid at standard conditions.

PAL - A Gaussian plume algorithm for Point, Area, and Line Sources--one of the EPA UNAMAP series of models. This short-term Gaussian steady-state program estimates concentrations of stable pollutants from point, area, and line sources.

Particle Density - The ratio of the mass of any substance to the volume occupied by it.

Probable Error - The magnitude of a deviation from a statistic which will be exceeded with a probability of 0.50, or on half the occasions.

Reflection Coefficient - Fraction of the material that reaches the ground surface by the combined processes of gravitational settling and atmospheric turbulence and is reflected from the surface.

Short-term Modeling - Application of a dispersion algorithm to estimate the impact of atmospheric pollutants emitted from various source configurations--time averaging period on the order of hours to a day.

Sigma y - Pasquill-Gifford horizontal cross-wind dispersion parameter.

Sigma z - Pasquill-Gifford vertical dispersion parameter.

SLAMS - State and Local Air Monitoring Station

Source Depletion Factor - The percentage reduction of particulate matter removed from the plume between the source of emissions and the receptors (a function of downwind distance).

Standard Deviation - For normal distributions, 68.27 percent of the sample is within one standard deviation on either side of the arithmetic mean.

STAR - STability ARray--a joint frequency distribution of wind speed, wind direction, and atmospheric stability.

SUNEDCO - Sunoco Energy Development Company

Tracer Measurement Method - A field test method employing a unique tracer material released to simulate emissions from a single source region. In this case sulfurhexafluoride (SF_6) was used.

TRC - TRC Environmental Consultants, Incorporated

TSP - Total Suspended Particulates--particles, within the size range of 100 to 0.1 .m diameter, ordinarily collected on glass fiber filters. The mass concentration of suspended particulates in the ambient air (.g/m^3) is computed as described in Title 40, Part 50 (Appendix B) Code of Federal Regulations (1979).

UNAMAP - Users Network for Applied Modeling of Air Pollution--a series of EPA approved atmospheric dispersion models.

Upwind-Downwind Measurement Method - A field measurement method employing two horizontal rows of hi-vol samplers downwind of the source and one sampling site outside of the influence of the source to measure background.

Virtual Point Source - The geographic location of a hypothetical point source in such a position that the initial standard deviation, σ_o, of the area source equals the standard deviation of the point source.

VMT - Vehicle Miles Traveled

WDEQ - Refers to the Air Quality Division of the Department of Environmental Quality of the State of Wyoming--regulatory agency enforcing the air pollution rules and regulations promulgated under the authority of the Wyoming Environmental Quality Act (1973).

Wet Days Ratio - Fraction of year which does not have "wet" days, i.e., days with more than 0.01 inches of rainfall. Reduction in particulate emissions because of rainfall is accounted for by neglecting emissions on "wet" days.

Whole Mine Emission Factor - Emission factor developed to represent all the individual mining operations as a single area source. Measurements of the whole mine emissions were obtained from a hi-vol array set up around the periphery of each mine.

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SECTION 1

EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

A study of particulate emissions from surface coal mining operations in the Powder River Basin of Wyoming was undertaken during the period from Fall 1978 through Summer 1979. The intent of the study was to develop particulate emission factors for the primary activities of mining operations. Data consisting of meteorological measurements and field concentrations of airbourne dust were obtained near primary dust generating activities at two operating mines during each of four seasons. The dust generating activities tested were: coal and overburden haul roads, coal dumping, train loading, overburden replacement, topsoil removal, and wind erosion on both stripped overburden and reclaimed land. In addition to these individual activities, each mine as a whole was tested as a single area source.

Particulate emission factors were developed from the field data collected during the yearlong measurement program. A summary of those emission factors is presented in Table 1.1 of this section. In addition to the development of emission factors representing the primary dust generating activities of surface coal mining, the field measurement program culminated in four significant findings which bear heavily on employment of emission factors in modeling. These findings are new and for the first time enable modeling studies to more accurately approximate real physical processes to produce predicted impacts that are more realistic when compared to actual measurements than are possible with current techniques. The findings are briefly listed below, and are discussed in more detail later in this section.

1) Particle deposition and gravitational settling are predominant physical processes which for the first time have been taken into account in the development of emission factors and in their application for modeling.

2) Many of the large particles that are generated by mining activities carried out below grade in the open pit do not escape into the ambient atmosphere.

3) Control of particulate emissions from haul roads is proportional to the amount of watering.

TABLE 1.1 EMISSION FACTOR SUMMARY

SOURCE	CONTROL MEASURES	EMISSION FACTOR AT SOURCE	APPARENT EMISSION AT 500 METERS	APPARENT EMISSION AT 1000 METERS
HAUL ROADS	No Control Average Watering	22.0 lb/VMT 5.6 lb/VMT	8.5 lb/VMT 2.0 lb/VMT	7.8 lb/VMT 1.8 lb/VMT
COAL DUMP	No Control Negative Pressure	0.066 lb/ton 0.036 lb/ton	0.024 lb/ton 0.013 lb/ton	0.022 lb/ton 0.012 lb/ton
TRAIN LOAD	No Control	0.028 lb/ton	0.010 lb/ton	0.009 lb/ton
OVERBURDEN REPLACEMENT	No Control	0.012 lb/ton	0.004 lb/ton	0.004 lb/ton
TOPSOIL REMOVAL	No Control	0.058 lb/ton	0.021 lb/ton	0.019 lb/ton
WIND EROSION	No Control	0.38 ton/acre-yr (At 4.7 m/sec mean Wind Speed)	Not Applicable	Not Applicable

4) The emission factors developed from measurements made in this study, when correctly applied, show significantly lower impact on both the near and far mine environment than do the approved Wyoming Department of Environmental Quality (WDEQ) factors employed with current modeling practices.

These four findings are explained as follows:

1) Particle deposition and gravitational settling are predominant physical processes which for the first time have been taken into account in the development of emission factors and in their application for modeling. One hundred and forty coincident measurements of dustfall and particle concentrations were made, permitting the computation of the effective settling velocities at many downwind distances from the source. The deposition and settling velocities derived from independent field measurements, exhibited a rapid decrease with distance, in complete accord with the accepted theory of particulate behavior. Particle size measurements were acquired for all tests from Millipore filter samples. These particle size measurements were used to compute deposition velocities. Figure 3-3 shows the close agreement between deposition velocities computed from the particle size data (solid line) and the dustfall/hi-vol data (dashed line).

The conclusions pertaining to the deposition processes emphasize the need to distinguish between emission factors applicable at the source (before large particles have fallen out of the plume) and factors as perceived some distance from the source where only small particles remain. For example, it was found that under average meteorological conditions (neutral stability and 10 mph winds), only about 35 percent of the emitted particulate mass remains in the atmosphere at a distance of 500 m from the source. roughly consistent with our study

2) Most of the large particles that are generated by mining activities carried out below grade in the open pit do not escape into the ambient atmosphere. It was found that the "whole mine" emission rates determined from measured emission factors and mine production figures were three times greater than the emission rates obtained by "back calculation" modeling from the particulate concentration measurements taken around the periphery of the pit. This finding indicates that approximately one-third of the local emissions escape from the pit area. The pit area was not as well ventilated as the

surrounding terrain and the increased residence time of the air permits most of the large particles to fall out before they were entrained into the air flow over the pit. It should be noted that the trapped particles do not constitute a health hazard for two specific reasons: 1) their size lies in the noninhalable range; and 2) particles are quickly removed by gravitational settling, thereby preventing any appreciable concentration build up.

3) Control of particulate emissions from haul roads is proportional to the amount of watering. A quantitative relationship was developed to express the effect of watering on haul road emissions. The results show that haul road emissions control is proportional to the amount of watering being done and that maximum practical control effort reduces emissions to a factor of 0.22 or 78 percent control.

4) The emission factors developed from measurements made in this study, when correctly applied, show significantly lower impact on both the near and far mine environment than do the approved WDEQ factors employed with current modeling practices. The emission factors for individual mining activities, as developed from measurements made during this study were found to be higher in most cases than those currently approved under regulations promulgated by the WDEQ. However, when correctly accounting for the pit trapping and particle settling, the impact of these emissions on the mine environment (both near and far) is significantly less than that predicted by currently used modeling practices.

In the following report, each of the topics discussed above are treated in depth in separate sections. Section 3 deals with particle deposition and the development of a source depletion function for dispersion modeling. The haul road emission measurements are discussed in detail in Section 4. Sections 5, 6, and 7 cover coal dumping and train loading, overburden replacement, topsoil removal, and wind erosion from disturbed land respectively. Measurements of "whole mine" emissions and a discussion of the pit trapping phenomenon are given in Section 8. Section 9 of Part 1 deals with estimating the confidence limits of the various measured emission factors.

SECTION 2

INTRODUCTION

2.0 INTRODUCTION

In June 1977 representatives from several coal mining companies in the Powder River Basin of Wyoming met to discuss air quality, a subject which was becoming increasingly important to their present and proposed surface mining operations in the Gillette region. Air quality considerations have become increasingly important because measures must be taken to assure that, as the mining activity of the region is developed, it does not result in damage to the environment through deteriorating air quality. The Wyoming Environmental Quality Act, passed in 1973, has created the Air Quality Division of the Department of Environmental Quality (WDEQ) with jurisdiction over air quality and to review and issue permits for stationary sources including coal mines. The mechanisms used to review and determine suitability for permitting include simulation of anticipated air quality through mathematical modeling—and those models are becoming more sophisticated and detailed. It, therefore, becomes essential to have credible measuring devices for emission factors as used in the modeling and is essential that these emission factors be proven valid for the region and the circumstances of the mining methods employed. The group sought to scientifically determine if the factors being employed by the WDEQ were sufficiently rigorous in representing operations currently ongoing for the surface mining in the region.

The group selected an independent consultant to accomplish two tasks: 1) to develop particulate emission factors that would accurately represent the ongoing and proposed surface mining operations within the Gillette region; and 2) to assess the impact of total suspended particles (TSP) generated by the mining operations on the environment by employing atmospheric dispersion modeling techniques.

A contract was signed in early 1978 with TRC ENVIRONMENTAL CONSULTANTS, INC. (TRC). Companies involved in the project include AMAX COAL COMPANY (AMAX), SUNOCO ENERGY DEVELOPMENT COMPANY (SUNEDCO), ATLANTIC RICHFIELD COMPANY (ARCO), CARTER MINING COMPANY (CARTER), and MOBIL OIL CORPORATION (MOBIL). The work covered by this contract is known as the Emission Factor Development Study (EDS).

A test plan which specified the field measurements needed to accomplish the EDS Study was developed by the companies and the consultant. It called for tests to be conducted at two mines, AMAX's Belle Ayr and SUNEDCO's Cordero mines during each of the four seasons. The actual field testing began in the Fall of 1978 and was completed in the Summer of 1979. In order to have a credible representative sample for the potential emission factors, the various mine sources to be studied were as follows: coal and overburden haul roads, coal dump, train load-out facility, overburden replacement, topsoil removal, wind erosion on reclaimed land, and wind erosion on stripped overburden. In addition to these individual sources, the mine itself, as a whole, was investigated as a single area source.

During the test program, three methods were utilized to make the emission measurements: a standard upwind-downwind method, a tracer method, and a flux method. The flux method is best suited to measurement of line sources which exhibit a uniform horizontal concentration pattern. The tracer method was used to measure the product dumping and train loading operations which are fixed point sources, and the upwind-downwind method was utilized for the remainder of the tests. In all cases, simultaneous measures of dustfall and particle size were made at several distances downwind of the source and at one location upwind.

As stated earlier, an essential element of the EDS Study was the investigation of particle settling. Because of settling and deposition, particles larger than about 20 μm will eventually be removed from the air. For this reason, a large proportion of the particulates emitted from mining operations will not be present beyond a few hundred feet from the source (Cowherd, et. al., 1974). If the effect of gravitational settling and dry deposition is neglected, then emission factors computed from field test data will be in error. Similarly, atmospheric dispersion models that are utilized to simulate the dispersion of heavy particulates, must include a rigorous treatment of dry deposition and gravitational settling if they are to accurately predict ambient concentrations.

Two independent methods were utilized to study the effects of deposition: dustfall measurements and particle size measurements. A strong correlation of the findings from the two methods indicate that the tests were highly successful. Section 3 of Part 1 gives a detailed discussion of the deposition measurements.

Section 4 discusses the field tests and data analyses associated with the largest source of particulate emissions—haul roads. Using the flux measurement method, the emissions from coal and overburden haul roads are quantified and the effects of water spray control as well as meteorological parameters and seasonal variability are examined.

Sections 5, 6, and 7 are given to the coal dump, train load-out facility, overburden replacement, topsoil removal, and wind erosion tests. The fixed point source nature of the coal dump and train load-out facility permit a tracer gas test method to be utilized to measure the emission rates. The remainder of the sources were measured using upwind-downwind sampling.

Section 8 covers the work performed in measuring the whole mine emission rates. These estimates were made utilizing hi-vol data collected at the periphery of the mines. Comparison of whole mine emission estimates with emissions predicted by summing the source specific factors indicates that only one-third of the total particulate mass emitted inside the pit area is transported beyond the perimeter of the pit. The trapped particles are all in the noninhalable size range.

Section 9 of Part 1 addresses the confidence level of all the EDS measurements. Small sample statistics are utilized to derive error limits for the 95 percent confidence level. In general, these limits range from ± 0.22 for the largest and most important emissions to ± 0.98 for the least important sources where only a small number of tests were made.

TABLE 3.1 - PARTICLE SIZE DATA

TEST CONDITION	SAMPLE NUMBER	DOWNWIND DISTANCE (m)	PARTICLE FRACTION IN DIAMETER INTERVAL (μm)										V_d (m/sec)
			<2	2-15	15-30	30-50	50-75	75-100	>100				
OVERBURDEN HAULROAD	31B	201	.92	.08	.002	.001	.001	0	0				0.22
"	32B	24	.93	.06	.006	.001	.002	.001	0				0.28
"	33B	28	.91	.07	.012	.003	.007	.003	.002				0.44
"	34B	227	.93	.069	.004	0	0	0	0				0.03
"	35B	264	.70	.29	.007	.004	.001	0	0				0.13
"	36B	62	.67	.31	.014	.003	.003	0	.001				0.40
"	37B	54	.73	.24	.014	.009	.003	.002	.001				0.38
"	38B	231	.90	.097	.003	0	0	0	0				0.02
COAL HAULROAD	40B	246	.90	.094	.004	.003	.001	0	0				0.11
COAL DUMP	41B	61	.55	.41	.025	.011	.004	0	0				0.11
"	42B	122	.81	.19	.003	.002	0	0	0				0.03
"	43B	61	.77	.22	.004	.001	0	.002	0				0.20
"	44B	122	.66	.33	.006	.003	0	0	0				0.03

SECTION 3

DRY DEPOSITION AND GRAVITATIONAL SETTLING

3.0 DRY DEPOSITION AND GRAVITATIONAL SETTLING

3.1 DISCUSSION

Since emissions from sources of particulate matter are normally estimated from measurements made at finite distances from the source, loss of material from the plume between the source and the measurement point will affect the emission rate estimate. If the source being measured generates a significant number of large particles, many of the particles will fall out before the plume reaches the measurement point, and the "apparent" emission rate as seen at the downwind point may be much smaller than the actual source emission rate. For this reason, it is most important that some means of measuring particle deposition be employed when making emission factor measurements.

During the EDS study, two methods were utilized to estimate the particle settling. The primary method employed dustfall buckets to measure dustfall at several locations downwind of the source for each test. The second method utilized Millipore filter samples from which the actual particle size distributions were determined for several locations downwind during each test.

Results of the dustfall measurements and the Millipore filter sampling demonstrate that deposition is very high in the first few hundred meters from the source and should be considered in emission factor development. It is also clear that particle settling is an important factor in estimating the impact of surface mining activity on the environment at property boundaries and at greater distances.

3.2 DUSTFALL MEASUREMENTS

Dustfall measurements were made at 3 to 4 locations downwind of the source during each test. Ten-inch diameter buckets were used with a small amount of liquid (water or isopropanol) covering the bottom to trap the particles. The dustfall buckets were exposed at a height of about four feet to keep them from being contaminated by material being blown along the ground.

Dustfall is a direct measure of the deposition actually taking place and thus has value in estimating source depletion, especially in this case where there are a large number of samples available. In order to demonstrate the general nature of the dustfall measurements, a few samples have been plotted as a function of distance and are shown in Figure 3-1. The rapid fall off with distance is typical of the dustfall data and demonstrates the existence of significant particle settling over the first few hundred meters downwind of the source. Also, it is seen that the data from different types of tests have similar dustfall characteristics.

Since dustfall data are inherently variable, it was decided to combine all the measurements into a single large sample. This was accomplished by normalizing all the dustfall measurements utilizing the associated particulate concentrations. The proportionality constant obtained in this way has dimensions of velocity and is called the deposition velocity, i.e.,

$$\frac{D(g/m^2 sec)}{\chi(g/m^3)} = V_d(m/sec). \qquad (3.1)$$

Approximately 140 dustfall samples were obtained with accompanying concentration measurements. A deposition velocity was derived for each sample and plotted as a function of distance from the source. A few individual tests are shown in Figure 3-2 with lines joining the associated points to demonstrate the general form of the deposition velocity function. The plotted points also show the approximate spread of the deposition velocity data.

In each of the tests an upwind dustfall measurement was obtained. Initially it was thought that the upwind sample would represent a background level that could be subtracted from the field of dustfall measurements downwind of the source being tested. However, upon reviewing the data it became apparent that influences from numerous other nearby sources produced a highly nonuniform distance related background that could not be reliably quantified relative to the positions of the test array. The end result was that no adjustments were made and the test data thus exhibit more "noise" than might otherwise have been the case.

show scatter

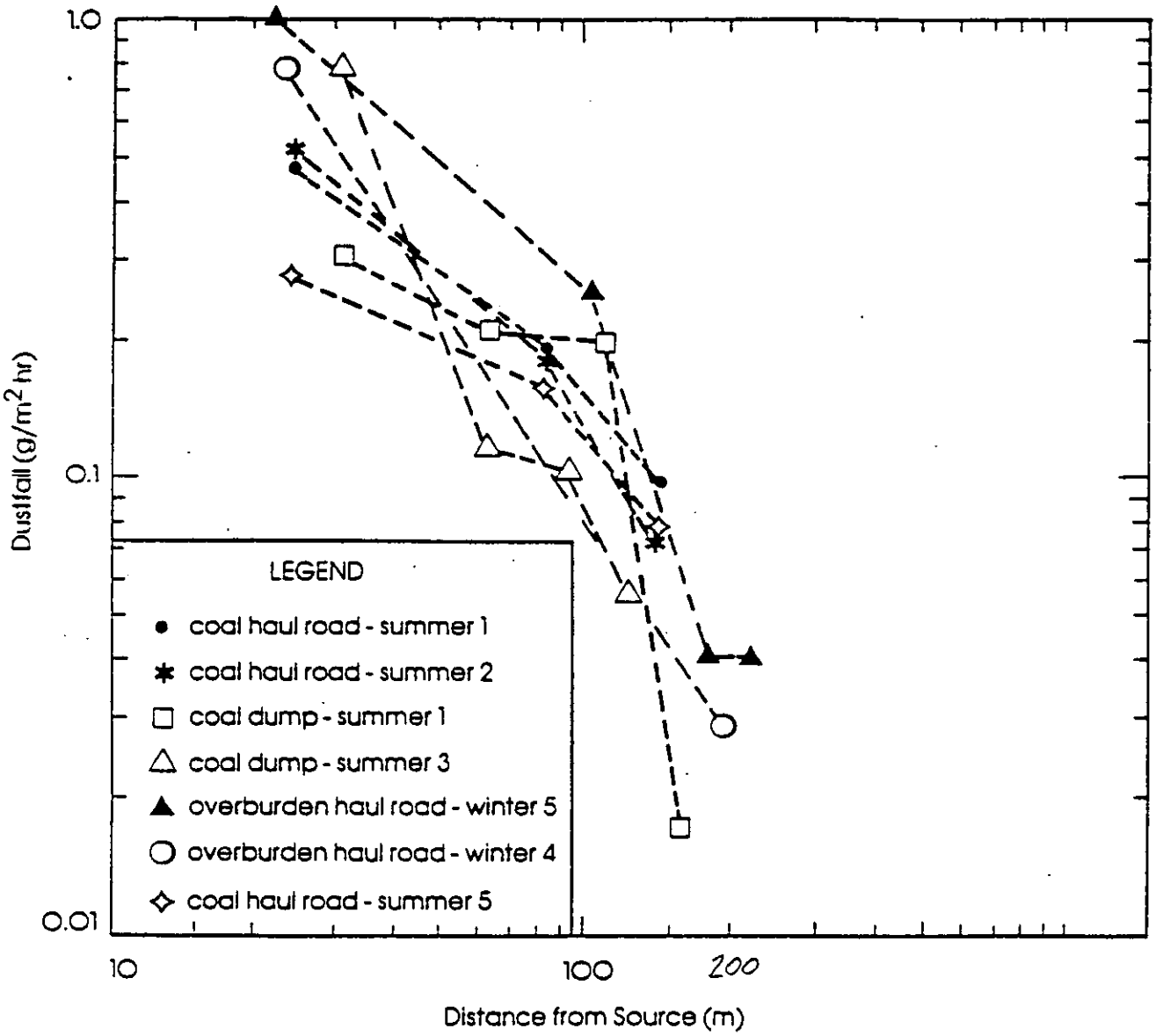

FIGURE 3-1 DUSTFALL MEASURED FOR VARIOUS SOURCES AS A FUNCTION OF DISTANCE FROM THE SOURCE

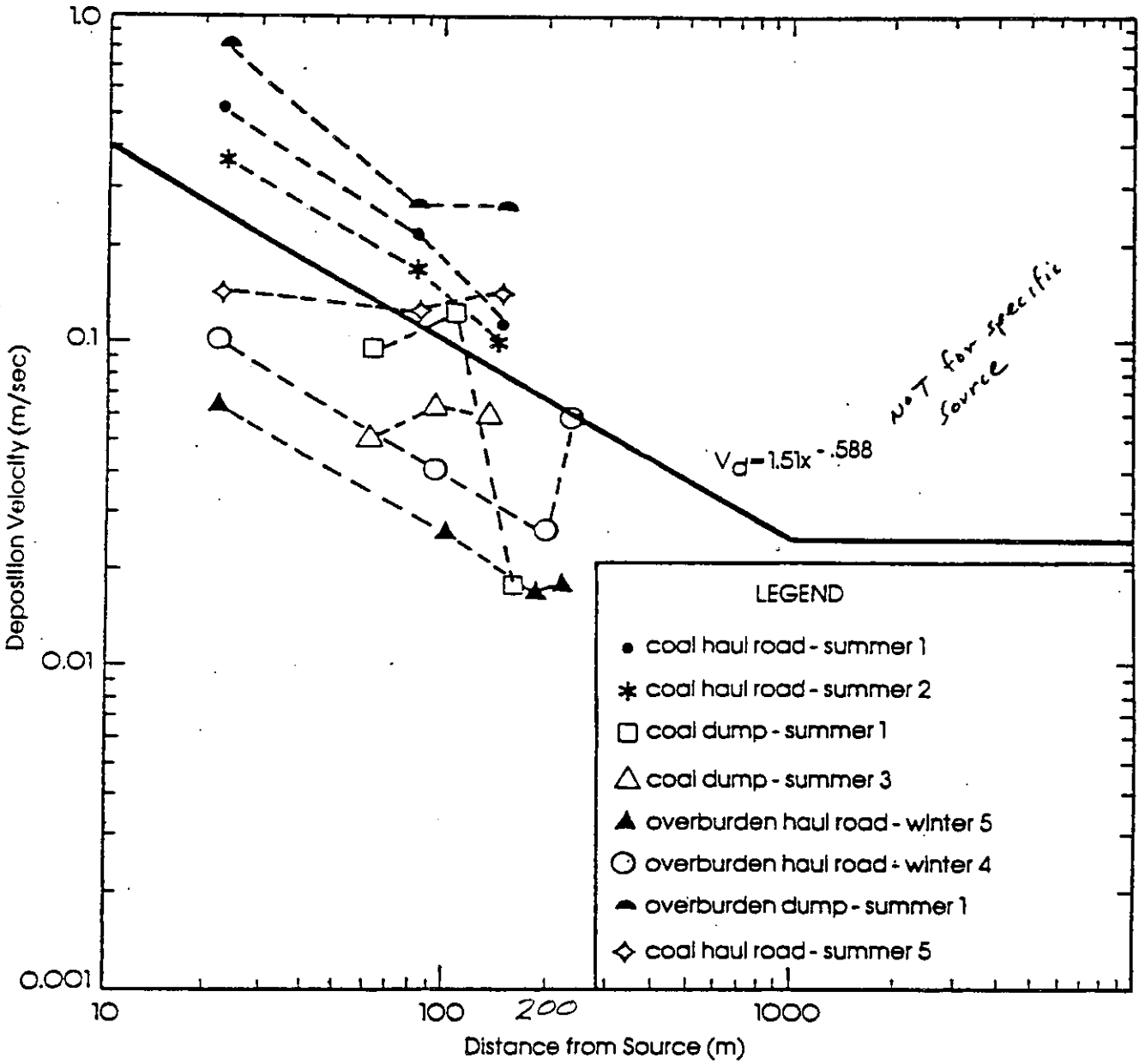

FIGURE 3-2 CHANGE OF EFFECTIVE DEPOSITION VELOCITY WITH DISTANCE FROM THE SOURCE FOR DUSTFALL/CONCENTRATION DATA

A test for normality showed the data to depart from the normal distribution, but it was reasoned that a larger sample of data would, by nature, have been normally distributed, thus a least-squares method was utilized to fit the data to a function of the form $V_d = ax^b$. The curve obtained in this way fit the data well in the region close to the source where all the measurements were made, but produced unrealistic values of V_d at large distances. The line shown in Figure 3-2 was obtained by fitting the data to the function given above, and at the same time forcing the line to pass through the point, x = 1,000 m, V_d = 0.025 m/sec. This constraint was necessary to ensure that the deposition velocity function would not only fit the data but would also produce results consistent with other existing measurements representative of conditions existing at greater distances.

what particle size?

Measurements given in Slade (1968) indicate that at distances of 1,000 m from the source, the deposition velocity ranges from a minimum of 0.01 m/sec to a maximum of 0.06 m/sec. This range is believed to be caused by varying atmospheric stability; the lower limit being associated with stable conditions. The choice of 0.025 m/sec at 1,000 m was based on a scientific judgment as to the value that would best represent average stability conditions. However, in the final analysis, the exact value chosen is not critical provided that it lies within the range indicated. Calculations show that the impact of the source on a receptor at a distance of 500 m or more is not highly sensitive to the value of the constraining point. The standard deviation of the deposition velocity data about the fitted curve is 0.12 m/sec.

?

At distances beyond 1,000 m, the deposition velocity is assumed to be constant. In this region, the remaining particles are all expected to be smaller than 20 μm and deposition is no longer significantly influenced by particle settling, but is primarily controlled by turbulence diffusion processes in combination with surface adsorption mechanisms.

$\frac{10\ cm^3}{0.785\ (37\ mm)^2}$

3.3 PARTICLE SIZE MEASUREMENTS

horizontally oriented, uncovered

Particulate samples were taken at three locations downwind of each source being tested. The samples were obtained by exposing 37 mm Millipore filters aspirated by a pump at the rate of 10 l/min. The filters were oriented upward during exposure so that even the largest particles would be collected. However, a problem was encountered with the Millipore samples. Due to the smooth surface of the filter (0.45 µm pore size), particles larger than about 30 µm did not adhere to the filter surface but rolled off the filter during handling. The problem was discovered after the first batch of filters was analyzed and no large particles were found even on those filters exposed within 20 m of the source. Subsequent investigation of the capsules which contained the filters showed that larger particles were present but were no longer on the filter surface. It seems reasonable to assume that this problem has occurred before in other studies and possibly not recognized. WOW

The samples taken during the EDS Study were totally sealed in their capsules after exposure. After transporting and handling, the large particles—no longer attached to the filter surface, were still contained in the sealed capsule. As a result, a method was developed to recover these large particles.

TRC engaged Dr. Robert Kuryvial, an expert in particle analysis, to assist with the analyses of the Millipore filters. Dr. Kuryvial subsequently developed a procedure that enabled the particle size information to be recovered. First the filter was carefully removed from the capsule. The open end of the capsule was then placed on top of a piece of glassine (very smooth surface paper) and the capsule tapped vigorously. The bulk of the particles contained within the capsule were thus deposited on the paper. A Camel hairbrush was then utilized to brush out any remaining residue. The paper was then formed into a channel and the particles contained were carefully redistributed back onto the Millipore filter. definitely not randomly distributed

The Millipore filters prepared in this manner were then processed using microscopic techniques. Each filter was mounted on a glass slide, cleared in 1.56 refractive index oil and a slip cover added. Point counting traverses

were made across the mounts in which a total of up to 1,000 particles were sized for each sample. The microscope magnification was set at 500X.

Representative samples were taken from different types of tests and for several distances from the source. About 40 Millipore filters were chosen for the special analysis. The data show that a significant number of particles up to and exceeding 100 μm diameter are indeed present in the region between 20 m and 100 μm from the source. Particle size distributions resulting from the Millipore filter analysis are shown in Table 3.1.

The analytical procedure utilized to obtain deposition velocities from the particle size information is as follows:

The concentration of particles having diameters in the interval (i) is,

$$X_i = n_i \rho \frac{\pi}{6} d_i^3 \tag{3.2}$$

where ρ = density of particles;

d_i = mass mean diameter of size interval (i);

n_i = number of particles per m^3 with diameters in interval (i); and

X_i = concentration in g/m^3.

The total concentration is then

$$X = \sum_i X_i = \frac{\pi}{6} \rho \sum_i (n_i d_i^3) \tag{3.3}$$

Similarly, the mass of material with diameters in interval (i) which falls out of one cubic meter is given by

$$M_i = n_i \rho \frac{\pi}{6} d_i^3 V_i \tag{3.4}$$

where V_i is the settling velocity of particles with diameter (i) in m/sec.

TABLE 3.1 - PARTICLE SIZE DATA (Continued)

TEST CONDITION	SAMPLE NUMBER	DOWNWIND DISTANCE (m)	PARTICLE FRACTION IN DIAMETER INTERVAL (μm)										V_d (m/sec)
			<2	2-15	15-30	30-50	50-75	75-100	>100				
OVERBURDEN REPLACEMENT	45B	98	.70	.26	.016	.010	.014	0	0				0.27
TOPSOIL REMOVAL	50B	92	.91	.081	.001	.002	.001	.001	0				0.15
"	51B	177	.95	.053	0	0	0	0	0				0.08
"	52B	92	.94	.058	.001	.003	.001	0	0				0.14
"	53B	177	.95	.050	.002	.002	0	0	0				0.08
COAL HAULROAD	60B	23	.58	.39	.011	.011	.007	.004	0				0.33
COAL DUMP	61B	61	.95	.048	.003	.002	0	0	.001				0.53
OVERBURDEN HAULROAD	62B	69	.78	.21	.007	.004	0	0	0				0.07
COAL DUMP	63B	61	.84	.15	.010	.004	.001	.001	0				0.22
OVERBURDEN HAULROAD	64B	55	.89	.11	.002	0	0	.001	0				0.52
COAL HAULROAD	65B	152	.61	.36	.020	.007	0	0	0				0.06
"	66B	133	.47	.50	.022	.002	.003	.001	0				0.24
OVERBURDEN HAULROAD	31A	180	.89	.11	.005	.001	0	0	0				0.05

[redacted] CONSTRUCTION	[redacted] SAM[redacted] NUMBER	[redacted] DOWNWIND [redacted] DISTANCE (m)	[redacted] PAR[redacted]E F[redacted]IO[redacted] DI[redacted]ER [redacted]RV[redacted]m) [redacted]										[redacted] d (m/sec)
			<2	2-15	15-30	30-50	50-75	75-100	>100				
OVERBURDEN HAULROAD	33A	192	.87	.10	.010	.008	.008	0	0				0.27
COAL HAULROAD	35A	276	.72	.27	.006	.004	0	0	0				0.05
"	37A	142	.79	.20	.011	.003	0	0	0				0.05
"	39A	139	.61	.38	.004	.008	0	0	.004				0.03
OVERBURDEN REPLACEMENT	41A	122	.75	.21	.020	.007	.007	0	0				0.24
"	43A	122	.89	.10	.006	.003	.002	.001	0				0.39
			<2	2-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	
OVERBURDEN HAULROAD	30A	22	.67	.30	.011	.007	.004	.001	.001	0	.001	.002	0.62
"	32A	23	.55	.38	.027	.017	.007	.013	0	0	.003	.003	0.54
COAL HAULROAD	34A	133	.53	.45	.013	.005	.005	0	0	0	0	0	0.11
"	36A	24	.44	.46	.039	.021	.018	.012	0	.003	.003	0	0.29
"	38A 1	23	.53	.40	.054	.006	.003	.007	.003	.001	.001	.001	0.35
OVERBURDEN REPLACEMENT	40A	79	.51	.47	.015	.010	0	0	0	0	0	0	0.07

TABLE 3.1 - PARTICLE SIZE DATA (Continued)

TEST CONDITION	SAMPLE NUMBER	DOWNWIND DISTANCE (m)	PARTICLE FRACTION IN DIAMETER INTERVAL (μm)										V_d (m/sec)
			<2	2-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	
OVERBURDEN REPLACEMENT	42A	79	.71	.28	.010	.003	.001	0	.001	0	0	0	0.19
OVERBURDEN HAULROAD	44A	56	.76	.22	.010	.004	.001	0	0	0	0	0	0.10

The total deposition is therefore:

$$D = \sum_i M_i = \rho \frac{\pi}{6} \sum_i (n_i d_i^3 V_i) \tag{3.5}$$

where D is in $g/m^2 sec$.

Having computed concentration and deposition, it is then possible to compute a deposition velocity from equations (3.1), (3.3), and (3.5),

$$V_d = \frac{D}{\chi} = \frac{\sum_i (n_i d_i^3 V_i)}{\sum_i (n_i d_i^3)} \quad . \tag{3.6}$$

Now the number fraction of particles in diameter interval (i) is given by:

$$f_i = \frac{n_i}{N} \tag{3.7}$$

where N is the total number of particles in one cubic meter.

Substituting (3.7) and (3.6) we have,

$$V_d = \frac{\sum_i (f_i d_i^3 V_i)}{\sum_i (f_i d_i^3)} \quad . \tag{3.8}$$

Utilizing equation (3.8), deposition velocities may now be calculated from the size fraction data obtained from the measured particle size distributions. The settling velocities, V_i, were computed for each diameter interval and for three different particle densities utilizing the Stokes Method (White, 1971). The Stokes velocities obtained are given in Table 3.2.

TABLE 3.2

STOKES LAW SETTLING VELOCITY (m/sec)

PARTICLE DIAMETER (μm)	PARTICLE DENSITY (g/cm^3)		
	$\rho = 1.5$	$\rho = 2.0$	$\rho = 2.5$
2	.00018	.00024	.00030
10	.0046	.0061	.0076
25	.0286	.038	.048
40	.073	.097	.122
55	.138	.184	.230
65	.193	.257	.322
70	.224	.298	.373
85	.330	.44	.55
90	.370	.49	.62
100	.457	.61	.76
115	.604	.81	1.01
130	.772	1.03	1.29

NOTE: $\rho = 1.5$ was utilized for Coal Dump Samples;

$\rho = 2.0$ was utilized for Coal Haulroad Samples; and

$\rho = 2.5$ was utilized for All Other Tests.

An average density for coal is 1.5 g/cm^3 and an average density for surface material (clay, silica, granite) is 2.5 g/cm^3 (Hudson, 1939). Therefore, a particle density of 1.5 g/cm^3 is used for the coal dump tests and 2.5 g/cm^3 for the overburden haul road, the overburden replacement and the topsoil removal tests. The coal haul road emissions were assumed to be a combination of coal and road surface material, thus a particle density of 2.0 g/cm^3 was utilized for these tests.

After computing the deposition velocities for each Millipore sample utilizing equation (3.8), the results were multiplied by a factor of 0.66 to account for the nonspherical shape of the particles (Slade, 1968, p. 203). The results of the deposition velocity analysis are included in Table 3.1.

As in the previous case, the data were fitted by the method of least-squares to the functional form $V_d = ax^b$. In this case the direct fit to the data produces a curve that is in very good agreement with the function generated from the dustfall data, and predicts a deposition velocity of 0.024 m/sec at a distance of 1,000 m from the source. This result lends good support to the previous decision to force the fit to go through (1,000., 0.025) in order to make the deposition velocity fall into a realistic range at large distances.

In order to be consistent with the dustfall analytical method, the deposition velocities derived from particle size measurements were also fitted with the line constrained to pass through the point (1,000., 0.025). The resulting curve is shown by the solid line in Figure 3-3. In this case, the constrained curve is very close to the line obtained by direct fitting of the data (not shown).

The dotted line in Figure 3-3 is the deposition function derived from the dustfall data and shown in Figure 3-2. Note that there is a very good agreement between the deposition velocity function determined in the two different and independent ways.

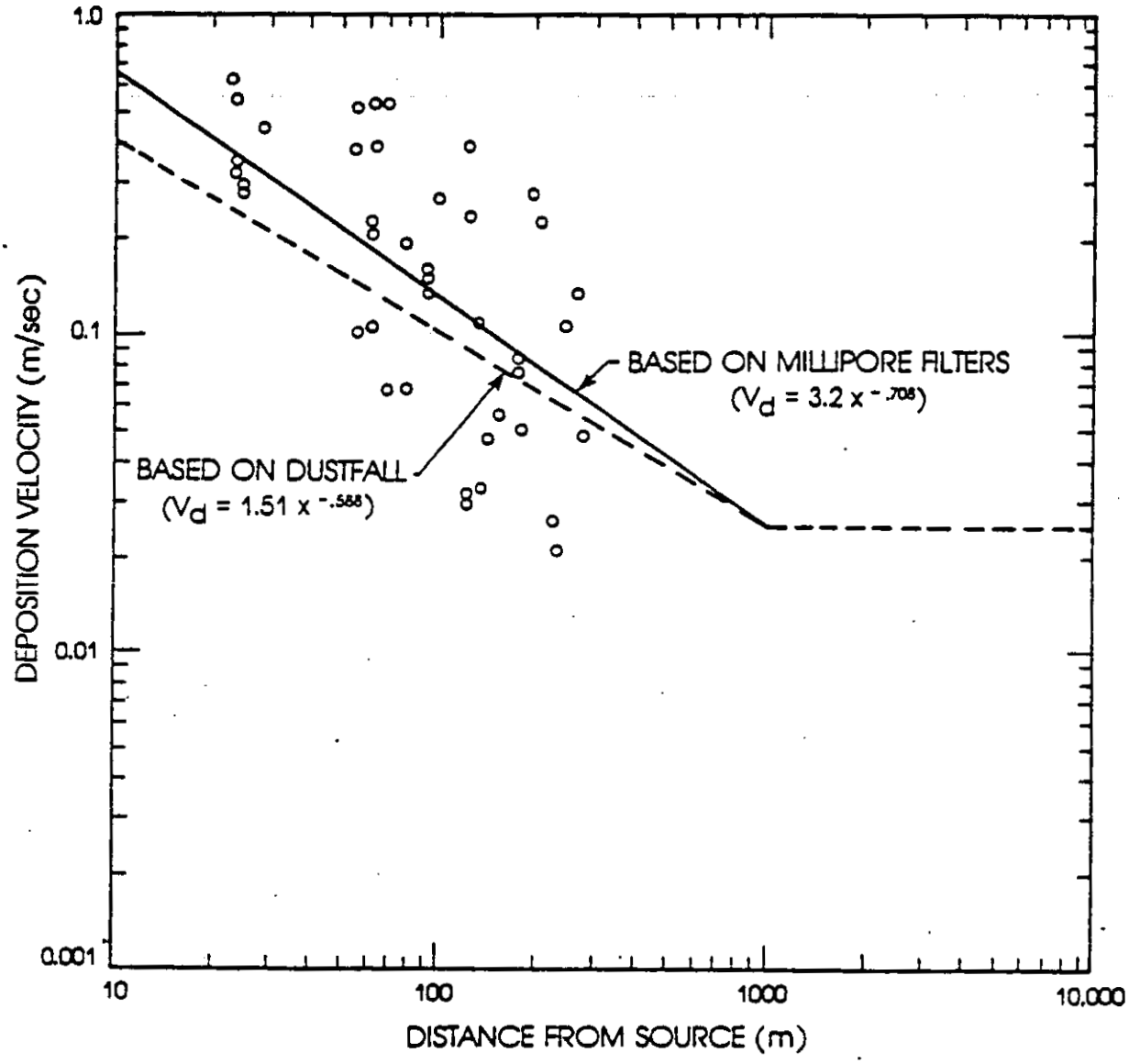

FIGURE 3-3 CHANGE OF EFFECTIVE DEPOSITION VELOCITY WITH DISTANCE FROM THE SOURCE FOR PARTICLE SIZE DATA AND STOKES LAW SETTLING VELOCITIES

The presence of large particles in emissions from the mine sources is thus well established and the settling of these particles in the first hundred meters is a process that should be considered when measuring and utilizing source emission factors. Since dustfall is a direct measure of deposition and since there was a great deal more of this information available than particle size distributions, it was judged best to utilize the deposition velocity curve associated with the dustfall measurements to develop the source depletion functions. The equation for the deposition velocity as given in Section 3.2 is,

$$V_d = 1.51(x)^{-.588} \quad . \tag{3.9}$$

3.4 APPARENT EMISSIONS AND SOURCE DEPLETION

Ordinarily, surface mining activities can not be contained and because of the nature of each activity it is necessary to make source determination measurements a short distance away. Due to the distance involved and the settling of large particles that occurs in that distance, the data collected will result in an "apparent" emission. This "apparent" emission will be lower than the actual emission in cases where large particles are involved and where settling of these large particles is significant. This is certainly the case in the EDS Study where dustfall and particle size measurements indicate large settling in the first few hundred meters. Settling has been identified and expressed in terms of the deposition velocity in Sections 3.2 and 3.3 above. The deposition velocity function to be utilized is the one given in Section 3.3.

Chamberlain (1953) has described a method for computing a source depletion relationship based upon deposition velocity. This source depletion approach is a technically acceptable way to deal with actual and "apparent" emissions as they apply in the EDS Study. In the original derivation, deposition velocity was treated as a constant because only suspended particles or gases were being considered. The EDS data, on the other hand, indicate that considerable settling is taking place and the resulting deposition velocity is a decreasing function with distance from the source. Therefore,

the Chamberlain method (Slade, 1968) must be modified to account for the varying deposition. (A derivation of the new source depletion factor is given in the appendices.) The resulting expression is:

Define symbols.

$$\frac{Q_x}{Q_o} = \exp\left\{\frac{-\sqrt{2/\pi}}{\bar{u}}\,\frac{a}{c}\left[\frac{(x + x_{virt})^{b-f+1} - (x)^{b-f+1}}{b-f+1}\right]\right\}. \qquad (3.10)$$

Figures 3-4 and 3-5 are plots of Q_x/Q_o for two different wind speeds and six stability classes. Note that the source depletion due to deposition can be very large close to the source, especially for light winds and a neutral to stable atmosphere.

Since deposition is clearly important close to the source, all the emission factor measurements have been corrected to zero distance utilizing the expression given in (3.10). This relationship will also be utilized in modeling the impact of particulates from the mining operations upon the environment.

In order to compute emission rates and source depletion values for the EDS tests, a Pasquill stability class was required. These were determined in each case by Turner's method utilizing wind speed, cloud cover and time of day (Turner, 1970).

3.5 GRAVITATIONAL SETTLING IN MODELING

Dispersion models that have provision for deposition require inputting particle size information. The Industrial Source Complex (ISC) Dispersion Model will accept particle mass fraction data, i.e., the source emissions broken down into fractions of the total mass that lie in various diameter ranges. In anticipation of modeling requirements, an average particle size distribution and a mass distribution have been developed from the particle size data.

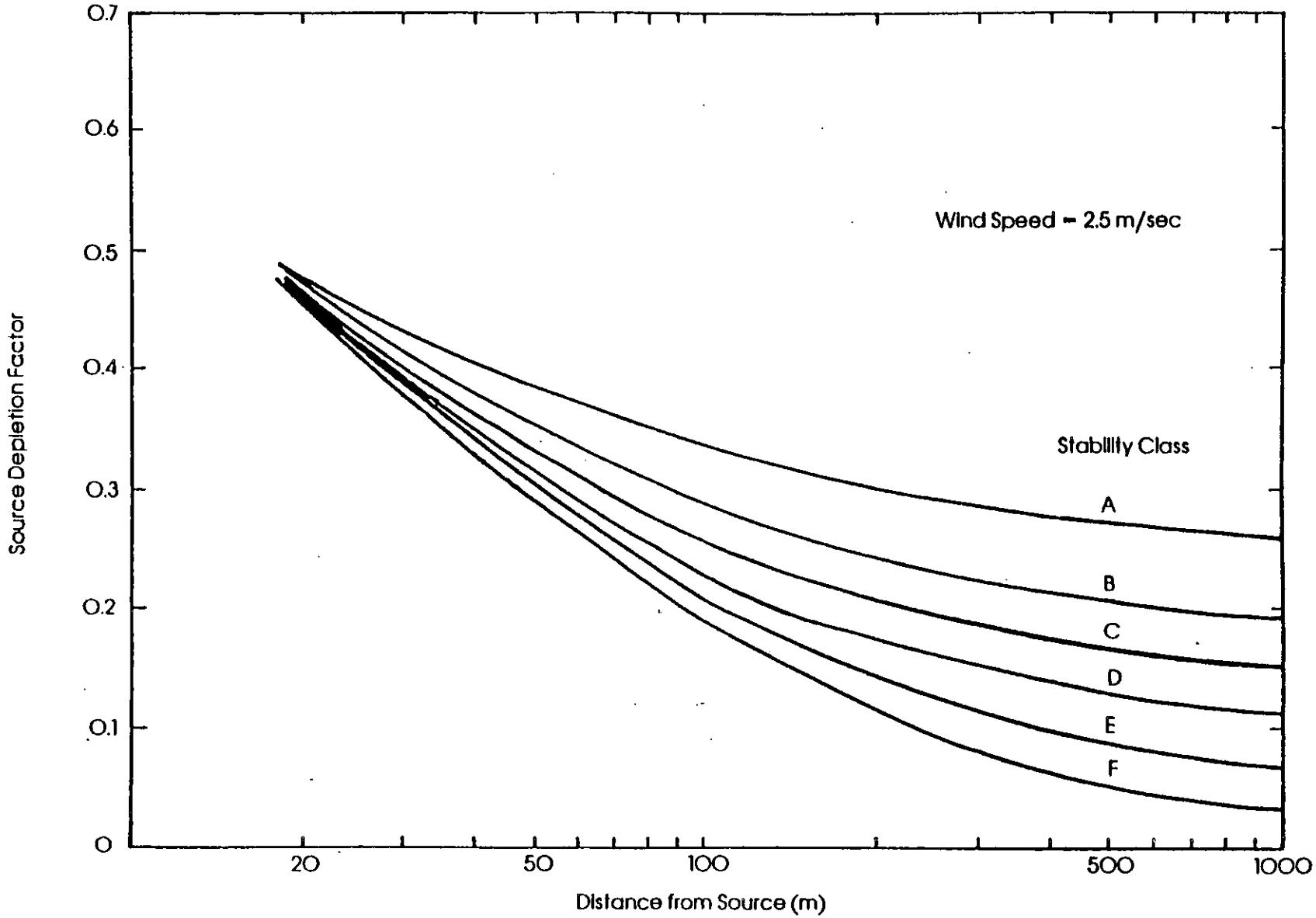

FIGURE 3-4 SOURCE DEPLETION FACTOR AS A FUNCTION OF DISTANCE FROM THE SOURCE AND ATMOSPHERIC STABILITY AT 2.5 m/sec WIND SPEED

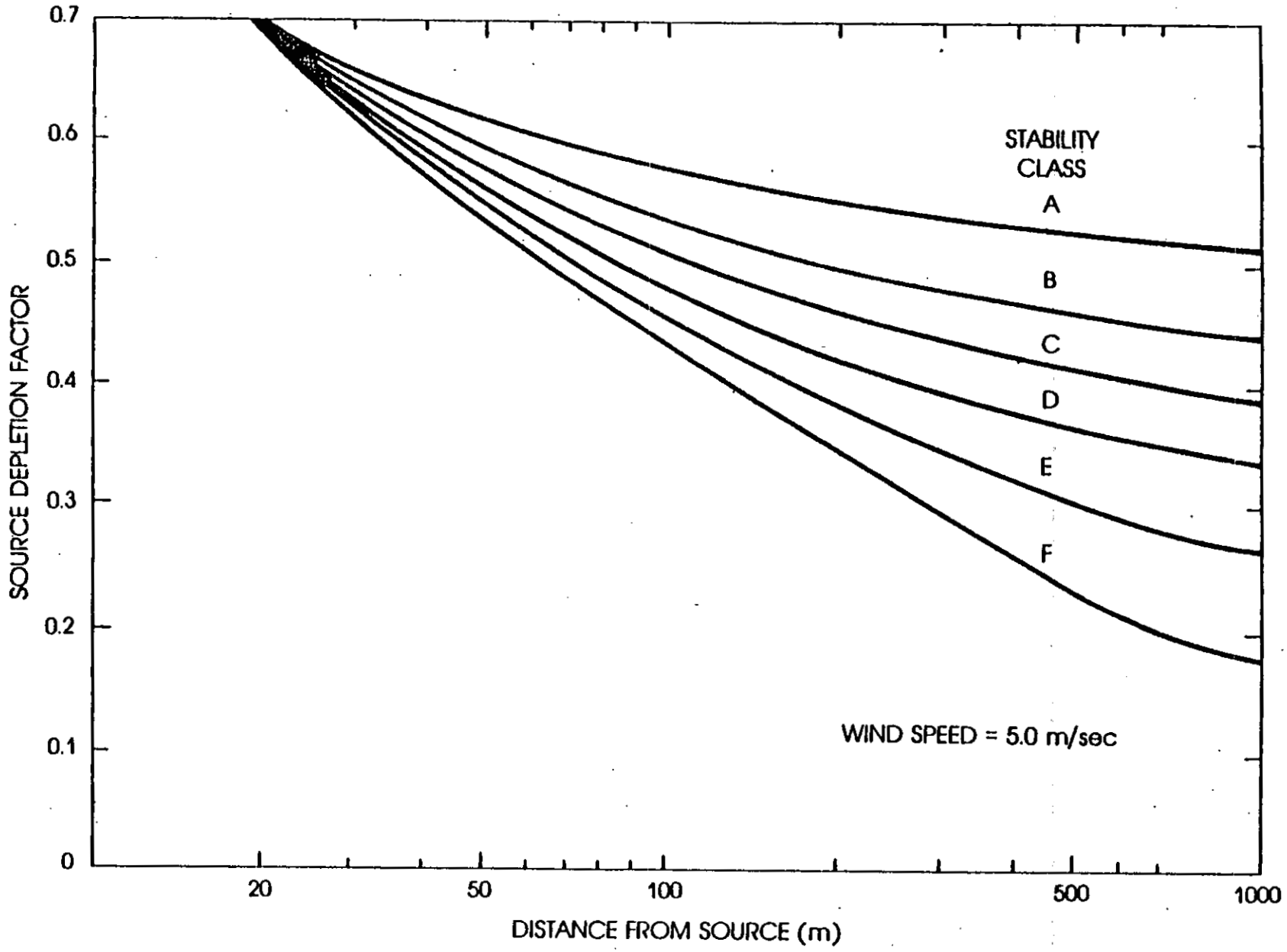

FIGURE 3-5 SOURCE DEPLETION FACTOR AS A FUNCTION OF DISTANCE FROM THE SOURCE AND ATMOSPHERIC STABILITY AT 5 m/sec WIND SPEED

In order to correctly simulate emissions at the source, only particle size data acquired close to the source should be utilized. The samples given in Table 3.1 that are judged satisfactory for this task are: 30A, 32A, 36A, 38A, 32B, 33B, and 60B.

Because of the problems encountered with the Millipore filter analysis, the individual size distributions are very irregular. Therefore, the data set was smoothed by averaging the size fractions in the various size ranges. The resulting distribution was then summed in a cumulative manner and the results utilized to generate the distribution shown in Figure 3-6.

As a cross check, a deposition velocity was calculated in the manner outlined in Section 3.3. The velocity obtained is 0.37 m/sec and agrees very well with the deposition velocity function derived in Section 3.3 and expressed in equation (3.9).

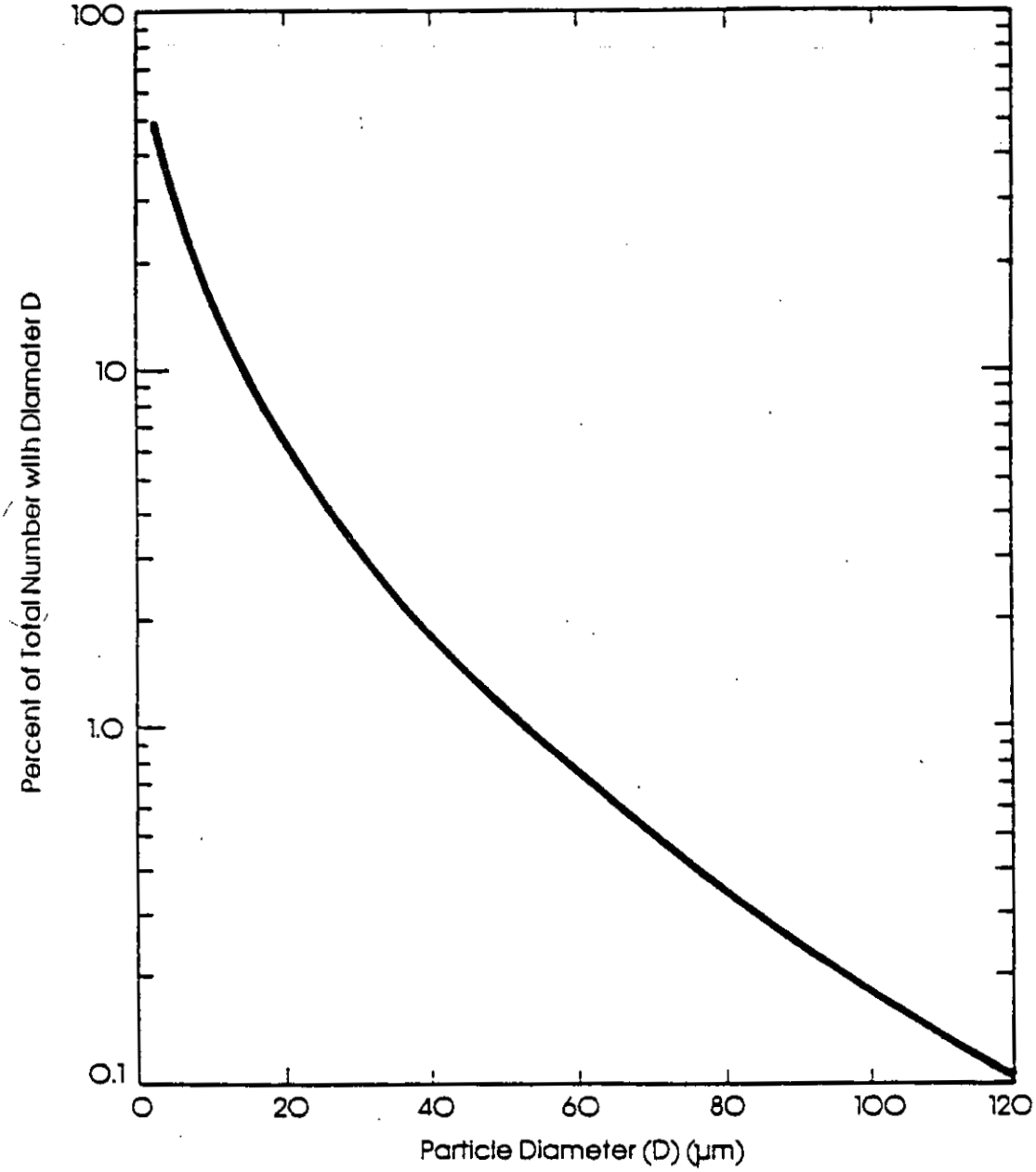

FIGURE 3-6 AVERAGE DISTRIUBTION OF PARTICLE SIZES FOR EDS EMISSIONS

SECTION 4

EMISSION FACTORS FOR COAL AND OVERBURDEN HAUL ROADS

4.0 EMISSION FACTORS FOR COAL AND OVERBURDEN HAUL ROADS

4.1 HAUL ROAD EMISSION MEASUREMENTS

It is generally accepted that coal and overburden haul roads are the largest source of emissions from surface coal mines. Therefore, it is most critical that an accurate emission factor be established for this source. The horizontal flux method provides a direct measure of emissions that does not require the use of dispersion equations. The test set-up is illustrated in Figure 4-1. Two towers are set up on the downwind side of the haul road and one tower on the upwind side. Hi-vol arrays are suspended from the towers in order to provide a measure of the vertical profiles of particulate concentrations upwind and downwind of the haul road. Wind measurements are made at the top and base of the tallest tower (Tower #3) to establish a vertical wind profile necessary for the horizontal flux computations.

The test procedure calls for one hour measurement periods wherein the average particulate concentration at the various tower levels are measured along with the wind speed and wind direction. A corresponding record is made of the number of haul truck passes, water truck passes, and the road surface condition prevailing during the test.

Assuming that the particulate plume is contained within the vertical extent of the downwind towers, the road emission can be computed as follows:

- At each tower, the vertical space is divided into layers centered on the hi-vol positions. Each hi-vol measurement is assumed to represent the average particulate concentration in that particular layer.

- The total horizontal flux of particulate matter through each layer is computed by multiplying the concentration for the layer by the layer thickness and the wind speed at that layer, i.e.,

$$f_i = X_i \, \Delta z_i \, \bar{u}_i \qquad (4.1)$$

where the units for f_i are g/m sec.

Idealized !

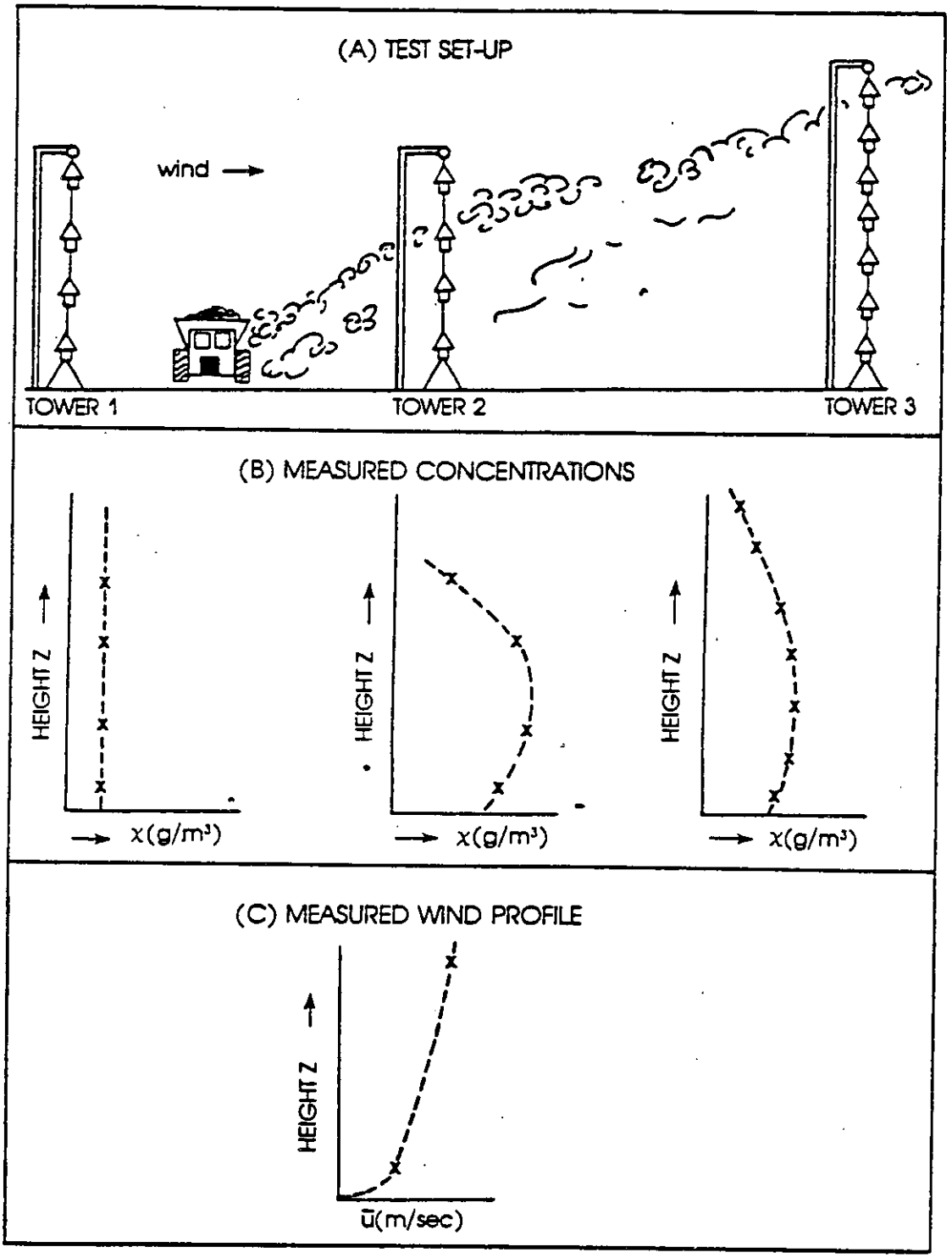

FIGURE 4-1 HAUL ROAD ANALYSIS AND SAMPLING TECHNIQUE

The total flux of particulates, F, intercepted by the tower is then obtained by summing the contributions from each of the layers involved.

- Having calculated the total fluxes through the two downwind towers, the haul road emission rates, as seen at Towers 2 and 3, are obtained by subtracting out the background flux through Tower 1. The background flux for Tower 3 is estimated by extending the upper concentration measured at Tower 1 to the height of Tower 3.

- Emission factors are obtained by multiplying the corrected fluxes by the number of seconds for the test, the number of meters in a mile, and dividing by the number of haul truck passages (N), e.g.,

$$E(g/VMT) = \frac{(F)(3600)(1609)}{N} \quad . \tag{4.2}$$

The emission factors, as defined above assume that the wind is blowing along the tower line and perpendicular to the road. If this is not the case, then corrections must be made to both the emission factor and the distance from the haul road to the measurement point. These corrections are as follows:

N.B Check

$$E_a = E_M \cos\theta \tag{4.3}$$

$$x = x_m/\cos\theta \tag{4.4}$$

where θ = angle between wind direction and the tower line, which is perpendicular to the road;

x_m = perpendicular distance from road to measurement point (m);

x = actual distance from emission point to measurement point (m);

E_m = measured emission factor (g/VMT); and

E_a = "apparent" emission factor (g/VMT).

Following the corrections made for wind direction, corrections must then be made for dry deposition and gravitational settling. Utilizing the actual distance, x, and the appropriate wind speed and stability class, the actual or zero distance emission factors are derived utilizing the procedures covered in Section 3. Table 4.1 shows all the haul road measurements obtained during the EDS Study complete with supporting data. The column headed Q_x gives the measured or "apparent" emission factor corrected for wind direction. The last column, Q_o, gives the emission factors corrected back to the source utilizing the source depletion factors. At the end of each set of tests, the averages are given along with the standard deviation for the set. All tests were run with vehicle speeds in the range of 22 to 24 mph.

Pedco! OLD MRI "Correct BACK"

Some of the tests experienced interference from a large source located upwind. In a few cases this interference was so large that it was not possible to remove the effect with any degree of confidence. In these cases an emission factor was not computed as indicated in the Table 4.1.

4.2 HAUL ROAD EMISSION CONTROL BY WATERING

It is apparent from observing haul road emissions over a period of time, that road surface moisture is the significant factor that governs the emissions. If the road surface is equally dry, it will emit as many particulates in the winter as in the summer. Furthermore, the source of existing surface moisture, whether from precipitation or from water trucks, appears to be immaterial.

In order to develop a relationship between the haul road emission factor and watering, some measure for the level of control was estimated. The method used, while not arbitrary, did require some judgment on the part of the observer. From field notes and personal observations it was judged that 6 water truck passes on the haul roads per hour, or 3 total coverages of the road, constituted a near maximum control effort. More watering than this would make the roads muddy and possibly slippery as well as creating a safety problem. Therefore, 3 total wettings of the road per hour was assigned a control factor of 1.0 or Full Practical Control, and of course, no watering is

TABLE 4.1 HAUL ROAD EMISSION FACTOR DATA

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/VMT)	DEPLETION FACTOR	Q_o (lb/VMT)
OVERBURDEN HAUL ROAD	1	T-3	270	3.1	C	1.14	0.27	4.22
CORDERO - WINTER	2	T-2	43	5.3	C	0.75	0.60	1.25
	3	T-2	50	4.9	C	1.10	0.56	1.96
	4	T-2	23	4.6	D	10.40	0.63	16.47
		T-3	192	4.6	D	3.03	0.39	7.77
	5	T-2	22	3.2	C	9.70	0.53	18.42
		T-3	180	3.2	C	9.40	0.30	31.33
	6	T-2	24	2.4	C	5.20	0.40	12.99
		T-3	201	2.4	C	4.85	0.19	25.53
	7	T-3	192	5.1	D	5.62	0.43	13.07
	8	T-3	227	5.2	D	10.50	0.42	25.0
	10	T-2	26	1.6	B	1.15	0.26	4.40
		T-3	212	1.6	B	2.21	0.11	20.09
MEAN FOR TESTS						5.0	0.36	14.0
STANDARD DEVIATION								9.8
OVERBURDEN HAUL ROAD	1	T-2	62	3.7	C	2.77	0.44	6.25
		T-3	264	3.7	C	2.42	0.33	7.33
CORDERÔ - SUMMER	2	T-2	69	3.3	B	3.98	0.41	9.64
		T-3	298	3.3	B	2.14	0.32	6.69
	3	T-2	57	4.5	C	1.47	0.40	3.66
		T-3	243	4.5	C	1.47	0.28	5.25
	4	T-2	57	4.5	C	7.44	0.52	14.31
		T-3	243	4.5	C	5.99	0.50	10.15
	5	T-2	23	3.68	B	0.67	0.57	1.18
		T-3	140	3.68	B	1.13	0.40	2.83
MEAN FOR TESTS						2.9	0.43	6.7
STANDARD DEVIATION								3.9

TABLE 4.1 HAUL ROAD EMISSION FACTOR DATA (Continued)

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/VMT)	DEPLETION FACTOR	Q_o (lb/VMT)
COAL HAUL ROAD	1	T-2	76	4.10	B	11.00	0.48	22.64
		T-3	161	4.10	B	9.10	0.43	21.16
CORDERO - SPRING	2	T-2	152	2.20	B	1.65	0.21	7.78
		T-3	317	2.20	B	2.10	0.18	11.60
	3	T-2	133	2.70	B	2.33	0.29	8.01
		T-3	276	2.70	B	1.03	0.25	4.06
	4	T-2	133	2.72	C	4.43	0.26	16.92
		T-3	276	2.70	C	3.98	0.22	18.34
	5	T-2	118	5.40	D	4.13	0.49	8.4
		T-3	246	5.40	D	4.25	0.43	9.88
	6	T-2	118	2.7	D	5.25	0.23	22.8
		T-3	246	2.7	D	4.15	0.18	23.1
MEAN FOR TESTS						4.4	0.30	14.6
STANDARD DEVIATION								6.9
COAL HAUL ROAD	1	T-2	24	7.6	D	9.10	0.75	12.06
		T-3	142	7.6	D	1.93	0.58	3.31
	2	T-2	23	7.3	D	2.51	0.75	3.35
		T-3	139	7.3	D	2.93	0.57	5.11
	3	T-2	23	8.6	D	11.14	0.78	14.22
		T-3	139	8.6	D	8.98	0.62	14.39
	4	T-2	25	3.5	B	9.82	0.54	18.18
		T-3	151	3.5	B	4.17	0.37	11.21
	5	T-2	23	3.7	B	7.86	0.57	13.76
		T-3	140	3.7	B	4.81	0.40	12.02
MEAN FOR TESTS						6.3	0.58	10.80
								5.10
HAUL ROAD SUMMARY								
MEAN FOR ALL TESTS						3.1	.27	11.5
STANDARD DEVIATION								7.4

0.0 Control. The haul road tests were then assigned a control factor related to the recorded number of total coverages of the road for each test.

Some of the tests had no watering but a degree of natural control was present due to weather, e.g., frozen surface, damp surface, rain, etc. Some judgments with regard to control factor were made in these instances. The information utilized to generate the final haul road emission expression is shown in Table 4.2. The column labeled "Measured Emissions", is the average of the measurements for each tower pair after being corrected for deposition depletion.

Figure 4-2 shows the plotted data with the least squares fitted curve. The correlation coefficient for the line is 0.67. The final emission factor expression for haul roads at zero distance is,

$$E = 22.0 - 5.47N \tag{4.5}$$

where E = emission factor (lb/VMT); and

N = number of road wettings per hour.

The standard deviation of the data about the line described by equation (4.5) is $\pm$ 5.6 lb/VMT compared with $\pm$ 7.7 lb/VMT for the whole data set irrespective of control effects.

4.3 OTHER HAUL ROAD EMISSION EFFECTS

In order to identify other possible effects on the haul road emissions, the watering or surface moisture control effects should first be removed. This can readily be done utilizing the haul road emission equation. Utilizing equation (4.5) the Zero Control Emission Factor E(0) for each data point given in Table 4.2 is

$$E(0) = E + 5.47N \tag{4.6}$$

where E is the measured emission factor.

TABLE 4.2

SUMMARY OF HAUL ROAD TESTS AND MEASUREMENTS

TEST	ROAD CONDITIONS	WATERING (COVERINGS PER HR.)	CONTROL FACTOR ESTIMATE	MEASURED EMISSIONS
OVERBURDEN HAUL ROAD - WINTER				
1	Road Frozen	0	1.0	4.2
2	Road Wet	0	1.0	1.3
3	Road Wet	0	1.0	2.0
4	Road Wet	0	0.5	16.5
	Road Wet	0	0.5	7.8
5	Road Dry	0.5	0.016	18.4
	Road Dry	0.5	0.016	31.3
6	Road Damp	0	0.5	13.0
	Road Damp	0	0.5	25.5
7	Road Damp	0	0.5	13.1
8	Road Damp	0	0.5	25.0
10	Road Damp	0	0.5	4.4
	Road Damp	0	0.5	20.1
OVERBURDEN HAUL ROAD - SUMMER				
1	Road Dry	2.0	0.67	6.3
	Road Dry	2.0	0.67	7.3
2	Road Dry	3.0	1.0	9.6
	Road Dry	3.0	1.0	6.7
3	Road Dry	2.5	0.83	3.7
	Road Dry	2.5	0.83	5.3
4	Road Dry	2.0	0.67	14.3
	Road Dry	2.0	0.67	10.1
5	Road Dry	2.0	0.67	1.2
	Road Dry	2.0	0.67	2.8

TABLE 4.2 (Continued)

SUMMARY OF HAUL ROAD TESTS AND MEASUREMENTS

TEST	ROAD CONDITIONS	WATERING (COVERAGES PER HR.)	CONTROL FACTOR ESTIMATE	MEASURED EMISSIONS
COAL HAUL ROAD - SPRING				
1	Road Dry	0.5	0.016	22.6
	Road Dry	0.5	0.016	21.2
2	Road Dry	3.0	1.0	7.8
	Road Dry	3.0	1.0	11.6
3	Road Dry	2.0	0.67	8.0
	Road Dry	2.0	0.67	4.1
4	Road Dry	1.0	0.33	16.9
	Road Dry	1.0	0.33	18.3
5	Light Rain-Road Wet	0	0.80	8.4
	Light Rain-Road Wet	0	0.80	9.9
6	Road Damp	0	0.50	22.8
	Road Damp	0	0.50	23.1
COAL HAUL ROAD - SUMMER				
1	Road Wet	0	0.80	12.1
	Road Wet	0	0.80	3.3
2	Road Dry	3.0	1.0	3.4
	Road Dry	3.0	1.0	5.1
3	Road Dry	0	0	14.2
	Road Dry	0	0	14.4
4	Road Dry	2.0	0.67	18.2
	Road Dry	2.0	0.67	11.2
5	Road Dry	2.5	0.83	13.8
	Road Dry	2.5	0.83	12.0

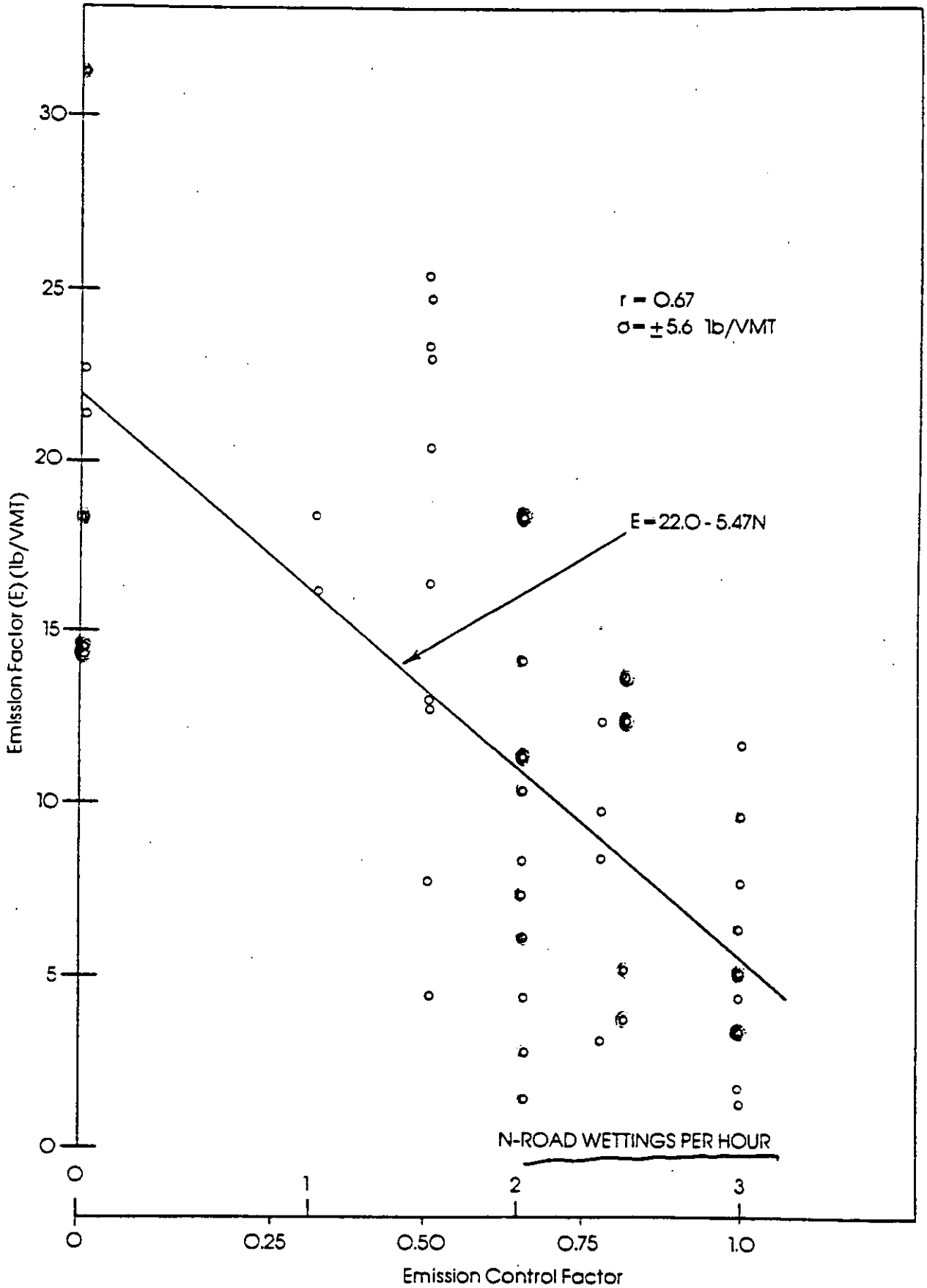

FIGURE 4-2 HAUL ROAD EMISSIONS AND ROAD SURFACE WETNESS

This new set of data was investigated for effects of wind speed, seasonal variability (other than surface moisture) and possible differences between the two types of haul roads. Plotting the individual test results as a function of wind speed showed that the correlation between emissions and wind speed is very low. Apparently, the action of the wheels and the vehicle wake are major factors in generating dust. There is some evidence that wind speed has a slight affect but this is so near the noise level of the measurements that it is not possible to identify the relationship with any degree of confidence. Differences in emissions between the two types of haul roads and variability with season are also below the noise level of the tests and appear not to be significant.

4.4 SILT CONTENT OF THE HAUL ROADS SURFACE

The emission factor expression for haul roads approved by the WDEQ contains a factor for the silt content of the road surface material. Therefore, in order to compare the EDS emission factor measurements with the state approved values, the silt content of the road surfaces was determined.

with coarse screens ?

Fourteen samples of the haul road surface material were taken and analyzed for silt content. A 200 mesh ASTM sieve was used to analyze all samples. The first six were taken in the summer and analyzed utilizing a wet screening process. These samples were taken from road surface material deposited at the edge of the road by the road grader and contained a large number of clay-silt agglomerates. The analyses showed silt contents that were much higher than the levels generally accepted for the region. Apparently the spill-out from the road grading process contains sub-surface material that is not truly representative of the road surface actually involved in the haul road emissions mechanism. ?

Eight more samples were taken during the Winter of 1979-80. These samples were obtained by sweeping the surface material from a strip across the road. Half of the samples were analyzed by the wet screening method as before,

and the other half were dry screened. The results of these latter tests were much different from the initial ones and much closer to accepted values of silt content. The test results on all the samples are shown in Table 4.3.

These data show that the method of sampling is more important than the screening process. The dry screened samples appear to give too low a silt content. The reason for this is believed to be due to "caking" of the material while being dried for screening. Drying was necessary because the samples contained a great deal of moisture. If it is assumed that the wet screened samples from the swept surface are the correct ones to use, the average silt content is 11.2 percent. On the other hand, if it is assumed that the dry screened samples give too low a result and the wet screened samples are too large, the overall average will be most representative. In this case the average silt content is 8.3 percent. The actual value probably lies somewhere between 8.3 and 11.2 percent. To try and identify silt content more closely would not be justified because the silt content is likely to vary this much from day to day with road maintenance.

?

Wet screening deagglomerates!

TABLE 4.3

HAUL ROAD SURFACE SILT CONTENT IN PERCENT

SAMPLING METHOD	ANALYSIS METHOD	COAL HAULROAD	OVERBURDEN HAULROAD
MATERIAL FROM SURFACE GRADING	WET SCREENING	25.8 24.3	36.8 44.9 37.4 39.3
MATERIAL SWEPT FROM SURFACE WITH BROOM	DRY SCREENING	6.0 8.1	2.3 4.9
	WET SCREENING	9.9 12.4	12.4 10.2

SECTION 5

EMISSION FACTORS FOR COAL DUMP AND TRAIN LOAD-OUT FACILITY

5.0 EMISSION FACTORS FOR COAL DUMP AND TRAIN LOAD-OUT FACILITY

5.1 COAL DUMP AND TRAIN LOAD-OUT EMISSION MEASUREMENTS

The coal dump and train load-out tests have been combined in this section because the same emission measurement method (the SF_6 tracer method) was utilized for both. The tracer method was chosen for the dumping and loading operations for several reasons. First, the area around the coal dump and train load-out facilities contains many buildings and structures. This complex terrain would certainly produce very nonuniform flow and subsequently a nonGaussian plume. Secondly, the coal dump facilities at both mines are located on the top of a high embankment. The slope of this embankment makes it unclear how one would treat the source elevation in a dispersion equation. Finally, the sources are fixed and localized enough to simulate with a point.

Location ?

The tracer measurement method involves simulation of the particulate source with a tracer gas source having a precisely known emission rate. Sulfurhexafluoride (SF_6) was chosen for the tracer because of its high detectability at very low concentrations and its very low ambient background levels.

A radial array of sampling stations was set up at 2 distances downwind of the source. The array was made large enough so that the plume centerline would be contained for a large variation in wind direction. The test set-up is shown in Figure 5-1. Hi-vol samplers, for measuring particulate concentrations, and SF_6 samplers were collocated at each sampling station. Before each test was begun, the SF_6 source was turned on and stabilized at a fixed flow-rate. During the test, air samples were collected in plastic bags by a battery powered sampler and corresponding hi-vol samples were obtained at each station. The air samples were analyzed for SF_6 concentration utilizing an electron capture gas chromatograph (GC). The SF_6 source emission rate was determined by weighing the SF_6 cylinder before and after the test and dividing the weight loss by the on-time.

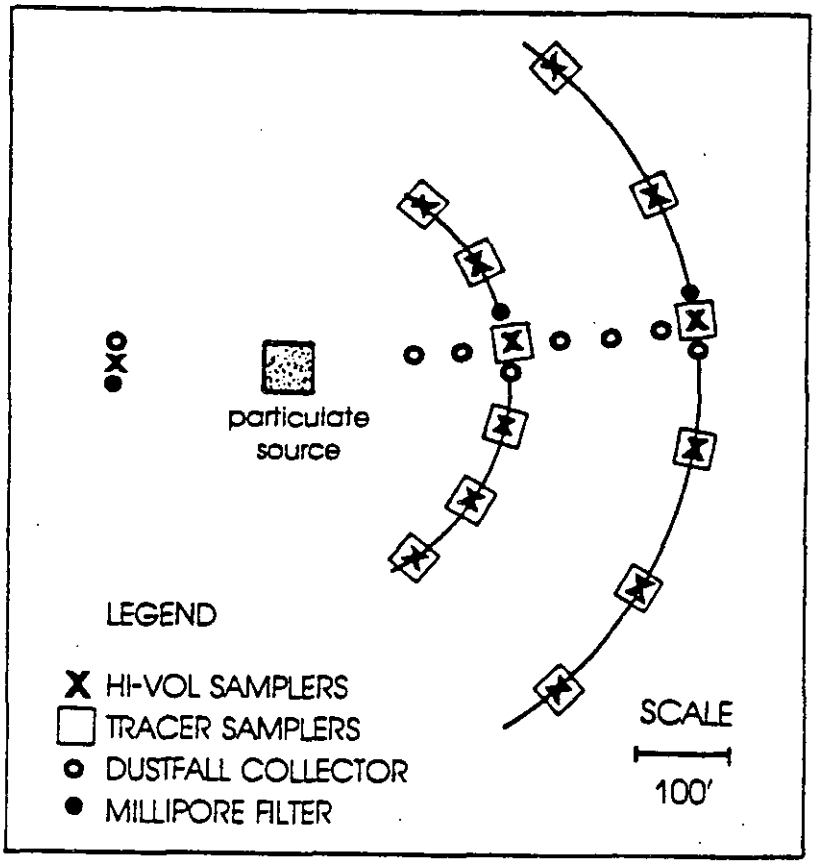

FIGURE 5-1 SAMPLING CONFIGURATION FOR THE TRACER SAMPLING METHOD

The tracer test method is based upon the premise that the particulate plume and the SF_6 plume are dispersed in the same way. This would only be true exactly for particles on the order of 20 μm and smaller. However, it is believed that the assumption is reasonably good for particles that are in the range recovered by a standard hi-vol. Assuming that the tracer gas and the particulate matter disperse in the same manner, it follows that at any given point in the plume downwind of the source, the ratio of the concentrations measured at that point should be the same as the ratio of the emission rates, i.e.,

$$\frac{X_p}{X_t} = \frac{Q_p}{Q_t} \tag{5.1}$$

where χ_p = measured particulate concentration (g/m^3);

χ_t = measured tracer concentration (g/m^3);

Q_d = particulate emission rate; and

Q_t = measured SF_6 emission rate.

With three of the parameters in (5.1) known, the particulate emission rate can be calculated.

5.2 THE TRACER TEST RESULTS

To demonstrate the characteristics of the data that were obtained in the tracer tests, the concentrations from two tests are shown in Figure 5-2. Figure 5-2(A) shows the results from Train Load Test No. 1 at Belle Ayr in the Fall of 1978. Lack of smoothness in the cross-wind particle concentrations is typical of these tests. However, the gross features of the measurements are in accord with dispersion theory. Figure 5-2(B) shows a case where there is obvious channeling of the plume. In this instance, it is believed that the berm along the edge of the embankment adjacent to the Coal Dump at Cordero is responsible for the narrow plume.

The results from all the tracer tests are given in Tables 5.1 and 5.2. All tests missing from Table 5.1 and Table 5.2 were dropped because of the failure to obtain an adequate sample volume for reliable SF_6 analysis.

There are several places in the tracer tests where errors could be introduced. First, the tracer point source test may not exactly simulate the dump zone, an area source. This condition would lead to an emission estimate that is too low. Secondly, large particles that are present in the plume may not all be sampled by the hi-vols. Again the data would lead to a low emission estimate. Finally, there is the possibility of contamination of the hi-vol array by nearby spurious sources other than the target source. In this latter case, the resulting error would be on the high side and tend to cancel the effects of the first two. While the extent to which each of these sources of error contributed to the measurements is unknown, it is helpful to understand that the errors are not additive.

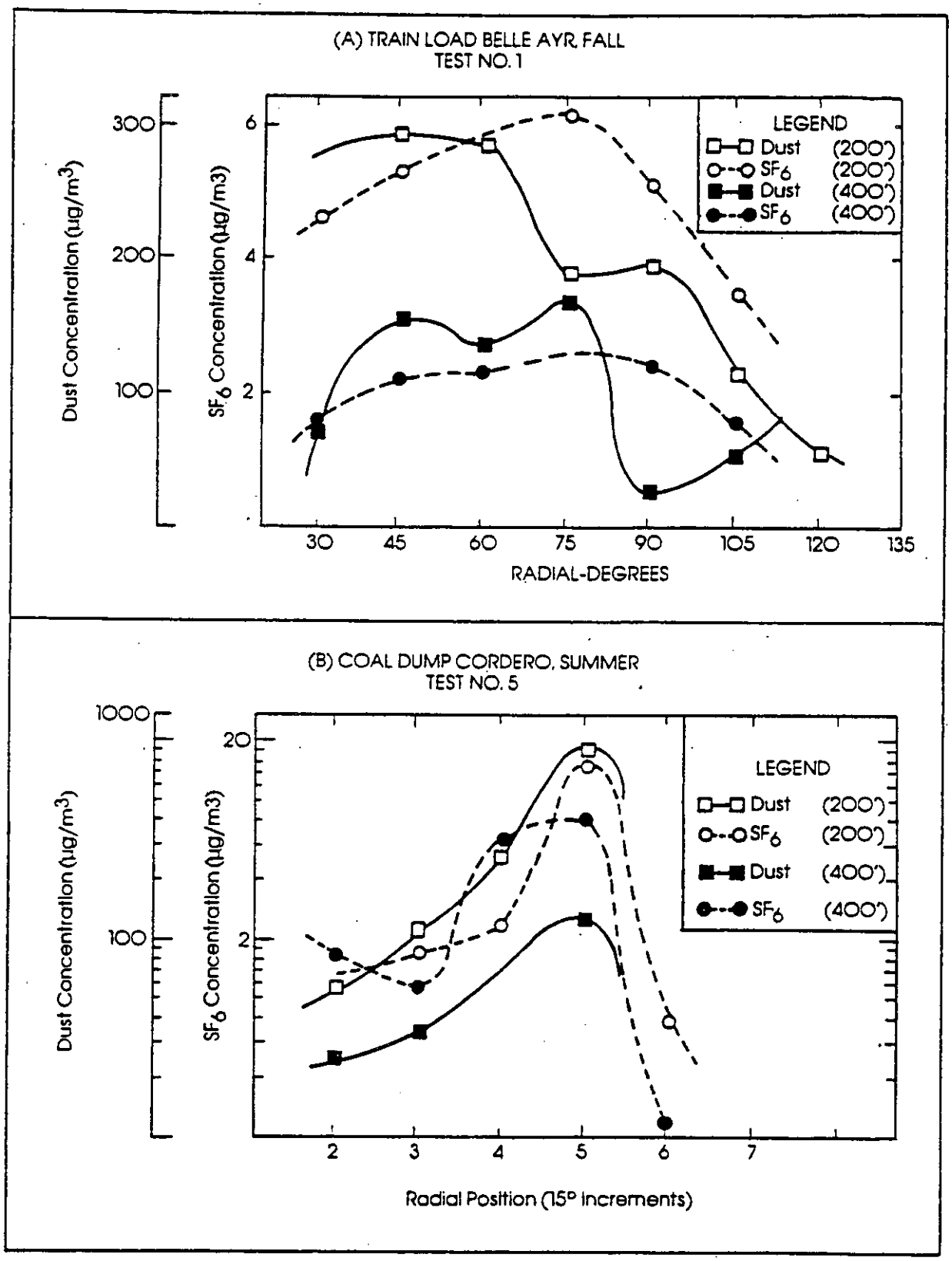

FIGURE 5-2 PARTICULATE AND TRACER CONCENTRATIONS AS A FUNCTION OF ANGULAR POSITION

TABLE 5.1 - COAL DUMPING EMISSION FACTOR DATA

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
COAL DUMPING CORDERO - FALL (Baghouse Not Working)	3	60-200	61	2.7	B	.0073	0.43	.017
		90-200	61	2.7	B	.0030	0.43	.007
		110-400	122	2.7	B	.0067	0.29	.024
MEAN FOR TESTS						.006	.38	.016
STANDARD DEVIATION								.009
COAL DUMPING CORDERO - SUMMER (Baghouse Operational)	1	2-200	61	3.4	C	.0035	0.41	.0085
		3-200	61	3.4	C	.0080	0.41	.0195
		4-200	61	3.4	C	.0046	0.41	.0110
		1-500	152	3.4	C	.0005	0.33	.0015
		2-500	152	3.4	C	.0015	0.33	.0045
		4-500	152	3.4	C	.0012	0.33	.0036
	2	3-200	61	2.7	B	.0023	0.35	.0066
		4-200	61	2.7	B	.0056	0.35	.0160
		5-200	61	2.7	B	.0028	0.35	.0080
		1-500	152	2.7	B	.0011	0.28	.0039
		2-500	152	2.7	B	.0090	0.28	.0320
		3-500	152	2.7	B	.0026	0.28	.0092
	3	1-200	61	3.1	B	.027	0.41	.066
		2-200	61	3.1	B	.019	0.41	.046
		4-200	61	3.1	B	.031	0.41	.076
		5-200	61	3.1	B	.013	0.41	.032
		5-400	122	3.1	B	.0063	0.35	.018
	4	2-200	61	3.1	B	.043	0.41	.105
		3-200	61	3.1	B	.058	0.41	.141
		5-200	61	3.1	B	.0099	0.41	.024
		3-400	122	3.1	B	.0047	0.35	.013
		4-400	122	3.1	B	.0042	0.35	.012
		5-400	122	3.1	B	.0120	0.35	.035
	5	2-200	61	2.2	B	.0056	0.28	.020
		3-200	61	2.2	B	.0162	0.28	.058
		4-200	61	2.2	B	.0175	0.28	.063
		5-200	61	2.2	B	.0075	0.28	.027
		6-200	61	2.2	B	.026	0.28	.093
		2-400	122	2.2	B	.0116	0.23	.050
		3-400	122	2.2	B	.0032	0.23	.014
		4-400	122	2.2	B	.0027	0.23	.012
		5-400	122	2.2	B	.0042	0.23	.018
	6	2-200	61	1.3	B	.0061	0.12	.051
		3-200	61	1.3	B	.0155	0.12	.129
		5-200	61	1.3	B	.0034	0.12	.028
		6-200	61	1.3	B	.0047	0.12	.039
MEAN FOR TESTS						.011	0.26	.043
STANDARD DEVIATION								.047

TABLE 5.1 - COAL DUMPING EMISSION FACTOR DATA (Continued)

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
COAL DUMPING BELLE AYR - WINTER (No Control)	2	120-200	61	1.3	B	.016	0.12	.133
		135-200	61	1.3	B	.016	0.12	.133
	3	075-200	61	2.1	B	.069	0.43	.160
		105-200	61	2.1	B	.018	0.43	.042
		120-200	61	2.1	B	.005	0.43	.012
MEAN FOR TESTS						.025	0.26	.096
STANDARD DEVIATION								.065
COAL DUMP SUMMARY (No Control) BELLE AYR - WINTER CORDERO - FALL								
MEAN FOR TEST						.018	0.27	.066
STANDARD DEVIATION								.064
(Control) CORDERO - SUMMER								
MEAN FOR TEST						.011	0.31	.036
STANLARD DEVIATION								.035

TABLE 5.2 - TRAIN LOADOUT EMISSION FACTOR DATA

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
TRAIN LOADOUT CORDERO - FALL	1	195-200	61	5.1	D	.014	.54	.026
		210-200	61	5.1	D	.016	.54	.030
		240-200	61	5.1	D	.008	.54	.015
		195-400	122	5.1	D	.013	.47	.028
		210-400	122	5.1	D	.012	.47	.026
MEAN FOR TEST						.012	.48	.025
STANDARD DEVIATION								.016
TRAIN LOADOUT BELLE AYR - FALL	1	45-200	61	1.8	B	.0034	.21	.016
		75-200	61	1.8	B	.0022	.21	.010
		90-200	61	1.8	B	.0056	.21	.027
		105-200	61	1.8	B	.0072	.21	.034
		30-400	122	1.8	B	.0092	.16	.058
		75-400	122	1.8	B	.0074	.16	.046
		90-400	122	1.8	B	.0012	.16	.008
MEAN FOR TEST						.005	.18	.028
STANDARD DEVIATION								.018
TRAIN LOAD SUMMARY								
MEAN FOR TEST						.009	.31	.027
STANDARD DEVIATION								.014

SECTION 6

EMISSION FACTORS FOR OVERBURDEN REPLACEMENT AND TOPSOIL REMOVAL

6.0 EMISSION FACTORS FOR OVERBURDEN REPLACEMENT AND TOPSOIL REMOVAL

6.1 OVERBURDEN REPLACEMENT AND TOPSOIL REMOVAL EMISSION MEASUREMENTS

Since the overburden replacement tests and the topsoil removal tests utilize the same upwind-downwind method of measurement, the test results are combined in this section. Figure 6-1 shows the basic test arrangement. Two rows of hi-vols are placed downwind of the source and one sample site is located outside of the influence of the source to measure background.

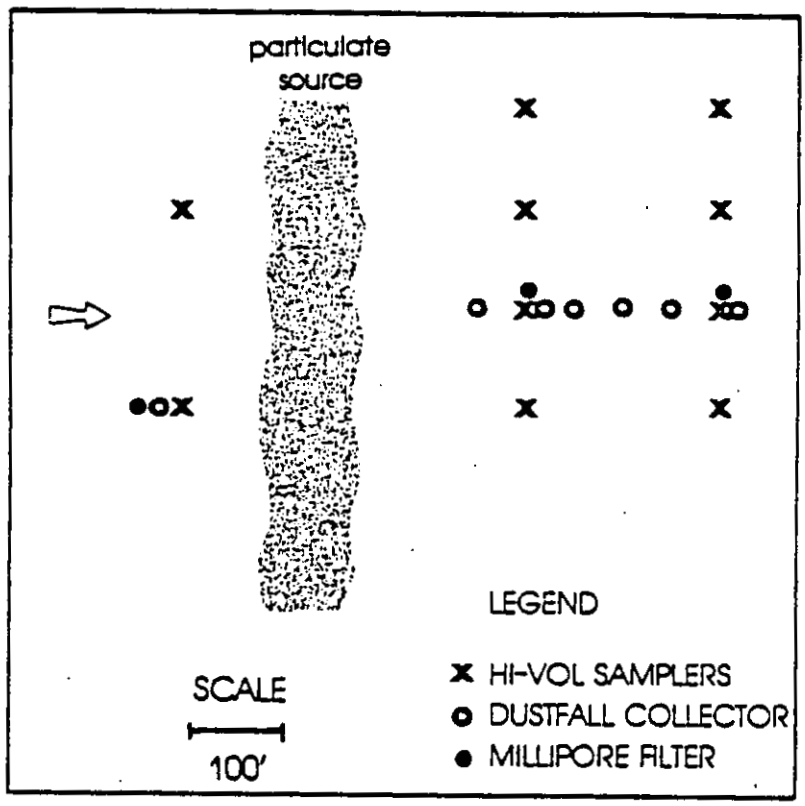

FIGURE 6-1 SAMPLING CONFIGURATION FOR UPWIND-DOWNWIND SAMPILNG METHOD

The tests were run for approximately one hour, with particulate concentrations being measured at each of the stations.

Emission factors were computed utilizing a dispersion equation for a finite line source. This equation is,

$$\chi(x,y,z,H) = \left\{\frac{Q}{\sqrt{2\pi}\ \sigma_z\ \bar{u}\ \sin\theta}\right\} \left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)\right]^2 + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)\right]^2\right\} \left\{\operatorname{erf}\left(\frac{y_1}{\sigma_y}\right) - \operatorname{erf}\left(\frac{y_2}{\sigma_y}\right)\right\} \tag{6.1}$$

where Q = emission rate ($g/m^2 sec$);

χ = particulate concentration at $(x, y, z)(g/m^3)$;

H = height of source (m);

z = dispersion coefficients (computed by method of Smith, 1973);

σ_y, σ_z = dispersion coefficients (computed by method of Smith, 1973);

y_1, y_2 = cross-wind end points of finite line;

$\bar{u}$ = wind speed (m/sec); and

θ = angle between line source and wind direction.

The analysis procedure was begun by first diagramming the test as in Figure 6-1 and establishing the wind direction relative to the test array. Coordinates of the various sampling points were then determined and the dispersion equation was solved for the "apparent" emission rate, Q_x, for each sampling point.

Before the concentration measurements were entered into the computation, background was removed by subtracting the concentration measured at the upwind station.

6.2 UPWIND-DOWNWIND TEST RESULTS

The emission factors obtained from the overburden replacement tests are given in Table 6.1 and the topsoil removal test results are shown in Table 6.2. Differences in the computed emissions between receptor points are believed to be due to departures from the assumptions made in the analysis method (i.e., nonuniform or nonGaussian plume), errors in establishing the dispersion coefficients, and departures of the real source from a true finite line source. Such problems are inherent due to the measurement and analytical methods. The variability between tests are due partly to errors in the measurements as discussed above and due partly to real variability in the source.

Emissions from shovel loading, overburden dumping, and scraper operations should be dependent upon a number of variables, such as, wind speed, wind direction relative to the operation, and moisture content of material being handled. The only one of these variables addressed during the EDS Study was wind speed. There does appear to be indications in the overburden replacement measurements that the wind speed is a factor. However, insufficient data were available to quantify the dependence of emissions on wind speed.

TABLE 6.1 - OVERBURDEN REPLACEMENT EMISSION FACTOR DATA

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
OVERBURDEN REPLACEMENT	1	2-1	52	1.7	B	5.39×10^{-5}	.19	.00028
		2-2	76	1.7	B	7.41×10^{-4}	.16	.0045
CORDERO - WINTER		2-3	104	1.7	B	7.23×10^{-4}	.15	.0050
		3-3	128	1.7	B	3.82×10^{-4}	.13	.0028
		4-2	120	1.7	B	5.80×10^{-4}	.14	.0042
	2	200-1	52	7.9	D	9.48×10^{-4}	.68	.0014
		200-2	67	7.9	D	4.74×10^{-3}	.66	.0072
		200-3	82	7.9	D	1.91×10^{-2}	.64	.029
		400-1	104	7.9	D	5.80×10^{-4}	.62	.0009
		400-2	120	7.9	D	2.95×10^{-4}	.61	.0005
		400-3	136	7.9	D	1.36×10^{-3}	.60	.0023
		400-4	152	7.9	D	6.89×10^{-3}	.59	.0117
MEAN FOR TEST						.003	.50	.0060
STANDARD DEVIATION								.008
OVERBURDEN REPLACEMENT	1	1	70	8.9	D	.016	.69	.023
		2	75	8.9	D	.010	.68	.015
		4	84	8.9	D	.011	.67	.017
CORDERO - SUMMER		5	88	8.9	D	.006	.67	.0089
		7	122	8.9	D	.0086	.60	.013
	2	1	70	6.7	D	.0098	.61	.016
		2	75	6.7	D	.018	.60	.029
		3	84	6.7	D	.014	.60	.024
		4	91	6.7	D	.011	.59	.019
		5	88	6.7	D	.0081	.58	.014
		6	91	6.7	D	.0037	.58	.0064
		7	122	6.7	D	.0048	.56	.0087
MEAN FOR TEST						.01	.63	.016
STANDARD DEVIATION								.007
OVERBURDEN REPLACEMENT	1	1	87	7.6	C	.0075	.65	.012
		2	91	7.6	C	.025	.64	.038
		3	98	7.6	C	.010	.64	.016
BELLE AYR - SPRING		4	101	7.6	C	.0026	.64	.004
	2	1	99	8.5	D	.017	.65	.027
		2	96	8.5	D	.0063	.65	.0097
		3	91	8.5	D	.0074	.65	.011
		4	88	8.5	D	.0012	.66	.0019
MEAN FOR TEST						.0096	.64	.015
STANDARD DEVIATION								.012

TABLE 6.1 - OVERBURDEN REPLACEMENT EMISSION FACTOR DATA (Continued)

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
OVERBURDEN REPLACEMENT	1	1	64	2.2	C	.005	.26	.020
		4	105	2.2	C	.00049	.21	.0023
		5	108	2.2	C	.00033	.21	.0016
BELLE AYR - SUMMER		6	110	2.2	C	.0022	.21	.010
		7	116	2.2	C	.0037	.21	.0178
MEAN FOR TEST						.0023	.23	.010
STANDARD DEVIATION								.008
OVERBURDEN REPLACEMENT SUMMARY								
MEAN FOR TEST						.006	.50	.012
STANDARD DEVIATION								.0095

TABLE 6.2 - TOPSOIL REMOVAL EMISSION FACTOR DATA

TEST TYPE AND LOCATION	TEST NO.	RECEPTOR LOCATION	DOWNWIND DISTANCE (m)	WIND SPEED (m/sec)	STABILITY CLASS	Q_x (lb/ton)	DEPLETION FACTOR	Q_o (lb/ton)
TOPSOIL REMOVAL	2	1	92	4.5	D	.065	.44	.148
		2	92	4.5	D	.022	.44	.050
BELLE AYR - SUMMER		3	92	4.5	D	.0067	.44	.015
		5	177	4.5	D	.018	.38	.047
		6	177	4.5	D	.027	.38	.071
	3	1	92	4.5	D	.037	.44	.084
		2	92	4.5	D	.012	.44	.027
		3	92	4.5	D	.012	.44	.027
		6	177	4.5	D	.021	.38	.055
TOPSOIL REMOVAL SUMMARY								
MEAN FOR TEST						.025	.42	.058
STANDARD DEVIATION								.04

SECTION 7

EMISSION FACTORS FOR WIND EROSION

7.0 EMISSION FACTORS FOR WIND EROSION

7.1 WIND EROSION EMISSION MEASUREMENTS

A series of 18 tests was run on areas of disturbed land at both the Belle Ayr and Cordero mines. Three kinds of exposed areas were tested: reclaimed or seeded land, stripped overburden, and graded overburden. The basic method of measurement involved setting up two lines of hi-vol receptors across the mean wind and with as large a separation distance as possible. The test set-up is shown in Figure 7-1. The tests were run for a duration of 1 to 2 hours.

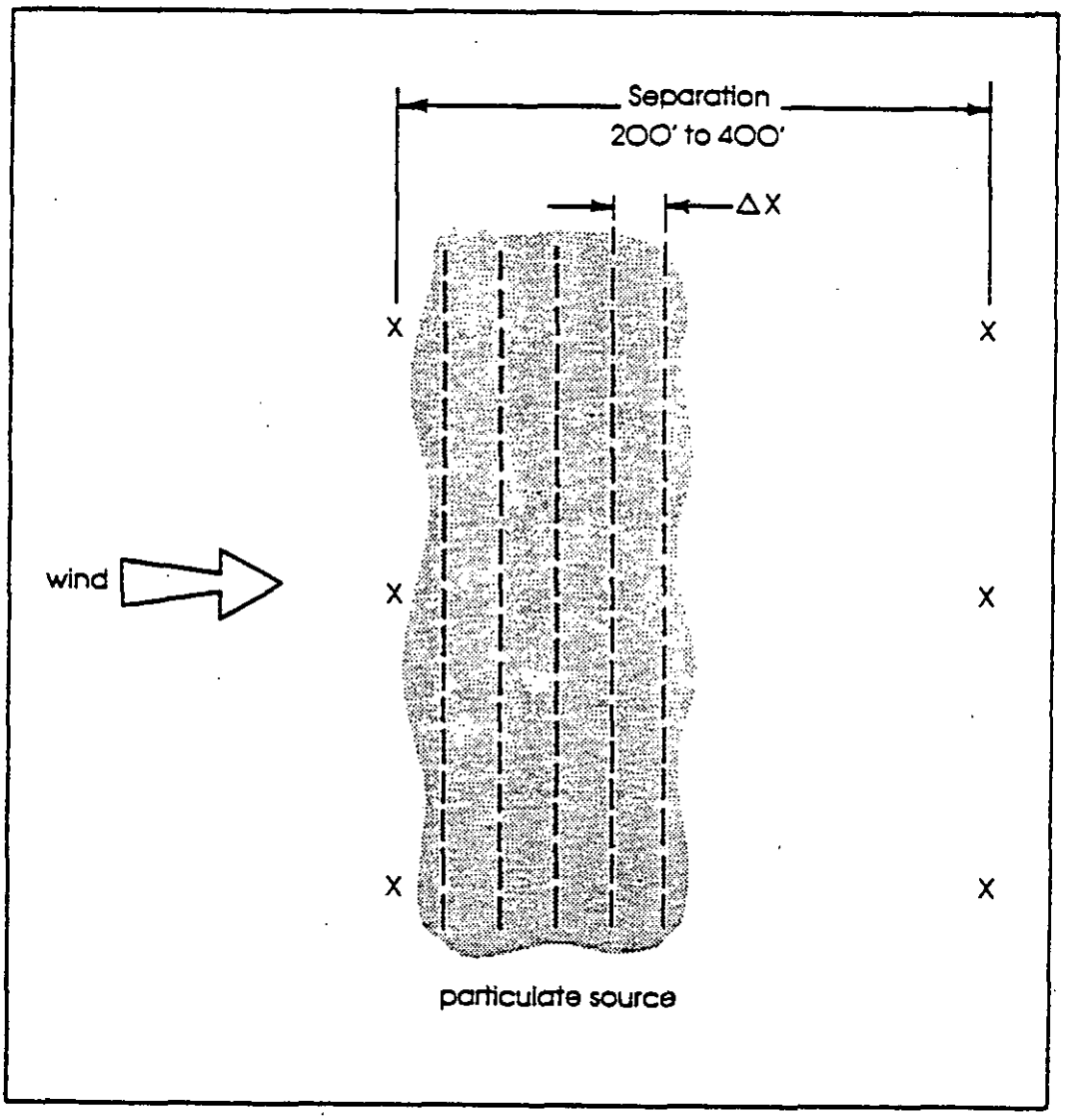

FIGURE 7-1 SAMPLER CONFIGURATION FOR WIND EROSION TESTS

Analysis of the test data is based upon simulating the area between the receptor lines with a set of infinite line sources. The difference in mean concentrations between the upwind and downwind lines is attributed to the source between the lines. The concentrations difference can be written as:

$$\chi(x,y,z,0) = \frac{\sqrt{2/\pi}\,Q}{\bar{u}}\left[\sum_{i}^{n}\frac{1}{\sigma_z}\exp\left(-\frac{z^2}{2\sigma_z^2}\right)\right]\Delta x \qquad (7.1)$$

and

$$Q = \frac{\chi\ \sqrt{\pi/2}\ \bar{u}}{\left[\sum_{i}^{n}\frac{1}{\sigma_z}\ \exp\left(-\frac{z^2}{2\sigma_z^2}\right)\right]\Delta x} \qquad (7.2)$$

where u = mean wind speed;

Q = area source strength;

χ = difference in concentration between upwind and downwind lines;

z = receptor height;

σ_z = vertical dispersion coefficient;

Δx = width of strip simulated by line source; and

n = number of line sources.

7.2 WIND EROSION TEST RESULTS

Results of the 18 tests are given in Table 7.1. The variability in the measurements and the absence of good correlation with wind speed are symptoms of the lack of sensitivity of the test method. The small differences between upwind and downwind concentrations produced by wind erosion emissions were generally of the same order of magnitude as the variability inherent in hi-vol measurements. As a result, measurement accuracy is low. The probable error limits for each test are included in Table 7.1. Probable error is defined as the error limits that correspond to the 50 percent confidence levels.

TABLE 7.1

WIND EROSION TEST RESULTS

TEST	TEST NO.	WIND SPEED (m/sec)	EMISSION (ton/acre yr)	PROBABLE ERROR (ton/acre yr)
BELLE AYR - SPRING				
STRIPPED OVERBURDEN	1	3.4	0.27	± 0.29
	2	4.0	2.10	± 5.46
RECLAIMED LAND	1	5.6	0.62	± 0.42
	2	4.5	0	-
CORDERO - SPRING				
GRADED OVERBURDEN	1	4.5	0	-
	2	4.5	0	-
RECLAIMED LAND	1	4.5	0	-
	2	4.5	0.36	± 0.15
BELLE AYR - SUMMER				
STRIPPED OVERBURDEN	1	5.6	0.50	± 0.92
	2	5.6	0	-
RECLAIMED LAND	1	7.8	0.24	± 1.82
	2	7.8	2.50	± 1.14
CORDERO - SUMMER				
GRADED OVERBURDEN	1	2.8	0	-
	2	2.7	0.25	± 0.36
	3	6.7	0	-
	4	6.7	0	-
RECLAIMED LAND	1	2.7	0	-
	2	2.4	0	-
AVERAGE			0.38	
STANDARD DEVIATION			0.73	

The method used to estimate the probable errors, listed in Table 7.1, is described below. First, the standard deviation of the concentration measurements were computed for each test. Then, the fractional error at the 50 percent confidence level was computed utilizing the method to be discussed in Section 9, i.e.,

$$f = \frac{\pm\, t(.75)s}{\bar{X}\sqrt{n-1}} \tag{7.3}$$

where X = mean concentration (g/m^3);

n = number of hi-vol measurements;

s = standard deviation of concentration measurements (g/m^3); and

$t(.75)$ = Students' t distribution, 75 percentile value.

The fraction error obtained in this way is doubled (to account for errors in both upwind and downwind measurements) and multiplied on the average concentration to get a concentration difference error. The concentration is then converted to tons/acre/yr utilizing equation (7.2). In most cases the probable error approaches or exceeds the emission rate estimate itself.

While individual tests have a low confidence level, the overall mean for the test set should be an indicator of the magnitude of wind erosion emissions. The mean value is 0.38 tons/acre/yr with a standard deviation of 0.73 tons/acre/yr. The average wind speed for the data set is 4.7 m/sec.

The expression used by the WDEQ for estimating wind erosion is:

$$E = AICKL'V' \tag{7.4}$$

where E = emission rate (tons/acre/yr);

K = ground surface roughness factor, varies from 0.5 to 1.0, 1.0 is normally used (unitless);

L' = unsheltered field width factor = 1.0 for 2000 ft or greater (unitless);

V' = vegetative cover factor = 1.0 (unitless);

I = soil erodibility = clay loam (tons/acre/yr);

A = portion of losses which become suspended = 0.025 for clay loam; and

C = climatic factor.

Utilizing equation (7.4), the emission rate obtained for 4.7 m/sec wind speed is 1.67 tons/acre/yr. Thus, the wind erosion measurements suggest that the actual wind erosion emissions are two to three times smaller than that obtained utilizing the emission factor currently in use by the WDEQ.

During the field test period it was observed that a thin crust would form on all soil after the first rain. This was most likely due to the high clay content of the soil. The crust appears to be very effective in stabilizing the surface against wind erosion except under very high wind conditions.

SECTION 8

EMISSION FACTORS FOR WHOLE MINE

8.0 EMISSION FACTORS FOR WHOLE MINE

8.1 WHOLE MINE EMISSION MEASUREMENTS

As part of the overall EDS Study, hi-vol arrays were set up around the periphery of each mine with the objective of obtaining measurements of the whole mine emission rates. The tests were run for 2 six hour periods each day, for 6 days at each mine, and for each of the four seasons. The basic set-up for the hi-vol arrays took the form of 5 radials spaced from northwest through south with an upwind sampler located southwest of the pit area. The radials consisted of an inner sampler located approximately 300 m from the pit and an outer site located about 500 m to 600 m from the pit. The peripheral sampling arrays for each mine are shown in Figure 8-1. The sampling array was set up to contain all the mining activity within the array.

A modeling approach is necessary to analyze the measurements collected by the peripheral hi-vol network, since the mining operation as a whole is too complex to make use of a simple dispersion equation for computing the source emissions. The peripheral tests were only six hours long, consequently, a short-term model is required. The Point, Area, and Line Source (PAL) dispersion model was chosen for the task because it is designed to handle the kind of sources involved and because it is accepted by the WDEQ.

The PAL model is not designed to work backward from a concentration measurement to an emission rate. Therefore, a method had to be developed to make this step.

The method used was to run the model with chosen values for emission rates and then compute the actual emission rates from the input-output ratios. Justification for this approach is based upon consideration of the dispersion process. The ratio of χ/Q is constant for given source to receptor spacing and given atmospheric conditions. Therefore, if Q_I and χ_o are the

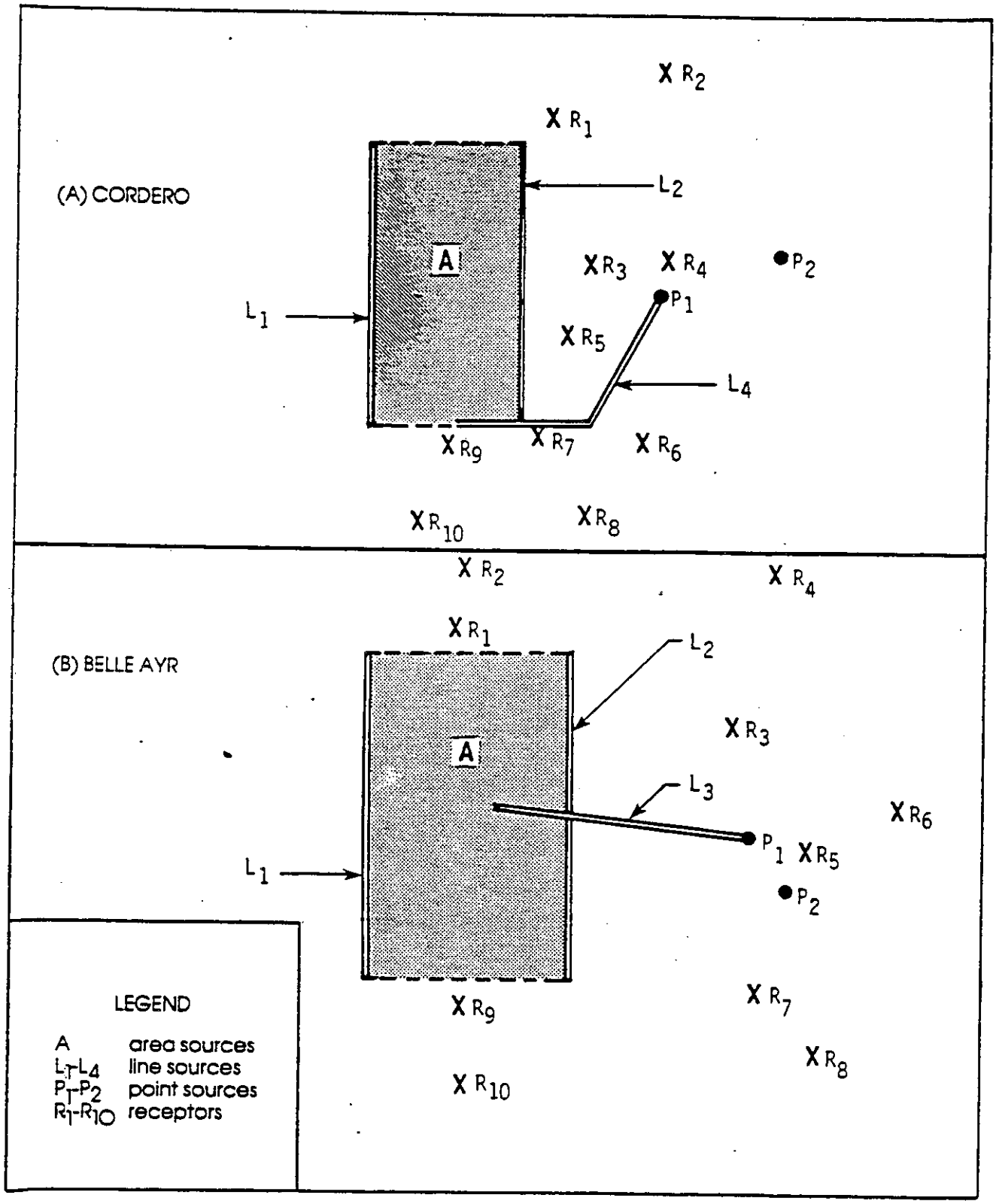

FIGURE 8-1 MINE MODELS

model input emission rate and the output concentration respectively, then the actual emission rate, Q_x, can be computed from the relationship

$$Q_x = \frac{Q_I}{\chi_o} \chi_M \tag{8.1}$$

where χ_M = measured concentration at the receptor being considered, corrected to remove background concentrations.

Each of the two mines (Belle Ayr and Cordero) is represented by simplified models consisting of an area source (the pit), several line sources (haul roads), and two point sources (the coal dump and train load-out facilities). Diagrams of the two mine models are shown in Figure 8-1.

The PAL model was run for each of the 6 hour tests conducted at each mine. Then, applying equation (8.1), an "apparent" mine emission rate Q_x was derived for each receptor location and each test period. Generally, 4 to 5 values for Q_x are obtained for a given test. These values are averaged to give a single "apparent" mine emission rate representing the test period. The term "apparent" emission rate is used here because the estimate of Q_x obtained is the emission as seen at the receptor and is somewhat smaller than the actual emission at the source because of deposition. Deposition will be treated later (Section 8.2).

A sample of the PAL model input and output for a single test is given in Figure 8-2. The test shown is for the Cordero Mine, Spring--Sequence 11. A sample computation for the test shown is given in Table 8.1.

8.2 CORRECTION FOR DEPOSITION

While the PAL model does not have provision for deposition, the results obtained through the modeling task can be adjusted for deposition. Since the

```
:ORDERO INPUT FOR PAL TO CALC. MINE EMISSION FACTOR                                    VERSION 78001
'INA =     .02000 PINL =     .02000
                SOURCE      WIND INCREASE
               INCLUDED     WITH  HEIGHT
  POINT          YES           YES
  AREA           YES           YES
'ORIZONTAL
 INE SOURCE      YES           YES
   CURVE
'ATH SOURCE       NO            NO
 SPECIAL
 INE SOURCE       NO            NO
 SPECIAL
 ATH SOURCE       NO            NO          AVERAGE     YES   DIURNAL    NO     HEIGHT AT WIND SPEED   10.0 METERS
* * P O I N T   S O U R C E S * * *
    NO.    POINT     PHYSICAL    STACK     STACK     STACK     VOLUME      COORDINATES        INITIAL SIGMAS
           SOURCE    HEIGHT      TEMP      GAS       DIAMETER  FLOW        EAST     NORTH     Y        Z
          STRENGTH   (METERS)    (DEG-K)   VELOCITY  (METERS)  (CU M/SEC)  (KM)     (KM)      (M)      (M)
           (G/SEC)                          (M/SEC)
    1       2.00       3.0       294.0      .00       .00       0.00       .975     .457     11.4      1.4
    2       2.00       3.0       294.0      .00       .00       0.00      1.402     .580     11.4      1.4
* * A R E A   S O U R C E S * * *
    NO.    AREA      AREA        COORDINATES        AREA SIZE
          SOURCE    SOURCE       SW-CORNER
         STRENGTH   HEIGHT      EAST     NORTH   EAST-WEST NORTH-SOUTH
       (G/SEC-M**2) (METERS)     (KM)     (KM)     (KM)      (KM)
    1   .00000500     0.0        .030     0.000    .550      1.005
* * H O R I Z O N T A L   L I N E   S O U R C E S * * *
    NO.    LINE      LINE        COORDINATES
          SOURCE    SOURCE       POINT A          POINT B          INITIAL SIGMAS                NO.    TOTAL    MEDIAN
         STRENGTH   HEIGHT      EAST     NORTH    EAST     NORTH    Y        Z                    OF     WIDTH    WIDTH
        (G/SEC-M)   (METERS)    (KM)     (KM)     (KM)     (KM)     (M)      (M)                  LANES  (METERS) (METERS
    1   .00050000     3.0       0.000    0.000    0.000    1.005    7.00     4.00
    2   .00050000     3.0        .500    0.000     .500    1.005    7.00     4.00
    3   .00050000     3.0        .300    0.000     .732    0.000    7.00     4.00
    4   .00050000     3.0        .732    0.000     .975     .457    7.00     4.00

* * R E C E P T O R S * * *
    NO.    RREC(KM)  SREC(KM)    Z (M)
     1      .244     1.036       2.4
     2      .305     1.341       2.4
     3      .762      .550       2.4
     4     1.098      .670       2.4
     5      .686      .305       2.4
     6      .930     -.070       2.4
     7      .564     -.060       2.4
     8      .747     -.305       2.4
     9      .290     -.070       2.4
    10      .152     -.335       2.4
* * M E T E O R O L O G Y * * *
    NO.  THETA(DEG)   U (M/SEC)   KST   HL (M)  T (DEG-K)        DIURNAL VARIATIONS (FRACTIONS OF GIVEN R)
                                                                 POINT    AREA    HORIZONAL  CURVED   SPECIAL  SPECIAL
                                                                                  LINE       PATH     LINE     PATH
     1.     300.      8.9        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000
     2.     310.      8.5        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000
     3.     295.      8.1        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000
     4.     285.      8.5        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000
     5.     275.      7.6        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000
     6.     315.      8.1        3     1400.      0.            1.0000   1.0000  1.0000     1.0000   1.0000   1.0000

AVERAGE CONCENTRATIONS FOR   6 HOURS.
* * C O N C E N T R A T I O N S   A T   R E C E P T O R S * * *
   CONCENTRATIONS IN GRAMS PER CUBIC METER                                  FROM      FROM      FROM
HOUR RECEPTOR    RECEPTOR COORDINATES    FROM      FROM      FROM      CURVED    SPECIAL   SPECIAL
       NO.     EAST     NORTH    HEIGHT  POINTS    AREAS     HORIZONAL PATHS     LINES     PATHS     TOTAL
                                                              LINES
  0    1        .244    1.036    2.40     0.       5.584E-08 3.301E-08 0.        0.        0.        8.988E-08
  0    2        .305    1.341    2.40     0.       0.        5.517E-29 0.        0.        0.        5.517E-29
  0    3        .762     .550    2.40     0.       7.478E-05 1.595E-06 0.        0.        0.        7.937E-05
  0    4       1.098     .670    2.40     7.003E-25 2.014E-05 1.323E-06 0.        0.        0.        2.146E-05
  0    5        .686     .305    2.40     0.       1.058E-04 6.721E-06 0.        0.        0.        1.125E-04
  0    6        .930    -.070    2.40     5.576E-21 5.155E-05 7.545E-06 0.        0.        0.        5.910E-05
  0    7        .564    -.060    2.40     0.       7.929E-05 8.919E-06 0.        0.        0.        8.821E-05
  0    8        .747    -.305    2.40     0.       2.103E-05 1.747E-06 0.        0.        0.        2.278E-05
  0    9        .290    -.070    2.40     0.       3.618E-05 2.111E-06 0.        0.        0.        3.829E-05
  0   10        .152    -.335    2.40     0.       0.        1.511E-09 0.        0.        0.        1.511E-09
```

FIGURE 8-2 - SAMPLE PAL MODEL INPUT - OUTPUT
CORDERO - SPRING SEQUENCE 11

TABLE 8.1

SAMPLE COMPUTATION OF THE APPARENT MINE EMISSION RATE

RECEPTOR	X_M g/m^3	X_o g/m^3	Q_I g/sec	Q_s g/sec
1	-	-	-	-
2	-	-	-	-
3	1.21×10^{-4}	7.94×10^{-5}	8.25	1.26
4	2.04×10^{-5}	2.15×10^{-5}	8.25	7.83
5	2.39×10^{-4}	1.13×10^{-4}	8.25	17.52
6	8.24×10^{-5}	5.91×10^{-5}	8.25	11.50
7	1.43×10^{-4}	8.82×10^{-5}	8.25	13.37
8	3.34×10^{-5}	2.28×10^{-5}	8.25	12.09
9	1.10×10^{-4}	3.83×10^{-5}	8.25	23.69
10	-	-	-	-

AVERAGE Q_x = 12.5 g/sec

source depletion factor, D, is independent of the source strength, it is correct to define D in terms of either the modeled or the actual sources, i.e.,

$$\frac{QI_x}{Q_I} = \frac{Q_x}{Q_o} = D \qquad (8.2)$$

where $QI_x = \sum_i q_{Ai} d_i + \sum_j q_{Lj} d_j + \sum_k q_{Pk} d_k$ (8.3)

and $Q_I = \sum_i q_{Ai} + \sum_j q_{Lj} + \sum_k q_{Pk}$

q_A = model input, unit area emission rate;

q_L = model input, unit line emission rate;

q_P = model input, point source emission rate;

D = overall depletion factor; and

d_i, d_j, d_k = depletion factors for each elemental area, line, and point source relative to a given receptor.

The elemental depletion factors (d_i, d_j, d_k) can be computed utilizing the method shown in the source depletion derivation found in the appendices. Hence QI_x and Q_I can be evaluated and then D for each receptor. Having obtained the effective depletion factor, the actual, or zero distance emission rate Q_o, can then be evaluated utilizing (8.2).

To continue the example calculations from Section 8.1, the depletion factors for the test are given in Table 8.2 along with the resulting estimated emission rates at the source.

TABLE 8.2
SAMPLE COMPUTATION OF ACTUAL MINE EMISSION RATE

RECEPTOR	D	Q_x(g/sec)	Q_o(g/sec)
3	.590	1.26	2.1
4	.586	7.83	13.4
5	.588	17.52	29.8
6	.574	11.50	20.0
7	.577	13.37	23.2
8	.568	12.09	21.3
9	.574	23.69	41.3
AVERAGE EMISSION RATE			21.6

The results of all the peripheral measurements are given in Tables 8.3 and 8.4. Tests run during periods when the mines were not working are not shown. Also, tests where the mean speed was very low are omitted because the dispersion model is not applicable under these conditions.

8.3 ATMOSPHERIC DISPERSION MODEL RESULTS

Average production rates for each mine and for each season were computed from data supplied by the respective mines for the specific periods of the test. Since train loading was very sporadic, the production rate was linked to the coal dumping operation. An emission factor was estimated for each season. The emission factor is defined as the total emission rate from all mining operations divided by the average coal dumping rate (CD), e.g.,

$$E_T = \frac{Q_o}{CD} \times \frac{3600}{453} \qquad (8.5)$$

where E_T = whole mine emission factor (lbs/ton of coal produced);
Q_o = sum of individual source emission rates (g/sec);
CD = coal dump rate (tons/hr);
3600 = sec/hr; and
453 = g/lb.

The final results of the mine factor measurements are given in Table 8.5. These overall emission factors were not completed for each individual six hour test period, but only for each season. The reason for this is that production rates based on coal dumping on a day-to-day basis is highly variable due to train scheduling. Total mine emissions, on the other hand, are relatively stable from day-to-day because coal trucks are normally diverted to overburden hauling when the silos are full. Since coal production averaged over the six day tests were fairly constant, the emission factors were computed for these periods. Note that the average emission factors for the two mines are very nearly the same. This result is expected since the two mines are in the same area and use the same kind of equipment and mining methods.

TABLE 8.3 - MINE EMISSION RATES

BELLE AYR

SEASON TEST NO.	DATE	TIME	Q_i (g/sec)	Q_o (g/sec)
FALL - 1	11/03	2200 - 0400	19.1	51
2	11/04	1000 - 1600	17.9	24
3	11/04	2200 - 0400	18.8	45
5	11/05	2200 - 0400	3.4	143
8	11/07	1000 - 1600	68.4	168
9	11/07	2200 - 0400	4.7	82
AVERAGE FALL			22.1	85
WINTER - 1	1/31	1000 - 1600	7.0	66
2	1/31	2100 -0300	4.2	10
3	2/01	0900 - 1500	3.8	55
6	2/02	2100 - 0300	10.5	56
7	2/03	0900 - 1500	6.7	31
8	2/03	2100 - 0300	1.3	39
9	2/04	0911 - 1500	6.1	28
10	2/04	2100 - 0300	10.9	50
11	2/05	0900 - 1500	5.3	13
12	2/05	2100 - 0300	4.7	19
AVERAGE WINTER			7.9	37

TABLE 8.3 (Continued)

SEASON TEST NO.	DATE	TIME	Q_x (g/sec)	Q_o (g/sec)
SPRING - 1	4/27	1000 - 1600	14.4	47
2	4/27	2100 - 0300	7.8	42
3	4/28	1000 - 1600	73.5	110
4	4/28	2100 - 0300	11.0	62
5	4/29	1000 - 1600	6.5	12
6	4/29	2100 - 0300	9.3	40
7	4/30	1000 - 1600	14.9	36
8	4/30	2100 - 0300	4.6	14
9	5/1	1000 - 1600	22.4	61
12	5/2	2100 - 1600	9.4	49
AVERAGE SPRING			17.4	47
SUMMER - 1	7/20	1000 - 1600	32.9	89
2	7/20	2100 - 0300	9.0	25
5	7/21	1000 - 1800	26.8	48
6	7/22	2100 - 0300	10.6	31
7	7/23	1000 - 1600	20.7	42
8	7/23	2100 - 0300	9.2	95
10	7/24	2100 - 0300	6.0	13
11	7/25	1000 - 1600	15.7	57
AVERAGE SUMMER			16.4	50
OVERALL AVERAGE			15.9	57

TABLE 8.4

MINE EMISSION RATES

CORDERO

SEASON	TEST NO.	DATE	TIME	Q_x (g/sec) actual	Q_o (g/sec) zero distance
FALL	2	10/26	1000-1600	15.8	28
	7	10/30	1000-1600	8.3	65
	9	10/31	1000-1600	14.3	46
	11	11/1	1000-1600	21.3	91
FALL AVERAGE				14.9	58
WINTER	4	1/24	1000-1600	15.6	34
	6	1/25	1000-1600	13.8	35
WINTER AVERAGE				14.7	35
SPRING	3	5/7	1000-1600	13.9	52
	5	5/8	1000-1600	19.3	35
	7	5/9	1000-1600	5.4	12
	11	5/11	1000-1600	12.5	22
SPRING AVERAGE				12.6	30
SUMMER	1	7/27	1000-1600	15.6	42
	7	7/30	1000-1600	8.9	24
	9	7/31	1000-1600	11.9	72
	11	8/1	1000-1600	9.9	25
SUMMER AVERAGE				11.2	41
OVERALL AVERAGE				13.4	41

TABLE 8.5

MINE EMISSION FACTORS

MINE	SEASON	COAL PRODUCTION (ton/hr)	EMISSION FACTOR (lb/ton)
CORDERO	Fall	1050	.44
	Winter	2650	.11
	Spring	2110	.11
	Summer	1442	.23
OVERALL AVERAGE		1813	.22
BELLE AYR	Fall	2200	.31
	Winter	1553	.19
	Spring	2236	.14
	Summer	1467	.27
OVERALL AVERAGE		1864	.23

The final step in the analysis of the whole mine emission is to compare the computed emission rates obtained by summing the rates from the individual operations with the rates obtained through modeling the peripheral concentration measurements. Utilizing the EDS emission factors and the actual production figures, total source emission rates were obtained for each mine. The results are given below:

	RATES FROM MODEL	COMPUTED RATES	Pit Trapping
BELLE AYR	53 g/sec	168 g/sec	68%
CORDERO	41 g/sec	111 g/sec	63%

The results of dispersion modeling and the emission factor measurements as given above show a large discrepency between the whole mine emission as actually seen at the peripheral receptors and the whole mine emissions computed utilizing the measured emission factors in conjunction with the mining activity figures. It is believed that this discrepency is the result of particle trapping in the pit.

Much of the mining activity takes place below the natural grade level of the surrounding terrain, i.e., in the pit. The air in the large cavity is decoupled to a certain extent from the boundary layer airflow and, therefore, is not ventilated as well as the terrain beyond. This reduced ventilation increases the residence time of the air in the pit and permits all the large particles to fall out before the air is finally entrained into the general flow above. As a result, the pit operations appear to have a much lower emission factor when viewed from a position outside the pit than when measured close to the source.

The effect of the pit in reducing the impact of surface coal mining operations on the environment is a significant finding. Part 2 of this Study has developed an approach for modeling the impact of open pit mines which utilizes a realistic simulation of material containment within the pit. The Industrial Source Complex (ISC) Model predicted reduced downwind impact from the pit which compares well with actual measurements. It has been found from this EDS Study that particle deposition and settling are significant processes for containing material within the pit and should be considered in future modeling applications.

SECTION 9

CONFIDENCE LEVEL OF THE EMISSION MEASUREMENTS

9.0 CONFIDENCE LEVEL OF THE EMISSION MEASUREMENTS

Since a number of independent measurements were obtained for each emission source tested, small sample statistical methods can be utilized to provide estimates of the accuracy of the mean emission factors in each case. Most standard texts on statistics will give an expression for the confidence limits on the sample mean (see the example, Spiegel, 1961). The expression for the 95 percent confidence limits is,

$$\mu - \left[\frac{t(.975)s}{\sqrt{n-1}}\right] \leq \bar{x} \leq \mu + \left[\frac{t(.975)s}{\sqrt{n-1}}\right] \qquad (9.1)$$

where μ = true mean for the parameter being measured;

$\bar{x}$ = mean for the sample;

s = standard deviation for the sample;

n = number of independent measurements in the sample; and

$t(.975)$ = value of Student's t distribution for $(n - 1)$ measurements and the 97.5 percentile.

The sample means and standard deviations for each set of measurements are given in the data tables included with each section. Utilizing this information, it is possible to estimate the confidence limits of the emission factor measurements.

A practical indicator of measurement accuracy is the fractional error, f. The fractional error limits at the 95 percent confidence level may be obtained from equation (9.1), i.e.,

$$\mu = \bar{x} \pm f = \bar{x} \pm \frac{t(.975)s}{\bar{x}\sqrt{n-1}} \qquad (9.2)$$

Equation (9.2) was utilized to generate the desired fractional error limits. The results are shown in Table 9.1.

TABLE 9.1

ERROR LIMITS FOR THE EMISSION MEASUREMENTS

EMISSION SOURCE	FRACTIONAL ERROR AT THE 95% CONFIDENCE LEVEL
Coal Dump (No Control)	± 0.86
Coal Dump (With Control)	± 0.33
Train Load (No Control)	± 0.64
Train Load (With Control)	± 0.89
Overburden Replacement	± 0.27
Topsoil Removal	± 0.56
Wind Erosion	± 0.98
Total Mine Emissions (Belle Ayr)	± 0.22
Total Mine Emissions (Cordero)	± 0.32
	ABSOLUTE ERROR LIMITS AT THE 95% CONFIDENCE LEVEL
Haulroads (*)	± 1.5 lb/VMT

(*) - Limits Given About the Value E = 22.0 - 5.47N

Since the haul road emissions are given in the form of an equation, the error limits are not shown as a fraction. In this case the error limits are computed about the emission factor function rather than about a fixed mean value. Thus, the fractional error changes with road moisture conditions. For example, at zero control the fractional error is $\pm 1.5/22$ or 0.07, whereas at control factor 1.0, the fractional error is $\pm 1.5/5.6$ or 0.27.

SECTION 10

INTERPRETATIONS AND CONCLUSIONS

10.0 INTERPRETATIONS AND CONCLUSIONS

Particle deposition plays a significant role in the process of dispersion of particulate emissions from surface mining operations. Particle sampling has shown clearly that particles with diameters in excess of 100 m became airborne from the mining operations. However, even more significantly, a large proportion of this material falls out in the first few hundred meters from the source. Due to this high rate of depletion of particulate matter, it is critical that dry deposition and gravitational settling be taken into account when making emission factor measurements. It is also essential that deposition be considered when modeling emission from surface mines.

Measurements of uncontrolled emissions on coal and overburden haul roads show the emission factor to be 22.0 $\pm$1.5 lb/VMT. Spraying water on the roads reduces the emissions in proportion to the application rate up to a maximum of 3 total coverages of the road per hour. At this point the emissions are reduced by 78 percent of their dry road value.

The ambient wind speed was found to have little measurable effect on the emission factors. Apparently the action of the wheels on the road surface, and the vehicle wake are the determining factors in generating emissions (for given road surface conditions).

Whole mine emissions were estimated from peripheral measurement of particulate concentrations utilizing the PAL short-term model. These data, when compared with whole mine emission rates derived from measured emission factors in conjunction with associated production rates, indicated that as much as 66 percent of the particulates generated in the pit do not escape into the free atmosphere. This is a significant finding and must be considered in any modeling effort if an accurate simulation of the dispersion process from a surface coal mine is to be realized.

Except for the topsoil removal operation and the wind erosion process, the emission factors obtained during the EDS Study were found to be higher than those measured by PEDCo (1978), and higher than those currently required by the WDEQ. The impact of these emissions on the environment, however, is less than current modeling practices predict because of the large amount of dry deposition and gravitational settling that occurs near particulate sources and in the pit.

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SECTION 1

EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

This part of the EDS Study covers modeling the impact of the surface mining operations as those operations are conducted in the Corridor of surface coal mine development in the Powder River Basin, Wyoming. The impact as it is addressed here includes that felt on the total suspended particulate (TSP) levels within the Corridor.

The modeling effort included a preliminary step of model verification. This step was followed by long-term and modeling to show the annual impact for the year 1988 when particulate emissions from the surface coal mining are expected to peak.

It was found from the verification effort that the Industrial Source Complex (ISC) Dispersion Model used in this study accurately predicted ground level concentration patterns. This includes the prediction of the concentration levels as well as the fall off of concentration patterns with distance from the sources. This is attributable to employment of: source specific emission factors, accurate settling and deposition functions, and measured particle size distributions. All these inputs were developed from site specific measurements made during the course of the EDS Study.

Long-term modeling for the Corridor, employing the verified ISC Model for the year 1988, shows the maximum predicted annual geometric mean concentration to be 46 $\mu g/m^3$. This maximum value is 14 $\mu g/m^3$ below the Wyoming Air Quality Standard of 60 $\mu g/m^3$ and is 12 $\mu g/m^3$ below the comparable value predicted by Wyoming Department of Environmental Quality (WDEQ) model predictions. This predicted value of 46 $\mu g/m^3$ is found at one location only and the next highest concentration is 42 $\mu g/m^3$. Predicted particulate impacts, of currently permitted mining at peak emissions, are significantly below the Wyoming Air Quality Standard.

SECTION 2

INTRODUCTION

2.0 INTRODUCTION

The modeling task of the EDS Study employed the extensive information developed and verified during Part 1 of the EDS Study so as to represent real life conditions by employing the most recent particulate concentration prediction modeling methods. In turn, an objective of the modeling part of the program has been to employ the latest scientific methods and data to enable prediction of the real impacts caused by various levels of surface coal mining activity as those predictions are needed for regulatory review in connection with the permitting of proposed levels of mining activities.

In order for the modeling to result in accurate representations of the end effects of surface mining, it was necessary to employ realistic emission factors, as well as a prediction methodology that represents real atmospheric processes. It was recognized early in the EDS Study that much of the emissions from the Powder River Basin surface coal mines are comprised of large particles which settle to the ground quickly—many particulates settle even before the emissions leave the confines of the mine itself. In order to adequately represent the behavior of emissions, especially the behavior of the large particles, it is necessary to employ models that rigorously represent the deposition removal of the large particles from the total particulate emissions.

When the EDS Study commenced in 1978, no commonly accepted regulatory model was available which represented the particulate deposition process. Due to this lack of standard accepted method it was anticipated that modification to the current (1978) atmospheric dispersion models might be necessary. However, while the EDS Study was devoted to making emission measurements, other efforts resulted in development of the Industrial Source Complex (ISC) Dispersion Model (EPA, 1979) for the Environmental Protection Agency (EPA). The EPA has recently approved and released the ISC Model for field employment. Review of this model, in the form appropriate for the EDS Study, shows it to have the right features for this application.

In preparation for employment of the ISC Model, a series of verification steps was designed so that the suitability and accuracy of the ISC Model could be fully determined. The verification steps used to judge the suitability of the ISC Model were comprised of a set of sample model runs where the output of those sample runs was compared to field measuremets that were made independent of those data that were employed for development of emission factors. Both short-term (6 hour) and long-term (annual) ISC Model predictions of particulate concentrations were compared to independent monitoring data.

The following sections include a description of the model verification input and the results of these verification runs. This step is followed by Corridor long-term modeling and finally these results are presented and interpreted.

SECTION 3

MODEL VERIFICATION

3.0 MODEL VERIFICATION

3.1 APPROACH

In order to determine if the ISC Model would accurately predict particulate concentrations at a mine, a verification task was accomplished. This task consisted of making sample model predictions for the AMAX Belle Ayr mine region employing input meteorological conditions that were present during periods when independent particulate concentrations were measured. In turn those model predictions were compared with the measured independent particulate concentrations. The degree of comparison determined the level of model verification, as further discussed in Sections 3.5 and 3.6.

The short-term impact of the particulate matter emitted by the various coal mining activities at the Belle Ayr mine was simulated by employing the short-term program of the ISC Model (ISCST). The model-predicted concentrations were generated for several periods when short-term particulate samples were taken with a network of hi-vol samplers. The network was comprised of several hi-vol samplers located around the periphery of the Belle Ayr mine and were operated during each of the four seasonal periods of the EDS field measurements. During each season, the network was employed to observe particulate concentrations for twelve six hour periods. Thus 48 sets of short-term particulate areal concentration distributions were available for comparison to model-predicted values.

Applying the ISC Model long-term program (ISCLT) to the Belle Ayr mine allowed comparisons between the model-predicted and measured particulate matter concentrations. The model receptors corresponded to the Belle Ayr "State and Local Air Monitoring Station" (SLAMS) hi-vol network that measures 24-hour suspended particulate concentrations on a six-day sampling schedule. To enable direct comparison of the predicted mean annual suspended particulate concentrations with the measured concentrations, annual arithmetic mean suspended particulate concentrations were calculated for each of the four Belle Ayr hi-vols. These four hi-vols, maintained by Belle Ayr mine personnel, comprise another independent data set.

This section will describe the process of verifying both the ISCST and the ISCLT programs. The topics to be discussed in detail include:

- application of ISC Model features;
- short-term and long-term model inputs; and
- results from the short-term and long-term verification runs.

3.2 APPLICATION OF ISC MODEL FEATURES

A detailed description of the ISC Model, a Gaussian plume dispersion model, and the appropriate model features are included in the appendices. This model accepts three types of sources (point, area, and volume). A combination of these source types enabled the ISC Model to be applied to the Belle Ayr surface coal mine. The point sources at Belle Ayr include the coal dump and the train load-out facility. The activities associated with stripped overburden, overburden and topsoil removal, coal pit, replacement of topsoil and overburden, and reclaimed land have been simulated as area sources. The ISC Model represents line sources as a series of small volume sources. Consequently, volume sources were chosen to represent the coal haul road (from the pit to the coal dump), the overburden haul road surrounding the coal pit, and the road between the shop/parking area and the southern portion of the coal pit (south road). Figure 3-1 illustrates the source configuraton modeled to simulate the mine operations for both the short-term (during four seasons corresponding to the 1978-1979 field testing program) and the long-term (1979 calendar year) model verification runs. The emissions from coal and overburden blasting were included with the western overburden haul road emissions allowing an accurate simulation of coal mining operations on the active side of the coal pit. The points along the line sources in Figure 3-1 represent the center of the volume sources used in approximating the roads. The features of the ISC Model exercised in this modeling task, to represent the sources of particulate matter, include plume rise, vertical wind profile, vertical profile of potential temperature, mixing heights, as well as dry deposition and gravitational settling. The proper simulation of these processes are briefly discussed below.

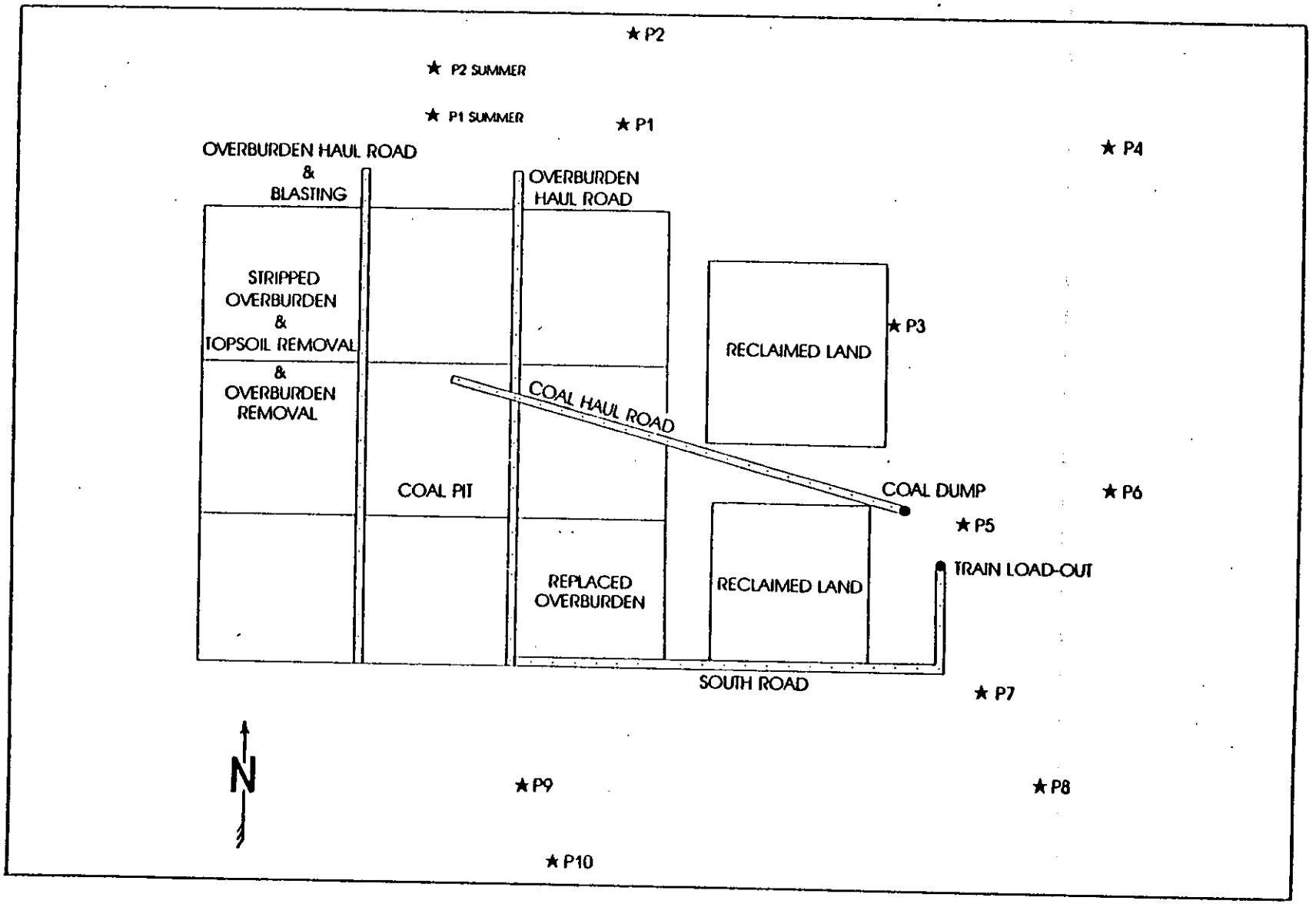

FIGURE 3-1 SOURCE CONFIGURATION USED TO SIMULATE AMAX'S BELLE AYR MINE IN THE ISC MODEL VERIFICATION TASK (LONG-TERM AND SHORT-TERM). THE PERIPHERAL HI-VOL NETWORK SURROUNDS THE MINE (REPRESENTED BY "STARS")

Originally, a plume rise expression was developed to simulate the behavior of plumes emitted from chimneys and stacks where the vertical displacement is due to a combination of momentum and thermal buoyancy. Particulate emissions from surface coal mining activities also rise in some cases; when they do, that rise is appropriately simulated in the model by representing only the momentum forces. Since thermal buoyancy is nonexistent when particulates are emitted in this case, the actual plume rise is simulated by setting the term for "stack exit temperature" to $0.0^{o}K$.

The ISC Model is designed to accept measured values for the wind profile, the potential temperature profile, and the mixing height. When measured values are not available, default values, representing mean atmospheric conditions, are implemented. The default values describing the wind profile and vertical potential temperature gradients were employed here. In determining those mixing heights, required by both programs (ISCST and ISCLT) the technique developed by Holzworth (1972) was used. Holzworth's afternoon (maximum) and morning (minimum) mixing heights are generally accepted to be representative of atmospheric conditions in a rural environment.

Evident from the field study, the phenomena of dry deposition and gravitational settling has a pronounced impact on the behavior of particulate matter emitted from surface coal mining activities. To simulate these processes a particle size distribution for each particulate source must be specified to the two ISC Model programs. Each of the particle size distributions can be characterized by three parameters:

- mass fraction of particulates;
- gravitational settling velocity for the mass mean diameter of the particulate size range; and
- reflection coefficient.

Petrographic analysis of the Millipore filter samples, collected during the EDS field measurements, distributed the accumulated particulates into 13 size categories ranging from 5 μm to 130 μm in diameter. The particulate sample consisted of several different materials. Using Stokes Law (White, 1971) to

calculate the gravitational settling velocity for each size category, enabled the development of source specific particle size distributions. The gravitational settling velocity, a function of particle density, was calculated for three types of particulate matter. An average density for coal is 1.5 g/cm^3 and an average density for surface material (clay, silica, granite) is 2.5 g/cm^3 (Hudson, 1939). Consequently, a particle density of 1.5 g/cm^3 was assumed for the coal dump/train load-out, and 2.5 g/cm^3 for the stripped overburden, overburden and topsoil removal, pit, overburden and topsoil replacement, and reclaimed land mining procedures—along with the overburden haul road and the south road. Since the particulate emissions from the coal haul road are a combination of coal and road surface material a particle density of 2.0 g/cm^3 was assumed (see the more detailed discussion in Part 1, Section 3). The reflection coefficient, analogous to the deposition velocity, is dependent on the gravitational settling velocity and was obtained for each of the 13 size categories.

The particle size distributions, summarized in Table 3.1, were measured using Millipore filters during the field measurement program. The model-predicted concentrations, however, are compared with hi-vol measured suspended particulate concentrations. The Millipore filters collected all particle sizes, whereas the hi-vols are designed to collect only particles smaller than 100 μm (40CFR50.11). In reality, hi-vols typically collect a few, but not all of the large particles suspended in the atmosphere. To simulate this hi-vol measurement bias, particles greater than 110 μm in diameter were not allowed. This was modeled by taking out the larger particles (about 10 percent of total mass) and increasing the total source strength by a like amount so as to retain consistency with the measured particle mass fractions. This adjusted particle size distribution was used in the model verification runs.

The resulting particle size distribution described all of the various operations associated with a surface coal mine, except for the silo exhaust. The silos are unique, since exceptionally large coal particulate matter is emitted. Consequently, a separate particle size distribution, developed from the same field and laboratory techniques as the three distributions discussed

TABLE 3.1 PARTICLE SIZE DISTRIBUTIONS ASSOCIATED WITH ALL THE SURFACE COAL MINING ACTIVITIES, EXCEPT THE SILO EXHAUSTS

MEAN DIAMETER OF RANGE (μm)	MASS FRACTION OF PARTICULATES	$\rho = 1.5$ g/cm^3		$\rho = 2.0$ g/cm^3		$\rho = 2.5$ g/cm^3	
		SETTLING VELOCITY (m/sec)	REFLECTION COEFFICIENT	SETTLING VELOCITY (m/sec)	REFLECTION COEFFICIENT	SETTLING VELOCITY (m/sec)	REFLECTION COEFFICIENT
5.	0.017	0.003	0.87	0.003	0.87	0.003	0.87
15.	0.043	0.013	0.76	0.017	0.72	0.020	0.71
25.	0.074	0.029	0.68	0.038	0.65	0.048	0.63
35.	0.084	0.059	0.59	0.075	0.55	0.096	0.51
45.	0.108	0.095	0.51	0.125	0.43	0.155	0.36
55.	0.094	0.138	0.40	0.184	0.28	0.230	0.17
65.	0.104	0.193	0.27	0.257	0.11	0.322	0.
75.	0.099	0.260	0.10	0.340	0	0.430	0.
85.	0.087	0.330	0	0.440	0	0.550	0.
95.	0.094	0.410	0	0.545	0	0.690	0.
105.	0.092	0.510	0	0.670	0	0.830	0.
115.	0.072	0.604	0	0.810	0	1.010	0.
125.	0.030	0.720	0	0.940	0	1.230	0.

above, was implemented. A particle density of 1.5 g/cm^3 was assumed for the coal particulates emitted from the silos. Table 3.2 details the particle size distribution associated with the silo exhausts at Belle Ayr.

Discrete receptor locations corresponded to the two hi-vol networks used in the verification runs (the peripheral network for the short-term modeling and the SLAMS network for the long-term modeling). Figure 3-1 illustrates the peripheral hi-vol network. The Belle Ayr SLAMS hi-vol network is shown in Figure 3-2.

3.3 INPUT FOR SHORT-TERM VERIFICATION RUNS

Belle Ayr's production during each of the six hour sampling periods of the peripheral hi-vol network was provided by AMAX (see Table 3.3 A-D). Applying the emission factors developed in this study (and presented in Part 1), emission rates for several of the surface coal mine operations, at Belle Ayr, were calculated. When emission factors were not available, the Wyoming Department of Environmental Quality's (WDEQ) recommended emission factors (WDEQ Memo, 1979) supplemented the initial data base.

Producing 15 million tons of coal per year, Belle Ayr operates three eight-hour shifts per day/six days per week with only a day shift on Sunday. The first shift beginning at 8 am extends to 4 pm; the second from 4 pm to midnight; the third shift begins at midnight and ends at 8 am the following day. The six-hour peripheral sampling periods, however, were 10 am to 4 pm and 10 pm to 4 am or 9 am to 3 pm and 9 pm to 3 am, depending on the season. Assuming the mine's production is constant within each shift, the Belle Ayr supplied production data was evenly prorated to simulate the mine's six-hour activities matching the short-term sampling period. In determining the vehicle miles traveled, it was assumed that the coal dump trucks held 110 tons, whereas the overburden dump trucks held 66 yd^3, an average of 105.5 tons. The road activity-produced particulate emissions were evenly divided among the volume sources representing each of the roads. The disturbed areas affected by wind erosion in 1978-1979 included the stripped overburden, graded overburden, and reclaimed land areas surrounding the coal pit. Aerial photographs taken during each seasonal field test period were

TABLE 3.2

PARTICLE SIZE DISTRIBUTION ASSOCIATED WITH BELLE AYR'S SILO EXHAUSTS

MEAN DIAMETER OF RANGE (μm)	MASS FRACTION OF PARTICULATES	$\rho = 1.5\ g/cm^3$	
		SETTLING VELOCITY (m/sec)	REFLECTION COEFFICIENT
7.5	0.009	0.005	0.85
22.5	0.014	0.025	0.70
40.0	0.0545	0.073	0.56
62.5	0.1025	0.177	0.31
87.5	0.1035	0.340	0.
112.5	0.1580	0.575	0.
137.5	0.3710	0.845	0.
162.5	0.1875	1.225	0.

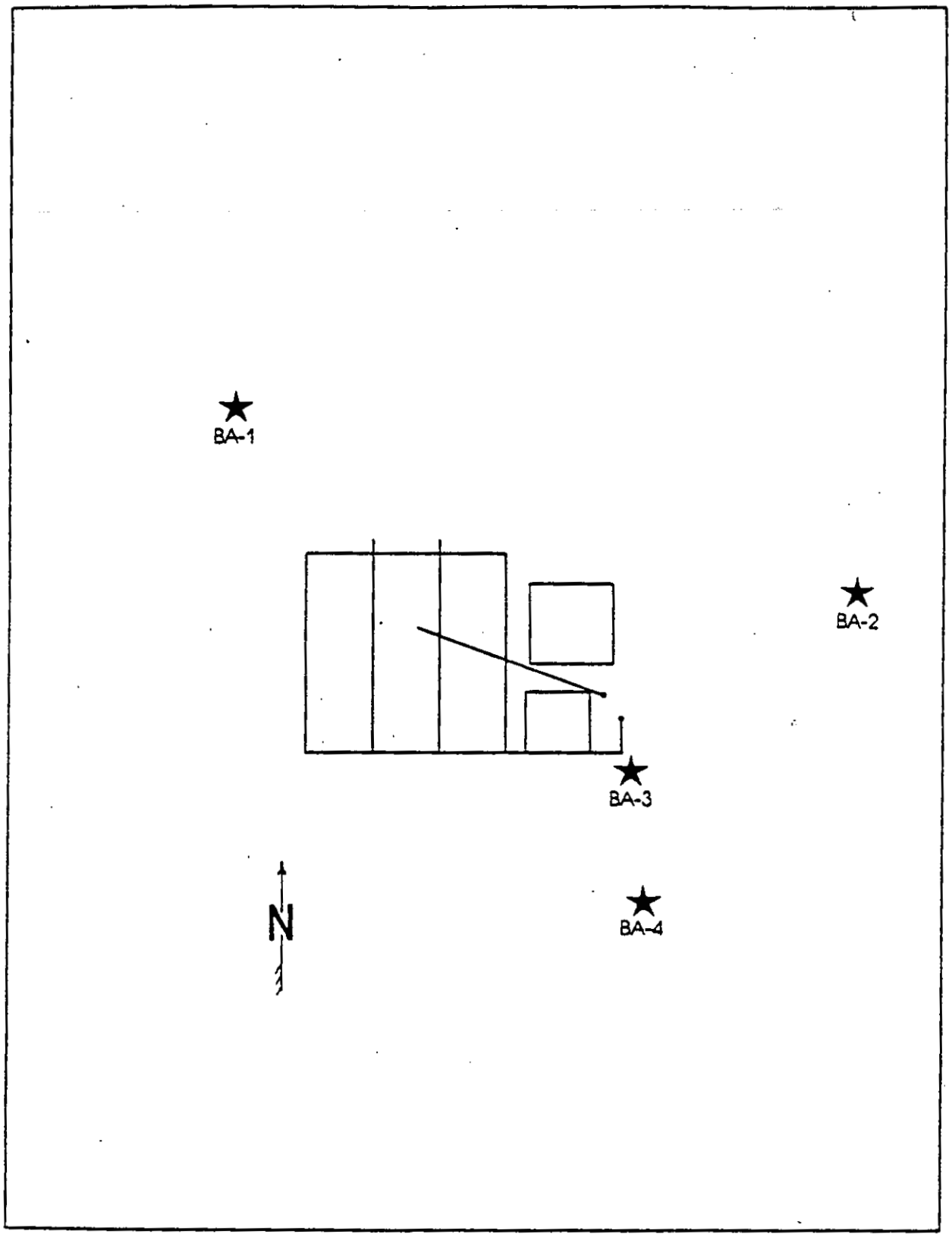

FIGURE 3-2 AMAX'S BELLE AYR MINE SLAMS HI-VOL NETWORK

TABLE 3.3 A

BELLE AYR PRODUCTION DATA FOR SHORT-TERM ISC MODEL VERIFICATION
FALL 1978

Sequence:	1	2	3	4	5	6	7	8	9	10	11	12
Date:	Nov 3-4	Nov 4	Nov 4-5	Nov 5	Nov 5-6	Nov 6	Nov 6-7	Nov 7	Nov 7-8	Nov 8	Nov 8-9	Nov 9
Time:	(10pm-4)	(10am-4)	(10pm-4)	(10am-4)	(10pm-4)	(10am-4)	(10pm-4)	(10am-4)	(10pm-4)	(10am-4)	(10pm-4)	(10am-4)
Coal Produced (tons)	4,925.5	19,595.3	17,067.3	19,674.8	0*	22,124.3	20,253.8	17,304.0	17,462.0	7,585.5	9,639.5	8,296.5
Overburden Removed: (yd^3)	29,568.0	22,126.5	16,011.0	0	0*	16,087.5	19,255.5	23,512.5	24,502.5	28,611.0	24,271.5	22,770.0
Topsoil Removed (yd^3):	0	2,437.5	0	0	0	2,437.5	0	2,437.5	0	2,437.5	0	0
Blasting												
Coal (#):	0	3	0	0	0	0	0	1	0	1	0	2
Overburden (#):	0	0	0	0	0	2	0	0	0	0	0	2
Train Load-out:												
Cars loaded (#)	50.5	225.0	193.0	109.0	108.8	225.0	133.8	214.0	215.0	222.0	81.5	106.0

*On Sundays Belle Ayr operates during only the day shift.

TABLE 3.3 B

BELLE AYR PRODUCTION DATA FOR SHORT-TERM ISC MODEL VERIFICATION
WINTER 1979

Sequence:	1	2	3	4	5	6	7	8	9	10	11	12
Date: Time:	Jan 31 (10:30am-4:30)	Jan 31-Feb 1 (9pm-3)	Feb 1 (9am-3)	Feb 1-2 (9pm-3)	Feb 2 (9am-3)	Feb 2-3 (9pm-3)	Feb 3 (9am-3)	Feb 3-4 (9pm-3)	Feb 4 (9am-3)	Feb 4-5 (9pm-3)	Feb 5 (9am-3)	Feb 5-6 (9pm-3)
Coal Produced (tons)	1,737.0	4,193.3	5,867.0	4,930.5	6,411.0	4,074.4	1,304.0	11,123.6	19,883.0	0*	28,685.0	15,687.0
Overburden Removed: (yd^3)	18,192.0	17,184.0	21,157.5	18,716.3	15,624.0	17,414.3	18,274.5	18,437.3	0	0*	17,298.0	15,647.3
Topsoil Removed (yd^3):	0	0	0	0	0	0	0	0	0	0	0	0
Blasting+												
Coal (#):	0	0	0	0	0	0	0	0	0	0	0	0
Overburden (#):	0	0	0	0	0	0	0	0	0	0	0	0
Train Load-out:												
Cars loaded (#)	0	0	0	116.6	0	39.8	102.0	81.0	216.0	121.5	110.0	120.4

*On Sundays Belle Ayr operates during only the day shift.

+No blasting occured within the hi-vol network's six hour sampling period.

TABLE 3.3 C

BELLE AYR PRODUCTION DATA FOR SHORT-TERM ISC MODEL VERIFICATION
SPRING 1979

Sequence:	1	2	3	4	5	6	7	8	9	10	11	12
Date: Time:	Apr 27 (10am-4)	Apr 27-28 (9pm-3)	Apr 28 (10am-4)	Apr 28-29 (9pm-3)	Apr 29 (10am-4)	Apr 29-30 (9pm-3)	Apr 30 (10am-4)	Apr 30-May 1 (9pm-3)	May 1 (10am-4)	May 1-2 (9pm-3)	May 2 (10am-4)	May 2-3 (9pm-3)
Coal Produced (tons)	11,403.8	11,403.8	10,513.5	10,513.5	0	0*	18,903.0	18,903.0	10,970.3	10,970.3	13,849.5	13,849.5
Overburden Removed: (yd^3)	18,691.5	18,691.5	22,044.8	22,044.8	0	0*	15,465.8	15,465.8	19,800.8	19,800.8	20,425.5	20,425.5
Topsoil Removed (yd^3):	0	0	0	0	0	0	0	0	0	0	0	0
Blasting												
Coal (#):	2	0	1	0	0	0	0	0	2	0	1	0
Overburden (#):	0	0	1	0	0	0	1	0	0	0	1	0
Train Load-out:												
Cars loaded (#)	106.0	163.9	108.0	0	108.0	81.4	213.0	83.3	218.0	81.8	217.0	123.0

*On Sundays Belle Ayr operates during only the day shift.

TABLE 3.3 D

BELLE AYR PRODUCTION DATA FOR SHORT-TERM ISC MODEL VERIFICATION
SUMMER 1979

Sequence:	1	2	3	4	5	6	7	8	9	10	11	12
Date: Time:	Jul 20 (10am-4)	Jul 20-21 (9pm-3)	Jul 21 (10am-4)	Jul 21-22 (9pm-3)	Jul 22 (10am-4)	Jul 22-23 (9pm-3)	Jul 23 (10am-4)	Jul 23-24 (9pm-3)	Jul 24 (10am-4)	Jul 24-25 (9pm-3)	Jul 25 (10am-4)	Jul 25-26 (9pm-3)
Coal Produced (tons)	9,541.5	12,110.3	11,038.5	9,251.6	0	0*	17,710.5	11,645.3	6,307.5	8,805.8	6,314.3	7,869.0
Overburden Removed: (yd^3)	19,305.0	16,458.8	21,087.0	24,453.0	0	0*	23,661.0	23,859.0	24,898.5	28,140.8	28,710.0	17,943.8
Topsoil Removed (yd^3):	2,137.5	0	2,137.5	0	0	0	2,137.5	0	2,137.5	0	2,137.5	0
Blasting												
Coal (#):	1	0	1	0	0	0	2	0	1	0	1	0
Overburden (#):	0	0	1	0	0	0	1	0	1	0	2	0
Train Load-out:												
Cars loaded (#)	218.0	120.4	110.0	82.9	0	79.5	100.0	79.1	105.0	80.3	0	160.1

*On Sundays Belle Ayr operates during only the day shift.

used to measure the total acres affected by wind erosion. During the winter field testing season, only a small portion of the graded overburden area was impacted by the wind due to the predominantly snow covered ground surface. Topsoil was removed, from the ground west of the coal pit, only during the day shift, excluding Sunday, of the fall and summer testing periods. Coal and overburden blasting took place only at the end of the first shift, between 3 and 4 pm. During the winter months, however, no blasting occurred within the hi-vol network's six-hour sampling period (9am to 3pm). Sixty percent of the total annual blasts are coal shots and forty percent are overburden shots.

The EDS determined particulate emission factors were applied to the following surface coal mining activities: coal dump, train load-out, overburden haul roads, overburden replacement, topsoil removal and wind erosion from stripped overburden, reclaimed land, and graded overburden. Emission factors recommended by the WDEQ were applied to the remaining mining activities: administrative travel within the mine, access roads, coal removal, blasting of coal and overburden, and overburden removal. Since the dry deposition and gravitational settling options of the ISC Model were employed, the "percent suspended" term was removed from WDEQ's emission factors. The emission factors associated with Belle Ayr's silo exhaust were obtained from stack tests and provided by Belle Ayr. Table 3.4 summarizes the emission factors employed in the short-term and long-term verification runs. In calculating some of the emission rates, the following information was also required:

- The coal capacity of each train car = 97.15 ton/car (Records at train load-out weighing station);
- Density of the overburden = 1.3 ton/yd^3 (Amax records); and
- Actual number of days where the precipitation amount is 0.01" or greater = 92 (site specific, Jensen, 1980).

The ISCST program calculates particulate concentrations using sequential hourly meteorological data. The following required meteorological parameters were extracted from Belle Ayr's meteorological data summaries (Jensen, 1980):

- mean wind speed;
- mean direction wind is blowing towards; and
- mean ambient air temperature;

TABLE 3.4

SUMMARY OF EMISSION FACTORS
USED IN THE
ISC MODEL VERIFICATION RUNS

MINING ACTIVITY	EMISSION FACTOR
Coal Dump*	0.066 lb/ton of coal
Train Load-out*	2.72 lb/train car
Coal & Overburden Haul Roads*	5.6 lb/vehicle mile traveled
Overburden Replacement*	0.021 lb/yd^3 of overburden[@]
Topsoil Removal*	0.0754 lb/yd^3 of topsoil[@@]
Wind Erosion*	0.38 lb/acre-year
Overburden Removal[+]	0.035 lb/yd^3 of overburden[@]
Administrative Travel[+**]	7.27 lb/vehicle mile traveled
Coal Removal[+]	0.017 lb/ton of coal
Overburden Blasting[+]	50 lb/overburden blast
Coal Blasting[+]	35 lb/coal blast
Silo Exhaust[++]	1.3 lb/hour (old prep. plat)
	5.4 lb/hour (new prep. plant)

*Emission factors developed by the EDS Study

**Emission factor = (0.81)(silt %)(speed/30)("wet days" ratio)/VMT

[+]WDEQ emission factors.

[++]Emission factor measured by a consultant for Belle Ayr Mine.

[@]Overburden density = 1.74 ton/yd^3

[@@]Topsoil density = 1.5 ton/yd^3

for each hour of the six-hour sampling period. Turner's (1970) method for determining the Pasquill stability class was employed, for each hour, using the Belle Ayr on-site meteorological data summaries mentioned above. Holzworth's (1972) procedure was applied to estimate the depth of the surface mixing layer. The resulting meteorological scenarios, used in simulating Belle Ayr's activities during the six hour sampling periods, are summarized in the appendices.

3.4 INPUT FOR LONG-TERM VERIFICATION RUN

To compare the ISC Model-predicted suspended particulate concentrations with the annual arithmetic mean measured suspended particulate concentrations, the average annual particulate emission rates were calculated. The same emission factors used in the short-term model verification run (tabulated in Table 3.4) were applied to the 1979 Belle Ayr production rates. The annual production rates at Belle Ayr coal mine, provided by AMAX, are summarized in Table 3.5. Proration of the 1979 production data was unnecessary in calculating the mine's average annual emission rates. When applicable, however, the same information used in calculating the six hour emission rates for the short-term verification runs were applied to the annual production data. An emission inventory for particulate matter emitted from coal mining activities was generated from the 1979 production data tabulated in Table 3.5. For the same source configuration defined earlier, illustrated in Figure 3-1, was used with the inclusion of the dirt roads surrounding the BA-1 and BA-2 hi-vols.

Three dirt roads contribute to the suspended particulate concentrations measured at the BA-1 and BA-2 hi-vols, as seen in Figure 3-4. The roads impacting BA-1 include the new Bishop Road, to the north, and county road T-7 South, to the east. Particulate emissions from the scoria road east of BA-2 contribute to the measured concentration. The travel on the BA-2 dirt road is generally restricted to deliveries to Belle Ayr and oil exploration east of the surface coal mine. This road was opened during the entire 1979 calendar year with no particulate emission controls applied to the road. Consequently, an accurate estimation of the particulate emissions from travel on this road is possible. On the other hand, several major changes in traffic patterns and

TABLE 3.5

AMAX'S BELLE AYR MINE'S 1979 PRODUCTION DATA

Overburden (yd^3)		23,509,000
Coal Produced (tons)		14,997,000
Topsoil Removed (yd^3)		610,500
Administrative Travel (VMT)		275,000
Scraper hours		3,403
Grader hours, overburden and coal		17,428
Old Preparation Plant (hours)		4,263
New Preparation Plant (hours)		1,390
Coal haul road length (mi)		1.08
South road length (mi)		1.00
Overburden haul road length (mi)		0.74
Blasts/yr (60% coal, 40% overburden)		303
BA-2 unpaved road (trips/day)		175
New Bishop Road (trips/day)	March-July, 1979	200
	July-December, 1979	750
T-7 South Road (trips/day)	Jan.-February, 1979	365
	March-December, 1979	0

configuration of the roads near BA-1 (new Bishop Road and T-7 South) make it nearly impossible to determine the actual particulate emissions from travel on these roads. Actual travel on the new Bishop Road (an unpaved dirt road) began in March 1979. This road, however, was subsequently paved (July 1979)—significantly decreasing the vehicle related particulate emissions. Furthermore, with no available method to estimate the particulates emitted from the construction of this road (prior to March 1979), the construction-caused emissions are not included in the 1979 emission inventory, Table 3.5. In summary, the particulates emitted at a high rate during a short period of time on the new Bishop Road could only be simulated as a significantly lower emission rate evenly distributed throughout the 1979 calendar year. Likewise, it is not possible to obtain a realistic estimate of the traffic related particulate emission rate from the T-7 South county road. Official closing of the county road T-7 South occurred during the latter part of February 1979. Although commuting to and from the Cordero mine was no longer the main use of T-7 South, travel on this portion of T-7 did continue until the Belle Ayr coal pit advanced to this road. Since it was impossible to estimate the actual amount of travel on T-7 South, no particulates emitted from this road subsequent of its official closing could be included in the emission inventory. Consequently, again the particulates emitted at a high rate during a short period of time (2 months) could only be simulated at a significantly lower emission rate evenly distributed throughout a twelve-month period.

The required meteorological data input to the ISCST and ISCLT programs differ greatly. The ISC Model short-term program calls for hourly data. The ISC Model long-term program, on the other hand, requires the annual wind and stability data to be summarized in STAR format (a joint frequency distribution of wind speed, wind direction, and Pasquill stability class). A STability ARray or STAR summary representative of the region surrounding the surface coal mine is essential to accurately simulate the mine's activities. From combining on-site wind data (direction and speed) with National Climatic Center (NCC) supplied STAR summary a new stability array, specific to the Belle Ayr mine, was generated. The STAR data for Moorcroft, Wyoming, a nearby town with similar meteorological, topographical, and meso-scale weather

characteristics as the Powder River Basin, was chosen for use in generating the site specific STAR data. It was assumed that the atmospheric stability conditions in Moorcroft, Wyoming and in the Corridor were similar. The Belle Ayr on-site wind direction (illustrated in Figure 3-3) and wind speed distribution is apportioned among the Pasquill stability classes as described by the Moorcroft, Wyoming STAR data.

ISCLT requires annual mixing height data for each wind speed and stability category. In applying the ISC Model to the long-term operations at Belle Ayr, a constant mixing height was assumed for each wind speed class. Variations of the mixing height do occur among the various Pasquill stability classes. Using Holzworth's (1972) average annual morning (minimum) and average annual afternoon (maximum) mixing heights, the following modification for each stability class was applied:

PASQUILL STABILITY CLASS	ADJUSTED MIXING HEIGHT
A	(1.5) (max. mixing height)
B	(max. mixing height)
C	(max. mixing height)
D	(average of max. and min. mixing height)
E	10,000 m
F	10,000 m

3.5 SHORT-TERM VERIFICATION RUNS

Input data for the ISC Model short-term (ISCST) program were developed for the 48 six-hour sampling periods collected by the peripheral hi-vol network. Easterly winds prevailed during ten of the sampling periods and due to location of the peripheral sampling network little or none of Belle Ayr's emissions impacted the network. Consequently, only the 38 short-term verification runs, where the mine's emissions were expected to have an impact on the peripheral hi-vol network, were performed. From these model runs a sample of 338 cases were obtained (the peripheral hi-vols were inoperative in 42 cases). A 'case' is defined as a hi-vol/receptor pair of measured/predicted particulate concentrations. A possible 10 cases exist for each model run (because 10 hi-vol samplers were located downwind of the mine). The results from each of the verification runs are presented in the appendices.

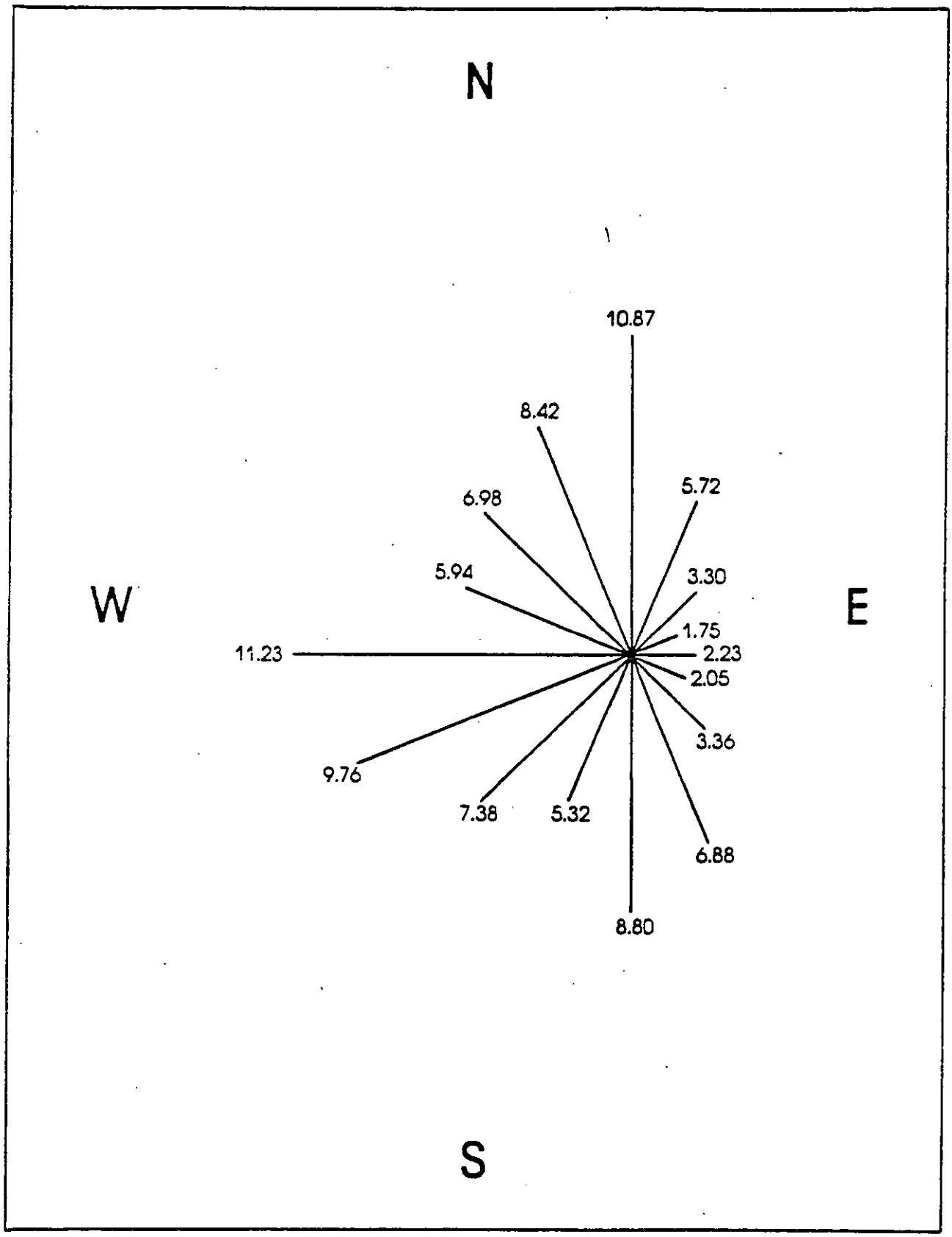

FIGURE 3-3 1979 ON-SITE WIND ROSE FOR AMAX'S BELLE AYR MINE (NUMBERS REPRESENT PERCENT OF TIME WIND BLOWS FROM INDICATED DIRECTION)

To quantify the performance of the ISC Model during the short-term model verification task, a standard "model performance measure" (Bowne, 1980) was used. After forming a ratio of the particulate concentration by ISCST to the hi-vol measured particulate concentration (i.e., predicted concentration/measured concentration), the values are tabulated into three categories. A ratio value within the range 0.5 to 2.0 defines "verification within a factor of two". Similarily, "verification within a factor of three" occurs when the ratio value is between 0.33 and 3.0. All other values are placed within the third category. Under the best of conditions, "model verification within a factor of two" can be achieved only 63 percent of the time. Similarily, "verification within a factor of three" will occur only 80 percent of the time (Londergan et. al., 1981). Model verification this good resulted only when the original gas tracer data, used to develop the Pasquill-Gifford curves for σ_y and σ_z, was applied to the atmospheric dispersion models (the "Prairie Grass" experiment), consequently this represents the ultimate limit of dispersion models. Under more realistic conditions (the "Hanford 67" experiment) the atmospheric dispersion models verified "within a factor of two" 40 percent of the time and model verification "within a factor of three" only 58 percent of the time.

A problem arose when the above analysis was performed on some of the model runs. In a few instances, the ISC Model-predicted particulate concentration was zero and the hi-vol measured value was small. Consequently, the predicted/measured ratio value was zero. A method was developed to include these cases. Hi-vols used to measure the suspended particulate concentration are accurate to within approximately 15 $\mu g/m^3$. Consequently, if the ISC Model-predicted particulate concentration was zero and the hi-vol measured (minus background) concentration was less than or equal to 10 $\mu g/m^3$, this was defined as "verification within a factor of two." Likewise, if the predicted value was zero and the measured (minus background) concentration was less than or equal to 15 $\mu g/m^3$, the ISCST program "verified within a factor of three."

For the entire sample, the ISC Model-predicted the TSP concentration to be "within a factor of two" of the measured TSP concentration for 41 percent of the cases. For 56 percent of the cases, the ISC Model-predicted concentrations were "within a factor of three" of the measured concentration.

Although excellent agreement between the model-predicted and measured particulate concentration exists, a critical review or screening of each case (receptor pairs of predicted and measured particulate concentrations) was performed to obtain a more representative set of cases. The details of this screening procedure are described below.

The ISCST Model-predicted TSP concentrations were subsequently compared to the measured TSP concentration at each hi-vol comprising the peripheral network. The following critical review (screening) was subsequently performed on each case (receptor pairs of predicted and measured particulate concentrations):

- Did the measured concentration pattern match the wind pattern modeled?

  Upon investigation, due to some wind instrument outages experienced during the course of the experimental program, the Belle Ayr meteorological wind summaries were sometimes comprised of measurements made at different locations. In some of these cases, the winds reported in the Belle Ayr meteorological summary did not coincide with the measured particulate concentration pattern. Those cases that did not match (50 cases) were withdrawn from the original sample of cases.

- Was the WDEQ defined annual average suspended particulate background level appropriate under the actual conditions present for each case?

  With some other cases, especially with high wind speeds, it was obvious that the WDEQ defined background concentration was not an appropriate value. When sufficient measured particulate data were available to determine an appropriate background value different from (either greater than or less than) WDEQ's background value, the measured suspended particulate concentrations were readjusted to reflect the actual background value. (In this situation no cases were withdrawn from the sample).

- Did the model calculate each predicted particulate concentration correctly?

  If a downwind receptor is within 100 m of a source, the ISC Model does not calculate the contribution of the source to the receptor. This 100 m restriction results since the Pasquill-Gifford curves for σ_y and σ_z do not include downwind distances less than 100 m. This is clearly a model deficiency and when it occurred the model-predicted particulate concentration was clearly in error; those cases (7 cases) were withdrawn from the initial sample of cases.

In summary, the above-mentioned screening process performed on the short-term verification runs resulted in some cases being withdrawn from the initial sample of 338 cases and others being recalculated based on the revised background levels.

Following the screening procedure outlined above, and summarized in Table 3.6, the sample size was reduced to 281 cases. After screening, the ISC Model-predicted the measured concentrations "within a factor of two" for 48 percent of the cases. This screening process also improved the percentage of the sample that fell "within a factor of three" (predicted particulate concentrations versus measured particulate concentration)--63 percent of the cases.

Comparing the short-term model-predicted particulate concentrations to the measured particulate concentrations, the ratio values are well within the bounds normally accepted for model verification purposes. In general, the ISC Model-predicted particulate concentration values were observed to be slightly lower than the corresponding measurement. This can be attributed to comparing the model-predicted concentrations (based on the Millipore filter-measured particle size distributions) to the hi-vol measured particulate concentrations (further discussed in the next section, Section 3.6). Although ISCST consistently underpredicted the actual particulate concentration, due to the input particle size distributions, the short-term version of the ISC Model has demonstrated that the impact from surface coal mining operations can be accurately predicted.

TABLE 3.6

SUMMARY OF SCREENING SHORT-TERM ISC MODEL VERIFICATION RUNS

EXPLANATION	CASES* WITHDRAWN
	(480 Total Number of Cases)
Easterly Winds	100
Hi-vols Inoperative	42
Wind Mismatch	50
ISC Model Deficiency	7
	(281 Cases After Screening)

* A "case" is defined as a hi-vol/receptor pair of measured/predicted particulate concentrations.

3.6 LONG-TERM VERIFICATION RUNS

To verify the long-term version of the ISC Model, the annual geometric mean (plus background) model-predicted particulate concentrations are compared to the geometric means of all the particulate concentrations measured during the 1979 calendar year. The SLAMS hi-vol network at Belle Ayr provided the independent data set for the long-term model comparison. Since only four cases (hi-vol/receptor pairs of measured/predicted particulate concentrations) exist, a standard statistical analysis of model performance can not be used to quantify model verification. Ideally, however, the ISC Model-predicted values should equally (in quantity and magnitude) overpredict and underpredict the hi-vol measured particulate concentrations.

The ISC Model calculates arithmetic mean particulate concentrations. Consequently, to compare these values with the measured particulate concentrations, the model-predicted concentrations must be adjusted to reflect geometric means with background levels added in. This was accomplished by using the formula $y = mx+b$, where y is the geometric mean plus background, x is the ISC Model-predicted arithmetic mean, m is the conversion factor from arithmetic mean to geometric mean concentrations (0.75), and b is the background concentration (15 $\mu g/m^3$).

The long-term version of the ISC Model accurately predicted the annual particulate concentrations at all of the hi-vol locations, as summarized in Table 3.7 and illustrated in Figure 3-4. As a result of the difficulty encountered in determining the actual emissions from the dirt roads near BA-1 (new Bishop Road and T-7 South), these particulate sources could not be simulated correctly by the ISC Model, as discussed in Section 3.4. Consequently, the dirt road contribution to the total predicted particulate concentration at BA-1 (Table 3.8) is unrealistically low. For comparison, the dirt road east of BA-2 almost solely impacts that single hi-vol, as seen in Table 3.8.

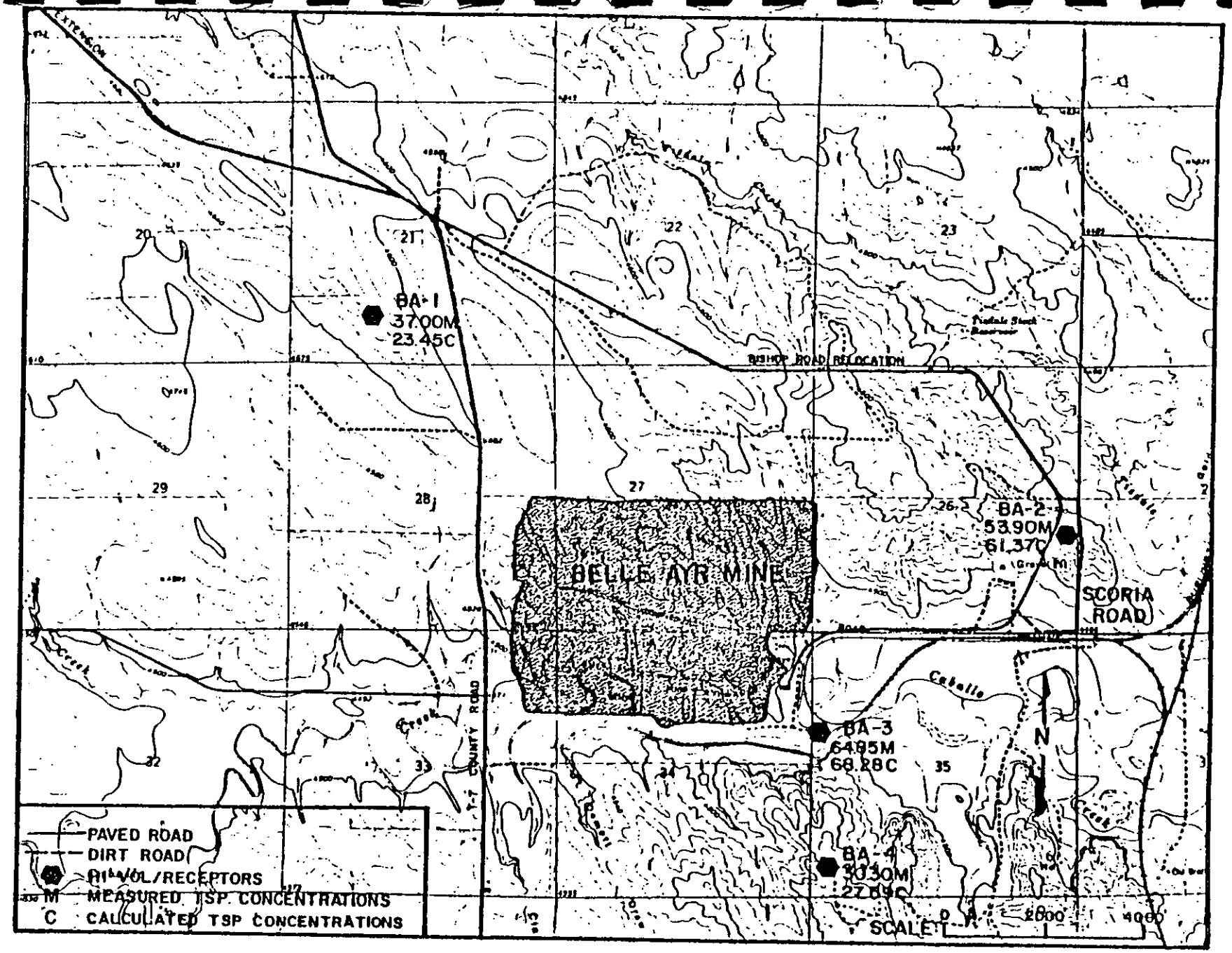

FIGURE 3-4 RESULTS OF THE LONG-TERM ISC MODEL VERIFICATION RUN

TABLE 3.8

THE CONTRIBUTION OF PARTICULATE CONCENTRATION ($\mu g/m^3$) FROM EACH SOURCE TO THE TOTAL PREDICTED ARITHMETIC MEAN CONCENTRATION AT EACH HI-VOL WITHIN THE SLAMS NETWORK (ISC LONG-TERM MODEL VERIFICATION RESULTS)

SOURCE	HI-VOL			
	BA-1	BA-2	BA-3	BA-4
Coal Dump	0.26	3.57	20.41	3.67
Train Load-out	0.12	1.24	17.88	1.85
Silo Exhaust	0.0	0.01	0.08	0.02
West Overburden Haul Road	2.34	2.11	3.44	1.73
East Overburden Haul Road	1.41	2.66	4.97	2.28
Coal Haul Road	1.14	4.44	12.43	4.01
South Road	0.08	0.37	7.18	0.79
Coal Pit	0.16	0.21	0.36	0.18
Overburden Replacement	0.20	0.53	1.06	0.45
Stripped Overburden, Topsoil and Overburden Removal	0.96	0.64	0.99	0.54
Reclaimed Land	0.04	0.19	1.08	0.25
T-7 South	1.90	0.13	0.15	0.11
New Bishop Road	2.49	0.14	0.18	0.14
BA-2 Dirt Road	0.15	45.57	0.82	0.77
TOTAL	11.26	61.83	71.04	16.78

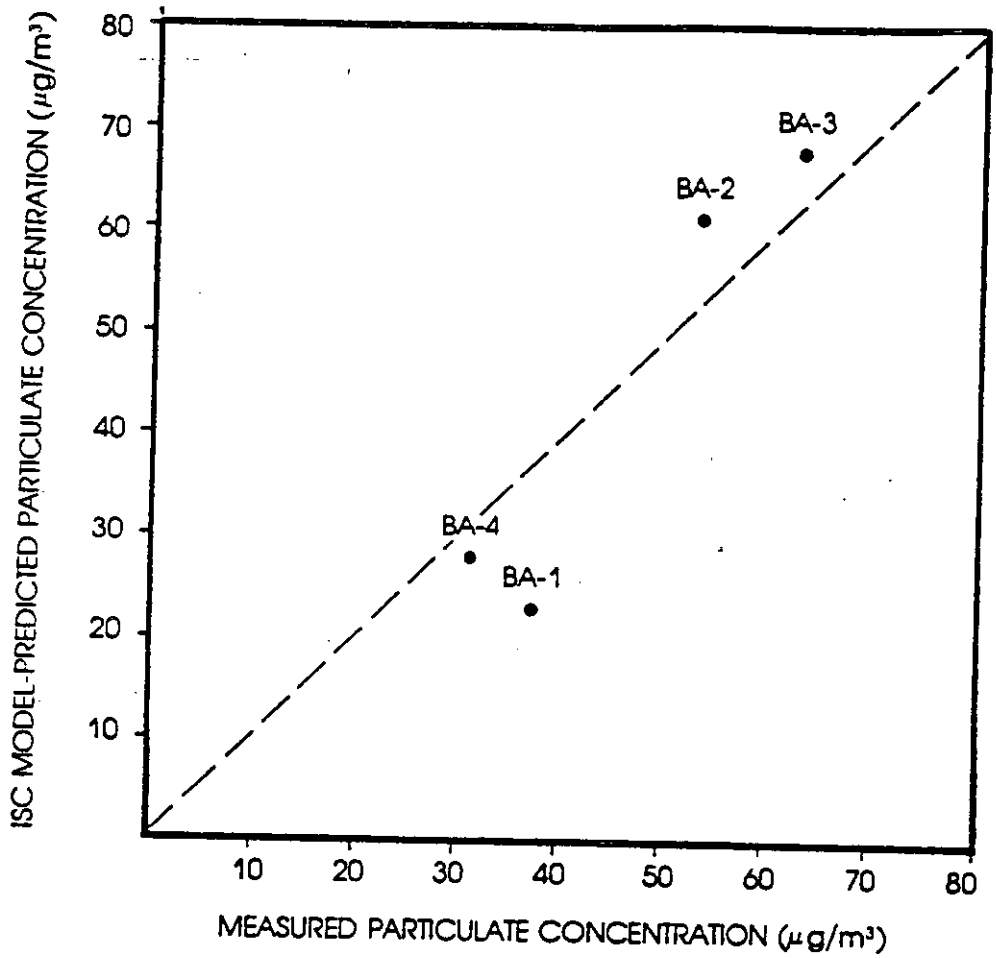

FIGURE 3-5 COMPARISON OF THE ISC LONG-TERM MODEL PREDICTED ANNUAL GEOMETRIC MEAN PARTICULATE CONCENTRATIONS (PLUS BACKGROUND) WITH THE MEASURED GEOMETRIC MEAN CONCENTRATIONS. (DOTTED LINE REPRESENTS PERFECT AGREEMENT)

TABLE 3.7

RESULTS FROM THE LONG-TERM ISC MODEL VERIFICATION RUN
ALL TSP CONCENTRATIONS ARE IN $\mu g/m^3$

BELLE AYR HI-VOL #	BA-1	BA-2	BA-3	BA-4
Measured Geometric Mean TSP Concentrations	37.00	53.90	64.85	30.30
ISC Model-Calculated TSP Concentrations (Geometric Mean Plus Background)	23.45	61.37	68.28	27.59

Although the traffic related emissions near BA-1 could not be accurately estimated, the long-term version of the ISC Model has been successfully verified, as seen in Figure 3-5. The successful verification of the ISC Model has demonstrated that the surface coal mining activities located in the Gillette Corridor of the Powder River Basin can be accurately simulated.

3.7 VERIFICATION SUMMARY

In summary, both the short-term and long-term programs of the ISC Model have yielded predictions of particulate concentrations very close to the actual hi-vol measured suspended particulate concentrations in almost all cases. When the short-term model-predicted particulate concentrations were compared to the measured particulate concentrations, the ratio values of predicted to measured concentrations were well within the bounds normally accepted for model verification purposes. The long-term version of the ISC Model demonstrated that it could also accurately simulate surface coal mining activities, even though the traffic related emissions near BA-1 could not be rigorously quantified. This successful verification of the ISC Model (for both the short-term and the long-term averaging periods) provides the confidence needed to accurately simulate the surface coal mining operations that generate particulate matter within the Powder River Basin.

SECTION 4

MODEL RUNS

4.0 MODEL RUNS

4.1 GENERAL DISCUSSION

To predict the air quality impact of the permitted mining activity south of Gillette, Wyoming, the ISC long-term model was applied to the region for the year of expected maximum impact, 1988. The regional modeling included six surface coal mines, all within close proximity of each other (defining the Corridor):

- CARTER MINING COMPANY's Caballo Mine;
- AMAX COAL COMPANY's Belle Ayr Mine;
- CONSOLIDATION COAL COMPANY's Pronghorn Mine;
- MOBIL OIL CORPORATION's Caballo Rojo Mine;
- SUNOCO ENERGY DEVELOPMENT COMPANY's Cordero Mine; and
- ATLANTIC RICHFIELD COMPANY's Coal Creek Mine.

The modeling method, as developed and described in Section 3, was used to predict the impacts of surface coal mining in the Gillette Corridor. Additionally, the model input parameters from WDEQ's long-term modeling were applied to the ISC Model to enable comparison. As mentioned, long-term modeling of the Corridor was performed for the 1988 calendar year. In this section, the two following topics will be discussed in detail:

- input for long-term Corridor modeling; and
- results of simulating the Corridor for the long-term.

4.2 LONG-TERM INPUT

The year of expected maximum impact on the regional air quality in the Corridor, including six coal mines, is the 1988 calendar year. Except for the EDS emission factors and deposition input, all other model input data duplicated WDEQ's simulation of the 1988 mining operations in the Corridor. In modeling surface coal mining activities in the State of Wyoming, the WDEQ uses a modified form of EPA's UNAMAP Climatological Dispersion Model (CDM)(EPA, 1973)--a rural, flat terrain, Gaussian plume dispersion model with

no gravitational settling or dry deposition of particulates—known as CDMW. In applying the ISC Model to the long-term regional modeling, a rural, flat terrain environment, similar to WDEQ's modeling, was assumed. As required by both the CDMW and ISCLT, the meteorological input data must be in STAR format (statistical summary of wind and atmospheric stability conditions). The "Central Cambell County" STAR data, provided by the WDEQ, meteorologically represented the Corridor simulated. Figure 4-1 illustrates the wind rose associated with the STAR data used. The same source configuraton used by WDEQ in their 1988 model run was maintained and applied to the ISC Model (displayed in Figure 4-2).

To calculate the emission rates for each source displayed in Figure 4-2, the EDS-developed emission factors and particle size distributions were used in conjunction with the permitted mining production rates for each mine. Public documents (Permit Applications, WDEQ Permit Analyses), available at the WDEQ, provided the required 1988 coal production rates for each of the six surface mines in the Corridor and have been summarized in Table 4.1. The equations with the control factors and production rates, used by WDEQ in their simulation of the Corridor, are listed in the appendices. The methods used to compute the emission rates for each type of source are detailed below. These methods duplicate WDEQ's Emission Inventories except for the emission factors used and the exclusion of WDEQ's "percent suspended" term. Instead, the particle size distribution, discussed in Section 3.2, was input to simulate the dry deposition and gravitational settling associated with the mining activities.

To calculate the particulate emission rates for each of the surface coal mining activities, the following WDEQ equations, adjusted for this task (as described above), were used. The emission factors listed Table 3.3 have been applied to these equations.

-Scraper Operations

$$\frac{(0.50\ \text{control})(32\ \text{lb/scraper-hr})(0.726\ \text{ratio}^{\text{"wet days}})(\#\ \text{scraper-hr/yr})(0.126)^{*}}{(8760\ \text{hr/yr})} = \text{g/sec}$$

*The conversion factor from lbs/hr to g/sec is 0.126.

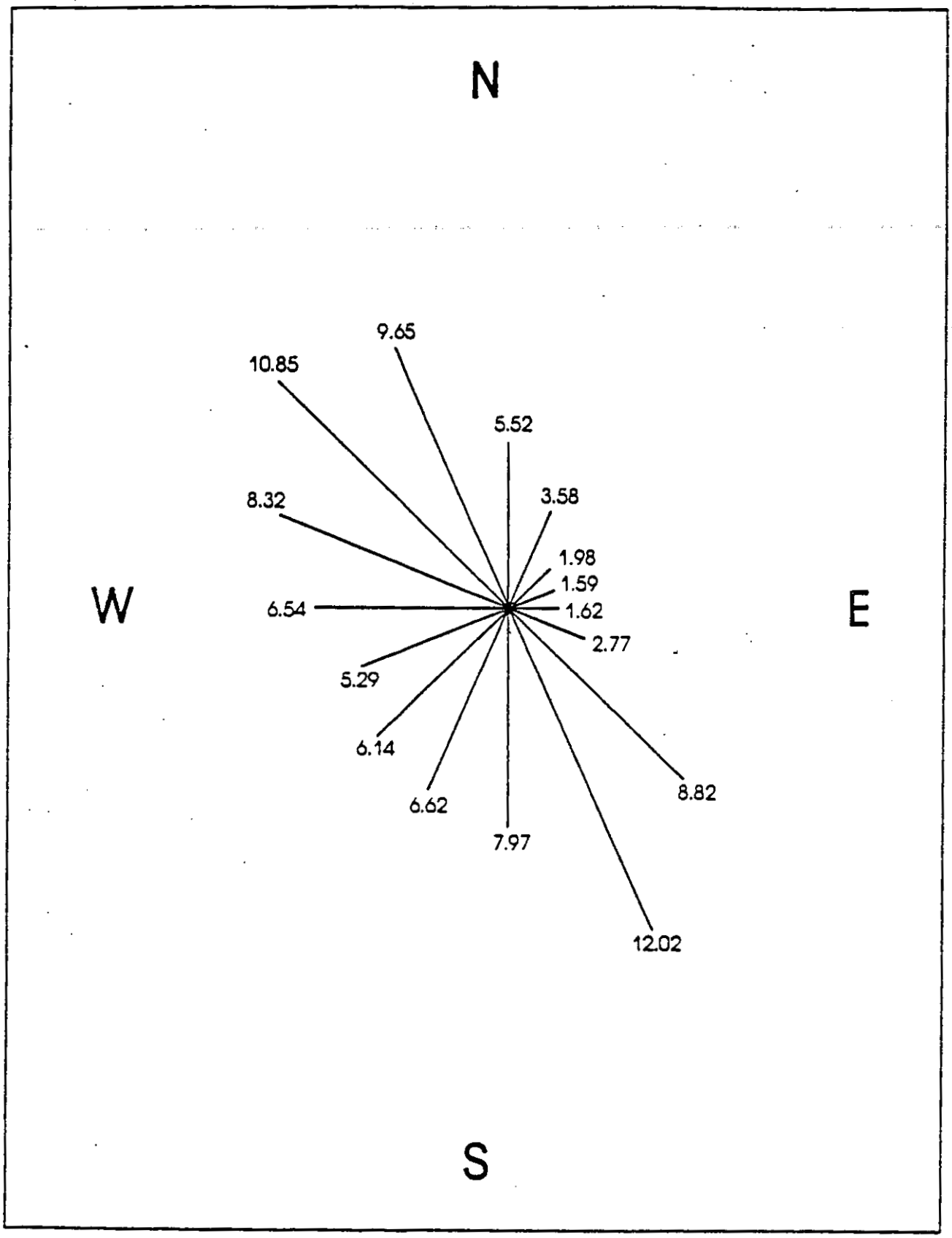

FIGURE 4-1 WIND ROSE ASSOCIATED WITH THE "CENTRAL CAMPBELL COUNTY" STAR DATA PROVIDED BY THE WYOMING DEQ (NUMBERS REPRESENT PERCENT OF TIME WIND BLOWS FROM THE INDICATED DIRECTION)

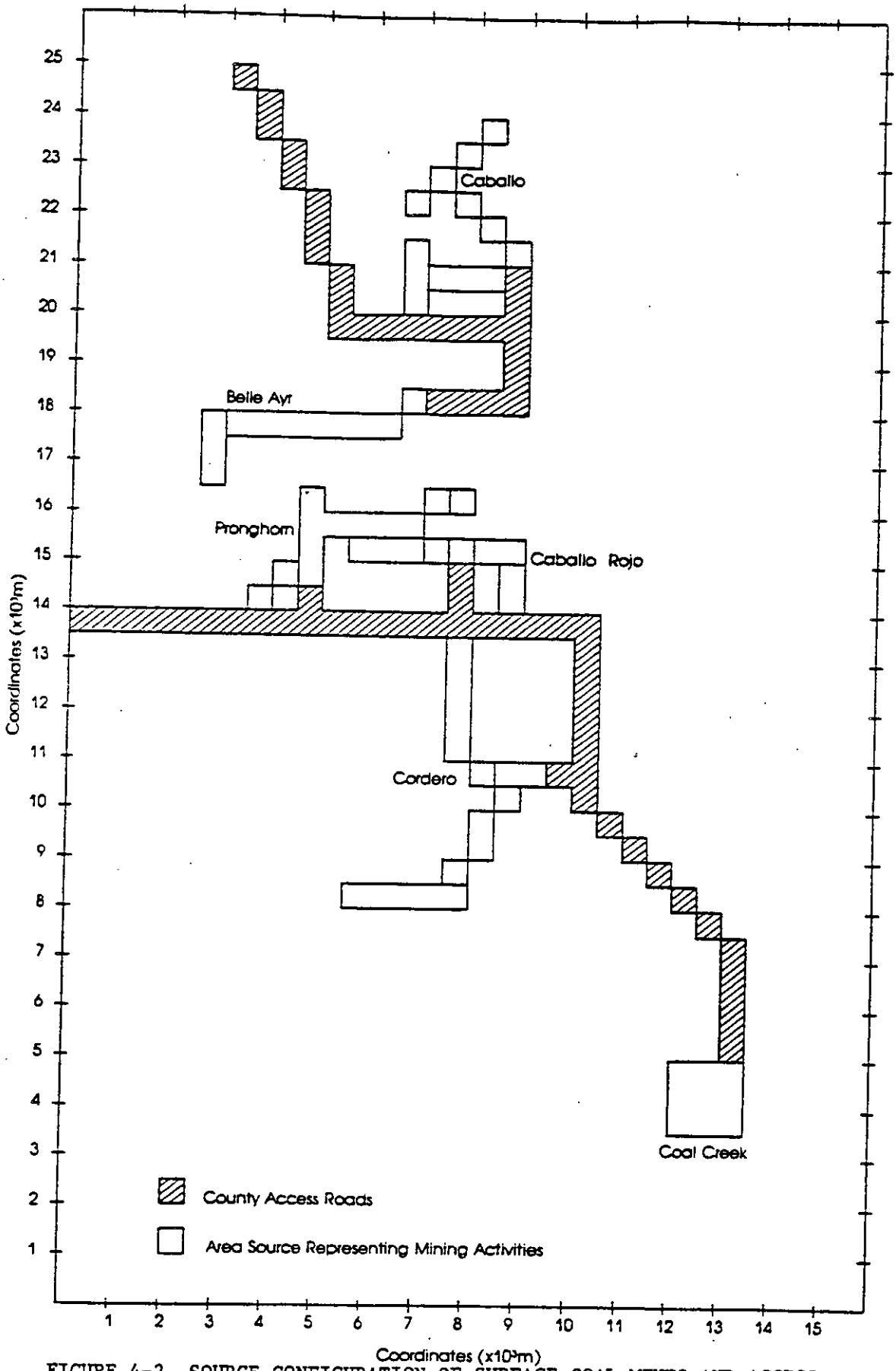

FIGURE 4-2 SOURCE CONFIGURATION OF SURFACE COAL MINES AND ACCESS ROADS USED TO DUPLICATE WDEQ'S 1988 GILLETTE CORRIDOR RUN

TABLE 4.1

1988 PRODUCTION DATA FOR CORRIDOR

(These Production Rates are Available from WDEQ Public Documents)

	AMAX Belle Ayr	CARTER Caballo	MOBIL Caballo Rojo	SUNEDCO Cordero	CONSOL Pronghorn	ARCO Coal Creek
Scraper Operations (hr/yr)	2.36×10^4	1.42×10^4	4.4×10^3	2.23×10^4	2832	9.75×10^3
Overburden Removal (yd^3/yr)	3.75×10^7	26.6×10^6	30.2×10^6	50.1×10^6	11.597×10^6	4.3×10^6
Coal Production (ton/yr)	25×10^6	12×10^6	15×10^6	24×10^6	5×10^6	18×10^6
Wind Erosion (acre/yr)	130	200	226	283	310	815
Coal Haul Roads (mi)	6.1	7.1	5.26	4.98	4.98	3.7
Overburden Haul Roads (mi)	0.8	1.0	1.2	0.8	3.36 for 8% 1.50 for 92%	1.14
Haul Road Repair (hr/yr)	8.53×10^3	8.53×10^3	5×10^3	7.11×10^3	1.326×10^4	2.0768×10^4
Overburden Blasting (blasts/yr)	312	600	250	365	104	250
Coal Blasting (blasts/yr)	208	300	300	365	104	250
Topsoil Removal (yd^3/yr)	2.1676×10^5	5.23×10^5	4.75×10^5	6.104×10^5	1.58×10^5	3×10^5
Access Road (trips/yr)	1.6762×10^5	7.727×10^4	1.625×10^4	1.5753×10^5		8.558×10^4

-Overburden Removal

Truck/Shovel

$$\frac{(0.02\ \text{lb/ton})(1.74\ \text{ton/yd}^3)(\#\ \text{yd}^3/\text{yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

Dragline

$$\frac{(0.04\ \text{lb/yd}^3)(1.74\ \text{ton/yd}^3)(\#\ \text{yd}^3/\text{yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Coal Removal (Frontend Loader or Truck/Shovel)

$$\frac{(0.003\ \text{lb/ton})(\#\ \text{ton/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Coal Dump

$$\frac{(\text{control factor})(0.066\ \text{lb/ton})(\#\ \text{ton/yr})(0.126)}{8760\ \text{hr/yr}} = \text{g/sec}$$

50% control factor for Caballo Rojo, Pronghorn, Coal Creek, and Belle Ayr
85% control factor for Cordero and Caballo

-Wind Erosion (assume 4.7 m/sec wind speed)

$$\frac{(0.38\ \text{ton/acre/yr})(2000\ \text{lb/ton})(\#\ \text{acre/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Coal Haul Roads (assume average watering for controlling particulate emissions)

$$\frac{(5.6\ \text{lbs/VMT})(\text{length of haul road-miles})(\#\ \text{ton/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Overburden Haul Roads (assume average watering for controlling particulate emissions)

$$\frac{(5.6\ \text{lbs/VMT})(\text{length of haul road-miles})(\#\ \text{yd}^3/\text{yr})(0.126)}{(8760\ \text{hr/yr})(\#\ \text{yd}^3/\text{hauling vehicle})} = \text{g/sec}$$

-Haul Road Repair

$$\frac{(0.50\ \text{control})(32\ \text{lb/grader-hr})(0.726\ \text{ratio}^{\text{"wet days}})(\#\ \text{grader hr/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Overburden Blasting

$$\frac{(50\ \text{lb/blast})(\#\ \text{overburden blasts/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Coal Blasting

$$\frac{(35\ \text{lbs/blast})(\#\ \text{coal blasts/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Crushers (Primary and Secondary)

$$\frac{(\text{control efficiency})(0.08\ \text{lbs/ton})(\#\ \text{tons/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Train Loading

$$\frac{(0.028\ \text{lbs/ton})(\#\ \text{tons/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Overburden Replacement

$$\frac{(0.012\ \text{lbs/ton})(1.74\ \text{ton/yd}^3)(\#\ \text{yd}^3\text{/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Access Road

$$\frac{(\text{control efficiency})(8.44\ \text{lb/VMT})(\#\ \text{trips/yr})(\#\ \text{miles/trip})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

-Topsoil Removal

$$\frac{(0.058\ \text{lbs/ton})(\text{topsoil density})(\#\ \text{yd}^3\text{/yr})(0.126)}{(8760\ \text{hr/yr})} = \text{g/sec}$$

TOPSOIL DENSITY PROVIDED BY EACH MINE

MINE	TON/YD^3
Caballo Rojo	1.40
Pronghorn	1.40
Cordero	1.76
Coal Creek	1.30
Belle Ayr	1.54
Caballo	1.54

Table 4.2 summarizes the resulting 1988 Emission Inventory for each of the six surface coal mines. The same distribution of the above described surface coal mining operations as used in WDEQ's simulation of the Corridor has been applied to the area source configuration illustrated in Figure 4-2.

4.3 LONG-TERM CORRIDOR MODEL RESULTS

The ISC Model results depicting the annual period are to be compared to the WDEQ dispersion analysis for the Corridor. WDEQ's model analysis is therefore included to facilitate this comparison. Figure 4-3 is the WDEQ isopleth map of their calculated annual geometric mean TSP concentrations due to the Corridor's mining activities. The important feature of Figure 4-3 is that the annual ambient air quality standard for total suspended particulates of 60 $\mu g/m^3$ will not be exceeded due to the mining activities associated with the six surface coal mines. In particular, the WDEQ predicted maximum annual average geometric mean TSP concentration due to 1988 mining operations, plus background, within the Corridor to be 58 $\mu g/m^3$.

The ISC Model long-term program predicts annual arithmetic mean TSP concentrations. In the Powder River Basin region, the background TSP concentration has been determined by WDEQ to be 15 $\mu g/m^3$ with a 0.75 conversion factor from an arithmetic to a geometric mean concentration. Applying these constants to the ISC Model-predicted TSP concentrations for the long-term Corridor run results in the isopleth map shown in Figure 4-4. The values on both maps represent the annual geometric mean TSP concentrations due to the 1988 mining operations within the Corridor plus a background concentration of 15 $\mu g/m^3$. As a result of simulating the Corridor's mining activities with a more sophisticated atmospheric dispersion model and using site specific emission factors for the various coal surface mining activities, a general improvement is seen in the predicted 1988 air quality impact from the six coal mines. The EDS-predicted lower particulate impact is due to the accurate simulation of dry deposition and gravitational settling. The isopleth pattern in Figure 4-4 (EDS model run) is similar to the isopleth pattern of Figure 4-3 (WDEQ model run). The maximum annual geometric mean TSP concentration, including background, as generated by the EDS model, however,

TABLE 4.2

1988 EMISSION INVENTORY FOR CORRIDOR

Emission Rates (g/sec) Developed by Applying EDS Emission Factors to Production Rates Available from WDEQ Public Documents (and Summarized in Volume II) Using the Equations Listed Above. If no Emission Rate is Listed, WDEQ did not Include the Source in Their Analysis of the Corridor.

	AMAX Belle Ayr	CARTER Caballo	MOBIL Caballo Rojo	SUNEDCO Cordero	CONSOL Pronghorn	ARCO Coal Creek
Scraper Operations	3.95	2.37	0.74	3.73	0.47	1.63
Overburden Removal	18.77	17.75	15.12	25.07	5.89	21.52
Coal Removal	1.08	0.52	0.64	1.03	0.21	0.78
Truck Dump	11.87	6.21	7.12	12.42	2.37	8.54
Wind Erosion	1.42	2.19	2.47	3.10	3.39	8.91
Coal Haul Roads	102.36	19.06	52.96	56.63	11.80	17.88
Overburden Haul Roads	35.04	14.62	31.05	33.04	16.85	40.41
Haul Road Repair	1.43	1.43	0.84	1.19	2.22	3.47
Overburden Blasting	0.23	0.43	0.18	0.26	0.08	0.18
Coal Blasting	0.10	0.15	0.15	0.19	0.05	0.01
Crushers		2.39	0.18	1.01 1.57	0.29	2.59 1.03
Train Loading			6.04		2.01	7.25
Silo Storage		0.30		0.58		
Barn Storage				1.16		
Trough Storage						0.52
Total Prep Plant	1.89					
Sampling Station		0.30				
Topsoil Removal	0.28	0.67	0.55	0.90	0.18	0.33
Overburden Replacement	11.26	8.00	9.07	15.04	3.48	12.92
Access Road	76.65	30.34	3.19	84.45	10.65	70.48

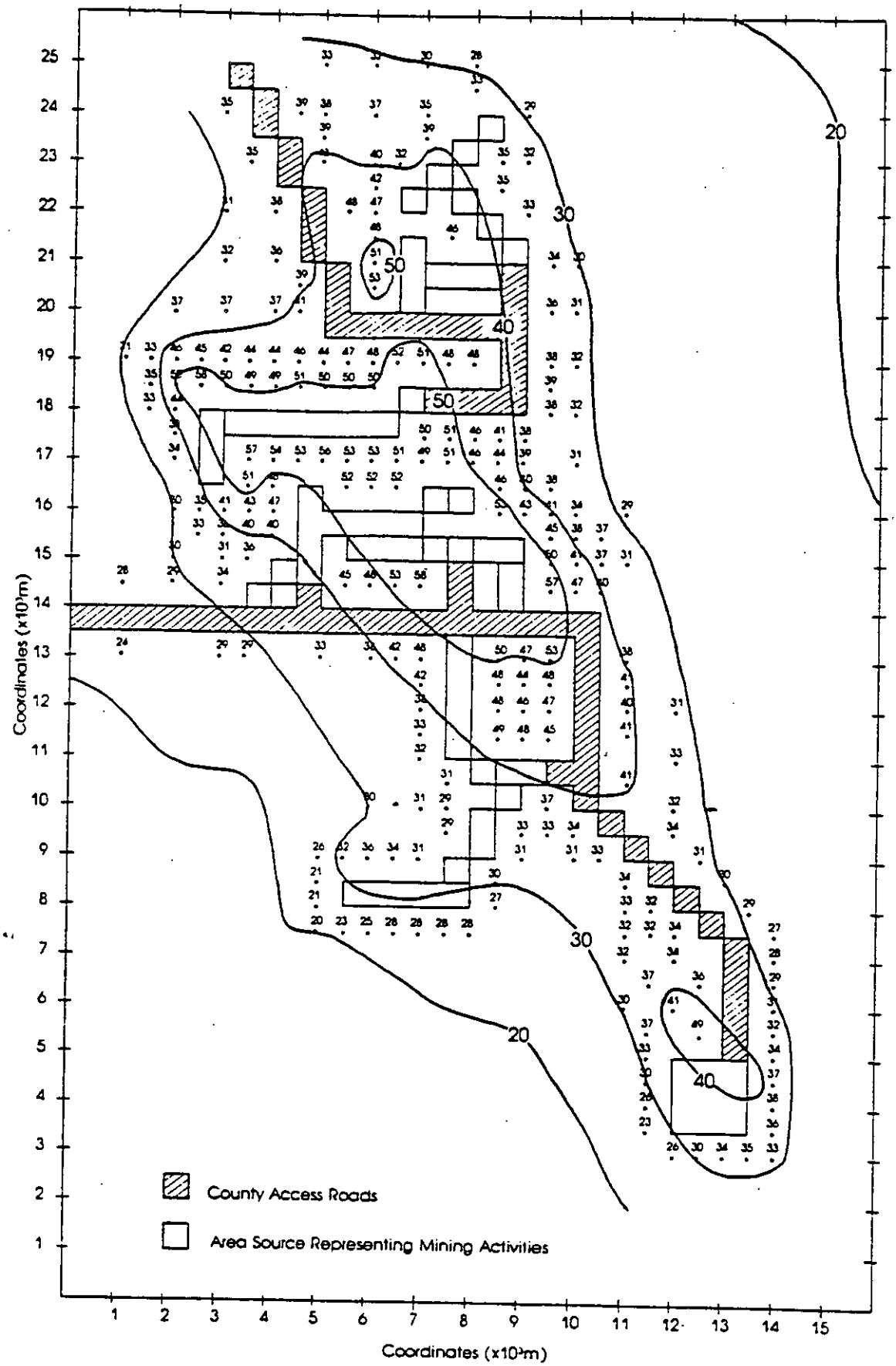

FIGURE 4-3 ANNUAL GEOMETRIC MEAN TSP CONCENTRATIONS ($\mu g/m^3$) DUE TO 1988 MINING OPERATIONS PLUS BACKGROUND AS MODELED BY WDEQ (WDEQ RUN #107)

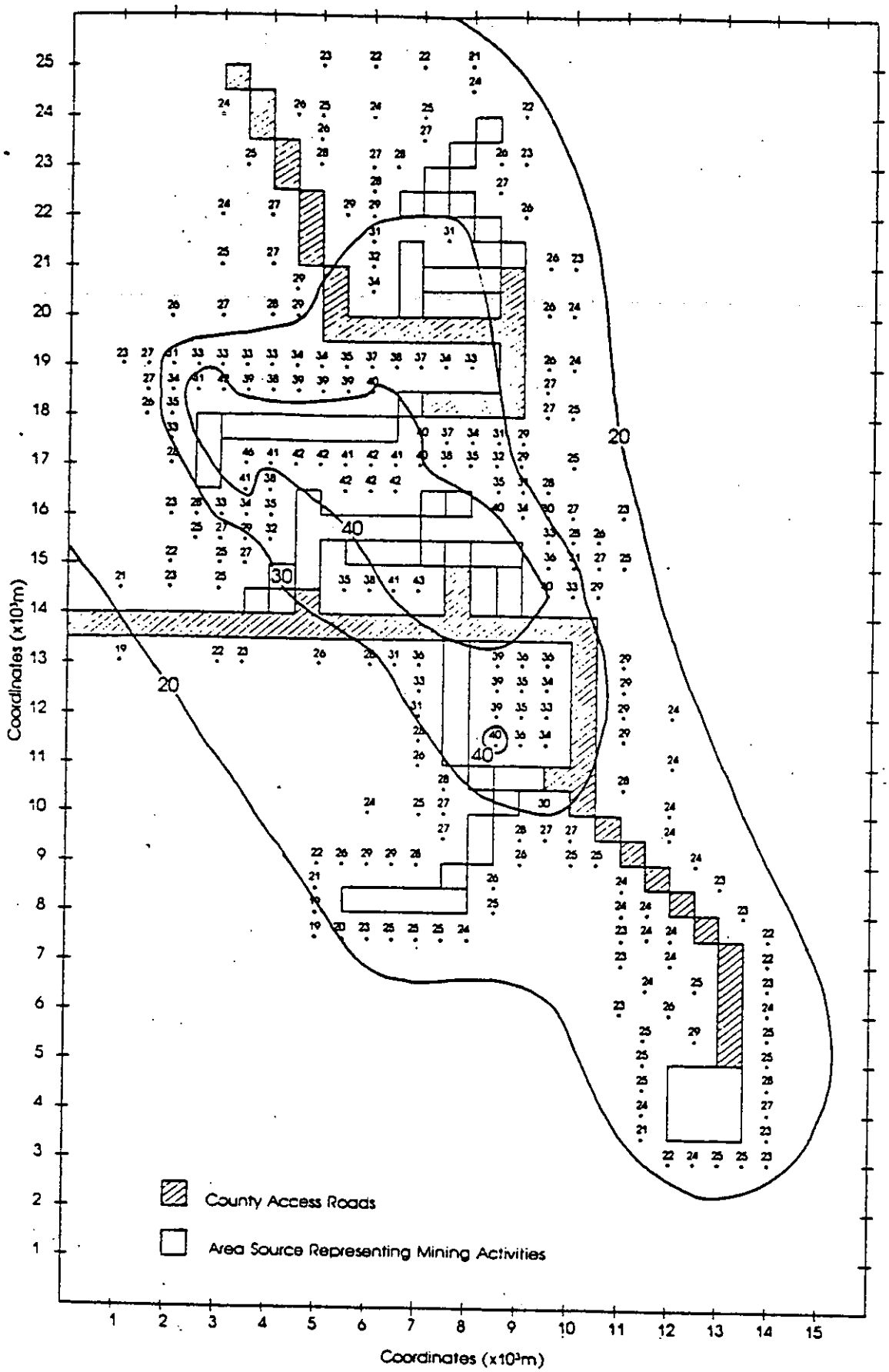

FIGURE 4-4 ANNUAL GEOMETRIC MEAN TSP CONCENTRATIONS ($\mu g/m^3$) DUE TO 1988 MINING OPERATIONS PLUS BACKGROUND AS MODELED BY EDS

is only 46 $\mu g/m^3$. The maximum concentration of 46 $\mu g/m^3$ is predicted by the ISC Model to occur at a grid location near the current BA-3 SLAMS hi-vol. This value is lower than current annual average measurements, see Figure 3-4, mainly due to the receptor grid size and due to the changing mine pit geometry and location as modeled by WDEQ, illustrated in Figure 4-2. Table 4.3 lists the output from the long-term Corridor run. Also included in Table 4.3 is the calculated TSP concentration contributed by separate sources at each receptor. These separate sources are:

- CARTER MINING COMPANY's Caballo Mine;
- AMAX COAL COMPANY's Belle Ayr Mine;
- MOBIL OIL CORPORATION's Caballo Rojo Mine; and
- ATLANTIC RICHFIELD COMPANY's Coal Creek Mine.

TABLE 4.3

ANNUAL MEAN TSP CONCENTRATIONS CONTRIBUTED BY CARTER'S CABALLO MINE TO EACH RECEPTOR IN THE CORRIDOR

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 51 *

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) FROM COMBINED SOURCES 1. -13.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
12000.0	3000.0	.101784	12500.0	3000.0	.103629	13000.0	3000.0	.105266
13500.0	3000.0	.107082	14000.0	3000.0	.110267	11500.0	3500.0	.109840
14000.0	3500.0	.116168	11500.0	4000.0	.110359	14000.0	4000.0	.122142
11500.0	4500.0	.116332	14000.0	4500.0	.128497	11500.0	5000.0	.122818
14000.0	5000.0	.135042	11500.0	5500.0	.129869	12500.0	5500.0	.135256
14000.0	5500.0	.142838	11000.0	6000.0	.134575	12000.0	6000.0	.140158
14000.0	6000.0	.150587	11500.0	6500.0	.145946	12500.0	6500.0	.154766
14000.0	6500.0	.159545	11000.0	7000.0	.151870	12000.0	7000.0	.159712
14000.0	7000.0	.168565	5000.0	7500.0	.100115	5500.0	7500.0	.101027
6000.0	7500.0	.105757	6500.0	7500.0	.112628	7000.0	7500.0	.119408
7500.0	7500.0	.124173	8000.0	7500.0	.130639	11000.0	7500.0	.161811
11500.0	7500.0	.165458	12500.0	7500.0	.172120	14000.0	7500.0	.179803
5000.0	8000.0	.105728	8500.0	8000.0	.146774	11000.0	8000.0	.172768
11500.0	8000.0	.177753	13500.0	8000.0	.189860	5000.0	8500.0	.111832
8500.0	8500.0	.157037	11000.0	8500.0	.184803	13000.0	8500.0	.201215
5000.0	9000.0	.116492	5500.0	9000.0	.122498	6000.0	9000.0	.126246
6500.0	9000.0	.135530	7000.0	9000.0	.144621	9000.0	9000.0	.175942
12000.0	9000.0	.188323	12500.0	9000.0	.193725	12500.0	9000.0	.213881
7500.0	9500.0	.161911	9000.0	9500.0	.189389	9500.0	9500.0	.196069
10000.0	9500.0	.232731	12000.0	9500.0	.227794	6000.0	10000.0	.143697
7000.0	10000.0	.166553	7500.0	10000.0	.178248	9500.0	10000.0	.211726
12000.0	10000.0	.244352	7500.0	10500.0	.188160	11000.0	10500.0	.258869
7000.0	11000.0	.194390	12000.0	11000.0	.285646	7000.0	11500.0	.211275
8500.0	11500.0	.251223	9000.0	11500.0	.263191	9500.0	11500.0	.272318
11000.0	11500.0	.306033	7000.0	12000.0	.230691	8500.0	12000.0	.275572
9000.0	12000.0	.288793	9500.0	12000.0	.298647	11000.0	12000.0	.334181
12000.0	12000.0	.337382	7000.0	12500.0	.253171	8500.0	12500.0	.303835
9000.0	12500.0	.318480	9500.0	12500.0	.330950	11000.0	12500.0	.365184
1000.0	13000.0	.139436	3000.0	13000.0	.151479	3500.0	13000.0	.170930
5000.0	13000.0	.206553	6000.0	13000.0	.228925	6500.0	13000.0	.259859
7000.0	13000.0	.279397	8500.0	13000.0	.336889	9000.0	13000.0	.353132
9500.0	13000.0	.371995	11000.0	13000.0	.402599	1000.0	14500.0	.123633
2000.0	14500.0	.198336	3000.0	14500.0	.175731	5500.0	14500.0	.287951
6000.0	14500.0	.311092	6500.0	14500.0	.351188	7000.0	14500.0	.391169
9500.0	14500.0	.548312	12000.0	14500.0	.552214	10500.0	14500.0	.554088
2000.0	15000.0	.158812	3000.0	15000.0	.187899	3500.0	15000.0	.207972
9500.0	15000.0	.621371	10000.0	15000.0	.623274	10500.0	15000.0	.625892
11000.0	15000.0	.626960	2500.0	15500.0	.180266	3000.0	15500.0	.201300
3500.0	15500.0	.222830	4000.0	15500.0	.258298	9500.0	15500.0	.711056
10000.0	15500.0	.711575	12500.0	15500.0	.709167	2000.0	16000.0	.169668
2500.0	16000.0	.191616	3000.0	16000.0	.213097	3500.0	16000.0	.239910
8000.0	16000.0	.231338	8500.0	16000.0	.288888	9000.0	16000.0	.823938
9500.0	16000.0	.817296	10000.0	16000.0	.819053	11000.0	16000.0	.824631
3500.0	16500.0	.256476	4000.0	16500.0	.294114	5500.0	16500.0	.458980

TABLE 4.3 CONTINUED

CONTRIBUTIONS BY CARTER'S CABALLO MINE CONTINUED

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 52 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) (CONT.) FROM COMBINED SOURCES 1. -13.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
6000.0	16500.0	.499490	6500.0	16500.0	.612259	8500.0	16500.0	.949242
9500.0	16500.0	.964382	5500.0	16500.0	.954278	2000.0	17000.0	.179691
3500.0	17000.0	.278265	4000.0	17000.0	.315680	4500.0	17000.0	.375366
5000.0	17000.0	.462682	5500.0	17000.0	.535662	6000.0	17000.0	.578385
6500.0	17000.0	.720677	7000.0	17000.0	.855394	7500.0	17000.0	.904342
8000.0	17000.0	1.252580	8500.0	17000.0	1.199533	9000.0	17000.0	1.190590
10000.0	17000.0	1.193886	2000.0	17500.0	.189950	7000.0	17500.0	1.044363
7500.0	17500.0	1.196633	6500.0	17500.0	1.334314	8500.0	17500.0	1.379953
9000.0	17500.0	1.385782	1500.0	18000.0	.169382	2000.0	18000.0	.193582
9500.0	18000.0	1.667035	10000.0	18000.0	1.610977	1500.0	18500.0	.176271
2000.0	18500.0	.202052	2500.0	18500.0	.237930	3000.0	18500.0	.283688
3500.0	18500.0	.323563	4000.0	18500.0	.390027	4500.0	18500.0	.487317
5000.0	18500.0	.620963	5500.0	18500.0	.820921	6000.0	18500.0	1.078301
9500.0	18500.0	2.026557	1000.0	19000.0	.158497	1500.0	19000.0	.180526
2000.0	19000.0	.236355	2500.0	19000.0	.280985	3000.0	19000.0	.291473
3500.0	19000.0	.363997	4000.0	19000.0	.427266	4500.0	19000.0	.528919
5000.0	19000.0	.684702	5500.0	19000.0	.996843	6000.0	19000.0	1.348376
6500.0	19000.0	1.970289	7000.0	19000.0	2.626906	7500.0	19000.0	3.061931
8000.0	19000.0	3.284139	9500.0	19000.0	2.521091	10000.0	19000.0	2.229009
2000.0	20000.0	.229402	3000.0	20000.0	.308517	4000.0	20000.0	.481918
9500.0	20000.0	.686810	9500.0	20000.0	3.970736	10000.0	20000.0	3.259909
9500.0	20500.0	.683240	6000.0	20500.0	3.623619	3000.0	21000.0	.371313
4000.0	21000.0	.593310	6000.0	21000.0	5.124697	9500.0	21000.0	6.421871
10000.0	21000.0	3.294537	6000.0	21500.0	6.155346	7500.0	21500.0	10.187049
3000.0	22000.0	.452607	4000.0	22000.0	.804557	5500.0	22000.0	3.234112
6000.0	22000.0	5.978974	9000.0	22000.0	8.004900	6000.0	22500.0	5.948054
8500.0	22500.0	9.202761	3500.0	23000.0	.755928	5000.0	23000.0	2.328305
6000.0	23000.0	5.566517	6500.0	23000.0	8.367484	8500.0	23000.0	8.820135
9000.0	23000.0	5.846879	5000.0	23500.0	2.378318	7000.0	23500.0	8.931895
3000.0	24000.0	.753569	4500.0	24000.0	1.795643	5000.0	24000.0	2.417291
6000.0	24000.0	4.397500	7000.0	24000.0	6.786925	9000.0	24000.0	4.339547
8000.0	24500.0	6.593138	5000.0	25000.0	2.356380	6000.0	25000.0	3.270071
7000.0	25000.0	4.371611	8000.0	25000.0	4.107197			

TABLE 4.3 CONTINUED

ANNUAL MEAN TSP CONCENTRATIONS CONTRIBUTED BY AMAX'S BELLE AYR MINE TO EACH RECEPTOR IN THE CORRIDOR

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 55 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) FROM COMBINED SOURCES 14. -24.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
12000.0	3000.0	.424479	12500.0	3000.0	.420476	13000.0	3000.0	.417165
13500.0	3000.0	.413471	14000.0	3000.0	.403710	11500.0	3500.0	.450634
14000.0	3500.0	.422718	11500.0	4000.0	.376667	14000.0	4000.0	.492878
11500.0	4500.0	.504321	14000.0	4500.0	.464272	11500.0	5000.0	.534286
14000.0	5000.0	.498785	11500.0	5500.0	.565710	12500.0	5500.0	.546747
14000.0	5500.0	.518318	11000.0	6000.0	.605980	12000.0	6000.0	.591145
14000.0	6000.0	.544407	11500.0	6500.0	.639511	12500.0	6500.0	.612032
14000.0	6500.0	.567296	11000.0	7000.0	.692175	12000.0	7000.0	.664305
14000.0	7000.0	.587739	5000.0	7500.0	.697112	5500.0	7500.0	.673513
6000.0	7500.0	.693844	6500.0	7500.0	.751457	7000.0	7500.0	.781393
7500.0	7500.0	.777167	8000.0	7500.0	.781569	11000.0	7500.0	.739905
11500.0	7500.0	.725655	12000.0	7500.0	.713367	14000.0	7500.0	.611133
5000.0	8000.0	.708936	9500.0	8000.0	.847912	11000.0	8000.0	.796384
11500.0	8000.0	.781277	13500.0	8000.0	.663976	5000.0	8500.0	.780592
8500.0	8500.0	.921603	11000.0	8500.0	.861120	13000.0	8500.0	.729996
5000.0	9000.0	.864149	5500.0	9000.0	.906243	6000.0	9000.0	.990105
6500.0	9000.0	1.012739	7000.0	9000.0	1.011674	9000.0	9000.0	.993194
12000.0	9000.0	.359690	12500.0	9000.0	.952318	12500.0	9000.0	.799313
7500.0	9500.0	1.116431	9000.0	9500.0	1.081828	9500.0	9500.0	1.066631
10000.0	9500.0	1.059386	12000.0	9500.0	.875523	6000.0	10000.0	1.239297
7000.0	10000.0	1.281511	7500.0	10000.0	1.235558	9500.0	10000.0	1.177753
12000.0	10000.0	.921292	7500.0	10500.0	1.370650	11000.0	10500.0	1.084260
7000.0	11000.0	1.599934	12000.0	11000.0	1.016573	7000.0	11500.0	1.799388
8500.0	11500.0	1.663652	9000.0	11500.0	1.525682	9500.0	11500.0	1.487899
11000.0	11500.0	1.218993	7000.0	12000.0	1.991090	8500.0	12000.0	1.820358
9000.0	12000.0	1.703490	9500.0	12000.0	1.601470	11000.0	12000.0	1.290044
12000.0	12000.0	1.108985	7000.0	12500.0	2.323227	8500.0	12500.0	1.975998
9000.0	12500.0	1.857082	9500.0	12500.0	1.725144	11000.0	12500.0	1.362478
10000.0	13000.0	1.156313	3000.0	13000.0	2.039047	3500.0	13000.0	2.161435
5000.0	13000.0	2.739519	6000.0	13000.0	2.718311	6500.0	13000.0	2.796267
7000.0	13000.0	2.652027	8500.0	13000.0	2.169786	9000.0	13000.0	2.030817
9500.0	13000.0	1.856341	11000.0	13000.0	1.436846	1000.0	14500.0	1.478735
2000.0	14500.0	2.462170	3000.0	14500.0	3.978237	5500.0	14500.0	3.829046
6000.0	14500.0	4.473988	6500.0	14500.0	4.147385	7000.0	14500.0	3.862237
9500.0	14500.0	2.326686	10000.0	14500.0	2.096290	10500.0	14500.0	1.841675
2000.0	15000.0	3.187869	3000.0	15000.0	5.508787	5500.0	15000.0	6.738228
9500.0	15000.0	2.953502	10000.0	15000.0	2.176978	10500.0	15000.0	1.876962
11000.0	15000.0	1.692415	2500.0	15500.0	6.274372	3000.0	15500.0	8.619136
3500.0	15500.0	9.931195	4000.0	15500.0	9.398981	9500.0	15500.0	2.629122
10000.0	15500.0	2.228371	10500.0	15500.0	1.924728	2000.0	16000.0	5.510301
2500.0	16000.0	10.487730	3000.0	16000.0	16.349763	3500.0	16000.0	15.863310
4000.0	16000.0	12.822896	8500.0	16000.0	3.820015	9000.0	16000.0	3.284782
9500.0	16000.0	2.718982	10000.0	16000.0	2.286360	11000.0	16000.0	1.684748
3500.0	16500.0	24.163096	4000.0	16500.0	18.710210	5500.0	16500.0	10.808783

TABLE 4.3 CONTINUED

CONTRIBUTIONS BY AMAX'S BELLE AYR MINE CONTINUED

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 54 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) (CONT.) FROM COMBINED SOURCES 19. -24.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
6000.0	16500.0	10.268952	6500.0	16500.0	9.152109	8500.0	16500.0	4.315723
9000.0	16500.0	3.399005	9500.0	16500.0	2.733072	2000.0	17000.0	12.407675
3500.0	17000.0	32.999294	4000.0	17000.0	21.169553	4500.0	17000.0	17.763101
5000.0	17000.0	16.120998	5500.0	17000.0	15.198966	6000.0	17000.0	14.309448
6500.0	17000.0	12.859883	7000.0	17000.0	10.277459	7500.0	17000.0	7.740030
8000.0	17000.0	5.913862	8500.0	17000.0	4.320079	9000.0	17000.0	3.170722
1000.0	17500.0	2.330678	2000.0	17500.0	17.817258	7000.0	17500.0	13.775758
7500.0	17500.0	9.343966	8000.0	17500.0	6.196850	8500.0	17500.0	4.568160
9000.0	17500.0	3.513619	1500.0	18000.0	9.911321	2000.0	18000.0	20.850690
9500.0	18000.0	2.637593	10000.0	18000.0	2.203920	1500.0	18500.0	10.652123
2000.0	18500.0	19.458123	2500.0	18500.0	28.258682	3000.0	18500.0	27.462963
3500.0	18500.0	22.367242	4000.0	18500.0	20.703896	4500.0	18500.0	19.718851
5000.0	18500.0	18.830642	5500.0	18500.0	18.019056	6000.0	18500.0	17.613256
9500.0	18500.0	2.295510	1000.0	19000.0	6.783396	1500.0	19000.0	10.525327
2000.0	19000.0	15.638361	2500.0	19000.0	17.890207	3000.0	19000.0	17.105009
3500.0	19000.0	15.263685	4000.0	19000.0	14.206148	4500.0	19000.0	13.640208
5000.0	19000.0	13.038676	5500.0	19000.0	12.398759	6000.0	19000.0	12.668973
6500.0	19000.0	13.213394	7000.0	19000.0	9.932819	7500.0	19000.0	6.108853
8000.0	19000.0	4.238910	9500.0	19000.0	2.127184	10000.0	19000.0	1.769767
2000.0	20000.0	9.454649	3000.0	20000.0	9.463262	4000.0	20000.0	8.618717
4500.0	20000.0	7.988833	9500.0	20000.0	1.726789	10000.0	20000.0	1.592903
4500.0	20500.0	6.654994	6000.0	20500.0	5.463699	3000.0	21000.0	6.297486
4000.0	21000.0	5.828517	6000.0	21000.0	4.294906	9500.0	21000.0	1.496346
10000.0	21000.0	1.282116	6000.0	21500.0	3.435959	7500.0	21500.0	2.222659
3000.0	22000.0	4.576540	4000.0	22000.0	4.061517	5500.0	22000.0	3.269779
6000.0	22000.0	2.881610	9000.0	22000.0	1.350562	6000.0	22500.0	2.463742
8500.0	22500.0	1.496992	3500.0	23000.0	3.195810	5000.0	23000.0	2.792902
6000.0	23000.0	2.135136	6500.0	23000.0	1.929755	8500.0	23000.0	1.316200
9000.0	23000.0	1.173769	5000.0	23500.0	2.343254	7000.0	23500.0	1.522565
3000.0	24000.0	2.658156	4500.0	24000.0	2.209692	5000.0	24000.0	2.027606
6000.0	24000.0	1.682277	7000.0	24000.0	1.365891	9000.0	24000.0	1.008616
8000.0	24500.0	1.047885	5000.0	25000.0	1.596828	6000.0	25000.0	1.387310
7000.0	25000.0	1.120370	8000.0	25000.0	.962519			

TABLE 4.3 CONTINUED

ANNUAL MEAN TSP CONCENTRATIONS CONTRIBUTED BY MOBIL'S CABALLO ROJO MINE TO EACH RECEPTOR IN THE CORRIDOR.

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 57 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) FROM COMBINED SOURCES 37. -45.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
12000.0	3000.0	.383841	12500.0	3000.0	.387428	13000.0	3000.0	.392481
13500.0	3000.0	.401065	14000.0	3000.0	.393498	11500.0	3500.0	.408488
14000.0	3500.0	.417675	11500.0	4000.0	.441571	14000.0	4000.0	.445138
11500.0	4500.0	.477621	14000.0	4500.0	.475621	11500.0	5000.0	.519482
14000.0	5000.0	.508578	11500.0	5500.0	.567492	12500.0	5500.0	.589956
14000.0	5500.0	.545513	11000.0	6000.0	.618132	12000.0	6000.0	.638447
14000.0	6000.0	.585561	11500.0	6500.0	.688830	12500.0	6500.0	.689973
14000.0	6500.0	.631674	11000.0	7000.0	.752862	12000.0	7000.0	.779880
14000.0	7000.0	.686678	5000.0	7500.0	.800966	5500.0	7500.0	.844503
6000.0	7500.0	.495789	6500.0	7500.0	.529697	7000.0	7500.0	.567497
7500.0	7500.0	.607100	8000.0	7500.0	.644800	11000.0	7500.0	.841970
11500.0	7500.0	.359511	12000.0	7500.0	.851120	14000.0	7500.0	.792070
5000.0	8000.0	.438139	6500.0	8000.0	.803342	11000.0	8000.0	.951551
11500.0	8000.0	.974296	13500.0	8000.0	.838003	5000.0	8500.0	.481929
8500.0	8500.0	.929982	11000.0	8500.0	1.092526	13000.0	8500.0	.955506
5000.0	9000.0	.529267	5500.0	9000.0	.591762	6000.0	9000.0	.670226
6500.0	9000.0	.765354	7000.0	9000.0	.816008	9000.0	9000.0	1.148401
10000.0	9000.0	1.189164	10500.0	9000.0	1.213256	12500.0	9000.0	1.101905
7500.0	9500.0	1.015197	9000.0	9500.0	1.337208	9500.0	9500.0	1.345540
10000.0	9500.0	1.374113	12000.0	9500.0	1.287172	6000.0	10000.0	.656745
7000.0	10000.0	1.110678	7500.0	10000.0	1.199086	9500.0	10000.0	1.579513
12000.0	10000.0	1.427628	7500.0	10500.0	1.447297	11000.0	10500.0	1.853930
7000.0	11000.0	1.531315	12000.0	11000.0	1.835870	7000.0	11500.0	1.845678
8500.0	11500.0	2.629592	9000.0	11500.0	2.791932	9500.0	11500.0	2.860789
11000.0	11500.0	2.440461	7000.0	12000.0	2.309295	8500.0	12000.0	3.317192
9000.0	12000.0	3.597028	9500.0	12000.0	3.734134	11000.0	12000.0	2.943784
12000.0	12000.0	2.082592	7000.0	12500.0	3.039858	8500.0	12500.0	4.445604
9000.0	12500.0	4.833478	9500.0	12500.0	4.971527	11000.0	12500.0	3.311670
1000.0	13000.0	.299402	3000.0	13000.0	.530963	3500.0	13000.0	.679586
5000.0	13000.0	1.458816	6000.0	13000.0	2.591229	6500.0	13000.0	3.288587
7000.0	13000.0	3.986043	8500.0	13000.0	6.196669	9000.0	13000.0	6.870920
9500.0	13000.0	6.738661	11000.0	13000.0	3.622428	1000.0	14500.0	.320892
2000.0	14500.0	.927339	3000.0	14500.0	.819823	5500.0	14500.0	5.290360
6000.0	14500.0	9.863606	6500.0	14500.0	13.223296	7000.0	14500.0	14.405132
9500.0	14500.0	15.488353	10000.0	14500.0	8.370902	10500.0	14500.0	5.391652
2000.0	15000.0	.533359	3000.0	15000.0	.738332	3500.0	15000.0	.925078
9500.0	15000.0	13.497962	10000.0	15000.0	7.496721	10500.0	15000.0	5.047530
11000.0	15000.0	3.692697	2500.0	15500.0	.651363	3000.0	15500.0	.801953
3500.0	15500.0	1.016883	4000.0	15500.0	1.834173	9500.0	15500.0	9.934778
10000.0	15500.0	6.180044	10500.0	15500.0	4.340440	2000.0	16000.0	.533306
2500.0	16000.0	.637475	3000.0	16000.0	.843428	3500.0	16000.0	1.237790
4000.0	16000.0	1.937165	8500.0	16000.0	16.525083	9000.0	16000.0	11.315691
9500.0	16000.0	7.004160	10000.0	16000.0	4.777355	11000.0	16000.0	2.686110
3500.0	16500.0	1.624063	4000.0	16500.0	2.475749	5500.0	16500.0	10.349319

TABLE 3.4 CONTINUED

CONTRIBUTIONS BY MOBIL'S CABALLO ROJO MINE CONTINUED

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 58 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) (CONT.) FROM COMBINED SOURCES 37. -45.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
6000.0	16500.0	12.369434	6500.0	16500.0	13.170988	8500.0	16500.0	10.097664
9000.0	16500.0	7.470703	9500.0	16500.0	5.239640	2000.0	17000.0	.780376
3500.0	17000.0	1.891108	4000.0	17000.0	2.952961	9500.0	17000.0	9.376517
5000.0	17000.0	6.447912	5500.0	17000.0	8.159360	6000.0	17000.0	9.935918
6500.0	17000.0	9.739802	7000.0	17000.0	9.781309	7500.0	17000.0	9.608174
8000.0	17000.0	8.692261	8500.0	17000.0	7.021707	9000.0	17000.0	5.320082
10000.0	17000.0	3.235994	2000.0	17500.0	.891192	7000.0	17500.0	7.388161
7500.0	17500.0	7.215952	8000.0	17500.0	6.259078	8500.0	17500.0	5.261061
9000.0	17500.0	4.170139	1500.0	18000.0	.793665	2000.0	18000.0	.972519
9500.0	18000.0	2.589221	10000.0	18000.0	2.297402	1500.0	18500.0	.846055
2000.0	18500.0	1.059897	2500.0	18500.0	1.406094	3000.0	18500.0	1.822425
3500.0	18500.0	2.372551	4000.0	18500.0	2.912191	4500.0	18500.0	3.735785
5000.0	18500.0	4.311662	5500.0	18500.0	4.700112	6000.0	18500.0	4.827782
9500.0	18500.0	2.210852	1000.0	19000.0	.745818	1500.0	19000.0	.912669
2000.0	19000.0	1.173893	2500.0	19000.0	1.582055	3000.0	19000.0	1.831612
3500.0	19000.0	2.247059	4000.0	19000.0	2.848804	4500.0	19000.0	3.392847
5000.0	19000.0	3.746036	5500.0	19000.0	3.962507	6000.0	19000.0	4.079982
6500.0	19000.0	4.049896	7000.0	19000.0	3.929627	7500.0	19000.0	3.492730
8000.0	19000.0	3.065683	9500.0	19000.0	1.893609	10000.0	19000.0	1.684771
2000.0	20000.0	1.251387	3000.0	20000.0	1.800658	8000.0	20000.0	2.484672
9500.0	20000.0	2.115727	9500.0	20000.0	1.408959	10000.0	20000.0	1.285808
4500.0	20500.0	2.443136	6000.0	20500.0	2.636093	3000.0	21000.0	1.678952
4000.0	21000.0	2.075953	6000.0	21000.0	2.316731	9500.0	21000.0	1.105770
10000.0	21000.0	1.029895	6000.0	21500.0	2.029767	7500.0	21500.0	1.595428
3000.0	22000.0	1.523208	4000.0	22000.0	1.739736	5500.0	22000.0	1.852805
6000.0	22000.0	1.769981	9000.0	22000.0	1.027253	6000.0	22500.0	1.551974
8500.0	22500.0	1.026787	3500.0	23000.0	1.417873	5000.0	23000.0	1.508025
6000.0	23000.0	1.376564	6500.0	23000.0	1.277144	8500.0	23000.0	.923151
9000.0	23000.0	.891795	5000.0	23500.0	1.372670	7000.0	23500.0	1.058564
3000.0	24000.0	1.179281	4500.0	24000.0	1.258309	5000.0	24000.0	1.243566
6000.0	24000.0	1.112360	7000.0	24000.0	.957718	9000.0	24000.0	.698331
8000.0	24500.0	.751695	5000.0	25000.0	1.016896	6000.0	25000.0	.919886
7000.0	25000.0	.796626	8000.0	25000.0	.690610			

TABLE 4.3 CONTINUED

ANNUAL MEAN TSP CONCENTRATIONS CONTRIBUTED BY ARCO'S COAL CREEK MINE TO EACH RECEPTOR IN THE CORRIDOR

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING MTOM WG DEQ'S 1980 CORRIDOR RUN # 107 ******** PAGE 61 **

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) DUE TO SOURCE 63 **

= DISCRETE RECEPTORS =

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
12000.0	3000.0	6.059145	12500.0	3000.0	8.772988	13000.0	3000.0	10.425856
13500.0	3000.0	10.259278	14000.0	3000.0	8.356800	11500.0	3500.0	5.329605
14000.0	3500.0	10.689143	13500.0	4000.0	8.242281	14000.0	4000.0	12.502714
13500.0	4500.0	9.727318	14000.0	4500.0	12.687048	11500.0	5000.0	9.703923
14000.0	5000.0	11.316516	13500.0	5500.0	8.739185	12500.0	5500.0	14.162185
13000.0	5500.0	7.927585	11000.0	6000.0	5.713885	12000.0	6000.0	9.422175
14000.0	6000.0	5.646675	11500.0	6500.0	6.288530	12500.0	6500.0	7.269957
14000.0	6500.0	4.272322	11000.0	7000.0	4.521846	12000.0	7000.0	5.655979
14000.0	7000.0	3.513124	5000.0	7500.0	.439432	5500.0	7500.0	.492762
6000.0	7500.0	.553637	6500.0	7500.0	.624254	7000.0	7500.0	.705211
7500.0	7500.0	.898387	8000.0	7500.0	1.197348	11000.0	7500.0	4.070831
11500.0	7500.0	4.675447	12000.0	7500.0	4.513711	14000.0	7500.0	2.868026
5000.0	8000.0	.447021	8500.0	8000.0	1.642281	11000.0	8000.0	3.670637
11500.0	8000.0	3.373349	13500.0	8000.0	2.832313	5000.0	8500.0	.450728
8500.0	8500.0	1.711899	11000.0	8500.0	3.325888	13000.0	8500.0	2.716543
5000.0	9000.0	.451356	5500.0	9000.0	.497300	6000.0	9000.0	.611445
6500.0	9000.0	.782825	7000.0	9000.0	.979430	9000.0	9000.0	1.776289
10000.0	9000.0	2.368170	10500.0	9000.0	2.701609	12500.0	9000.0	2.499739
7500.0	9500.0	1.261053	9000.0	9500.0	1.693389	9500.0	9500.0	1.942438
10000.0	9500.0	2.234689	12000.0	9500.0	2.274174	6000.0	10000.0	.765836
7000.0	10000.0	1.100212	7500.0	10000.0	1.202451	9500.0	10000.0	1.833331
12000.0	10000.0	1.951299	7500.0	10500.0	1.144284	11000.0	10500.0	1.868044
7000.0	11000.0	1.008038	12000.0	11000.0	1.523286	7000.0	11500.0	.963328
8500.0	11500.0	1.263623	9000.0	11500.0	1.421053	9500.0	11500.0	1.585931
11000.0	11500.0	1.448288	7000.0	12000.0	.919970	8500.0	12000.0	1.222089
9000.0	12000.0	1.362678	9500.0	12000.0	1.508839	11000.0	12000.0	1.284517
12000.0	12000.0	1.238815	7000.0	12500.0	.882459	8500.0	12500.0	1.180632
9000.0	12500.0	1.306808	9500.0	12500.0	1.374535	11000.0	12500.0	1.144309
1000.0	13000.0	.254414	3000.0	13000.0	.431434	3500.0	13000.0	.499292
5000.0	13000.0	.654079	6000.0	13000.0	.742710	8500.0	13000.0	.793419
7000.0	13000.0	.352260	8500.0	13000.0	1.139433	9000.0	13000.0	1.253198
9500.0	13000.0	1.242768	11000.0	13000.0	1.036873	1000.0	14500.0	.298802
2000.0	14500.0	.391993	3000.0	14500.0	.471466	5500.0	14500.0	.634967
6000.0	14500.0	.676887	6500.0	14500.0	.720575	7000.0	14500.0	.780999
9500.0	14500.0	.935074	10000.0	14500.0	.881220	10500.0	14500.0	.839173
2000.0	15000.0	.411185	3000.0	15000.0	.460661	3500.0	15000.0	.487033
9500.0	15000.0	.855016	10000.0	15000.0	.803895	10500.0	15000.0	.779276
11000.0	15000.0	.755543	2500.0	15500.0	.426058	3000.0	15500.0	.499638
3500.0	15500.0	.474367	4000.0	15500.0	.501622	9500.0	15500.0	.781740
10000.0	15500.0	.744972	10500.0	15500.0	.725560	2000.0	16000.0	.395327
2500.0	16000.0	.416500	3000.0	16000.0	.438509	3500.0	16000.0	.463138
4000.0	16000.0	.491669	8500.0	16000.0	.797760	9000.0	16000.0	.761257
9500.0	16000.0	.720131	11000.0	16000.0	.695752	11000.0	16000.0	.656202
3500.0	16500.0	.454688	4000.0	16500.0	.481496	5500.0	16500.0	.568444

TABLE 4.3

CONTRIBUTIONS BY ARCO'S COAL CREEK MINE CONTINUED

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 62 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) DUE TO SOURCE 63 (CONT.) **

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
6000.0	16500.0	.602960	6500.0	16500.0	.655724	8500.0	16500.0	.737367
9000.0	16500.0	.702282	9500.0	16500.0	.666433	2000.0	17000.0	.378537
3500.0	17000.0	.496632	4000.0	17000.0	.471200	4500.0	17000.0	.497369
5000.0	17000.0	.524477	5500.0	17000.0	.552482	6000.0	17000.0	.592387
6500.0	17000.0	.641549	7000.0	17000.0	.692255	7500.0	17000.0	.739513
8000.0	17000.0	.712875	8500.0	17000.0	.682797	9000.0	17000.0	.649169
10000.0	17000.0	.610733	2000.0	17500.0	.371360	7000.0	17500.0	.674389
7500.0	17500.0	.688285	8000.0	17500.0	.642395	8500.0	17500.0	.633400
9000.0	17500.0	.601204	1500.0	18000.0	.396917	2000.0	18000.0	.366058
9500.0	18000.0	.553694	10000.0	18000.0	.540320	1500.0	18500.0	.342333
2000.0	18500.0	.360513	2500.0	18500.0	.379408	3000.0	18500.0	.399013
3500.0	18500.0	.419316	4000.0	18500.0	.440299	4500.0	18500.0	.461335
5000.0	18500.0	.484193	5500.0	18500.0	.519475	6000.0	18500.0	.558433
9500.0	18500.0	.522380	1000.0	19000.0	.320971	1500.0	19000.0	.337523
2000.0	19000.0	.354791	2500.0	19000.0	.372701	3000.0	19000.0	.391244
3500.0	19000.0	.410406	4000.0	19000.0	.430169	4500.0	19000.0	.450506
5000.0	19000.0	.474742	5500.0	19000.0	.510253	6000.0	19000.0	.546795
6500.0	19000.0	.544289	7000.0	19000.0	.581074	7500.0	19000.0	.559883
8000.0	19000.0	.536453	9500.0	19000.0	.493643	10000.0	19000.0	.481462
2000.0	20000.0	.343138	3000.0	20000.0	.375718	4000.0	20000.0	.410382
9500.0	20000.0	.529253	9500.0	20000.0	.552854	10000.0	20000.0	.531775
4500.0	20500.0	.423203	6000.0	20500.0	.512060	3000.0	21000.0	.360859
4000.0	21000.0	.391580	6000.0	21000.0	.484469	9500.0	21000.0	.399545
10000.0	21000.0	.389469	6000.0	21500.0	.437264	7500.0	21500.0	.410942
3000.0	22000.0	.346554	4000.0	22000.0	.380840	5500.0	22000.0	.446021
6000.0	22000.0	.432348	9000.0	22000.0	.370798	6000.0	22500.0	.409181
8500.0	22500.0	.361236	3500.0	23000.0	.349554	5000.0	23000.0	.412634
6000.0	23000.0	.347643	6500.0	23000.0	.373600	8500.0	23000.0	.345364
9000.0	23000.0	.338090	5000.0	23500.0	.391983	7000.0	23500.0	.348372
3000.0	24000.0	.322220	4500.0	24000.0	.379121	5000.0	24000.0	.372658
6000.0	24000.0	.348908	7000.0	24000.0	.333981	9000.0	24000.0	.310001
8000.0	24500.0	.309776	5000.0	25000.0	.337609	6000.0	25000.0	.316465
7000.0	25000.0	.307751	8000.0	25000.0	.297383			

TABLE 4.3 CONTINUED

ANNUAL ARITHMETIC MEAN TSP CONCENTRATION DUE TO 1988 MINING OPERATIONS FOR THE GILLETTE CORRIDOR (WITHOUT BACKGROUND)

**** ISCLT ********** EDS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 63. **

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) FROM COMBINED SOURCES 1, -131,

DISCRETE RECEPTORS

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
12000.0	3000.0	8.932832	12500.0	3000.0	11.630026	13000.0	3000.0	13.289867
13500.0	3000.0	12.924287	14000.0	3000.0	11.191462	11500.0	3500.0	8.452019
14000.0	3500.0	13.513308	11500.0	4000.0	11.629688	14000.0	4000.0	16.000156
11500.0	4500.0	13.416858	14000.0	4500.0	16.737727	11500.0	5000.0	13.733947
14000.0	5000.0	16.096780	11500.0	5500.0	13.159260	12500.0	5500.0	19.021833
14000.0	5500.0	13.288373	11000.0	6000.0	10.679700	12000.0	6000.0	13.470687
14000.0	6000.0	11.410643	11500.0	6500.0	11.768103	12500.0	6500.0	13.590713
14000.0	6500.0	10.332679	11000.0	7000.0	10.637339	12000.0	7000.0	12.068984
14000.0	7000.0	9.579163	5000.0	3500.0	9.660958	5500.0	7500.0	6.831837
6000.0	7500.0	10.509641	6500.0	7500.0	13.106829	7000.0	7500.0	13.668502
7500.0	7500.0	12.688655	5000.0	1500.0	11.903592	11000.0	7500.0	10.907135
11500.0	7500.0	11.665691	12000.0	7500.0	11.912765	14000.0	7500.0	8.156269
5000.0	8000.0	5.366747	8500.0	8000.0	12.637439	11000.0	8000.0	11.606154
11500.0	8000.0	12.025322	13500.0	8000.0	9.849302	5000.0	8500.0	7.525849
8500.0	8500.0	14.376243	11000.0	8500.0	12.591009	13000.0	8500.0	10.698058
5000.0	9000.0	8.938640	5500.0	9000.0	14.200552	6000.0	9000.0	18.040708
6500.0	9000.0	18.705829	7000.0	9000.0	17.204833	9000.0	9000.0	14.931352
10000.0	9000.0	13.564507	10500.0	9000.0	13.517078	12500.0	9000.0	11.501530
7500.0	9500.0	15.349895	9000.0	9500.0	17.556088	9500.0	9500.0	16.412631
10000.0	9500.0	15.722196	12000.0	9500.0	12.631653	6000.0	10000.0	11.694284
7000.0	10000.0	13.286563	7500.0	10000.0	15.363070	9500.0	10000.0	20.432865
12000.0	10000.0	12.044116	3500.0	10500.0	16.838854	11000.0	10500.0	17.388450
7000.0	11000.0	14.631751	12000.0	11000.0	11.953634	7000.0	11500.0	17.570670
8500.0	11500.0	12.826409	9000.0	11500.0	28.425839	9500.0	11500.0	25.326370
11000.0	11500.0	18.022635	7000.0	12000.0	21.241382	8500.0	12000.0	31.632010
9000.0	12000.0	26.105989	9500.0	12000.0	24.314930	11000.0	12000.0	18.274236
12000.0	12000.0	11.696696	7000.0	12500.0	24.544111	8500.0	12500.0	31.633152
9000.0	12500.0	26.133502	9500.0	12500.0	25.123887	11000.0	12500.0	18.375721
10000.0	13000.0	5.748890	3000.0	13000.0	9.280523	3500.0	13000.0	10.243463
5000.0	13000.0	14.306329	6000.0	13000.0	17.540792	6500.0	13000.0	20.933578
7000.0	13000.0	27.696698	8500.0	13000.0	32.225897	9000.0	13000.0	28.246545
9500.0	13000.0	27.449194	11000.0	13500.0	18.159096	1000.0	14500.0	7.998479
2000.0	14500.0	10.177312	3000.0	14500.0	13.177767	5500.0	14500.0	22.091298
6000.0	14500.0	30.587755	6500.0	14500.0	34.343843	7000.0	14500.0	37.043535
9500.0	14500.0	33.791295	10000.0	14500.0	24.590319	10500.0	14500.0	18.426893
2000.0	15000.0	9.572675	3000.0	15000.0	13.450307	3500.0	15000.0	16.073015
5500.0	15000.0	28.552463	10000.0	15000.0	20.662988	10500.0	15000.0	16.139203
11000.0	15000.0	12.968351	2500.0	15500.0	12.787312	3000.0	15500.0	16.096663
3500.0	15500.0	19.062977	4000.0	15500.0	22.369439	9500.0	15500.0	23.606157
10000.0	15500.0	17.919336	10500.0	15500.0	14.463988	2000.0	16000.0	10.945964
2500.0	16000.0	16.664314	3000.0	16000.0	23.701626	3500.0	16000.0	25.303518
9000.0	16000.0	26.568929	8500.0	16000.0	32.976269	9000.0	16000.0	25.733237
9500.0	16000.0	19.458103	10000.0	16000.0	15.683101	11000.0	16000.0	11.042916
3500.0	16500.0	34.086421	4000.0	16500.0	31.091105	5500.0	16500.0	35.534353

TABLE 4.3 CONTINUED

GILLETTE CORRIDOR CONCENTRATIONS CONTINUED

**** ISCLT ********** EOS LONG TERM ISC MODEL SIMULATING WYOMING DEQ'S 1988 CORRIDOR RUN # 107 ******** PAGE 69 ****

** ANNUAL GROUND LEVEL CONCENTRATION (MICROGRAMS PER CUBIC METER) (CONT.) FROM COMBINED SOURCES 1. -131.

- DISCRETE RECEPTORS -

X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION	X DISTANCE (METERS)	Y DISTANCE (METERS)	CONCENTRATION
6000.0	16500.0	35.981176	6500.0	16500.0	35.834336	8500.0	16500.0	26.044840
9000.0	16500.0	21.201645	9500.0	16500.0	17.200493	2000.0	17000.0	17.038898
3500.0	17000.0	41.139701	9000.0	17000.0	35.000661	9500.0	17000.0	35.279572
5000.0	17000.0	35.381839	5500.0	17000.0	35.143533	6000.0	17000.0	35.342916
6500.0	17000.0	34.584758	7000.0	17000.0	32.917345	7500.0	17000.0	30.833736
8000.0	17000.0	27.363052	8500.0	17000.0	22.380971	9000.0	17000.0	18.731470
10000.0	17000.0	13.661694	2000.0	17500.0	23.376992	7000.0	17500.0	32.934518
7500.0	17500.0	28.937986	8000.0	17500.0	24.870365	8500.0	17500.0	21.332895
9000.0	17500.0	18.320212	1500.0	18000.0	19.232870	2000.0	18000.0	26.941806
9500.0	18000.0	15.372666	10000.0	18000.0	12.929452	1500.0	18500.0	15.503572
2000.0	18500.0	25.103862	2500.0	18500.0	34.918810	3000.0	18500.0	35.260225
3500.0	18500.0	32.328189	4000.0	18500.0	31.057811	4500.0	18500.0	31.554706
5000.0	18500.0	31.927828	5500.0	18500.0	32.270379	6000.0	18500.0	33.007365
9500.0	18500.0	15.272445	1000.0	19000.0	11.037350	1500.0	19000.0	15.412110
2000.0	19000.0	21.302034	2500.0	19000.0	24.398241	3000.0	19000.0	24.630217
3500.0	19000.0	23.943206	4000.0	19000.0	23.955514	4500.0	19000.0	24.801558
5000.0	19000.0	25.730643	5500.0	19000.0	26.909072	6000.0	19000.0	28.929631
6500.0	19000.0	30.799228	7000.0	19000.0	28.903605	7500.0	19000.0	25.602105
8000.0	19000.0	23.476412	9500.0	19000.0	15.261277	10000.0	19000.0	12.132832
2000.0	20000.0	14.941563	3000.0	20000.0	16.571383	4000.0	20000.0	17.787790
9500.0	20000.0	19.181417	9500.0	20000.0	19.553261	10000.0	20000.0	11.562845
4500.0	20500.0	18.788121	6000.0	20500.0	25.568981	3000.0	21000.0	13.119600
9000.0	21000.0	15.504401	6000.0	21000.0	23.258332	9500.0	21000.0	14.261165
10000.0	21000.0	12.412787	6000.0	21500.0	21.569923	7500.0	21500.0	21.607229
3000.0	22000.0	11.514238	4000.0	22000.0	15.573971	5500.0	22000.0	19.177769
6000.0	22000.0	19.316016	9000.0	22000.0	14.872618	6000.0	22500.0	17.546974
8500.0	22500.0	15.910275	3500.0	23000.0	13.085531	5000.0	23000.0	17.208527
6000.0	23000.0	15.669036	6500.0	23000.0	17.486470	8500.0	23000.0	14.932507
9000.0	23000.0	11.292252	5000.0	23500.0	14.704193	7000.0	23500.0	16.231668
3000.0	24000.0	11.391556	4500.0	24000.0	14.879716	5000.0	24000.0	12.821497
6000.0	24000.0	12.268458	7000.0	24000.0	13.333207	9000.0	24000.0	8.853723
8000.0	24500.0	11.497423	5000.0	25000.0	10.016342	6000.0	25000.0	9.601182
7000.0	25000.0	9.691773	8000.0	25000.0	8.573399			

SECTION 5

INTERPRETATIONS AND CONCLUSIONS

5.0 INTERPRETATIONS AND CONCLUSIONS

Part 2 has involved a model (the ISC Model) with a level of sophistication above prior EPA approved atmospheric dispersion models. In verifying both the short-term and long-term programs of the ISC Model, site specific data were employed. Accurate production information, field developed emission factors and particle size distributions, and on-site meteorological data comprised the input for both programs of the ISC Model. The model-predicted particulate concentrations were compared with an independent set of data composed of site specific hi-vol measurements for both the short-term and long-term simulations of the surface coal mining activities at AMAX COAL COMPANY'S Belle Ayr Mine. By comparing these data sets, the ISC Model has verified very well. Verification of the WDEQ-modified CDM model (CDMW) with input and output data specific to the Powder River Basin is unknown.

The ISC Model-predicted impact of particulate matter from the 1988 permitted mining activities within the Gillette Corridor show maximum annual geometric mean concentrations to be 14 $\mu g/m^3$ lower than the Wyoming Air Quality Standard and 12 $\mu g/m^3$ below the WDEQ's CDMW-predicted TSP concentrations. An important observation from the long-term ISC Model run, is the limited areal extent of the particulate impact, i.e., the maximum particulate impact from each mine is confined to separate regions in the immediate vicinity of the mine.

Evident from both the ISC Model verification runs and the Corridor model run, the EDS developed emission factors accurately describe the surface coal mining operations measured. The successful ISC Model verification runs (short-term and long-term) are attributable to emission factors specific to the coal mining activities. If the developed emission factors were not accurate, the ISC Model would not have verified--even though this model represents state-of-the-science dispersion theory. The surface coal mine specific emission factors enabled an accurate simulation of the particulate impact from the Gillette Corridor of mines.

From the various applications of the long-term and short-term programs of the ISC Model, it is apparent that the technical capabilities of this model are greater than other atmospheric dispersion models. All of the predicted particulate concentrations obtained from the ISC Model applications appear to simulate the mining operations in a physically sound manner—with the exception of the 100 m radius surrounding each source. The correct simulation of observed phenomena results from a combination of site specific input data and an accurate model of various processes associated with atmospheric dispersion.

The modeling has shown that application of the EDS developed emission factors requires an exact simulation of the large particle behavior. Therefore, if these developed emission factors are to be used in atmospheric dispersion models, then these factors must be used in the ISC Model or a model that handles gravitational settling and dry deposition in an equivalent manner.

From the modeling performed during this task, there is strong evidence that the high volume air sampler is indeed biased when collecting particulates larger than 100 μm in diameter. Consequently, if the measurement technique used to collect the particle size distributions to be input into the dispersion model is not equivalent to the technique (hi-vols) used in collecting the field data for comparison to the model-predicted particulate concentrations, the model results will be biased accordingly.

In summary, the validity of the modeling exercise described in Part 2 is critically dependent upon three factors:

- the accuracy/representativeness of the EDS emission factors;
- the realistic simulation of gravitational settling and dry deposition in application of the developed emission factors;
- application of an atmospheric dispersion model sophisticated enough to accurately simulate real processes (the ISC Model).

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Tom Pace

COAL MINING EMISSION FACTOR DEVELOPMENT AND MODELING STUDY

APPENDICES

TRC ENVIRONMENTAL CONSULTANTS, INC.

PREPARED BY:

DONALD L. SHEARER
RAE ANN DOUGHERTY
CALVIN C. EASTERBROOK

TRC PROJECT #0908-D10-05
JULY 1981

8775 EAST ORCHARD ROAD
SUITE 816
ENGLEWOOD
COLORADO 80111
(303) 779-4940

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APPENDIX A

DERIVATION OF THE SOURCE DEPLETION FACTOR

A.0 DERIVATION OF THE SOURCE DEPLETION FACTOR

A.1 INTRODUCTION

Hi-vol measured particulate concentrations result in a calculated "apparent" emission rate which is lower than the actual emission rate since the largest particles settle out of the atmosphere between the particulate source and the hi-vol receptor. Chamberlain (1953) has described a method for computing a source depletion relationship based on deposition velocity. In the original derivation of this relationship, deposition velocity was treated as a constant because suspended particulates and gases were considered. The EDS data, however, indicated significant gravitational settling causing the resulting deposition velocity to be a decreasing function with increasing distance from the source. The remainder of Appendix A describes a derivation of a new source depletion factor--a modification of Chamberlain's method.

A.2 MATHEMATICAL DERIVATION

Utilizing the method of Chamberlain, (Slade, 1968) the source depletion or deposition factor is derived as follows:

From Volume I, Part 1, Section 3.2, equation (3.1), the deposition rate is given by,

$$D(x,y) = V_d(x)\,\chi(x,y,0) \qquad (A.1)$$

and

$$\chi(x,y,0) = \frac{Q(x)}{u\sigma_y\sigma_z}\exp(-y^2/2\sigma_y^2) \qquad (A.2)$$

where $Q(x)$ = "apparent" emission rate as seen at distance x

The exponential terms with receptor height (z) and source height (H) have been neglected in (A.2) because they are very small relative to the y^2 term when considering surface measurements of surface mining operations.

The rate of change of "apparent" emission rate with distance from the source is equal to the deposition taking place across the plume, i.e.,

$$\frac{\partial Q(x)}{\partial x} = 2\int_0^{\infty} D\,(x,y)dy \qquad (A.3)$$

Substituting (A.1) and (A.2) into (A.3) and integrating,

$$\frac{\partial Q(x)}{\partial x} = \frac{\sqrt{2/\pi}\; V_d(x)\; Q(x)}{\bar{u}\sigma_z(x)} \qquad (A.4)$$

Rearranging (A.4)

$$\int_0^x \frac{dQ(x)}{Q(x)} = -\frac{\sqrt{2/\pi}}{\bar{u}}\int_0^x \frac{V_d(x)}{\sigma_z(x)}\,dx \qquad (A.5)$$

By substituting analytical expressions for V_d and σ_z as a function of x and integrating the result, the result is an analytical expression for depletion of the source Q_o with distance. The expression for $V_d(x)$ has been derived from measurements, Volume I, Part 1, Section 3.3, equation (3.9). An expression of similar form for σ_z has been developed by Smith (1973).

$$\sigma_z = cx^f \qquad (A.6)$$

where c and f are constants which depend upon stability class.

Substituting (3.9) and (A.6) into (A.5), the resulting expression can be integrated and yields

$$\ln\frac{Q(x)}{Q_o} = -\frac{\sqrt{2/\pi}}{\bar{u}}\left[\left(\frac{a}{c}\right)\;\frac{x^{b-f+1}}{b-f+1}\right]_0^x \qquad (A.7)$$

Equation (A.7) applies to a point source only. However, the expression may be modified to be utilized with an extended source by moving the point source upwind of the real source a given distance. The extended source is thus simulated by a virtual point source at a distance, x_{virt}, upwind of the actual source. This virtual distance is a function of the size of the source and the atmospheric stability.

The virtual distances are computed utilizing equation (A.6). First, it is estimated that the average height of the sources being simulated is 10 ft or 3.05 m. Next, it is assumed that the source height is 2.15 σ_{zo}. Thus,

$$\sigma_{zo} = \frac{3.05}{2.15} = 1.42 \text{ m} \tag{A.8}$$

The virtual distances, x_{virt}, are then computed for each stability class utilizing equation (A.6), e.g.,

$$(x_{virt})^f = \sigma_{zo}/c \tag{A.9}$$

The values for the constants and the virtual distances are given in the Table A.1.

TABLE A.1

VIRTUAL DISTANCE WITH THE APPROPRIATE CONSTANTS FOR EACH STABILITY CLASS

STABILITY CLASS	c	f	x_{virt}(m)
A	0.2793	0.90	6.08
B	0.2255	0.85	8.70
C	0.2229	0.80	10.10
D	0.1994	0.76	13.21
E	0.1485	0.73	22.00
F	0.1173	0.67	41.27

Equation (A.7) may now be modifed to apply to the extended sources by changing the limits of integration to x_{virt} and $(x + x_{virt})$.

$$\ln \frac{Q(x)}{Q_o} = \frac{-\sqrt{2/\pi}}{\bar{u}} \left(\frac{a}{c}\right) \left[\frac{(x + x_{virt})^{b-f+1} - (x_{virt})^{b-f+1}}{b-f+1} \right] \tag{A.10}$$

and

$$\frac{Q(x)}{Q_o} = \exp \left\{ \frac{-\sqrt{2/\pi}}{\bar{u}} \left(\frac{a}{c}\right) \left[\frac{(x + x_{virt})^{b-f+1} - (x_{virt})^{b-f+1}}{b-f+1} \right] \right\} \tag{A.11}$$

APPENDIX B

ISC MODEL AS APPLIED TO THE EDS STUDY

B.0 ISC MODEL AS APPLIED TO THE EDS STUDY

B.1 GENERAL DESCRIPTION OF THE ISC MODEL

The Industrial Source Complex (ISC) Dispersion Model has been recently released by the Environmental Protection Agency (EPA) to perform complicated air quality impact analyses for a wide variety of source types, including surface coal mines. The ISC Model combines various analytical dispersion modeling techniques in two computer programs, a short-term version and a long-term version. The ISC Model short-term program (ISCST) is an updated version of the EPA Single Source (CRSTER) Model. The ISC Model long-term program (ISCLT), a sector-averaged model, updates and combines the features of two EPA UNAMAP models: Climatological Dispersion Model (CDM) and Air Quality Display Model (AQDM). Both programs (ISCST and ISCLT) of this comprehensive model include the same features. The feature options exercised for this modeling task, each to be discussed in detail, include:

- plume rise due to momentum and buoyancy as a function of downwind distance;
- emissions from a combination of point, area, line, and volume sources with physical separation of the multiple sources;
- application-defined receptor grid;
- effects of gravitational settling and dry deposition;
- dispersion coefficients and mixing depths for a rural environment;
- simulation of site specific atmospheric conditions.

The same basic dispersion model assumptions apply to both programs (ISCST and ISCLT). The steady-state Gaussian plume equation for a continuous source is used to calculate ground-level particulate concentrations for point, volume, and line sources. The area source model is based on the dispersion equation for a continuous and finite cross-wind line source. This extremely flexible model calculates particulate concentrations using sequential hourly meteorological data for the short-term (6 and 24 hour) and a joint frequency distribution of wind speed, wind direction, and Pasquill stability class for

the long-term (annual) values. A technical discussion of each of the model's features, as well as the required input, and the resulting output format is included in the remainder of this Appendix.

B.2 PLUME RISE

The ISC Model calculates the plume rise, using a generalized form of Briggs (1971, 1975) equations, as a function of downwind distance, momentum, and thermal buoyancy. Separate plume rise equations exist for neutral/unstable and stable atmospheric conditions. For applications involving stack emissions the effective stack height of a plume is a combination of the physical stack height and the plume rise. For simulation of surface coal mining activities, however, only the physical height of fugitive dust emissions, e.g., height of the stockpile and height of wake from haul trucks, are of concern.

B.3 SOURCE TYPES

The ISC Model programs (ISCST and ISCLT) accept the following source types: point, area, and volume; line sources are simulated by multiple volume sources. The dispersion of particulate emissions from "stacks" (point sources) are determined using the steady-state Gaussian plume equation for a continuous elevated source. The area and volume source options are used to simulate the impact of particulate emissions from a variety of the surface coal mining operations, such as reclaimed land and stripped overburden (area sources) and coal and overburden haul roads (volume sources). The area source model is based on the equation for a continuous and finite cross-wind line source. Since each area source must be square, the effects of an irregular shaped area source can be simulated by a series of multiple squares approximating the source's actual geometry, as illustrated in Figure B-1. Note the size of the individual area sources varies; the only requirement is that each area source must have the same north-south and east-west dimensions. In general, no plume rise exists with area sources; consequently, the effective emission height is equivalent to the physical height of the source of particulate emissions.

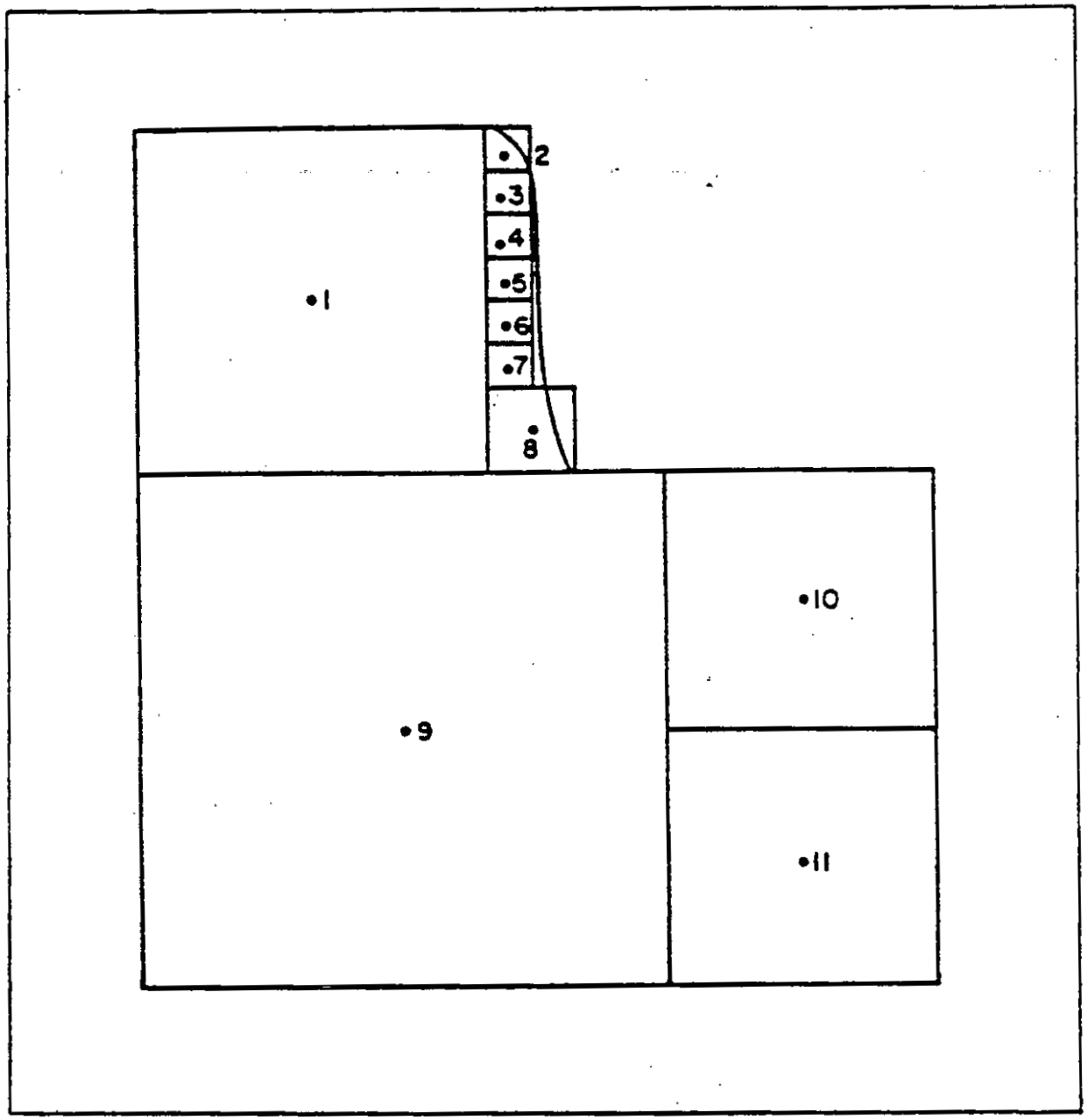

FIGURE B-1 REPRESENTATION OF AN IRREGULARLY SHAPED AREA SOURCE BY 11 SQUARE AREA SOURCES (ISC DISPERSION MODEL USER'S GUIDE, 1979).

The steady-state Gaussian plume equation for a continuous source is also used to calculate ground-level particulate concentrations contributed by volume source emissions. As with the area source model, the north-south and east-west dimensions of each volume source must be the same. A coal or overburden haul road (line source) is represented by a series of multiple volume sources. To represent a line source exactly, equally divide the line source into N volume sources, where N is given by the length of the line source divided by its width. This, however, is usually not practical—so a haul road is simulated by an approximate representation, as illustrated in Figure B-2. In spacing a smaller number of volume sources at equal intervals (not to exceed twice the width of the line source) an approximate representation of the line source is achieved. As suggested in Figure B-2, setting the user specified initial lateral dimension, σ_{yo}, equal to 2W/2.15, where W is the width of the source, results in overlapping Gaussian distributions for the individual sources assuring a reasonable representation of the haul roads. As with area sources, generally no plume rise occurs from volume sources. Consequently, the effective source emission height is set equal to the physical height of particulate emissions.

It is important to note a peculiarity of the ISC Model. If the distance between a receptor and a downwind source is less than 100 m, a warning message is printed in the output and no suspended particulate concentrations are calculated for that source-receptor combination. No other receptors are affected however. The ISC Model consistently underpredicts the ground-level particulate concentration at a receptor within 100 m of a source. This 100 m restriction arises from the fact that the Pasquill-Gifford curves begin at 100 m. All source types (point, area, volume, and line) are affected by this limitation.

B.4 RECEPTOR GRID

Selection of a Cartesian (x,y) or a polar (r,θ) receptor grid system allows the user to design the ISC Model output for the specific application. Since a combination of multiple sources, not located at the same point,

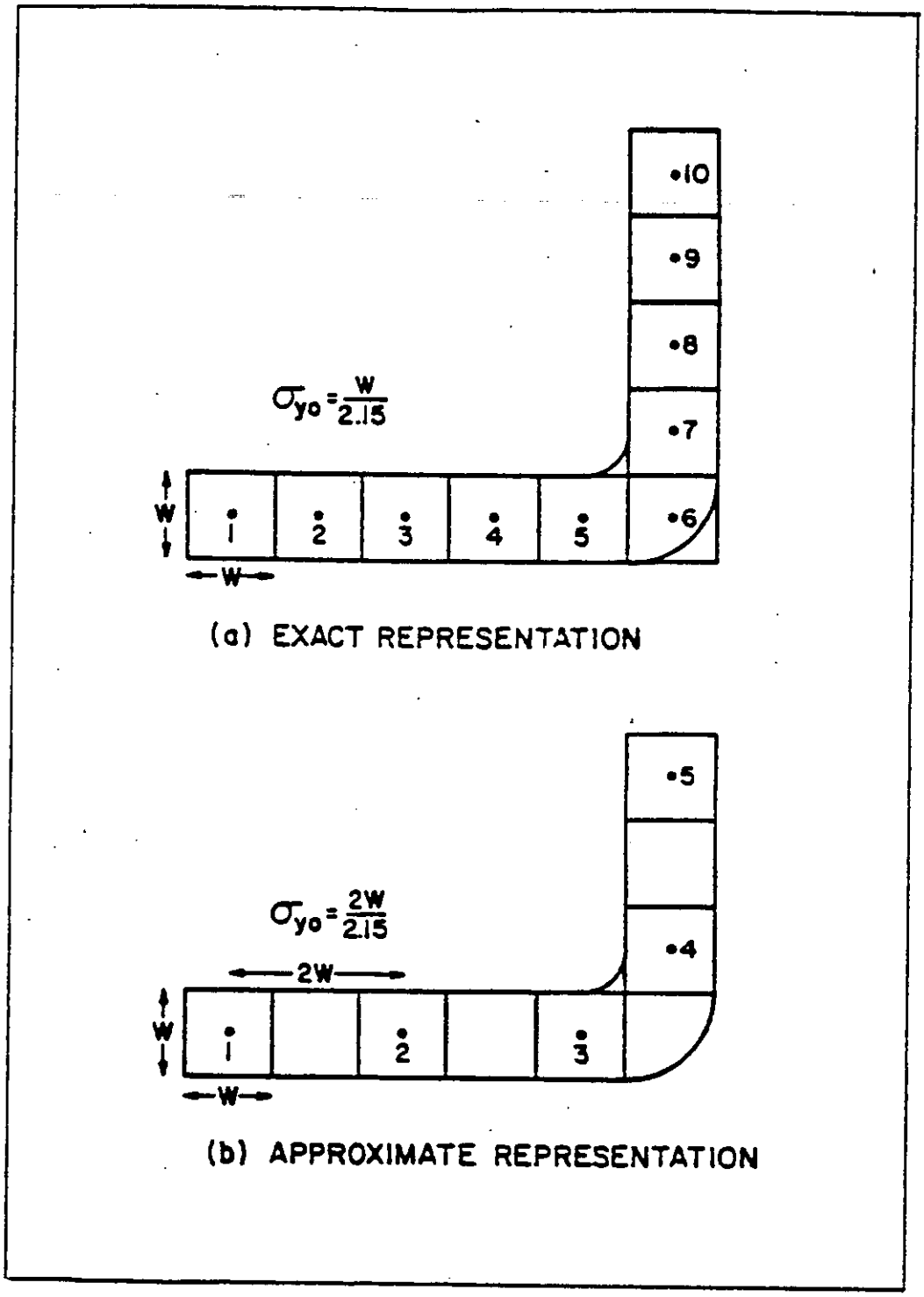

FIGURE B-2 EXACT AND APPROXIMATE REPRESENTATIONS OF A LINE SOURCE BY MULTIPLE VOLUME SOURCES (ISC DISPERSION MODEL USER'S GUIDE, 1979).

comprise surface coal mines, the Cartesian co-ordinate system was chosen. In the Cartesian grid system, the x-axis is positive to the east of the origin, user defined for each application, and the y-axis is positive to the north. Discrete (arbitrarily placed) receptor points can supplement the Cartesian grid. In applying the ISC Model to the coal mines in Gillette, Wyoming, discrete receptor points corresponded to the locations of high volume air samplers (hi-vols) surrounding the mines.

B.5 SETTLING AND DEPOSITION

The effects of gravitational settling and dry deposition on ambient concentrations can be neglected for small particulates (diameters less than about 20 μm). The small particulates tend to remain suspended in the atmosphere for long distances. The larger particulates, however, are brought to the ground surface by a combination of gravitational settling and atmospheric turbulence. Additionally, small particulates are generally reflected from the ground surface, whereas the large particulates that come in contact with the surface, usually are completely or partially retained at the surface. The ISC Model includes the effects of both dry deposition and gravitational settling. The Dumbauld, et.al. (1976) dry deposition model, used in the ISC Dispersion Model, assumes that a user specified fraction of the material that comes into contact with the ground surface is reflected from the surface back into the atmosphere. The reflection coefficient, analogous to the deposition velocity in other deposition models, is a function of the gravitational settling velocity. This relationship is illustrated in Figure B-3. Figure B-4 illustrates the vertical concentration profiles for complete reflection from the ground ($\gamma = 1.0$), 50 percent reflection ($\gamma = 0.5$), and complete retention at the surface ($\gamma = 0.0$). Gravitational settling of the large particulates results in a tilted plume with the plume axis inclined to the horizontal. Using McDonald's (1960) technique the graviational settling velocity can be determined for all particulate sizes.

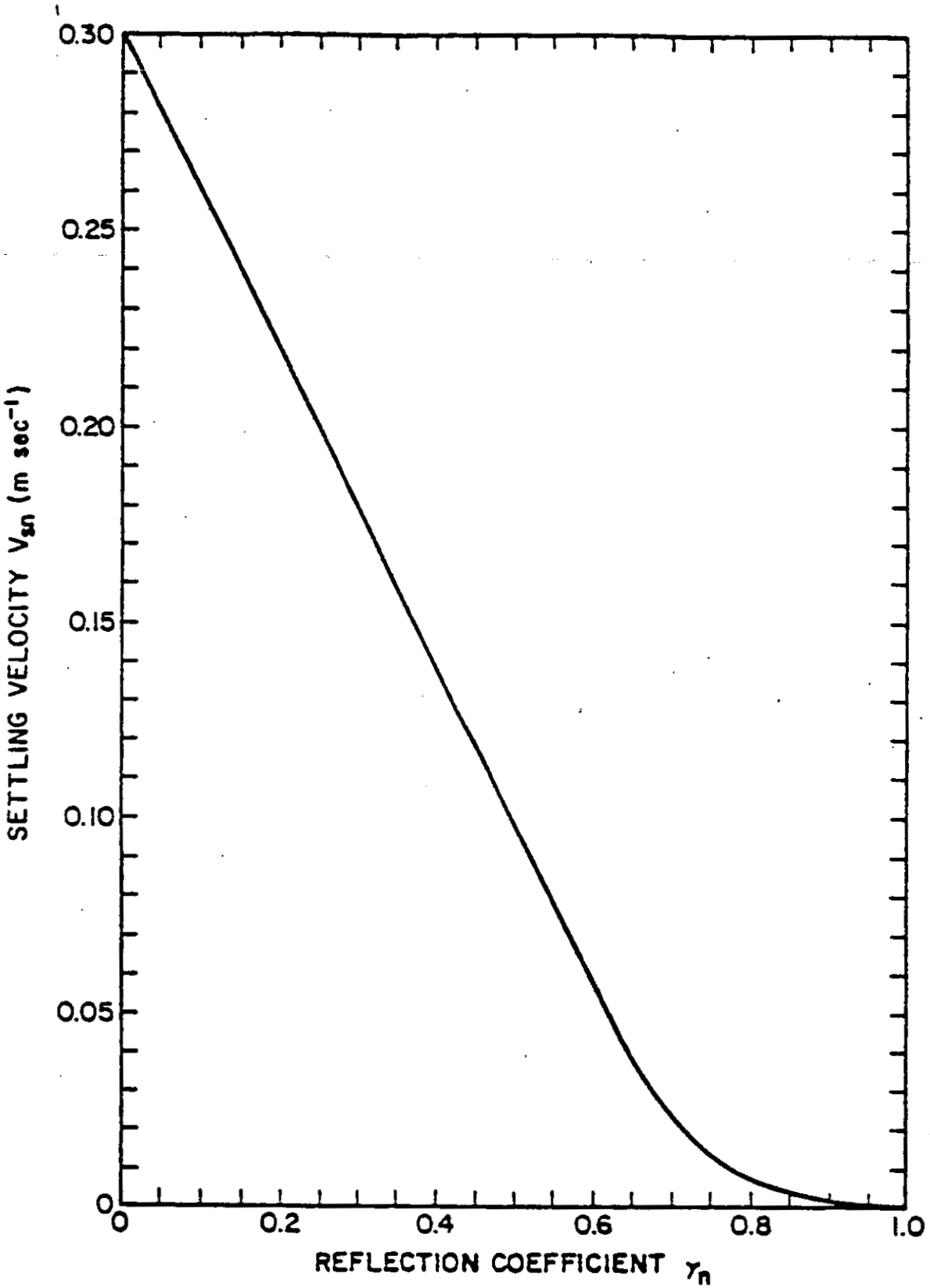

FIGURE B-3 RELATIONSHIP BETWEEN THE GRAVITATIONAL SETTLING VELOCITY AND THE REFLECTION COEFFICIENT SUGGESTED BY DUMBAULD et al. (1976) (ISC DISPERSION MODEL USER'S GUIDE, 1979).

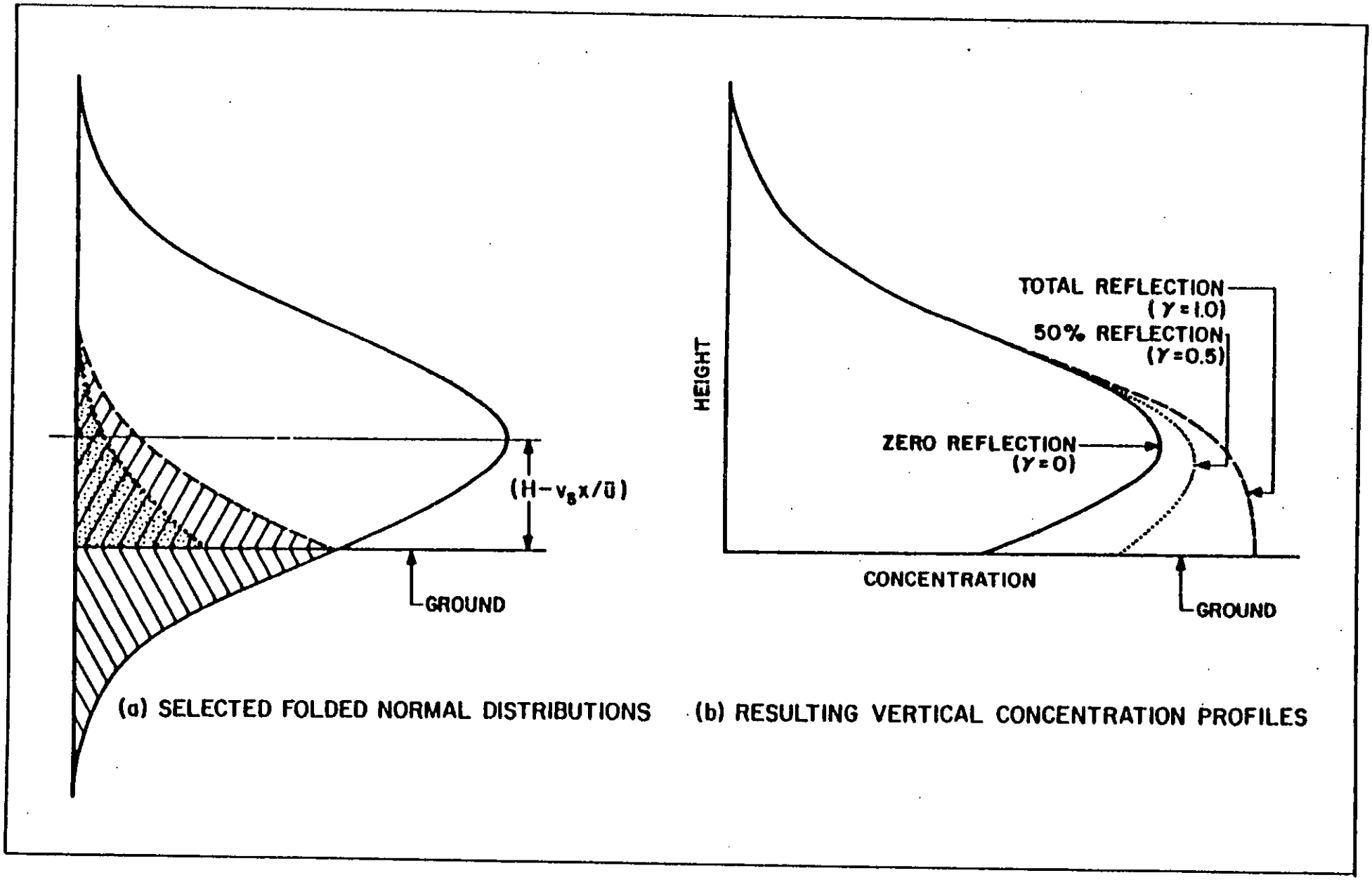

FIGURE B-4 ILLUSTRATION OF VERTICAL CONCENTRATION PROFILES FOR REFLECTION COEFFICIENTS OF 0., 0.5, and 1.0 (ISC DISPERSION MODEL USER'S GUIDE, 1979).

For each source of particulate matter, the total emissions are subdivided into several size categories. The particle size distribution can be described by three parameters, input into the ISC Model computer programs, for each category:

- mass fraction of particulates;
- reflection coefficient; and
- gravitational settling velocity for the mass mean diameter of the particulate size range.

The total particulate concentration from each source is computed by summing over the array of size categories.

B.6 RURAL MODE

Both computer programs of the ISC Model have one Rural and two Urban options. In simulating the surface coal mines in the Powder River Basin, the rural mixing heights and dispersion coefficients were used in calculating the particulate concentrations.

Determination of the mixing heights is based on the currently accepted procedure developed by Holzworth (1972). Since the morning (minimum) and afternoon (maximum) mixing heights, developed by Holzworth, were determined from data representing urban environments, the ISC Model adjusts the mixing layer depths for the Rural mode.

Unlike the two Urban modes, that account for the enhanced turbulence often associated with urban areas, the Rural mode's lateral and vertical dispersion coefficients (σ_y and σ_z respectively) are determined using the actual Pasquill stability category. (Note the ISC Model's redefinition of extremely stable "G" category to the very stable "F" category.) The disperison coefficients, a function of downwind distance, are calculated using equations that approximately fit the Pasquill-Gifford curves (Turner, 1970).

B.7 SITE SPECIFIC

To assure the ISC Model conforms as closely to a specific site as possible, the user may input site specific values of the wind-profile exponent and the vertical potential temperature gradients--for each combination of wind speed and Pasquill stability category. When an insufficient quantity of on-site meteorological data to determine site specific values, the ISC Model uses the default values given in Table B.1.

TABLE B.1

DEFAULT VALUES FOR THE WIND-PROFILE EXPONENTS AND VERTICAL POTENTIAL TEMPERATURE GRADIENTS

PASQUILL STABILITY CATEGORY	WIND-PROFILE EXPONENT	VERTICAL POTENTIAL TEMPERATURE GRADIENT (°K/m)
A	0.10	0.000
B	0.15	0.000
C	0.20	0.000
D	0.25	0.000
E	0.30	0.020
F	0.30	0.035

B.8 INPUT

Applying the ISC Model to the coal mines near Gillette, Wyoming, the following data are required for each source:

- Cartesian x,y coordinates of the source with respect to the user-defined origin (m);
- source elevation (meters above mean sea level);
- particulate emission rate (g/sec);
- mass fraction of particulates in each size category;
- gravitational settling velocity for the particulates in each size category (m/sec); and
- surface reflection coefficient for particulates in each size category.

In addition, point sources require the stack parameters (height, diameter, exit velocity, and exit temperature) for the plume rise calculations. The effective particulate emission height and dimensions (width of square area source and the initial horizontal and vertical dimensions of volume sources) are required for each area and volume source.

Each program (ISCST and ISCLT) of the ISC Dispersion Model have different meteorological input requirements. The short-term program (ISCST) calculates particulate concentrations using sequential hourly meteorological data; whereas the long-term program (ISCLT) uses an annual statistical meteorological summary to determine the annual average concentration. Consequently, the following meteorological data are required for each hour ISCST is applied:

- mean wind speed (m/sec);
- direction wind is blowing toward (degrees);
- ambient air temperature (^{o}K);
- depth of surface mixing layer (m); and
- Pasquill stability class.

Regular annual STAR (STability ARray) data are the primary meteorological input required by the ISCLT program. STAR data, statistical tabulation of the joint frequency of occurrence of wind speed, wind direction, and Pasquill stability class, are available from the National Climatic Center (NCC) in Asheville, North Carolina. Parameters also required by ISCLT include:

- annual mixing height (m) for each wind speed and stability category; and
- annual mean ambient air temperature (^{o}K) for each stability category.

B.9 OUTPUT

The extremely flexible ISC Model has several output format options available to allow the user to tailor the data presentation to each specific application. For the ISCST and ISCLT model runs that were discussed in Volume I, the following tables were included:

- program control parameters, source data, and receptor data;
- meteorological data (hourly values for each day for short-term, and annual STAR data for long-term); and
- particulate concentrations calculated (6 or 24 hour for short-term and annual average for long-term) for the desired combination of sources for all receptors.

Several sources of different types simulate the variety of operations associated with a surface coal mine. To evaluate the impact of the entire mine operation (all the mines in the region) on the surrounding receptors, the ISC Model allows the sources comprising each mine or type of mine operation to be reported separately for each receptor. This output format is valuable in evaluating the impact of each type of mine operation simulated in the model verification runs and each individual mine modeled in the 1988 Gillette Corridor runs.

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APPENDIX C

ACTUAL METEOROLOGICAL CONDITIONS INPUT FOR SHORT-TERM ISC MODEL VERIFICATION RUNS

*** FALL 1 3-4NOV78 10PM-4AM ***

* METEOROLOGICAL DATA FOR DAY 308 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	1.79	250.0	278.0	.0000	4	.2500	.000000
2	.0	4.02	250.0	278.0	.0000	4	.2500	.000000
3	.0	5.81	250.0	278.0	.0000	4	.2500	.000000
4	.0	6.71	250.0	278.0	.0000	4	.2500	.000000
5	.0	6.26	250.0	278.0	.0000	4	.2500	.000000
6	.0	7.15	250.0	277.0	.0000	4	.2500	.000000

*** FALL 2 4NOV78 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 309 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	68.0	15.20	1200.0	288.0	.0000	2	.1500	.00000 0
2	68.0	15.65	1200.0	289.0	.0000	2	.1500	.00000 0
3	68.0	16.54	1200.0	292.0	.0000	2	.1500	.00000 0
4	113.0	16.99	1200.0	291.0	.0000	2	.1500	.00000 0
5	113.0	13.41	1200.0	291.0	.0000	2	.1500	.00000 0
6	90.0	10.28	1200.0	291.0	.0000	2	.1500	.00000 0

*** FALL 3 4-5NOV78 10PM-4AM ***

* METEOROLOGICAL DATA FOR DAY 309 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	203.0	8.05	250.0	274.0	.0000	4	.2500	.00000 0
2	90.0	5.36	250.0	272.0	.0000	4	.2500	.00000 0
3	315.0	1.79	250.0	272.0	.0000	4	.2500	.00000 0
4	293.0	1.79	250.0	270.0	.0000	4	.2500	.00000 0
5	338.0	1.79	250.0	269.0	.0000	4	.2500	.00000 0
6	23.0	.68	250.0	268.0	.0000	4	.2500	.00000 0

*** FALL 5 5-6NOV78 10PM-4AM ***

* METEOROLOGICAL DATA FOR DAY 31 C *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	3.58	250.0	267.0	.0000	4	.2500	.000000
2	.0	.89	250.0	266.0	.0000	4	.2500	.000000
3	.0	1.34	250.0	266.0	.0000	4	.2500	.000000
4	.0	1.34	250.0	265.0	.0000	4	.2500	.000000
5	23.0	.89	250.0	264.0	.0000	4	.2500	.000000
6	23.0	.89	250.0	265.0	.0000	4	.2500	.000000

*** FALL 7 6-7NOV78 10PM-4AM ***

* METEOROLOGICAL DATA FOR DAY 311 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	90.0	1.79	250.0	272.0	.0000	4	.2500	.000000
2	90.0	.89	250.0	272.0	.0000	4	.2500	.000000
3	77.0	.44	250.0	273.0	.0000	4	.2500	.000000
4	77.0	.89	250.0	274.0	.0000	4	.2500	.000000
5	90.0	1.34	250.0	275.0	.0000	4	.2500	.000000
6	56.0	.44	250.0	274.0	.0000	4	.2500	.000000

*** FALL 8 7NOV78 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 312 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	43.0	1.34	1200.0	287.0	.0000	3	.2000	.000000
2	56.0	.44	1200.0	289.0	.0000	3	.2000	.000000
3	63.0	.89	1200.0	289.0	.0000	3	.2000	.000000
4	65.0	1.79	1200.0	291.0	.0000	3	.2000	.000000
5	77.0	4.47	1200.0	291.0	.0000	3	.2000	.000000
6	70.0	5.36	1200.0	289.0	.0000	3	.2000	.000000

*** FALL 9 7-8NOV78 10PM-4AM ***

* METEOROLOGICAL DATA FOR DAY 312 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	16.0	1.79	250.0	281.0	.0000	4	.2500	.00000 C
2	36.0	2.24	250.0	281.0	.0000	4	.2500	.00000 C
3	56.0	2.68	250.0	282.0	.0000	4	.2500	.00000 C
4	90.0	2.24	250.0	282.0	.0000	4	.2500	.00000 C
5	158.0	1.34	250.0	281.0	.0000	4	.2500	.00000 C
6	56.0	1.34	250.0	281.0	.0000	4	.2500	.00000 C

*** FALL 10 8NOV78 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 313 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	16.0	.89	1200.0	290.0	.0000	3	.2000	.000000
2	356.0	.89	1200.0	292.0	.0000	3	.2000	.000000
3	9.0	1.34	1200.0	292.0	.0000	3	.2000	.000000
4	124.0	2.24	1200.0	292.0	.0000	3	.2000	.000000
5	347.0	1.34	1200.0	292.0	.0000	3	.2000	.000000
6	353.0	2.24	1200.0	293.0	.0000	3	.2000	.000000

*** FALL 12 9NOV79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 314 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	104.0	2.24	1200.0	277.0	.0000	4	.2500	.000000
2	124.0	.44	1200.0	276.0	.0000	4	.2500	.000000
3	191.0	.44	1200.0	273.0	.0000	4	.2500	.000000
4	259.0	4.47	1200.0	272.0	.0000	4	.2500	.000000
5	259.0	8.05	1200.0	271.0	.0000	4	.2500	.000000
6	232.0	8.94	1200.0	271.0	.0000	4	.2500	.000000

*** WINTER 1 31 JAN 79 1030AM 430PM ***

* METEOROLOGICAL DATA FOR DAY 31 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	2.24	1000.0	257.0	.0000	3	.2000	.000000
2	.0	1.79	1000.0	257.0	.0000	3	.2000	.000000
3	.0	1.34	1000.0	257.0	.0000	3	.2000	.000000
4	23.0	1.79	1000.0	257.0	.0000	3	.2000	.000000
5	.0	2.68	1000.0	257.0	.0000	3	.2000	.000000
6	.0	3.13	1000.0	257.0	.0000	3	.2000	.000000

*** WINTER 2 31JAN 1FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY 31 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	9.82	300.0	256.0	.0000	4	.2500	.000000
2	338.0	7.62	300.0	255.0	.0000	4	.2500	.000000
3	.0	7.60	300.0	256.0	.0000	4	.2500	.000000
4	.0	6.26	300.0	256.0	.0000	4	.2500	.000000
5	23.0	3.58	300.0	257.0	.0000	4	.2500	.000000
6	90.0	3.13	300.0	256.0	.0000	4	.2500	.000000

*** WINTER 3 1FEB79 9AM 3PM ***

* METEOROLOGICAL DATA FOR DAY 32 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	113.0	.89	1000.0	251.0	.0000	3	.2000	.000000
2	158.0	1.79	1000.0	253.0	.0000	3	.2000	.000000
3	135.0	1.79	1000.0	254.0	.0000	3	.2000	.000000
4	203.0	3.13	1000.0	255.0	.0000	3	.2000	.000000
5	203.0	1.79	1000.0	255.0	.0000	3	.2000	.000000
6	113.0	1.34	1000.0	255.0	.0000	3	.2000	.000000

*** WINTER 4 1-2FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY 32 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	100.0	1.79	300.0	249.0	.0000	4	.2500	.000000
2	150.0	.89	300.0	249.0	.0000	4	.2500	.000000
3	120.0	.45	300.0	249.0	.0000	4	.2500	.000000
4	90.0	.45	300.0	249.0	.0000	4	.2500	.000000
5	60.0	.45	300.0	249.0	.0000	4	.2500	.000000
6	60.0	.89	300.0	249.0	.0000	4	.2500	.000000

*** WINTER 5 2FEB79 9AM 3PM ***

* METEOROLOGICAL DATA FOR DAY 33 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	330.0	.89	1000.0	253.0	.0000	2	.1500	.000000
2	23.0	.89	1000.0	253.0	.0000	2	.1500	.000000
3	23.0	.89	1000.0	253.0	.0000	2	.1500	.000000
4	45.0	1.79	1000.0	253.0	.0000	2	.1500	.000000
5	23.0	.89	1000.0	253.0	.0000	2	.1500	.000000
6	.0	.89	1000.0	253.0	.0000	2	.1500	.000000

*** WINTER 6 2-3FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY 33 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	3.13	300.0	248.0	.0000	4	.2500	.000000
2	.0	4.92	300.0	248.0	.0000	4	.2500	.000000
3	.0	4.92	300.0	248.0	.0000	4	.2500	.000000
4	.0	2.68	300.0	249.0	.0000	4	.2500	.000000
5	338.0	1.34	300.0	249.0	.0000	4	.2500	.000000
6	45.0	1.79	300.0	249.0	.0000	4	.2500	.000000

*** WINTER 7 3FEB79 9AM 3PM ***

* METEOROLOGICAL DATA FOR DAY 34 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	68.0	3.13	1000.0	263.0	.0000	3	.2000	.000000
2	90.0	2.68	1000.0	263.0	.0000	3	.2000	.000000
3	90.0	4.02	1000.0	263.0	.0000	3	.2000	.000000
4	90.0	4.02	1000.0	263.0	.0000	3	.2000	.000000
5	23.0	2.24	1000.0	264.0	.0000	3	.2000	.000000
6	23.0	2.68	1000.0	264.0	.0000	3	.2000	.000000

*** WINTER 8 3-4FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY , 34 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	1.79	300.0	263.0	.0000	4	.2500	.00000C
2	.0	2.68	300.0	262.0	.0000	4	.2500	.00000C
3	.0	3.13	300.0	262.0	.0000	4	.2500	.00000C
4	338.0	.89	300.0	262.0	.0000	4	.2500	.00000C
5	158.0	.89	300.0	263.0	.0000	4	.2500	.00000C
6	158.0	.45	300.0	263.0	.0000	4	.2500	.00000C

*** WINTER 9 4FEB79 9AM 3PM ***

* METEOROLOGICAL DATA FOR DAY 35 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	180.0	3.58	1000.0	263.0	.0000	3	.2000	.000000
2	158.0	4.02	1000.0	263.0	.0000	3	.2000	.000000
3	135.0	4.92	1000.0	263.0	.0000	3	.2000	.000000
4	135.0	3.13	1000.0	263.0	.0000	3	.2000	.000000
5	45.0	.89	1000.0	263.0	.0000	3	.2000	.000000
6	45.0	2.68	1000.0	263.0	.0000	3	.2000	.000000

*** WINTER 1C 4-5FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY 35 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	68.0	6.26	300.0	260.0	.0000	4	.2500	.00000 C
2	68.0	5.36	300.0	260.0	.0000	4	.2500	.00000 C
3	68.0	5.36	300.0	260.0	.0000	4	.2500	.00000 C
4	90.0	5.81	300.0	260.0	.0000	4	.2500	.00000 C
5	90.0	7.60	300.0	260.0	.0000	4	.2500	.00000 C
6	90.0	10.73	300.0	261.0	.0000	4	.2500	.00000 C

*** WINTER 11 5FEB79 9AM 3PM ***

* METEOROLOGICAL DATA FOR DAY 36 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	90.0	8.49	1000.0	267.0	.0000	4	.2500	.000000
2	90.0	7.15	1000.0	268.0	.0000	4	.2500	.000000
3	90.0	7.15	1000.0	269.0	.0000	4	.2500	.000000
4	150.0	5.36	1000.0	269.0	.0000	4	.2500	.000000
5	23.0	4.92	1000.0	270.0	.0000	4	.2500	.000000
6	23.0	4.02	1000.0	271.0	.0000	4	.2500	.000000

*** WINTER 12 5-6FEB79 9PM 3AM ***

* METEOROLOGICAL DATA FOR DAY 36 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	45.0	2.68	300.0	268.0	.0000	4	.2500	.000000
2	90.0	2.68	300.0	267.0	.0000	4	.2500	.000000
3	135.0	4.92	300.0	267.0	.0000	4	.2500	.000000
4	135.0	4.02	300.0	268.0	.0000	4	.2500	.000000
5	158.0	4.92	300.0	268.0	.0000	4	.2500	.000000
6	158.0	4.02	300.0	269.0	.0000	4	.2500	.000000

*** SPRING1 27APR79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 117 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	130.0	3.13	1400.0	280.0	.0000	3	.2000	.000000
2	140.0	2.68	1400.0	282.0	.0000	3	.2000	.000000
3	150.0	2.68	1400.0	283.0	.0000	3	.2000	.000000
4	140.0	4.92	1400.0	284.0	.0000	3	.2000	.000000
5	130.0	5.36	1400.0	284.0	.0000	3	.2000	.000000
6	145.0	5.58	1400.0	285.0	.0000	3	.2000	.000000

*** SPRING2 27-28APR79 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 117 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	270.0	3.13	400.0	277.0	.0000	4	.2500	.000000
2	345.0	2.68	400.0	276.0	.0000	4	.2500	.000000
3	20.0	1.79	400.0	275.0	.0000	4	.2500	.000000
4	350.0	4.02	400.0	274.0	.0000	4	.2500	.000000
5	.0	4.92	400.0	273.0	.0000	4	.2500	.000000
6	45.0	3.58	400.0	273.0	.0000	4	.2500	.000000

*** SPRING 3 28APR79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 118 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	155.0	13.86	1400.0	282.0	.0000	4	.2500	.000000
2	150.0	13.86	1400.0	284.0	.0000	4	.2500	.000000
3	145.0	14.75	1400.0	284.0	.0000	4	.2500	.000000
4	150.0	13.86	1400.0	284.0	.0000	4	.2500	.000000
5	165.0	13.41	1400.0	283.0	.0000	4	.2500	.000000
6	170.0	13.86	1400.0	282.0	.0000	4	.2500	.000000

*** SPRING 4 28-29APR79 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 118 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	170.0	4.92	400.0	274.0	.0000	4	.2500	.000000
2	175.0	3.58	400.0	273.0	.0000	4	.2500	.000000
3	170.0	1.79	400.0	270.0	.0000	4	.2500	.000000
4	60.0	2.68	400.0	269.0	.0000	4	.2500	.000000
5	55.0	3.58	400.0	269.0	.0000	4	.2500	.000000
6	75.0	2.68	400.0	268.0	.0000	4	.2500	.000000

*** SPRING 5 29APR79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 119 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	140.0	6.26	1400.0	285.0	.0000	4	.2500	.000000
2	145.0	7.60	1400.0	286.0	.0000	4	.2500	.000000
3	160.0	8.94	1400.0	287.0	.0000	4	.2500	.000000
4	150.0	10.73	1400.0	286.0	.0000	4	.2500	.000000
5	165.0	10.73	1400.0	285.0	.0000	4	.2500	.000000
6	160.0	9.62	1400.0	283.0	.0000	4	.2500	.000000

*** SPRING 7 30APR79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 120 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	15.0	7.15	1400.0	286.0	.0000	4	.2500	.000000
2	20.0	6.71	1400.0	287.0	.0000	4	.2500	.000000
3	5.0	6.26	1400.0	287.0	.0000	4	.2500	.000000
4	5.0	5.81	1400.0	289.0	.0000	4	.2500	.000000
5	.0	6.26	1400.0	289.0	.0000	4	.2500	.000000
6	355.0	6.26	1400.0	289.0	.0000	4	.2500	.000000

*** SPRING 8 30APR-1MAY79 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 120 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	190.0	9.39	400.0	278.0	.0000	4	.2500	.000000
2	215.0	6.71	400.0	277.0	.0000	4	.2500	.000000
3	200.0	4.92	400.0	277.0	.0000	4	.2500	.000000
4	210.0	3.58	400.0	277.0	.0000	4	.2500	.000000
5	150.0	2.24	400.0	277.0	.0000	4	.2500	.000000
6	160.0	4.02	400.0	276.0	.0000	4	.2500	.000000

*** SPRING 9 1MAY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 121 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	210.0	4.47	1400.0	284.0	.0000	3	.2000	.000000
2	200.0	4.92	1400.0	284.0	.0000	3	.2000	.000000
3	200.0	4.47	1400.0	285.0	.0000	3	.2000	.000000
4	200.0	4.02	1400.0	285.0	.0000	3	.2000	.000000
5	205.0	5.36	1400.0	286.0	.0000	3	.2000	.000000
6	210.0	5.36	1400.0	286.0	.0000	3	.2000	.000000

*** SPRING 10 1-2MAY79 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 121 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	210.0	8.05	400.0	279.0	.0000	4	.2500	.000000
2	195.0	8.49	400.0	277.0	.0000	4	.2500	.000000
3	190.0	9.39	400.0	276.0	.0000	4	.2500	.000000
4	190.0	9.39	400.0	275.0	.0000	4	.2500	.000000
5	195.0	8.94	400.0	275.0	.0000	4	.2500	.000000
6	200.0	9.39	400.0	274.0	.0000	4	.2500	.000000

*** SPRING11 2MAY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 122 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	220.0	8.05	1400.0	272.0	.0000	4	.2500	.000000
2	230.0	5.39	1400.0	273.0	.0000	4	.2500	.000000
3	200.0	6.26	1400.0	273.0	.0000	4	.2500	.000000
4	190.0	5.81	1400.0	273.0	.0000	4	.2500	.000000
5	200.0	5.36	1400.0	273.0	.0000	4	.2500	.000000
6	205.0	4.92	1400.0	273.0	.0000	4	.2500	.000000

*** SUMMER1 7DJULY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 201 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	.0	4.92	1550.0	303.0	.0000	3	.2000	.000000
2	10.0	4.47	1550.0	302.0	.0000	3	.2000	.000000
3	30.0	4.92	1550.0	302.0	.0000	3	.2000	.000000
4	35.0	5.36	1550.0	302.0	.0000	3	.2000	.000000
5	50.0	4.47	1550.0	302.0	.0000	3	.2000	.000000
6	60.0	4.02	1550.0	302.0	.0000	3	.2000	.000000

*** SUMMER 5 22JULY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 203 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	395.0	8.94	1550.0	305.0	.0000	3	.2000	.000000
2	395.0	8.49	1550.0	306.0	.0000	3	.2000	.000000
3	390.0	8.05	1550.0	307.0	.0000	3	.2000	.000000
4	45.0	7.60	1550.0	308.0	.0000	3	.2000	.000000
5	50.0	8.94	1550.0	307.0	.0000	3	.2000	.000000
6	50.0	7.15	1550.0	308.0	.0000	3	.2000	.000000

*** SUMMER 6 22-23JULY79 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 203 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	185.0	8.49	300.0	294.0	.0000	4	.2500	.000000
2	170.0	7.60	300.0	292.0	.0000	4	.2500	.000000
3	65.0	2.68	300.0	291.0	.0000	4	.2500	.000000
4	115.0	4.02	300.0	290.0	.0000	4	.2500	.000000
5	100.0	4.02	300.0	289.0	.0000	4	.2500	.000000
6	100.0	4.47	300.0	289.0	.0000	4	.2500	.000000

*** SUMMER 7 23JULY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 204 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	165.0	8.94	1550.0	291.0	.0000	4	.2500	.000000
2	170.0	8.05	1550.0	300.0	.0000	4	.2500	.000000
3	160.0	8.49	1550.0	296.0	.0000	4	.2500	.000000
4	175.0	9.49	1550.0	297.0	.0000	4	.2500	.000000
5	175.0	7.15	1550.0	297.0	.0000	4	.2500	.000000
6	170.0	7.15	1550.0	297.0	.0000	4	.2500	.000000

*** SUMMER 8 23-24JULY 9PM-3AM ***

* METEOROLOGICAL DATA FOR DAY 204 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	160.0	2.68	300.0	291.0	.0000	4	.2500	.000000
2	185.0	1.79	300.0	292.0	.0000	4	.2500	.000000
3	155.0	2.68	300.0	291.0	.0000	4	.2500	.000000
4	195.0	1.79	300.0	290.0	.0000	4	.2500	.000000
5	.0	1.79	300.0	289.0	.0000	4	.2500	.000000
6	50.0	3.58	300.0	289.0	.0000	4	.2500	.000000

*** SUMMER 9 24JULY79 10AM-4PM ***

* METEOROLOGICAL DATA FOR DAY 205 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	203.0	2.68	1550.0	299.0	.0000	4	.2500	.00000
2	207.0	2.68	1550.0	301.0	.0000	4	.2500	.00000
3	240.0	3.13	1550.0	302.0	.0000	4	.2500	.00000
4	202.0	3.58	1550.0	303.0	.0000	4	.2500	.00000
5	223.0	3.58	1550.0	303.0	.0000	4	.2500	.00000
6	229.0	3.13	1550.0	303.0	.0000	4	.2500	.00000

*** SUMMER 11 25JULY79 10AM-4PM ***

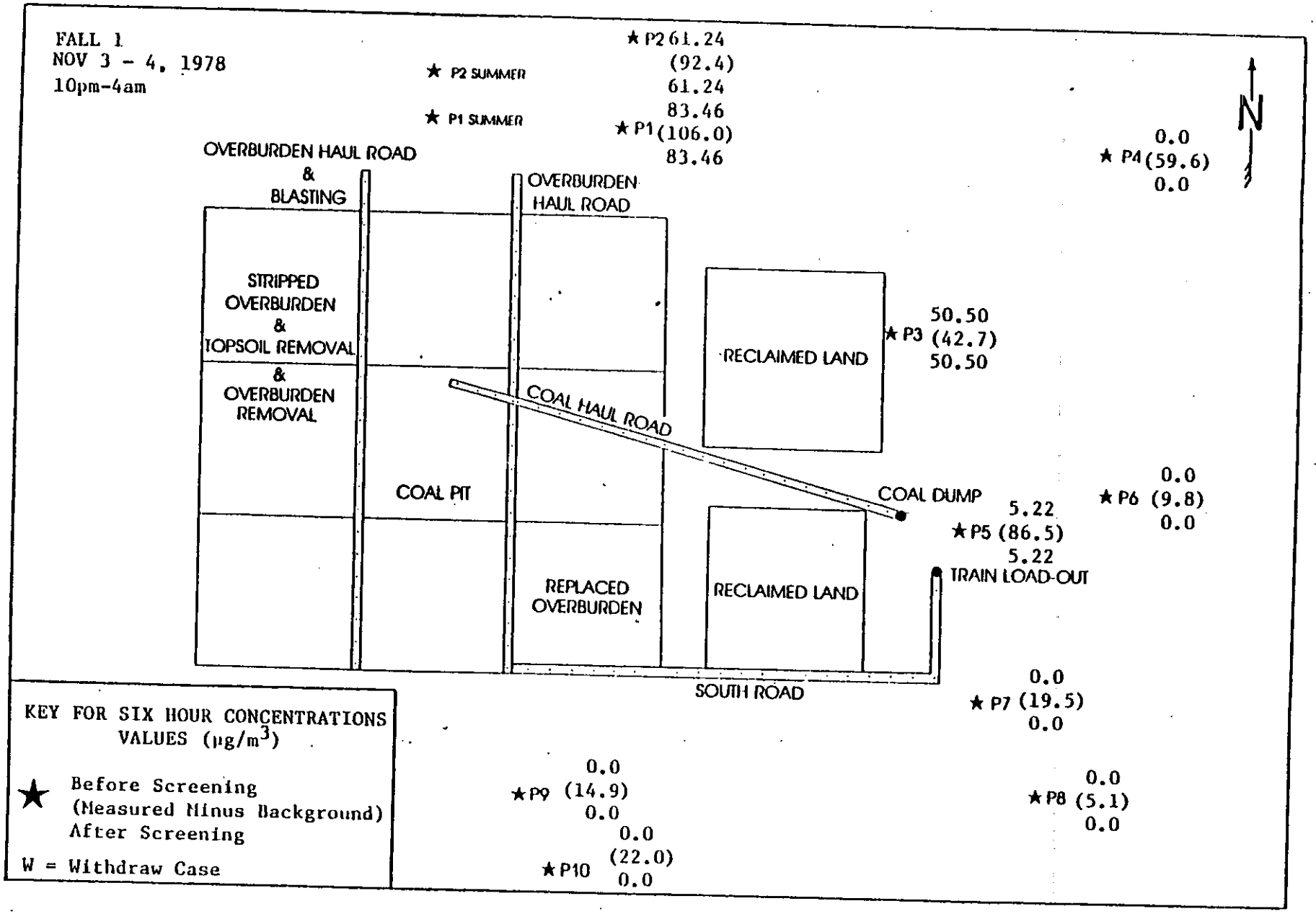
* METEOROLOGICAL DATA FOR DAY 206 *

HOUR	FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	POT. TEMP. GRADIENT (DEG. K PER METER)	STABILITY CATEGORY	WIND PROFILE EXPONENT	DECAY COEFFICIENT (PER SEC)
1	310.0	5.81	1550.0	298.0	.0000	4	.2500	.000000
2	320.0	6.71	1550.0	299.0	.0000	4	.2500	.000000
3	335.0	4.47	1550.0	301.0	.0000	4	.2500	.000000
4	340.0	3.58	1550.0	301.0	.0000	4	.2500	.000000
5	310.0	2.24	1550.0	302.0	.0000	4	.2500	.000000
6	320.0	2.68	1550.0	302.0	.0000	4	.2500	.000000

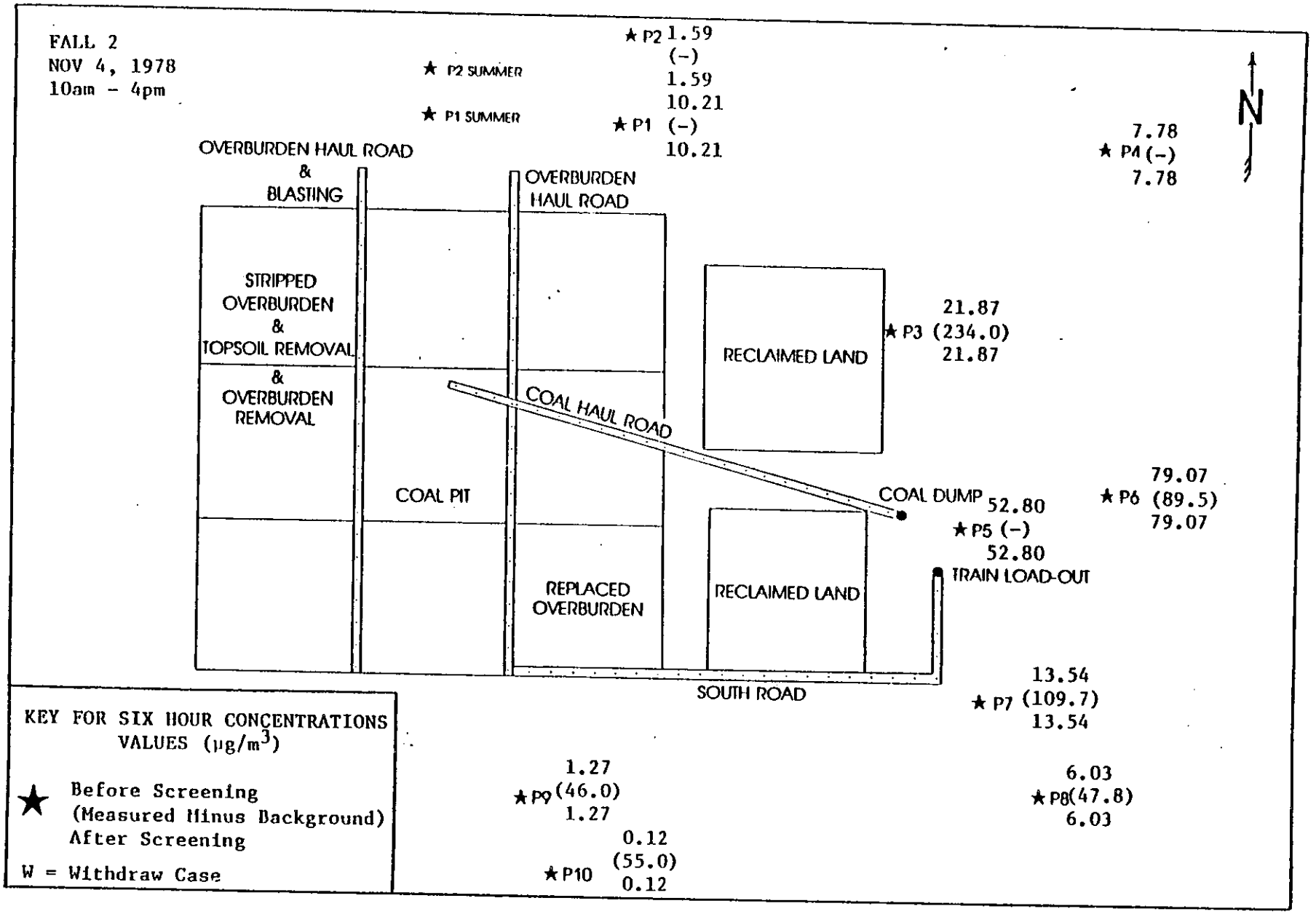
APPENDIX D

RESULTS FROM SHORT-TERM ISC MODEL VERIFICATION RUNS

SHORT-TERM ISC MODEL VERIFICATION RESULTS



SHORT-TERM ISC MODEL VERIFICATION RESULTS



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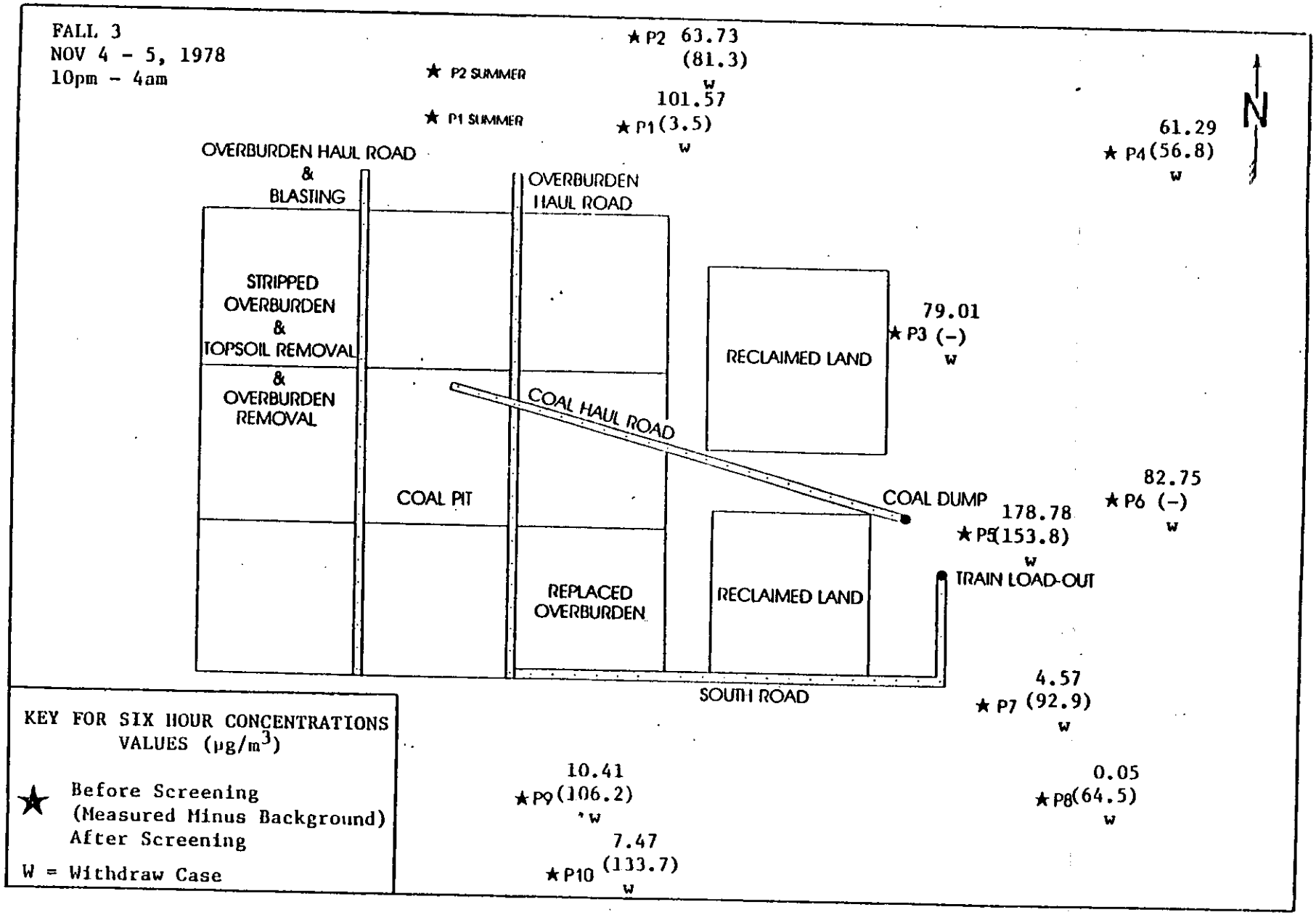
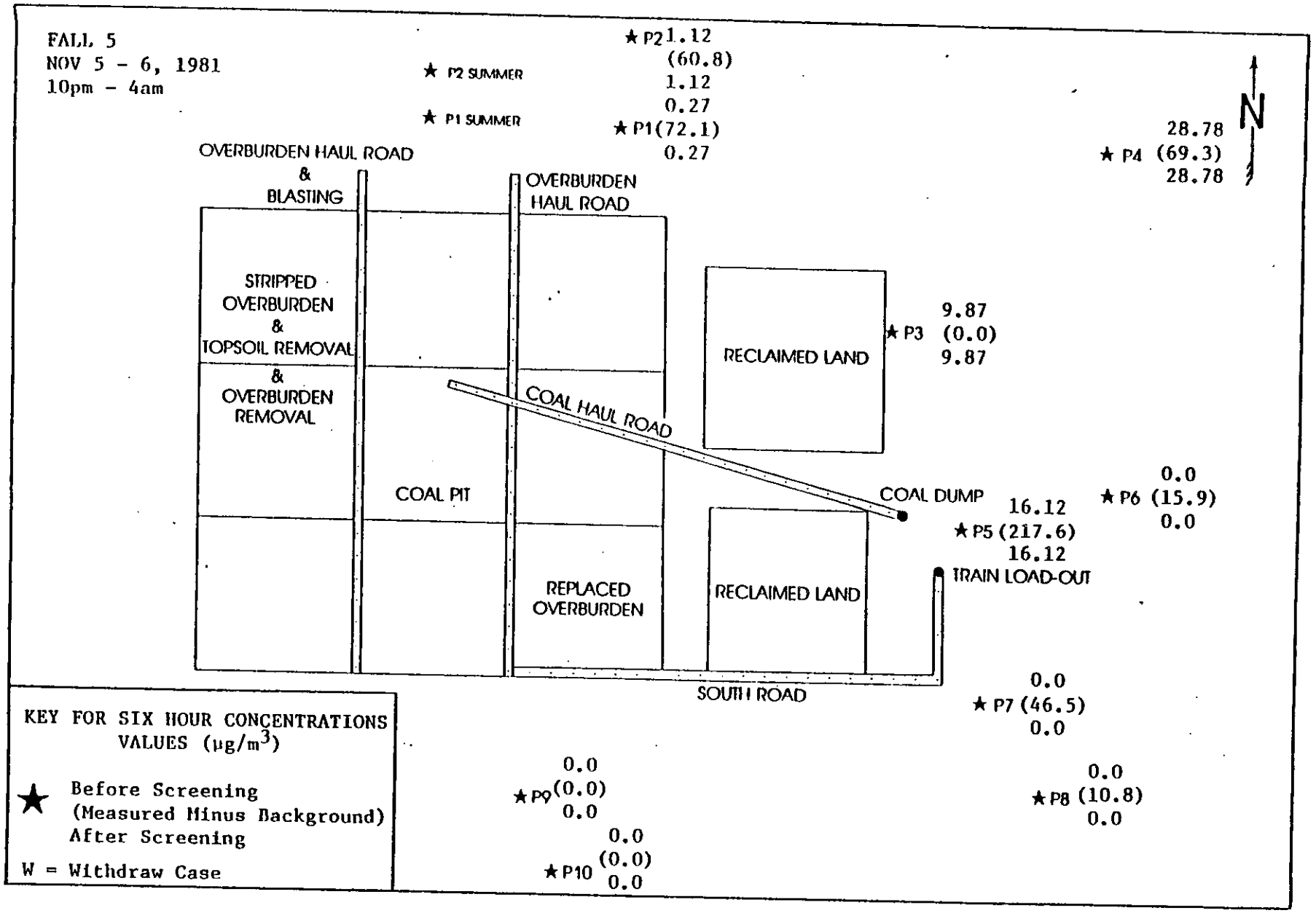


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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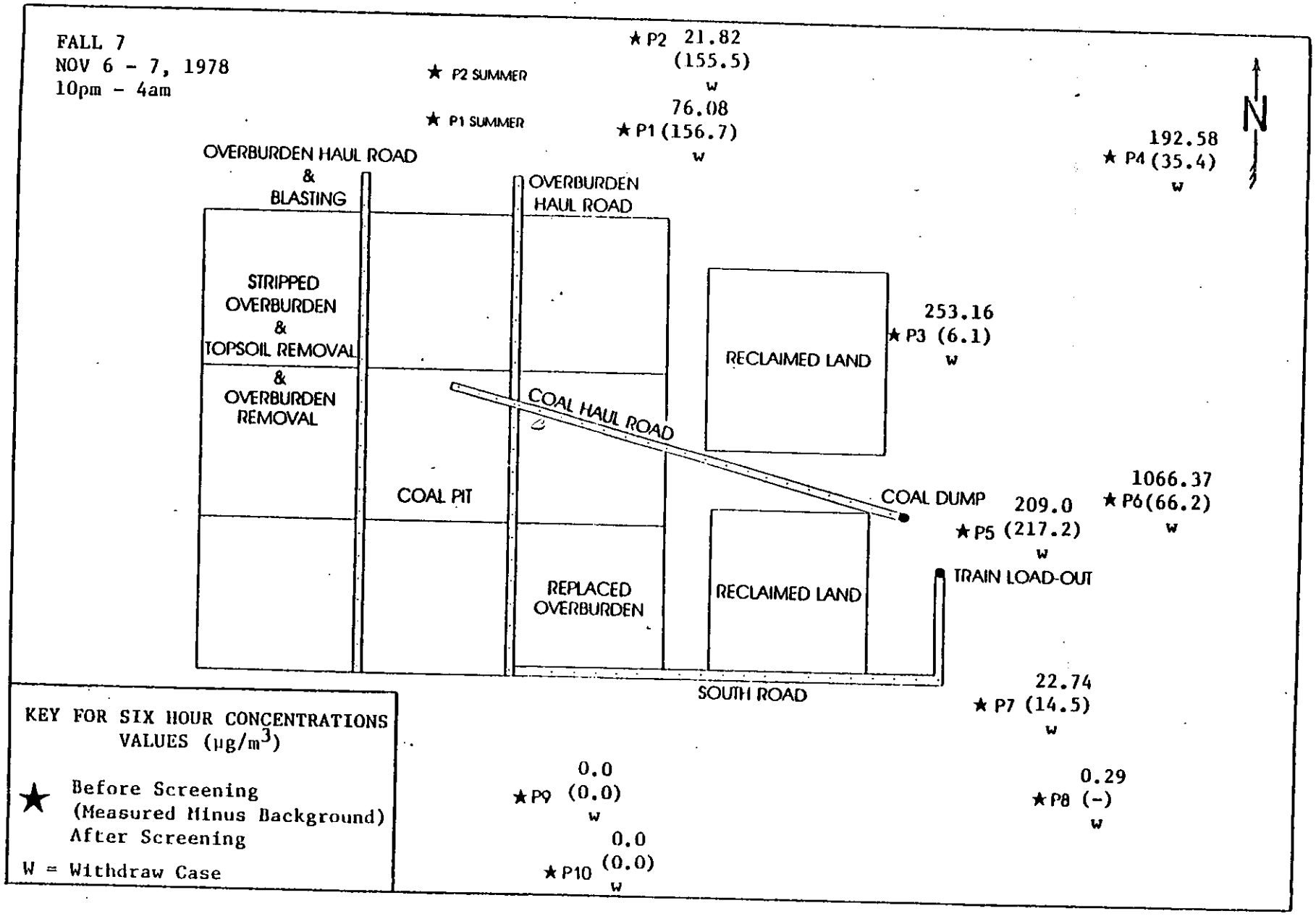
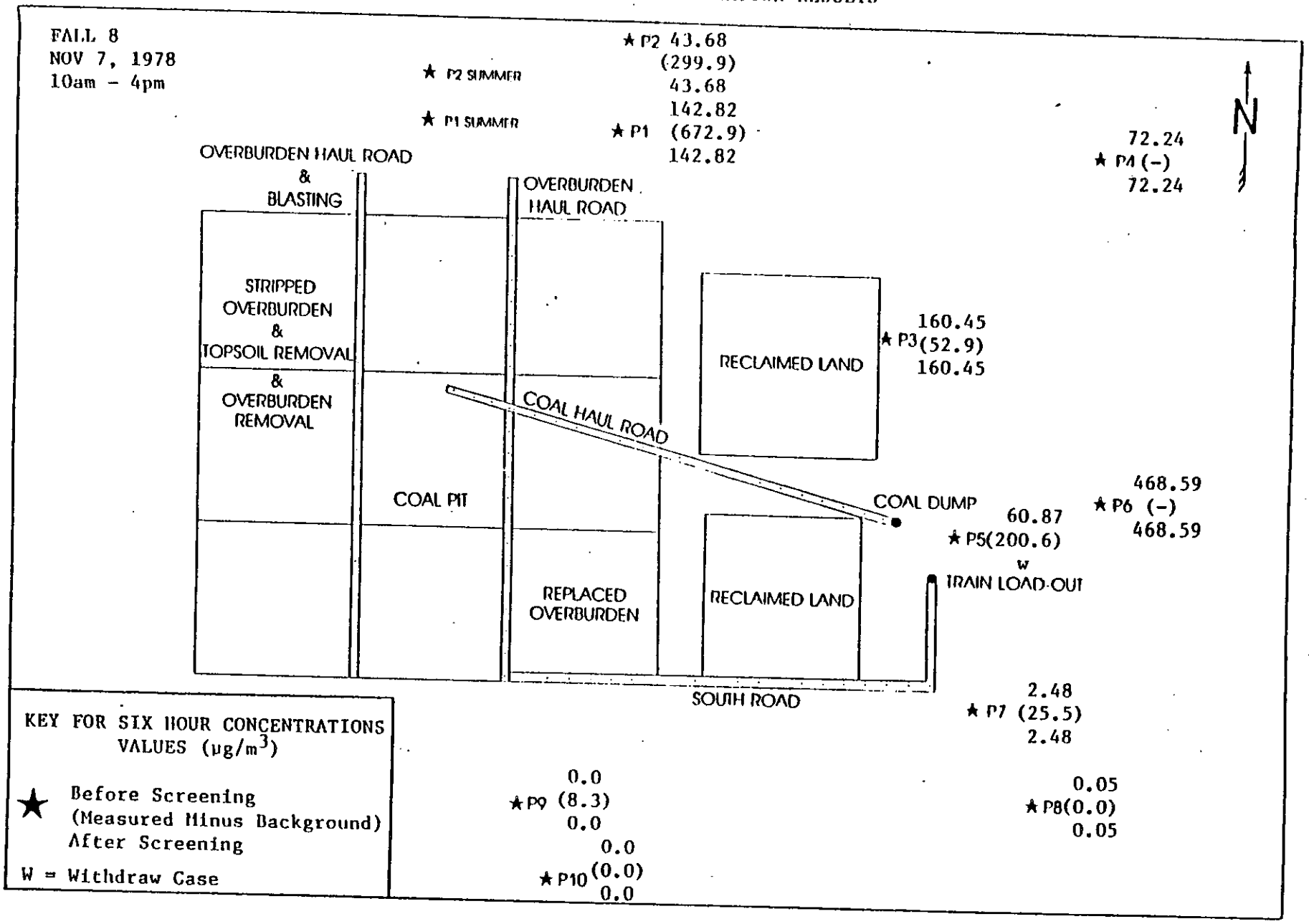


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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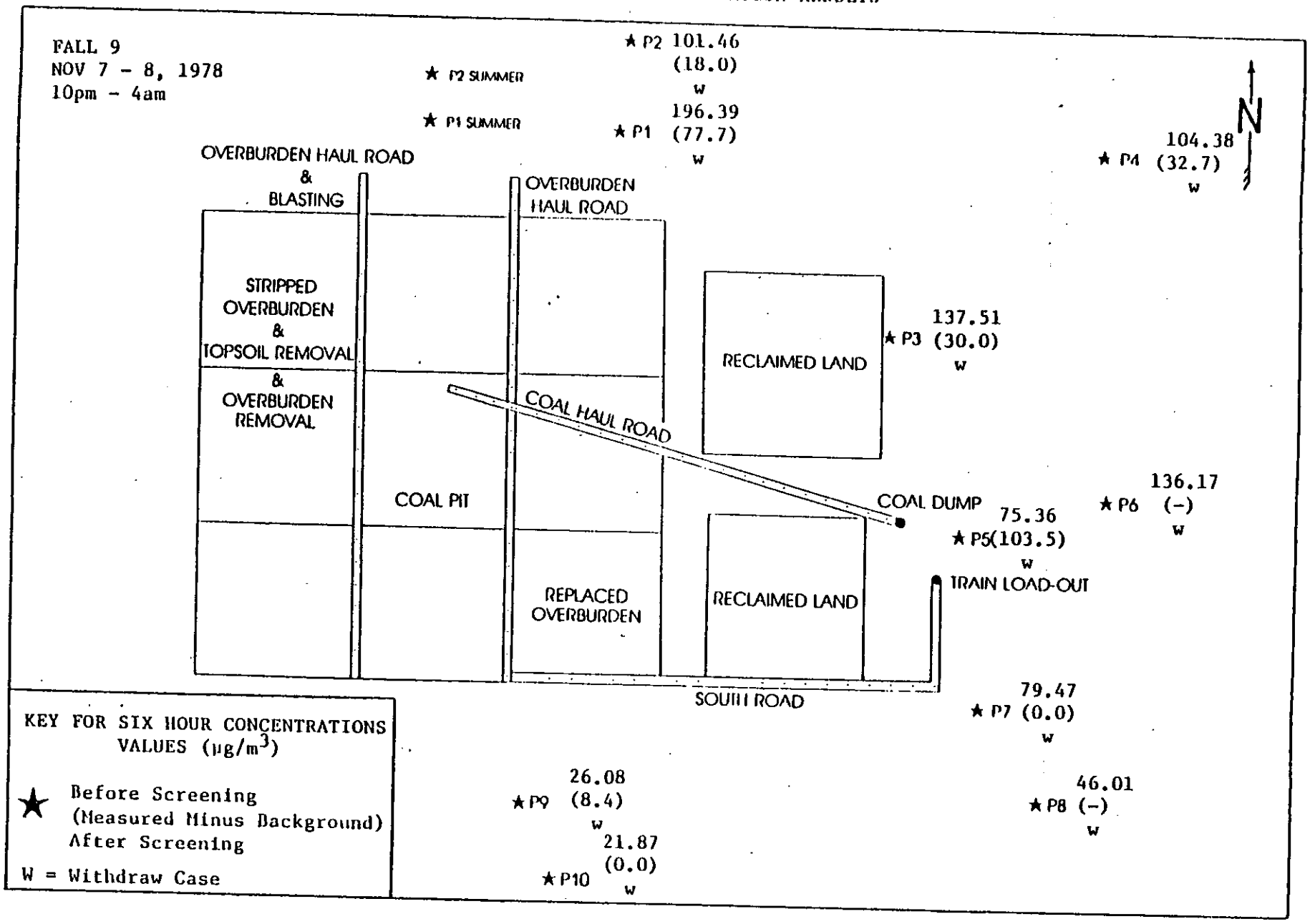

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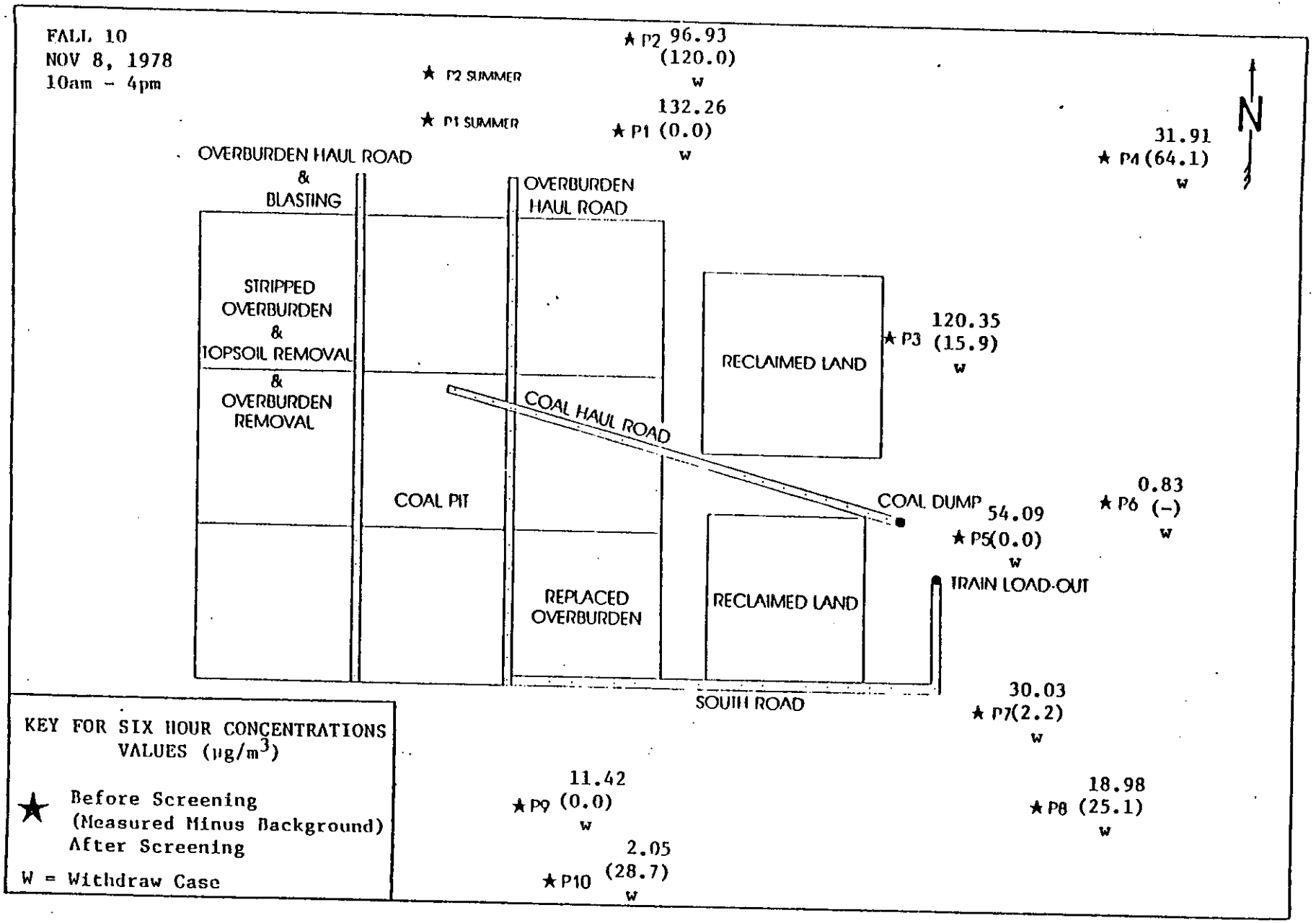
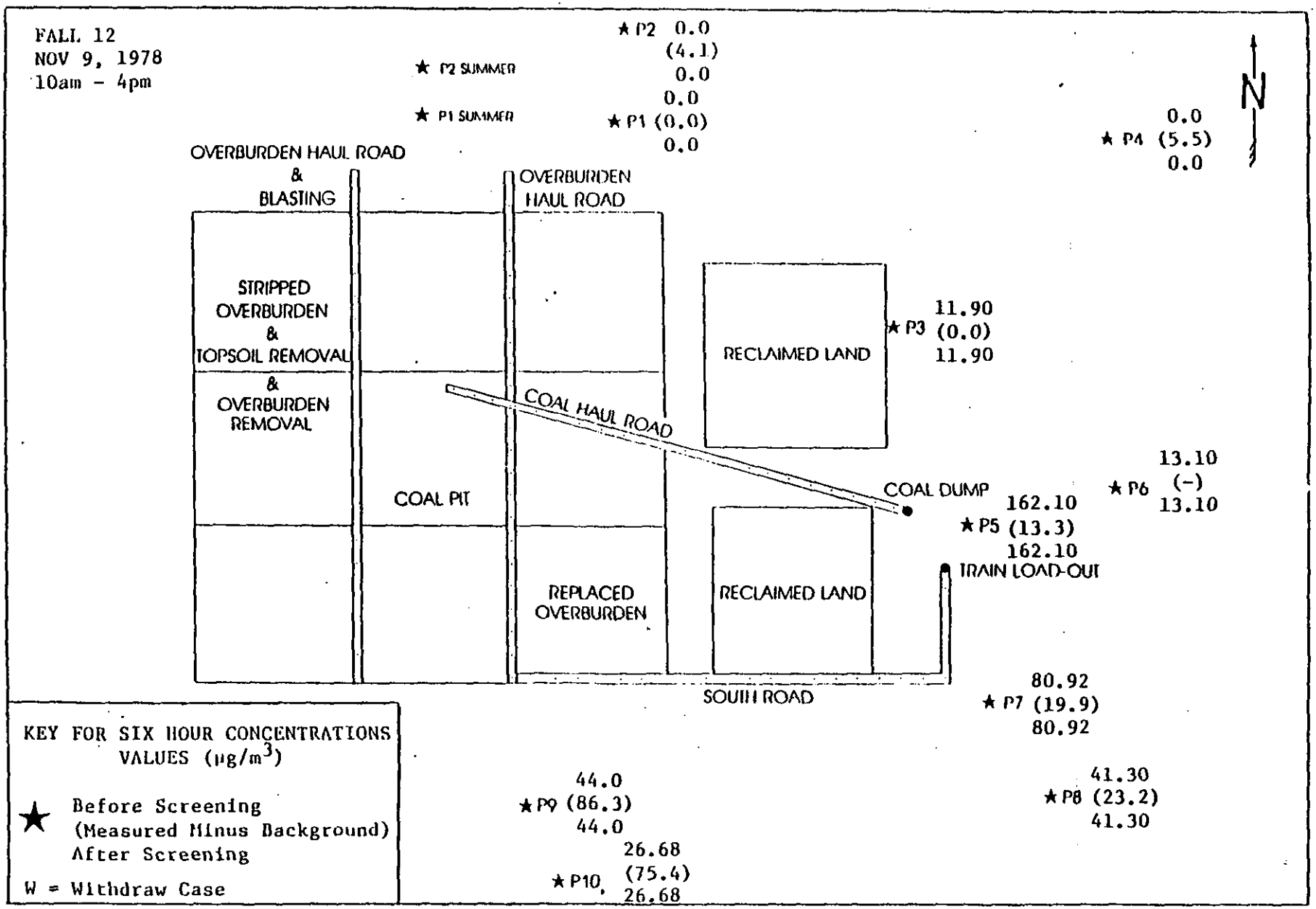
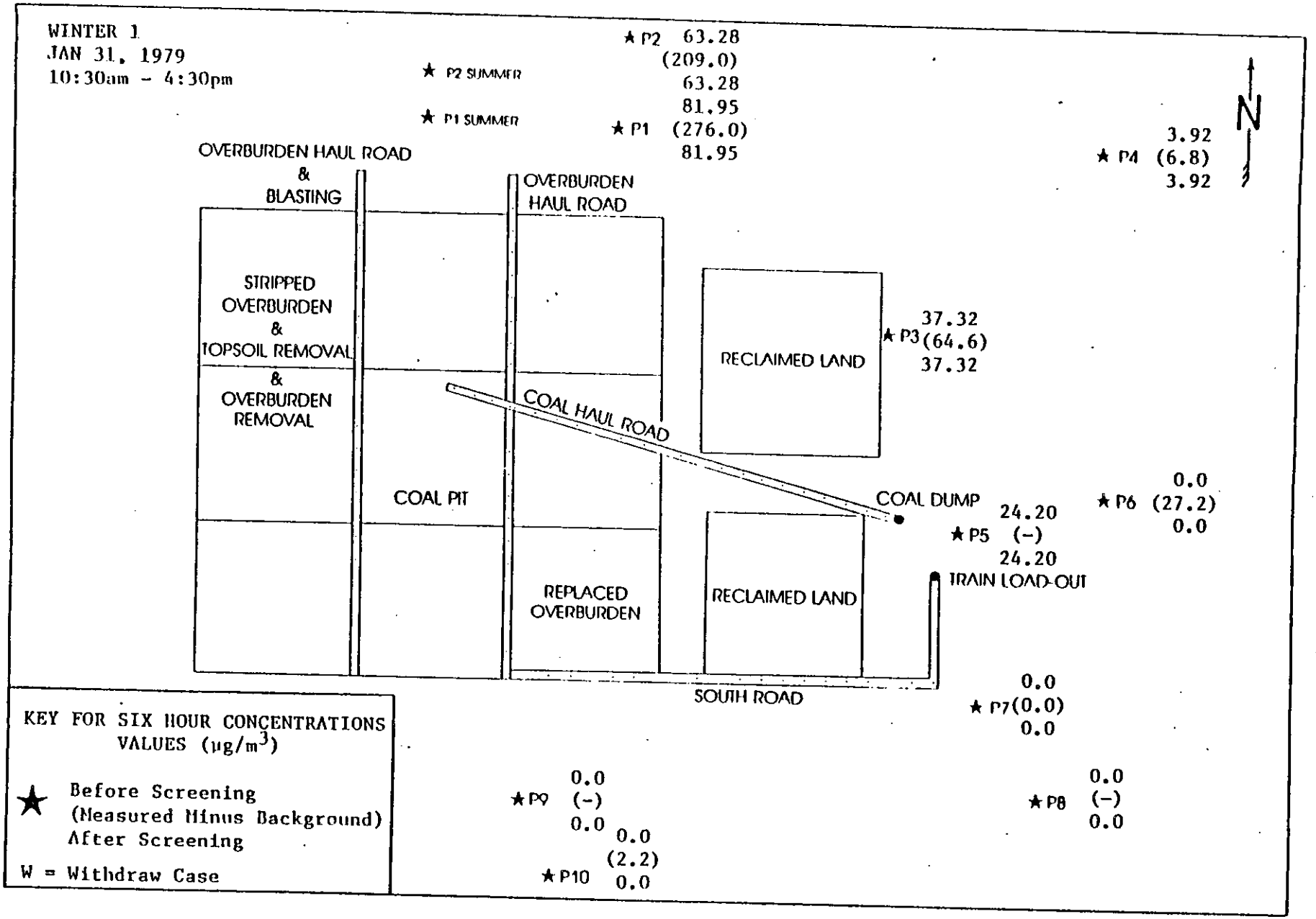


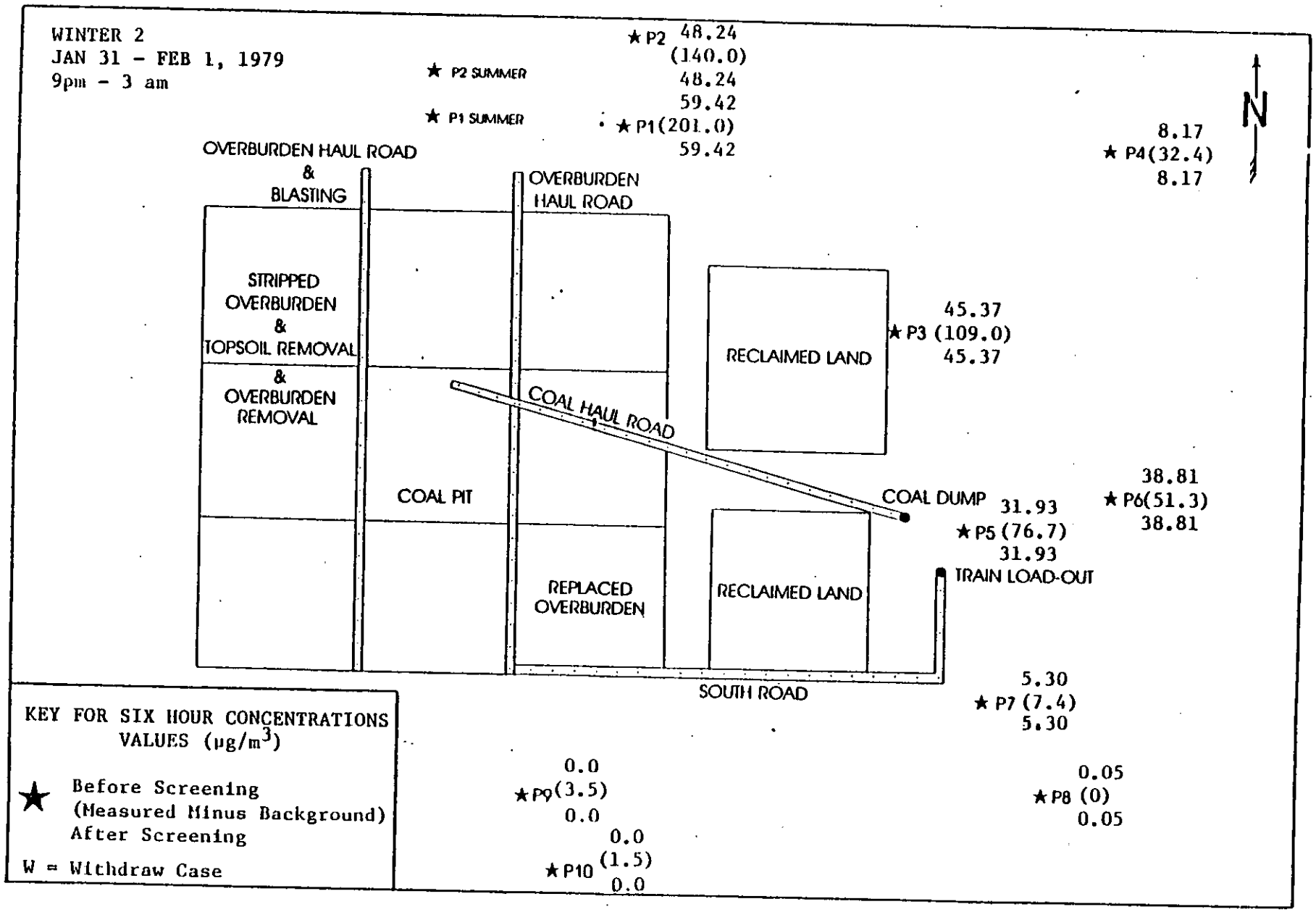
SHORT-TERM ISC MODEL VERIFICATION RESULTS



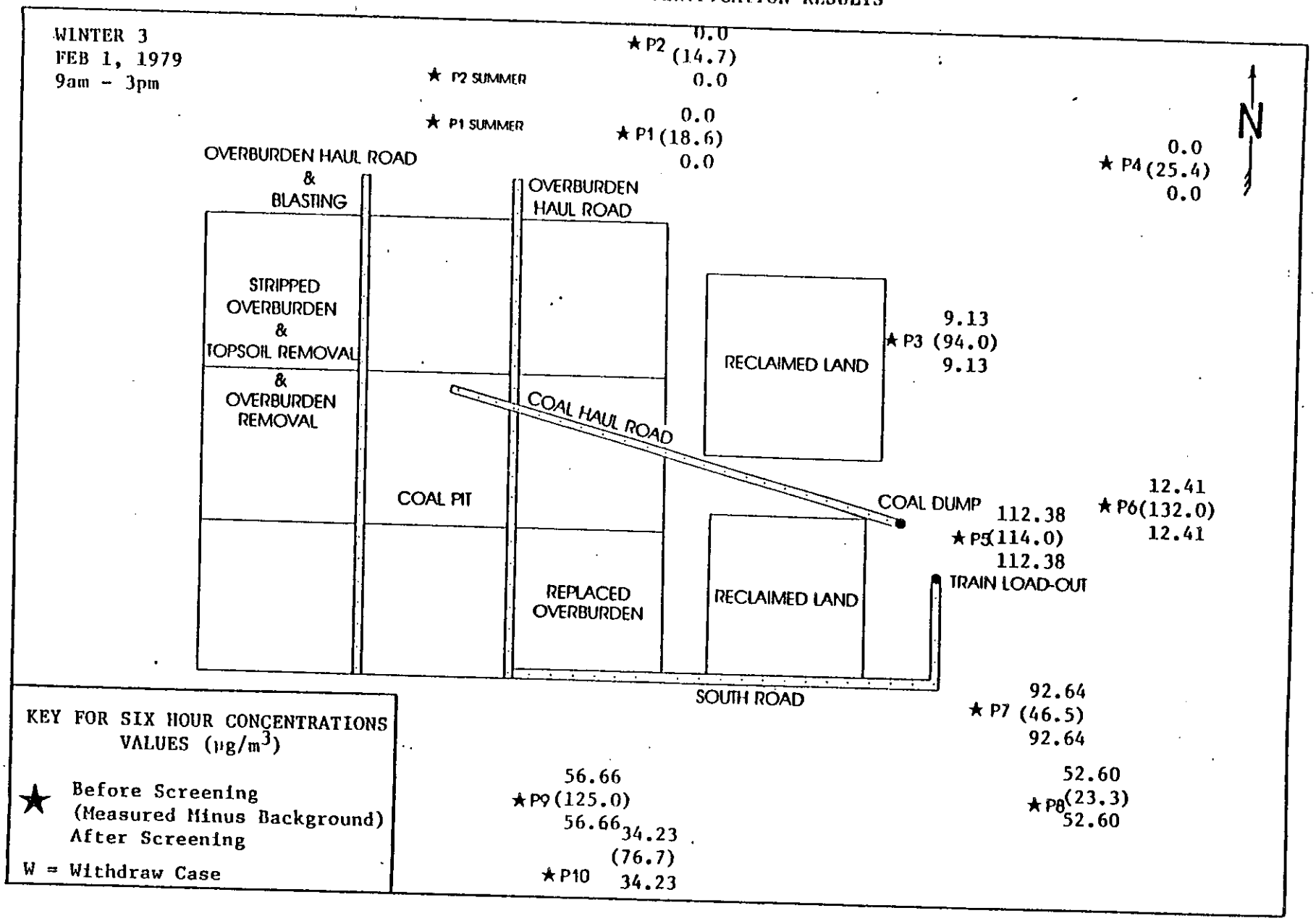
SHORT-TERM ISC MODEL VERIFICATION RESULTS



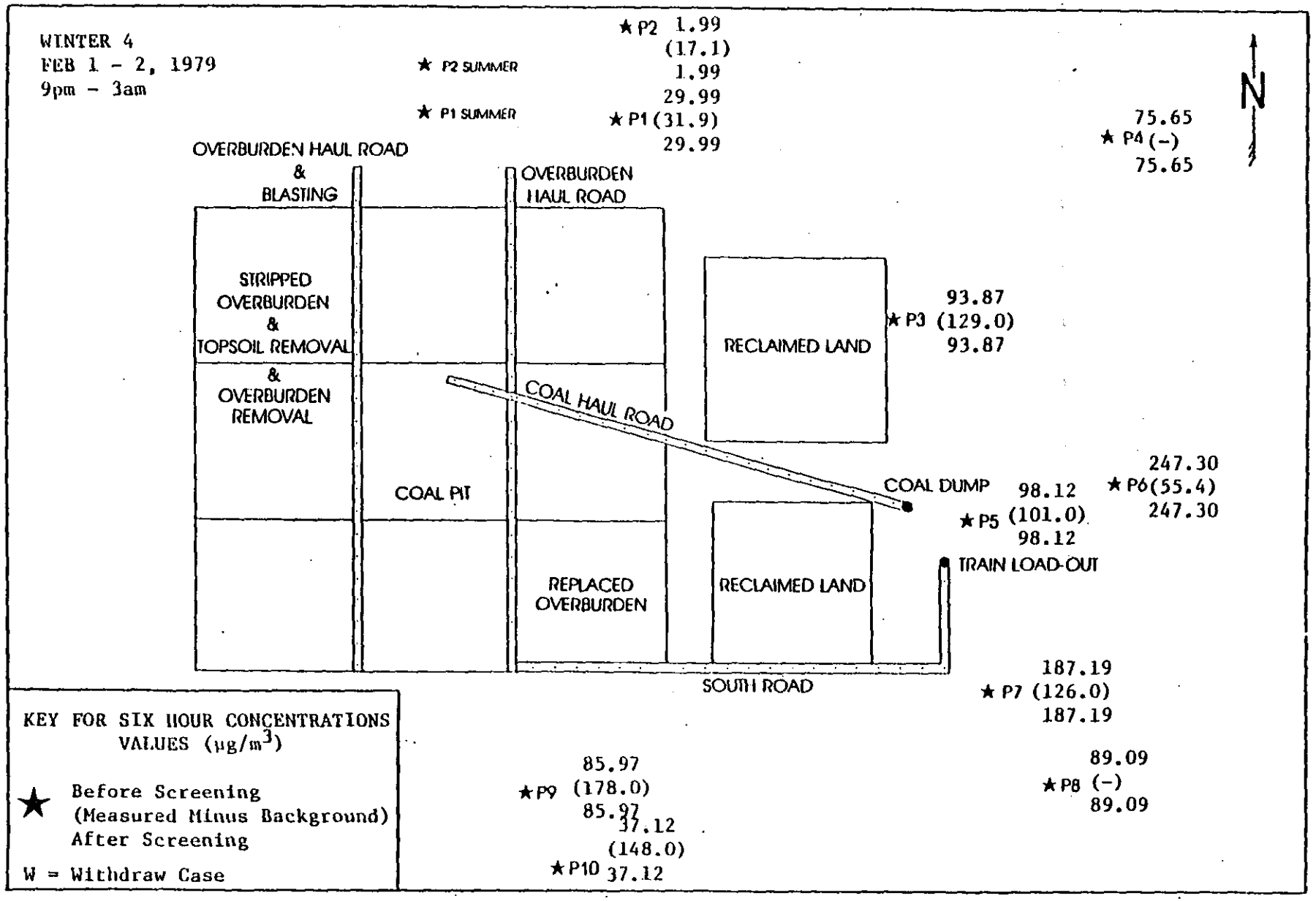
SHORT-TERM ISC MODEL VERIFICATION RESULTS



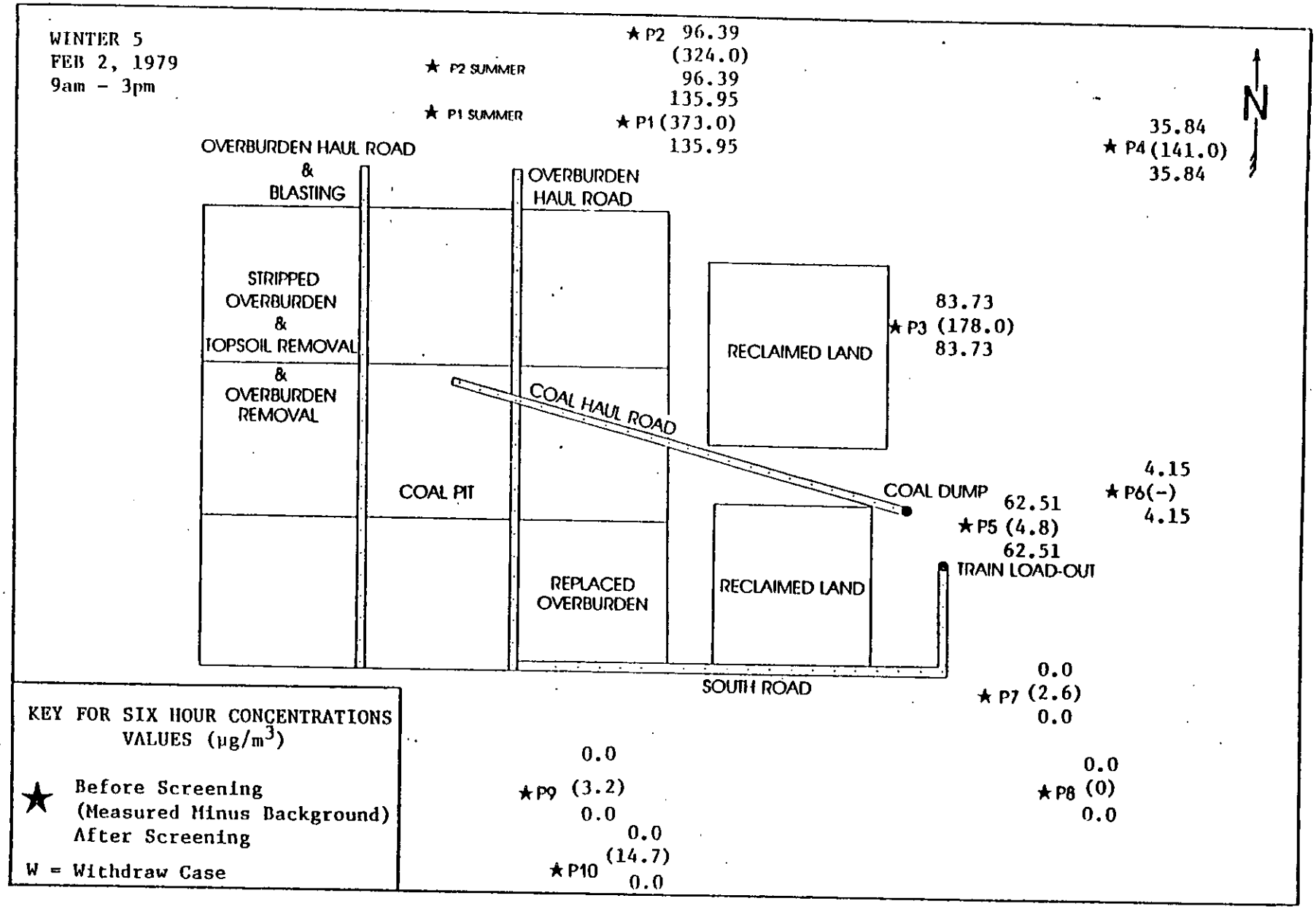
SHORT-TERM ISC MODEL VERIFICATION RESULTS



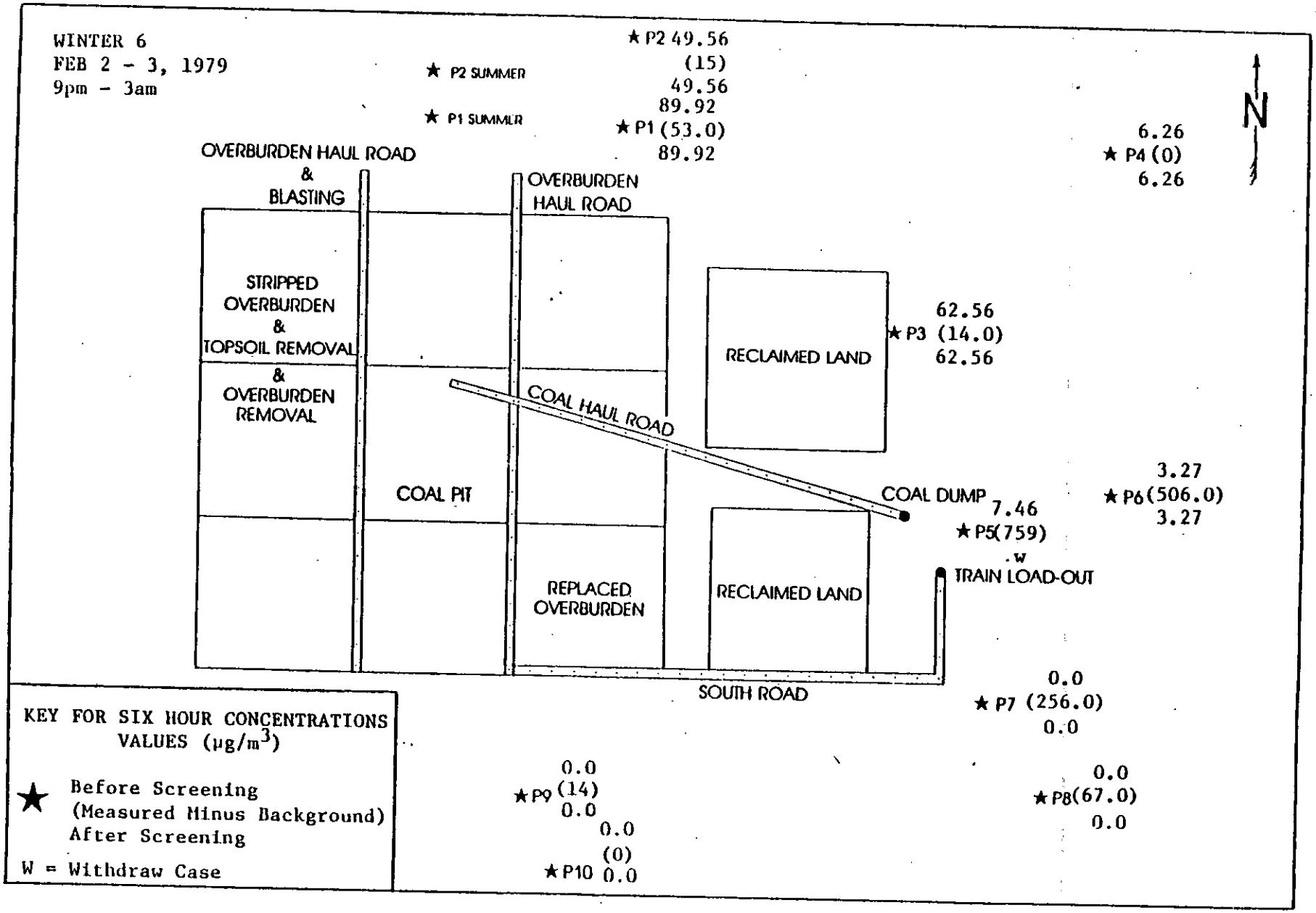
SHORT-TERM ISC MODEL VERIFICATION RESULTS



SHORT-TERM ISC MODEL VERIFICATION RESULTS



SHORT-TERM ISC MODEL VERIFICATION RESULTS



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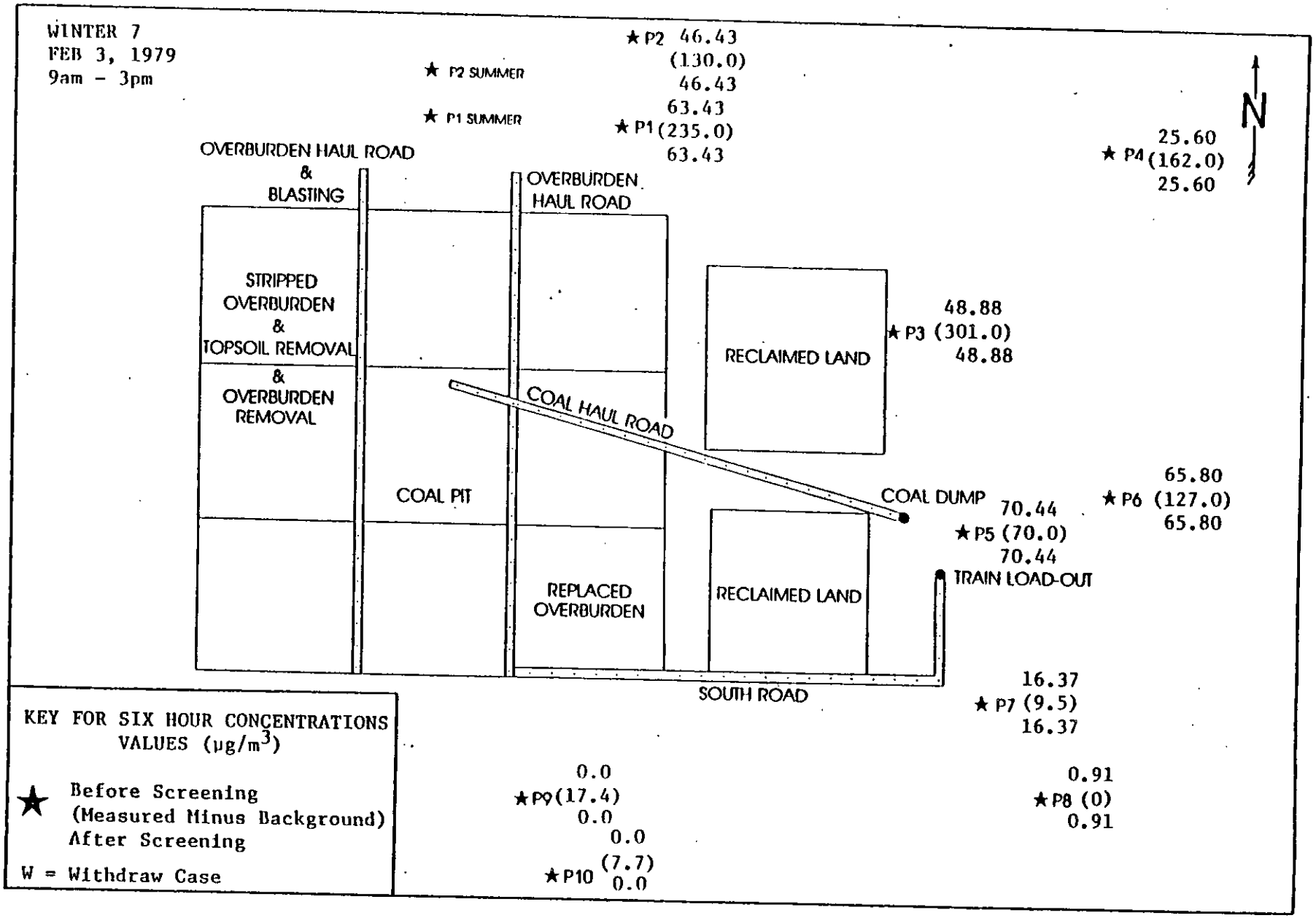
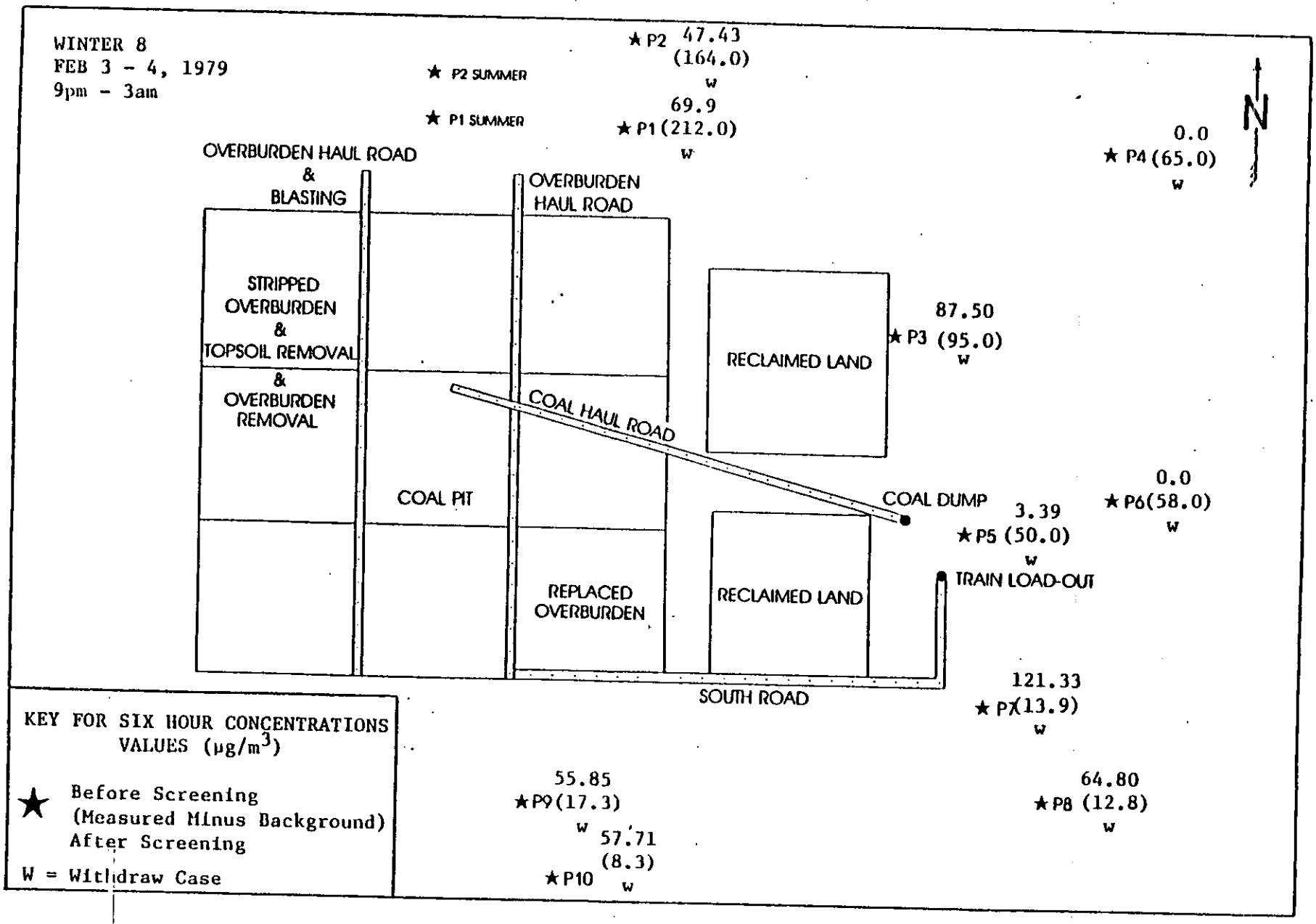


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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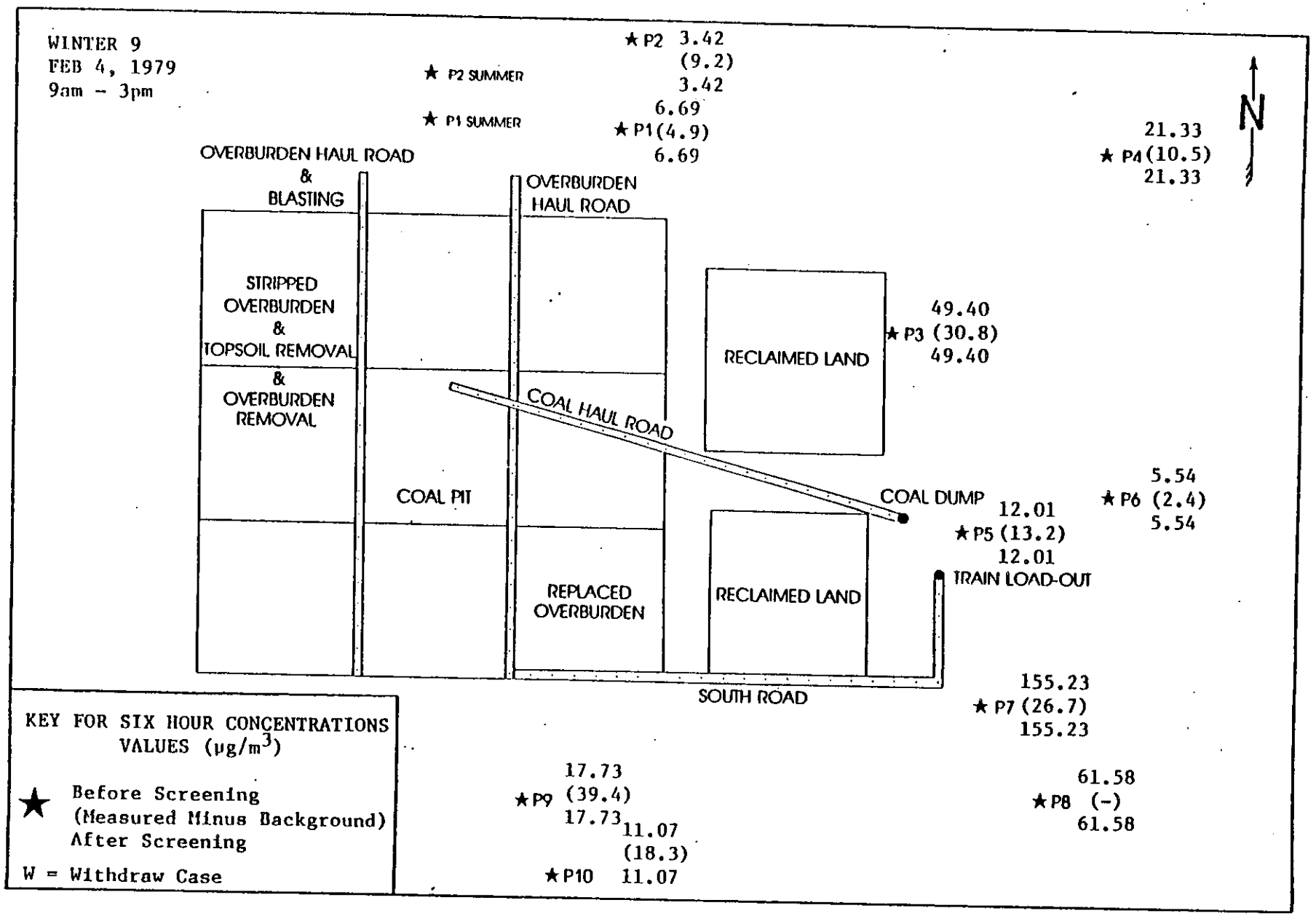
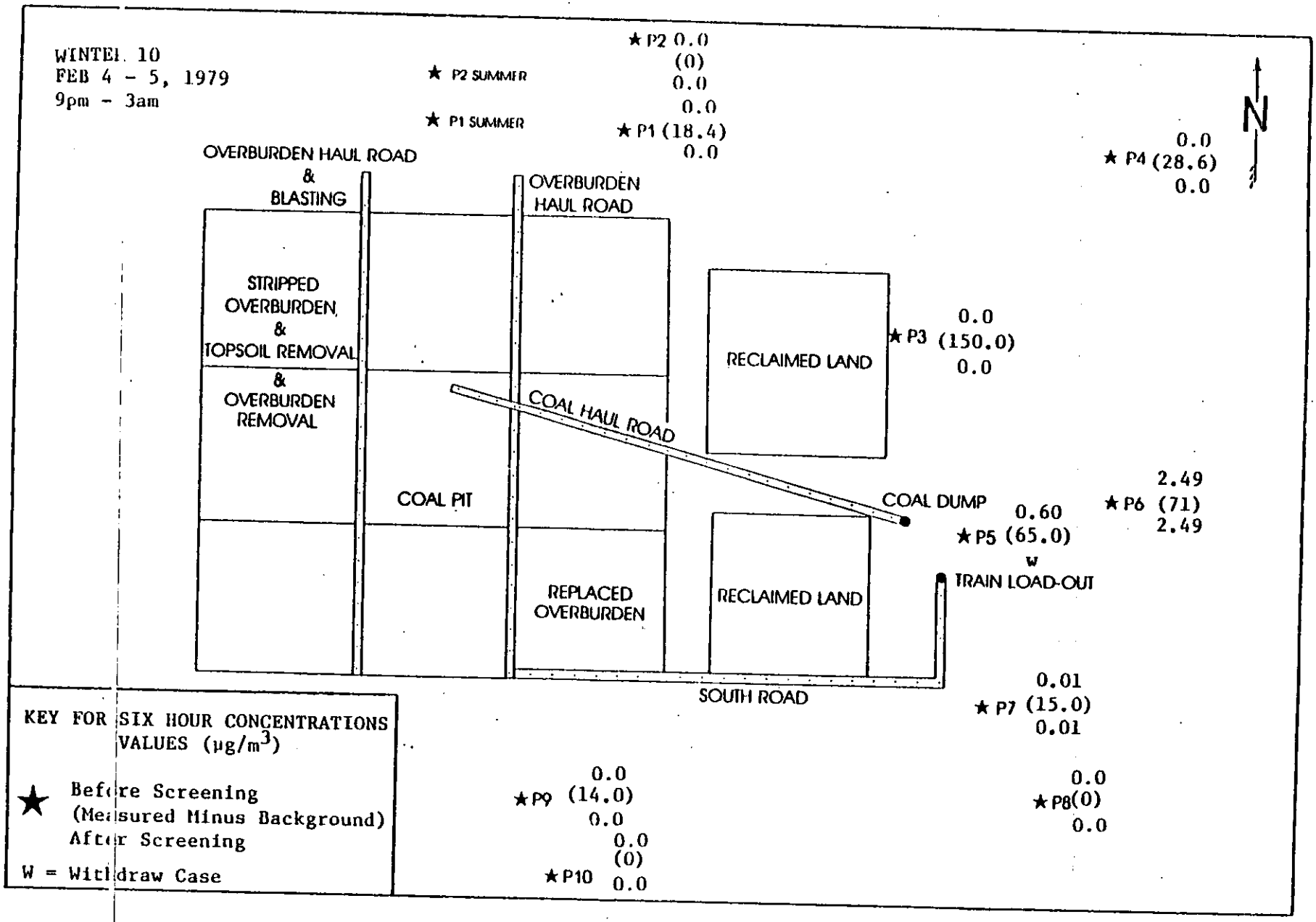


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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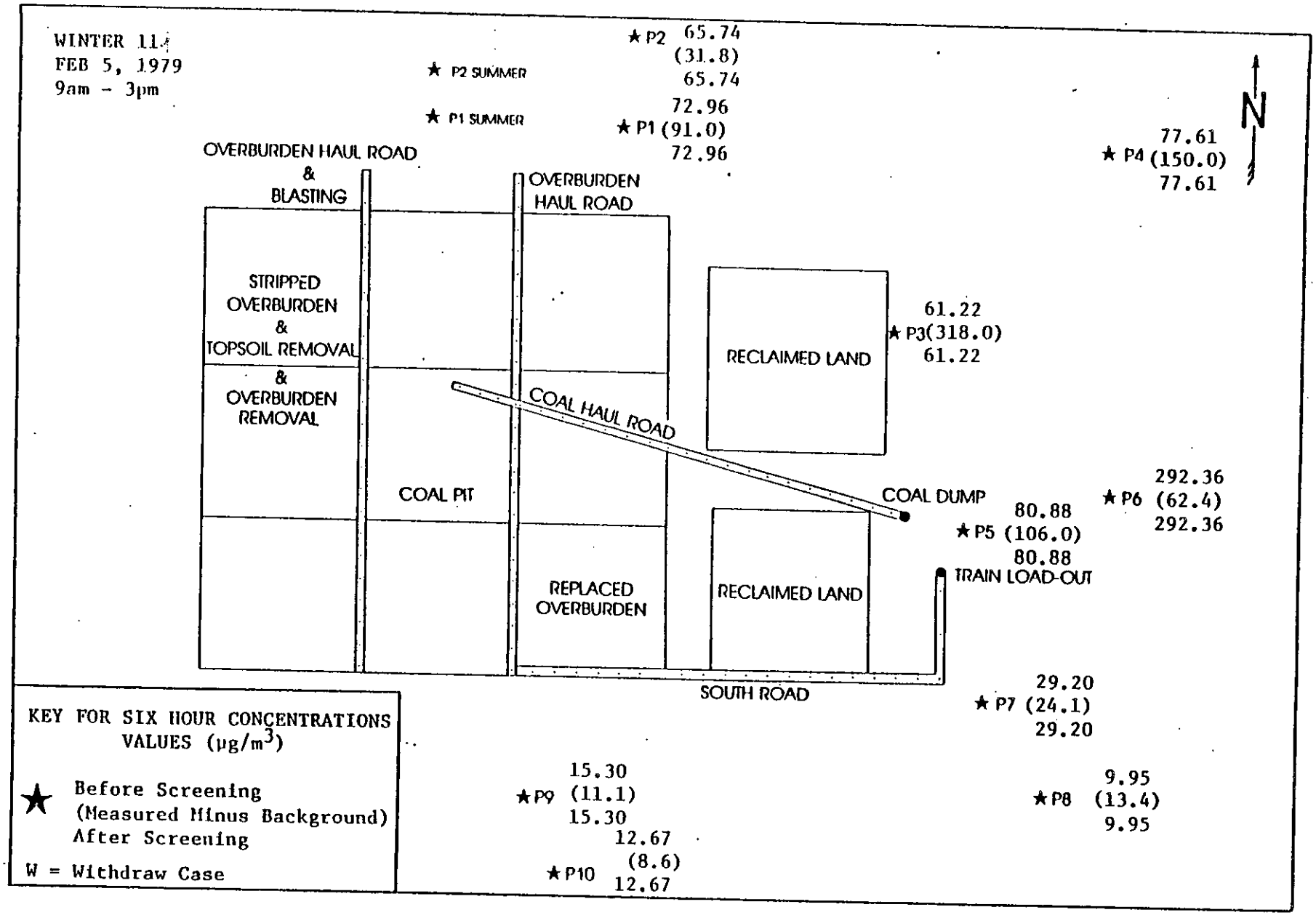
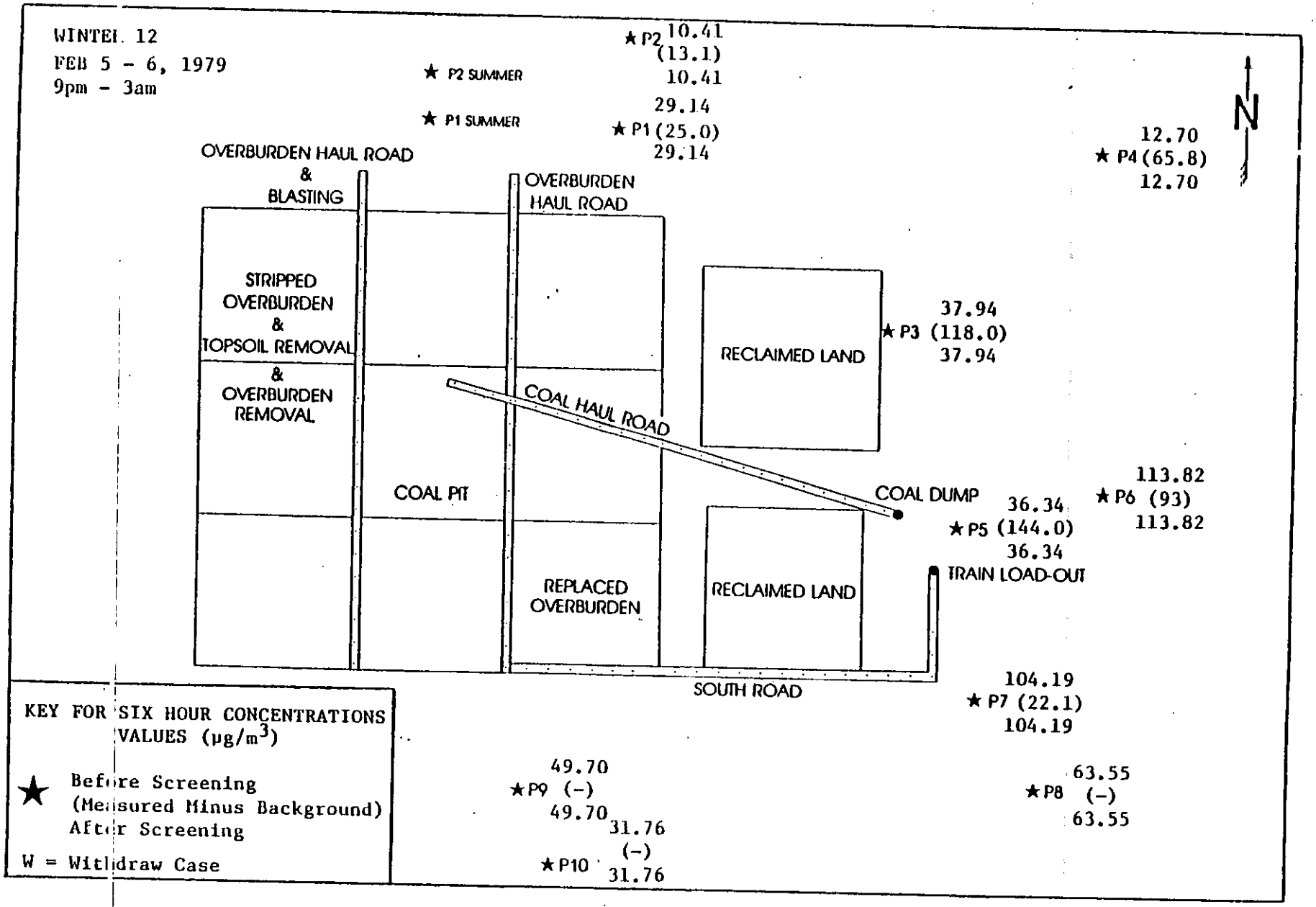


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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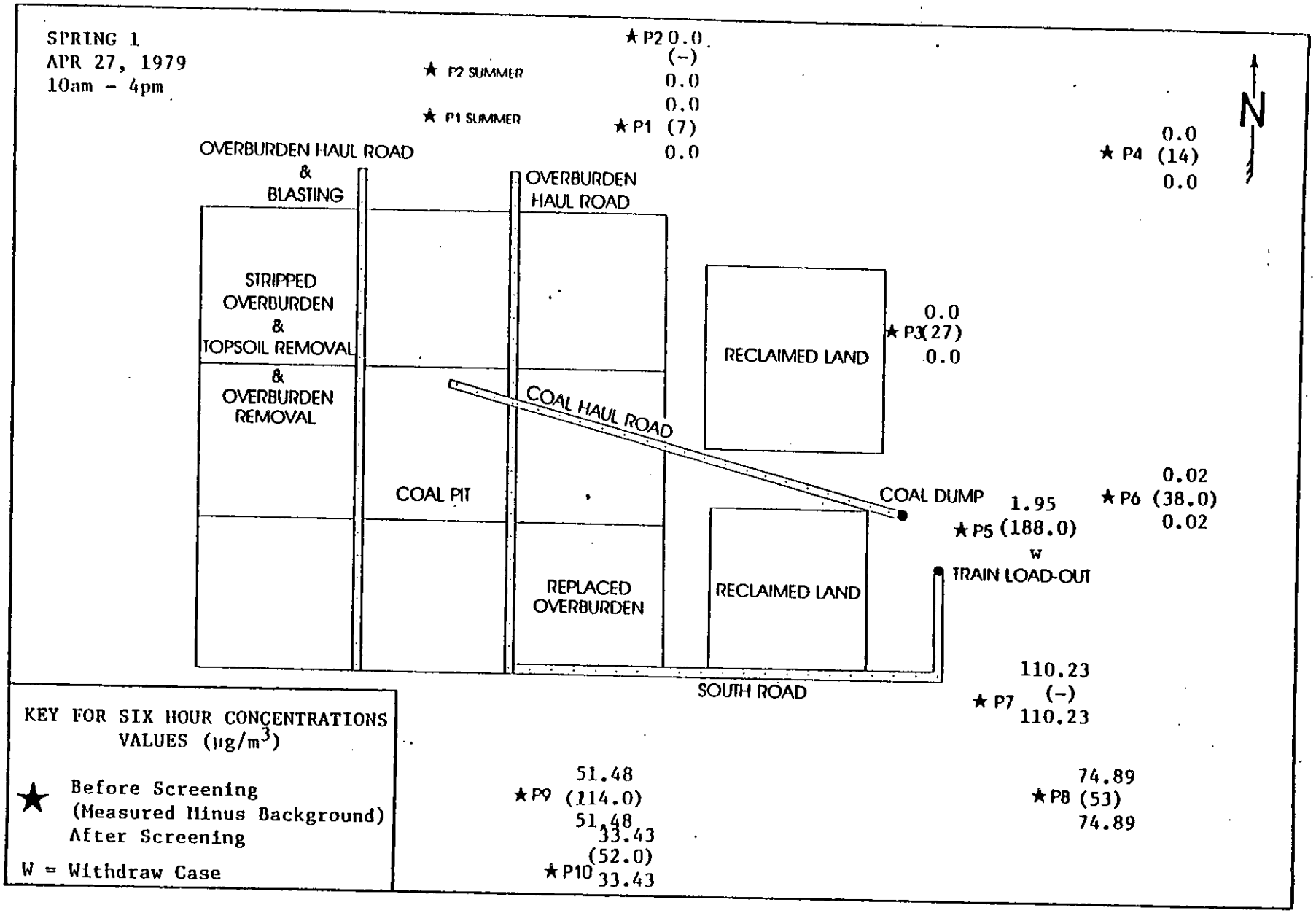

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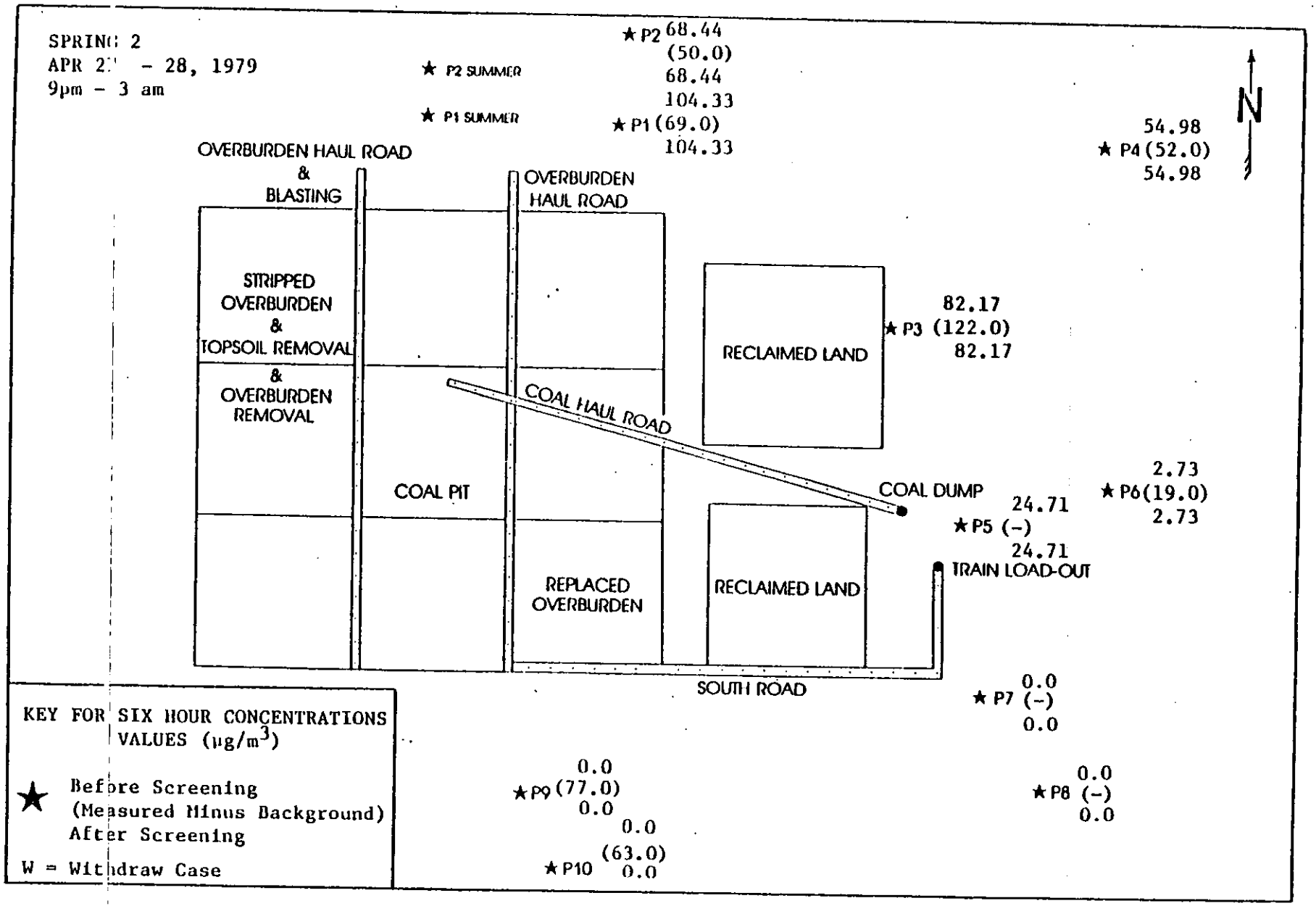

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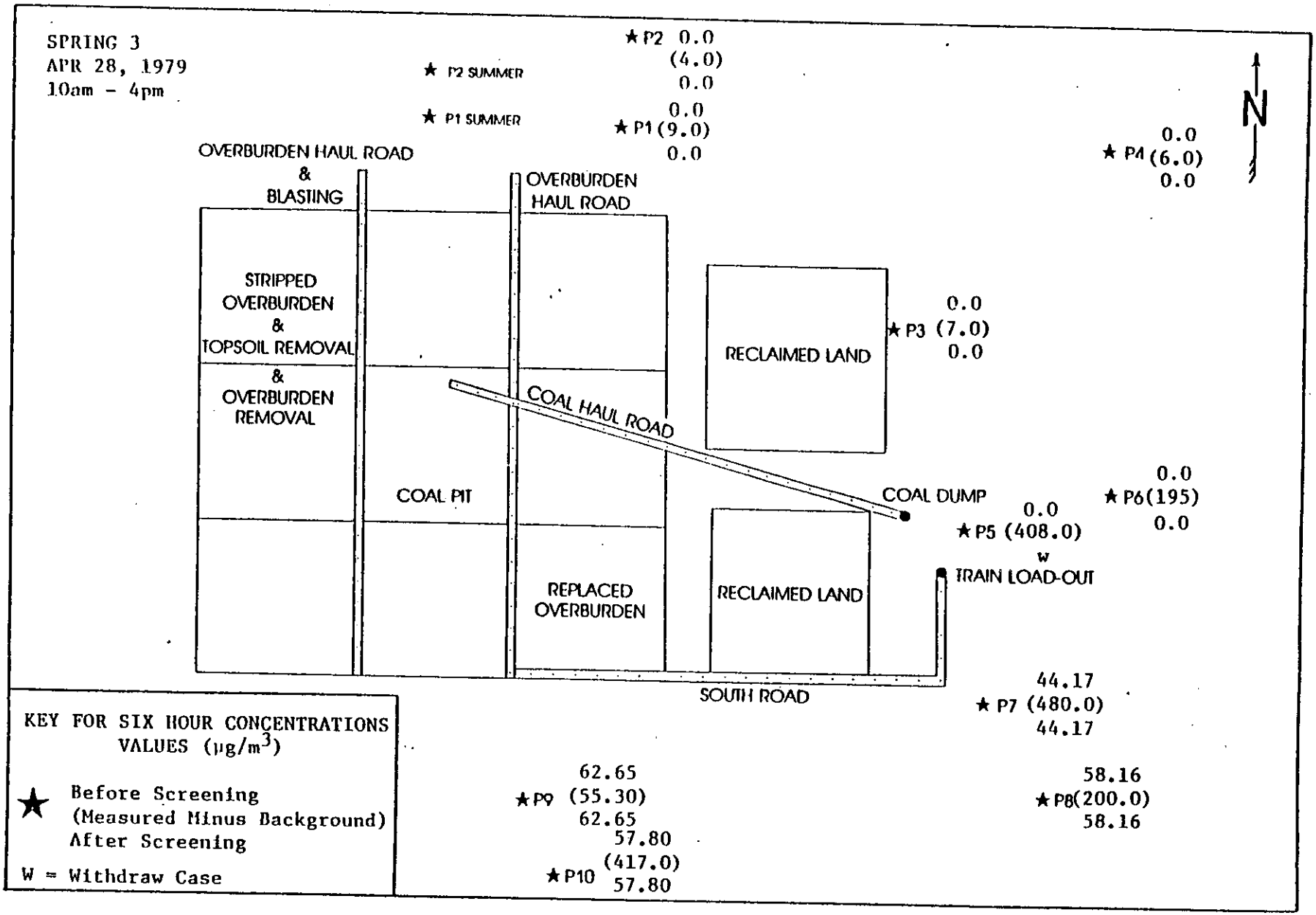

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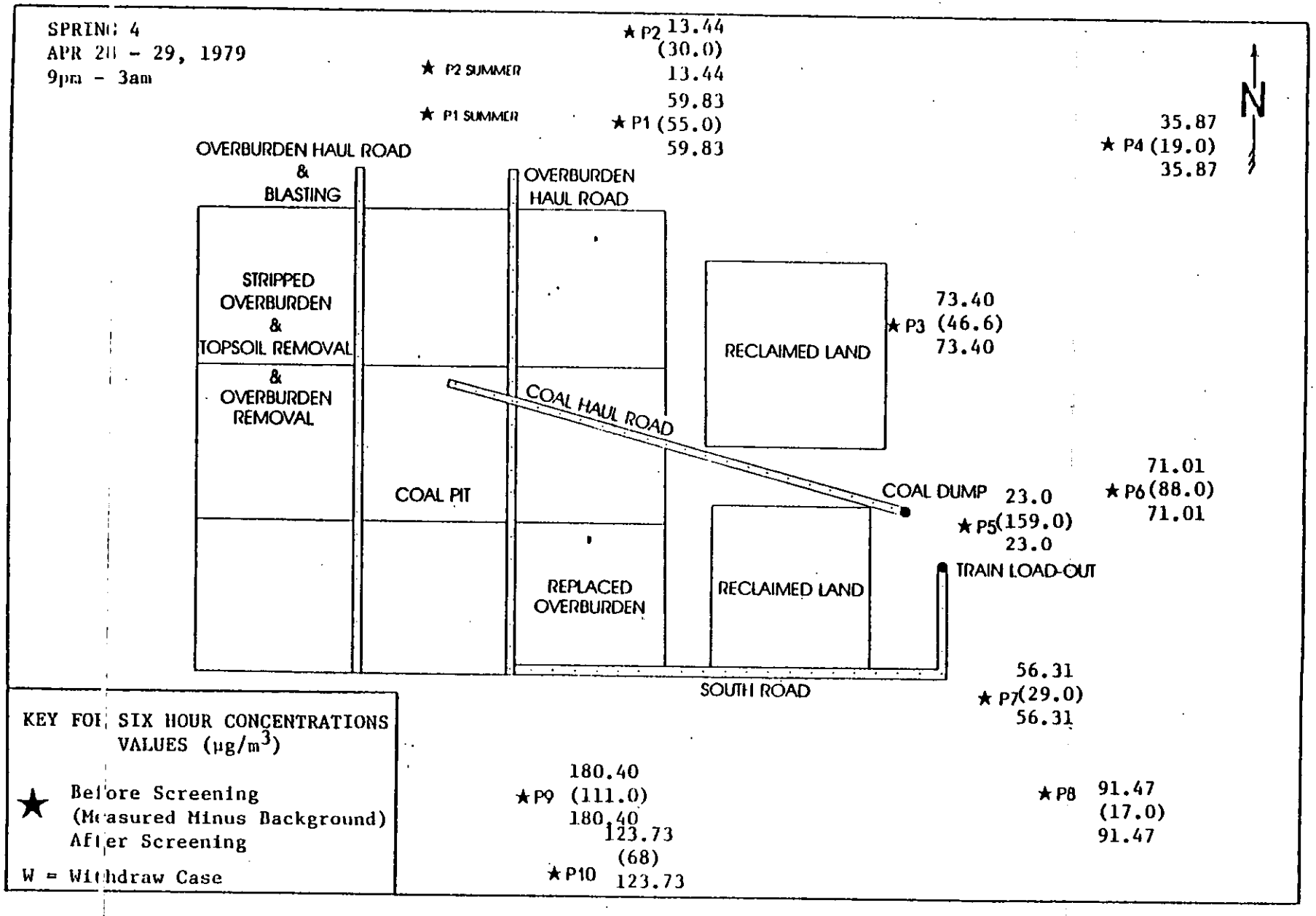
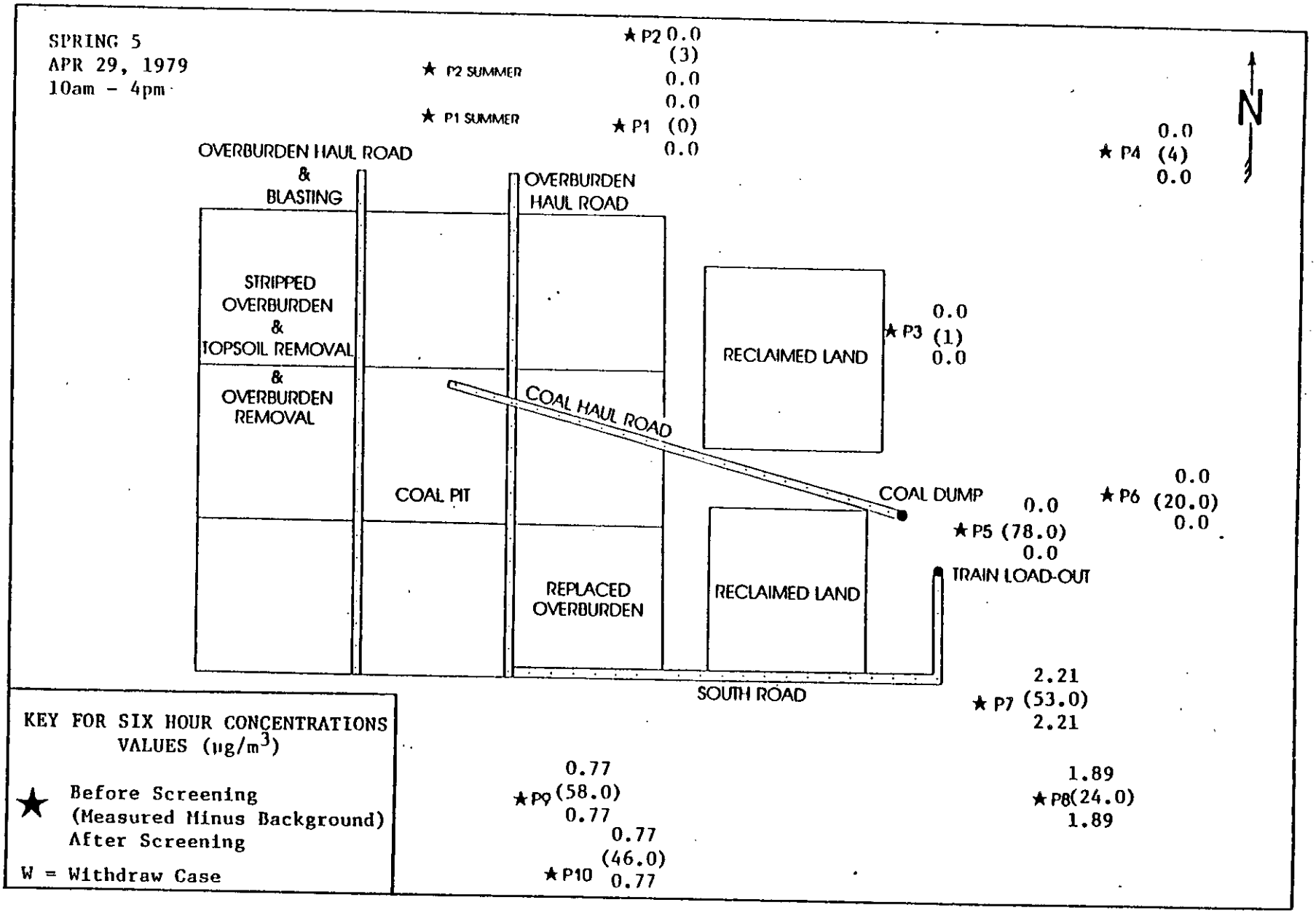


SHORT-TERM ISC MODEL VERIFICATION RESULTS



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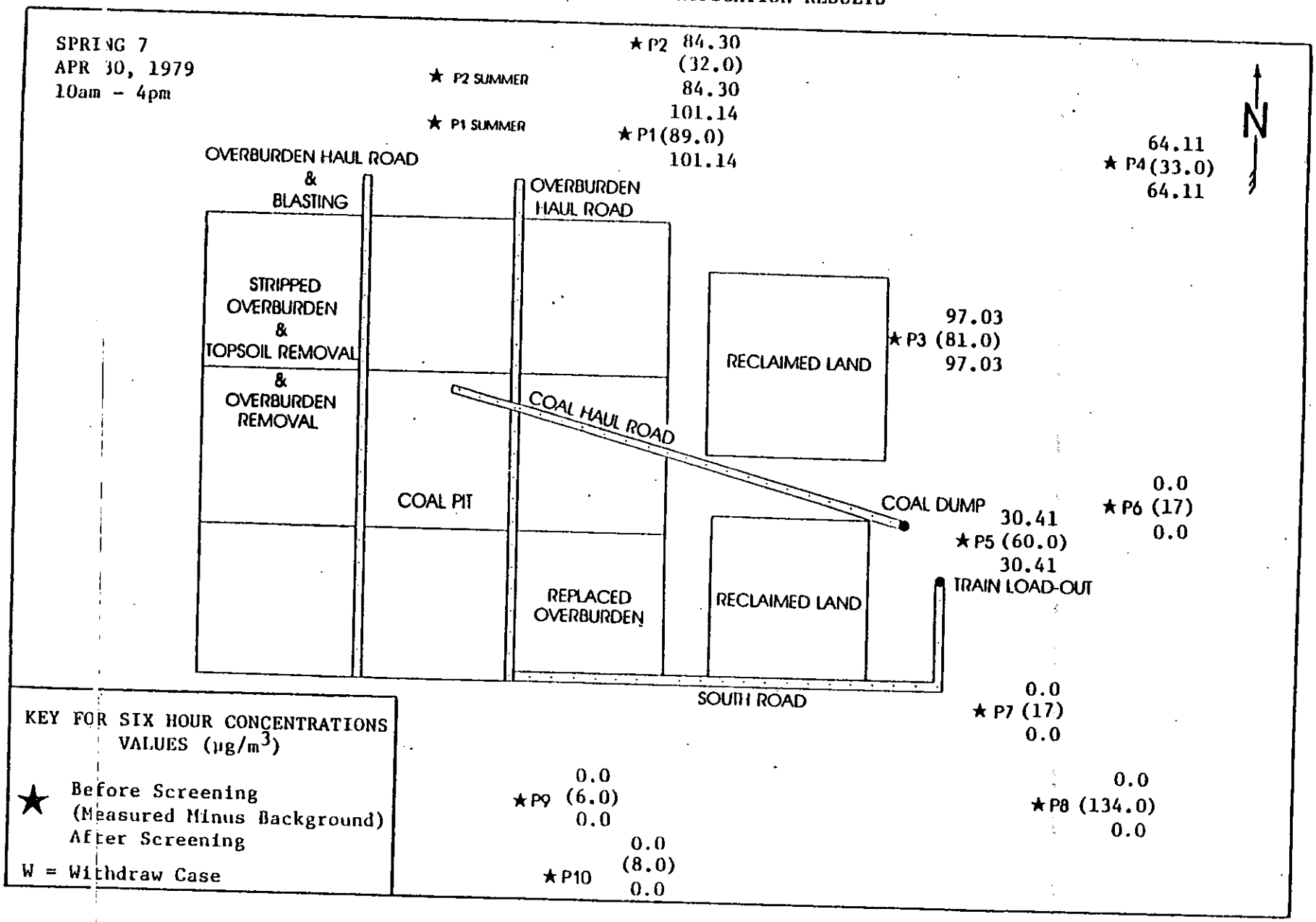

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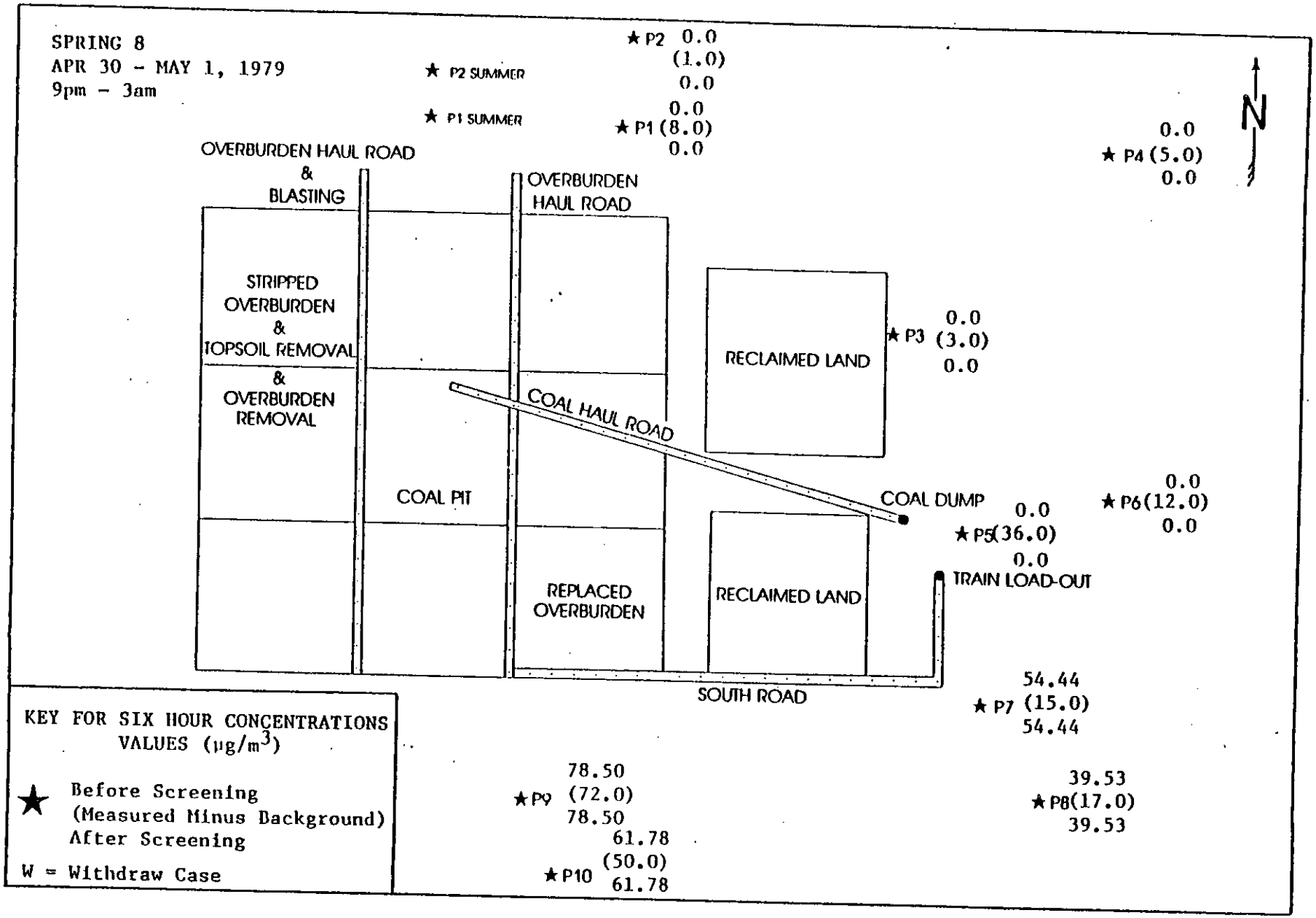

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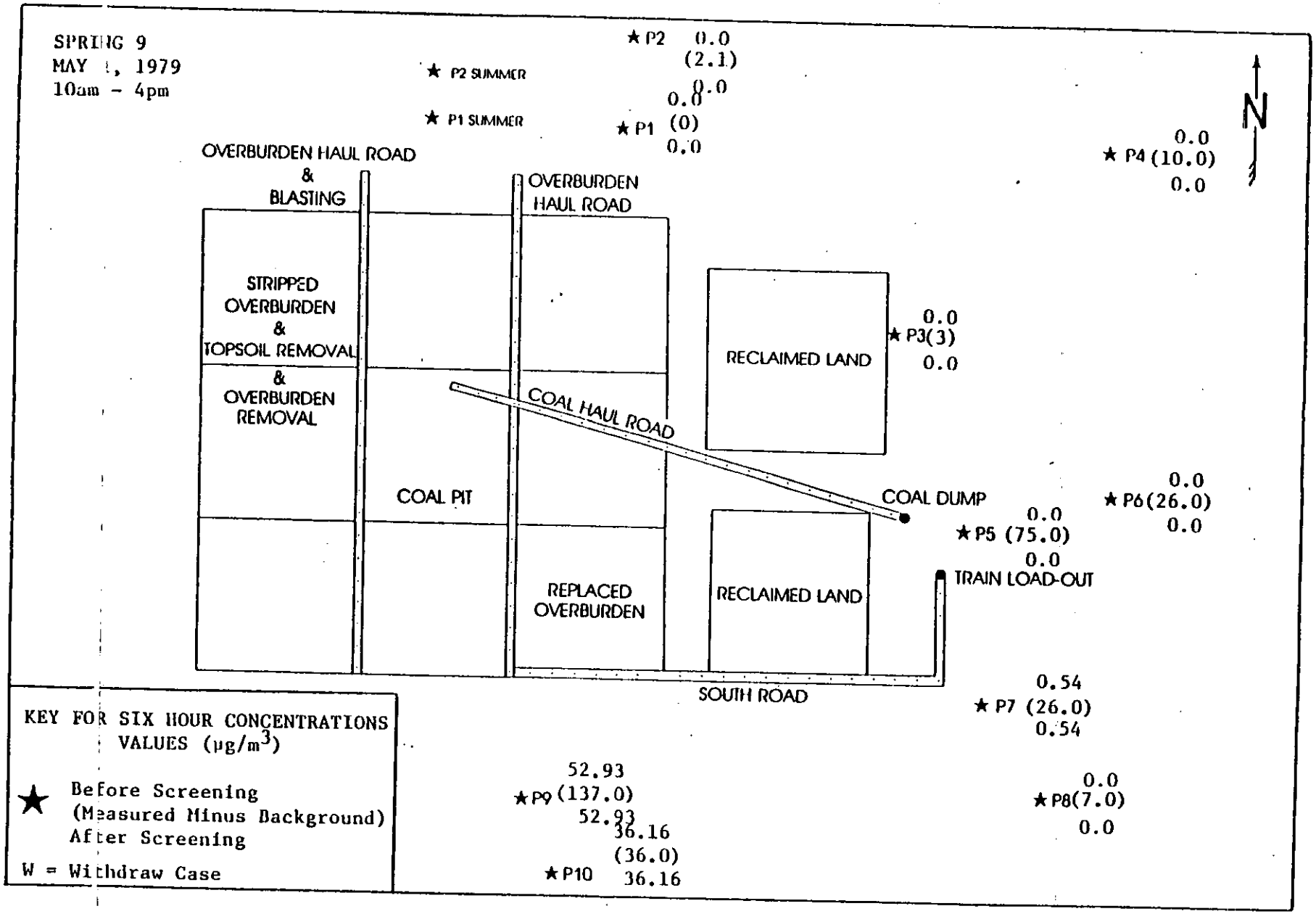

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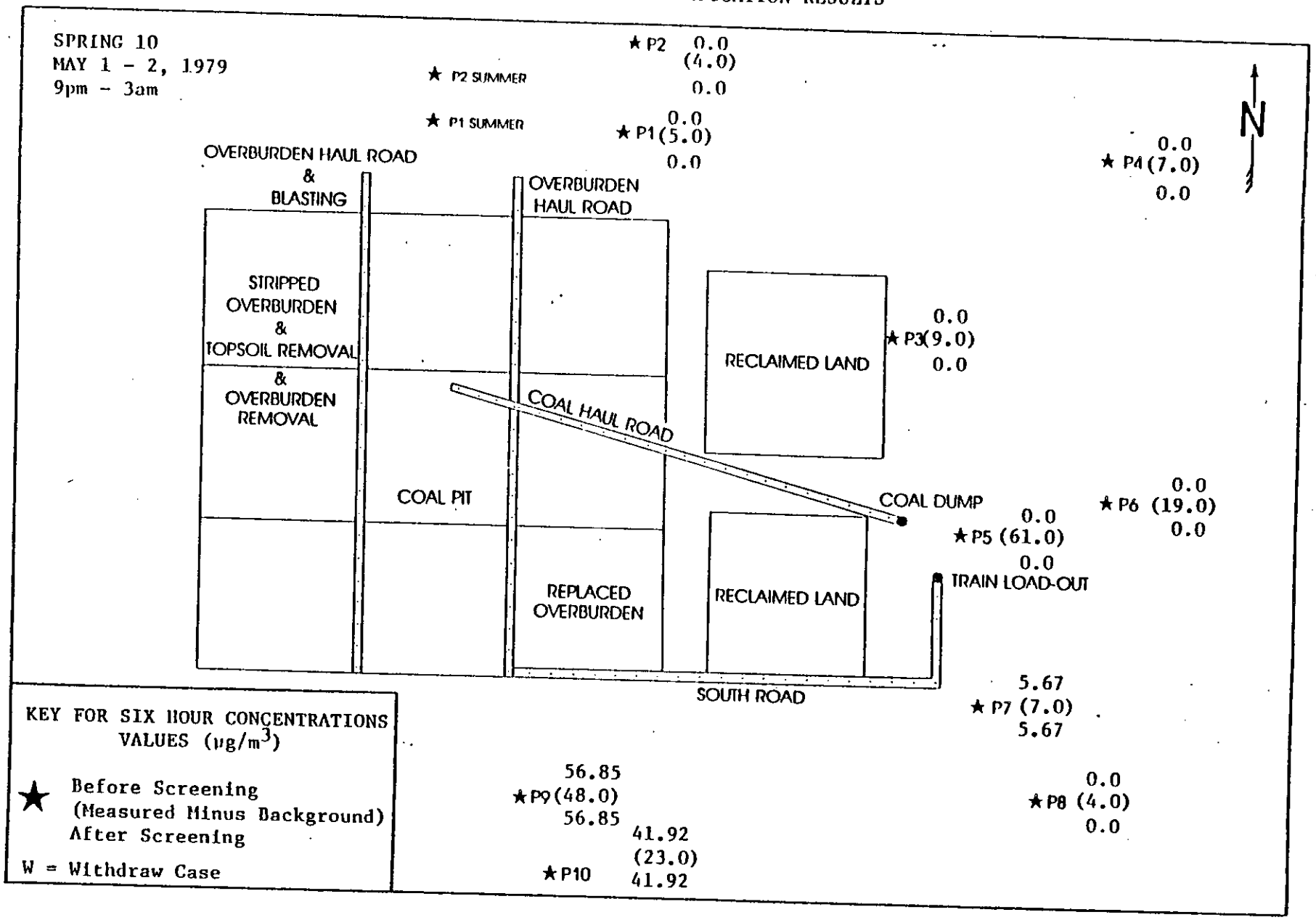

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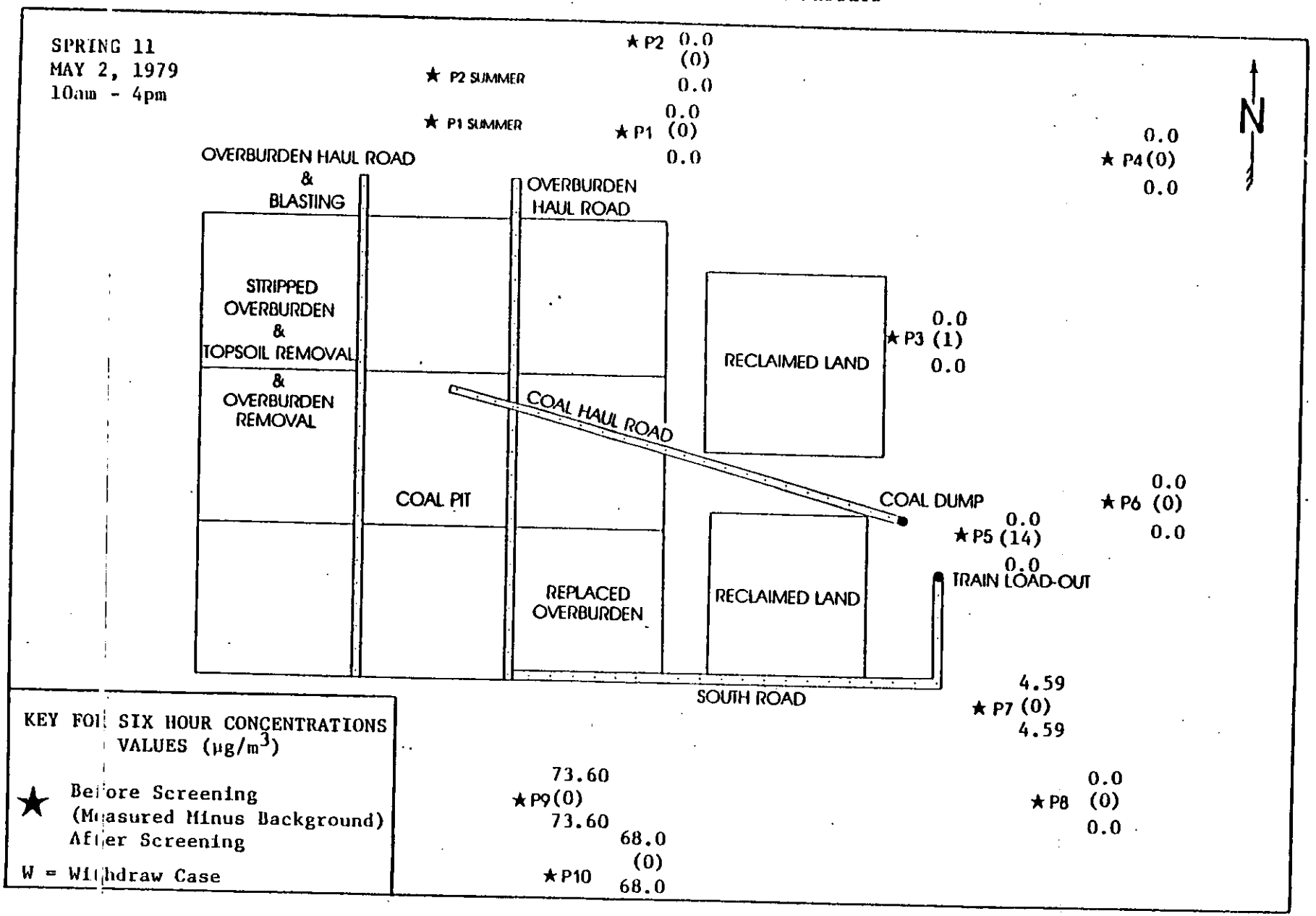

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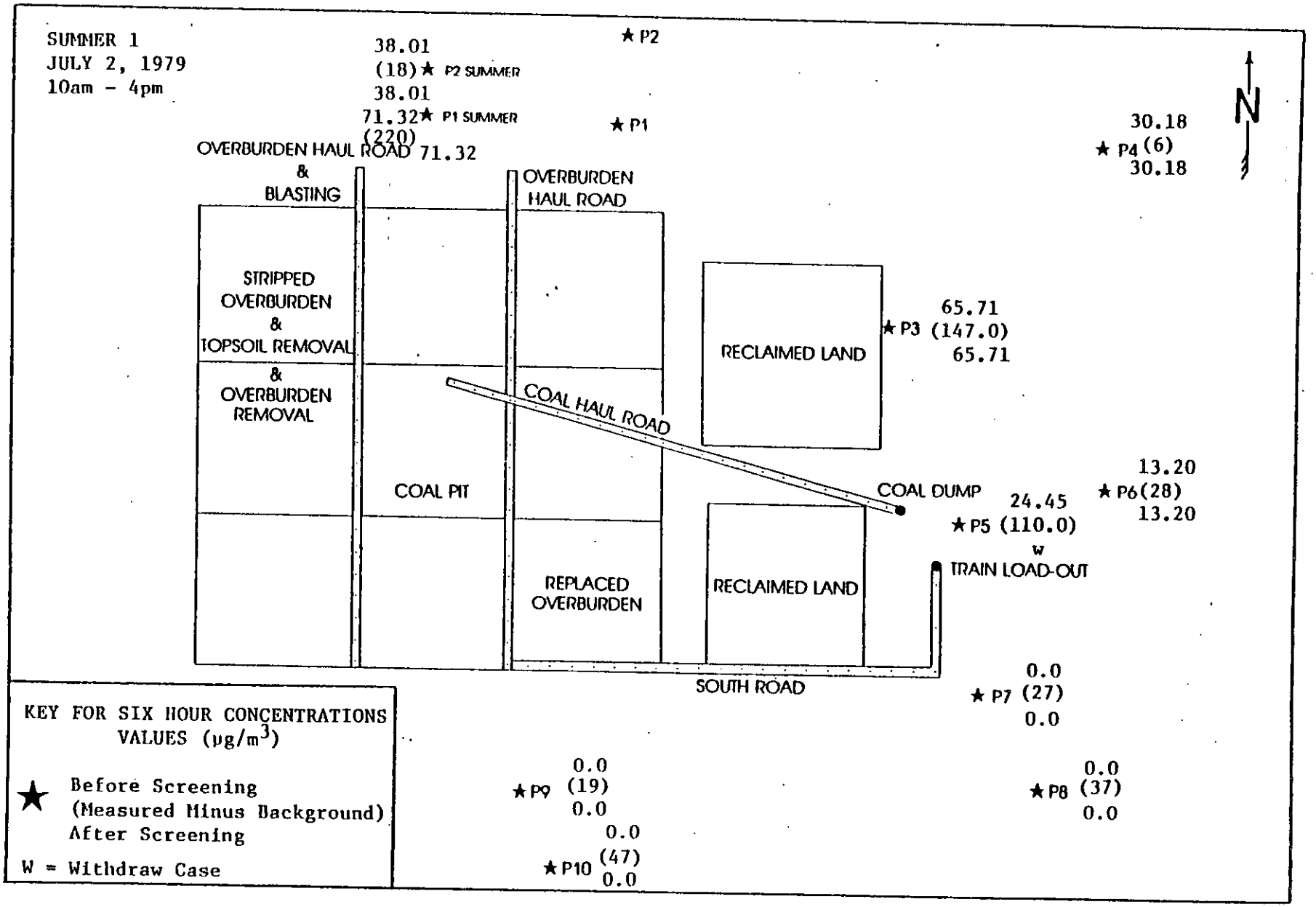

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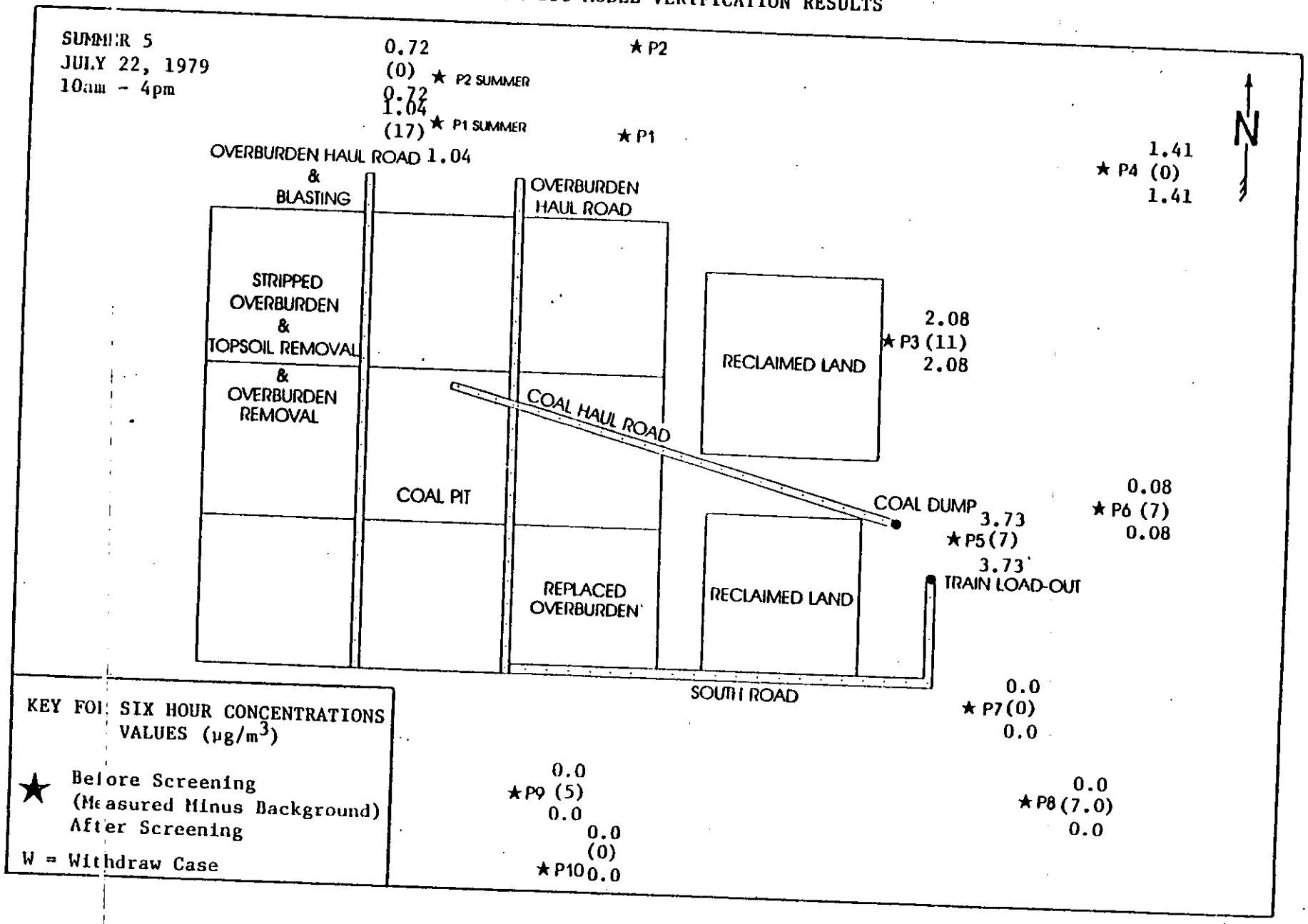

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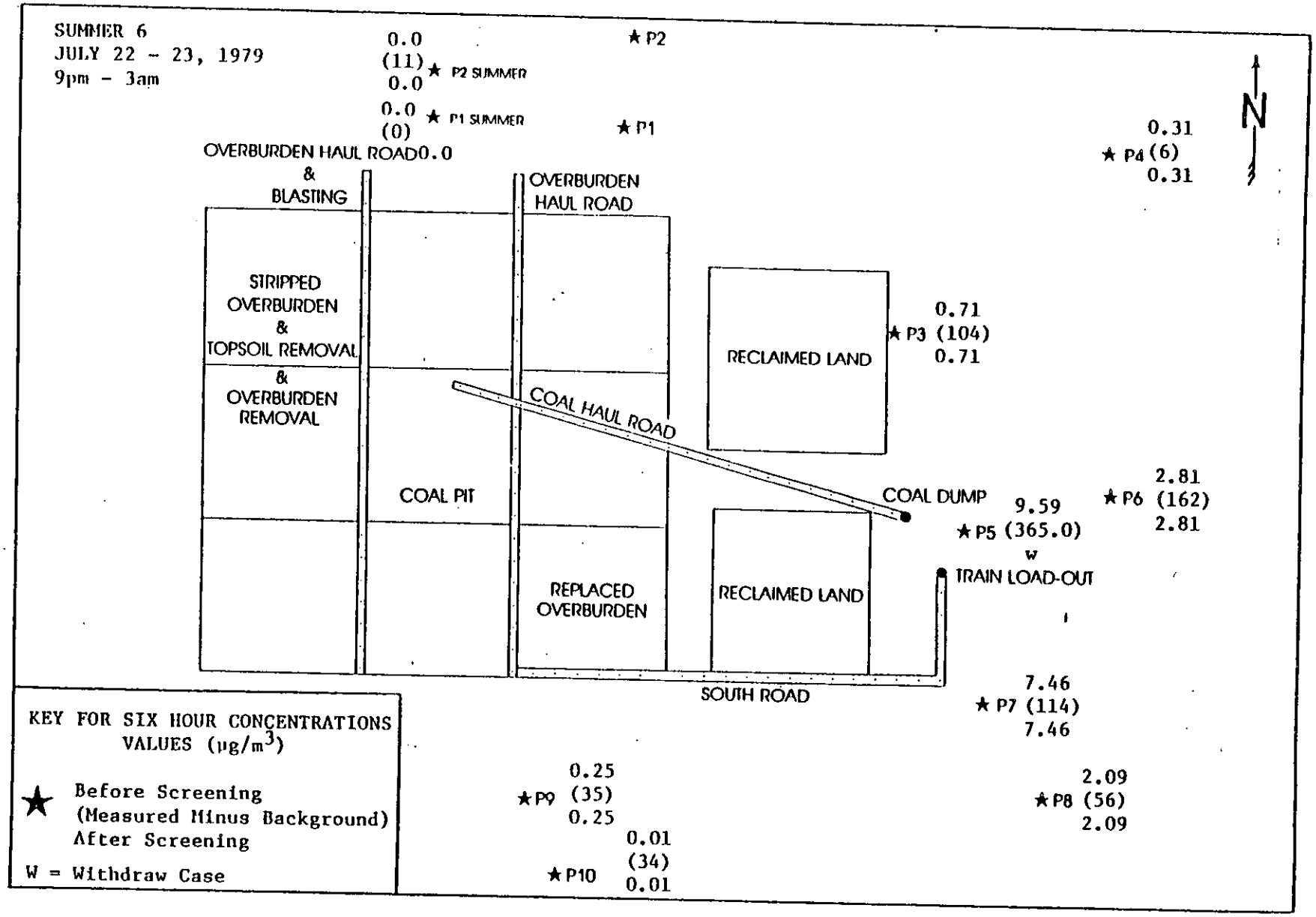

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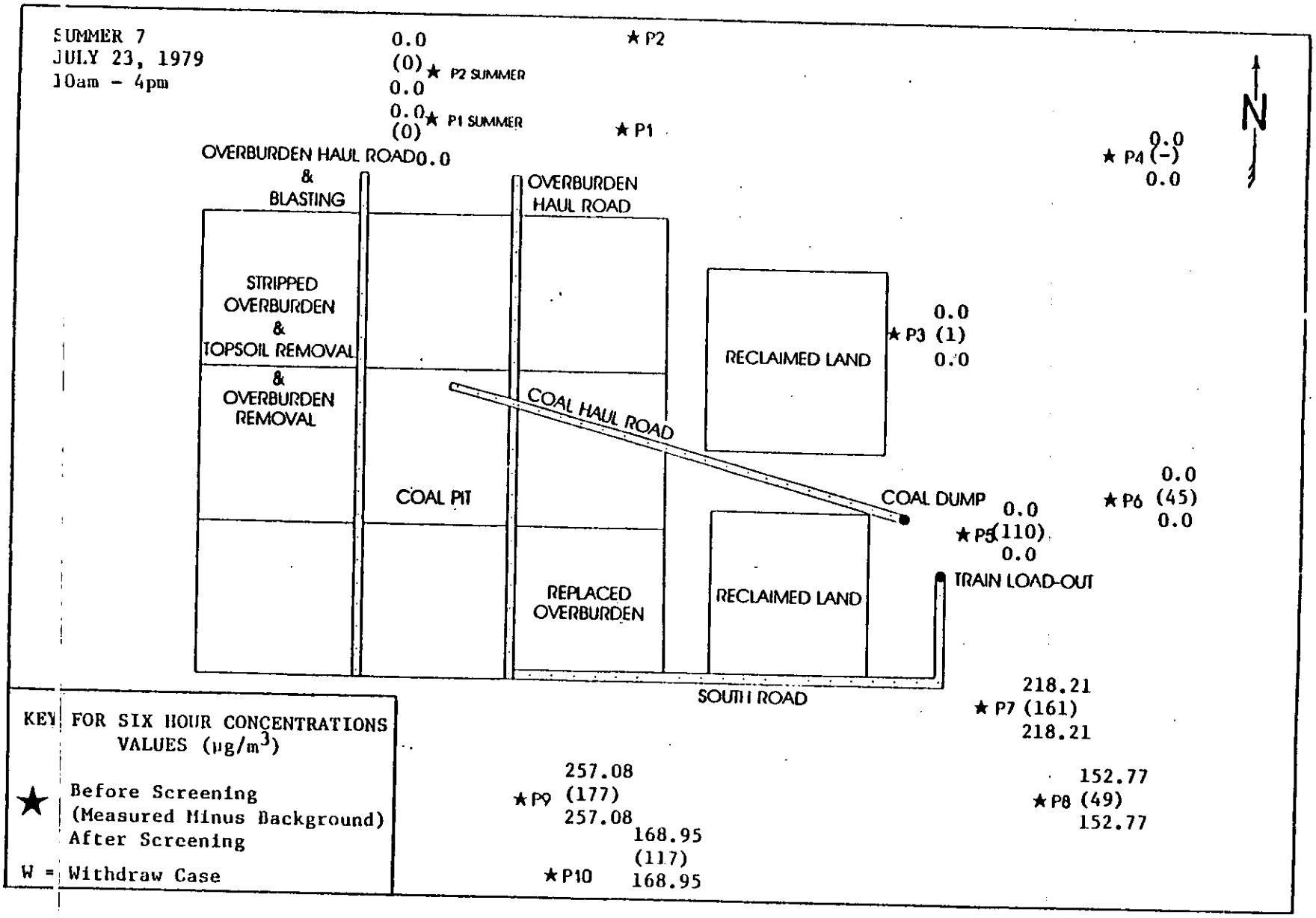

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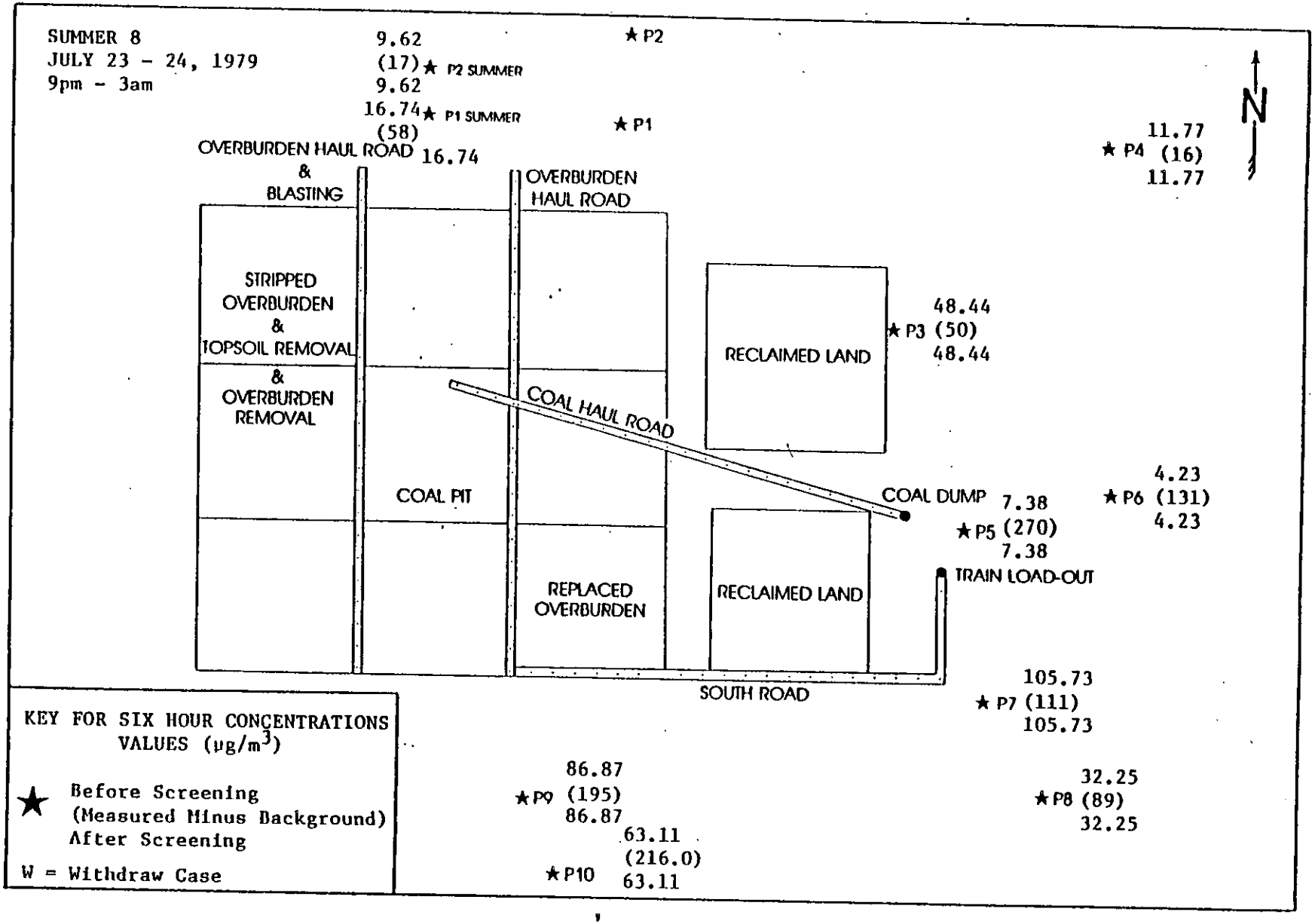

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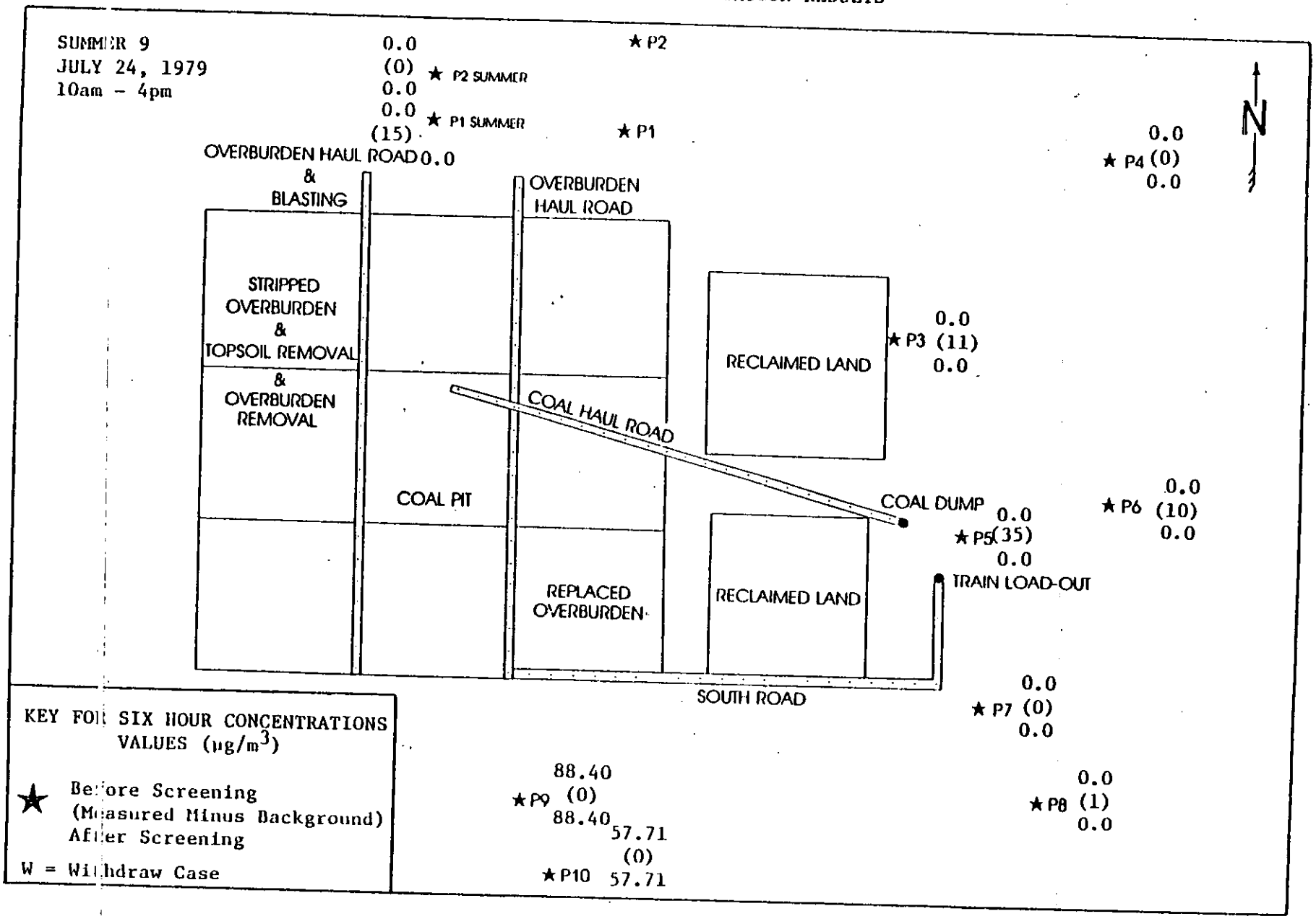

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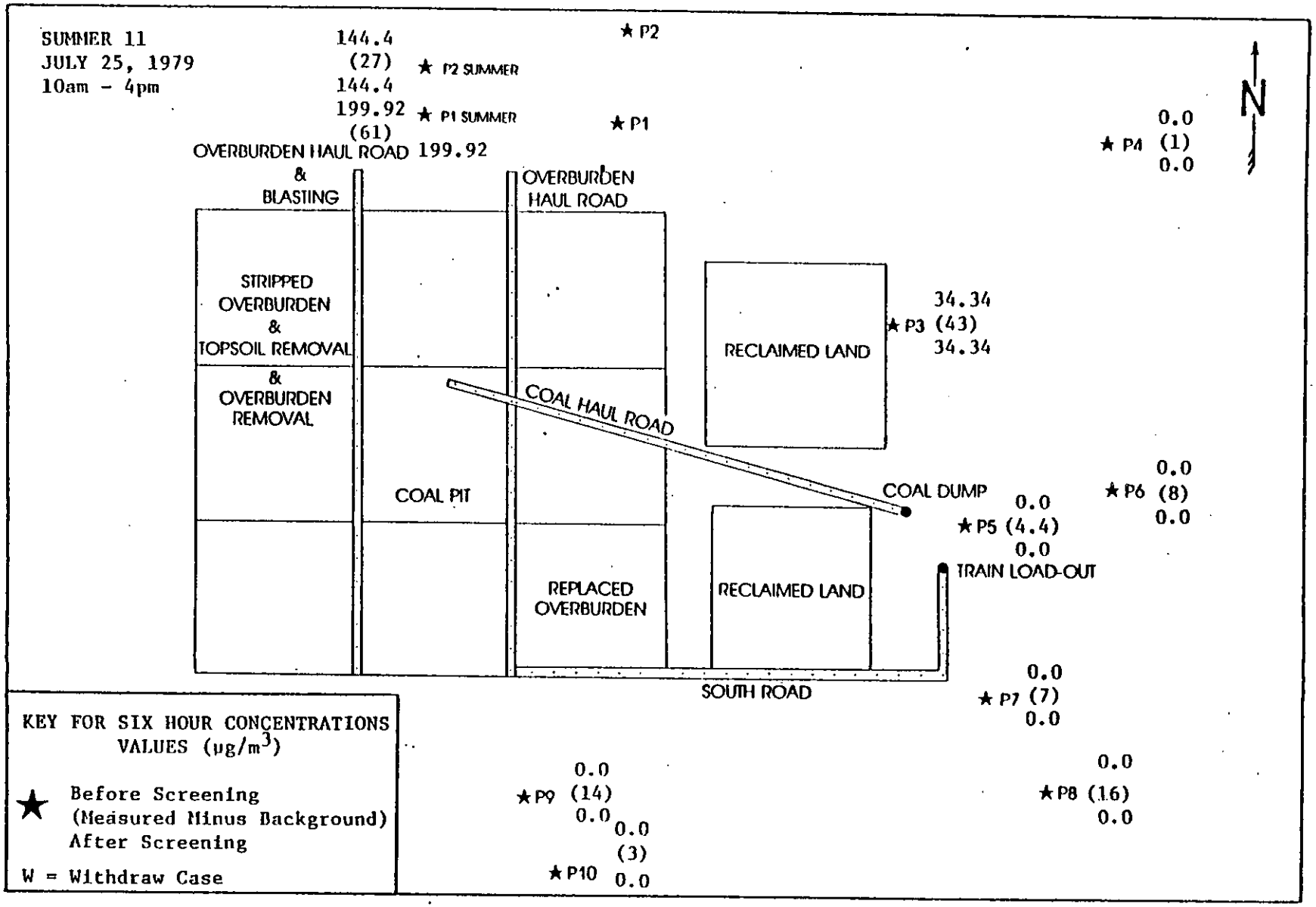

APPENDIX E

EMISSION RATE CALCULATIONS USED FOR INPUT INTO WDEQ'S CORRIDOR MODEL RUNS

TABLE E.1
CARTER MINING COMPANY
CABALLO MINE

		lb/hr	g/se
1. Scraper Operations - 50% Control			
$\frac{(0.50)(32\ \text{lb/scraper-hr})(.726)(5\ \text{scrapers}))(2840\ \text{hr/scraper})}{(8760\ \text{hr/yr})}$	=	18.8	2.37
2. Overburden Removal			
Truck/Shovel - 75% Suspended			
$\frac{(0.02\ \text{lb/ton})(0.75)(26.6 \times 10^6\ \text{yd}^3/\text{yr})(1.74\ \text{ton/yd}^3)(2)}{(8760\ \text{hr/yr})(3)}$	=	52.8	6.66
Dragline - 75% Suspended			
$\frac{(0.04\ \text{lb/yd}^3)(0.75)(26.6 \times 10^6\ \text{yd}^3/\text{yr})(1.74\ \text{ton/yd}^3)(1)}{(8760\ \text{hr/yr})(3)}$	=	52.8	6.66
3. Coal Removal - 70% Suspended			
Frontend Loader or Truck/Shovel			
$\frac{(0.003\ \text{lb/ton})(0.70)(12 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})}$	=	2.9	0.36
4. Truck Dump - 85% Control 75% Suspended			
$\frac{(0.017\ \text{lb/ton})(0.75)(0.15)(12 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})}$	=	2.6	0.33

TABLE E.1 (Cont'd)

		lb/hr	g/sec
5. Wind Erosion			
$\frac{(0.25\ \text{ton/acre/yr})(2000\ \text{lb/ton})(200\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	11.4	1.44
6. Coal Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.50)(3.48\ \text{lb/VMT})(7.1\ \text{mi})(6 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(180\ \text{ton/vehicle})}$	=	47.0	5.93
7. Overburden Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.50(1.96\ \text{lb/VMT})(1.0\ \text{mi})(26.6 \times 10^6\ \text{yd}^3\text{/yr})(1.74\ \text{ton/yd}^3)(2)}{(8760\ \text{hr/yr})(170\ \text{ton/vehicle})(3)}$	=	20.3	2.56
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(8.53 \times 10^3\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	11.3	1.43

TABLE E.1 (Cont'd)

		lb/hr	g/sec
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ \text{lb/blast})(0.75)(600\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	2.6	0.32
Coal			
$\frac{(35\ \text{lb/blast})(0.75)(300\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	0.9	0.11
10. Primary and Secondary Crushing			
$\frac{(12 \times 10^6\ \text{ton/yr})(47\ \text{lb/hr})}{(8760\ \text{hr/yr})(3400\ \text{ton/yr})}$	=	18.9	2.39
11. Sampling Station			
$\frac{(12 \times 10^6\ \text{ton/yr})(6\ \text{lb/hr})}{(8760\ \text{hr/yr})(3400\ \text{ton/hr})}$	=	2.4	0.30
12. Silos			
$\frac{(12 \times 10^6\ \text{ton/yr})(6\ \text{lb/hr})}{(8760\ \text{hr/yr})(3400\ \text{ton/hr})}$	=	2.4	0.30

TABLE E.2 (Cont'd)

		lb/hr	g/sec
5. Wind Erosion			
$\frac{(0.25\ \text{ton/acre/yr})(2000\ \text{lb/ton})(130\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	7.4	0.94
6. Coal Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.50)(3.48\ \text{lb/VMT})(6.1\ \text{mi})(25 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(120\ \text{ton/vehicle})}$	=	252.4	31.83
7. Overburden Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.50)(1.96\ \text{lb/VMT})(0.8\ \text{mi})(25 \times 10^6\ \text{ton/yr})(1.74\ \text{ton/yd}^3)(1.5\ \text{yd}^3/\text{ton Stripping Ratio})}{(8760\ \text{hr/yr})(120\ \text{ton/vehicle})}$	=	48.7	6.14
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(8.53 \times 10^3\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	11.3	1.43

TABLE E.2 (Cont'd)

		lb/hr	g/se
5. Wind Erosion			
$\frac{(0.25\ \text{ton/acre/yr})(2000\ \text{lb/ton})(130\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	7.4	0.9
6. Coal Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.50)(3.48\ \text{lb/VMT})(6.1\ \text{mi})(25 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(120\ \text{ton/vehicle})}$	=	252.4	31.8
7. Overburden Haul Roads - 50% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.50)(1.96\ \text{lb/VMT})(0.8\ \text{mi})(25 \times 10^6\ \text{ton/yr})(1.74\ \text{ton/yd}^3)(1.5\ \text{yd}^3/\text{ton Stripping Ratio})}{(8760\ \text{hr/yr})(120\ \text{ton/vehicle})}$	=	48.7	6.14
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(8.53 \times 10^3\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	11.3	1.43

TABLE E.2 (Cont'd)

		lb/hr	g/se
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ \text{lb/blast})(0.75)(6\ \text{blasts/wk})(52\ \text{wk/yr})}{(8760\ \text{hr/yr})}$	=	1.3	0.17
Coal			
$\frac{(35\ \text{lb/blast})(0.75)(4\ \text{blasts/wk})(52\ \text{wk/yr})}{(8760\ \text{hr/yr})}$	=	0.6	0.08
10. Total Prep Plant	=	15.0	1.89

TABLE E.3
CONSOLIDATION COAL COMPANY
PRONGHORN MINE

		lb/hr	g/sec
1. Scraper Operations - 50% Control			
$\frac{(0.50)(32\ lb/scraper\text{-}hr)(.726)(2832\ hr/yr)}{(8760\ hr/yr)}$	=	3.8	0.47
2. Overburden Removal			
Truck/Shovel - 75% Suspended			
$\frac{(0.02\ lb/ton)(0.75)(11.597 \times 10^6\ yd^3/yr)(1.74\ ton/yd^3)}{(8760\ hr/yr)}$	=	34.6	4.36
Dragline - 75% Suspended			
$\frac{(0.04\ lb/yd^3)(0.75)}{(8760\ hr/yr)}$	=	-	-
3. Coal Removal - 70% Suspended			
Frontend Loader or Truck/Shovel			
$\frac{(0.003\ lb/ton)(0.70)(5 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	1.2	0.15
4. Truck Dump - 50% Control 75% Suspended			
$\frac{(0.017\ lb/ton)(0.75)(0.50)(5 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	3.6	0.46

TABLE E.3 (Cont'd)

		lb/hr	g/sec
5. Wind Erosion			
$\frac{(0.25\ \text{ton/acre/yr})(2000\ \text{lb/ton})(310\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	17.7	2.23
6. Coal Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.40)(3.48\ \text{lb/VMT})(4.98\ \text{mi})(5 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(170\ \text{ton/vehicle})}$	=	23.3	2.94
7. Overburden Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.40)(1.96\ \text{lb/VMT})[(3.36\ \text{mi})(0.95 \times 10^6\ \text{yd}^3/\text{yr}) + (1.5\ \text{mi})(10.7 \times 10^6\ \text{yd}^3/\text{yr})]}{(8760\ \text{hr/yr})(92\ \text{yd}^3/\text{vehicle})}$	=	18.7	2.36
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(13{,}260\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	17.6	2.22

TABLE E.3 (Cont'd)

		lb/hr	g/sec
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ \text{lb/blast})(0.75)(2\ \text{blasts/wk})(52\ \text{wk/yr})}{(8760\ \text{hr/yr})}$	=	0.4	0.06
Coal			
$\frac{(35\ \text{lb/blast})(0.75)(2\ \text{blasts/wk})(52\ \text{wk/yr})}{(8760\ \text{hr/yr})}$	=	0.3	0.04
10. Crushing - 95% Control			
$\frac{(0.08\ \text{lb/ton})(5 \times 10^6\ \text{ton/yr})(0.05)}{(8760\ \text{hr/yr})}$	=	2.3	0.29
11. Train Loading - 90% Control			
$\frac{(0.02\ \text{lb/ton})(5 \times 10^6\ \text{ton/yr})(0.1)}{(8760\ \text{hr/yr})}$	=	1.1	0.14

TABLE E.4
MOBIL OIL CORPORATION
CABALLO ROJO MINE

		lb/hr	g/sec
1. Scraper Operations - 50% Control			
$\frac{(0.50)(32\ lb/scraper\text{-}hr)(.726)(4400\ hr/yr)}{(8760\ hr/yr)}$	=	5.8	0.74
2. Overburden Removal			
Truck/Shovel - 75% Suspended			
$\frac{(0.02\ lb/ton)(0.75)(30.2 \times 10^6\ yd^3/yr)(1.74\ ton/yd^3)}{(8760\ hr/yr)}$	=	90.0	11.35
Dragline - 75% Suspended			
$\frac{(0.04\ lb/yd^3)(0.75)}{(8760\ hr/yr)}$	=	-	-
3. Coal Removal - 70% Suspended			
Frontend Loader or Truck/Shovel			
$\frac{(0.003\ lb/ton)(0.70)(15 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	3.6	0.45
4. Truck Dump - 50% Control 75% Suspended			
$\frac{(0.017\ lb/ton)(0.75)(0.50)(15 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	10.9	1.38

TABLE E.4 (Cont'd)

		lb/hr	g/sec
5. Wind Erosion			
$\frac{(0.15\ \text{ton/acre/yr})(2000\ \text{lb/ton})(226\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	12.9	1.63
6. Coal Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.40)(3.48\ \text{lb/VMT})(5.26\ \text{mi})(15 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(120\ \text{ton/vehicle})}$	=	104.5	13.18
7. Overburden Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.40)(1.96\ \text{lb/VMT})(1.2\ \text{mi})(30.2 \times 10^6\ \text{yd}^3\text{/yr})}{(8760\ \text{hr/yr})(94\ \text{yd}^3\text{/vehicle})}$	=	34.5	4.35
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(5000\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	6.6	0.84

TABLE E.4 (Cont'd)

		lb/hr	g/sec
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ \text{lb/blast})(0.75)(250\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	1.1	0.13
Coal			
$\frac{(35\ \text{lb/blast})(0.75)(300\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	0.9	0.11
10. Primary and Secondary Crusher - 99% Control			
$\frac{(0.08\ \text{lb/ton})(15 \times 10^6\ \text{ton/yr})(0.01)}{(8760\ \text{hr/yr})}$	=	1.4	0.18
11. Train Loading - 90% Control			
$\frac{(0.007\ \text{lb/ton})(15 \times 10^6\ \text{ton/yr})(0.1)}{(8760\ \text{hr/yr})}$	=	1.2	0.15

TABLE E.5
SUNOCO ENERGY DEVELOPMENT COMPANY
CORDERO MINE

		lb/hr	g/sec
1. Scraper Operations - 50% Control			
$\frac{(0.50)(32\ \text{lb/scraper-hr})(.726)(2.23 \times 10^4\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	29.6	3.73
2. Overburden Removal			
Truck/Shovel - 75% Suspended			
$\frac{(0.02\ \text{lb/ton})(0.75)(50.1 \times 10^6\ \text{yd}^3/\text{yr})(1.74\ \text{ton/yd}^3)}{(8760\ \text{hr/yr})}$	=	149.3	18.82
Dragline - 75% Suspended			
$\frac{(0.04\ \text{lb/yd}^3)(0.75)}{(8760\ \text{hr/yr})}$	=	-	-
3. Coal Removal - 70% Suspended			
Frontend Loader or Truck/Shovel			
$\frac{(0.003\ \text{lb/ton})(0.70)(24 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})}$	=	5.8	0.73
4. Truck Dump - 85% Control 75% Suspended			
$\frac{(0.017\ \text{lb/ton})(0.75)(0.15)(24 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})}$	=	5.2	0.66

TABLE E.5 (Cont'd)

		lb/hr	g/sec
5. Wind Erosion			
$\frac{(0.25\ \text{ton/acre/yr})(2000\ \text{lb/ton})(283\ \text{acre/yr})}{(8760\ \text{hr/yr})}$	=	16.2	2.04
6. Coal Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{20}{30}\right)^2\left(\frac{365-100}{365}\right) = 3.48\ \text{lb/VMT}$			
$\frac{(0.40)(3.48\ \text{lb/VMT})(4.98\ \text{mi})(24 \times 10^6\ \text{ton/yr})}{(8760\ \text{hr/yr})(170\ \text{ton/vehicle})}$	=	111.7	14.09
7. Overburden Haul Roads - 60% Control, 62% Suspended			
Emission Factor:			
$\underset{\text{Tires}}{(0.62)}\underset{\text{Silt}}{(2.5)(0.81)(8.6)}\left(\frac{15}{30}\right)^2\left(\frac{365-100}{365}\right) = 1.96\ \text{lb/VMT}$			
$\frac{(0.40)(1.96\ \text{lb/VMT})(0.8\ \text{mi})(50.1 \times 10^6\ \text{yd}^3\text{/yr})(1.74\ \text{ton/yd}^3)}{(8760\ \text{hr/yr})(170\ \text{ton/vehicle})}$	=	36.7	4.63
8. Haul Road Repair - 50% Control			
$\frac{(32\ \text{lb/grader-hr})(0.50)(.726)(7.11 \times 10^3\ \text{hr/yr})}{(8760\ \text{hr/yr})}$	=	9.4	1.19

TABLE E.5 (Cont'd)

		lb/hr	g/sec
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ lb/blast)(0.75)(1\ blast/day)(365\ day/yr)}{(8760\ hr/yr)}$	=	1.6	0.20
Coal			
$\frac{(35\ lb/blast)(0.75)(1\ blast/day)(365\ day/yr)}{(8760\ hr/yr)}$	=	1.1	0.14
10. Primary Crushing	=	8.0	1.01
11. Secondary Crushing	=	4.5	0.57
12. Silo Storage	=	4.6	0.58
13. Barn Storage	=	9.2	1.16

TABLE E.6
ATLANTIC RICHFIELD COMPANY
COAL CREEK MINE

		lb/hr	g/sec
1. Scraper Operations - 50% Control			
$\frac{(0.50)(32\ lb/scraper\text{-}hr)(.726)(9750\ hr/yr)}{(8760\ hr/yr)}$	=	12.9	1.63
2. Overburden Removal			
Truck/Shovel - 75% Suspended			
$\frac{(0.02\ lb/ton)(0.75)(4.30 \times 10^6\ yd^3/yr)(1.74\ ton/yd^3)}{(8760\ hr/yr)}$	=	128.1	16.16
Dragline - 75% Suspended			
$\frac{(0.04\ lb/yd^3)(0.75)}{(8760\ hr/yr)}$	=	-	-
3. Coal Removal - 70% Suspended			
Frontend Loader or Truck/Shovel			
$\frac{(0.003\ lb/ton)(0.70)(18 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	4.3	0.54
4. Truck Dump - 50% Control 75% Suspended			
$\frac{(0.017\ lb/ton)(0.75)(0.50)(18 \times 10^6\ ton/yr)}{(8760\ hr/yr)}$	=	13.1	1.65

TABLE E.6 (Cont'd)

		lb/hr	g/sec
9. Blasting - 75% Suspended			
Overburden			
$\frac{(50\ \text{lb/blast})(0.75)(250\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	1.1	0.13
Coal			
$\frac{(35\ \text{lb/blast})(0.75)(250\ \text{blasts/yr})}{(8760\ \text{hr/yr})}$	=	0.7	0.09
10. Primary Crushing - 0.0005% Material Crushed			
$\frac{(5 \times 10^{-6})(18 \times 10^{6}\ \text{ton/yr})(2000\ \text{lb/ton})}{(8760\ \text{hr/yr})}$	=	20.5	2.59
11. Secondary Crushing - 0.0002% Material Crushed			
$\frac{(2 \times 10^{-6})(18 \times 10^{6}\ \text{ton/yr})(2000\ \text{lb/ton})}{(8760\ \text{hr/yr})}$	=	8.2	1.03
12. Trough Storage - 0.0001% Material Handled			
$\frac{(1 \times 10^{-6})(18 \times 10^{6}\ \text{ton/yr})(2000\ \text{lb/ton})}{(8760\ \text{hr/yr})}$	=	4.1	0.52
13. Train Loading	=	4.1	0.52