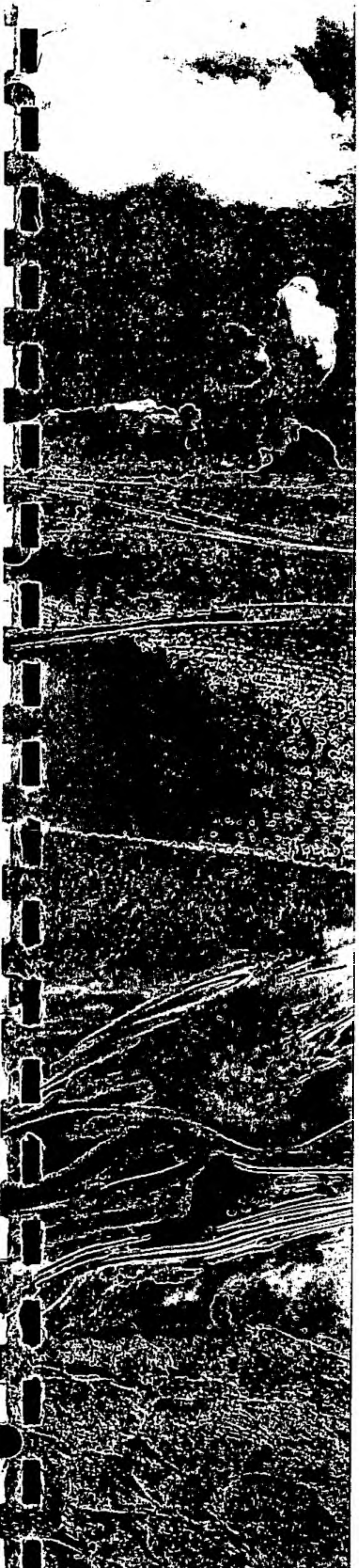


National Centre for Risk Analysis & Options Appraisal

Guidance for Estimating the Air Quality Impact of Stationary Sources

GN 24

November 1998

ENVIRONMENT AGENCY

PREFACE

Scope

This Guidance is the result of research instigated by the Environment Agency. It is a paper-based system for making first estimates of the impacts of stationary pollution sources on local air quality, so that informed decisions can be made on whether or not it is necessary to do more refined analysis such as detailed computer modelling. The Guidance is therefore useful for scoping purposes and for guiding modelling effort onto priority situations.

The Guidance is designed to be a practical manual rather than an air pollution textbook. It therefore focuses on the basic information and steps needed to estimate air quality impacts rather than on the theoretical background. It can be applied to emissions from existing or proposed industrial processes where these emissions are from elevated stationary sources i.e. from stacks.

Potential Users

The Guidance should be useful to a range of users including:

- Process operators, for demonstrating to regulators that their emissions are acceptable.
- Regulators with responsibility for authorising process emissions.
- Local authorities undertaking reviews and assessments of local air quality.
- Other interested parties such as residents' groups and environmental organisations.

It is assumed that the user has access to data on the pollutant emissions and discharge conditions of the specific source or sources being studied, and up-to-date information on relevant prevailing air pollutant concentrations due to other sources i.e. on ambient or background concentrations.

Ways of Using Output

The output from the Guidance can be used in a number of ways:

- To judge if pollutant emissions pose lesser or greater risks to the achievement of air quality criteria, and hence to decide if more detailed modelling and analysis are warranted.

- To identify approximate distances over which air quality impacts are likely to extend from individual stacks.

- To assess the air-quality implications of changes in discharge conditions such as stack height, efflux heat and efflux momentum.

- To check how sensitive predicted impacts are to particular input data and assumptions, such as climate and surface roughness.

- To get a quick initial check on the results of detailed modelling studies submitted as part of applications under Integrated Pollution Control, Local Air Pollution Control or planning regulations.

Application to Local Air Quality Management (LAQM)

The Guidance can be used as part of the review and assessment of air quality as set out for Local Authorities under Part IV of the Environment Act 1995. This review and assessment is designed to help Local Authorities to achieve the Objectives of the National Air Quality Strategy (NAQS) by 2005, and the Guidance can be used alongside other publications in this area from the Department of Environment, Transport and the Regions (DETR), the Welsh Office and the Scottish Office. These publications are:

- The United Kingdom National Air Quality Strategy (CM 3587, 1997).
- Framework for review and assessment of air quality (LAQM. G1(97)).
- Developing local air quality plans and strategies: the principal considerations (LAQM. G2(97)).
- Air quality and traffic management (LAQM. G3(97)).
- Air quality and land use planning (LAQM. G4(97)).
- Monitoring for air quality reviews and assessments (LAQM. TG1(98)).
- Preparation and use of atmospheric emissions inventories (LAQM. TG2(98)).
- Selection and use of dispersion models (LAQM. TG3(98)).
- Review and assessment: Pollutant specific guidance (LAQM, TG4 (98)).

The review and assessment of air quality by Local Authorities involves three stages:

1. **Initial screening** to identify potentially "significant" sources of pollution, using the Local Authority's general knowledge of relevant industrial and transport activities and of situations where individuals may be exposed.

2. **Scoping** exercises to give quick estimates of specific air-pollutant sources and impacts, notably due to chimney stacks and road traffic.

3. **Detailed modelling** of the air-quality impact of chimney stacks and road traffic in situations where this is justified by the results of scoping.

If at the end of stage 3 it appears that a NAQS Objective may not be achieved by 2005, the Local Authority will need to declare an Air Quality Management Area and to develop a programme of local action to improve air quality. Local Authorities may use this Guidance to help with work under stage 2 ("scoping"), and many Local Authorities will find that the advice and outputs obtained enable them to make a decision not to continue to stage 3 ("detailed modelling"), in particular situations.

The method in the Guidance focuses on impacts from single stacks, but includes a conservative procedure for estimating the combined impacts of a few stacks. The method is not generally appropriate for estimating the combined impacts of large numbers of stacks, e.g. in extensive industrial areas, and such situations are likely to require detailed modelling under stage 3.

Assumptions and Caveats

The Guidance is designed to give users clear step-by-step instructions rather than to explain all the technical details. However, where important technical caveats or assumptions apply they are marked by superscripted numbers and explained as "Technical Notes" in Chapter 9. This system of notes prevents the flow of the main text (Chapters 1-8) being broken up by detailed technical explanations. Further information on some of the more complex assumptions and technical issues is given in Annex IV.

ADMS

The air dispersion model used in the production of the Guidance is the Atmospheric Dispersion Modelling System (ADMS) developed by Cambridge Environmental Research Consultants Ltd. ADMS is widely used in the UK, and is an example of the new generation of air dispersion models which have been developed during the past decade to take account of improvements in scientific understanding of atmospheric dispersion.

Accuracy of Chart Method

The Guidance contains a set of look-up charts which use contours to summarise the results of computerised dispersion calculations for a wide range of release conditions. The charts are used to estimate the air quality impacts of stationary sources, as given by the maximum ground-level concentration and its distance from the stack. When using the Guidance it is important to be aware of the likely accuracy of the method. This was assessed by comparing results from the charts with results from separate computer calculations. It was found that values of maximum concentrations from the charts tended to overestimate those from separate calculations by typically 20-30%. This tendency to overestimate is one of several conservatisms and uncertainties which must be taken into account when deciding if the Guidance results for a particular case justify proceeding to more detailed modelling. The main conservatisms and uncertainties are discussed in the Guidance, and some broad advice is given on when to proceed to more detailed modelling or analysis in cases involving long-term and short-term impacts.

Project Management

This Guidance has been developed from the results of contracted research undertaken at Det Norske Veritas (DNV), London, under the leadership of Dr. Tim Fowler. Some additional technical support was provided under contract by Cambridge Environmental Research Consultants (CERC), Cambridge, under the leadership of Dr. Christine McHugh. The Project Manager at the Environment Agency was Dr. Roger Timmis of the Agency's National Centre for Risk Analysis and Options Appraisal (NCRAOA).

Contents

ACRONYMS. SYMBOLS AND UNITS

Atmospheric Dispersion Modelling System	ADMS
Department of Environment, Transport and the Regions	DETR
National Air Quality Strategy	NAQS
Expert Panel on Air Quality Standards	EPAQS

Symbols	Terms and Parameter	Units
AQC	Air quality criterion	ppb, $\mu g/m^3$
AC	Ambient concentration in background air	ppb, $\mu g/m^3$
E	Pollutant emission rate	g/s
GPC	Group process contribution, based on coincident maxima	$\mu g/m^3$
GPEC	Group predicted environmental concentrations, based on coincident maxima (= GPC + AC)	$\mu g/m^3$
M	Efflux momentum	m^4/s^2
M_m	Molecular mass of pollutant	g/mole
NGLC	Normalised ground level concentration at position of maximum for 1g/s emission	$ng/m^3/g/s$
PC	Process contribution at position of maximum	ng/m^3, $\mu g/m^3$
PEC	Predicted environmental concentration, at position of maximum (=PC + AC)	$\mu g/m^3$
Q	Efflux heat	MW
r	Radius of stack flue	m
r_{eq}	Equivalent combined radius of multiple flues	m
T_a	Ambient temperature	K
T_{rel}	Temperature of exhaust gases released	K
V_{rel}	Volume flow of exhaust gases at release conditions	m^3/s
w	Velocity of exhaust gases at release conditions	m/s

Units of Concentration

Concentrations of air pollutants are expressed on either a mass or a volumetric basis. Using the mass basis, concentrations are expressed as a mass of pollutant per unit volume of polluted air e.g. micrograms per cubic metre ($\mu g/m^3$). Using the volumetric basis, they are expressed as a volume of polluted gas per unit volume of polluted air e.g. parts per million (ppm).

The mass basis can be used for all pollutant types i.e. for gases and particles, but the volumetric basis can only be used for gases. Concentrations expressed using the mass basis change if the temperature of the polluted air changes, but concentrations expressed using the volumetric basis do not change with temperature.

The following diagrams show how to convert between scales of concentration units for (A) the mass basis and (B) the volumetric basis.

(A)

ng/m³ nano-	÷1000 → / ← ×1000	µg/m³ micro-	÷1000 → / ← ×1000	mg/m³ milli-	÷1000 → / ← ×1000	g/m³

(B)

ppb	÷1000 → / ← ×1000	ppm

The results of dispersion modelling calculations are usually first expressed on a mass basis (A), but may subsequently be converted to a volumetric basis for comparison purposes.

The following equation allows mass-based concentrations to be converted to volumetric-based concentrations (specifically from $\mu g/m^3$ to ppb):

$$C\ (ppb) = C(\mu g/m^3)\left(\frac{22.4}{M_m}\right) \times \left(\frac{T}{273}\right)$$

Where T is the temperature (in Kelvin) of the air containing pollutant(s), and M_m is the molecular mass of the pollutant, e.g. as given in the table below:

Pollutant	Benzene	1,3 Butadiene	Carbon monoxide	Nitrogen dioxide	Lead	Sulphur dioxide
M_m	78	54	28	46	207	64

GLOSSARY OF TERMS

Air quality criteria	Generic term for air quality objectives and standards.
Air quality objectives	These are part of the UK National Air Quality Strategy and indicate the degree of compliance with air quality standards which should be achieved by a given date. Specifically, the NAQS sets objectives for the degree of compliance with certain EPAQS air quality standards by 2005.
Air quality standards	These are limits on the atmospheric concentrations of specific pollutants and are designed to protect human health and/or the environment. For example, standards for protection of human health have been recommended in the UK for certain pollutants by the Expert Panel on Air Quality Standards (EPAQS).
Ambient concentration	Also called background concentration or ambient air quality. This is commonly obtained from measurements made in the general vicinity of the stack(s) under consideration but at places where the air quality is not significantly influenced by the stack(s).
Ambient temperature	Also called background temperature. This is usually the average measured air temperature in the locality. It is assumed to be 15°C in this Guidance.
Case	A case is a particular stack impact situation, as defined by the set of input data needed to estimate the maximum impact of a specific stack under particular operating conditions and for a particular pollutant and temporal statistic. The temporal statistic is usually chosen to match a relevant air-quality criterion, and the maximum impact is expressed as the highest ground-level concentration and its distance from the stack.
Efflux heat	The excess heat of the gases that are released from a stack relative to ambient, neglecting latent heat effects; expressed in units of MW.
Efflux momentum	The momentum of the gases that are released from a stack in units of m^4/s^2.
Equivalent radius	A stack may have several internal flues. The cross-sectional areas of each of these may be summed and the total re-expressed as the radius of a notional single flue. This is then the equivalent radius, which is used in subsequent estimates of the stack impacts.
Group	A group is a set of input data made up of cases from two or more different stacks operating simultaneously.
Group predicted environmental concentration	The estimated maximum total ground-level concentration due to the combined impacts of a group of stacks, as represented by their group process contribution, plus other sources as represented by the ambient concentration.
Group process contribution	The estimated maximum ground-level concentration due to a group of stacks based on a pessimistic assumption that their individual maxima occur in the same place.
Normalised ground level concentration	The concentration at ground level due to emissions from a stack of a nominal pollutant at a unit emission rate. In this Guidance the normalised ground level concentration is that at the position at maximum ground level concentration and is based on a unit emission rate of 1 g/s.
Percentile	Refers to the position of a particular concentration value within an overall ranking of values from a measured or modelled concentration series. The 100th percentile is the highest ranked concentration in the series and the 50th percentile concentration is the middle ranked concentration. Some short-term air-quality objectives are specified in terms of a percentile and a concentration value; this means that measured or modelled

concentrations should remain below the specified value for the specified percentage of overall time.

Periodicity — The frequency and duration of a particular operational mode for a process stack.

Predicted environmental concentration — The estimated maximum total ground-level concentration due to the combined impact of a single stack, as represented by its process contribution, plus other sources as represented by the ambient concentration.

Process contribution — The estimated maximum ground level concentration due to an individual stack.

Stack — An elevated point of release of gases containing pollutants. Usually, the stack is a chimney and is described by the height of release above ground level and by the internal radius of the flue. The stack may contain several flues whose internal apertures must be combined into an equivalent radius for dispersion modelling purposes.

Stationary source — Any stack from which gases containing pollutants are released on a planned and regular basis.

Study area — The area used for assessing the impacts of stack(s) on air quality. The area may be taken initially as that within 5 km of the stack(s) of interest but this range may need to be refined (increased or decreased) in the light of the distances over which impacts are estimated to occur. The characteristics of the study area affect the choice of several parameters, including: surface roughness, meteorological type, air quality criteria for protection of sensitive receptor types in the area, ambient concentration estimates, and the definition of stack groups.

Surface roughness — The movement of wind over obstacles on the ground, such as buildings and trees, creates mechanical air turbulence which effects the dispersion of pollutants. This effect of obstacles is represented by a parameter known as the aerodynamic "surface roughness" length of the surface. As a general rule the surface roughness increases with increasing height and decreasing spacing of the surface obstacles.

Temporal statistic — The overall time basis of an air-quality criterion or impact estimate. This always includes the averaging time of individual concentration values, e.g. 1-hour average. In cases involving a time series of individual values, it also includes the period covered by the series (e.g. 1 year) and the percentile i.e. the value of concentration which is exceeded for a given percentage of the period (e.g. the 99th percentile is the value exceeded for 1% of the period).

1. INTRODUCTION

1.1 Objective

The objective of this document is to provide pre-calculated charts for estimating local air pollution impacts due to stack emissions. It is assumed that the user already knows about the relevant process conditions and ambient concentrations (i.e. about local background air pollutant concentrations due to other sources), and so these aspects are not discussed in detail. The document explains how this information can be used to estimate the maximum ground-level concentrations of pollutants and to compare them with relevant air-quality criteria.

1.2 Structure

After this introductory chapter (1) the document has a sequence of six chapters (2 - 7) which explain how to estimate stack impacts using a staged approach. Each chapter has an icon to identify the relevant stage; these icons are shown in Figure 1.1 which also contains a brief overview of each stage.

The next chapter (8) contains a worked example showing how the Guidance can be used for situations involving one process stack, and also for situations involving a few process stacks operating in the same area.

Where assumptions have been made or where caveats exist, these are highlighted by the use of Technical Notes, which are explained in Chapter 9 and are indicated in the text by superscripted numbers.

The document is completed by a chapter (10) of references, and by four annexes (I-IV) which contain the following key materials for using and understanding the Guidance:

- Worksheets for recording calculations (Annex I).
- The National Air Quality Strategy Objectives (Annex II).
- Look-up charts showing the results of dispersion calculations (Annex III).
- An explanation of some of the more complex technical issues (Annex IV).

The document is presented in a ring-bound form in order to facilitate updating. For example, the air quality objectives of the National Air Quality Strategy are currently being reviewed, so that the pages of Annex II may need to be replaced / updated in due course.

1.3 Worksheets

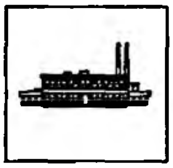
A set of worksheets have been developed to record the data used and generated in the calculations. The first two worksheets (1 and 2) collate basic information on the geographical setting and the engineering details of the release. This basic information is then used to compose cases for which impact estimates are required, and the details of these cases and estimates are entered in a pair of worksheets (3a and 3b). The final worksheet (4) records information for making conservative estimates of the combined impacts of groups of a few stacks. The titles of the worksheets are:

- Worksheet 1 : "Basic Geographical Information".
- Worksheet 2 : "Basic Engineering Information".
- Worksheet 3a : "Case Definition and Dispersion Estimates".
- Worksheet 3b : "Process Contributions and Assessment".
- Worksheet 4 : "Impact Estimates for Stack Groups".

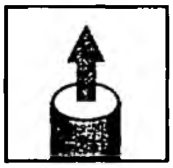
Instructions for completing the worksheets are given in the sequence of six explanatory chapters (2 – 7). In addition, a set of worksheets has been completed for the example in Chapter 8 and is included at the end of that chapter. By completing the worksheets users can ensure that all relevant stages of the Guidance have been considered, and that there is a clear record of the cases examined and of the results obtained.

Annex I contains a set of blank copies of the worksheets which can be copied as required.

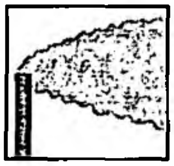
Figure 1.1 Overview of Chapters 2 – 7, with associated icons



2: Case Definition identifies specific situations for which estimated stack impacts are required and collates basic geographical and engineering information for each situation. It covers information on site and local area characteristics, air quality criteria, operational parameters and mass emission rates for each pollutant and situation of interest.



3: Identification of Discharge Conditions derives values of the discharges of heat and momentum in the stack plume for individual cases, for use in later stages of impact estimation.



4: Estimate of Pollutant Dispersion explains how to obtain first estimates of the maximum concentration contributed by the process to air pollution at ground level, and of the distance of this maximum from the source.

5: Ambient and Predicted Environmental Concentrations is concerned with obtaining a value of the local ground level concentration of pollutant(s) due to other processes. This value is then added to the estimate of the maximum concentration contributed by the process to predict the maximum environmental concentration due to all sources.

6: Comparison with Air Quality Criteria shows how the significance of the predicted environmental concentration can be assessed by comparing it to recognised criteria, such as standards, objectives and guidelines. This assessment is useful for purposes of local air quality management e.g. under Part IV of the Environment Act 1995.

7. Definition and Evaluation of Groups considers situations where the releases from a few stacks in the same area make a combined contribution to the predicted environmental concentration. Guidance is given on how to estimate the total ground-level concentration on a conservative basis.

1.4 Applicability

The workbook provides a method for estimating the maximum process contribution to an environmental concentration in the vicinity of a process plant, and the approximate location at which this maximum occurs.

Areas for Application:

This information can be used in a number of ways:

- To judge if pollutant emissions pose lesser or greater risks to the achievement of air quality criteria, and hence to decide if more detailed modelling and analysis are warranted.

- To identify approximate distances over which air quality impacts are likely to extend from individual stacks.
- To assess the air-quality implications of changes in discharge conditions such as stack height, efflux heat and efflux momentum.
- To check how sensitive predicted impacts are to particular input data and assumptions, such as climate and surface roughness.
- To get a quick initial check on the results of detailed modelling studies submitted as part of applications under Integrated Pollution Control, Local Air Pollution Control or planning regulations.

Limitations:

The Guidance applies primarily to situations where a stack(s) is releasing a gaseous or gas-like pollutant(s) within a buoyant plume(s), and where there are no significant nearby buildings or slopes to complicate dispersion. It is less applicable in other situations, and hence it is necessary to check if any of the following apply:

- The stack is in an area where there are significant local variations in ground level i.e. where the ground rises above the stack height within a distance of 10 stack heights [1].
- The stack height is outside the range covered i.e. outside the range 20 to 200 metres. If the stack exceeds 200 m then this height should be used, although the user should bear in mind that the result will be conservative; however, if the stack is less than 20 m the Guidance is inapplicable.
- The stack is near a building which rises to more than about 40% of the stack height [2], and which lies closer than 5 stack heights' distance from the stack.
- The pollutant in the release comprises particles with diameters of more than a few tens of micrometres. Such particles are large enough for their dispersion to be affected by settling under gravity, so that they are not dispersed in the assumed gas-like manner.
- The bulk density of the efflux gases is significantly higher or lower than for air under the same conditions, or the release temperature is significantly below ambient air temperature[3].
- The exit velocity is outside the range 10 – 25 m/s.
- The efflux heat and momentum are such that, when plotted on the look-up chart, the situation lies in the grey-shaded region of the chart where there is additional uncertainty up to a factor of 2 associated with the results[4].

If any of these situations applies to the stack(s) being studied, then the method may not be applicable, or only applicable with appropriate additional precautions.

2. CASE DEFINITION

2.1 Introduction

A case is a specific set of circumstances for which an estimate of the maximum impact of a stack is needed. A case applies to a particular stack, operating condition, pollutant and temporal statistic[5], and it is effectively defined by the input data used to make the estimate. Different cases may be defined for a stack by changing specific parameters such as the stack height, the operating conditions, or the pollutant.

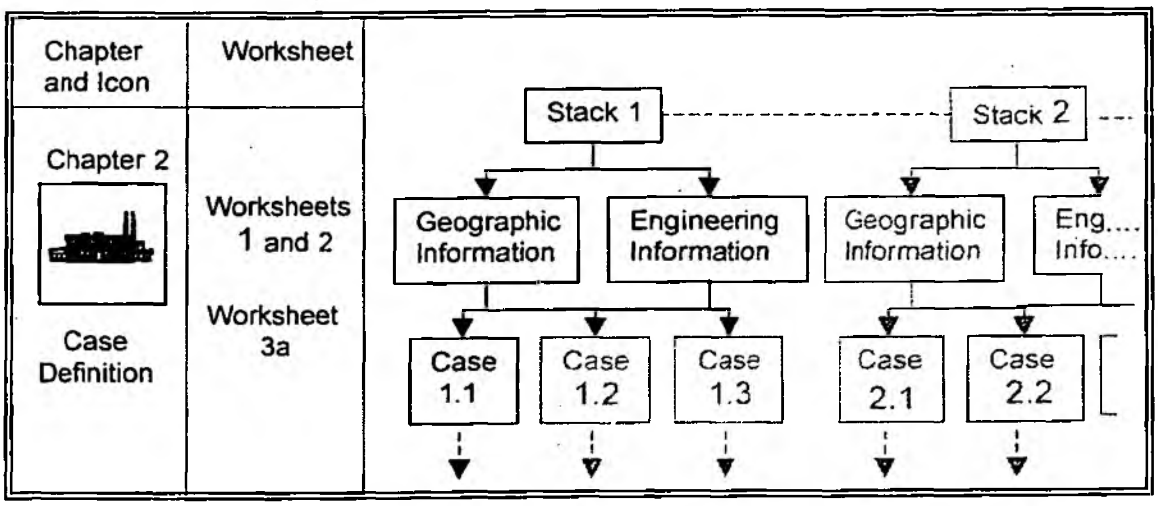
Case definition is the first stage of impact estimation and involves:

- collating basic information on the release situation ;
- using this information to identify the set(s) of circumstances for which estimates are needed;
- entering all these details on relevant worksheets.

The first step is to collate basic information, covering the geographical setting and the engineering details of the stack, as explained in Sections 2.2 and 2.3 respectively. This information is then used to compose specific case(s) for which impact estimate(s) are needed and to record some preliminary data for these estimates, as explained in Section 2.4.

This chapter focuses on defining cases for individual stacks but also explains how information for a few stacks can be recorded together for the sake of convenience. A schematic overview of this first stage of the Guidance is given in Figure 2.1, which includes the chapter number, icon and worksheets associated with this stage. In later chapters this diagram will be extended to include further stages of the Guidance, thereby building up the full picture.

Figure 2.1 Schematic Overview of Defining Cases



2.2 Basic Geographical Information

The geographical information needed to estimate stack impacts falls under 5 headings:

- Stack number(s), name(s) and position(s)
- Extent of the study area
- Surface roughness
- Types and positions of sensitive receptors
- Meteorological type

The following paragraphs explain how to identify appropriate information under each heading and to record it on the relevant Worksheet (1). If there is uncertainty over which value of a parameter to choose it may be necessary to use a conservative value, or to test how sensitive the results are to the value chosen by varying it between cases. The paragraphs therefore give advice on conservative values and sensitivity tests, where relevant.

Stack Number(s). Name(s) and Position(s)

The name of each stack is entered under an identification number on Worksheet 1; this number is unique to the stack and is used as a prefix to identify cases relating to the stack on later Worksheets (3a, 3b and 4). The position of the stack should be defined to at least 100m resolution using Ordnance Survey grid co-ordinates, and the nature of the process should be briefly described.

Extent of Study Area

Obtain a large scale (1:50,000 or more detailed) Ordnance Survey map of the area and mark the positions of the stack(s) to be assessed. Define the extent of an initial study area by drawing a border round the position(s), leaving at least 5 km between the stack(s) and the border, and briefly describe this area on Worksheet 1. The extent of this area may be refined at a later stage in the light of the estimated distance range of stack impacts.

Surface Roughness

The surface roughness of the study area is estimated by assessing the general height and spacing of surface obstacles from a map, site visit, aerial photographs and/or local enquiries. As a general rule the higher and closer together the objects on the surface are, the greater the surface roughness . The most appropriate value of surface roughness should be selected from Table 2.1 which shows all the values covered in this Guidance. If the situation falls between the values of surface roughness on Table 2.1, choose the higher value as this will be more conservative. Enter the appropriate surface roughness on Worksheet 1.

Table 2.1 Surface Roughness Definition (Turner, 1994)

Land Use	Surface Roughness (m)
Cities, woodlands	1.0
Parkland, open suburbia	0.5
Agricultural areas	0.3
Root crops, open grassland	0.1

Sensitive receptors

The type(s) of receptor present in the study area must be identified at this stage because different receptors are sensitive to pollutant impacts over different periods, and the type(s) of receptor therefore affects the choice of temporal statistic(s) used when estimating impacts. For example if an area contains people and vegetation, then the temporal statistics of interest for sulphur dioxide (SO_2) impacts are likely to be short-term (because people are sensitive to short-term SO_2) and long-term (because vegetation is sensitive to long-term SO_2); however, if the area only contains people then only short-term statistics are likely to be of interest.

In the case of NAQS Objectives for the protection of human health it is necessary to identify how long people will be exposed to pollutant impacts at their locations, as this also affects the choice of temporal statistic. If the location is a non-occupational situation where people are only briefly and occasionally exposed, then the statistics of interest are those for short-term Objectives i.e. for sulphur dioxide and hourly nitrogen dioxide. If the location is one where longer-term exposures may occur (e.g. near housing, schools and hospitals) then the statistics of interest are also those for longer-term Objectives i.e. for benzene, 1,3 Butadiene, carbon monoxide, PM10, lead and annual nitrogen dioxide.

On Worksheet 1 record the type(s) and locations of sensitive receptor(s) present in the study area and any relevant duration(s) of exposure. This entry should describe the general pattern of land use and should note any features which may be particularly sensitive to air pollution, such as:

1. *Populated areas*: these often contain potentially sensitive situations such as schools, playing fields, hospitals, nursing homes and infant nurseries.
2. *Agricultural areas*: e.g. crops/market gardens, woodlands and specialist growers.
3. *Areas of special interest or amenity*: e.g. public spaces, National Parks, Nature Reserves and Sites of Special Scientific Interest (SSSIs).

The positions of identified receptors should be clearly located e.g. by marking on an Ordnance Survey map.

<u>Meteorological Type</u>

The Guidance provides pre-calculated dispersion results for three types of meteorological regime found in Great Britain, as shown in Table 2.2. The regimes comprise a widely applicable default type (Type 1), and two more specialised types covering East Coast locations (Type 2) and locations with strong wind channelling (Type 3). The regimes were chosen so that users could assess the possible variation in impact estimates due to uncertainties in the meteorology at a location, as explained in Annex IV, Section 3.5. Use Table 2.1 to identify which meteorological type is most appropriate for the situation under study and enter it on Worksheet 1. If it is not clear which type is most appropriate, the user should define cases for all three types, and evaluate and compare these in order to identify the most conservative type.

Table 2.2 Meteorological Types included in this Guidance

Meteorological Type	Broad Area of Application	Based on
Type 1 (Default)	Inland, western and southern Britain including coasts, except east coast	Elmdon (Birmingham Airport)
Type 2 (East Coast)	Locations near (within about 10 km of) east coasts of Britain	Kilnsea (Spurn Head)
Type 3 (Channelled)	Locations where wind is strongly channelled by topography e.g. hills bounding an estuary	Turnhouse (Edinburgh Airport)

2.3 Basic Engineering Information

The basic engineering information needed to estimate stack impacts falls under six headings:

- Stack height
- Operational mode
- Flues
- Pollutants
- Release temperature
- Release velocity

The following paragraphs explain the information needed under each heading, which should be entered on Worksheet 2 under the relevant stack number and name (copied from Worksheet 1). The entries should include technical details and comments on the implications of these details for case definitions. For example, entries under "Pollutants" should include details of the substances released, and comments on relevant air quality criteria for these substances which will need to be considered when defining cases.

<u>Stack height</u>

Enter the height of the stack above ground level. Use this height together with details of the heights and positions of nearby buildings to check if any building rises to more than 40% of the stack height within a distance of 5 stack heights from the stack. If any building within this distance exceeds 40%, this Guidance is inapplicable and more detailed modelling and analysis should be considered.

Operational Mode

A process discharging through a stack will typically operate in a number of different modes. Each mode may result in the release of different types and rates of substances, with different periodicities (i.e. different durations and frequencies), and requiring consideration of different air-quality criteria. Enter the operational modes for which impact estimates are needed; this will involve at least one normal mode and may include several other modes such as start-up, shut down, stand-by, abnormal utilisation, firing with back-up fuel, and operation with a reduced number of flues or with pollution control equipment off-line. Entries should describe each mode, including its periodicity and the type of fuel and/or feedstock used.

Flues

Enter the total number of flues in the stack and their internal radii. Also enter the number of flues in use for each operational mode and their internal radii.

Pollutants

Enter the type(s) and mass emission rate(s)[6] of pollutant substances released under each mode, which should match the fuel used and other aspects of the mode e.g. feedstock, firing temperature, status of control equipment. Use the information on pollutants, periodicities and sensitive receptors (from Worksheet 1) to identify relevant air-quality criteria to be considered when defining case(s) for each mode, and enter these criteria.

Release Temperature

Enter the exit temperature of the efflux gases for each mode. The exit temperature is often the sme for all flues within a multi-flue stack, but if this is not the case it is necessary to enter a separate temperature for each flue.

Release Velocity

Enter the exit velocity of the efflux gases for each mode. This should be given at the temperature conditions of the efflux gases, and should indicate the number and size of flues in operation. The exit velocity is often the same for all flues within a multi-flue stack, but if this is not the case it is necessary to enter a separate velocity for each flue. The Guidance is only appropriate for velocities in the range of 10 – 25 m/s, and there is an extra uncertainty of about 15% in impact estimates for velocities near the extremes of this range[7].

2.4 Definition of Cases

The basic geographical and engineering information on Worksheets 1 and 2 is now used to compose specific cases for which impact estimates are needed. Each case is defined by particular details which are abstracted from the worksheets and entered on the first part of Worksheet 3a against "Case Definition". The details used to define each case fall under 11 headings:

- Outline description
- Mode/Pollutant
- Meteorological Type
- Temporal Statistic
- Stack Height
- Chart Number
- Surface Roughness
- Flues
- Release Temperature
- Release Velocity
- Pollutant Emission Rate

The following paragraphs explain how to abstract the details needed under each heading and to record them on Worksheet 3a. A stack number (as in Worksheets 1 and 2) and a case number (e.g. 1.1 to denote Stack 1, Case 1) should be entered at the top of Worksheet 3a before starting on the details of each case.

Outline description

This should summarise the main circumstances of the case, so as to give a context for subsequent details. It should record: the type of process attached to the stack, the mode and periodicity of operation, and the pollutant, receptor and air-quality criterion of concern. It should be clear from the description that there is consistency between the timescales involved in: the operational mode, the potential harmful effect of the pollutant on relevant receptors, and the choice of air-quality criterion.

Mode/Pollutant

The mode of operation and pollutant of concern are entered here, for ease of reference.

Meteorological Type

Enter the Met. Type number and site (in brackets) from Worksheet 1.

Temporal Statistic

Enter against "Criterion" the temporal statistic of the air quality criterion with which the impact estimate is to be compared e.g. if the criterion for comparison is the short-term nitrogen dioxide Objective of the NAQS enter "100th percentile of hourly-average values in year".

The look-up charts in this Guidance do not cover every temporal statistic of interest for air quality but a selection as listed below:

- Annual average.
- 99.9th percentile of hourly average concentrations over a year.
- 100th percentile of hourly average concentrations over a year.

If the temporal statistic of the relevant air quality criterion is one of the three charted statistics, enter its details against "Charted" e.g. for the above case of short-term nitrogen dioxide enter "100^{th} percentile of hourly-average values in a year" against "Charted".

However, if the temporal statistic of the air quality criterion is not one of those charted, the user should obtain impact values using a 'similar statistic' for which charts are available. Table 2.3 shows when it is necessary to select and use charts for 'similar statistics' in order to obtain impact values for comparison with NAQS Objectives. For example if the air quality criterion of interest is the NAQS SO_2 objective (i.e. the 99.9^{th} percentile of 15 minute averages over a year), this is not charted, and the user should therefore select and use charts for the 99.9^{th} percentile of hourly-averages over a year, which is the necessary 'similar statistic'. For cases involving NAQS Objectives, identify any necessary 'similar statistic' from Table 2.3 and enter its details against "Charted". Section 4.4 of Chapter 4 gives some conservative factors for converting impact values obtained with 'similar statistics' so that they approximate more closely to values for the temporal statistic of the relevant NAQS Objective.

Table 2.3 Selection of Temporal Statistics for NAQS Objectives

Pollutant	Temporal Statistic of NAQS Objectives	Is the NAQS Objective statistic available from Charts?	Charted 'similar statistic' to be used when the NAQS Objective statistic is not available*
1,3 Butadiene	Running Annual Average	YES[8]	-
Benzene	Running Annual Average	YES[9]	-
CO	100%ile of running 8 hr means over a year	NO	100%ile of hourly-averages over a year
Lead	Annual Average	YES	-
NO_2	Annual Average	YES	-
	100%ile of hourly-averages over a year	YES	-
PM_{10}	99%ile of running 24 hr means over a year[10]	NO	99.9%ile of hourly-averages over a year
SO_2	99.9%ile of 15 minute averages over a year	NO	99.9%ile of hourly-averages over a year

* Used to obtain an initial impact value which is then refined using a conversion factor as explained in Chapter 4

Stack Height

Enter the true stack height (as in Worksheet 2) against "Actual". This Guidance contains pre-calculated charts for 11 stack heights: 20, 30, 40, 50, 60, 70, 85, 100, 120, 150 and 200 metres. If the true stack height matches one of these values, re-enter the true height against "Charted". However, if there is no match the user should enter whichever charted value lies closest to and below the true height, as a conservative approach[11].

Chart Number

Charts for estimating stack impacts have been prepared covering the 3 meteorological types, the 3 temporal statistics and the 11 stack heights. The charts are summarised and numbered from 1 to 99 in Table 2.4. Use the entries made on Worksheet 3a under "Met. Type", "Temporal Statistic: Charted" and "Stack Height: Charted" to identify the number of the chart needed for the current case and enter this against "Chart Number".

Table 2.4 Chart Numbers for Maximum Ground-Level Concentration Charts

Met Type	Temporal Statistic	Stack Height										
		20m	30m	40m	50m	60m	70m	85m	100m	120m	150m	200m
Type 1 (Default)	Annual	1	2	3	4	5	6	7	8	9	10	11
	99.9%ile	12	13	14	15	16	17	18	19	20	21	22
	100%ile	23	24	25	26	27	28	29	30	31	32	33
Type 2 (East Coast)	Annual	34	35	36	37	38	39	40	41	42	43	44
	99.9%ile	45	46	47	48	49	50	51	52	53	54	55
	100%ile	56	57	58	59	60	61	62	63	64	65	66
Type 3 (Channelled)	Annual	67	68	69	70	71	72	73	74	75	76	77
	99.9%ile	78	79	80	81	82	83	84	85	86	87	88
	100%ile	89	90	91	92	93	94	95	96	97	98	99

Surface Roughness

Enter the chosen value of surface roughness from Worksheet 1 which will be 0.1, 0.3, 0.5 or 1.0 m. The charts have four panels corresponding to these four surface roughnesses, so that the value entered shows which panel to use for estimating impacts.

Flues

Enter the number of flues in use for the relevant mode and their internal radii, as in Worksheet 2.

Release Temperature

Enter the exit temperature of the efflux gases for the relevant mode and flue(s), as in Worksheet 2.

Release Velocity

Enter the exit velocity of the efflux gases for the relevant mode and flue(s), as in Worksheet 2.

Pollutant Emission Rate

Enter the mass emission rate of the relevant pollutant for the relevant mode, as in Worksheet 2.

The details discussed under the above 11 headings should be entered on Worksheet 3a for each case. Begin by entering an outline description of each case in a separate column against the first heading, and then enter other details against the remaining headings for each case/column in turn. This order of working will mean that the overall extent of the impact situations to be covered is clear at an early stage (i.e. before dealing with more specific details) and will help to ensure that all necessary cases are identified. The completion of entries against all 11 headings means that the cases for impact estimation are now defined.

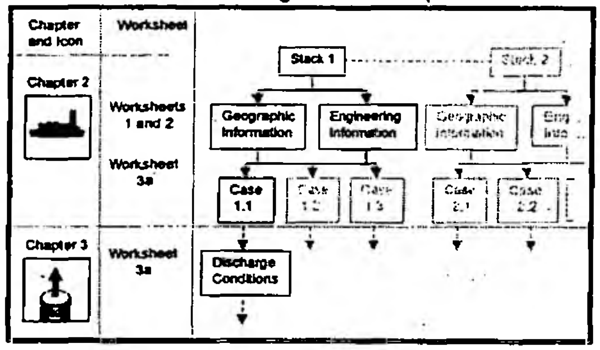
3. IDENTIFICATION OF DISCHARGE CONDITIONS

3.1 Introduction

This chapter explains how to derive values of the discharges of heat and momentum in the stack plume for individual cases. The values are needed for making estimates of pollutant dispersion in the next chapter and are considered under 4 headings:

- Equivalent Radius
- Volume Flow
- Efflux Heat
- Efflux Momentum

Schematic Background to Chapter 3



The following paragraphs describe the workings under each heading, and the results obtained are entered in the lower part of Worksheet 3a against "Discharge Conditions".

3.2 Instructions

<u>Equivalent Radius, r_{eq} (m)</u>

If a stack has more than one flue it is necessary to identify for each case the number of flues in operation and their internal radii, as explained under "Flues" in Section 2.3. For subsequent discharge calculations it is then necessary to sum the cross-sectional areas of the flues and to express the total area as the radius of a notional single flue i.e. the "equivalent radius", r_{eq} (in metres). For each case of multiple flues calculate the equivalent radius of the flues in operation and enter it on Worksheet 3a[12].

<u>Volume Flow, V_{rel} (m^3/s)</u>

Calculate the volume flow (V_{rel} in m^3/s) of the flue gases for each case using the efflux velocity (from Section 2.3) and the radius or equivalent radius (r or r_{eq}), and enter it against "Volume Flow" in Worksheet 3a for use in later calculations[13]. Note that the flow is that prevailing at the actual conditions of the release, rather than at any standardised conditions.

<u>Efflux Heat, Q (MW)</u>

The heat output from a stack affects the amount of plume rise, and hence the impact of the stack plume at ground level. In order to take account of this, the look-up charts cover a range of efflux heats (on their vertical axes) and it is therefore necessary to calculate the heat output of the stack before using the charts. Calculate the efflux heat (Q, in MW) for each case using the volume flow of the flue gases under release conditions (V_{rel}, in m^3/s), the associated release temperature (T_{rel}, in K), and the equation below (taken from Technical Guidance Note (Dispersion), D1)[14]. Enter the value against "Efflux Heat" on Worksheet 3a.

$$Q = \frac{V_{rel}}{2.9} \cdot \left(1 - \frac{283}{T_{rel}}\right)$$

<u>Efflux Momentum, M (m^4/s^2)</u>

The momentum of the stack gases also affects the plume rise, and hence the impact of the stack plume at ground level. The look-up charts take account of the effect of momentum by covering a range of efflux momenta (on their horizontal axes) and it is therefore necessary to calculate the momentum output of the stack before using the charts. Calculate the efflux momentum (M, in m^4/s^2) for each case using the stack radius or the equivalent radius (r or r_{eq}), the volume flow (V_{rel}, in m^3/s), the associated release temperature (T_{rel}, in K), and the equation below (based on HMIP Technical Guidance Note D1)[14]. Enter the value against "Efflux Momentum" on Worksheet 3a.

$$M = \frac{283}{T_{rel}} \cdot \frac{(V_{rel})^2}{\pi r^2}$$

The conditions of discharge of heat and momentum have now been identified for each case, ready for use with the pre-calculated dispersion charts.

4. ESTIMATE OF POLLUTANT DISPERSION

4.1 Introduction

This chapter explains how to obtain a first estimate of the maximum air-quality impact of a process stack, by using the outputs from previous chapters as inputs to pre-calculated dispersion charts. Impacts are estimated for individual cases and are expressed in terms of the maximum contribution of the process to ground-level concentrations and the distance of the maximum from the stack.

The dispersion charts show the results of model calculations for an emission rate of 1 g/s of any pollutant, and cover a range of meteorological types, temporal statistics, stack heights and surface roughnesses, as explained in Sections 2.3-2.4 and summarised in Table 4.1. The charts are located in Annex III; Annex IV describes the derivation of the charts and the assumptions on which they are based.

Schematic Background to Chapter 4

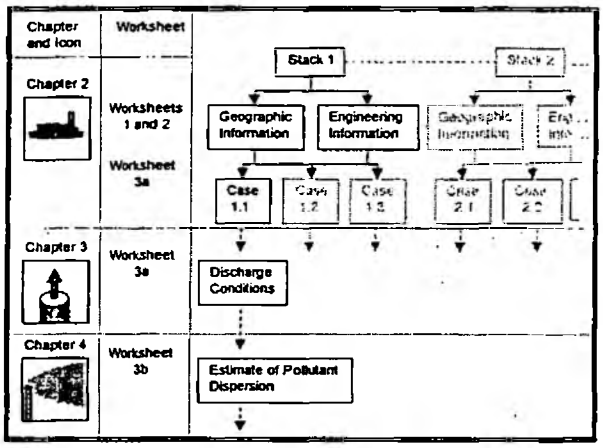


Table 4.1 Options covered by available dispersion charts

Option group	No. of Options	Description of options
Meteorological Type	3	Default (Elmdon) East Coast (Kilnsea) Channelled (Turnhouse)
Temporal Statistic	3	Annual average 99.9th percentile of hourly averages in year 100th percentile of hourly averages in year
Stack Height	11	20, 30, 40, 50, 60, 70, 85, 100, 120, 150, 200 m
Surface Roughness	4	0.1, 0.3, 0.5, 1.0 m

There are four aspects to consider when making dispersion estimates from the charts:

- Initial data requirements
- Reading of dispersion values
- Conversion between temporal statistics
- Calculation of process contribution

The following sections explain the use of the charts by considering each aspect in turn.

4.2 Initial Data Requirements

The following data have been established in previous chapters for each defined case of stack emissions, and are required for making dispersion estimates:

- **Criterion Temporal Statistic**: as given in Worksheet 3a; this is the temporal statistic of the chosen air quality criterion.

- **Charted Temporal Statistic**: as given in Worksheet 3a; this is one of the 3 statistics charted in the Guidance and is either the criterion temporal statistic (when the charts cover this) or a 'similar statistic' (when the charts do not cover the criterion temporal statistic).

- **Chart Number**: as given in Worksheet 3a on the basis of the relevant "Met. Type", "Temporal Statistic: Charted", and "Stack Height: Charted".

- **Surface Roughness (m)**: as given in Worksheet 3a on the basis of the "Surface Roughness" information in Worksheet 1.

- **Efflux Heat, Q** (MW): as given in Worksheet 3a on the basis of the relevant "Volume Flow" and "Release Temperature".

- **Efflux Momentum, M** (m^4/s^2): as given in Worksheet 3a on the basis of the relevant "Volume Flow" and "Release Temperature".

- **Pollutant Emission Rate, E** (g/s): as given in Worksheet 3a on the basis of the type of pollutant and the mass emission rate given in Worksheet 2 under "Pollutants".

4.3 Reading of Dispersion Values

The following steps explain how to read dispersion values off the dispersion charts for each case:

- Use the Chart Number to find the relevant chart and choose the panel on this chart corresponding to the defined Surface Roughness.

- Values of Efflux Heat (Q) and Efflux Momentum (M) are shown on the vertical and horizontal axes of the charts respectively, using logarithmic scales. Find the position where the values of Q and M intersect.

  [Hint: use a ruler and sharp pencil for the sake of accuracy, and take note of logarithmic scales].

- The charts contain two fields of contours. The solid contours show the normalised maximum ground-level concentration (NGLC) in nanograms per cubic metre (ng/m^3) for a unit emission rate (1 g/s), and are labelled in non-italic and underlined type. If the intersection of Q and M lies on a solid contour, read off the value of NGLC; alternatively, if it lies between two contours, interpolate the value of NGLC between them. Enter the value of NGLC obtained against "Initial NGLC: Amount" in Worksheet 3b.

  [Hint: if the intersection is in a closed contour (e.g. a circle) or is otherwise not clearly between two contours, make a conservative estimate of NGLC by taking the value of the next highest contour in sequence from whatever contour lies closest to the intersection.]

- The dashed contours show the distance in metres from the stack to the position of maximum ground-level concentration, and are labelled in italic type. Obtain the distance value by interpolating from relevant dashed contours to the intersection of Q and M, and enter the value against "Initial NGLC: Distance" in Worksheet 3b.

Should the point of intersection of your process fall into the grey-shaded region of the look-up charts, it must be noted that whilst the contours in this region are useful for rough scoping purposes, there will be increased uncertainty associated with the results obtained from this region[4]. The uncertainty associated with reading from this area is approximately double that of reading from the rest of the chart.

4.4 Conversions between temporal statistics

In cases where the available charts do not cover the temporal statistic of the chosen air-quality criterion, it is necessary to make estimates using a 'similar statistic' for which charts are available, as explained in Section 2.4. For example the charts do not cover the 99.9th percentile of 15-minute averages, so that if this is the temporal statistic of the chosen air-quality criterion, it is necessary to use the 99.9th percentile of 1-hour averages, because this is the closest 'similar statistic' for which charts are available as indicated in Table 2.3.

In Worksheet 3a the temporal statistic of the chosen air-quality criterion is shown by the "Temporal Statistic: Criterion", and the temporal statistic of the chart used is shown by the "Temporal Statistic: Charted". The two statistics are the same in cases where the charts available cover the chosen criterion, but they differ in cases where the charts available do not cover the criterion and it is necessary to use charts for a 'similar statistic'.

This section considers cases where the "Temporal Statistic: Criterion" differs from the "Temporal Statistic: Charted" and where the chosen air-quality criterion is a NAQS Objective. It explains how to convert the impact values obtained using charts for 'similar statistics' into estimates which are closer to results for the temporal statistic of the chosen NAQS Objective. The conversions are applied to initial values of the maximum normalised ground level concentration (NGLC), and are calculated for both the maximum concentration amount and the distance from the stack to the maximum.

If the Criterion and Charted Temporal Statistics on Worksheet 3a are the same, there is no need for conversion. Show this by putting a cross in the "Conversion Required" box, and copy the value of "Initial NGLC: Amount" from the top of Worksheet 3b into the "Final NGLC: Amount" box. Similarly, copy the value of "Initial NGLC: Distance" into the "Final NGLC: Distance" box.

If the Criterion and Chartered Temporal Statistics on Worksheet 3a differ, conversion is needed. Show this by putting a tick in the "Conversion Required" box. Then:

- Select appropriate conversion factors for "Initial NGLC: Amount" and "Initial NGLC: Distance" from Table 4.2 i.e. factors corresponding to the Criterion and Charted Temporal Statistics.
- Enter the selected factors onto Worksheet 3b against the relevant "Conversion Factor" boxes.
- Multiply the value of "Initial NGLC: Amount" from the top of Worksheet 3b by the factor for "Conversion Factor: Amount", and enter the product in the "Final NGLC: Amount" box.
- Similarly, multiply the value of "Initial NGLC: Distance" by the factor for "Conversion Factor: Distance", and enter the product in the "Final NGLC: Distance" box.

The contents of the boxes for "Final NGLC: Amount" and "Final NGLC: Distance" are now converted values which take account of any difference between the temporal statistic of the chart used (i.e. of the "Similar Statistic") and that of the chosen NAQS Objective.

Table 4.2: Factors for converting between temporal statistics

		Temporal Statistic of "similar statistic" available from Charts			
		99.9th percentile of 1 hour averages in year		100th percentile of 1hour averages in year	
Temporal Statistic of NAQS Objective		Factor for NGLC Amount	Factor for NGLC Distance	Factor for NGLC Amount	Factor for NGLC Distance
	99.9th percentile of 15minute averages in year (Sulphur Dioxide)	1.34[15]	1[16]	N/A	N/A
	100th percentile of 8-hour running averages in year (Carbon Monoxide)	N/A	N/A	0.7[17]	2[18]
	99th percentile of 24-hour averages in year[10] (PM_{10})	0.6[19]	2[20]	N/A	N/A

4.5 Calculation of process contribution

The final estimate of the amount of the maximum normalised ground level concentration (i.e. of "Final NGLC: Amount") entered in worksheet 3b is based on a unit emission rate of 1 gram per second of a notional pollutant. In order to obtain the contribution of the process to the actual maximum ground-level concentration of a specific pollutant, it is necessary to multiply this normalised estimate by the actual pollutant emission rate in grams per second. This section gives instructions for doing this, and also explains how to convert the calculated process contribution (PC) into convenient units for combining with estimates of ambient concentrations and for comparing with air quality criteria.

For each case:

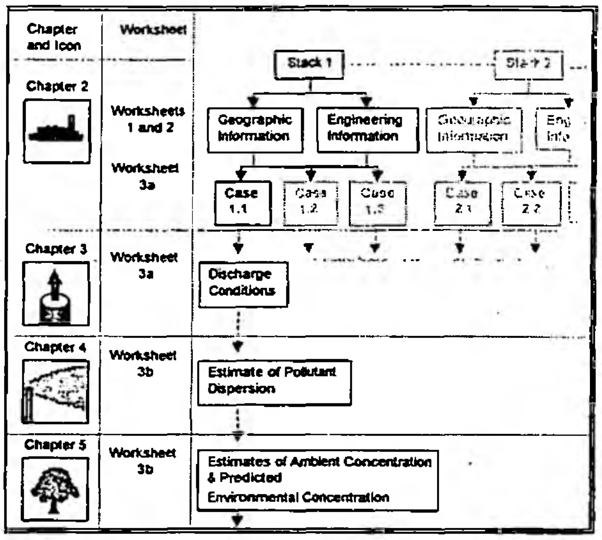
- Multiply the value of "Final NGLC: Amount" from Worksheet 3b by the actual "Pollutant Emission Rate" from Worksheet 3a, and enter the product against "Process Contribution (PC, in ng/m^3)" in Worksheet 3b.
- Divide the value of "Process Contribution (PC, in ng/m^3)" by 1000 to convert to units of μg/m^3 and enter the quotient against "Process Contribution (PC, in μg/m^3)" in Worksheet 3b.

This completes the calculation of process contributions for individual cases.

5. AMBIENT AND PREDICTED ENVIRONMENTAL CONCENTRATIONS

5.1 Introduction

Schematic Background to Chapter 5



This chapter gives guidance on estimating values of the ambient concentration (AC) of pollutants in background air around the study area. It also explains how the ambient concentration is combined with the process contribution (PC) from Chapter 4 to give an estimate of the maximum total concentration at ground level, which is the 'predicted environmental concentration' (PEC). Some additional guidance on estimating appropriate ambient concentrations for NAQS pollutants is given in the government's pollutant-specific guidance (DETR et al, 1998, LAQM. TG4).

5.2 Compatibility considerations

The values of estimated ambient concentrations must be compatible with the aims of the study and the details of each case of stack impacts. There are several aspects of compatibility to consider :

- The pollutant type for which estimates of ambient concentration are made;
- The date or year to which the estimates apply;
- How to ensure that the time basis of the estimates is appropriate for combining with the process contributions;
- How to exclude relevant stack impacts from the estimates so that these impacts are not "double counted" in the predicted environmental concentration.

The following paragraphs give guidance on these aspects.

<u>Pollutant type</u>

Ambient concentration estimates should be for the same pollutant type as the relevant case of stack impacts. For example, in cases involving particulates the estimate should be for an appropriate size fraction e.g. the PM_{10} fraction for cases involving the NAQS Objective for particulates.

<u>Date</u>

In general, estimates of ambient concentration should relate to the date when the air quality criterion of interest becomes effective. For criteria which are already effective, this will usually mean estimating the current ambient concentration e.g. using the most recent measurements available. However, for criteria which relate to future air quality (e.g. NAQS Objectives) it will mean estimating what ambient concentrations will be by the relevant future date (e.g. by 2005 for NAQS Objectives). If estimates of future ambient concentrations are not available, it may be possible to proceed by extrapolating from recent local trends or national emission projections, or even by using current concentrations if these represent an acceptable conservative approach.

Compatibility of time bases

As explained in Section 5.1, estimates of the ambient concentration (AC) are needed for combining with estimates of the process contribution (PC) to give values of the predicted environmental concentration (PEC). One possible approach is to estimate a value of AC for the same temporal statistic as for the value of PC, and then to add these values to give the PEC. However, this approach is only valid if relevant percentile events within the concentration time series of AC and PC occur simultaneously, which generally is only realistic for long-term statistics. For example, it is realistic for long-term statistics like annual averages, because for these there is only one event (the annual average), which occurs simultaneously, so that the AC can be simply added to the PC to give the PEC.

However, if the temporal statistic of interest is short-term, such as the 100th percentile of 1-hour averages in a year, it is necessary to take account of the fact that relevant percentile events within the concentration time series of AC and PC may not occur simultaneously. In particular, the fact that the 100th percentile of ambient concentrations may not occur at the same time as the 100th percentile of process contributions means that it could be unduly conservative to obtain the 100th percentile of PEC by simply adding the 100th percentiles of AC and PC, i.e. by assuming that they occur simultaneously. Such a conservative approach will only be useful for very basic screening purposes i.e. to show that even with the most pessimistic assumptions there is no likelihood of exceeding an air quality criterion.

A more realistic approach to estimating the PEC for short-term statistics is to assume that there is only limited coincidence of relevant high-percentile events within the concentration time series of AC and PC. This is done by taking a more frequently-occurring value of AC (e.g. a lower percentile, or a multiple of the annual mean), and adding this to the relevant high percentile value of PC. Advice on this approach is given in relation to NAQS Objectives in the government's pollutant-specific guidance (DETR et al., 1998, LAQM. TG4). For example for short-term sulphur dioxide, it suggests taking twice the annual-average as a more frequently-occurring value of AC, and adding this to the high-percentile of PC to give a realistic PEC. In cases involving short-term statistics, users of the present Guidance should consider what more frequently-occurring value of AC they need in order to make a realistic estimate of PEC; for practical scoping purposes the most recent advice available is that given in the pollutant-specific guidance.

Avoidance of "double counting"

Ideally, estimates of ambient concentration should exclude any impacts due to the specific process under study and should only include impacts due to other sources. This is relatively easy to achieve if the stack is not yet built/operating, because a value can be estimated from recent local measurements which will contain no impacts from the process.

However, in many cases a process stack is already operating, and it may then be necessary to use local measurements which already contain some contribution from the process because they are within the general area of stack impacts. Using such measurements will cause some "double counting" of relevant stack impacts in the predicted environmental concentration, making this a more conservative estimate.

The estimates of stack impacts made in Chapter 4 include a value for the distance from the stack to the position of maximum ground level concentration as given by "Final NGLC: Distance" in Worksheet 3b. In order to reduce the risk of "double counting", this distance should be borne in mind when judging how much separation to allow between an existing stack and any measurements used to estimate ambient concentrations. Ideally, such measurements should be separated from the stack by several multiples of the distance value[21]; but this is not always possible and often the disadvantages of "double counting" must be set against the advantages of using local measurements when available.

5.3 Types of ambient concentration estimate

The accuracy of the estimate of ambient concentration made for a given case of stack impacts depends on the quantity, quality and proximity of local air-quality measurements or of other data used. It is useful to identify three types of estimate, which tend to use different types of information and generally give different levels of accuracy, as outlined below.

Local measurements in incoming air

Ideally, an estimate of ambient concentration will relate to the concentration in air arriving with the wind in the vicinity of the stack, but not actually containing any impact from the stack. In practice for an existing stack, this means measurements made upwind of the stack (e.g. in the prevailing upwind direction) and at a sufficient separation from it (e.g. at several multiples of the distance to the relevant maximum concentration), but otherwise in the same type of area (i.e. having similar land-use, emissions and dispersion). This type of information is likely to give the most accurate estimates of ambient concentration, particularly if the measurements cover several years.

Local measurements containing stack impacts

In many cases the ideal separation does not exist between the stack of interest and any local measurements available for estimating ambient concentrations. The measurements may also represent a compromise in terms of the period of measurements or because they are from a somewhat different type of area, so that ambient concentrations estimated with these data are also compromise values.

Generic data

In cases where there are no local measurements, it is necessary to estimate ambient concentrations from generic data on air quality in similar areas e.g. in areas with similar land-use in the same region. Out of the three types, estimates based on generic data are likely to have the greatest uncertainty.

For the purposes of this Guidance it is assumed that the user is able to obtain relevant data on local air quality and to deduce from these an appropriate estimate of ambient concentration, taking account of the points in sections 5.2 and 5.3. Information on how to obtain relevant data from the DETR national monitoring network is given in Technical Note 22 in Chapter 9. If the values available are in ppb, convert them to ug/m^3 using the equation in the Units Section at the front of the Guidance.

5.4 Calculation of Predicted Environmental Concentration

Predicted environmental concentrations are calculated using the following instructions for each case:

- Enter the relevant estimate of ambient concentration (AC, in ug/m^3) against "Ambient Concentration" in Worksheet 3b.
- Identify the relevant estimate of process contribution (PC, in ug/m^3) against "Process Contribution" in the preceding line of Worksheet 3b, and add it to the estimate of ambient concentration.
- Enter the sum of AC and PC against "Predicted Environmental Concentration" (PEC, in ug/m^3).

The entered value of predicted environmental concentration corresponds to the maximum total ground-level concentration due to the process stack (as given by the process contribution) and all other sources (as given by the ambient concentration). If it is assumed that ambient concentrations are similar across the whole study area, then the distance of the predicted environmental concentration from the stack is the same as for the process contribution (as given by "Final NGLC: Distance" in Worksheet 3b).

The guidance available for the second stage of NAQS review and assessment explains that for this purpose it may be necessary to take account of an additional roadside contribution to overall pollutant concentrations in situations near busy roads (DETR et al, 1998, LAQM. TG4). In these situations the overall concentration for review and assessment of relevant pollutants would be made up of:

(a) The PEC, as defined above and covering stack impacts and the general background ambient concentration.

(b) An estimate of the "roadside contribution" from nearby traffic impacts based on the methodology in the Design Manual for Roads and Bridges (Highways Agency, 1995) which is currently being updated for use in connection with the NAQS.

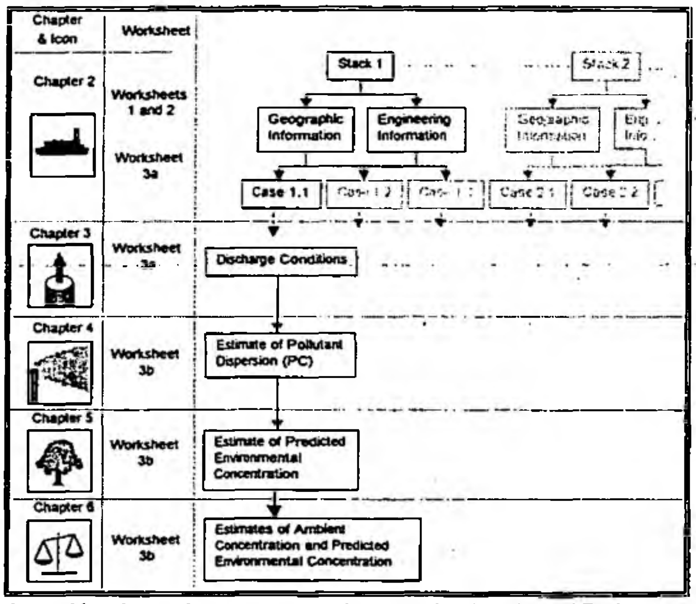
Users should therefore note that the PEC obtained from the present Guidance is the maximum total ground-level concentration in situations away from the vicinity of busy roads, and that in situations near busy roads it may be necessary to add a "roadside contribution" in order to cover the overall impact of all sources for NAQS purposes.

6. COMPARISON WITH AIR QUALITY CRITERIA

6.1 Introduction

This chapter explains how to compare predicted environmental concentrations for each case with relevant air-quality criteria, and gives some advice on interpreting the results of such comparisons. The advice includes a discussion of the main conservatisms and uncertainties in the predicted environmental concentration, and of the need and options for more detailed modelling and analysis of particular cases.

Schematic Background to Chapter 6



6.2 Calculation of PEC/AQC

The predicted environmental concentration (PEC) is compared with the relevant air quality criterion (AQC) for each case by expressing the PEC as a percentage of the AQC, as follows:

- Enter the value of the relevant air quality criterion (in ug/m^3) against "Air Quality Criterion" in Worksheet 3b; the value must match the criterion identified against "Outline Description" and "Temporal Statistic: Criterion" on Worksheet 3a.

- Divide the value of PEC (in ug/m^3) by the criterion and express the quotient as a percentage; enter the percentage value against "PEC as % of AQC" on Worksheet 3b.

In many cases the air quality criterion of interest will be an Objective of the National Air Quality Strategy. The values of NAQS Objectives (in ug/m^3) are therefore listed in Annex II for convenience.

On a simple interpretation, exceedences of the AQC are likely in cases where PEC/AQC exceeds 100%, so that further modelling and analysis would seem necessary in such cases. Similarly, compliance with the AQC is likely in cases where PEC/AQC is less than 100%, so that further modelling and analysis would seem less necessary in such cases. However, before deciding on whether or not to proceed with further work, users should consider the main conservatisms and uncertainties in the method, and compare these with the margin by which PEC/AQC is greater or less than 100%.

6.3 Conservatisms, uncertainties and assessment

This section identifies the main conservatisms and approximations which may affect the results of PEC (and hence of PEC/AQC) for individual stacks, and discusses how to assess the need for further modelling and analysis.

<u>Conservatisms</u>

The following are aspects of the method which, if applicable, will tend to make the estimated PEC larger than the true value, i.e. to make it conservative:

- It may have been assumed, pessimistically, that all the emitted pollutants are of a particular type e.g. that all oxides of nitrogen are NO_2 or that all particulates are PM10.
- The stack height used may be lower than the true height because charts are only available for selected stack heights.
- The surface roughness used may be higher than the true roughness because charts are only available for selected surface roughnesses.
- The mass emission rate of pollutants may have been a worst case value which is unlikely to persist throughout the operating period of interest.

- The ambient concentration may already contain some contribution from stack impacts, which would introduce an element of double counting into the PEC.
- It may have been assumed, pessimistically, that high-percentile events in the series of ambient concentrations occur at the same time as high-percentile events in the series of process contributions.
- When reading the chart it may have been necessary to estimate the value of concentration by extrapolating upwards to the next highest contour value.
- It may have been assumed that the ambient concentration at some future date (e.g. 2005 for NAQS Objectives) is the same as the current concentration, despite the prospect of some improvement occurring as a result of national and local controls.

Uncertainties

The following are aspects of the method which, if applicable, will tend to make the estimated PEC vary from the true value but not always in the same direction (more or less); these aspects are therefore uncertainties:

- There will be uncertainties in the values of discharge data used for estimating stack impacts.
- There will be uncertainties associated with meteorological data for 3 reasons. Firstly, because the Met. Type chosen may not be very representative of the stack locality. Secondly, because of meteorological variations from year to year. Thirdly, because the charts are based on statistically–grouped meteorological data (rather than on ungrouped sequential data) which introduces an extra uncertainty as explained in Section 3.5 of Annex IV.
- Tests of the human error associated with reading from the charts indicate that most users can read to within 10% but that larger errors can occur, i.e. mostly within 20% but up to a factor of 2 in extreme cases (see Annex IV, Section 5.2).
- The value read from the charts may come from the area shaded grey in the lower part of each chart, where release temperatures are close to ambient and an extra uncertainty of up to a factor of 2 may arise (see Technical Note 4).
- The estimate of ambient concentration may not be very representative of the locality.
- The estimates will be affected by the uncertainties inherent in all atmospheric dispersion modelling. These inherent uncertainties tend to be lower for long-term statistics such as annual-averages, and higher for short-term statistics such as 100^{th} percentiles of 1-hour averages. It is difficult to generalise, but for new-generation models these inherent uncertainties are likely to be in the order of a few 10s of percent for long-term estimates, and may approach a factor of 2 for short-term estimates.

Assessment

In order to assess if more detailed modelling and analysis is needed, users should identify the conservatisms and uncertainties in each case and compare their overall effect with the value of PEC/AQC. Some of the effects of conservatisms and uncertainties were investigated by comparing results obtained from the charts with separate computer calculations for a range of cases, as described in Section 5.3 of Annex IV. It was found that results from the charts tended to overestimate the calculated amounts of process contributions by typically 20-30%. However, this investigation did not include the effect of using statistical (rather than sequential) meteorological data – which is likely to reduce the amount of overestimation, or the effects of some other uncertainties such as the inherent uncertainties in dispersion modelling and ambient concentration estimates. Based on these considerations and the comparisons in Annex IV, the following broad advice is given for assessing when more detailed modelling and assessment is necessary:

- In cases involving long-term averages, more detailed modelling and analysis is likely to be necessary if PEC/AQC exceeds 70%, unless there are specific reasons to the contrary. In other words, a PEC/AQC of over 70% represents a significant risk of exceeding the AQC when compared to the typical uncertainties and conservatisms for long-term estimates, so that further modelling and analysis is advisable in such cases. In this context a long-term statistic would be one which summarises the overall effect of process emissions and meteorology over most or all of a year, such as an annual average. The above advice for long-term statistics therefore applies to the NAQS annual average Objectives for benzene, 1,3 Butadiene, lead and nitrogen dioxide.

- The typical uncertainties in estimates of short-term statistics are probably about twice as great as those for long-term statistics. In cases involving short-term statistics it is therefore advisable to allow about twice as much latitude between the AQC and the threshold at which more detailed modelling and analysis should be considered. Accordingly it is suggested that, in cases involving short-term statistics, users should proceed to more detailed modelling and analysis if PEC/AQC exceeds 40%, unless there are specific reasons to the contrary. In this context a short-term statistic is one which focuses on adverse impacts during a small fraction of a year, such as a high percentile of the hourly averages in a year. The above advice for short-term statistics therefore applies to the NAQS Objectives for peak nitrogen dioxide (i.e. the 100th percentile of hourly averages in a year) and sulphur dioxide (i.e. the 99.9th percentile of 15-minute averages in a year). The NAQS Objectives for carbon monoxide (100th percentile of running 8-hour averages in a year) and PM10 (99th percentile of 24-hour running means in a year[10]) are not quite so short-term as those for peak nitrogen dioxide and sulphur dioxide. However, they are still relatively short term compared to annual averages, and the advice to consider further work if PEC/AQC exceeds 40% should therefore be applied to the NAQS Objectives for CO and PM10 as well.

- Further modelling and analysis would be fully justified in any case (long–term or short-term) where PEC/AQC exceeds 100%, i.e. where an exceedence of the AQC is predicted.

The above advice, on the thresholds at which more detailed modelling and analysis should be considered, should be treated as broad guidance which may need to be adapted to specific circumstances. For example, it may be appropriate to raise the thresholds in situations where the stationary sources contribute a small proportion of the PEC and/or where the estimate of ambient concentration is particularly secure. Conversely, it may be appropriate to lower the thresholds in situations where stationary sources contribute a high proportion of the PEC and/or where the estimate of ambient concentration is particularly uncertain. Users should enter the main points arising from the assessment of each case in the "Assessment/Options" box at the bottom of Worksheet 3b. these points should include any special conservatisms and uncertainties which apply, the likelihood of exceeding the AQC, and the user's judgement about the need for more detailed modelling and analysis.

6.4 Options for more detailed analysis

The extent of any more detailed analysis should be in line with the risk of exceeding an air quality criterion, as shown by the value of PEC/AQC and by considering the conservatisms and uncertainties involved. Depending on the risk, the options can range from relatively minor revisions e.g. removal of excessive conservatisms, to a more extensive re-appraisal e.g. detailed site-specific calculations with a computer model.

The main options available are listed below in approximate order of effort, so that those requiring less effort/resources appear before those requiring greater effort/resources. Users should begin by implementing the earlier options, so as to obtain a refined value of PEC/AQC, and should proceed to the later options if the extra effort is warranted by the remaining risk of exceeding the AQC.

Users should consider the following options:

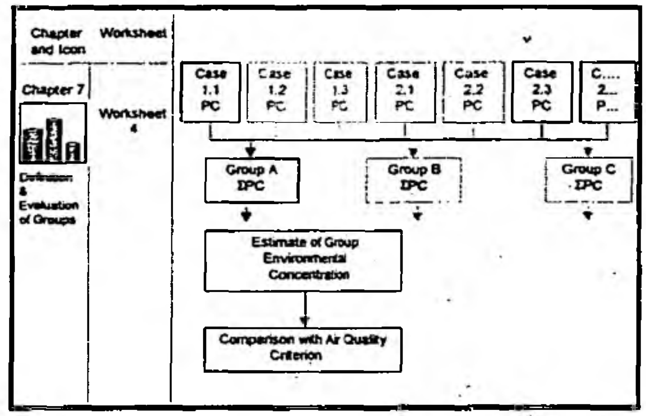
- Re-consideration of conservatisms, with a view to removing any which are unrealistic or implausible.
- Reduction of uncertainties e.g. by acquiring improved data on emissions, discharge conditions, and/or ambient concentrations.
- Exclusion of types of receptor which are beyond the estimated geographical extent of stack impacts e.g. ecosystems which the impacts are not estimated to reach. Any air quality criteria and temporal statistics which are specifically associated with these types of receptor should also be excluded.
- Estimation of further cases with changes to particular parameters, to show how sensitive the results are to these parameters and hence how much further analysis may be warranted.
- Detailed dispersion modelling calculations using site-specific meteorology.

Users may record their judgements on the most appropriate option(s) for further analysis in the "Assessment/Options" box at the bottom of worksheet 3b.

7. DEFINITION AND EVALUATION OF GROUPS

7.1 Introduction

Schematic Background to Chapter 7



When there is more than one stationary source in a study area, it is necessary to consider situations where the impacts of the sources may combine. This chapter presents a conservative method for estimating the combined impact of a few sources located in the same area, for scoping purposes. Such situations involving combinations of a few sources are called "groups". The method is explained below in two sections covering the definition of groups (7.2) and the evaluation of combined impacts (7.3). Worksheet 4 also explains how the input data and results for groups are recorded.

The method assumes that the positions of maximum impact due to the sources in each group coincide, which is a pessimistic assumption and makes the method conservative in this respect. Because of this conservatism, the method is only appropriate for scoping the combined impacts of a few stacks (e.g. up to 5), and is not appropriate for scoping situations involving many stacks (e.g. intensively developed industrial areas) - where multiple-source modelling is likely to be necessary.

Chapter 8 includes an example of how to define and evaluate a situation involving a group of two nearby stacks (see Section 8.5).

7.2 Definition of Groups

Chapter 2 explains how basic information on the geography and engineering of an individual stack is used to define specific cases of pollutant impacts for scoping purposes. A group is defined by taking one case for each of a few individual stacks in the same area, and composing them into a joint impact situation. In order for the group to be valid for scoping purposes, the cases must be a consistent and plausible set of circumstances and be matched to the air-quality criterion of interest. The following paragraphs explain the aspects to be considered when composing a group from cases for individual stacks.

<u>Study area</u>

The stacks in the group must be close enough for their impacts to potentially overlap. An initial approach is to consider stacks lying within the same study area i.e. within a 5km radius as explained in Section 2.2. This approach may then be refined using the values of distances to maxima obtained for individual cases in Worksheet 3b i.e. values of "Final NGLC: Distance". In general, this means taking several times the distance to maximum as the effective range of impact of each stack, and using these effective ranges to check on the potential for overlapping of impacts, and hence on which stacks to include in the group[21].

<u>Surface roughness, receptors, Met. type</u>

These aspects of geographical information will generally be the same for each stack within a group. If there are differences or uncertainties between stacks (e.g. in surface roughness) then their effect on combined impacts can be tested by defining and evaluating groups for different values (e.g. for different values of surface roughness).

Operational mode, pollutant and air-quality criterion

The operational modes for each case in the group need to be a plausible set of circumstances, which involve releases of the same pollutant from each stack and can be related to the same air-quality criterion. For example, a set of normal operating modes would be a plausible set of circumstances for assessing the impacts of nitrogen dioxide from a group of stacks in relation to the NAQS annual-average Objective. Avoid defining groups where the combination of modes is highly improbable (e.g. a group with all stacks in stand-by mode at once) unless there are specific reasons to do so (e.g. because all stacks are likely to switch to stand-by fuel simultaneously because of a general interruption to the normal gas supply).

Temporal statistic

The temporal statistics for each case in the group will follow logically from the consideration of operational mode, pollutant and air quality criterion. In general, short-term temporal statistics need to be considered for all modes which emit pollutants having short-term air-quality criteria. This is because relevant short-term incidents of elevated concentrations may occur during any mode ie during both routine and non-routine operation. However, in general, long-term temporal statistics only need to be considered for long-term modes (e.g. routine operation), because it is only these modes which persist for long enough to effect long-term statistics.

The cases in a group will always have the same temporal statistic i.e. the charts used for the various stacks will all be for the same temporal statistic. Thus for the example of nitrogen dioxide under the previous heading, annual average charts would be used for every stack.

Ambient concentration

In any group situation it will be necessary to identify a value for the impact of emissions from sources outside the group. This corresponds to the ambient concentration for individual stacks, and the considerations discussed in Sections 5.2 and 5.3 will again apply. In most group situations the value of ambient concentration will be based on the value(s) for relevant individual cases in Worksheet 3b.

Having considered these aspects, users should define groups from appropriate combinations of cases for individual stacks. In general, it will be necessary to define several groups covering different combinations of stacks, modes, pollutants and air-quality criteria. Instructions for recording and evaluating groups are given in the next section.

7.3 Evaluation of combined impacts

Groups are recorded and evaluated in Worksheet 4, and users will need the following information for each defined group:

- The reference numbers of the cases in the group, from Worksheets 3a and 3b.
- The name of the pollutant in each case, as entered against "Mode/Pollutant" on Worksheet 3a; this should be the same for all cases in the group.
- The temporal statistic of each case, as entered against "Temporal Statistic: Charted " on Worksheet 3a; this will generally be the same for all cases in the group.
- The process contributions (PC) for each case, as entered against "Process Contribution (ug/m^3)" on Worksheet 3b.
- The appropriate value of ambient concentration (AC); this will usually be the same as for individual case(s) on Worksheet 3b.

The following instructions explain how to enter this information on Worksheet 4 and to evaluate the combined impact of each group:

- Start by giving each group a unique letter for identification purposes, and enter this in the "Group" column so that each group has a line in the Worksheet.
- For each group/line enter the information on "Reference Numbers", "Pollutant", "Temporal Statistic", "Process Contribution for each Case", "Ambient Concentration", and "AQC" (Air Quality Criterion) in the relevant column.
- For each group/line add the values of "Process Contribution" (PC) for all cases and enter the combined value in the "Group Process Contribution (GPC)" column. The GPC is then the maximum combined impact of all stacks under the pessimistic assumption that all of the individual maxima occur in the same place.
- For each group/line add the "Group Process Contribution" (GPC) to the "Ambient Concentration" (AC) and enter the sum in the "Group Predicted Environmental Concentration (GPEC)" column. The GPEC is then the maximum combined impact of (a) all stacks in the group and (b) all other sources.
- For each group/line divide the "Group Predicted Environmental Concentration" (GPEC) by the "Air Quality Criterion" (AQC) and enter the result as a percentage in the "GPEC as % of AQC" column. The value of GPEC/AQC shows how close the total impact of the stacks and other sources might come to the air quality criterion if the stack impacts are assumed to coincide.

The values of GPEC/AQC should be interpreted and commented on in the same way as for individual stack impacts as described in Sections 6.3 – 6.5. However, users should note the following additional points which apply to groups:

- The assumption that all maxima occur in the same place is an extra conservatism, which was not necessary for individual stacks. In practice this means that situations which do not approach the suggested thresholds (of PEC/AQC >70% for long term statistics and PEC/AQC >40% for short term statistics) can be discounted from further analysis with more confidence.
- The amount of extra conservatism will be greater for groups containing stacks which are widely spaced and have dissimilar heights and discharge conditions. Conversely, the amount of extra conservatism will be less for groups containing stacks which are close together and have similar heights and discharge conditions.
- The results of group calculations are particularly useful for identifying which combinations of process operations have the greatest potential to impair air quality, and hence for identifying any priority situations for more detailed analysis.
- If the value of GPEC/AQC exceeds the suggested thresholds then users should consider the options for more detailed analysis as described in Section 6.4; in this context it should be noted that any detailed modelling would be for a few stacks together rather than for a single stack.

8. WORKED EXAMPLE

8.1 Introduction

This chapter illustrates the steps involved in obtaining a first estimate of air quality impacts from a process stack, using the example of a hypothetical site for a combined cycle gas turbine (CCGT) power station operated by 'Electro'. Sections 8.2 – 8.4 outline the calculations required for a single stack at this site. Section 8.5 shows how the Guidance can be applied to a situation where the impacts of the Electro process are combined with those of a second process stack, the 'Meado' brewery, to give the combined impact for a 'group' of stacks.

The Electro power station is designed to generate electricity for the national grid. The station is primarily fuelled by natural gas, but it is also equipped to burn distillate oil as a standby fuel. The exhaust gases from the gas turbines are dispersed at high level via a single stack with a single flue.

For the purposes of this example, the procedures to be followed for NO_2 and SO_2 releases only will be illustrated. However it should be noted that these procedures should be followed for all pollutants to be considered, which for the Electro stack would include PM_{10} for distillate firing. The example is designed around an assessment of compliance with the National Air Quality Strategy Objectives, but it should be noted that the Guidance can easily be used for comparison with other air quality criteria.

In this example all NO_X is considered to be in the form of NO_2. This is a conservative assumption made to simplify the example; it should be noted that pollutant-specific guidance has been published which gives advice on the use of less conservative assumptions on the ratio of NO_X to NO_2 (DETR, 1998, LAQM. TG4).

The main approach in this chapter is to describe examples using the standard sequence of worksheets. The worksheets completed for the example are inserted at the end of Chapter 8 and can be used as an aide-memoire to the Guidance as a whole. The Worksheets are numbered E1, E2, E3a/E and E3b/E (for the Electro stack), E3a/M and E3b/M (for the Meado stack), and E4 (for groups containing both stacks). The details of the workings in worksheets E1 and E2 are explained in an additional 'commentary' column which has been added to each of these worksheets. Some specific issues arising from the example have been identified and are discussed in a series of paragraphs in the following four sections:

Section 8.2 Case Definition
Section 8.3 Discharge Conditions
Section 8.4 Process Contribution and Assessment
Section 8.5 Group Definition and Assessment

The above order of sections matches the order of the worksheets and of previous Chapters (2 – 7). Thus the first two sections correspond to Chapters 2 and 3 respectively, the third section corresponds to Chapters 4 – 6, and the last section corresponds to Chapter 7. In the text below bold lettering is used to identify specific headings which appear in the relevant worksheets.

8.2 Case Definition

- The Worksheets covering basic geographical and engineering information are completed for all stacks under consideration; Electro and Meado are therefore both entered against **stack name** on worksheets E1 and E2.

- The **extent of the study area** is a region from which information is gathered for estimating stack impacts. It is suggested that a radius of 5km around the stack is used initially as a minimum range for consideration, based on experience of typical industrial stacks impacts. However, the extent of the study area may need to be refined at a later stage in the light of estimated distances to maximum concentrations.

- For Electro the choice of **Surface Roughness** and **Met Type** is straightforward, as it is clear that the most relevant roughness length is 0.1m and that the most relevant meteorological regime provided by the Guidance is Type 1 (default). As noted in the accompanying completed worksheets, this is because the Electro stack is surrounded by open grassland and is in the

Midlands (i.e. in the same region as the Type 1 site at Elmdon). If there is uncertainty about the Surface Roughness and/or Met Type, calculations should be performed for a range of possible values in order to show the sensitivity of the results to this uncertainty. The combination of Surface Roughness and Met Type which produces the highest Ground Level Concentration should then be used for assessment against Air Quality Criteria, as a conservative approach.

- The choice of temporal statistic for impact estimates is affected by the type(s) of **sensitive receptor(s)** present in the study area. It is therefore important to consider all likely receptor types before proceeding.

- An examination of the contours on an Ordnance Survey map showed that the terrain around the Electro site did not rise above the **stack height** within a distance corresponding to 10 stack heights (the stack is 75m high and so this distance is 750 metres). A site plan showed that the heights of all buildings within 5 stack heights (i.e. 375m) were less than 40% of the stack height (i.e. less than 30 metres high). The Guidance is therefore applicable to Electro. An examination of the Meado site gave similar results, so the Guidance applies in this case also.

- Long term impacts should be considered in cases where an **operational mode** lasts for a high proportion of the year. For example, annual average impacts should be considered in cases involving routine operation, or where non-routine operations may continue over extended periods.

- The **pollutants** emitted during the different operating modes are matched with appropriate NAQS Objectives from Annex II. This is done by matching (a) the type of pollutant(s) and the choice of temporal statistics for these pollutants, to (b) the duration and frequency of the relevant mode(s). This is shown below for NO_2.

Operational mode	Pollutant	Temporal Statistic	NAQS Objective ($\mu g/m^3$)
Short term (Stand-by)	NO_2	*100%ile of 1hour averages in a year*	*287*
Long term (Routine)	NO_2	*100%ile of 1hour averages in a year*	*287*
Long term (Routine)	NO_2	*Annual Average*	*40*

- It should be noted that the values of **Efflux velocity** for the Electro stack (15 and 17m/s) are within the acceptable range of 10 – 25 m/s. However, one of the values for the Meado Stack (10m/s) is at the lower end of this range, and an extra uncertainty of 15% therefore applies to impact estimates in this case.

8.3 Discharge Conditions

- The parameters listed on the worksheets under the **discharge conditions** section are used in the calculation of Efflux Heat (Q) and Momentum (M). Box 8.1 shows all the details of this calculation for normal operation of the Electro stack.

- The Electro power station only has one flue within its stack. However, many stacks will operate with more that one flue. This will require the calculation of a single **Equivalent Radius** (**r_{eq}**) to represent the effective combined radius of the individual flues as shown in Worksheet E2 for the Meado Stack.

Box 8.1: Summary of Calculations of Q and M for Normal Operation at Electro

Discharge Values

		Normal
• Volume flow of flue gas under release conditions,	V_{rel} (m^3/s) =	396
• Flue gas exit temperature,	T_{rel} (K) =	373
• Radius of stack,	r (m) =	2.9

Calculation

- Efflux Heat from the stack, Q, in MW
- Momentum of the exhaust gases , M, in m^4/s^2

$$Q\ (MW) = \frac{V_{rel}}{2.9} \cdot \left(1 - \frac{283}{T_{rel}}\right) \qquad M\ (m^4/s^2) = \frac{283}{T_{rel}} \cdot \frac{(V_{rel})^2}{\pi r^2}$$

Therefore for Electro, the Efflux Heat and Momentum of exhaust gases are:

$$Q = \frac{396}{2.9} \times \left(1 - \frac{283}{373}\right) = 33\ \text{MW} \qquad M = \frac{283}{373} \times \frac{(396)^2}{\pi (2.9)^2} = 4500\ m^4/s^2$$

8.4 Process Contribution and Assessment

- A value for the **Initial NGLC** is estimated using the air dispersion look-up charts found in Annex III of this Guidance. Box 8.2 shows how the look-up charts are used to estimate a value of Initial NGLC for one of the Electro Cases. Box 8.2 also gives information on how to convert the Initial NGLC into the Process Contribution PC in $\mu g/m^3$ using the Emission rate E for the operational mode used in the case. This calculation is also shown in the completed worksheet E3b.

- Box 8.3 shows how the **Predicted Environmental Concentration** was estimated in the Electro example using the annual average ambient NO_2 concentration **(AC)**.

Box 8.3 Obtaining the Annual Average PEC for Normal Emission of NO_2 for Electro

The ambient pollutant concentration (AC) is added to the process contribution from the appropriate cases to calculate the predicted environmental concentration (PEC) for that case. For example for Case 1.2 from Worksheet E3b, the annual average ambient NO_2 concentration, AC, near the Electro power station is 15 $\mu g/m^3$. This is added to the process contribution calculated for case 1.2 to give the predicted environmental concentration. It is then entered into the Worksheet E3b against PEC.

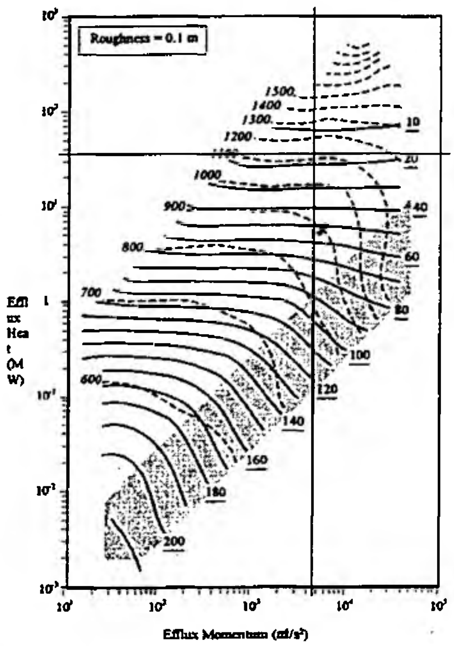
Annual average NO_2 PEC = AC + PC
= 15 + 0.765
= 15.8 $\mu g/m^3$

Box 8.2 Dispersion Estimate for Normal Operation at Electro

Look-up charts are used to assess the dispersion of the pollutants from the stack. A set of charts has been developed for different meteorological conditions, averaging periods, stack heights and surface roughness lengths. Thus for the Electro station the information used to select the appropriate chart is:

- Stack height: The stack height is 75m and there are sets of charts for 70m and 85m stack heights, so the chart for the lower stack height of 70m is selected, for a conservative approach.
- Surface roughness: 0.1 m as rural area, with mainly open grassland (see Table 2.1).
- Meteorological conditions: The set of charts developed with meteorological data from Type 1 (default) is selected (see Table 2.2).
- Discharge conditions: For normal conditions a heat of 33 MW and momentum of 4500 m^4/s^2 have been calculated (see Box 8.1).
- Temporal Statistics: Annual average, 99.9th percentile of 1-hour and 100th percentile of 1-hour are selected, dependent on case (see completed worksheets E1, E2, E3a/E & E3b/E).

Each chart represents a particular Met. Type, stack height and temporal statistic as indicated in Table 2.4. There are 4 panels on a chart, representing different surface roughnesses. Therefore for an annual average, with the characteristics noted above, the upper left panel of Chart Number 6 is appropriate. To find the Initial NGLC and the distance where it occurs for normal operational mode, the point of intersection of the relevant heat output and momentum value is found as shown below.



The Initial NGLC: Amount value is obtained by extrapolating between the solid lines, and the Initial NGLC: Distance value is obtained by extrapolating between the dotted lines. Therefore, for the Electro power station operating under normal conditions, the annual average Initial NGLC: Amount is 17 $ng/m^3/g/s$ and the corresponding Initial NGLC: Distances is 1120 m from the stack. Because the charted temporal statistic is the same as the criterion temporal statistic (both annual-average as entered on Worksheet E3a/E) there is no need to convert the Initial NGLC values which can therefore be entered as the Final: NGLC values. The process contribution from the stack is then obtained by multiplying the Final NGLC: Amount with the emission rate for the normal operational mode, which is 45 g/s (given in Box 8.1).

Process Contribution (PC) = Final NGLC x Emission rate
= 17 x 45
= 765 ng/m^3
= 0.765 $\mu g/m^3$

- The predicted environmental concentration (PEC) can be compared with relevant **Air Quality Criteria (AQC)** to assess the relative significance of the stack impacts e.g. for Local Air Quality Management purposes.

Table 8.1 is from Worksheet E3b/E and shows the ratios used to assess the NO_2 and SO_2 results for Electro in line with the advice given in Sections 6.3 and 6.4 . Case 1.2 is a long-term case (annual-average NO_2) and has PEC/AQC <70%, so that further analysis is probably unwarranted in this case. However, cases 1.1, 1.3 and 1.4 are short-term (100th percentile of 1-hour average NO_2, and 99.9th percentile of 15-minute SO_2,) and have PEC/AQC >40%, so that further analysis is probably warranted in all of these cases. This might involve reconsidering the conservatisms made, to check if a more realistic approach would significantly alter the calculated percentage; if not, it would be necessary to consider more detailed computer modelling.

The results discussed above are for operations at the Electro stack only. Cases involving possible combined impacts with the nearby 'Meado' stack are considered in the next section.

Table 8.1 Interpretation of NO_2 and SO_2 results for Electro

Stack Number:	1			
Case Number:	**1.1 (Short-term NO_2)**	**1.2 (Long-term NO_2)**	**1.3 (Short-term NO_2)**	**1.4 (Short-term SO_2)**
Predicted Environmental Concentration; PEC ($\mu g/m^3$)	130	15.8	180	201
Air Quality Criteria; AQC ($\mu g/m^3$)	287	40	287	266
PEC as % of AQC	45	40	63	76

8.5 Group Definition and Assessment

In study areas with more than one stack, scenarios showing the different possible stack combinations operating at specific averaging periods must be defined: Both Electro and Meado emit NO_2 and SO_2 and they both operate under normal and stand-by/upset operating modes as shown in Worksheets E3a/E, E3b/E, E3a/M and E3b/M.

- **Worksheet E4** shows the number of groups which can be defined for plausible combinations of cases as discussed in Section 7.2.

- Possible groups of combined stack impacts are composed by combining relevant case for the two individual stacks. There are a total of seven possible groups covering three combinations of pollutant and temporal statistic as indicated below:

  - NO_2 Long term: [1.2 & 2.2].
  - NO_2 Short term: [1.1 & 2.1], [1.1 & 2.3], [1.3 & 2.1], [1.3 & 2.3].
  - SO_2 Short term: [1.4 & 2.4], [1.4 & 2.5]

Where [1.2 & 2.2] refers to [Electro case 1.2 & Meado case 2.2] etc.

- The group definition and evaluation of the sum of process contributions part of Worksheet E4 is shown below in Table 8.2.

Table 8.2 Case Definition and Process Contributions from Worksheet E4

Group	Case Numbers and Details			Process Contributions	
	Cases in Group	Pollutant	Averaging period	PCs from the individual cases: from Worksheet E3b	GPC ($\mu g/m^3$)
A	1.1 & 2.1	NO_2	100%ile of 1 hour	90 + 40.3	130
B	1.1 & 2.3	NO_2	100%ile of 1 hour	90 + 43.2	133
C	1.3 & 2.1	NO_2	100%ile of 1 hour	140 + 40.3	180
D	1.3 & 2.3	NO_2	100%ile of 1 hour	140 + 43.2	183
E	1.2 & 2.2	NO_2	Annual Average	0.8 + 0.5	1.3
F	1.4 & 2.4	SO_2	99.9%ile of 15 mins	101 + 226	327
G	1.4 & 2.5	SO_2	99.9%ile of 15 mins	101 + 242	343

The GPEC and comparison with AQC section of Worksheet E4 is shown in Table 8.3. The predicted environmental concentration for a group is obtained in the same way as with a case. The sum of process contributions is added to the relevant ambient concentration value and compared with the air quality criterion.

In this example for two stacks, we can see that for NO_2 all the short-term impacts (Groups A-D) are estimated to give GPEC/AQC >40%, so that further analysis is probably warranted in these cases. However, the combined long-term impact for NO_2 (Group E) is estimated to give GPEC/AQC < 70% so that further analysis is probably unwarranted in this case. However, the short-term impacts of SO_2 (Groups F and G) are both predicted to give GPEC/AQC >100%, so that further analysis is fully justified in these cases. The above points of interpretation are summarised in the "Assessment/Options" section of Worksheet E4.

Table 8.3 GPEC and AQC comparison from Worksheet E4

GPEC and Comparison with AQC					
Group	Pollutant	AQC value $\mu g/m^3$ (timescale)	Ambient Concentration (AC) ($\mu g/m^3$)	GPEC ($\mu g/m^3$)	GPEC as % of AQC
A	NO_2	287 (short-term)	40	170	59
B	NO_2	287 (short-term)	40	173	60
C	NO_2	287 (short-term)	40	220	77
D	NO_2	287 (short-term)	40	223	78
E	NO_2	40 (long-term)	15	16.3	41
F	SO_2	266(short-term)	100	427	161
G	SO_2	266(short-term)	100	443	167

Worksheet E1: Basic Geographical Information

Stack No	1	2	Commentary
Stack Name	**Electro main stack**	**Meado main stack**	
Stack (including position and process type)	Located in the Midlands. The Electro stack releases the combustion products from a CCGT power station. (Add Ordnance Survey Co-ordinates)	Located in the Midlands. The Meado stack releases the combustion products arising from a brewery. (Add Ordnance Survey Co-ordinates)	
Extent of Study Area	Relatively flat rural area for 5km around the stack.	As for the Electro stack (stack 1)	*The Electro and Meado stacks are located in an open grassland area with relatively little surrounding development. The area considered at this stage should be approximately 5 km around each stack of interest.*
Surface Roughness (from Table 2.1)	0.1m owing to open grassland location	0.1m owing to open grassland location	*The Surface roughness should be estimated using the values in Table 2.1 in Chapter 2.*
Sensitive Receptors	The receptors of interest are human populations, who are potentially exposed over both short-term periods (e.g. at non-occupational locations) and long-term periods (e.g. at 2 schools and hospital)	As for the Electro stack (stack 1)	*The main receptors of interest are human beings. This has implications for the temporal statistics which will be used. The pollutants emitted from Electro & Meado (see Worksheet 2) mean that both long and short term air quality impacts are of interest for protection of human health.*
Met Type (from Table 2.2)	Type 1 (Default), corresponding to Elmdon. This choice is in keeping with the Midlands location of the Electro stack.	As for the Electro stack (stack 1)	*Elmdon is chosen due to the Inland location of both stacks.*

Worksheet E2: Basic Engineering Information

Stack No*	1	2	Commentary
Stack Name*	**Electro main stack**	**Meado main stack**	
Stack Height (including buildings)	75 m. There are no buildings of a height greater than 40% of the stack height within a distance of 5 stack heights.	62m. There are no buildings of a height greater than 40% of the stack height within a distance of 5 stack heights.	*This section of the worksheet should be used to record general information regarding the physical dimensions of the stack and neighbouring buildings.*
Operational Mode (including fuel type and periodicity of each mode)	The Electro stack has two modes: **Normal**: involves gas-firing for long periods. **Standby**: Involves oil firing for short periods	The Meado stack has two modes: **Normal**: Involves oil firing for long periods. **Upset**: Involves oil firing for short periods.	*The pollutants released by all operational modes should be considered and the type of receptors and the impact of the pollutants should be considered when assessing the temporal statistic to be used.*
Flues (including number of flues and their radii)	The main Electro stack only has one flue with a radius of 2.9m	The Meado stack has two flues of radii 0.48m. The equivalent radius is thus: $\sqrt{(0.48)^2 + (0.48)^2}$ = 0.68m	*Where the stack has 2 or more flues the equivalent radius is calculated using the formula given in Technical Note 12.*
Pollutants (including rates of emission and relevant air quality criteria)	NO_2 : 45 g/s normal 70 g/s standby SO_2 : 75 g/s standby NO_2 : Annual (normal) 100%ile of 1 hour (normal & standby) SO_2 : 99.9%ile of 15-minute (standby)	NO_2 : 4.2 g/s normal 5.9 g/s upset SO_2 : 26.3 g/s normal 36.9 g/s upset NO_2 : Annual (normal) 100%ile of 1 hour (normal & upset) SO_2 : 99.9%ile of 15-min (normal & upset)	*When defining cases it is important to consider all operational modes of the plant and the pollutants which these modes release.*
Release Temperature	The release temperature is: 373 K (normal) 413 K (standby)	The release temperature is: 416 K (normal) 473 K (upset)	
Release Velocity	The efflux velocity is: 15 m/s (normal) 17 m/s (standby)	The efflux velocity is: 10 m/s (normal) 14.3 m/s (upset)	

*Copy from Worksheet 1

Worksheet E3a/E: Case Definition and Dispersion Estimates

Stack Number:			1				
Case Number:			1.1	1.2	1.3	1.4	
Case Definition Discharge Conditions	Outline description		Electro stack. 2 operational modes: Normal and Stand-by. There are 3 sensitive receptors in the area: 2 schools and a hospital. Target organism is human being. Case 1.1 is Normal Operation, with AQC = NAQS short term NO_2 objective	As for case 1.1 AQC = NAQS long term NO_2 objective	As for case 1.1 but Stand-by operational mode AQC = NAQS short term NO_2 objective	As for case 1.1 but Stand-by operational mode AQC =NAQS SO_2 objective	
	Mode / Pollutant		Normal / NO_2	Normal / NO_2	Stand-by / NO_2	Stand-by / SO_2	
	Met Type (Site)		1 (Elmdon)	1 (Elmdon)	1 (Elmdon)	1 (Elmdon)	
	Temporal Statistic	Criterion	100% of 1hour	Annual Average	100% of 1hour	99.9%ile of 15 minutes	
		Charted	"	"	"	99.9%ile of 1 hour	
	Stack Height	Actual	75	75	75	75	
		Charted	70	70	70	70	
	Chart Number		28	6	28	17	
	Surface Roughness (m)		0.1	0.1	0.1	0.1	
	Flues	Number	1	1	1	1	
		Radii	2.9	2.9	2.9	2.9	
	Release Temperature: T_{rel} (K)		373	373	413	413	
	Release Velocity: w (m/s)		15	15	17	17	
	Pollutant Emission Rate; E (g/s)		45	45	70	75	
Discharge Conditions	Equivalent Radius: r_{eq} (m)		2.9	2.9	2.9	2.9	
	Volume Flow: V_{rel} (m^3/s)		396	396	450	450	
	Efflux Heat Q (MW)		33	33	48.8	48.8	
	Efflux Momentum M (m^4/s^2)		4500	4500	5250	5250	

Worksheet E3b/E: Process Contributions and Assessment

Stack Number *:			1				
Case Number *:			1.1	1.2	1.3	1.4	
Estimate of Pollutant Dispersion	Initial NGLC (Amount = ng/m³/g/s)	Amount	2000	17	2000	1000	
		Distance (m)	1060	1120	1070	920	
	Conversion required		✗	✗	✗	✓	
	Conversion factors	Amount				1.34	
		Distance				1	
	Final NGLC (Amount = ng/m³/g/s)	Amount	2000	17	2000	1340	
		Distance	1060	1120	1070	920	
	Process Contribution PC (ng/m³)		90,000	765	140,000	101,000	
	Process Contribution PC (µg/m³)		90	0.8	140	101	
AC & PEC	Ambient Concentration; AC (µg/m³)		40	15	40	100	
	Predicted Environmental Concentration; PEC (µg/m³)		130	15.8	180	201	
cf. AQC	Air Quality Criterion; AQC (µg/m³)		287	40	287	266	
	PEC as % of AQC		45	40	63	76	
Assessment / Options:			Initial NGLC estimated by extrapolating to highest adjacent contour. AQC value taken from the National Air Quality Strategy. AC value derived from DETR national air quality monitoring network. 1.1 is a short-term case and more analysis is probably warranted since PEC >40% of AQC	AQC value taken from the National Air Quality Strategy. AC value derived from DETR national air quality monitoring network. More analysis is probably unwarranted since PEC <70% AQC for this long-term case.	Initial NGLC estimated by extrapolating to highest adjacent contour. AQC value taken from the National Air Quality Strategy. AC value derived from DETR national air quality monitoring network. More analysis is probably warranted since PEC >40% of AQC for this short-term case.	AQC value taken from the National Air Quality Strategy. AC value derived from DETR national air quality monitoring network. More analysis is probably warranted since PEC > 40% AQC for this short-term case.	

* Copy from preceding Worksheet

Worksheet E3a/M: Case Definition and Dispersion Estimates

Stack Number:			2				
Case Number:			2.1	2.2	2.3	2.4	2.5
Case Definition Discharge Conditions	Outline description		Meado Stack: Stack has 2 operational modes: Normal and Upset. There are 3 sensitive receptors in the area: 2 schools and a hospital. Target organism is human being. Case 2.1 is Normal Operation. AQC is NAQS short term NO_2 objective	As for case 2.1 AQC is NAQS long term NO_2 objective	As for case 2.1 but Upset operational mode AQC is NAQS short term NO_2 objective	As for case 2.1 AQC is NAQS SO_2 objective	As for case 2.1 but Upset operational mode AQC is NAQS SO_2 objective
	Mode / Pollutant		Normal / NO_2	Normal / NO_2	Up-set / NO_2	Normal / SO_2	Up-set / SO_2
	Met Type (Site)		1 (Elmdon)	1 (Elmdon)	1 (Elmdon)	1 (Elmdon)	1 (Elmdon)
	Temporal Statistic	Actual	100%ile of 1 hour	Annual Average	100%ile of 1 hour	99.9%ile of 15 minutes	99.9%ile of 15 minutes
		Charted	"	"	"	99.9%ile of 1 hour	99.9%ile of 1 hour
	Stack Height	Actual	62	62	62	62	62
		Charted	60	60	60	60	60
	Chart Number		27	5	27	16	16
	Surface Roughness (m)		0.1	0.1	0.1	0.1	0.1
	Flues	Number	2	2	2	2	2
		Radii(m)	both 0.48	both 0.48	both 0.48	both 0.48	both 0.48
	Release Temperature: T_{rel} (K)		416	416	473	416	473
	Release Velocity: w (m/s)		10	10	14.3	10	14.3
	Pollutant emission rate; E (g/s)		4.2	4.2	5.9	26.3	36.9
Discharge Conditions	Equivalent Radius: r_{eq} (m)		0.68	0.68	0.68	0.68	0.68
	Volume Flow: V_{rel} (m^3/s)		14.7	14.7	21.0	14.7	21.0
	Efflux Heat Q (MW)		1.61	1.61	2.91	1.61	2.91
	Efflux Momentum M (m^4/s^4)		99.9	99.9	180	99.9	180

Worksheet E3b/M: Process Contributions and Assessment

Stack Number*:			2				
Case Number *:			2.1	2.2	2.3	2.4	2.5
Estimate of Pollution Dispersion	Initial NGLC (Amount = ng/m³/g/s)	Amount	9600	115	7330	6400	4900
		Distance (m)	200	635	195	250	300
	Conversion required		✗	✗	✗	✓	✓
	Conversion factors	Amount				1.34	1.34
		Distance				1	1
	Final NGLC (Amount = ng/m³/g/s)	Amount	9600	115	7330	8576	6566
		Distance	200	635	195	250	300
	Process Contribution PC (ng/m³)		40,300	483	43,200	226,000	242,000
	Process Contribution PC (µg/m³)		40.3	0.5	43.2	226	242
AC & PEC	Ambient Concentration; AC (µg/m³)		116	50	116	88	88
	Predicted Environmental Concentration; PEC (µg/m³)		156	50.5	159	314	330
cf. AQC	Air Quality Criterion; AQC (µg/m³)		287	40	287	266	266
	PEC as % of AQC		54	126	55	118	124
Assessment / Options:			AQC taken from NAQS. AC value derived from DETR national air quality monitoring network. More analysis is probably warranted since PEC > 40% AQC for this short-term case.	AQC taken from NAQS. AC value derived from DETR national air quality monitoring network. More analysis is fully justified since PEC >AQC.	AQC taken from NAQs. AC value derived from DETR national air quality monitoring network. More analysis is probably warranted since PEC > 40% AQC for this short-term case.	AQC taken from NAQS. AC value derived from DETR national air quality monitoring network. More analysis is fully justified since PEC > AQC.	AQC taken from NAQS. AC value derived from DETR national air quality monitoring network. More analysis is fully justified since PEC > AQC.

* Copy from preceding Worksheet

Worksheet E4: Impact Estimates for Stack Groups

Group	Details of Cases in Group			Process Contributions		Group Predicted Environmental Concentration (GPEC) and Comparison with Air Quality Criterion (AQC)				Assessment/Options
	Reference Numbers	Pollutant	Temporal Statistic	For each case (PC, μg/m³)	For Group (GPC, μg/m³)	Ambient Concentration (AC, μg/m³)	GPEC (μg/m³)	AQC (μg/m³)	GPEC as % of AQC	
A	1.1 & 2.1	NO_2	100%ile of 1 hour	90 + 40.3	130	40	170	287	59	More analysis probably warranted since GPEC > 40% of AQC for this short-term case.
B	1.1 & 2.3	NO_2	100%ile of 1 hour	90 + 43.2	133	40	173	287	60	More analysis probably warranted since GPEC > 40% of AQC for this short-term case.
C	1.3 & 2.1	NO_2	100%ile of 1 hour	140 + 40.3	180	40	220	287	77	More analysis probably warranted since GPEC >40% of AQC for this short-term case.
D	1.3 & 2.3	NO_2	100%ile of 1 hour	140 + 43.2	183	40	223	287	78	More analysis probably warranted since GPEC >40% of AQC for this short-term case.
E	1.2 & 2.2	NO_2	Annual Average	0.8 + 0.5	1.3	15	16.3	40	41	More analysis probably unwarranted since GPEC <70% of AQC for this long-term case.
F	1.4 & 2.4	SO_2	99.9%ile of 15 minutes	101 + 226	327	100	427	266	161	More analysis fully justified by GPEC >AQC
G	1.4 & 2.5	SO_2	99.9%ile of 15 minutes	101 + 242	343	100	443	266	167	More analysis fully justified by GPEC >AQC

9. TECHNICAL NOTES

This chapter contains a series of numbered technical notes which have been referenced by superscript numbers in chapters 1 – 7. The notes explain important technical caveats or assumptions which are more conveniently presented here, so as to avoid interrupting the flow of the main text, as explained in the Preface.

[1] The criterion associated with this caveat is that the ground must not rise above the stack height within a distance of ten stack heights. This can be checked by using an Ordnance Survey map. This is a generally accepted rule of thumb for effects of sloping terrain on dispersion (taken from Technical Guidance Note (Dispersion) D1).

[2] The criterion associated with this caveat is that there must be no buildings closer than five stack heights that are taller than 40% of the stack height. This can be checked by using a site map, a local area map from the Planning Department at the Local Authority, or by a site visit. This criterion is a generally accepted rule of thumb for avoiding situations where buildings affect dispersion (based on Technical Guidance Note (Dispersion) D1).

[3] It is assumed that the release has the same density as air would have at the relevant release temperature and has some positive buoyancy relative to the ambient atmosphere. If this is not approximately the case then the Guidance methodology will not be applicable because e.g. plumes which are significantly denser than air will not disperse normally but will slump downwards on leaving the stack.

[4] The grey-shaded areas on the bottom of the charts are needed because of a discrepancy in the values of ambient temperature used in a) the model and b) the individual calculations on which the charts are based. In practice the discrepancy is only significant for situations involving plumes whose temperatures are within a few degrees of the ambient temperature; these situations correspond to the grey areas, where the discrepancy introduces an extra uncertainty.

The extra uncertainty arises because the temperature assumed for ambient (namely 15°C) is higher than or equal to the temperatures used for chart calculation in the grey areas (namely 10.5°C and 15°C), so that these calculations were effectively for emissions slightly colder than ambient. Trial calculations were undertaken to investigate the scale of the extra uncertainty and to establish an appropriate course of action. The possibility of excluding the relevant contours from the charts was considered, but the trial calculations showed that although the effect of the temperature discrepancy was significant it did not negate the value of the contours for rough scoping purposes. The contours are therefore included but with the caveat of additional uncertainty as noted in the text. When calculating values of efflux heat (Q) and efflux momentum (M) with this Guidance, the ambient temperature should be assumed to be 283K (10^0C) so that the values obtained are consistent with the method used to define grey areas and hence with the advice to allow for greater uncertainty in these areas.

[5] All air-quality criteria apply to a specific averaging time (e.g. 15 minutes, 1 hour, 1 year), and some also apply to particular percentiles of concentration values over a defined period (e.g. to the 99.9^{th} percentile of 15-minute averages over a calendar year). The "temporal statistic" of an air-quality criterion is its overall time basis as given by the averaging time, and by the percentile and period of values where relevant. The term applies similarly to impact estimates, which are commonly made on the same time bases as air quality criteria so that the estimates can be readily compared with the criteria.

[6] The mass emission rate of a pollutant can be derived from several sources of information including: the results of monitoring equipment associated with the source, the process guidance limit, information on fuel and combustion conditions, and historical data for a similar process. The Environmental Analysis Co-operative (1995) has given general advice on estimating source emission rates.

[7] The methodology assumes that the velocity is 15 m/s. This is the generally recommended minimum value given in Technical Guidance Note (Dispersion), D1. However, it must be noted that if the velocity is sufficiently different from 15 m/s there will be an error associated with the end result. A limited sensitivity test over a range of velocities (10–25 m/s) using a 100m stack height, 0.1 roughness length and the Elmdon Met type, suggested that this error is in the order of 15%.

[8] The temporal statistic of the NAQs objective for 1,3 Butadiene is a running annual average ie the highest average for any 12-month period ending in a given calendar year. This statistic is somewhat different to that for the charts of annual averages which simply show averages for the 12-month period January-December. The difference between the running and January-December annual averages will tend to make the concentration amounts obtained from the charts lower than the amounts which would have been obtained on a running average basis. However, this tendency has been taken into account later in the Guidance, when giving advice on when it may be necessary to consider doing more detailed modelling and analysis. In view of this advice it is appropriate for practical scoping purposes to indicate that the available annual-average charts correspond to the required temporal statistic of the NAQs objective ie. to put YES in column 3 of Table 2.3.

[9] The temporal statistic of the NAQs objective for 1,3 Benzene is a running annual average ie the highest average for any 12-month period ending in a given calendar year. This statistic is somewhat different to that for the charts of annual averages which simply show averages for the 12-month period January-December. The difference between the running and January-December annual averages will tend to make the concentration amounts obtained from the charts lower than the amounts which would have been obtained on a running average basis. However, this tendency has been taken into account later in the Guidance, when giving advice on when it may be necessary to consider doing more detailed modelling and analysis. In view of this advice it is appropriate for practical scoping purposes to indicate that the available annual-average charts correspond to the required temporal statistic of the NAQs objective ie. to put YES in column 3 of Table 2.3.

[10] The NAQS objective is based on evaluating the highest 24-hour running mean for each day in the year, ranking these means, and then requiring that the 4th ranked mean does not exceed $50\mu g/m^3$.

[11] The height of the emission affects the distance the plume will travel before reaching ground level and so it is important to choose the most appropriate stack height. As explained in the main text, if the height of the stack under study falls between two values assume the stack height is equal to the lower value, to be conservative. The range of heights in the Guidance has been derived from real examples found in '*An Assessment of the Effects of Industrial Releases of Nitrogen Oxides in the East Thames Corridor*' (HMIP, 1993).

[12] If there are multiple flues in the stack, calculate an equivalent radius, using the equation:

$$r_{eq} = \sqrt{r_1^2 + r_2^2 + \dots + r_n^2}$$

where r_{eq} = the calculated radius for the combined flues in the stack
r_1 = the radius of one of the flues in the stack
r_2 = the radius of a second flue in the stack
r_n = the radii of subsequent flues in the stack

[13] Equation for calculating volume flow rate: $V_{rel} = w.\pi.r^2$

Where w = velocity of pollutant release
V_{rel} = volume flow rate of pollutant release
r^2 = the square of the radius of the flue (or the square of the effective radius if there are two or more flues)

[14] A series of nomograms for estimating values of Q and M can be found in Technical Guidance Note (Dispersion) D1.

[15] Adapted from D. Bruce Turner. Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modelling, 2nd edition, 1994.

[16] This factor is suggested as it is assumed that the meteorological conditions and plume trajectories which give rise to the maximum ground level concentration over a one hour averaging period are likely to be similar to those for the fifteen minute periods which make up that hour. Therefore, in the absence of any data to contrary, a factor of 1 is proposed.

[17] This factor is based on sample calculations for a range of stacks from 30m to 150m in height, and using efflux parameters towards the centre of the charted values of Q and M. Factors were obtained by dividing results for NAQS objective statistics (calculated with sequential meteorological data) by results for charted similar statistics (calculated with statistical meteorological data). The sample gave a range of factors from 0.55 (150m stack) to 0.73 (30m stack). A conversion factor of 0.7 is entered for reasons of conservatism.

[18] This factor is based on calculations similar to those described in Technical Note 17. This sample gave a range of factors from 1.35 – 1.87. A conversion factor of 2 is entered as this will result in the definition of a conservative range of potential stack impacts i.e. a range towards the upper bound of the sample.

[19] This factor is based on calculations similar to those described in Technical Note 17. This sample gave a range of factors from 0.19 (150m stack) to 0.62 (30m stack). A conversion factor of 0.6 is entered for reasons of conservatism.

[20] This factor is based on calculations similar to those described in Technical Note 17. This sample gave a range of factors from 1.07 – 2.00. A conversion factor of 2 is entered as this will result in the definition of a conservative range of potential stack impacts i.e. a range towards the upper bound of the sample.

[21] The effective range of stack impacts was investigated by calculating ground level concentration profiles along a line from the stack through the position of maximum concentration, for a sample of cases. The effective range was taken as the distance beyond the maximum at which concentrations had fallen to 25% of the maximum, and was expressed as a multiple of the distance to maximum. It was found that there was a wide variation in the resulting effective ranges, so that it was not possible to characterise these ranges by a single value of the multiple. The best general guidance that can be given is that the effective ranges of stack impacts defined on this basis are likely to be several multiples of the distance to maximum e.g. 5 – 10 times this distance.

[22] The DETR national monitoring network covers pollutants such as SO_2, NO_x, O_3, CO, fine particulates (PM_{10}), 25 hydrocarbons, black smoke, lead, cadmium, chromium, cobalt, iron, manganese nickel, vanadium, zinc, dioxins, furans, PCBs and PAHs.

These data are available from the National Environmental Technology Centre at AEA Technology, Culham, Abingdon, Oxfordshire. Tel: 01235 463072. Fax: 01235 463011. Data are also available via the Internet. Internet address: http://www.environment.detr.gov.uk/airq/aqinfo.html or http://www.aeat.co.uk/netcen/airqual/welcome.html

Many local authorities undertake monitoring in their area and therefore may be another source of information on local air quality. The Environmental Analysis Co-operative (1995, 1999) has given general advice on estimating ambient concentrations.

10. REFERENCES

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ANNEX I

Worksheets

EXPLANATION OF WORKSHEETS

The worksheets in this annex are for use in conjunction with the guidance given in this document. They can help to give a clear and auditable record of the work carried out by the user.

This annex contains five blank worksheets which are provided as master copies, which can be reproduced when needed. The procedure for completing worksheets is explained in each chapter and illustrated in the worked example in chapter 8.

The five worksheets are:

Worksheet 1:	Basic Geographical Information
Worksheet 2:	Basic Engineering information
Worksheet 3a:	Case Definition and Dispersion Estimates
Worksheet 3b:	Process Contributions and Assessment
Worksheet 4:	Impact Estimates for Stack Groups

It should be noted that worksheets 3a and 3b have been designed as a pair of worksheets which lie on facing pages, so that information can be readily cross-referenced between them.

Worksheet 1: Basic Geographical Information

Stack No	Stack Name	Stack (including position and process type)	Study Area	Surface Roughness (from Table 2.1)	Receptors	Met Type (from Table 2.2)
1						
2						
3						

Worksheet 2: Basic Engineering Information

Stack No	1	2	3
Stack Name*			
Stack Height (including buildings)			
Operational Mode (including fuel type and periodicity of each mode)			
Flues (including number of flues and their radii)			
Pollutants (including rates of emission and relevant air quality criteria)			
Release Temperature			
Release Velocity			

*Copy from Worksheet 1

Worksheet 3a: Case Definition and Dispersion Estimates

Stack Number:							
Case Number:							
Case Definition	Outline description						
	Mode / Pollutant		/	/	/	/	/
	Met Type (Site)						
	Temporal Statistic	Criterion					
		Charted					
	Stack Height	Actual					
		Charted					
	Chart Number						
	Surface Roughness (m)						
	Flues	Number					
		Radii					
	Release Temperature: T_{rel} (K)						
	Release Velocity: w (m/s)						
	Pollutant Emission Rate; E (g/s)						
Discharge Conditions	Equivalent Radius: r_{eq} (m)						
	Volume Flow: V_{rel} (m^3/s)						
	Efflux Heat Q (MW)						
	Efflux Momentum M (m^4/s^2)						

Worksheet 3b: Process Contributions and Assessment

Stack Number *:							
Case Number *:							
Estimate of Pollutant Dispersion	Initial NGLC (Amount = ng/m^3/g/s)	Amount					
		Distance (m)					
	Conversion required						
	Conversion factors	Amount					
		Distance					
	Final NGLC (Amount = ng/m^3/g/s)	Amount					
		Distance					
	Process Contribution PC (ng/m^3)						
	Process Contribution PC (μg/m^3)						
AC & PEC	Ambient Concentration; AC (μg/m^3)						
	Predicted Environmental Concentration; PEC (μg/m^3)						
cf. AQC	Air Quality Criteria; AQC (μg/m^3)						
	PEC as % of AQC						
Assessment / Options:							

* Copy from preceding Worksheet

Worksheet 4 : Impact Estimates for Stack Groups

Group	Details of Cases in Group			Process Contributions		Group Predicted Environmental Concentration (GPEC) and Comparison with Air Quality Criterion (AQC)				Assessment/Options
	Reference Number	Pollutant	Temporal Statistic	For each case (PC, µg/m³)	For Group (GPC, µg/m³)	Ambient Concentration (AC, µg/m³)	GPEC (µg/m³)	AQC (µg/m³)	GPEC as % of AQC	

ANNEX II

National Air Quality Strategy Objectives

The specific Objectives from UK National Air Quality Strategy National Air Quality Strategy are outlined in Table II.I using units of mass per unit volume. This table also includes the original EPAQS standards which were used when developing the Objectives. With the exception of ozone, the Objectives are now in regulation; however they are currently being reviewed, so may need to be updated in due course.

Table II.1 Standards and Specific Objectives from UK National Air Quality Strategy

Pollutant	Standard		Specific Objective by 2005
	Concentration ($\mu g/m^3$) (i)	Measured as	(ug/m^3) (i)
Benzene	16	running annual mean	16
1,3-Butadiene	2	running annual mean	2
CO	11,650	running 8-hour mean	11,650
Lead	0.5	annual mean	0.5
NO_2	287	1-hour mean	287 measured as 100th percentile of 1 hour
	40	annual mean	40
Ozone	100	running 8-hour mean	100 measured as 97th percentile
PM_{10}	50	running 24-hour mean (ii)	50 measured as 99th percentile
SO_2	266	15-minute mean	266 measured as 99.9th percentile

(i) Values for all pollutants, except PM10 are converted from concentration expressed on a volume per unit volume basis (i.e. ppb or ppm), as specified in the NAQS, to concentration expressed on a mass per unit volume basis. The temperature assumed for this conversion is 20°C.

(ii) Based on evaluating the highest 24-hour running mean for each day in the year, ranking these means, and the requiring that the 4th ranked mean does not exceed 50$\mu g/m^3$.

ANNEX III

Air Dispersion Look-up Charts

ANNEX III - Air Dispersion Look-up Charts

This annex contains the air dispersion look-up charts that are described under "chart number" in section 2.4 of Chapter 4.The reference numbers of the charts are as given in the following table.

Chart Numbers for Maximum Ground Level Concentration Charts

Met Type	Temporal Statistic	Stack Height										
		20m	30m	40m	50m	60m	70m	85m	100 m	120m	150 m	200m
Type 1 (Default)	Annual	1	2	3	4	5	6	7	8	9	10	11
	99.9%ile	12	13	14	15	16	17	18	19	20	21	22
	100%ile	23	24	25	26	27	28	29	30	31	32	33
Type 2 (East Coast)	Annual	34	35	36	37	38	39	40	41	42	43	44
	99.9%ile	45	46	47	48	49	50	51	52	53	54	55
	100%ile	56	57	58	59	60	61	62	63	64	65	66
Type 3 (Channelled)	Annual	67	68	69	70	71	72	73	74	75	76	77
	99.9%ile	78	79	80	81	82	83	84	85	86	87	88
	100%ile	89	90	91	92	93	94	95	96	97	98	99

Chart 1	Maximum Ground Level Concentration	Annual Average	20m Stack	Elmdon (Met Type 1) ADMS 2

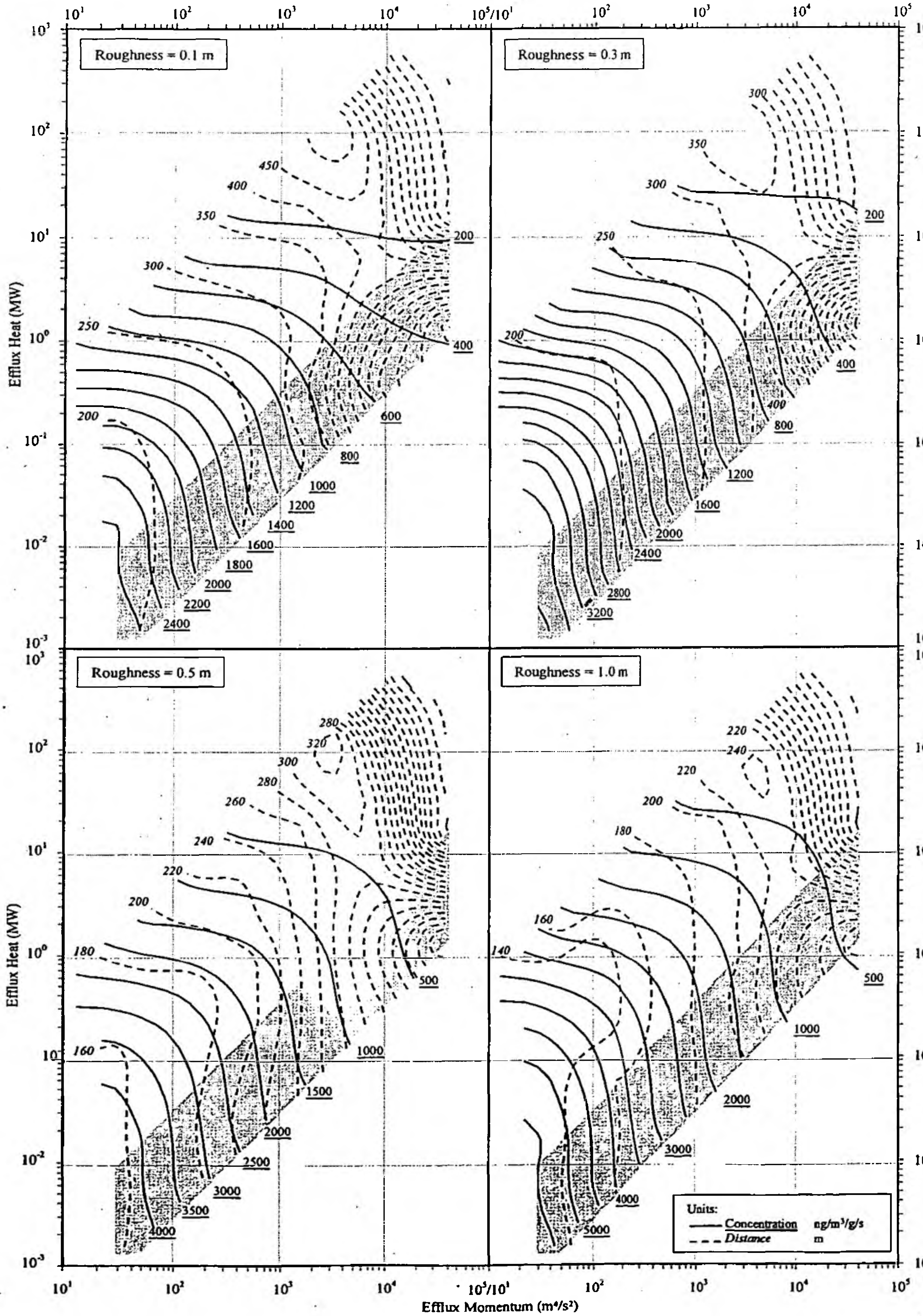


Chart 2	Maximum Ground Level Concentration	Annual Average	30m Stack	Elmdon (Met Type 1)	ADMS2

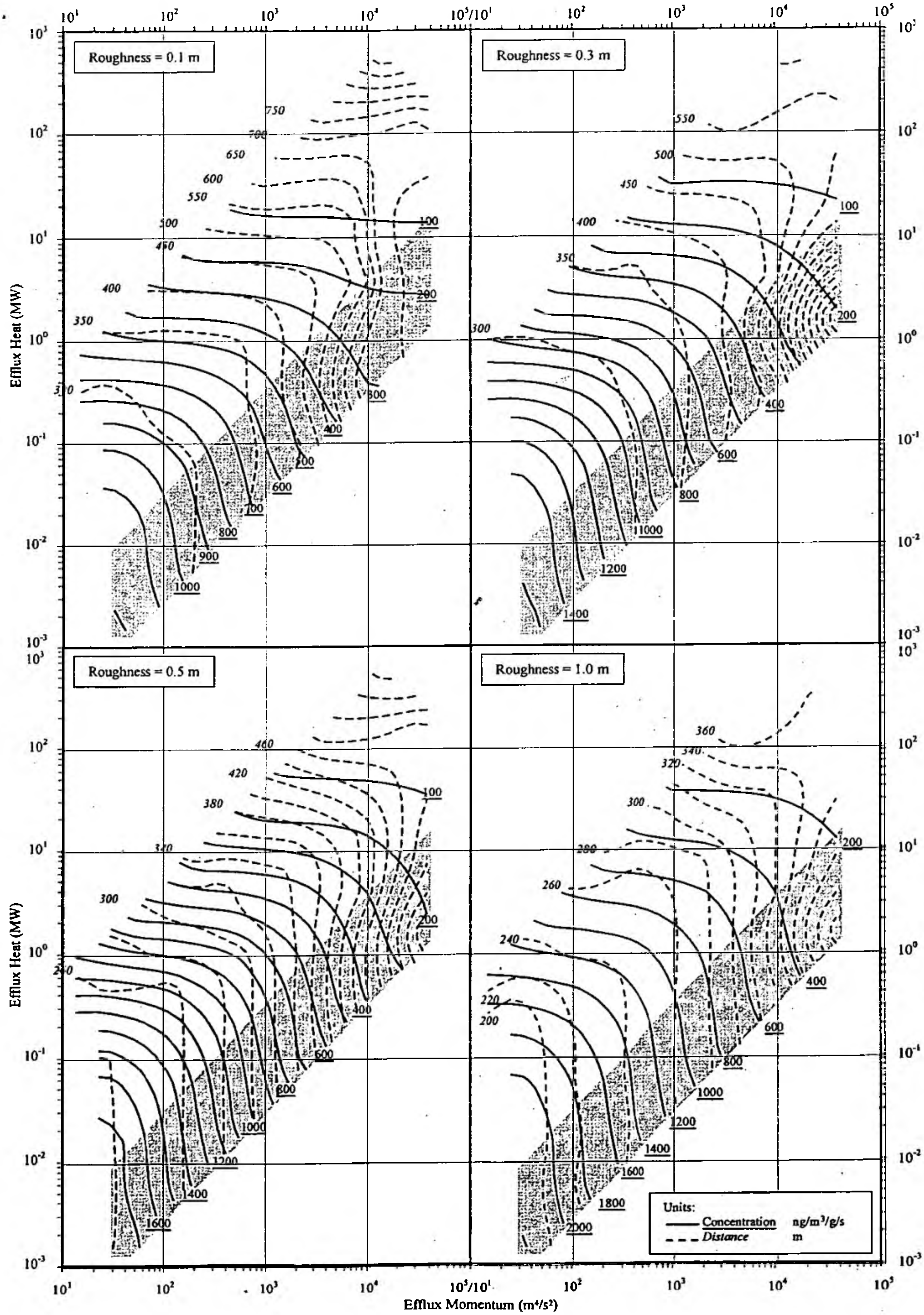


Chart 3	Maximum Ground Level Concentration	Annual Average	40m Stack	Elmdon (Met Type 1)	ADMS2

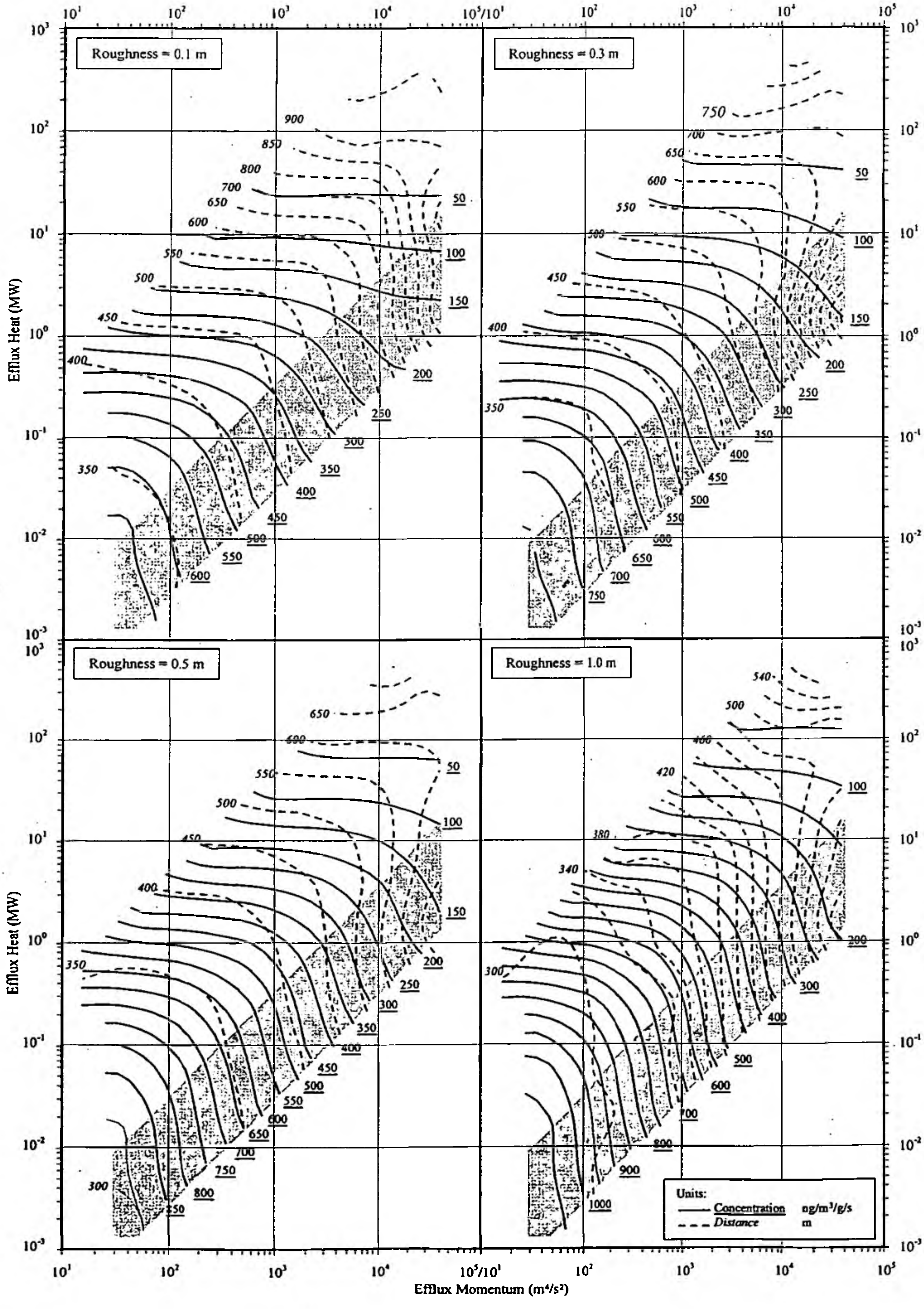


Chart 4	Maximum Ground Level Concentration	Annual Average	50m Stack	Elmdon (Met Type 1)	ADMS2

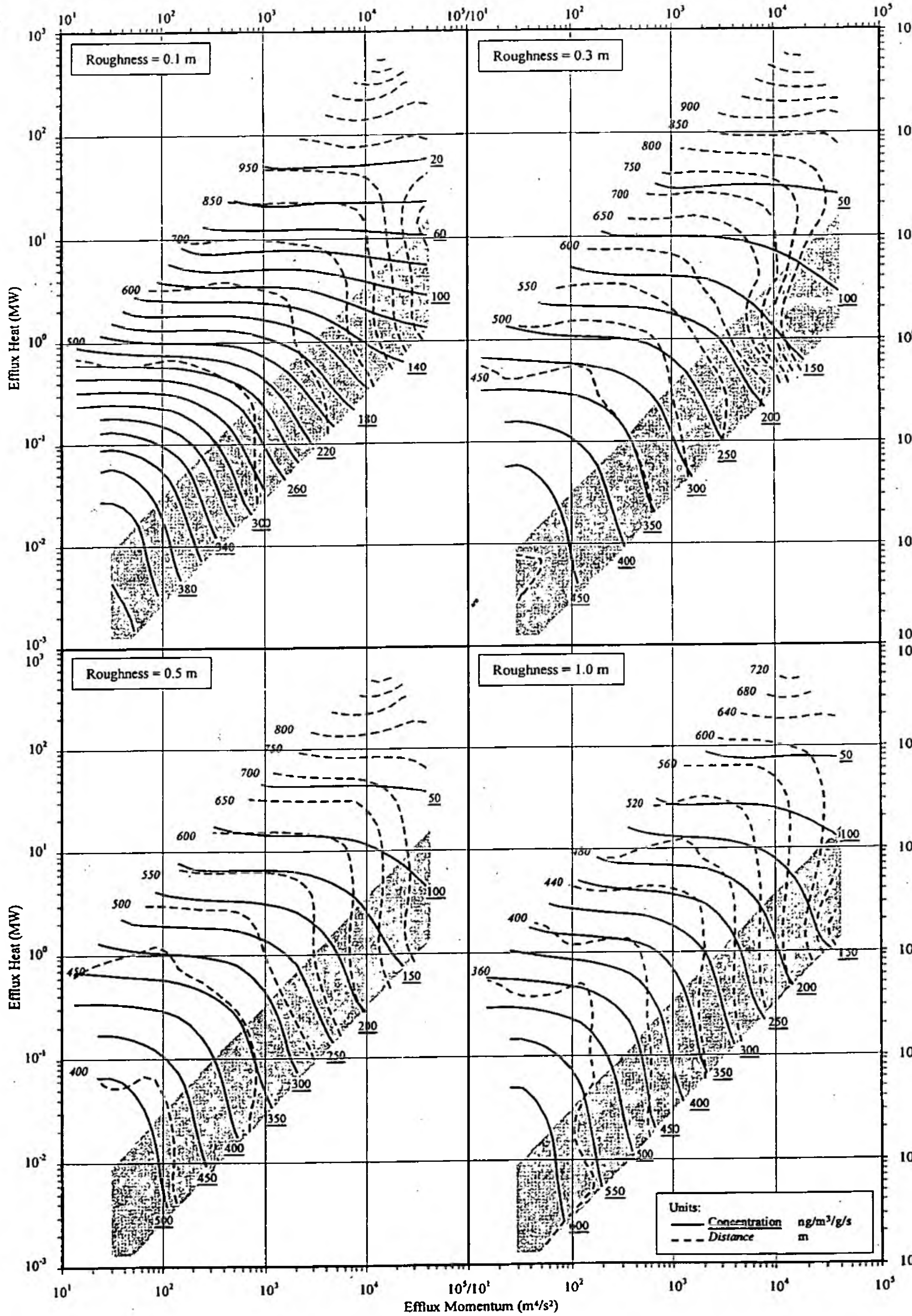


Chart 5	Maximum Ground Level Concentration	Annual Average	60m Stack	Elmdon (Met Type 1)	ADMS2

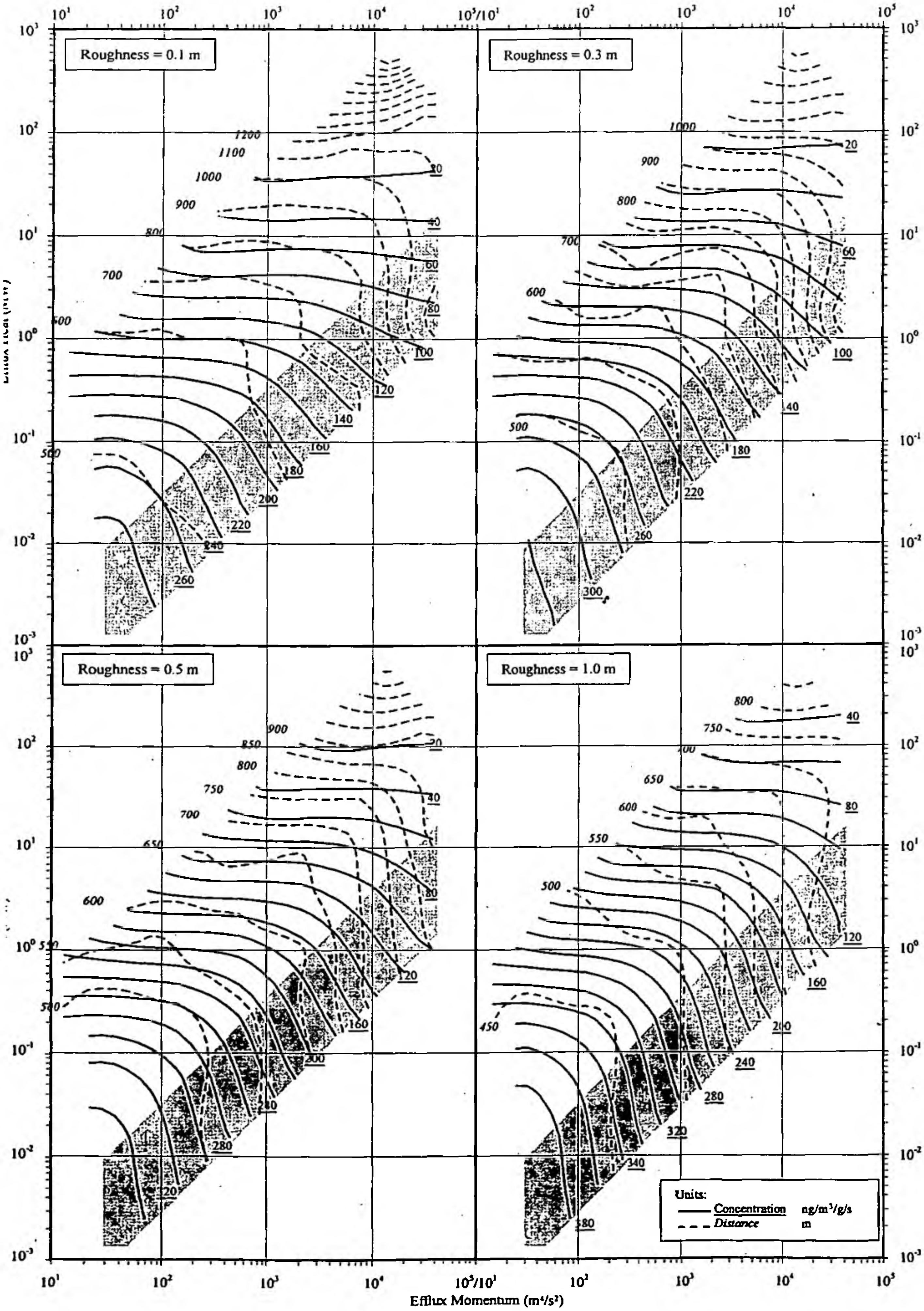


Chart 6	Maximum Ground Level Concentration	Annual Average	70m Stack	Elmdon (Met Type 1)	ADMS2

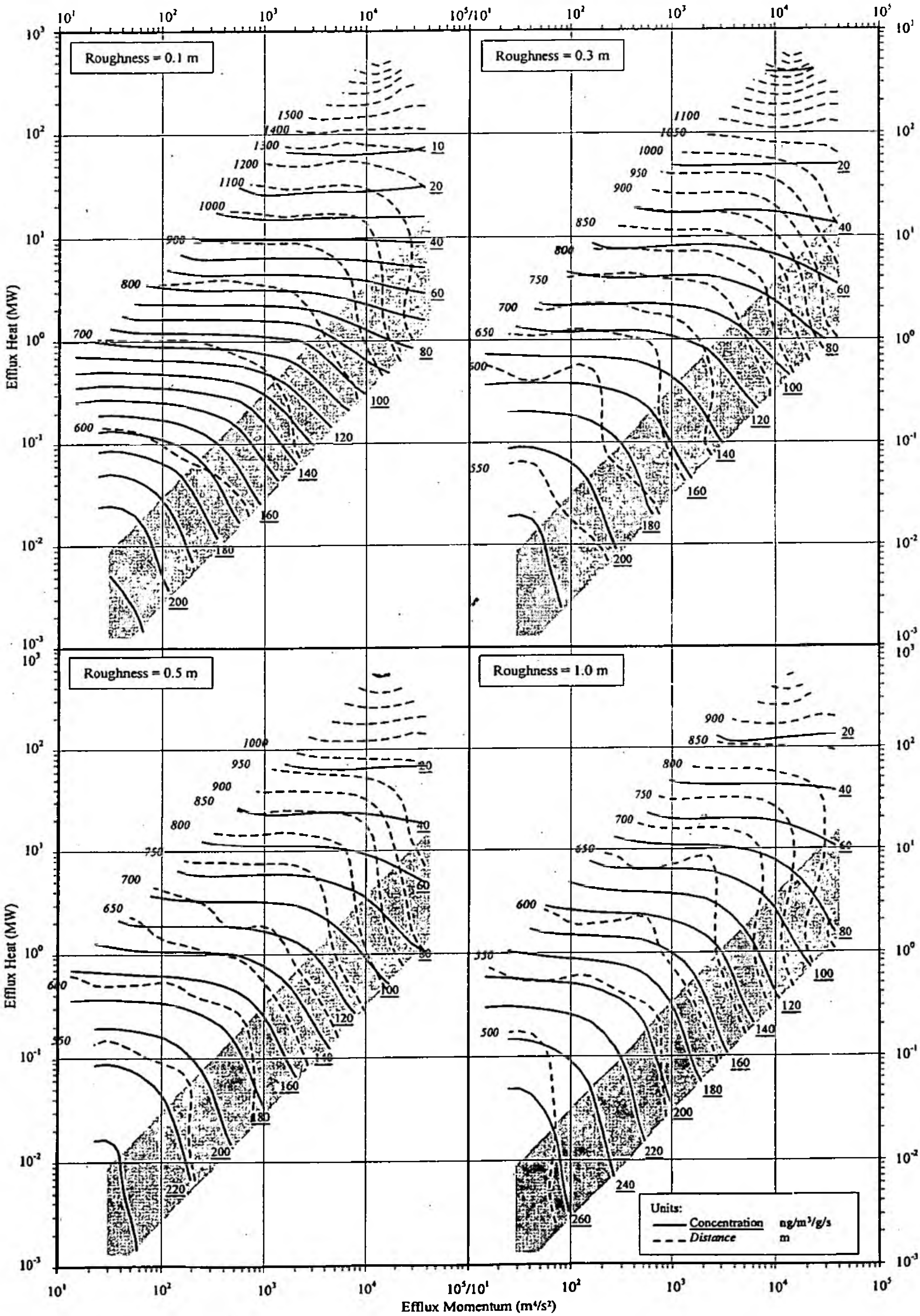


Chart 7	Maximum Ground Level Concentration	Annual Average	85m Stack	Elmdon (Met Type 1)	ADMS2

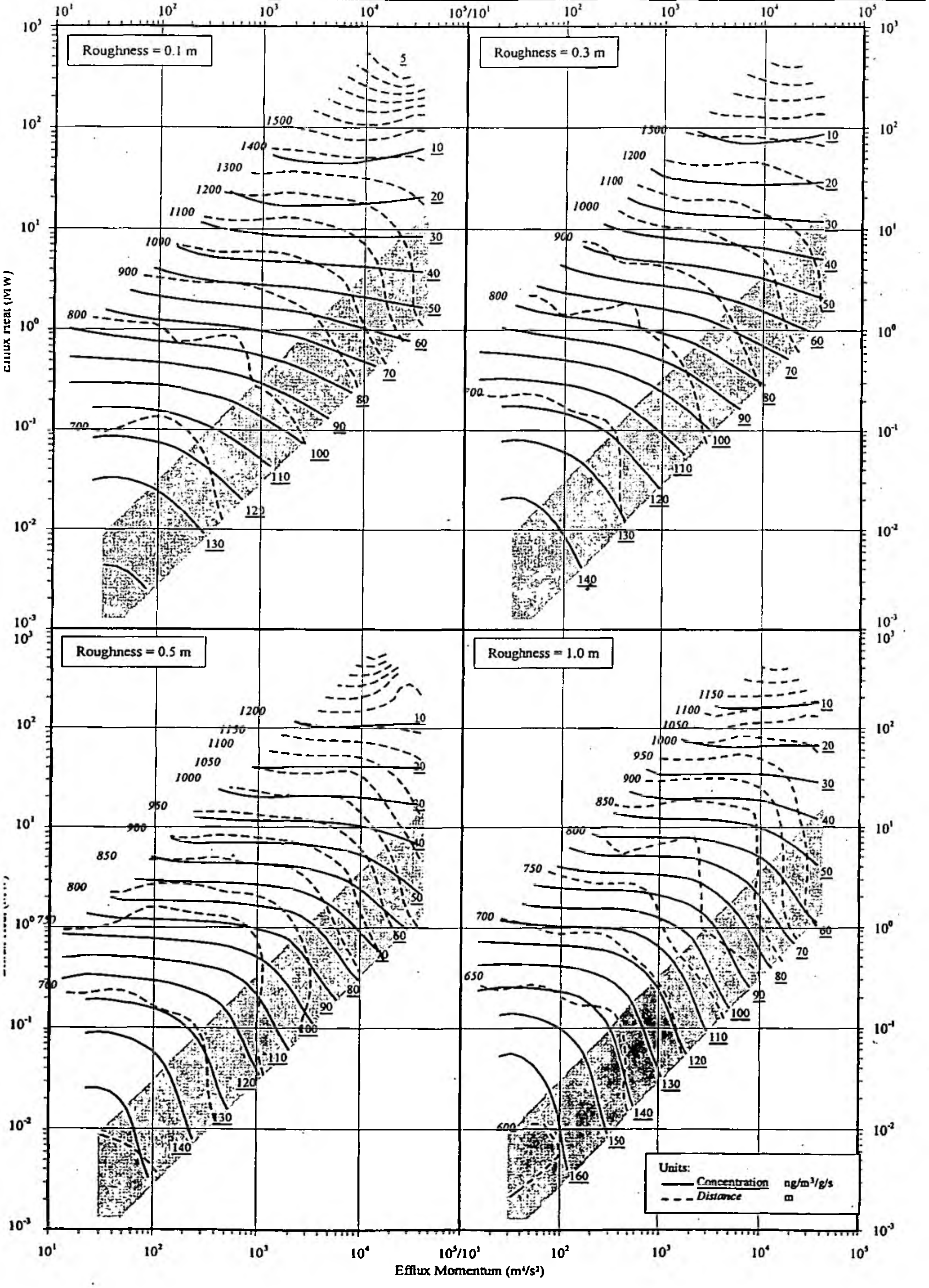


Chart 8	Maximum Ground Level Concentration	Annual Average	100m Stack	Elmdon (Met Type 1)	ADMS2

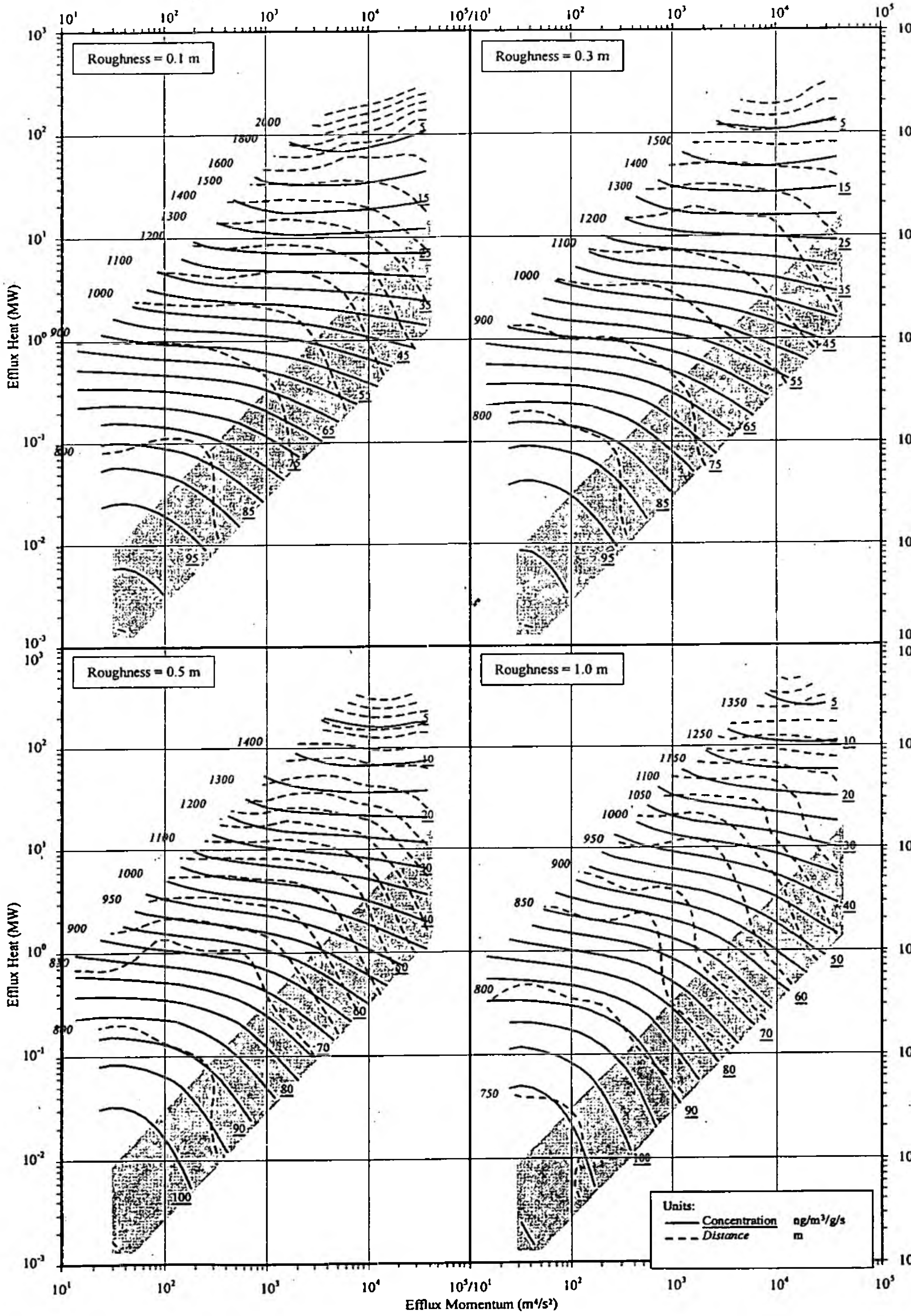


Chart 9	Maximum Ground Level Concentration	Annual Average	120m Stack	Elmdon (Met Type 1)	ADMS2

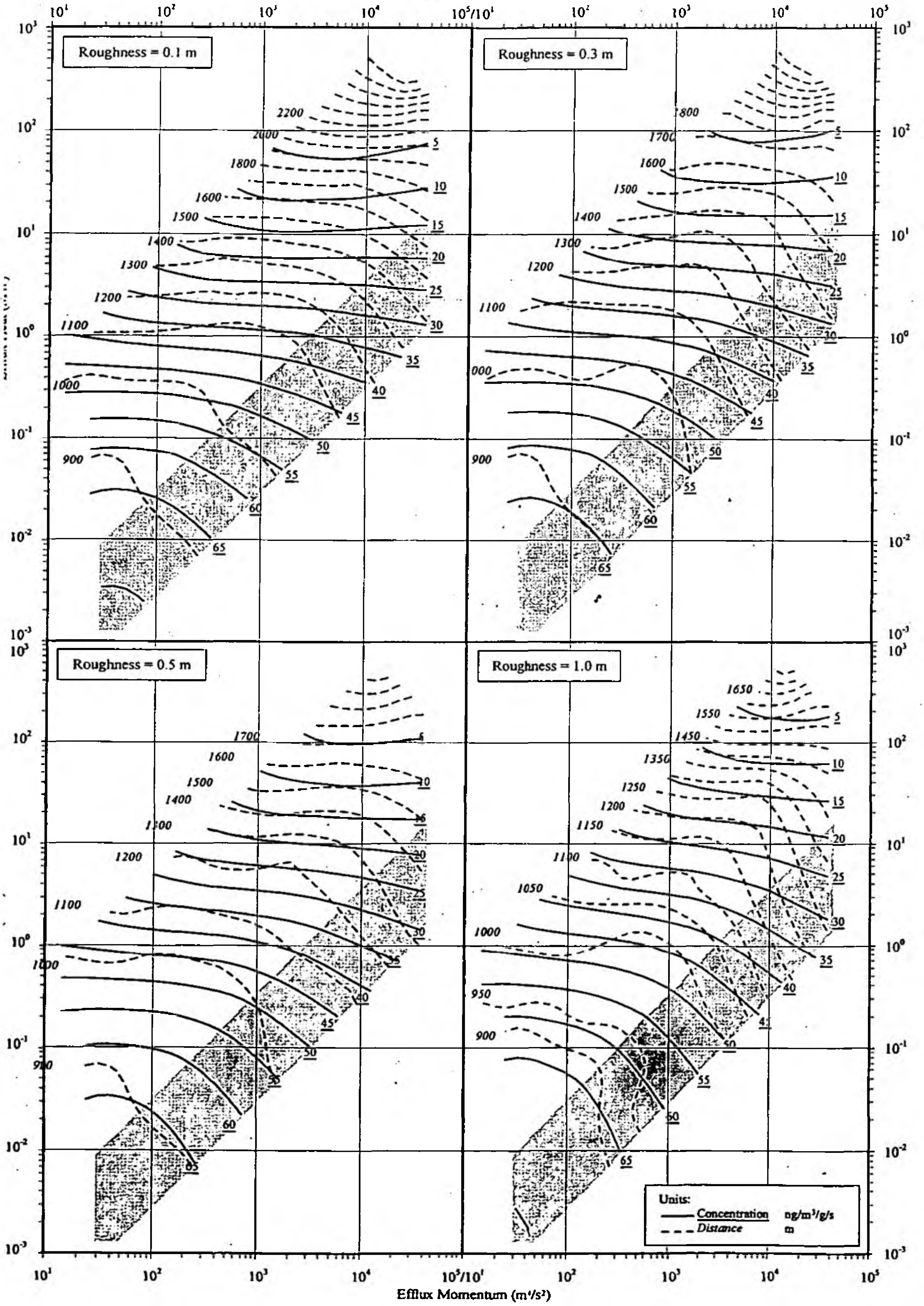


Chart 10	Maximum Ground Level Concentration	Annual Average	150m Stack	Elmdon (Met Type 1)	ADMS2

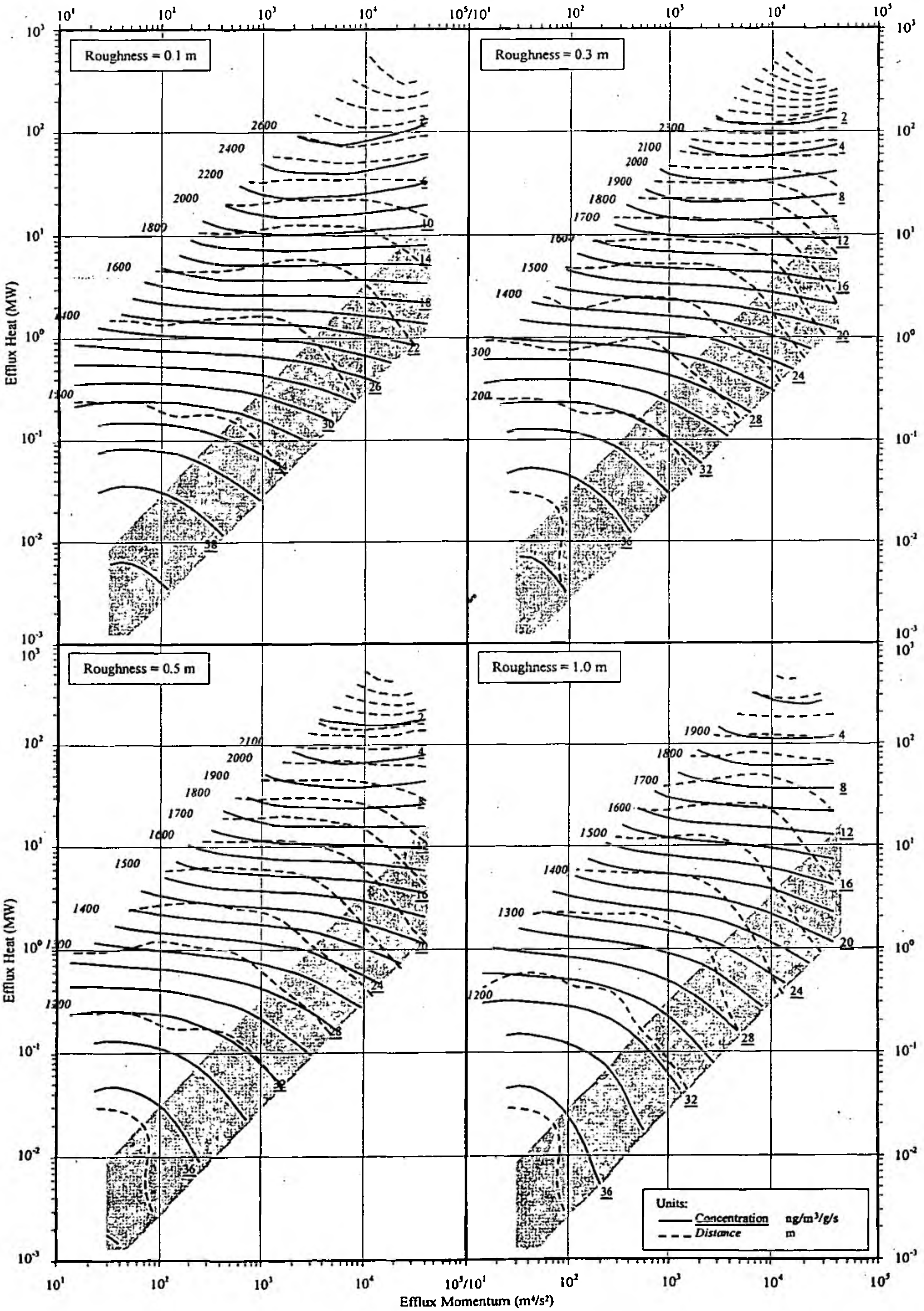


Chart 11	Maximum Ground Level Concentration	Annual Average	200m Stack	Elmdon (Met Type 1)	ADMS2

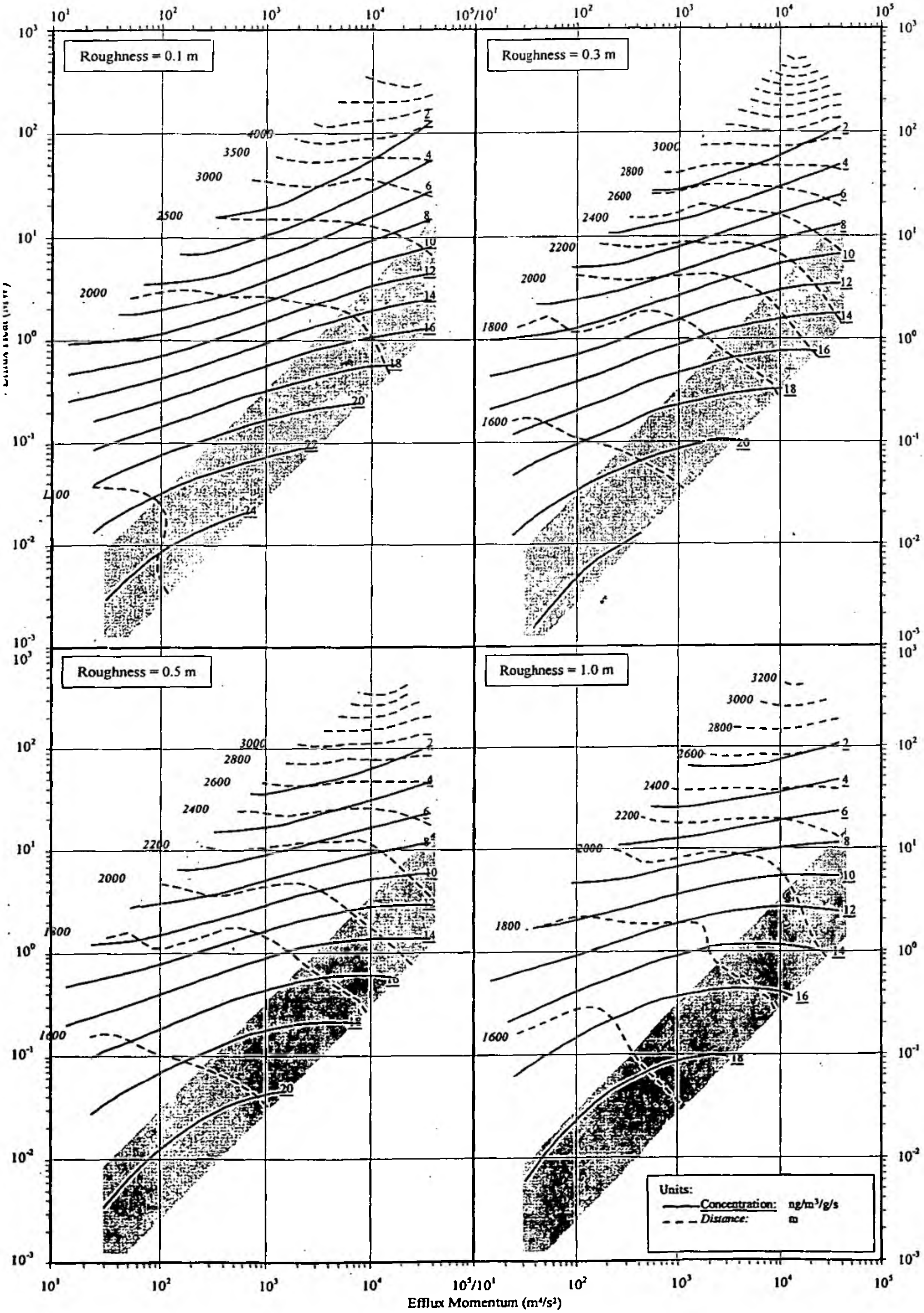


Chart 12	Maximum Ground Level Concentration	99.9th Percentile	20m Stack	Elmdon (Met Type 1)	ADMS2

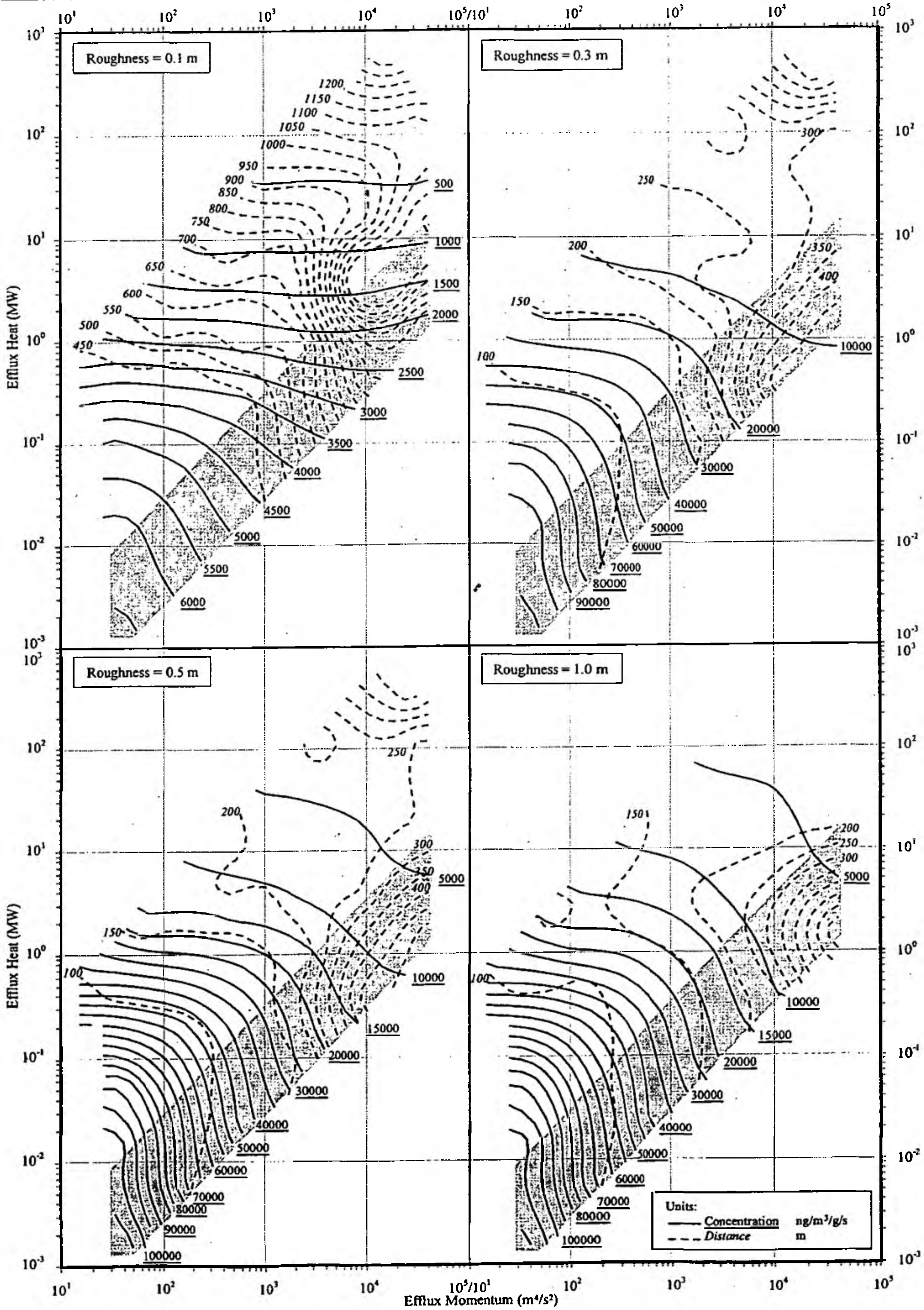


Chart 13	Maximum Ground Level Concentration	99.9th Percentile	30m Stack	Elmdon (Met.Type 1)	ADMS2

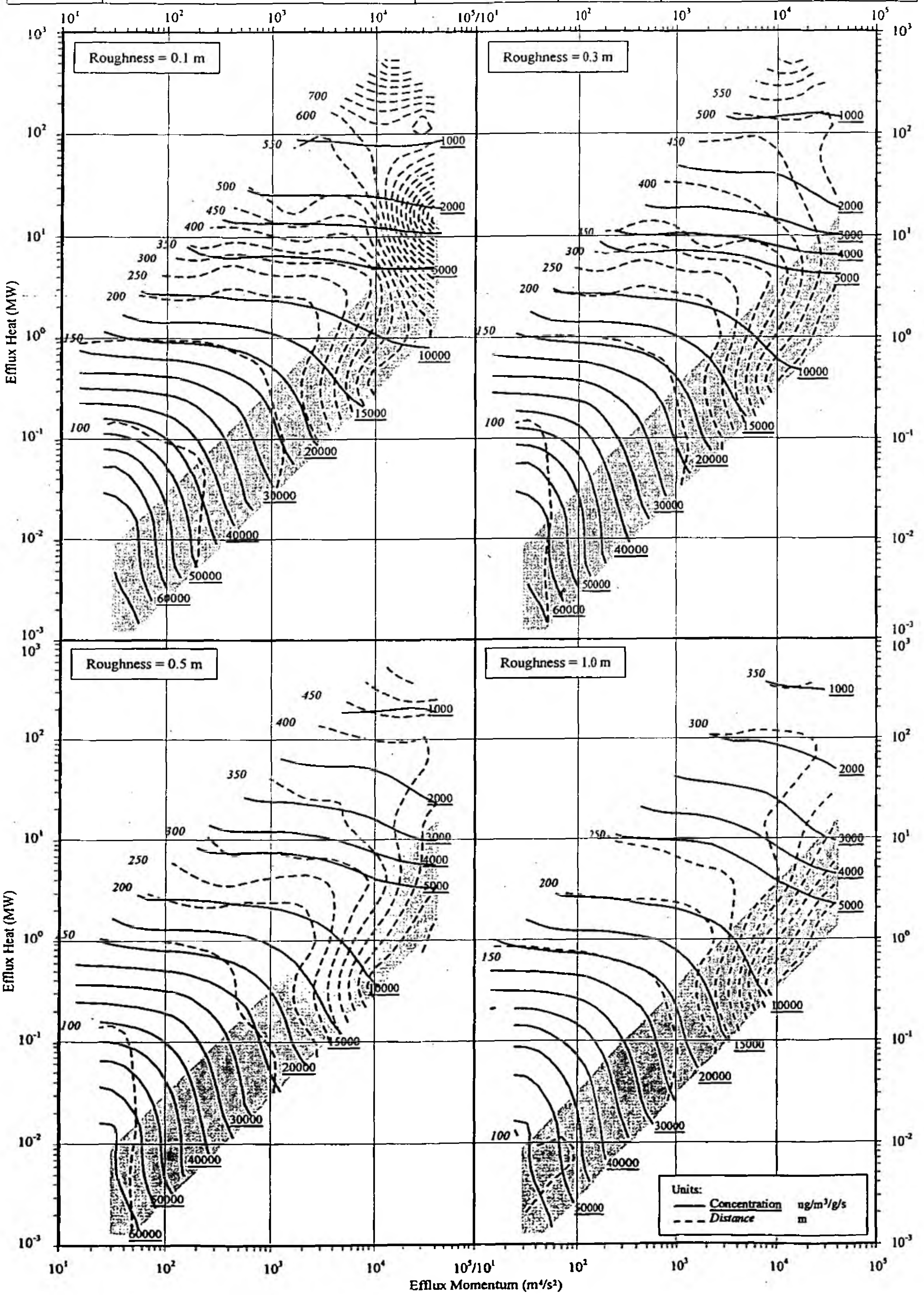


Chart 14	Maximum Ground Level Concentration	99.9th Percentile	40m Stack	Elmdon (Met Type 1)	ADMS2

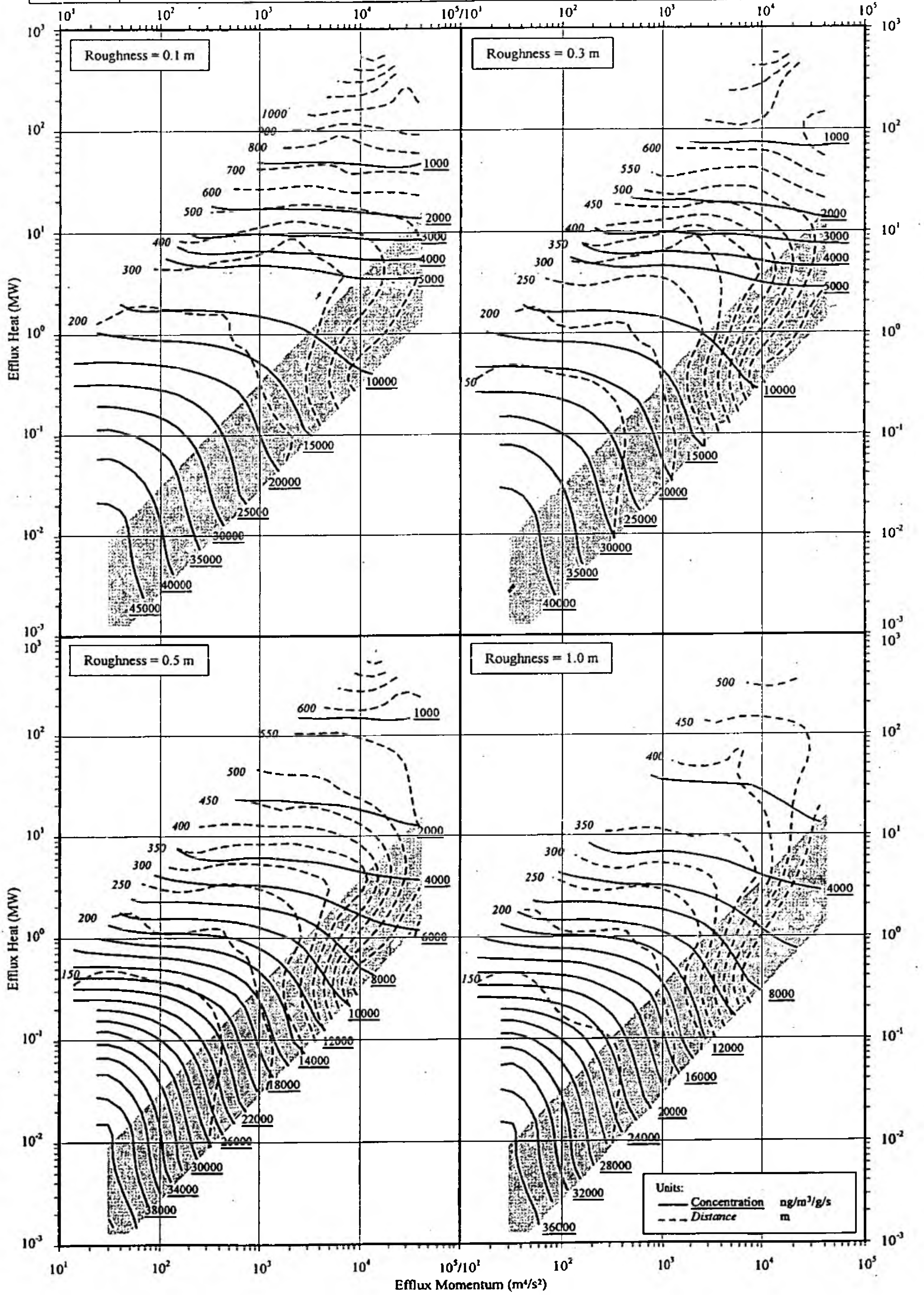


Chart 15	Maximum Ground Level Concentration	99.9th Percentile	50m Stack	Elmdon (Met Type 1)	ADMS2

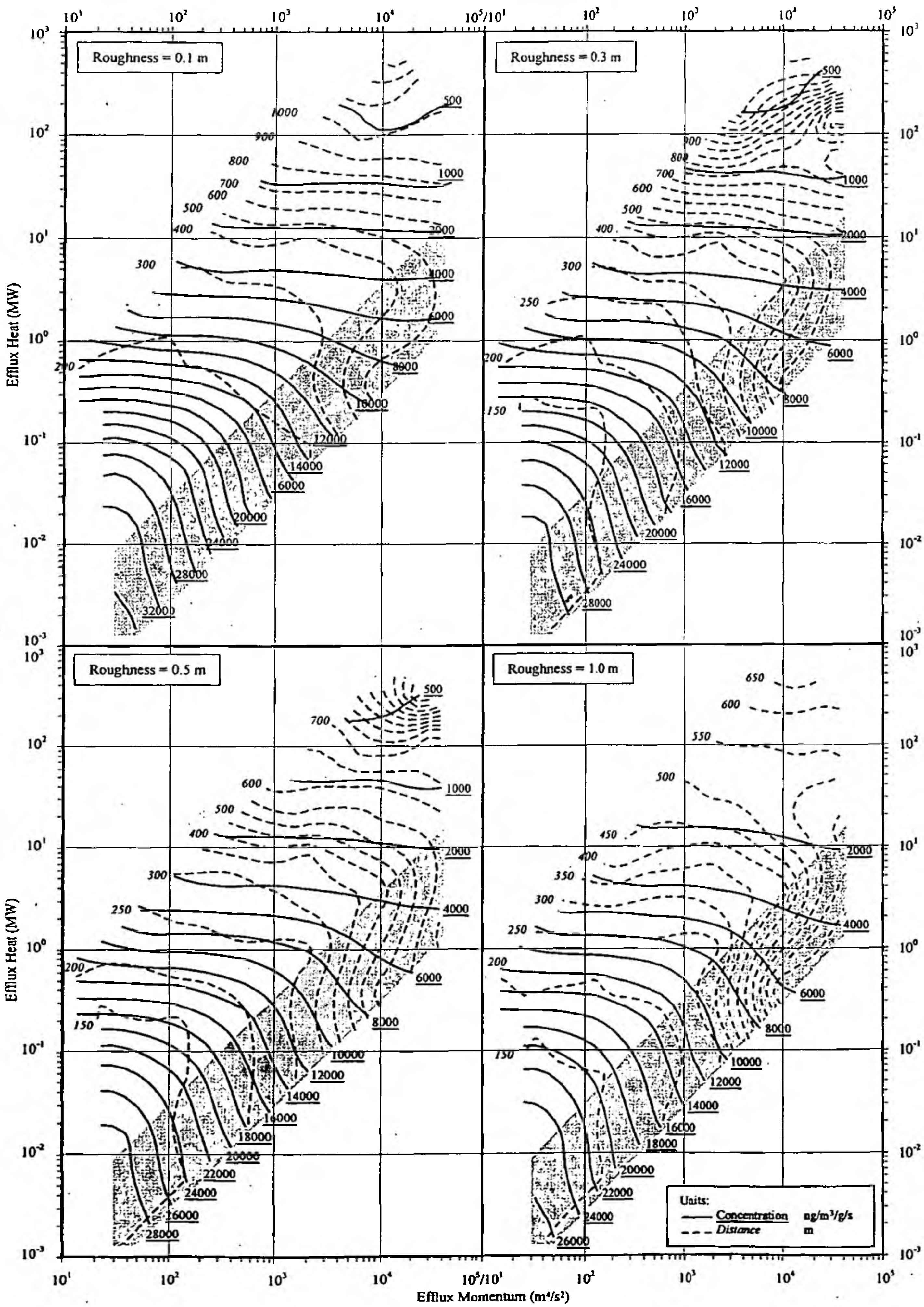


Chart 16	Maximum Ground Level Concentration	99.9th Percentile	60m Stack	Elmdon (Met Type 1)	ADMS2

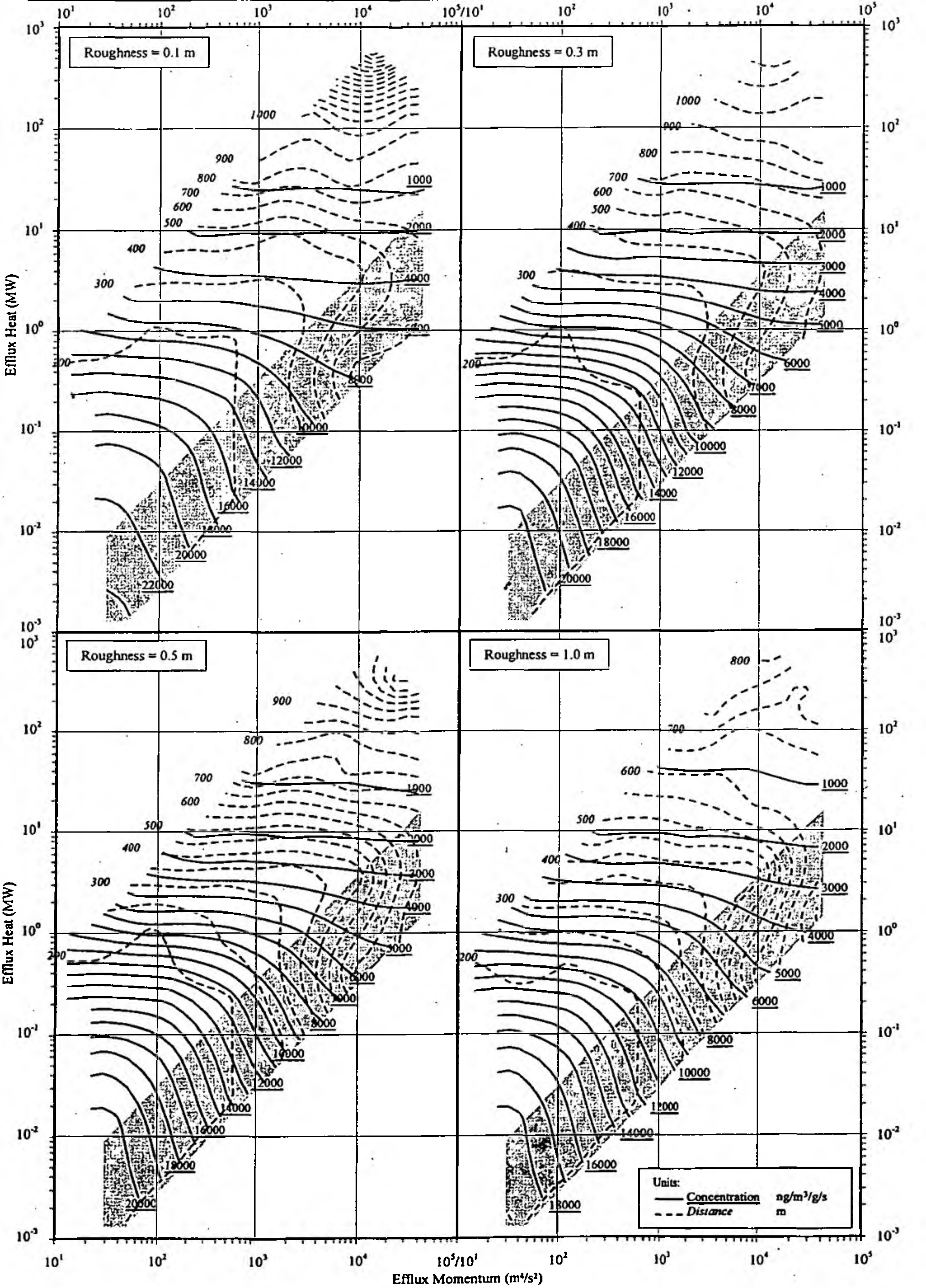


Chart 17	Maximum Ground Level Concentration	99.9th Percentile	70m Stack	Elmdon (Met Type 1)	ADMS2

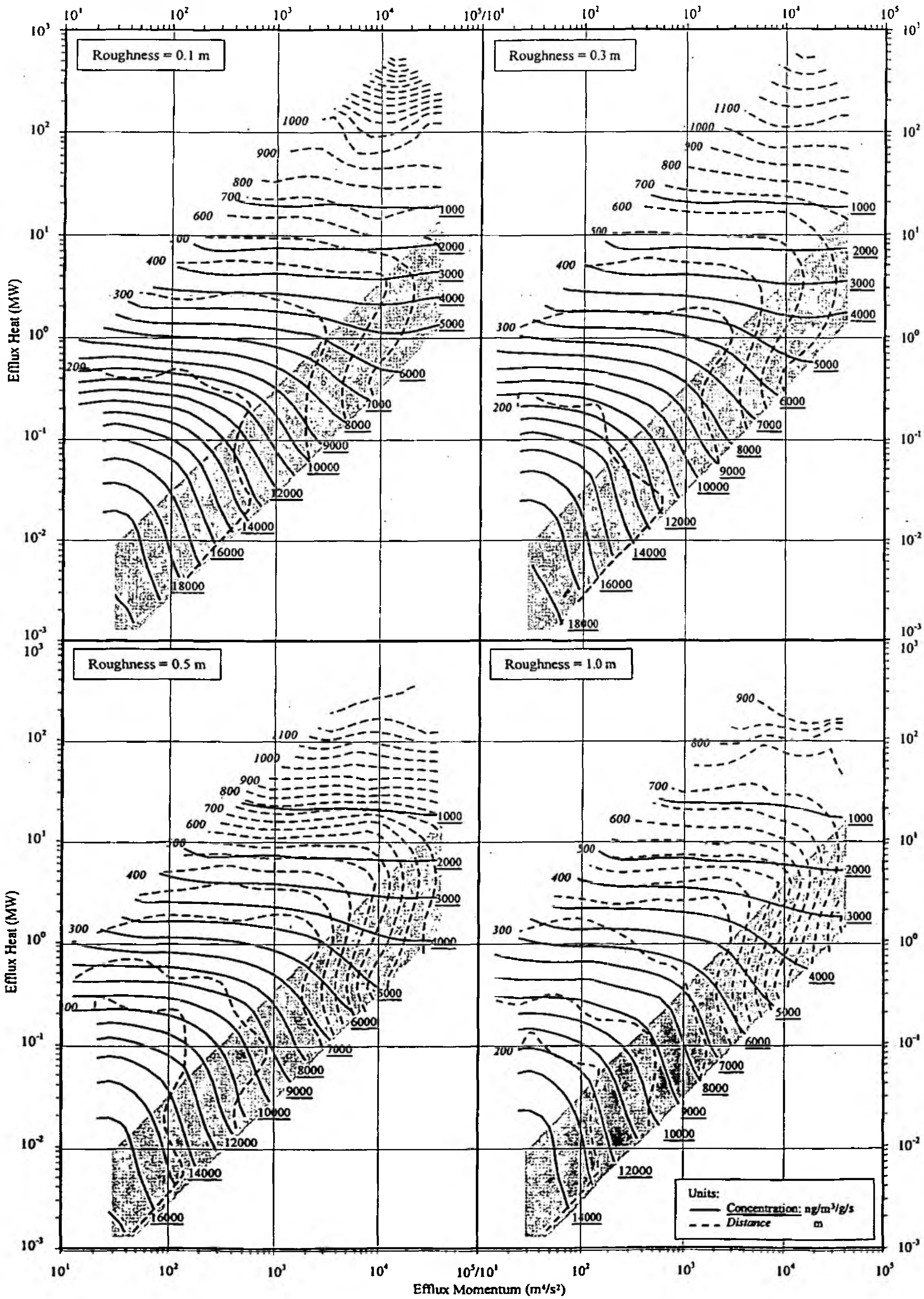


Chart 18	Maximum Ground Level Concentration	99.9th Percentile	85m Stack	Elmdon (Met Type 1)	ADMS2

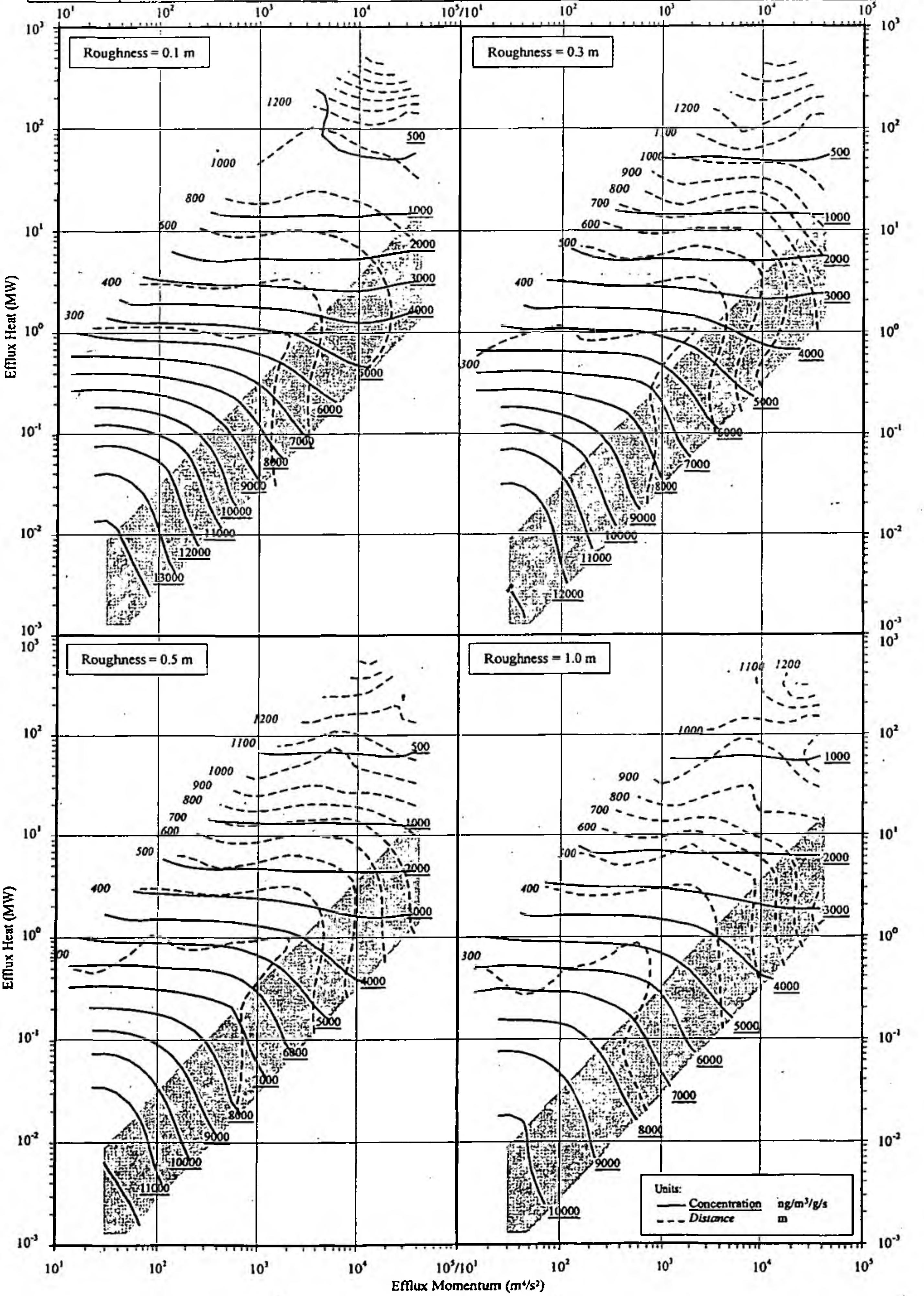


Chart 19	**Maximum Ground Level Concentration**	**99.9th Percentile**	**100m Stack**	**Elmdon (Met Type 1)**	**ADMS2**

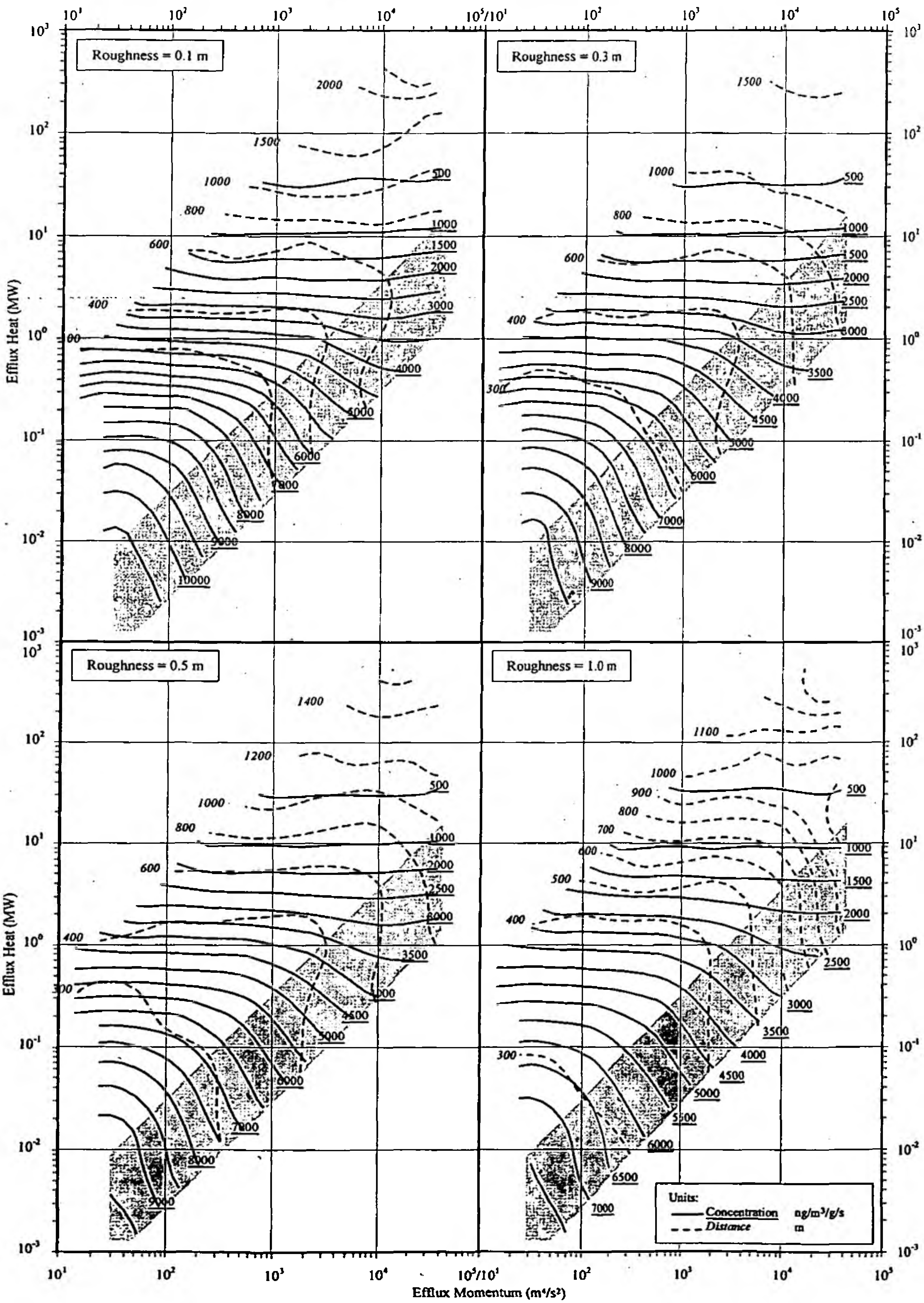


Chart 20	Maximum Ground Level Concentration	99.9th Percentile	120m Stack	Elmdon (Met Type 1)	ADMS2

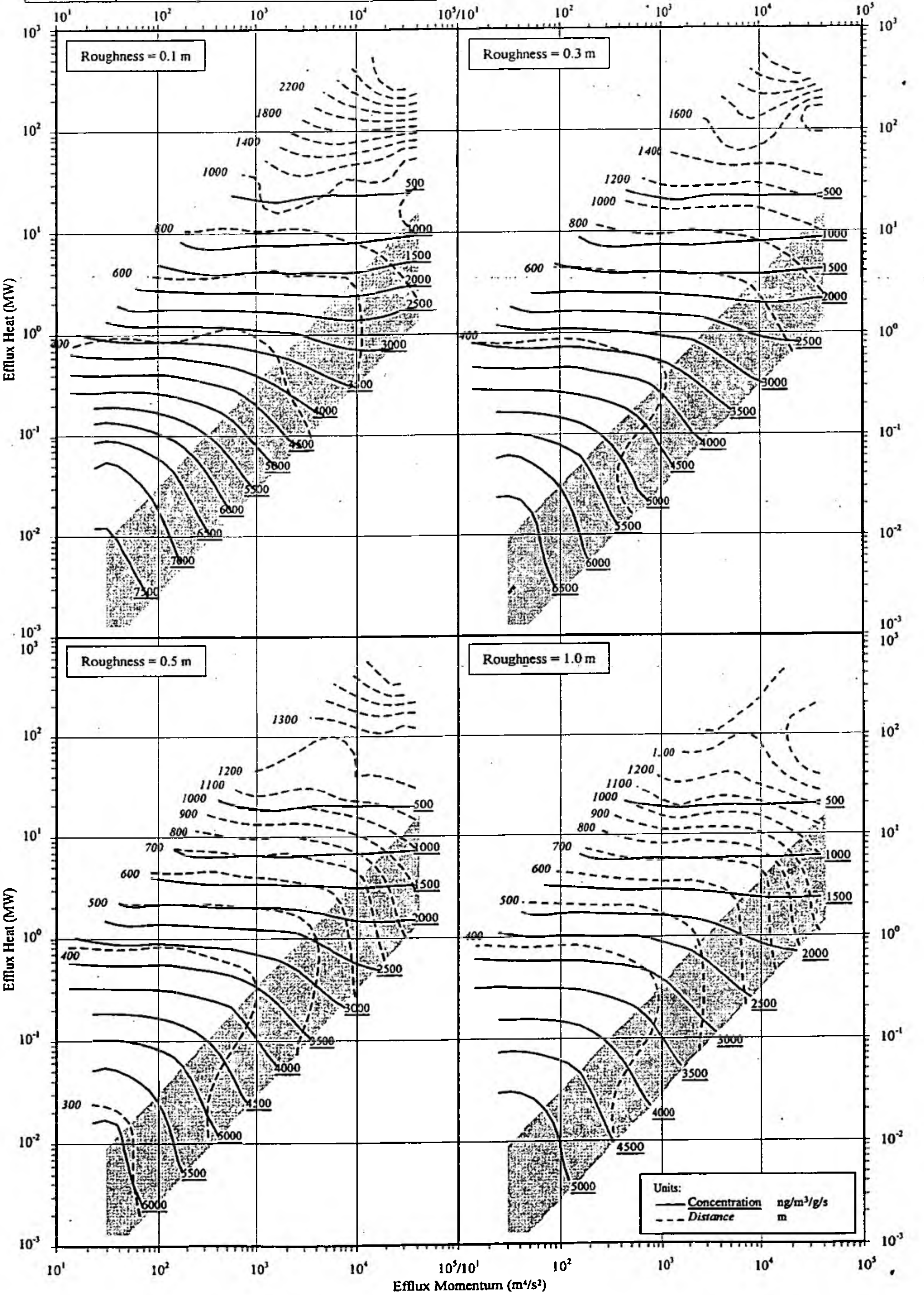


Chart 21	Maximum Ground Level Concentration	99.9th Percentile	150m Stack	Elmdon (Met Type 1)	ADMS2

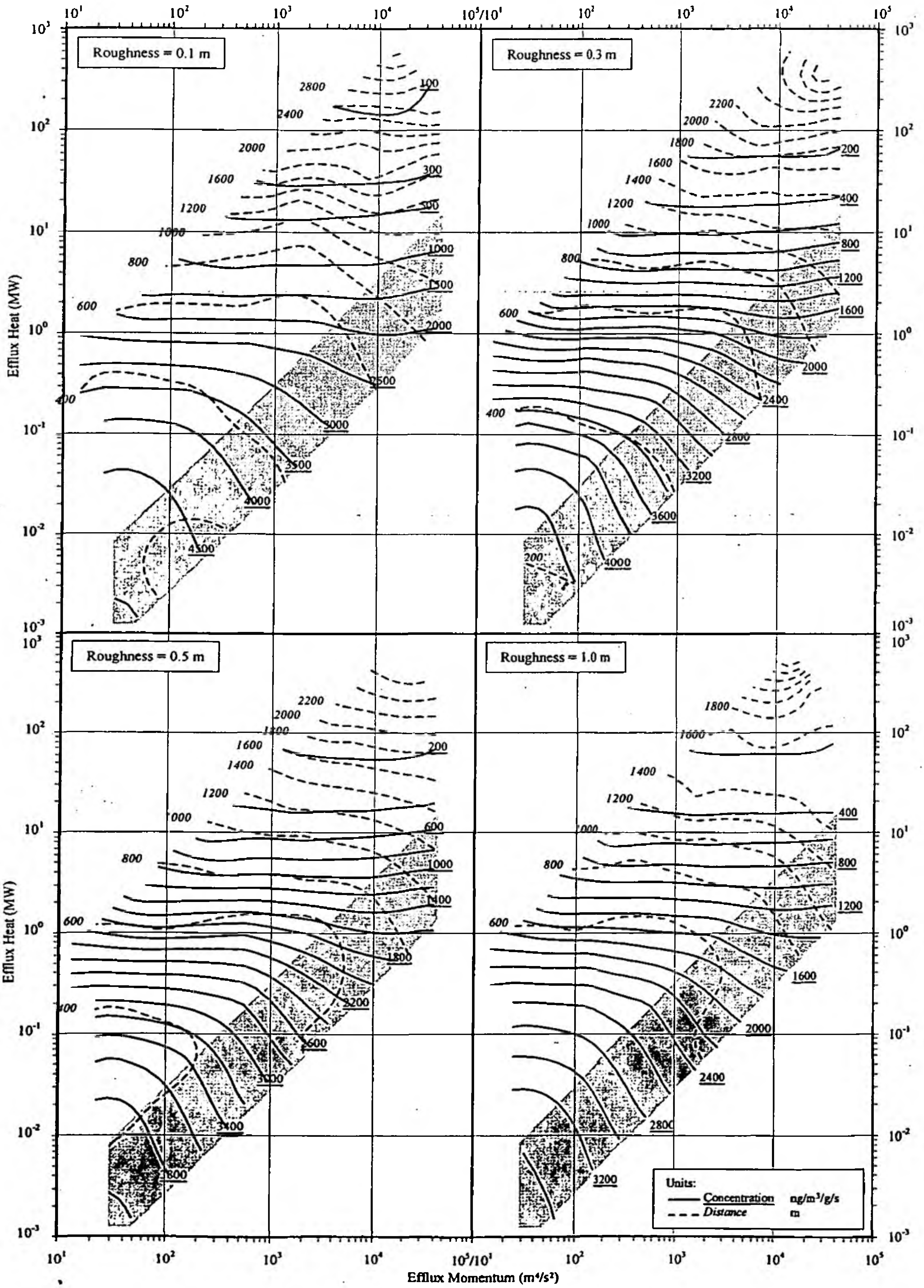


Chart 22	Maximum Ground Level Concentration	99.9th Percentile	200m Stack	Elmdon (Met Type 1)	ADMS2

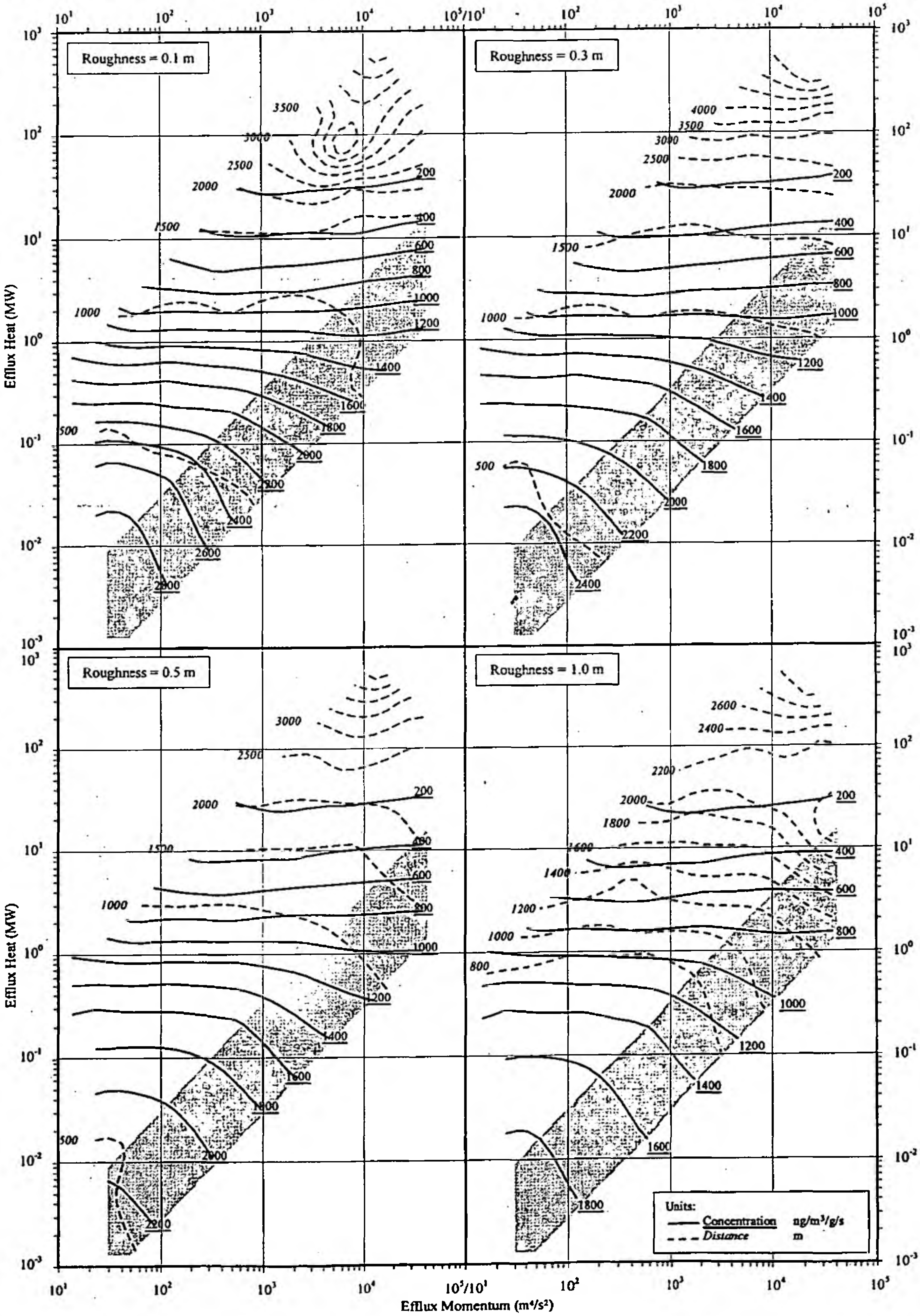


Chart 23	Maximum Ground Level Concentration	100th Percentile	20m Stack	Elmdon (Met Type 1)	ADMS2

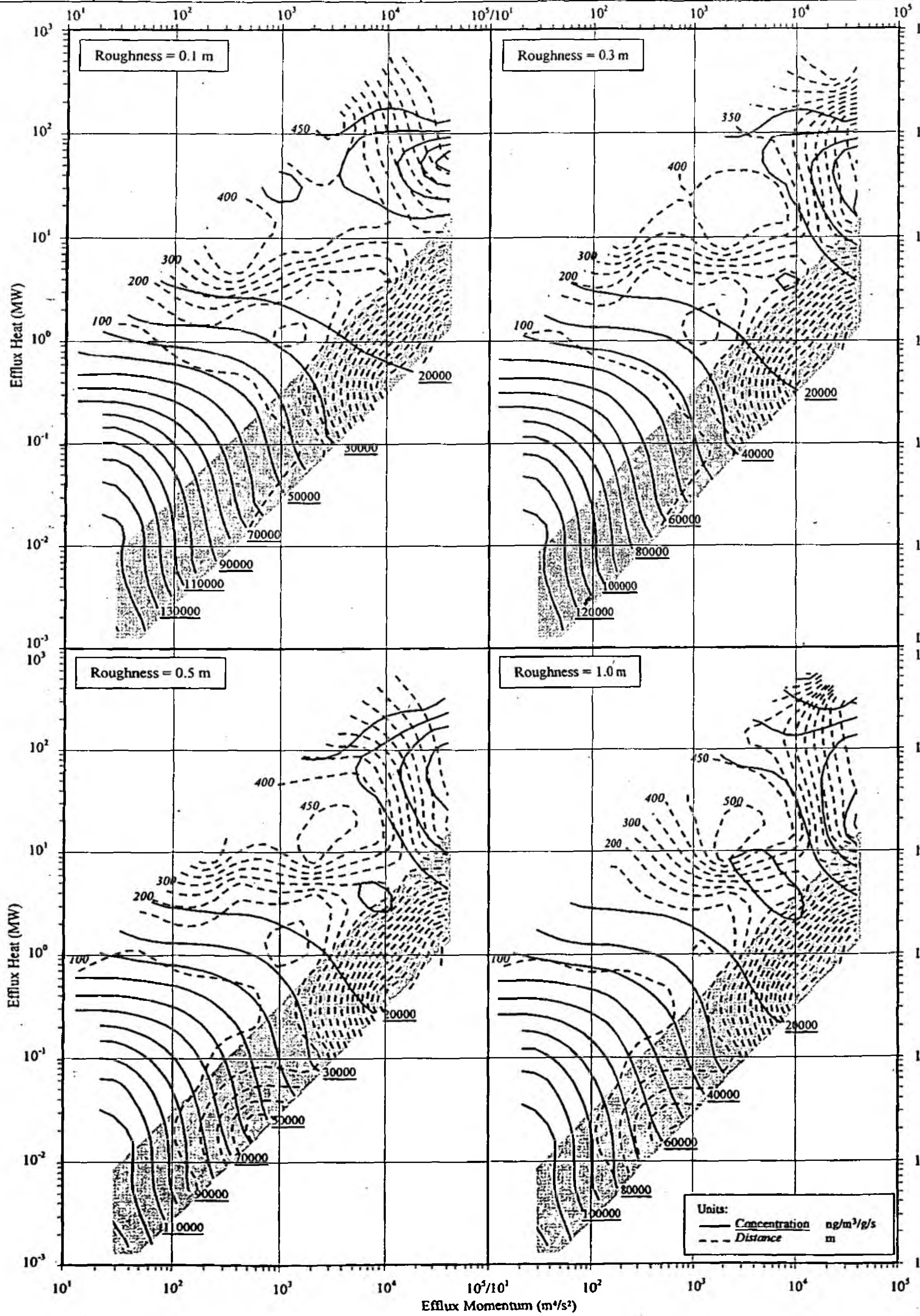


Chart 24	Maximum Ground Level Concentration	100th Percentile	30m Stack	Elmdon (Met Type 1)	ADMS2

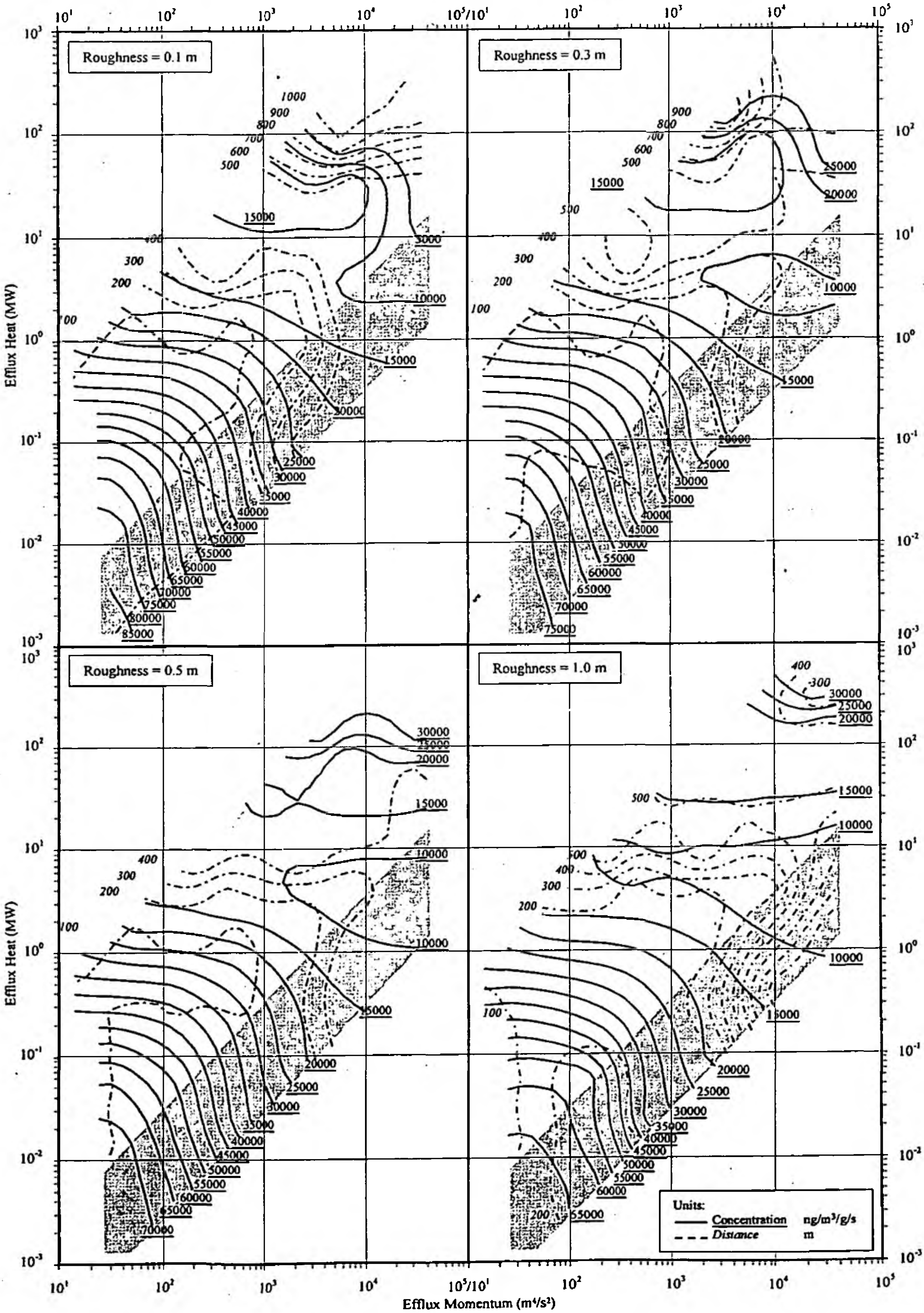


Chart 25	Maximum Ground Level Concentration	100th Percentile	40m Stack	Elmdon (Met Type 1)	ADMS2

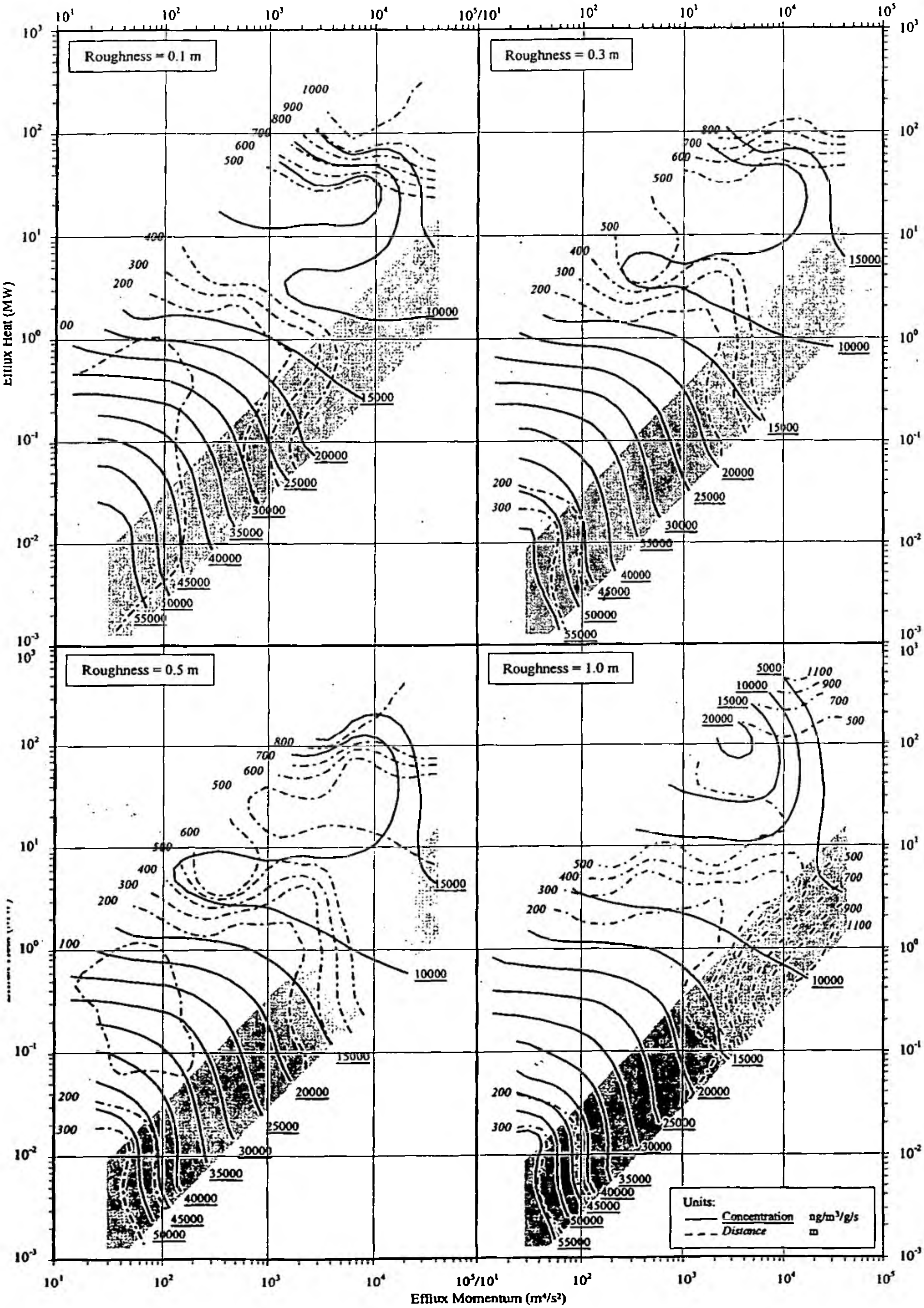


Chart 26	**Maximum Ground Level Concentration**	**100th Percentile**	**50m Stack**	**Elmdon (Met Type 1)**	**ADMS2**

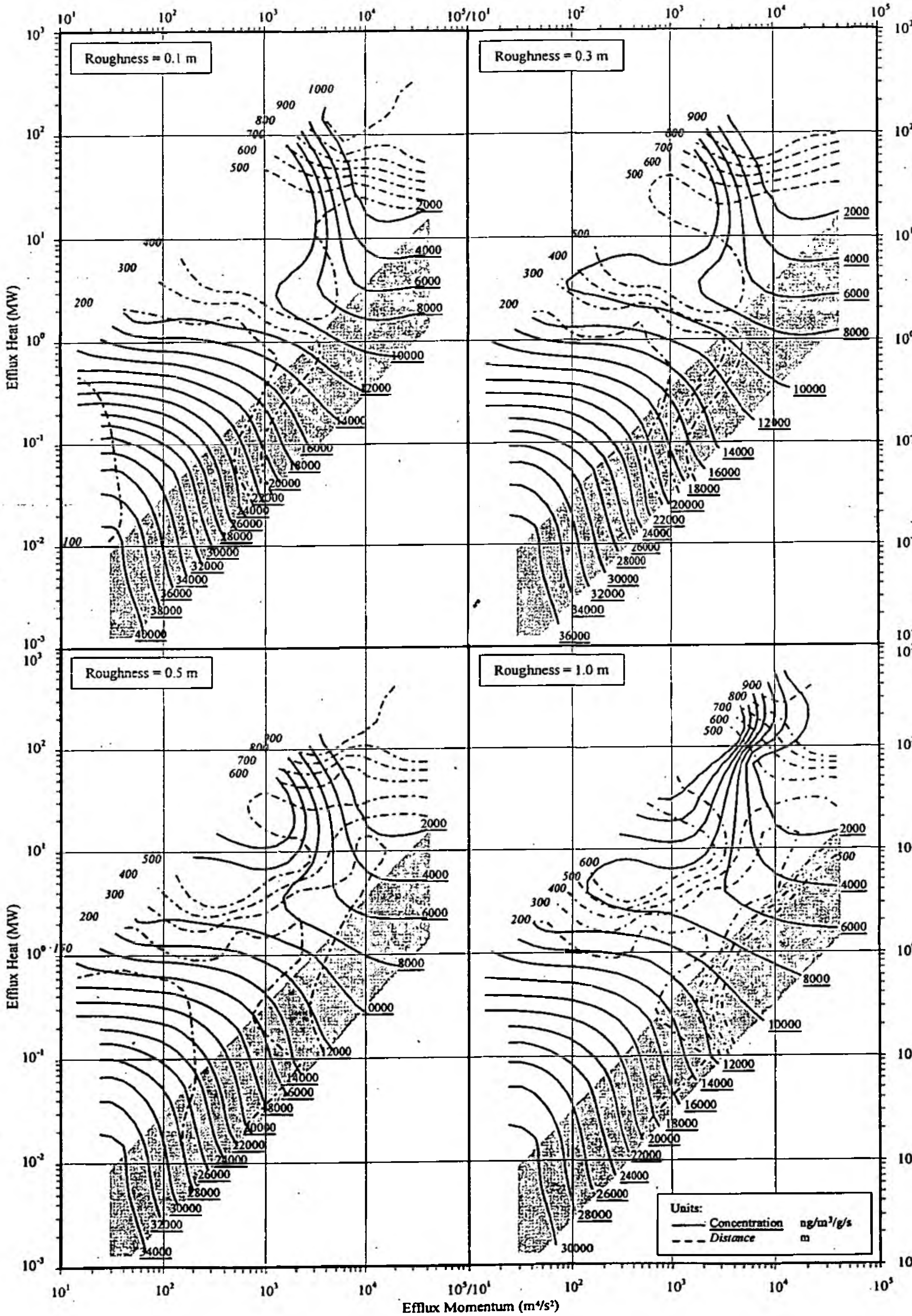


Chart 27	Maximum Ground Level Concentration	100th Percentile	60m Stack	Elmdon (Met Type 1)	ADMS2

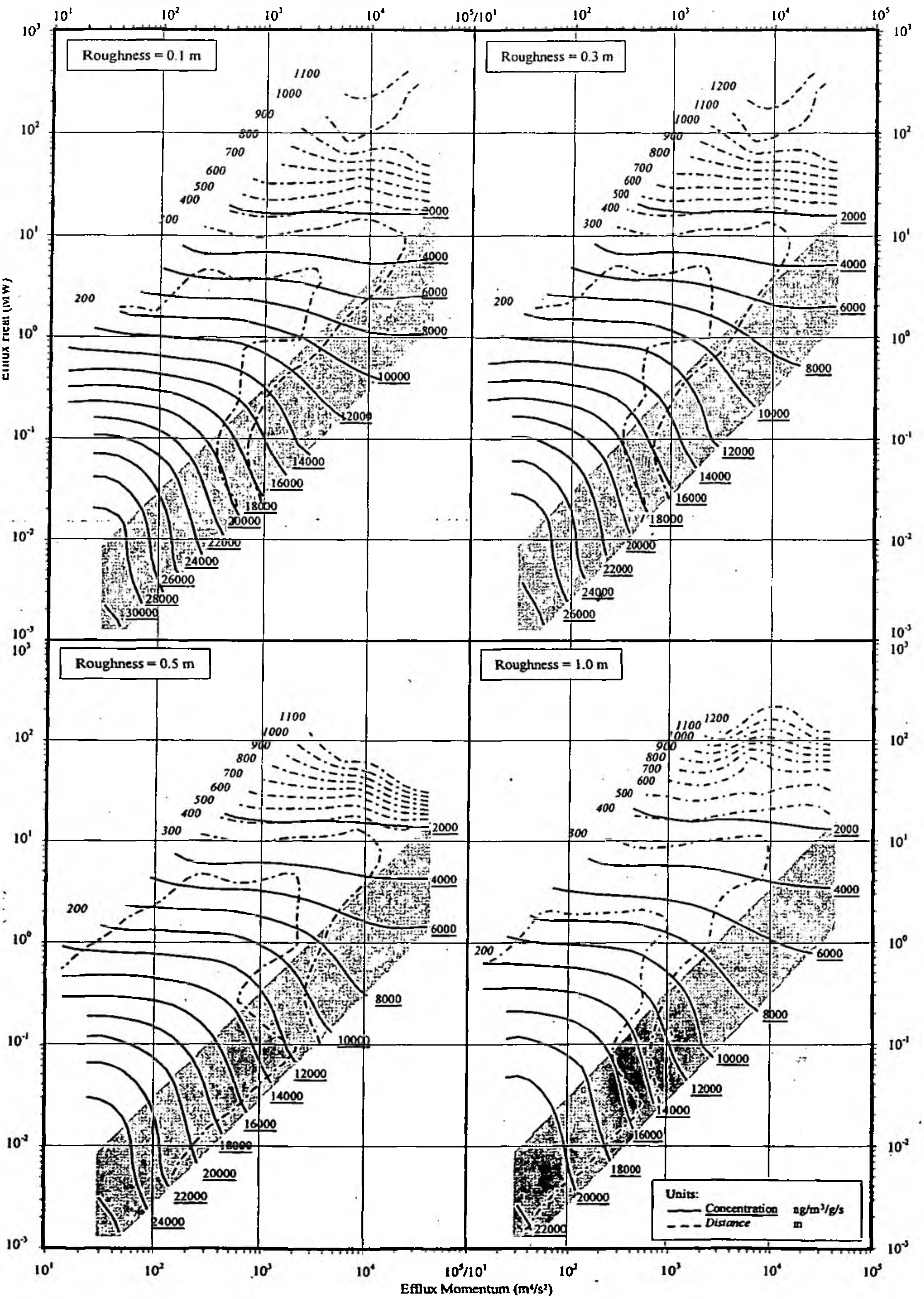


Chart 28	Maximum Ground Level Concentration	100th Percentile	70m Stack	Elmdon (Met Type 1)	ADMS2

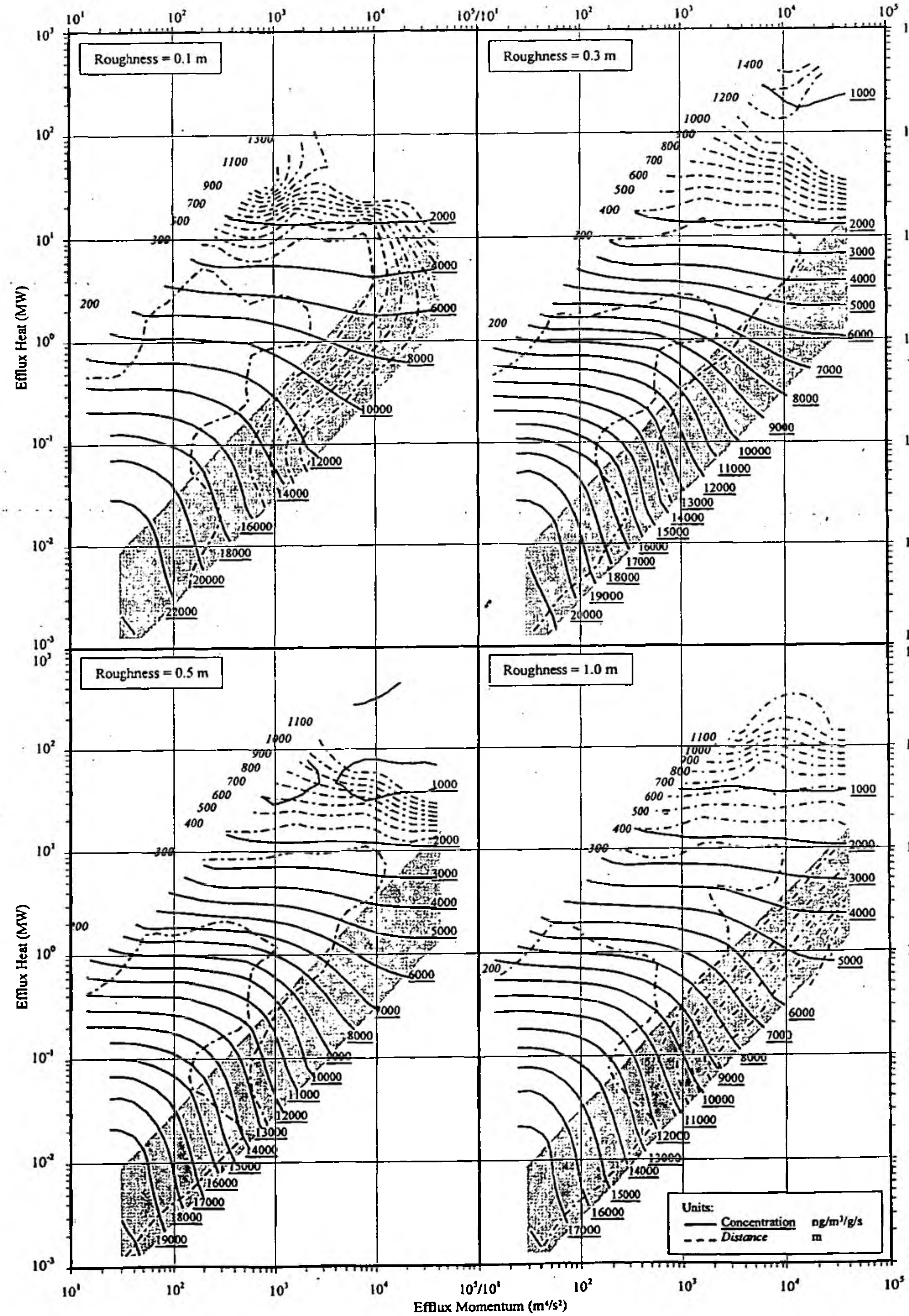


Chart 29	Maximum Ground Level Concentration	100th Percentile	85m Stack	Elmdon (Met Type 1)	ADMS2

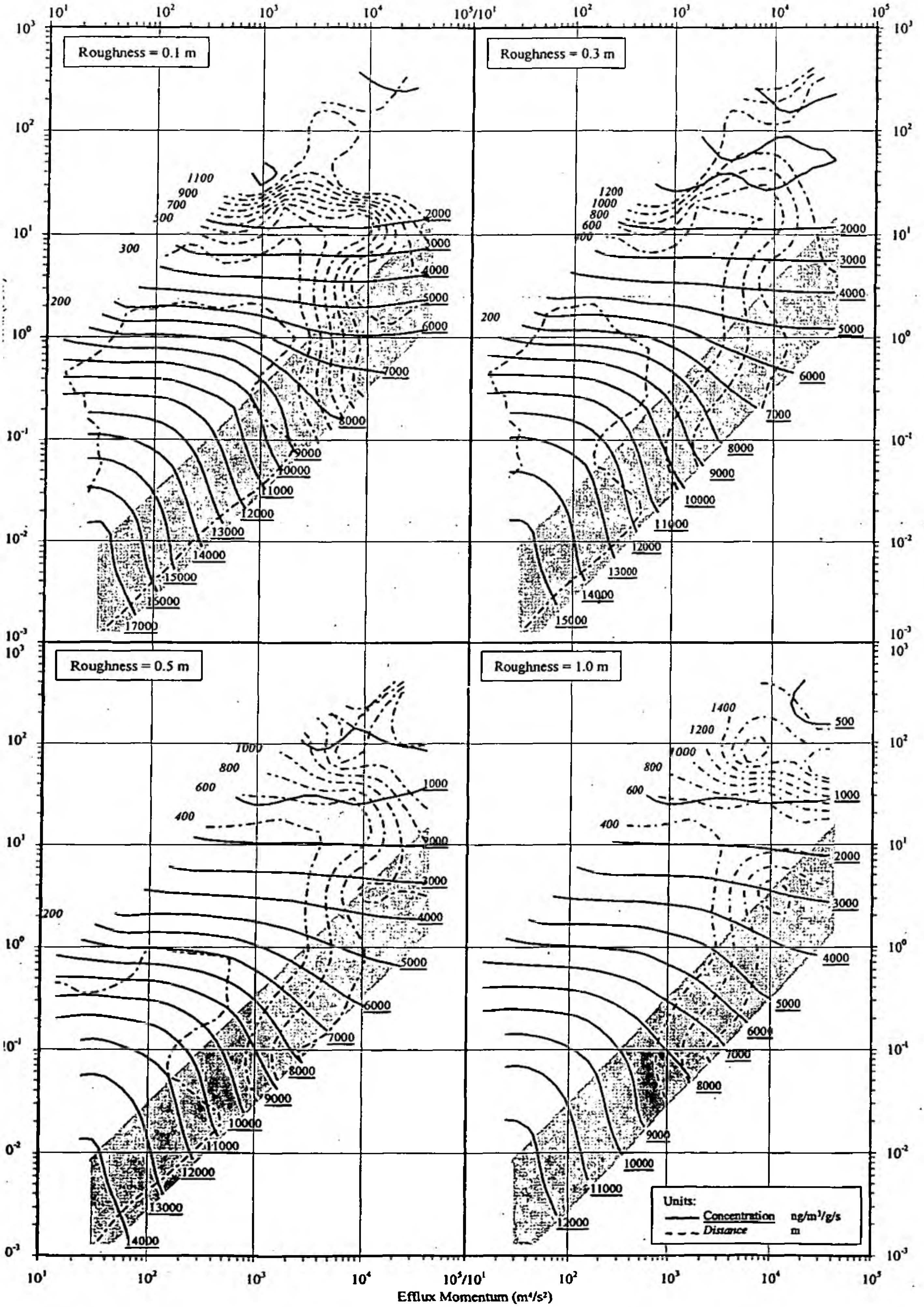


Chart 30	Maximum Ground Level Concentration	100th Percentile	100m Stack	Elmdon (Met Type 1)	ADMS2

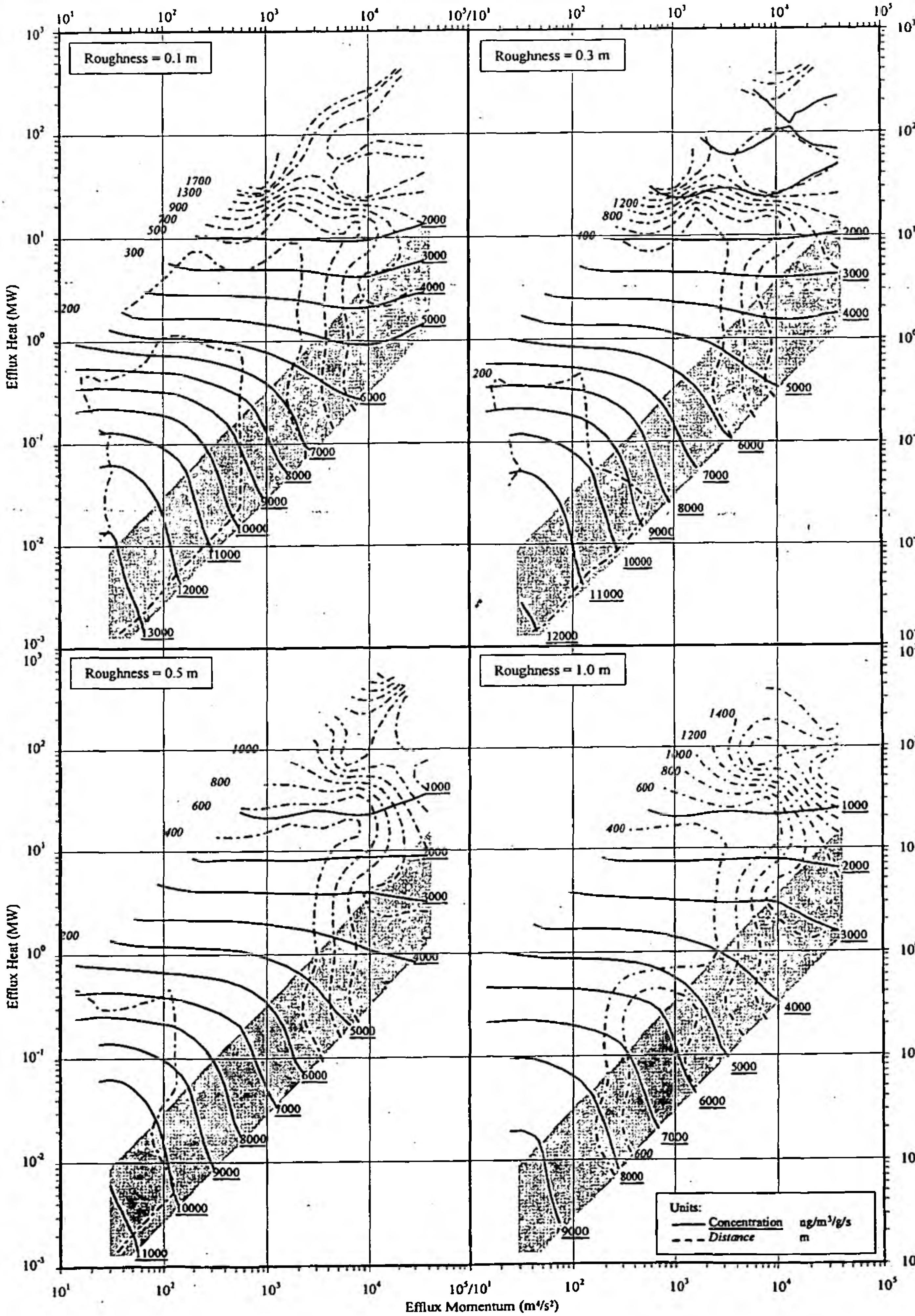


Chart 31	Maximum Ground Level Concentration	100th Percentile	120m Stack	Elmdon (Met Type 1)	ADMS2

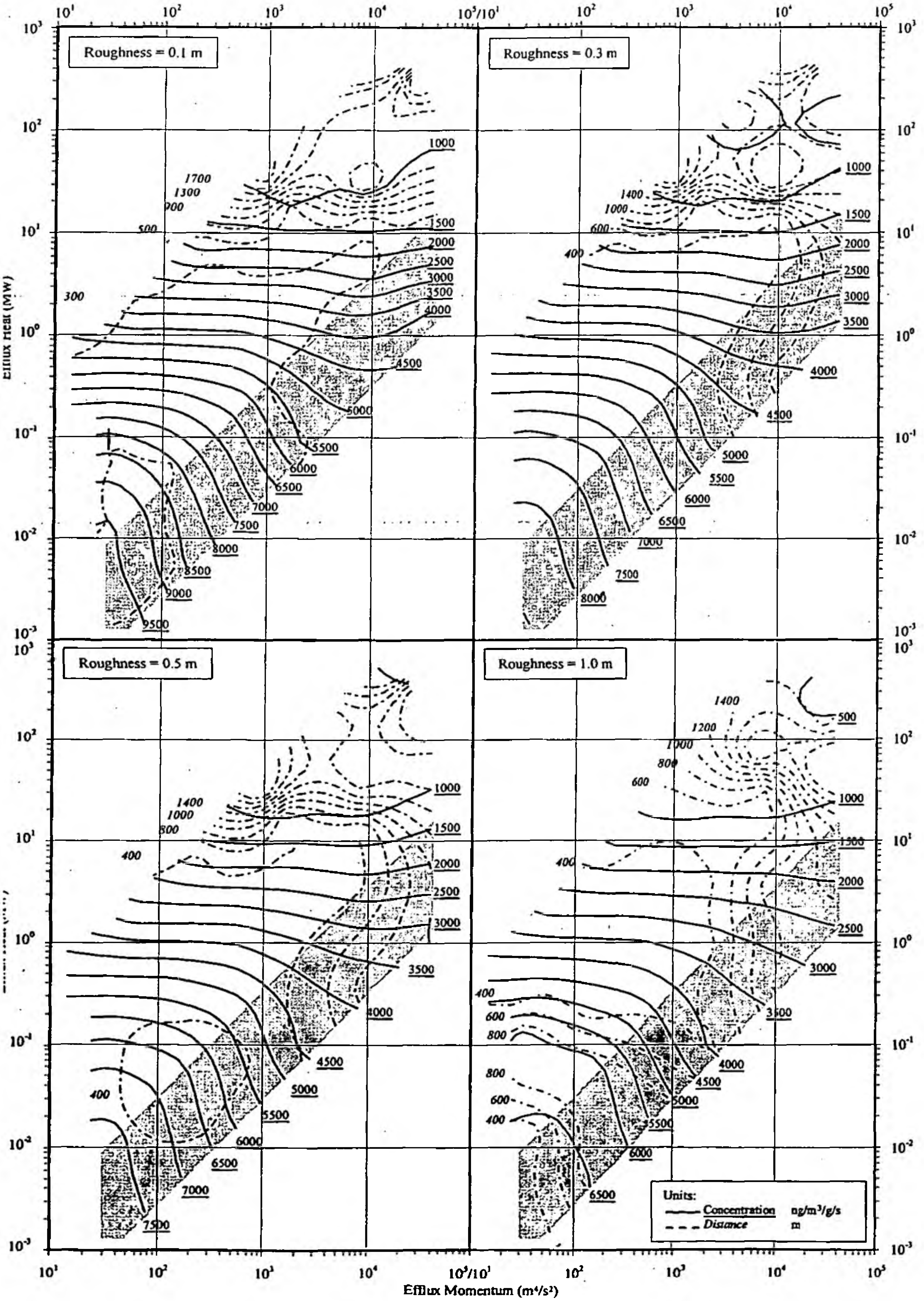


Chart 32	Maximum Ground Level Concentration	100th Percentile	150m Stack	Elmdon (Met Type 1)	ADMS2

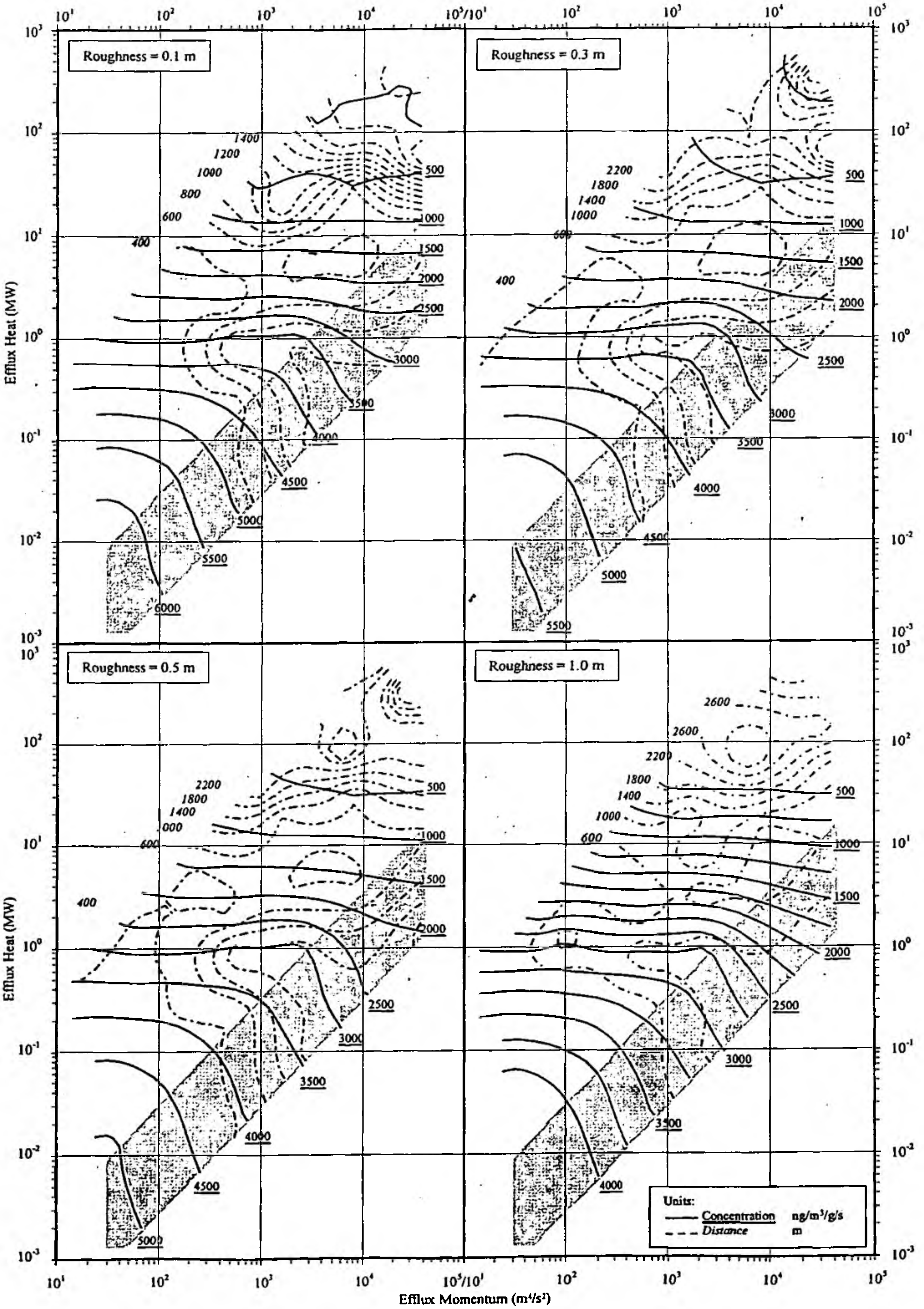


Chart 33	Maximum Ground Level Concentration	100th Percentile	200m Stack	Elmdon (Met Type 1)	ADMS2

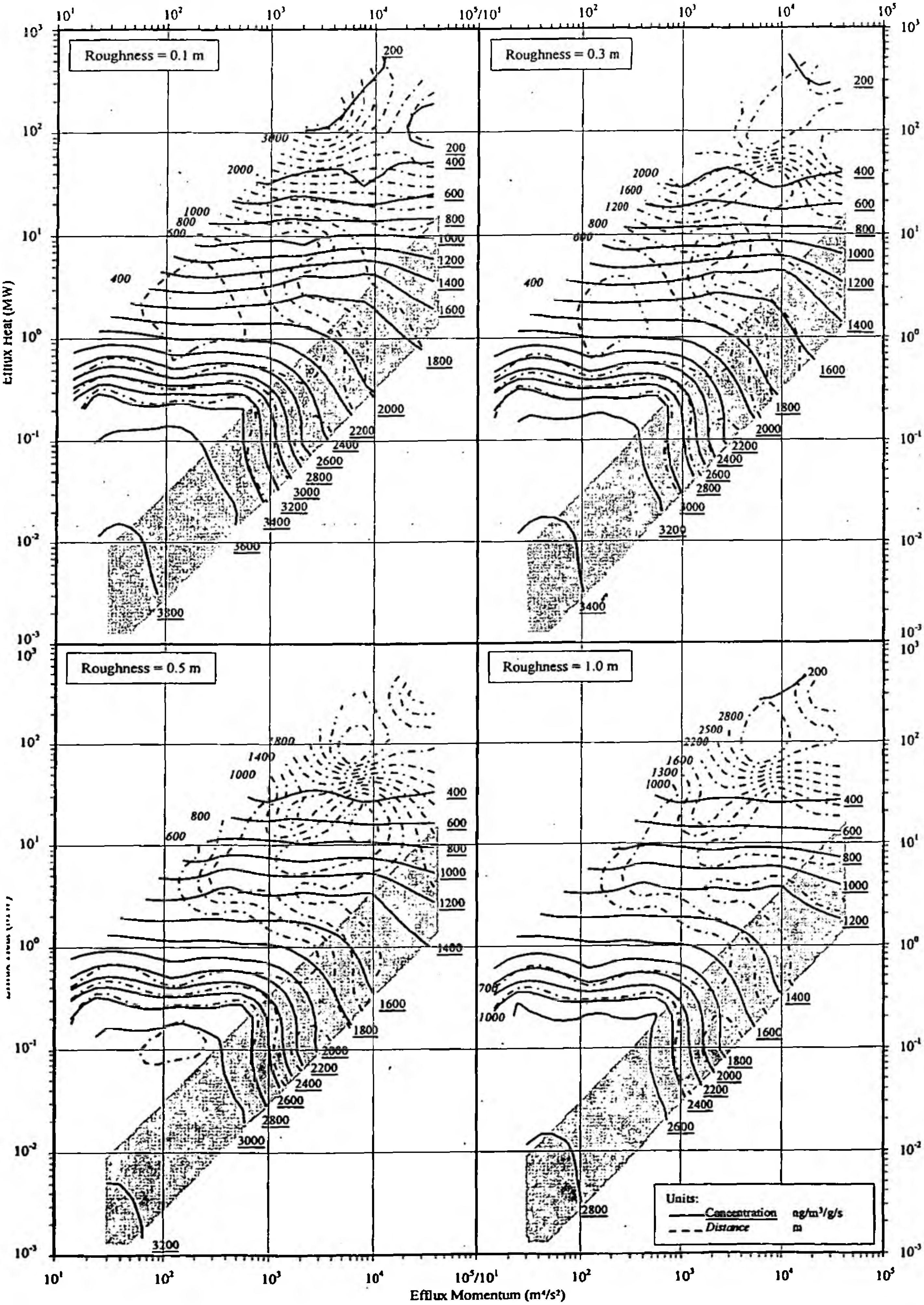


Chart 34	Maximum Ground Level Concentration	Annual Average	20m Stack	Kilnsea (Met Type 2)	ADMS2

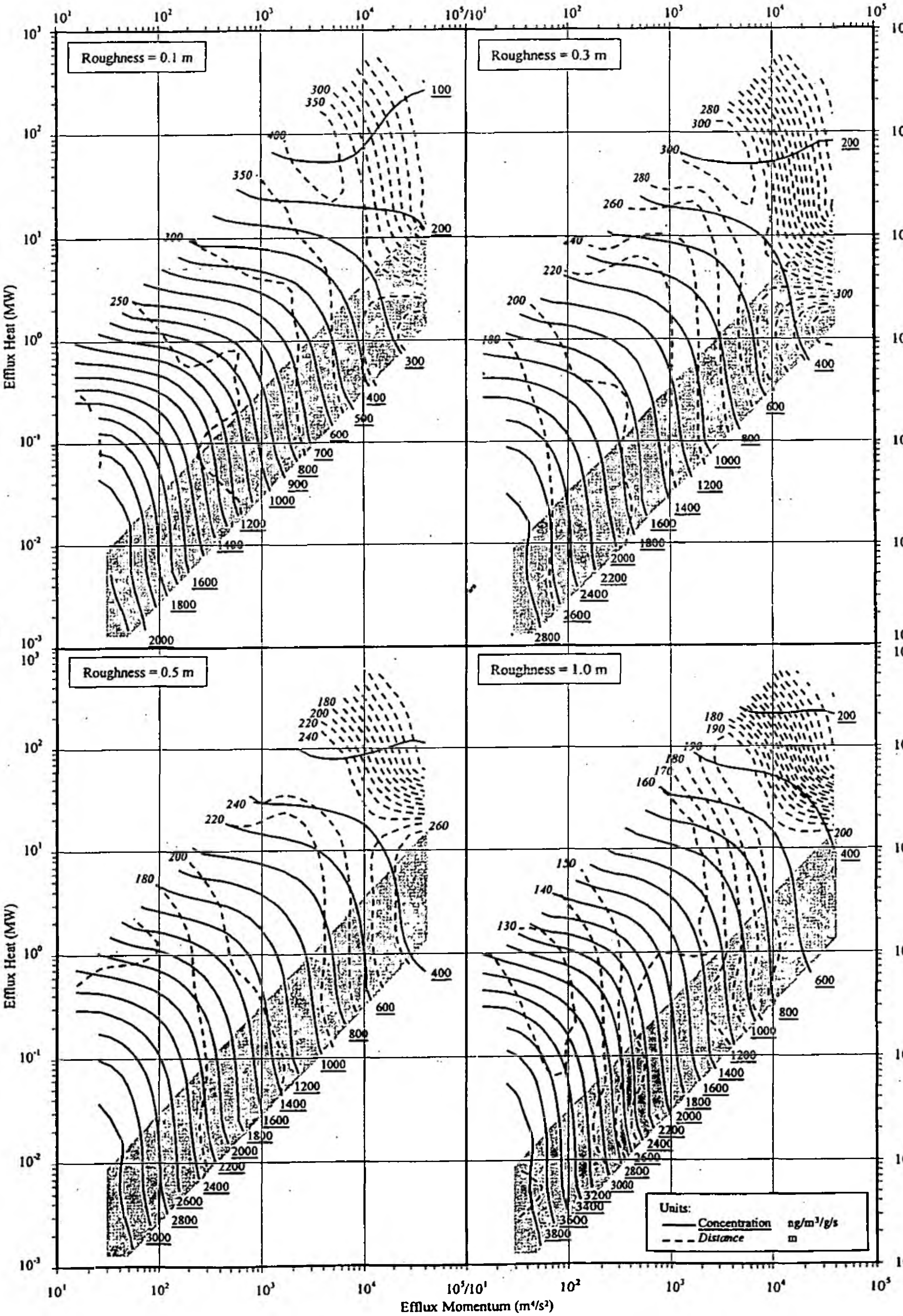


Chart 35	Maximum Ground Level Concentration	Annual Average	30m Stack	Kilnsea (Met Type 2)	ADMS2

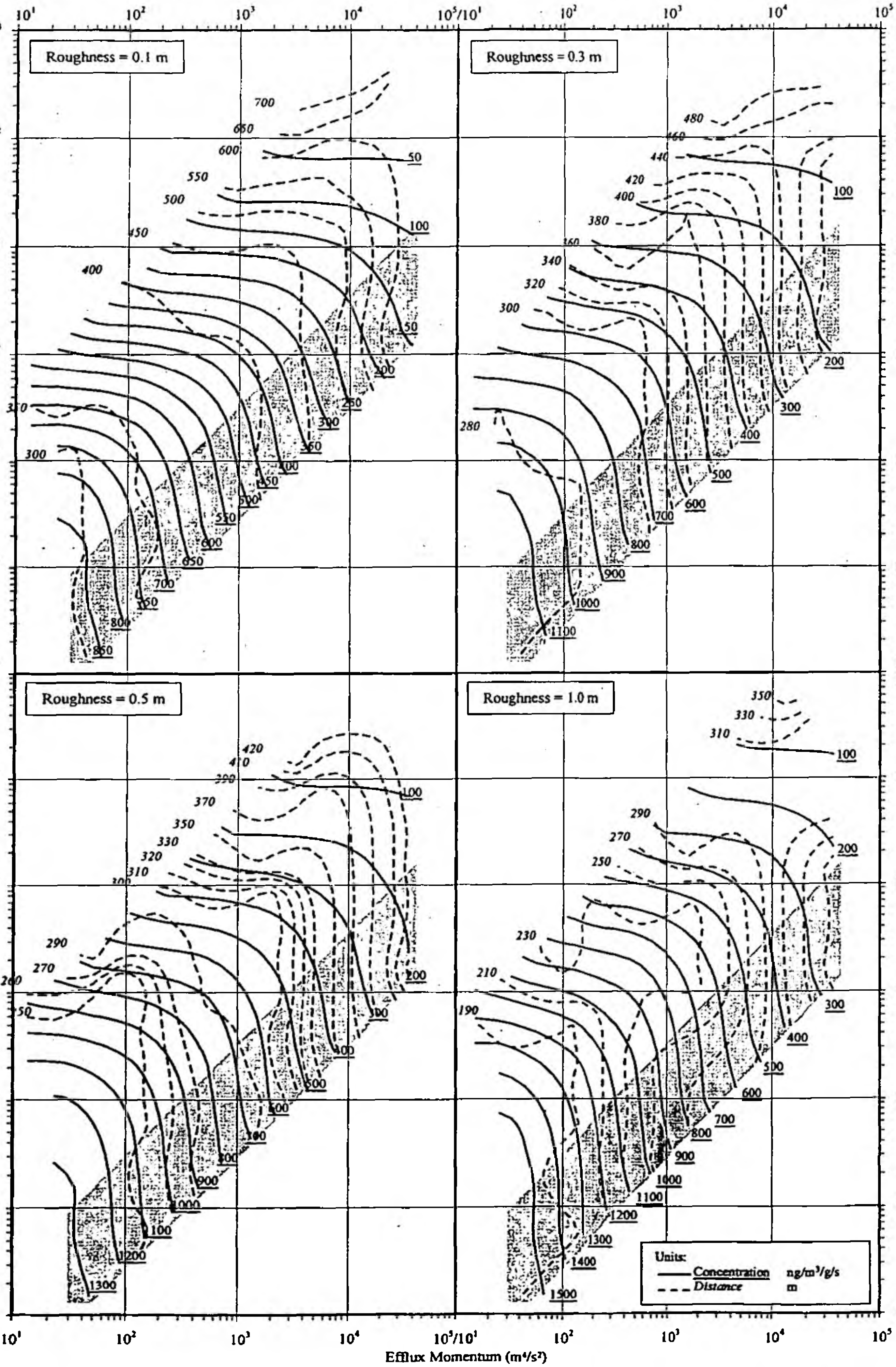


Chart 36	Maximum Ground Level Concentration	Annual Average	40m Stack	Kilnsea (Met Type 2)	ADMS2

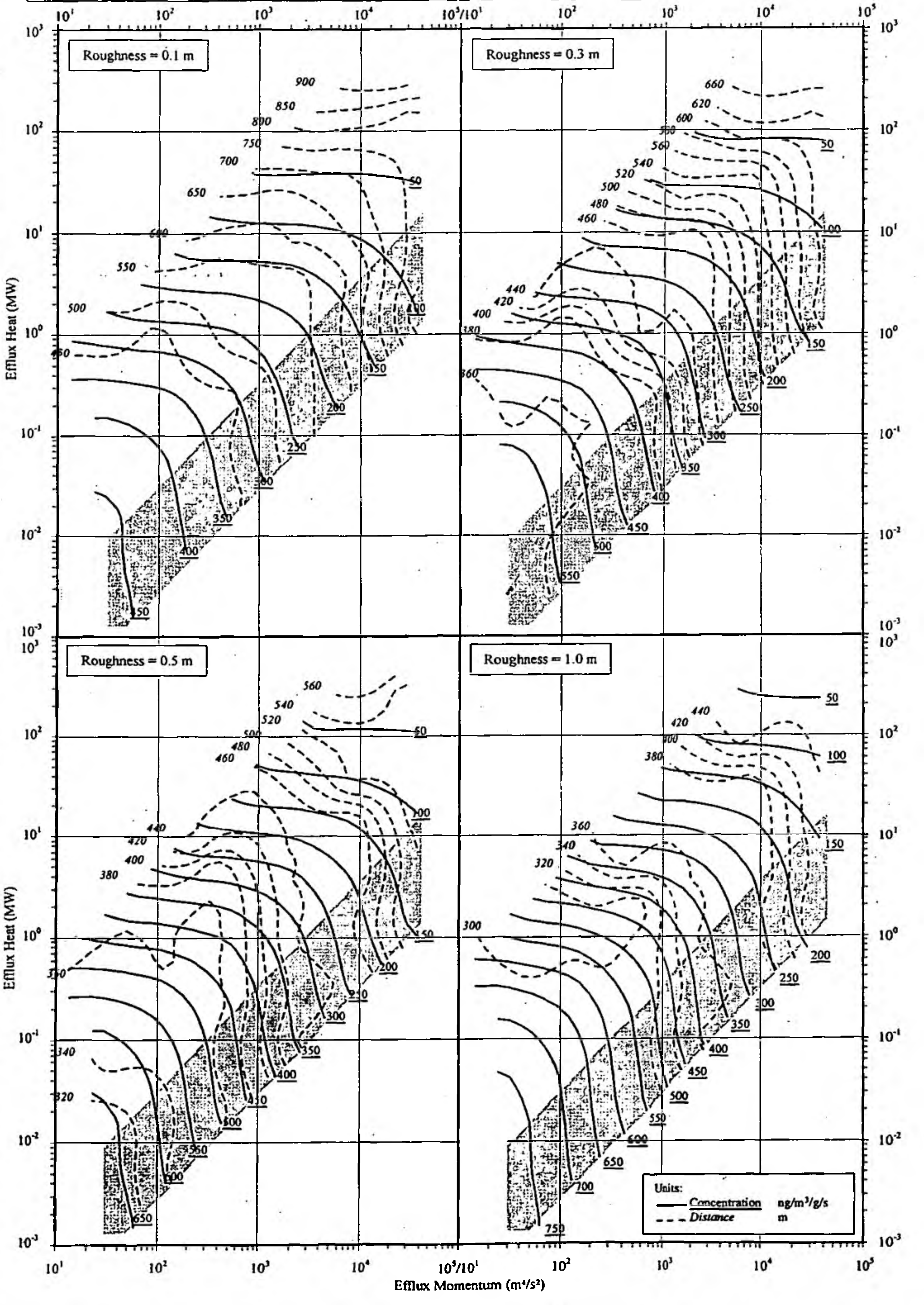


Chart 37	Maximum Ground Level Concentration	Annual Average	50m Stack	Kilnsea (Met Type 2)	ADMS2

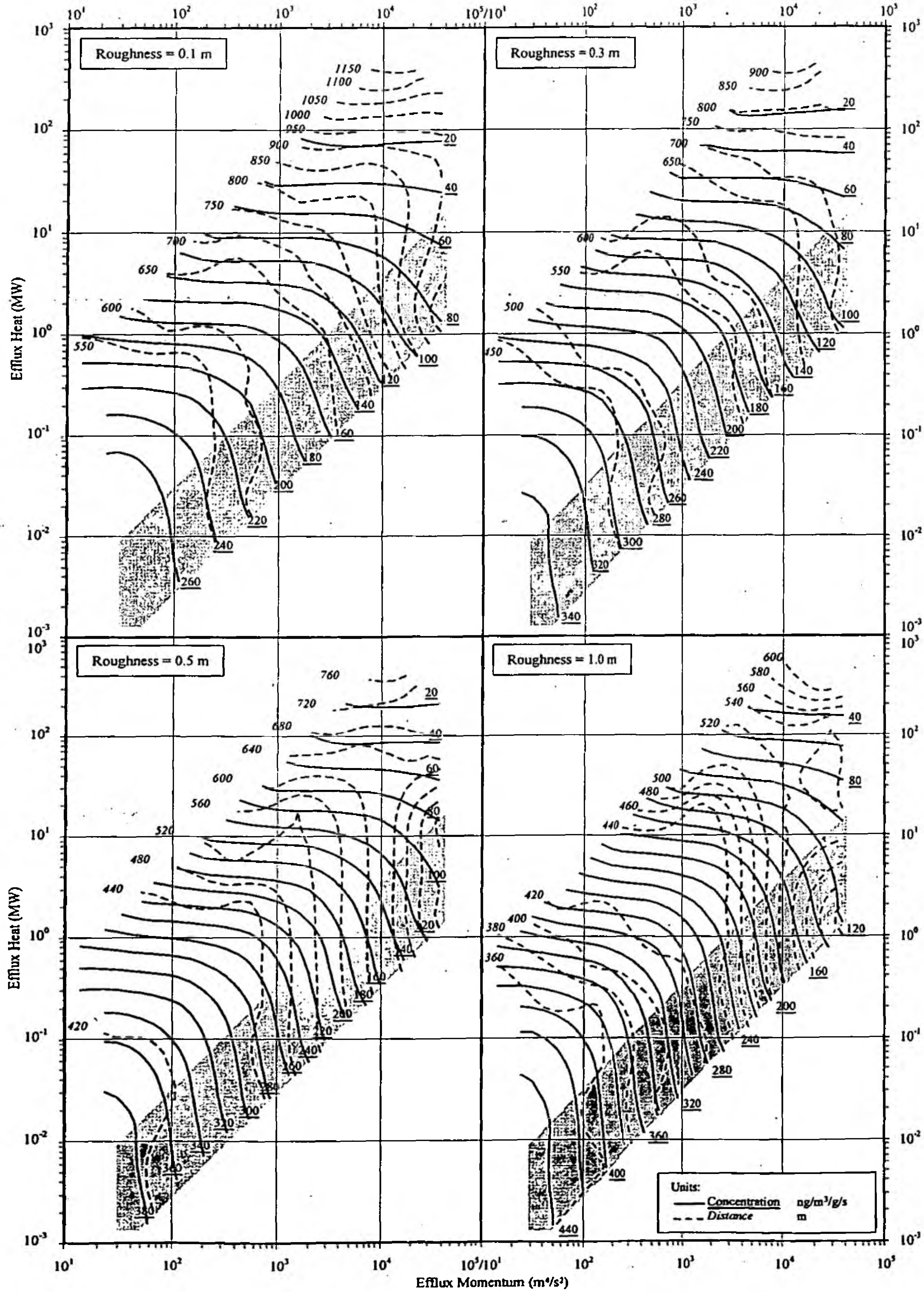


Chart 38	Maximum Ground Level Concentration	Annual Average	60m Stack	Kilnsea (Met Type 2)	ADMS2

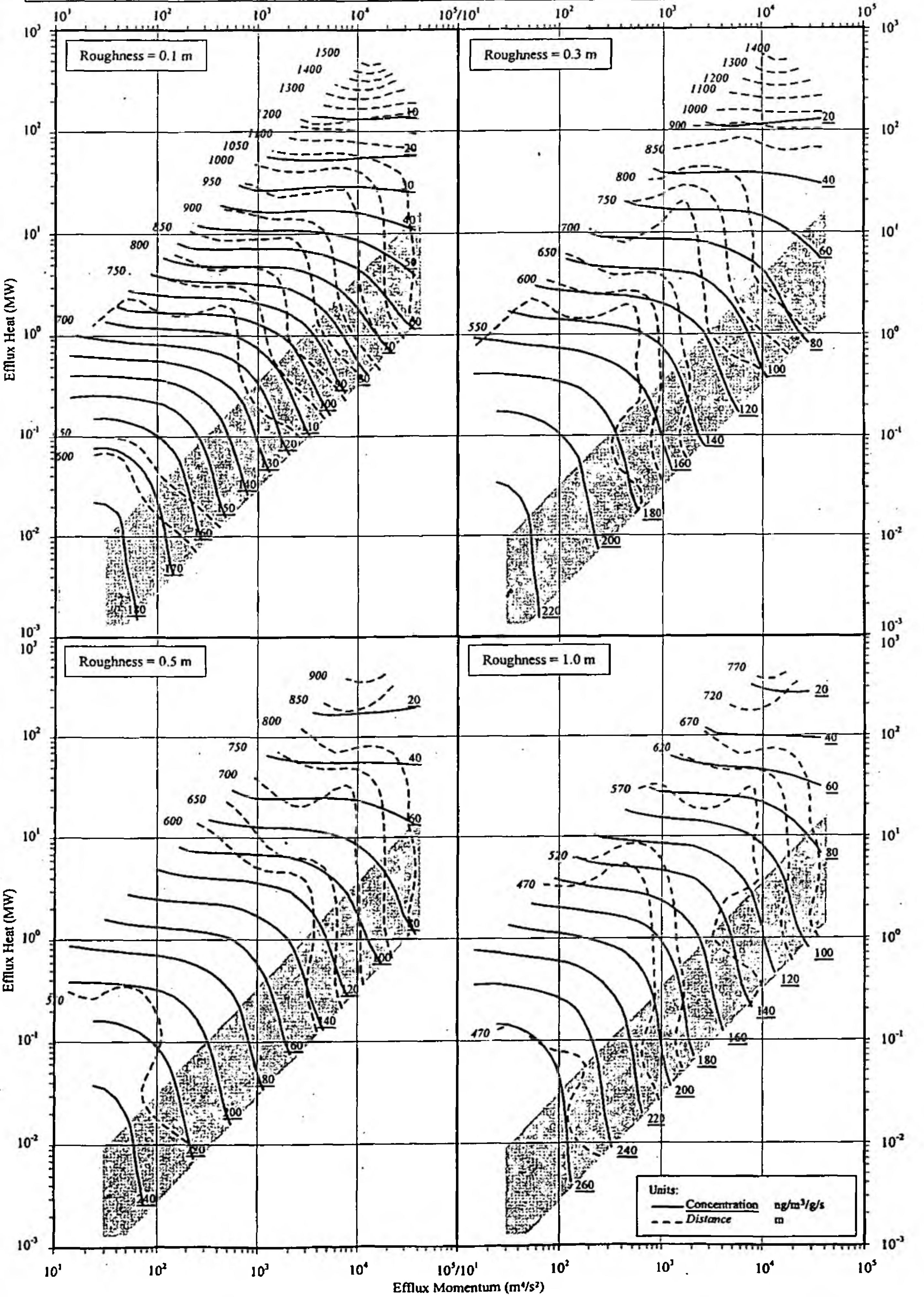


Chart 39	Maximum Ground Level Concentration	Annual Average	70m Stack	Kilnsea (Met Type 2)	ADMS2

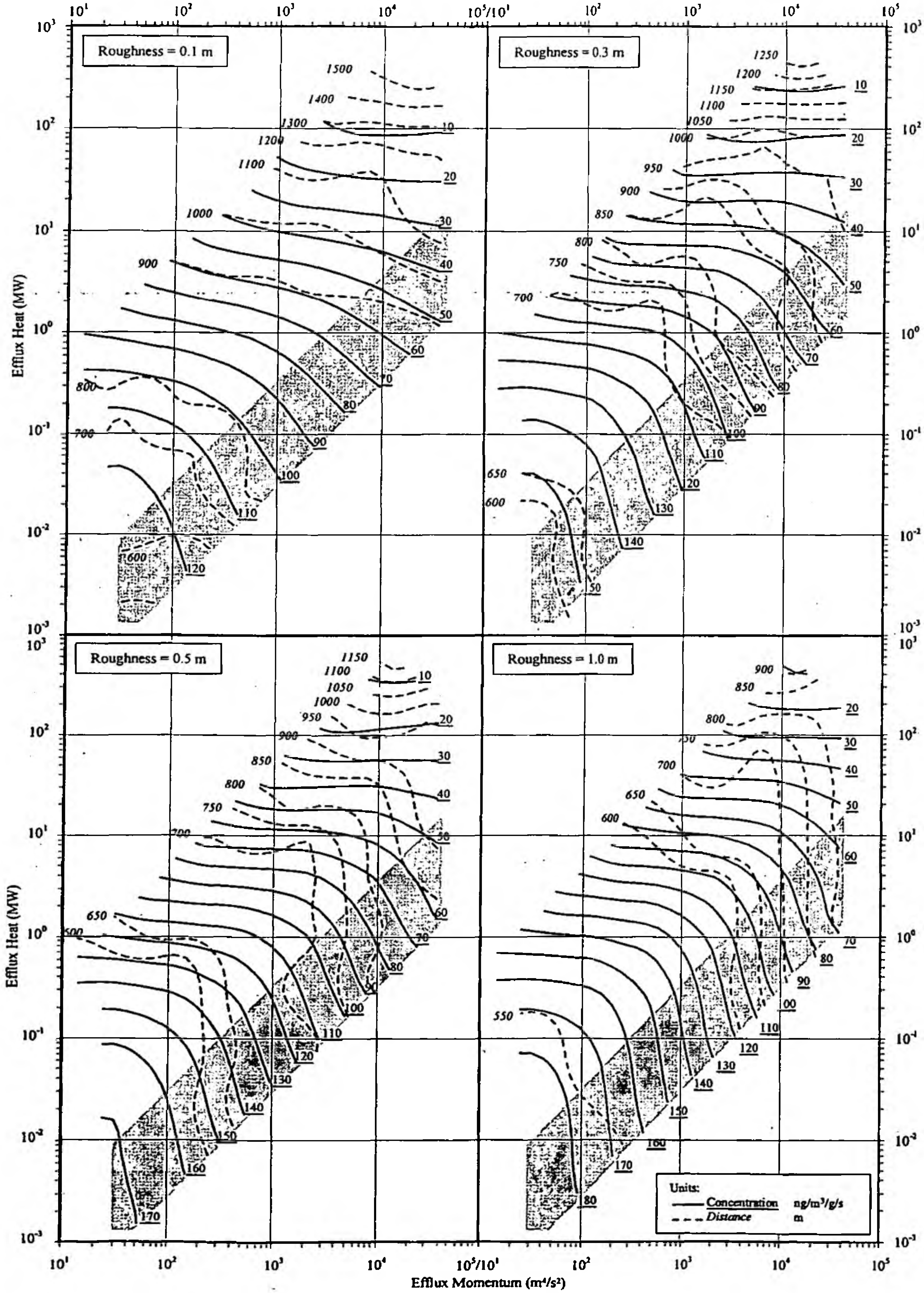


Chart 40	Maximum Ground Level Concentration	Annual Average	85m Stack	Kilnsea (Met Type 2)	ADMS2

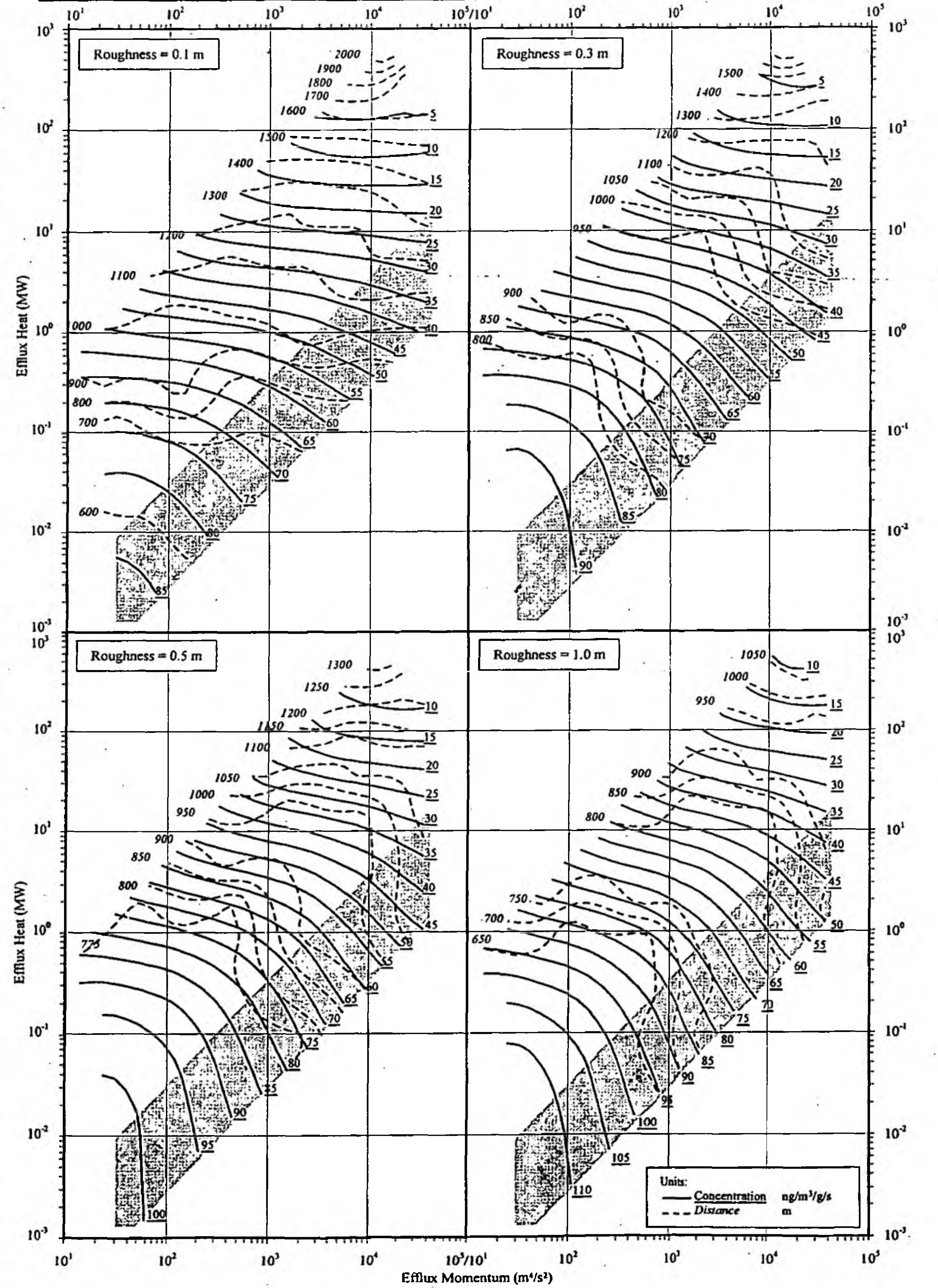


Chart 41	Maximum Ground Level Concentration	Annual Average	100m Stack	Kilnsea (Met Type 2)	ADMS2

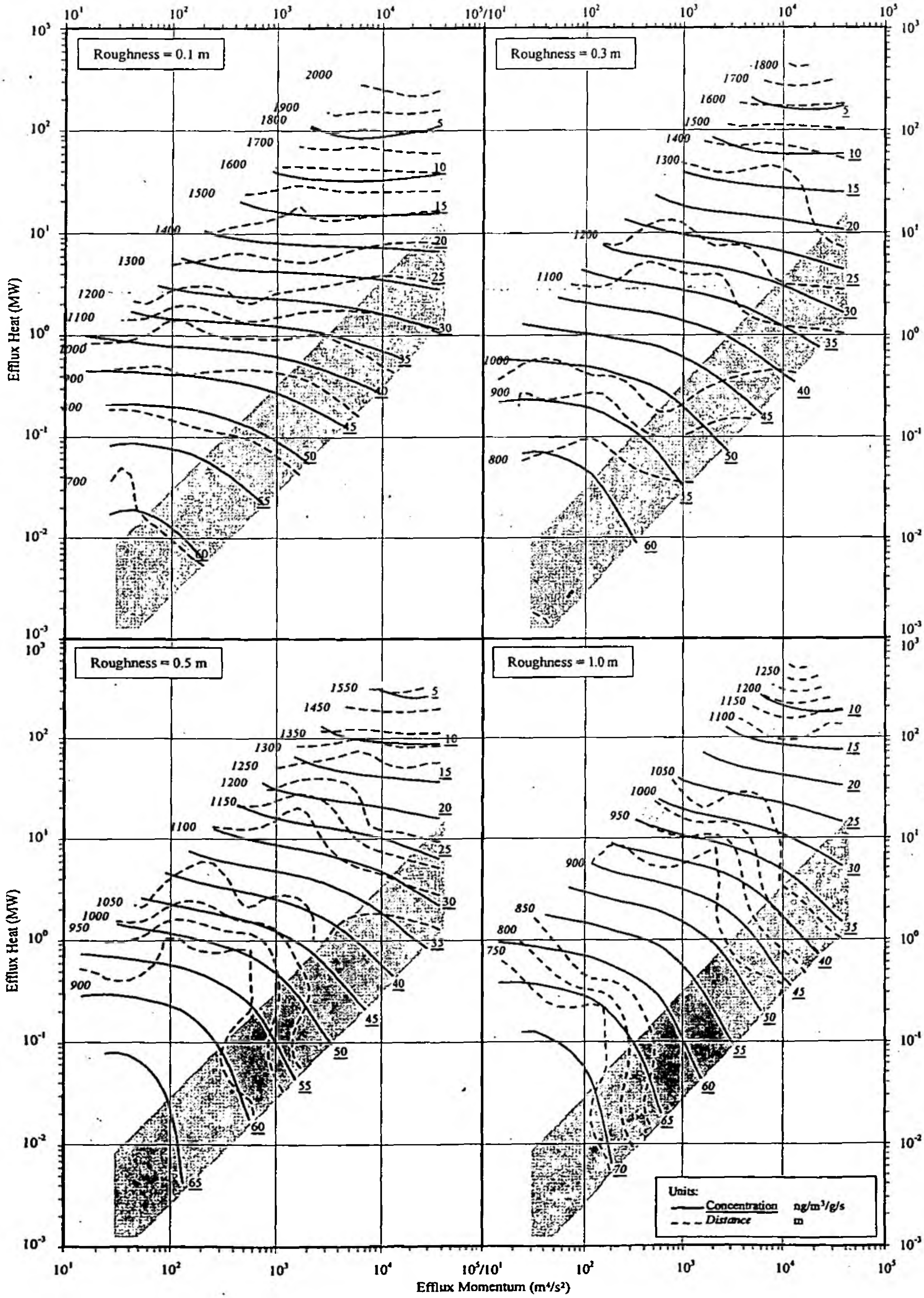


Chart 42	Maximum Ground Level Concentration	Annual Average	120m Stack	Kilnsea (Met Type 2)	ADMS2

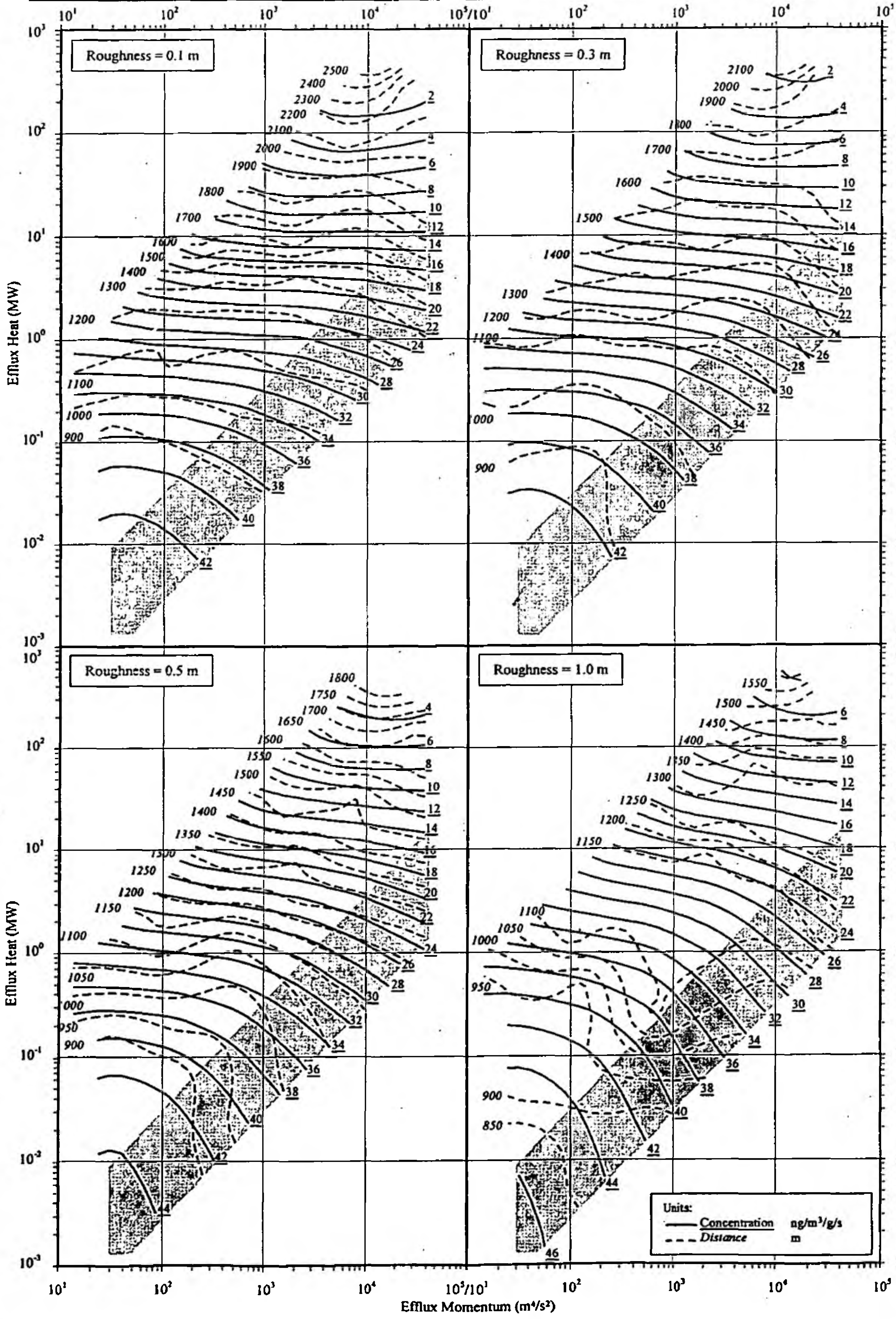


Chart 43	Maximum Ground Level Concentration	Annual Average	150m Stack	Kilnsea (Met Type 2)	ADMS2

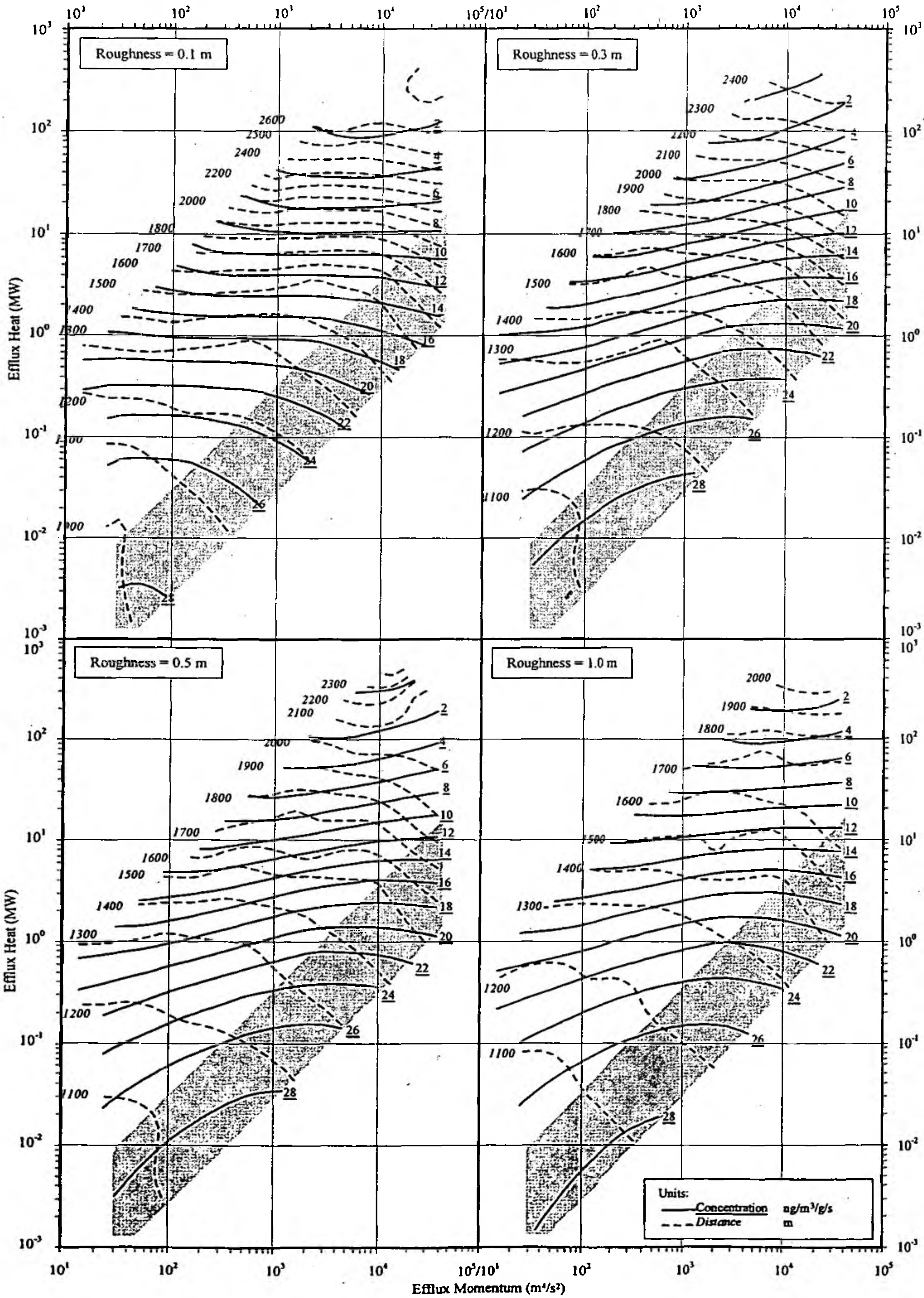


Chart 44	Maximum Ground Level Concentration	Annual Average	200m Stack	Kilnsea (Met Type 2)	ADMS2

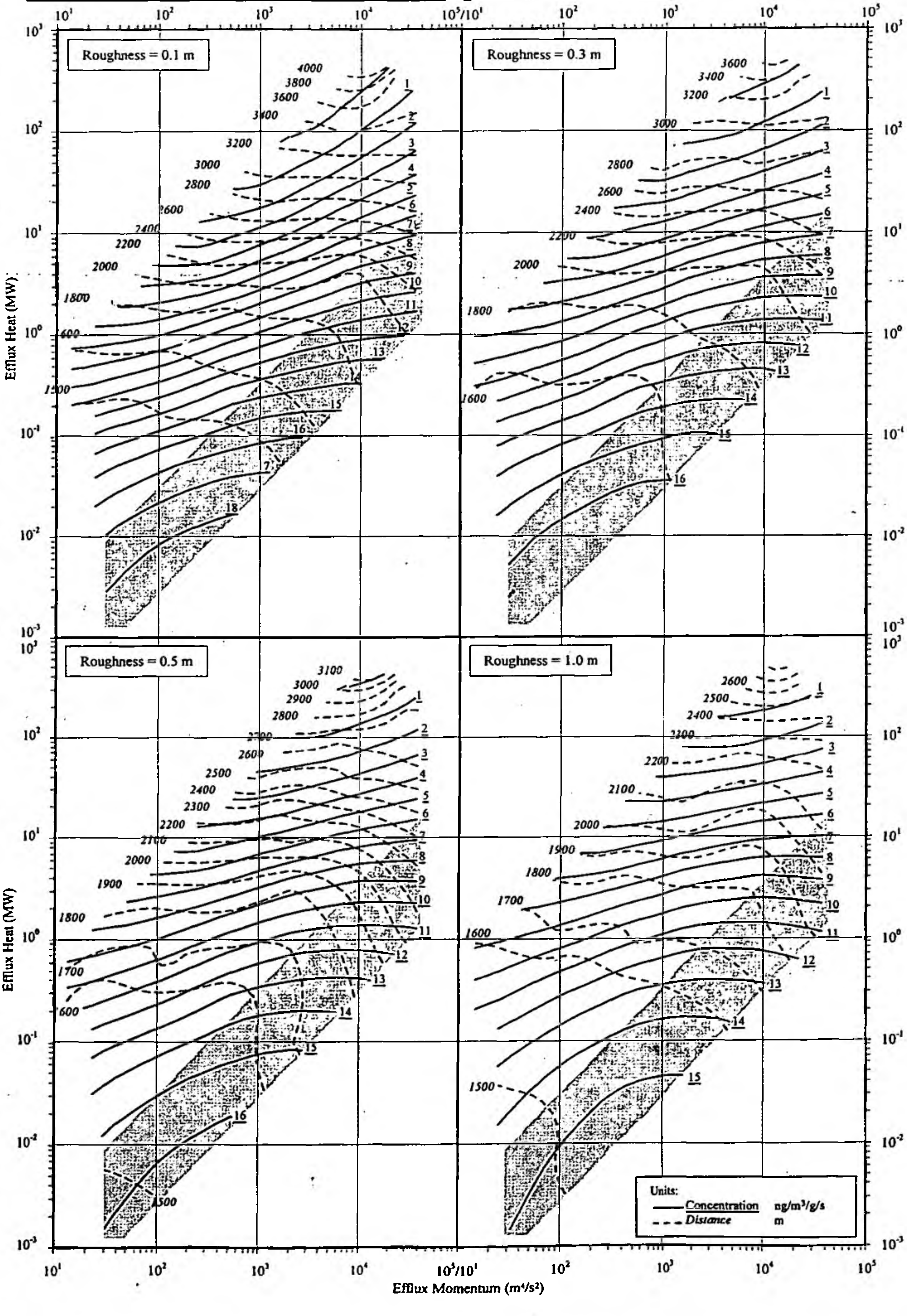


Chart 45	Maximum Ground Level Concentration	99.9th Percentile	20m Stack	Kilnsea (Met Type 2)	ADMS2

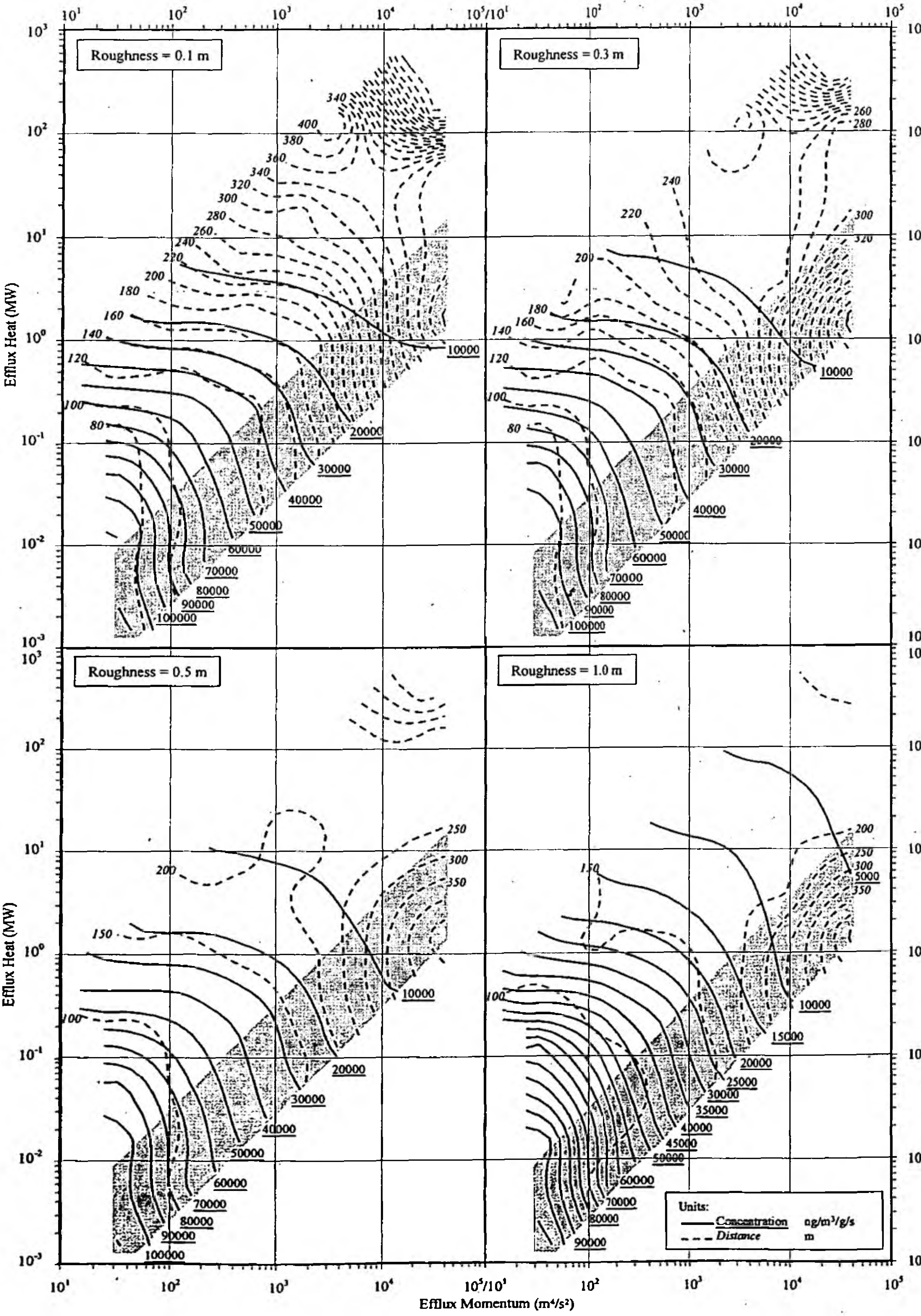


Chart 46	Maximum Ground Level Concentration	99.9th Percentile	30m Stack	Kilnsea (Met Type 2)	ADMS2

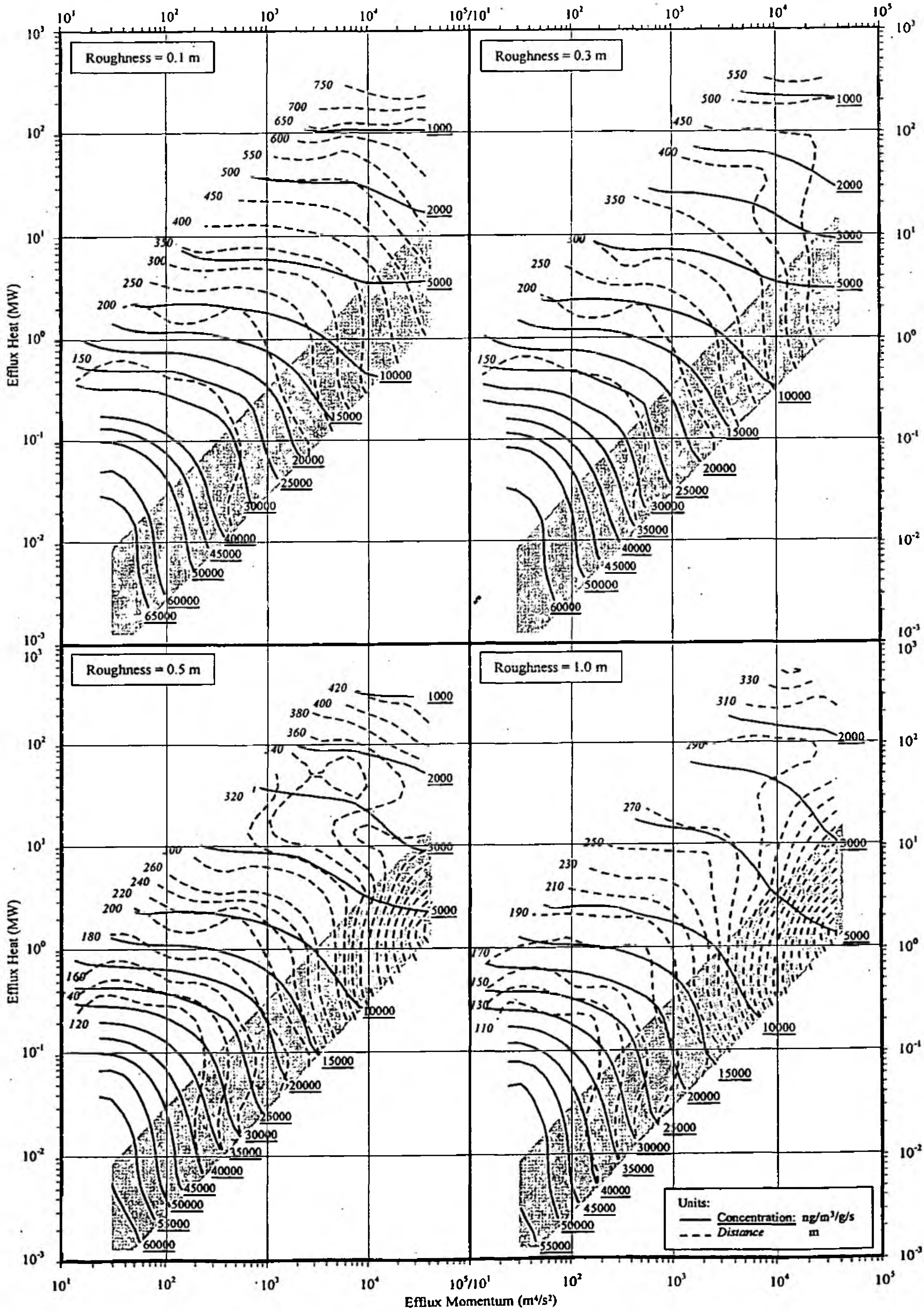


Chart 47	Maximum Ground Level Concentration	99.9th Percentile	40m Stack	Kilnsea (Met Type 2)	ADMS2

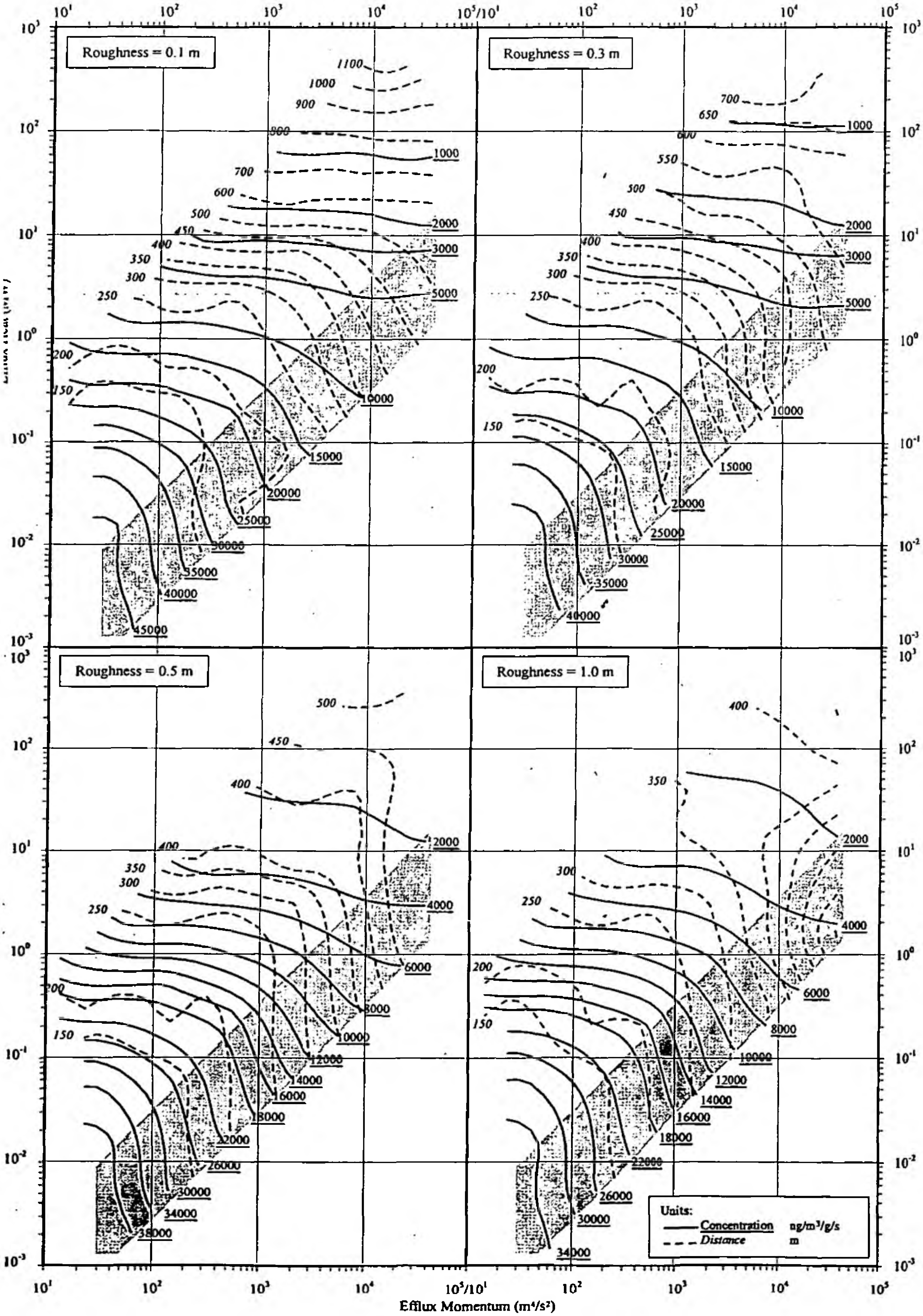


Chart 48	Maximum Ground Level Concentration	99.9th Percentile	50m Stack	Kilnsea (Met Type 2)	ADMS2

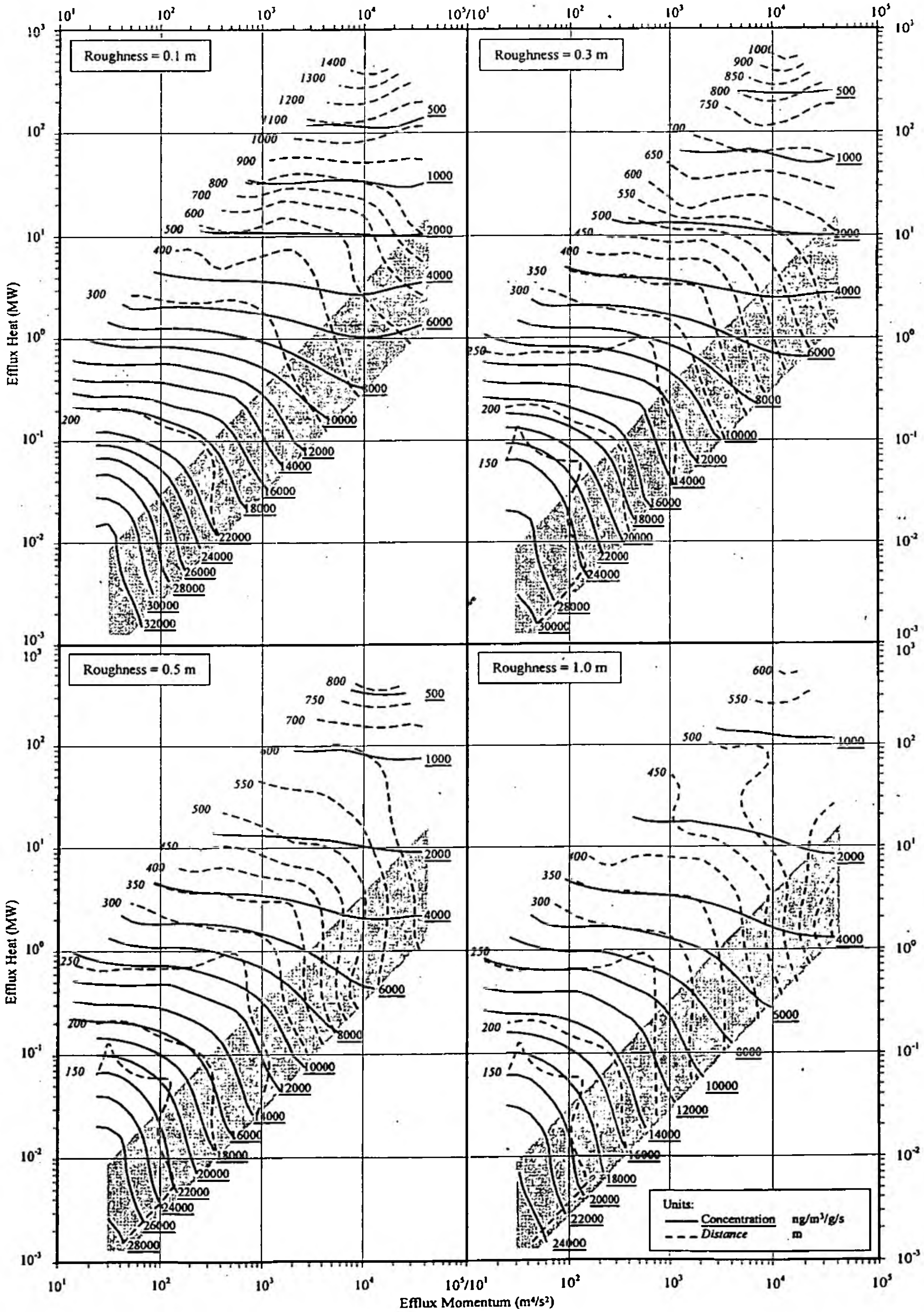


Chart 49	Maximum Ground Level Concentration	99.9th Percentile	60m Stack	Kilnsea (Met Type 2)	ADMS2

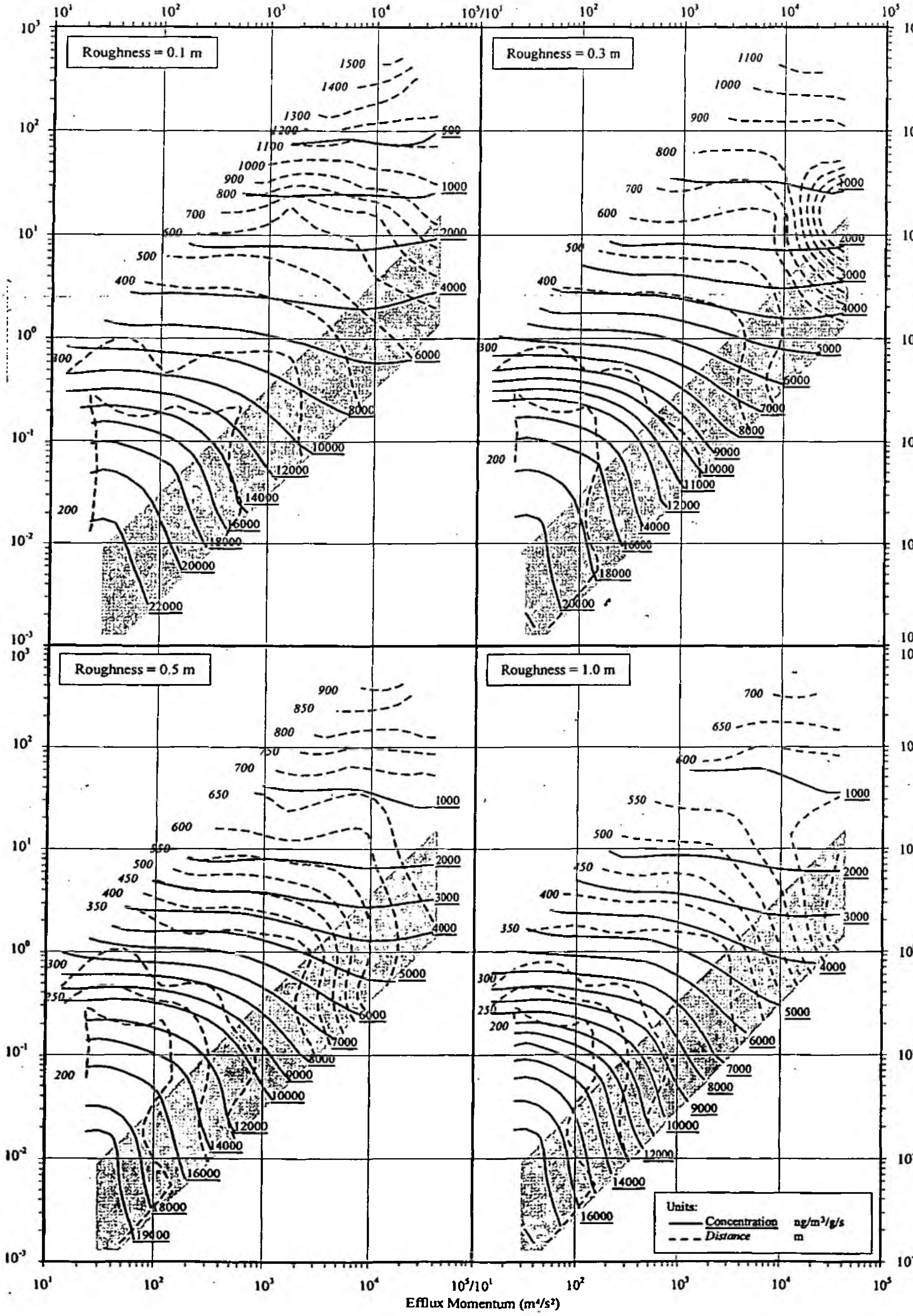


Chart 50	Maximum Ground Level Concentration	99.9th Percentile	70m Stack	Kilnsea (Met Type 2)	ADMS2

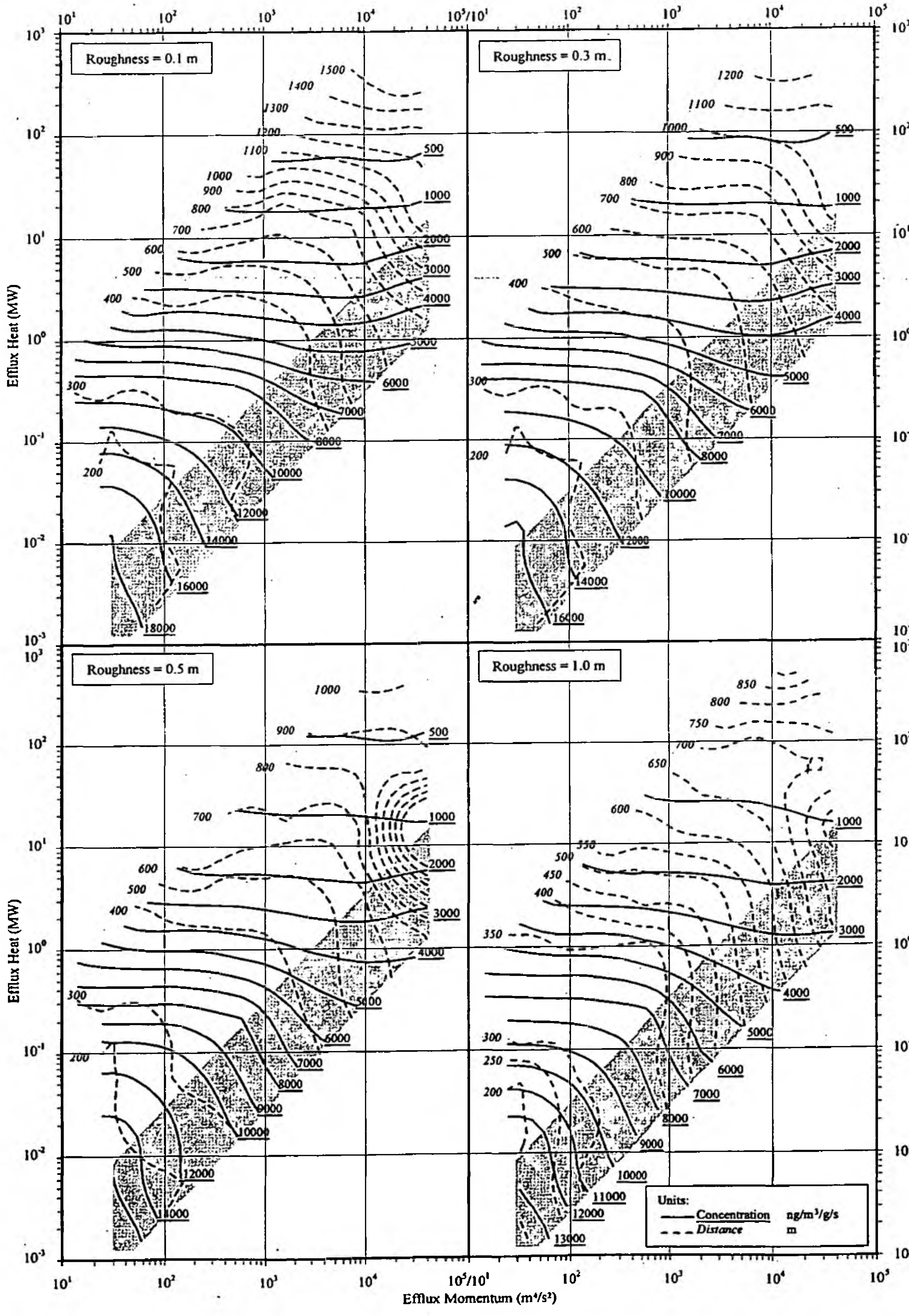


Chart 51	Maximum Ground Level Concentration	99.9th Percentile	85m Stack	Kilnsea (Met Type 2)	ADMS2

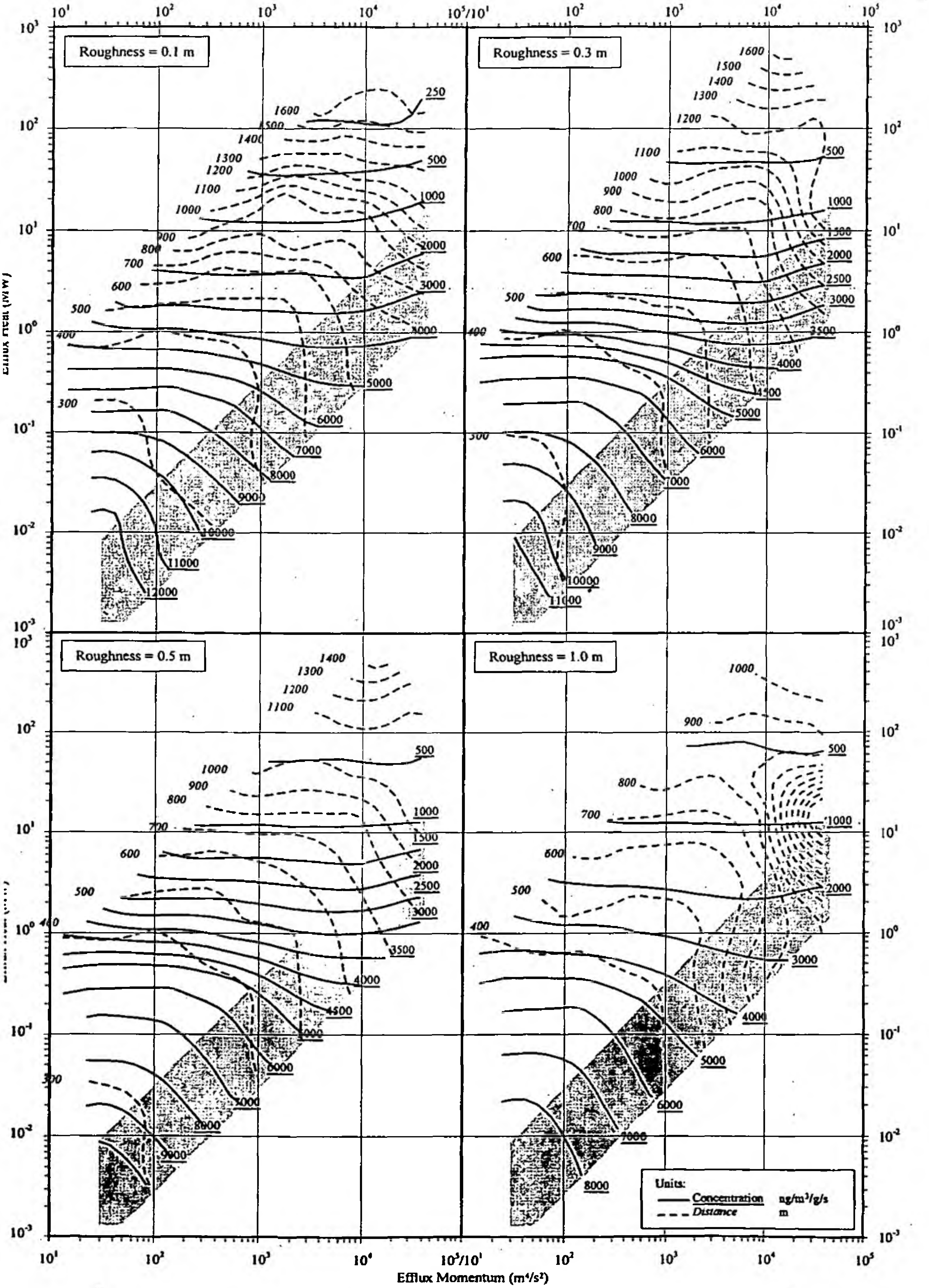


Chart 52	Maximum Ground Level Concentration	99.9th Percentile	100m Stack	Kilnsea (Met Type 2)	ADMS2

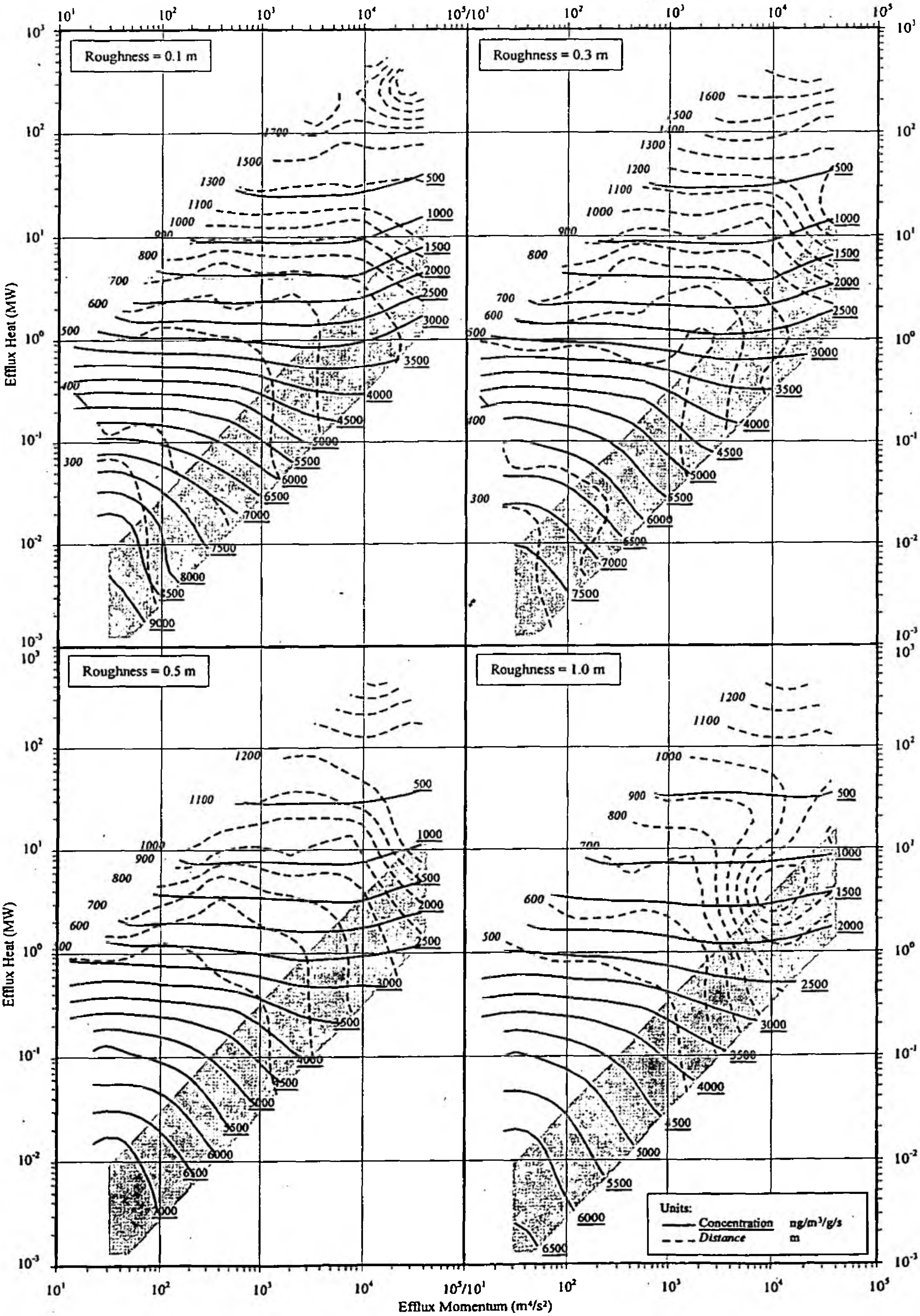


Chart 53	Maximum Ground Level Concentration	99.9th Percentile	120m Stack	Kilnsea (Met Type 2)	ADMS2

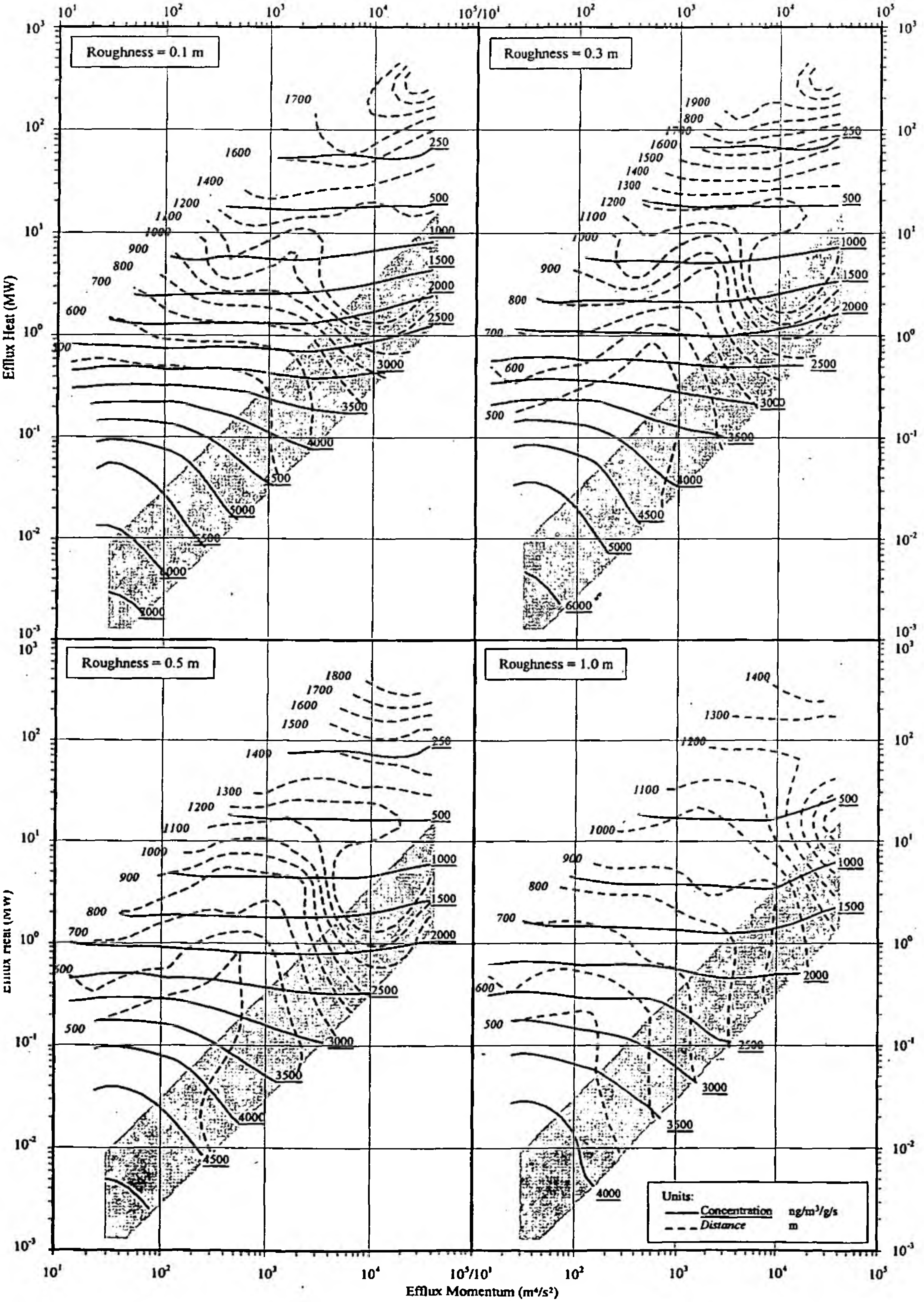


Chart 54	Maximum Ground Level Concentration	99.9th Percentile	150m Stack	Kilnsea (Met Type 2)	ADMS2

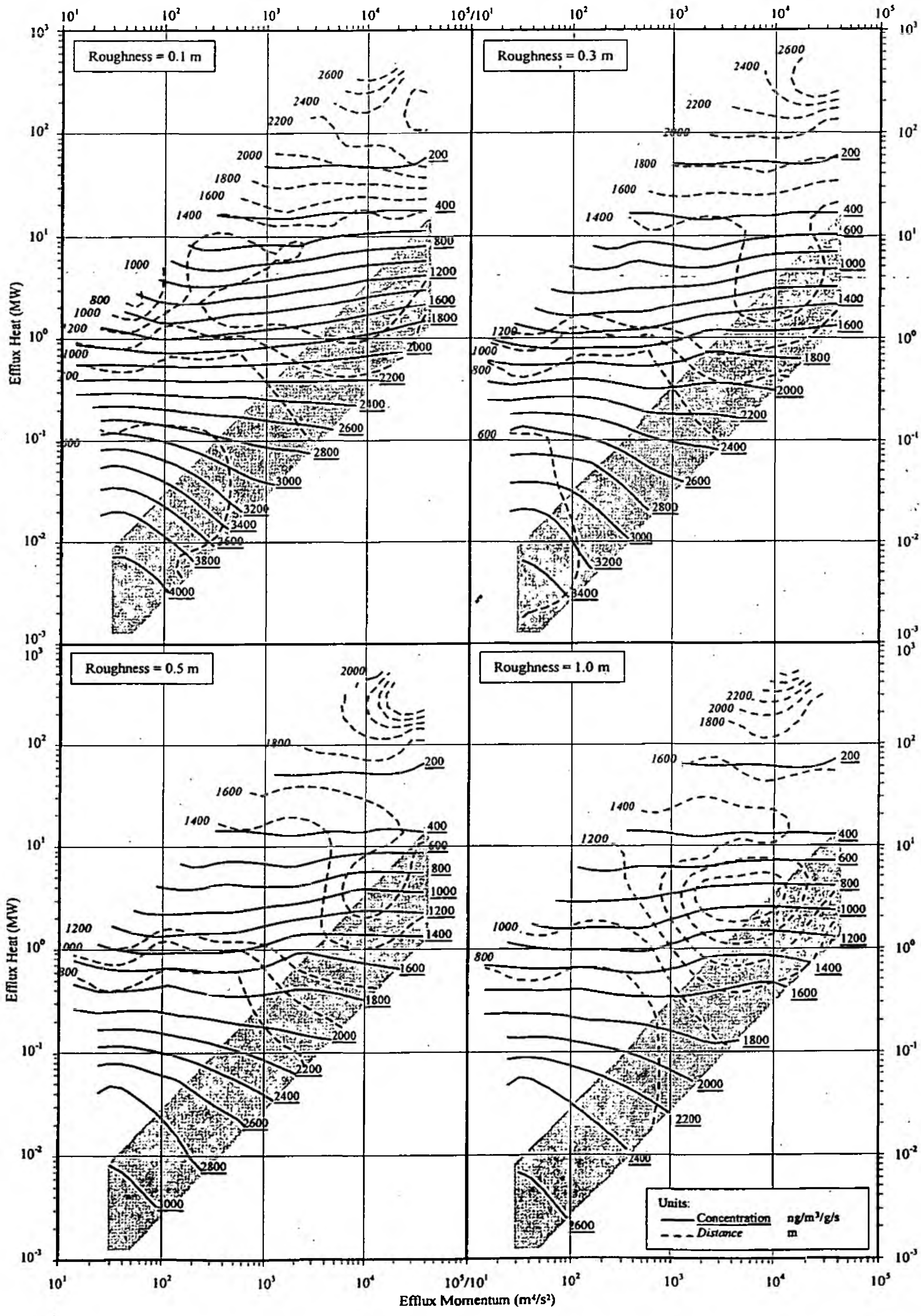


Chart 55	Maximum Ground Level Concentration	99.9th Percentile	200m Stack	Kilnsea (Met Type 2)	ADMS2

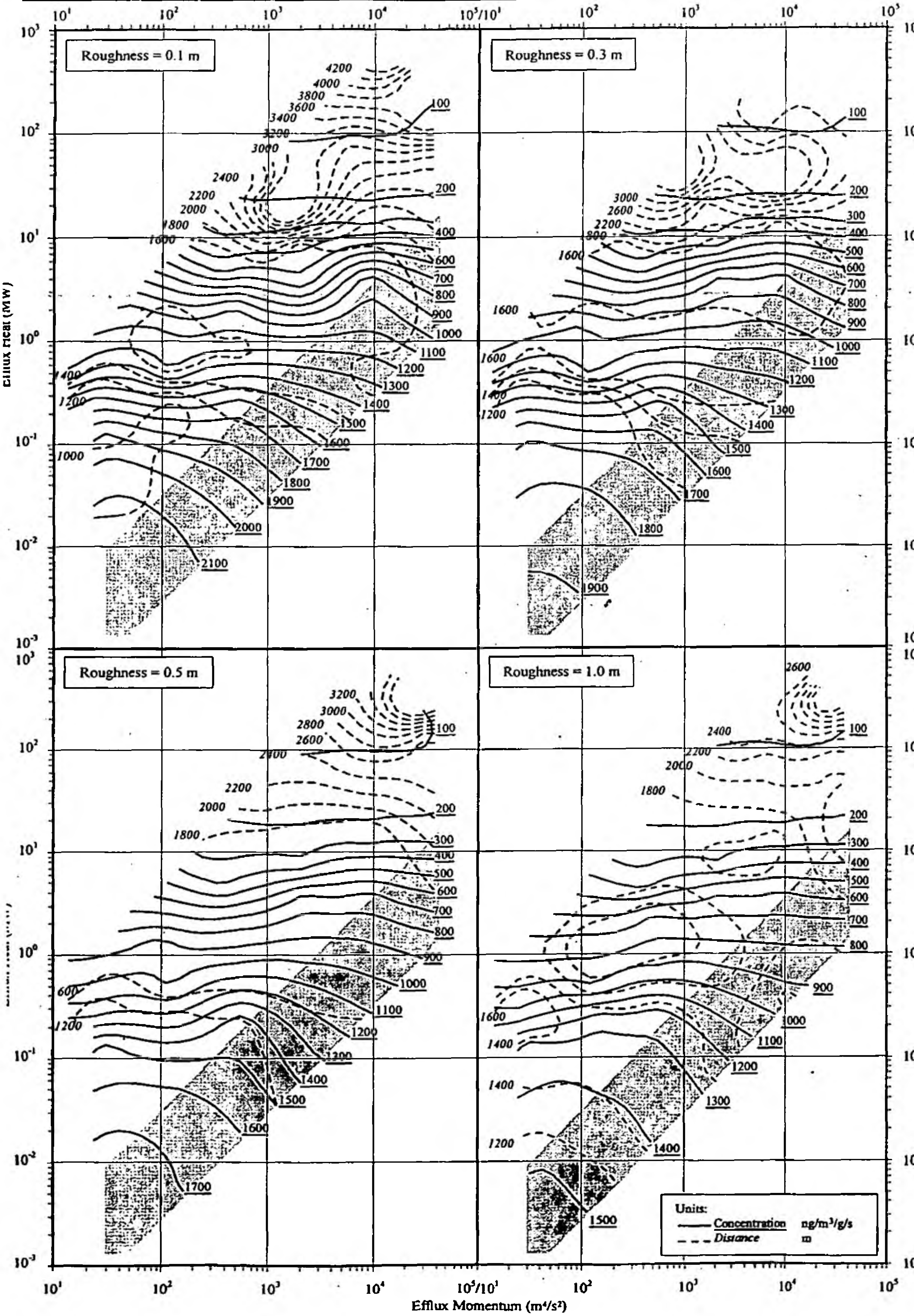


Chart 56	Maximum Ground Level Concentration	100th Percentile	20m Stack	Kilnsea (Met Type 2)	ADMS2

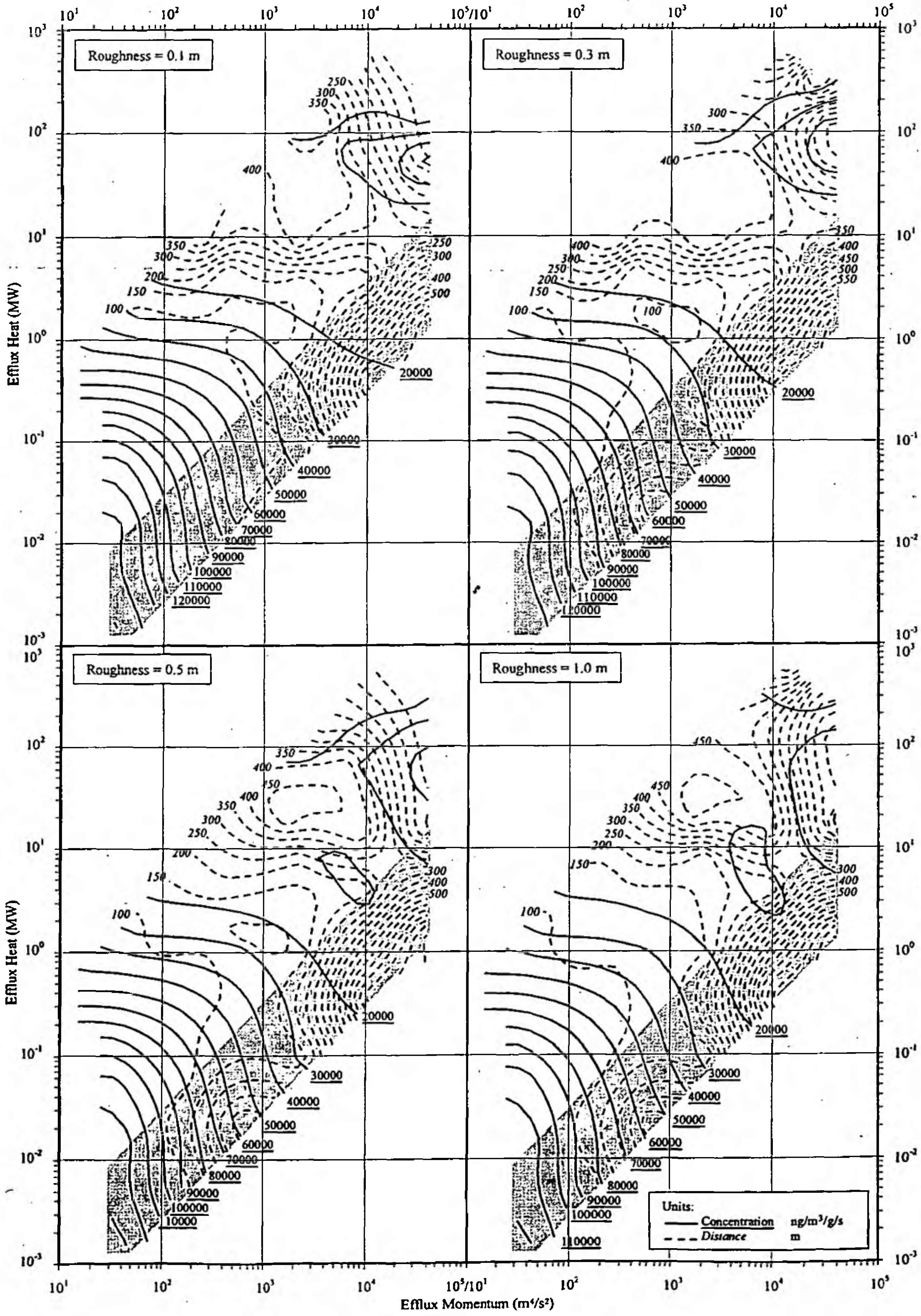


Chart 57	Maximum Ground Level Concentration	100th Percentile	30m Stack	Kilnsea (Met Type 2)	ADMS2

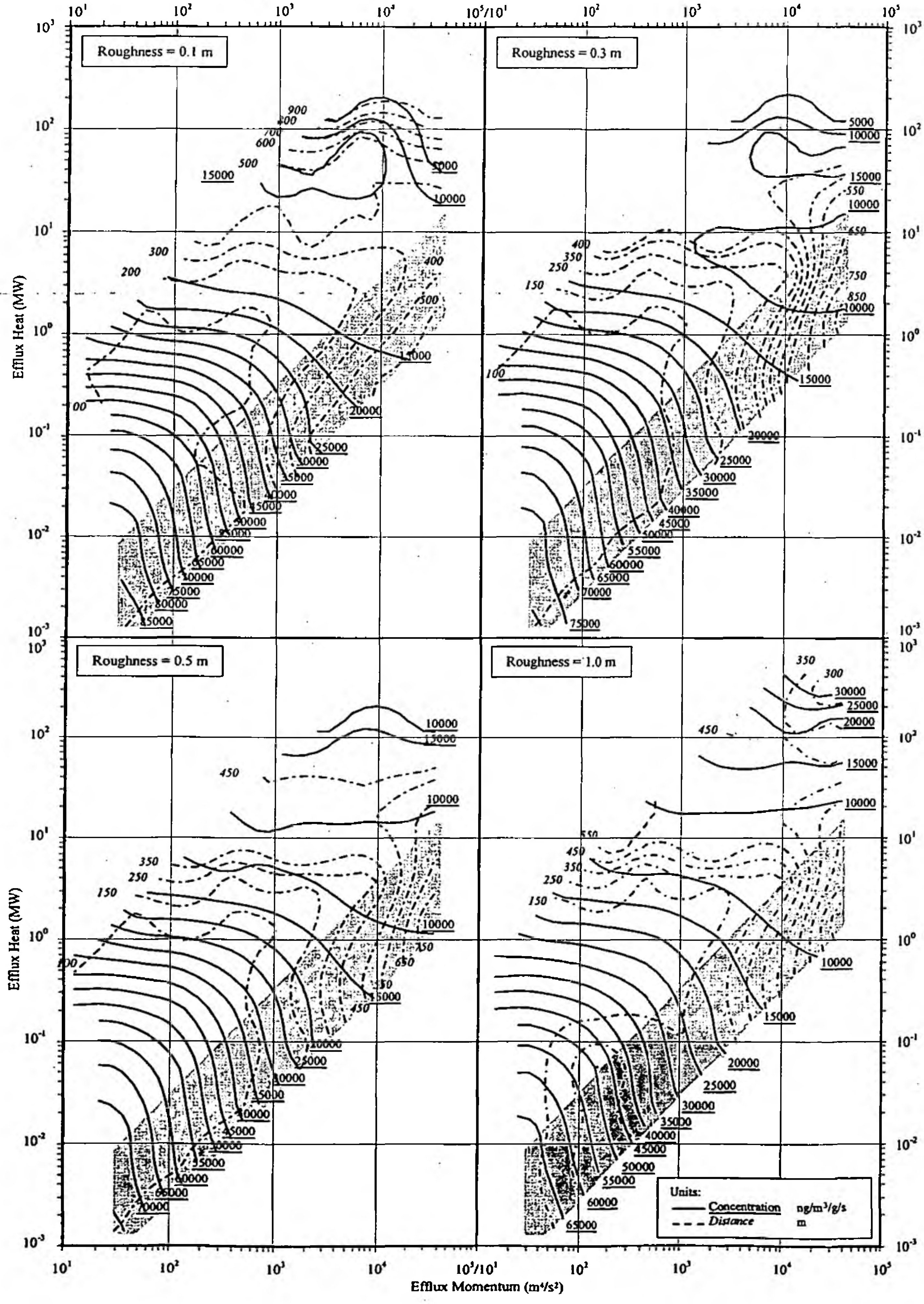


Chart 58	Maximum Ground Level Concentration	100th Percentile	40m Stack	Kilnsea (Met Type 2)	ADMS2

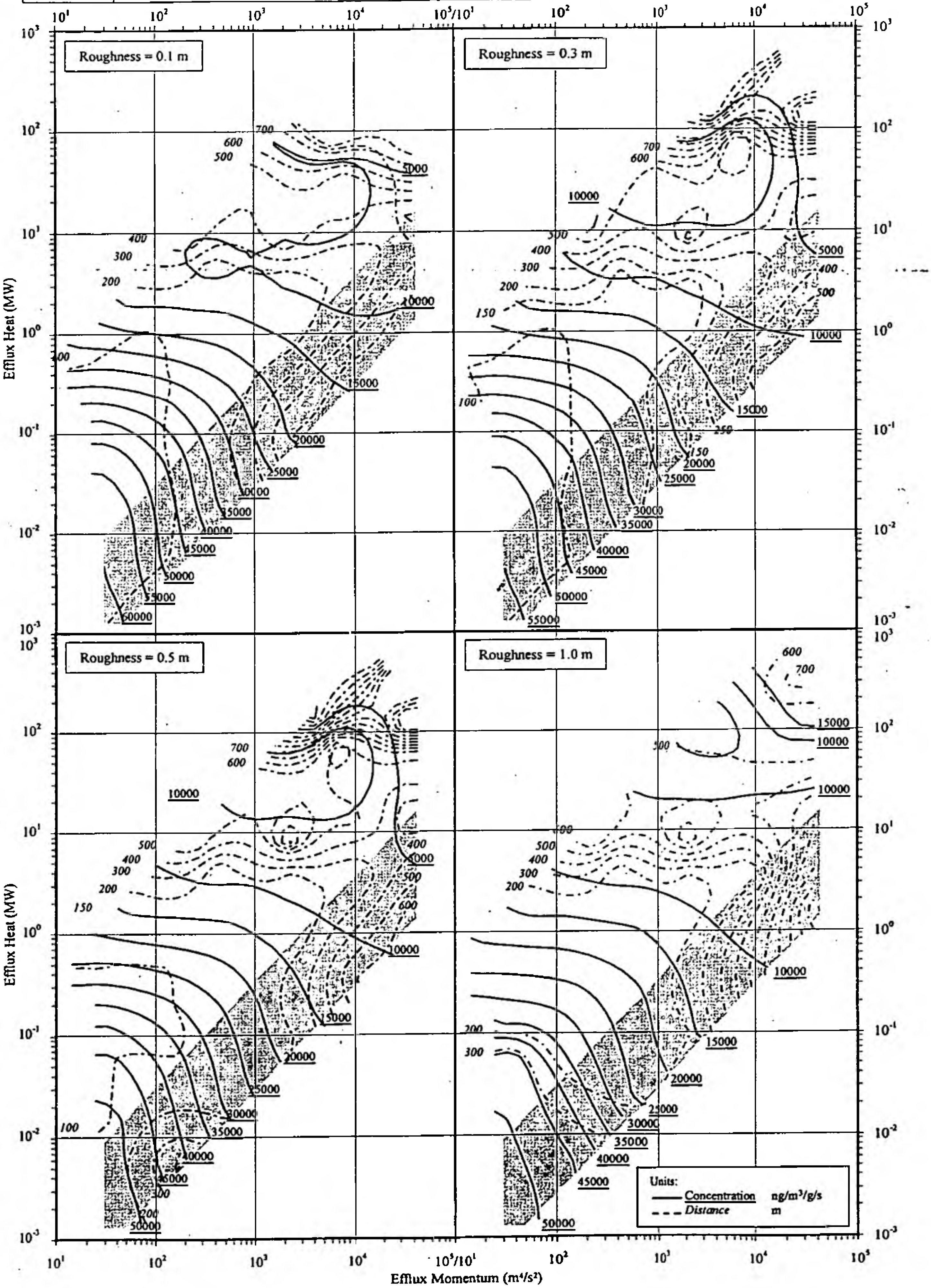


Chart 59	Maximum Ground Level Concentration	100th Percentile	50m Stack	Kilnsea (Met Type 2)	ADMS2

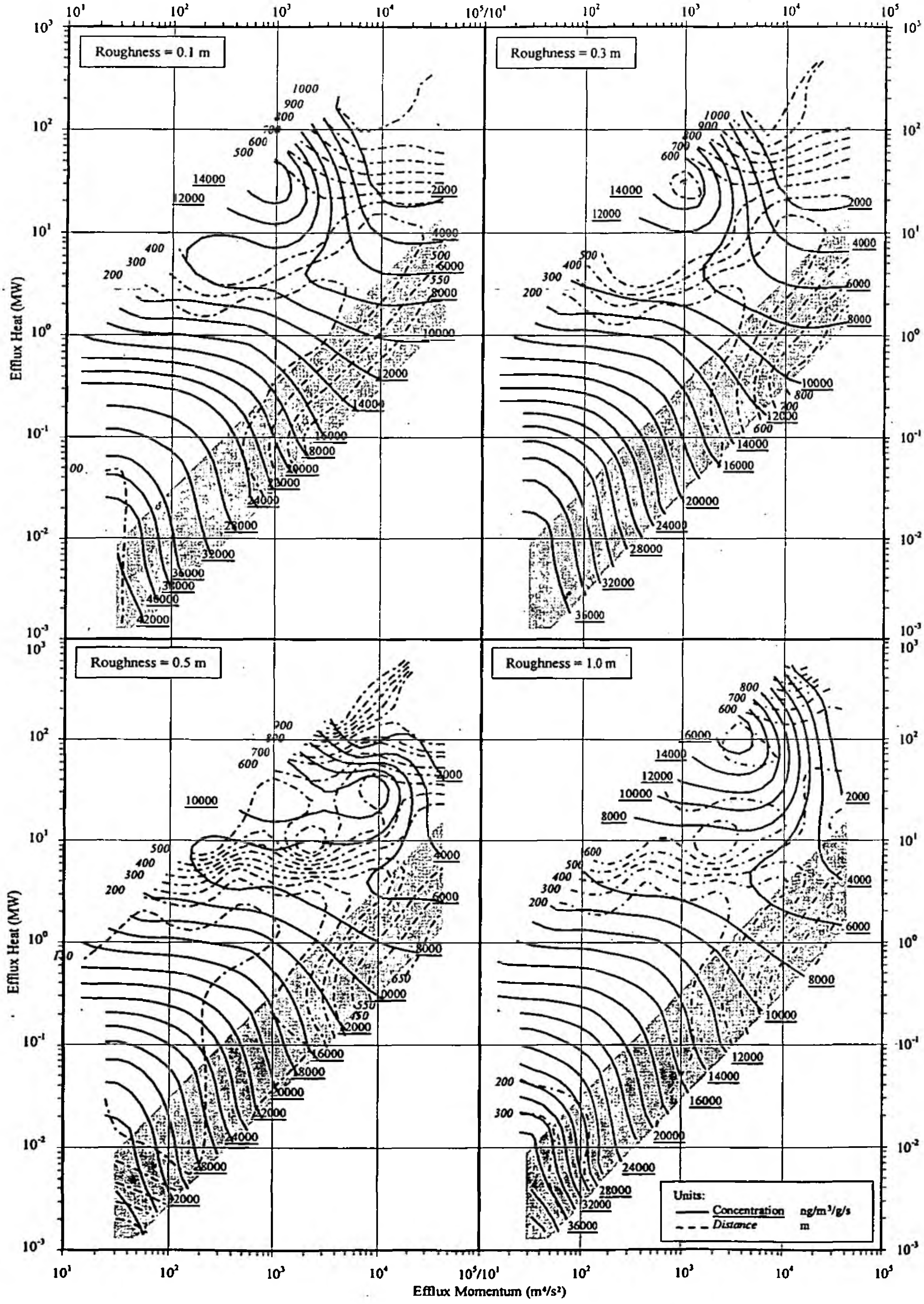


Chart 60	Maximum Ground Level Concentration	100^{th} Percentile	60m Stack	Kilnsea (Met Type 2)	ADMS2

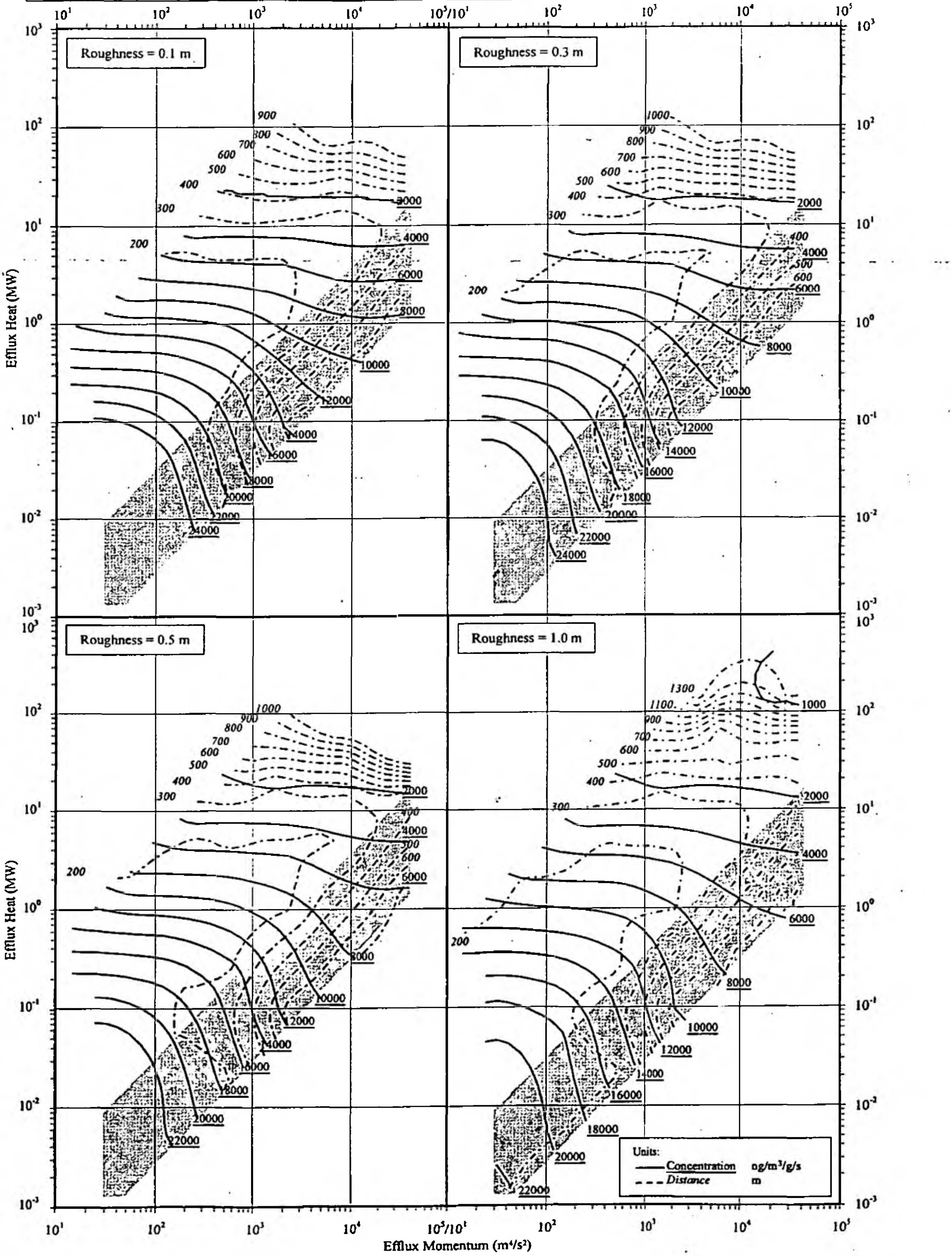


Chart 61	Maximum Ground Level Concentration	100th Percentile	70m Stack	Kilnsea (Met Type 2)	ADMS2

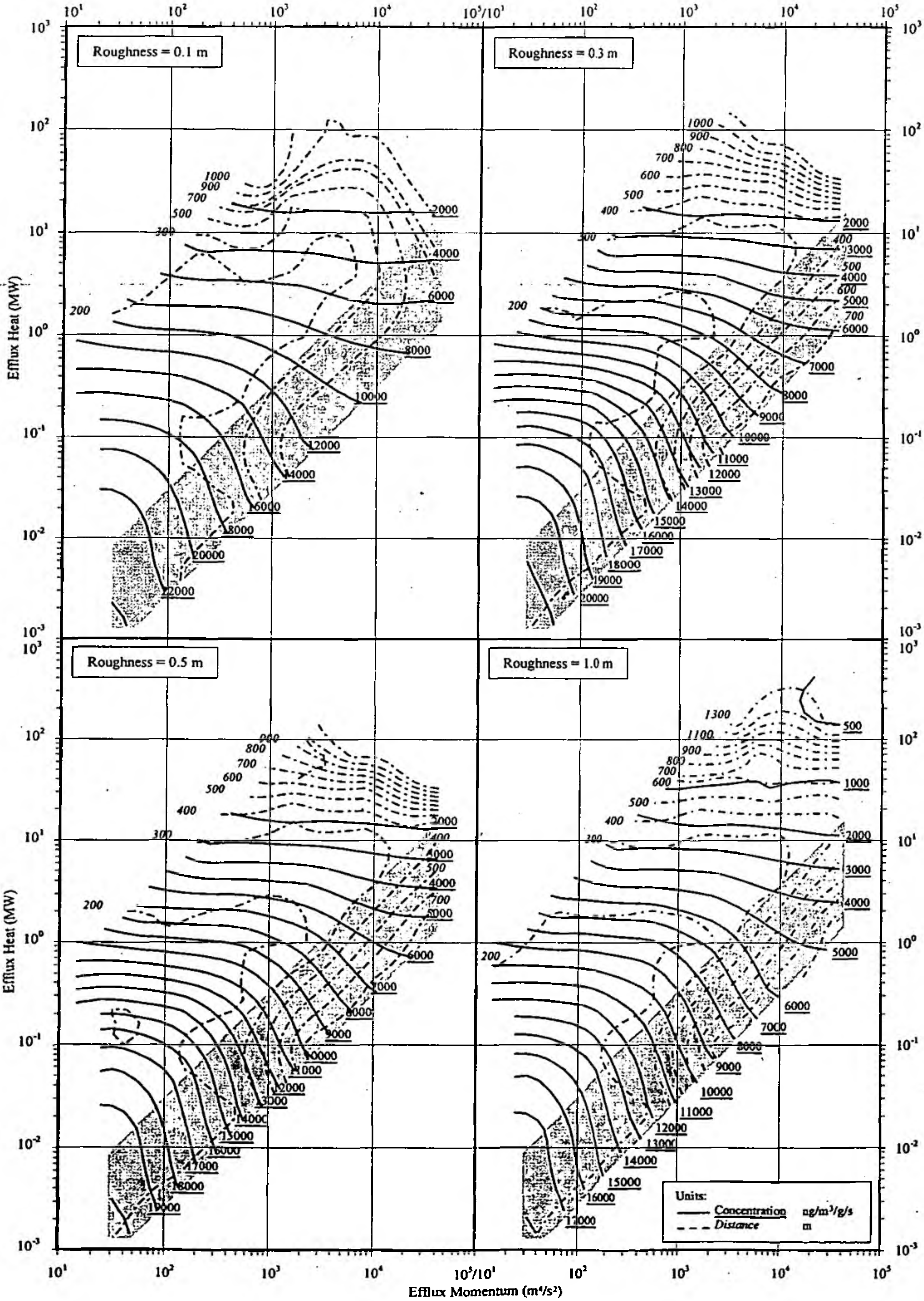


Chart 62	Maximum Ground Level Concentration	100th Percentile	85m Stack	Kilnsea (Met Type 2)	ADMS2

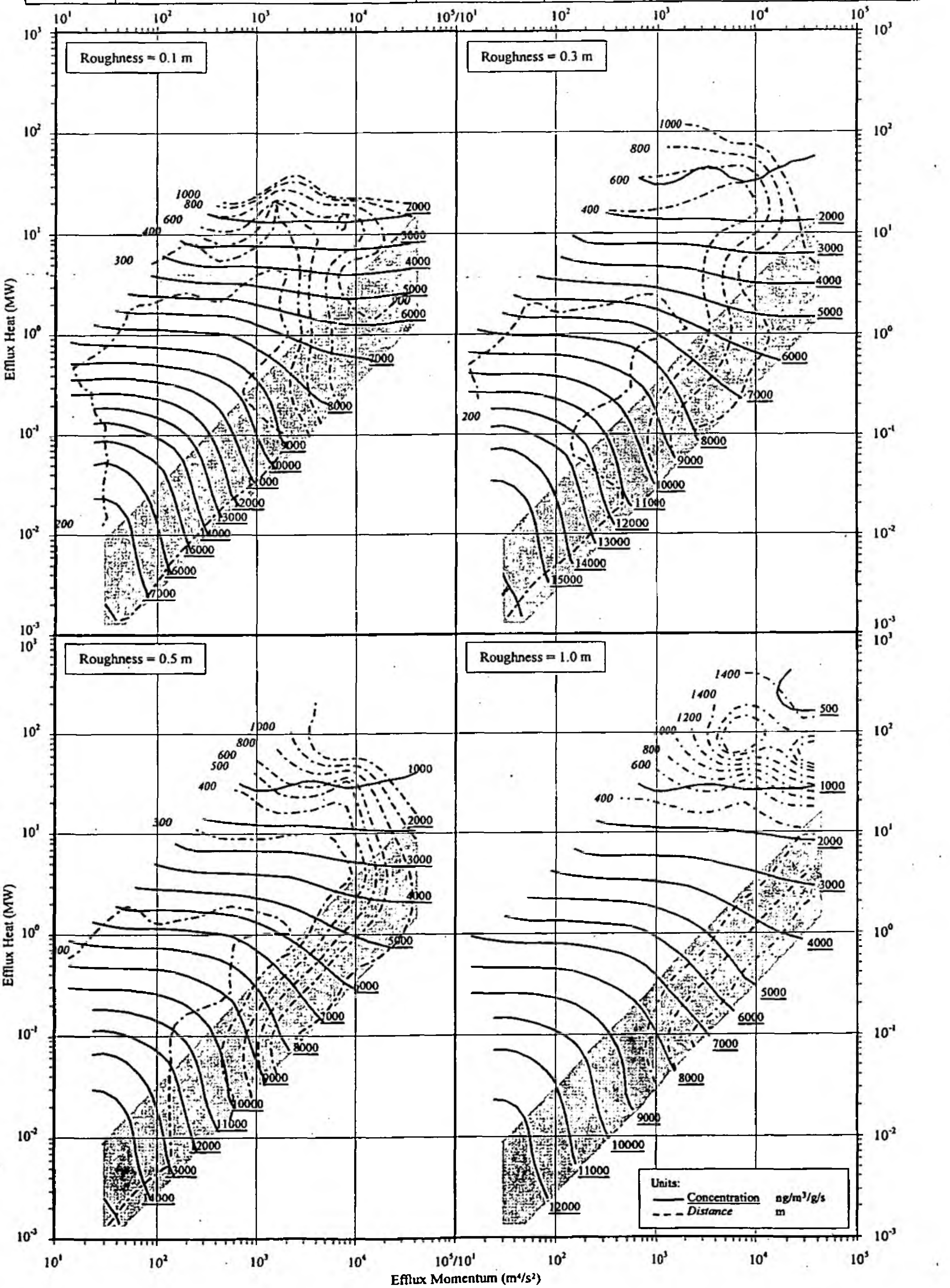


Chart 63	Maximum Ground Level Concentration	100th Percentile	100m Stack	Kilnsea (Met Type 2)	ADMS2

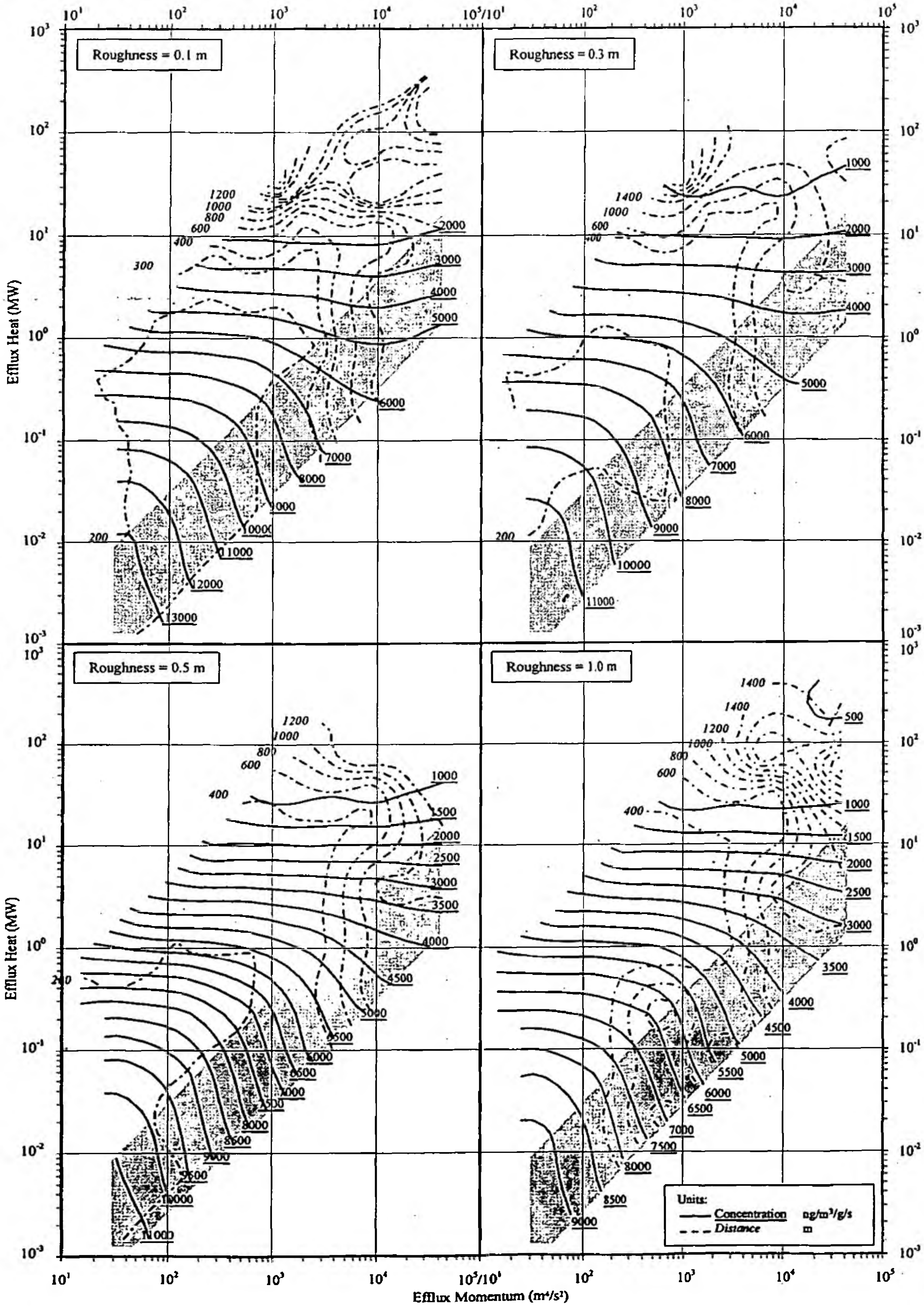


Chart 64	Maximum Ground Level Concentration	100th Percentile	120m Stack	Kilnsea (Met Type 2)	ADMS2

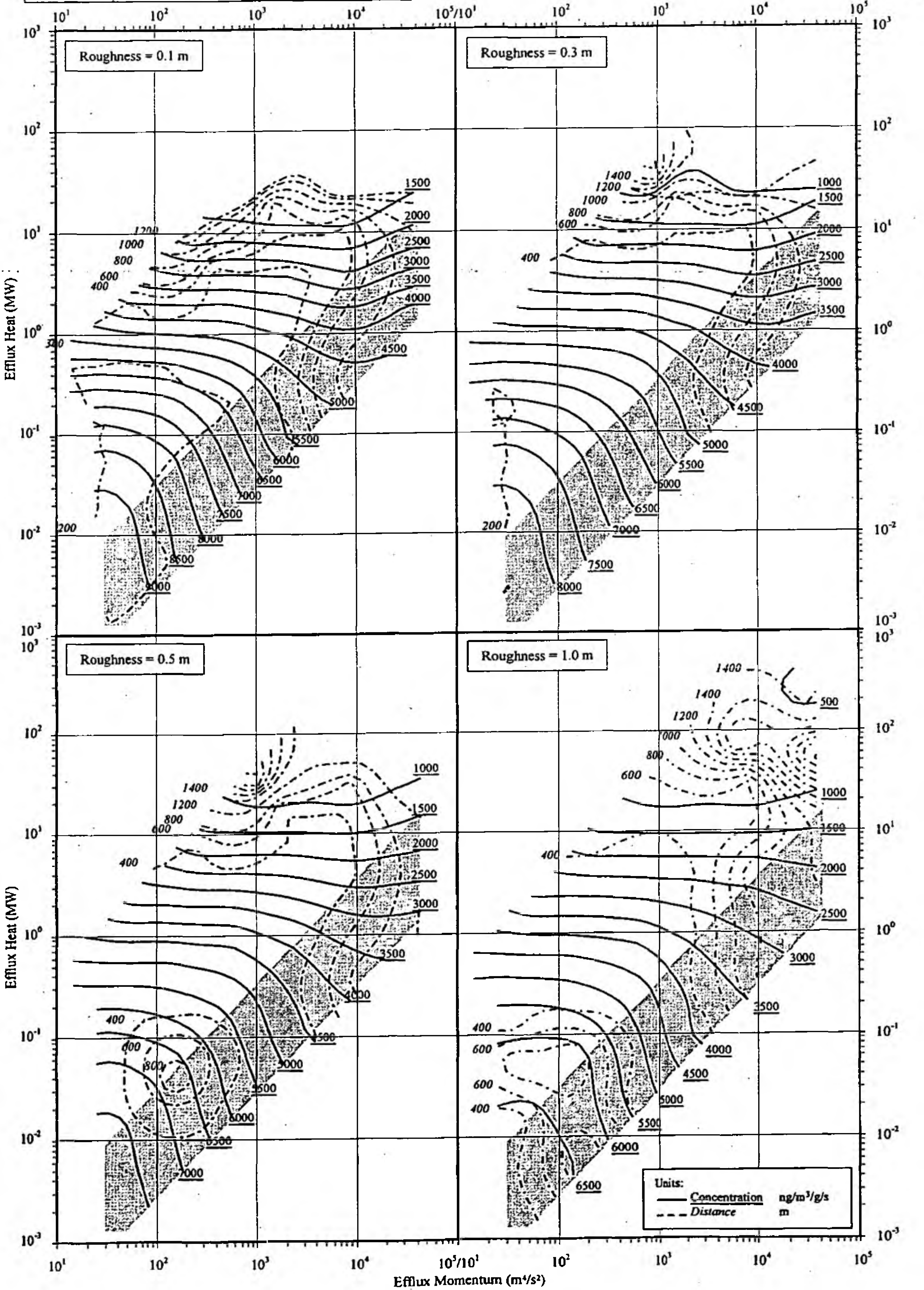


Chart 65	Maximum Ground Level Concentration	100th Percentile	150m Stack	Kilnsea (Met Type 2)	ADMS2

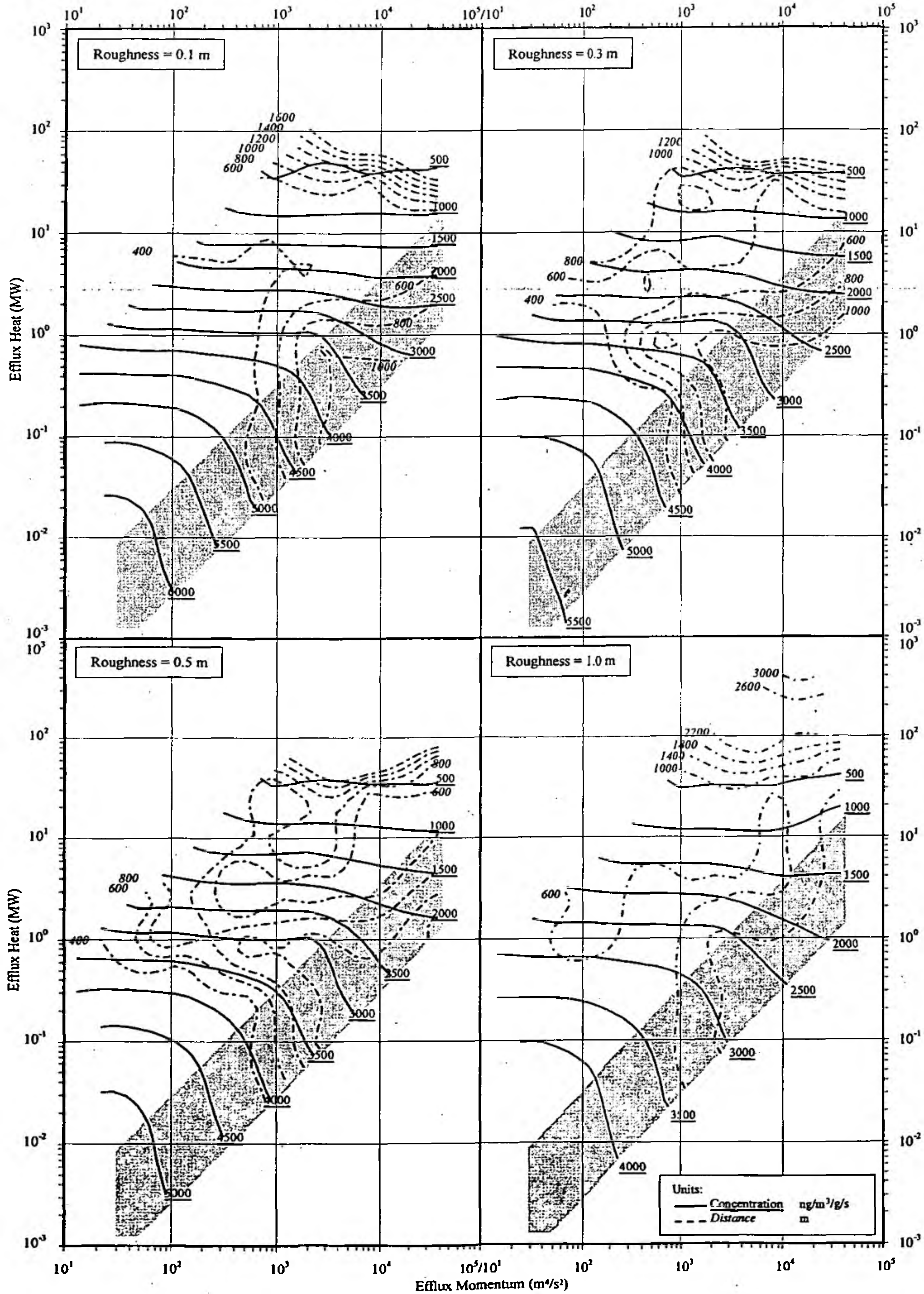


Chart 66	Maximum Ground Level Concentration	100th Percentile	200m Stack	Kilnsea (Met Type 2)	ADMS2

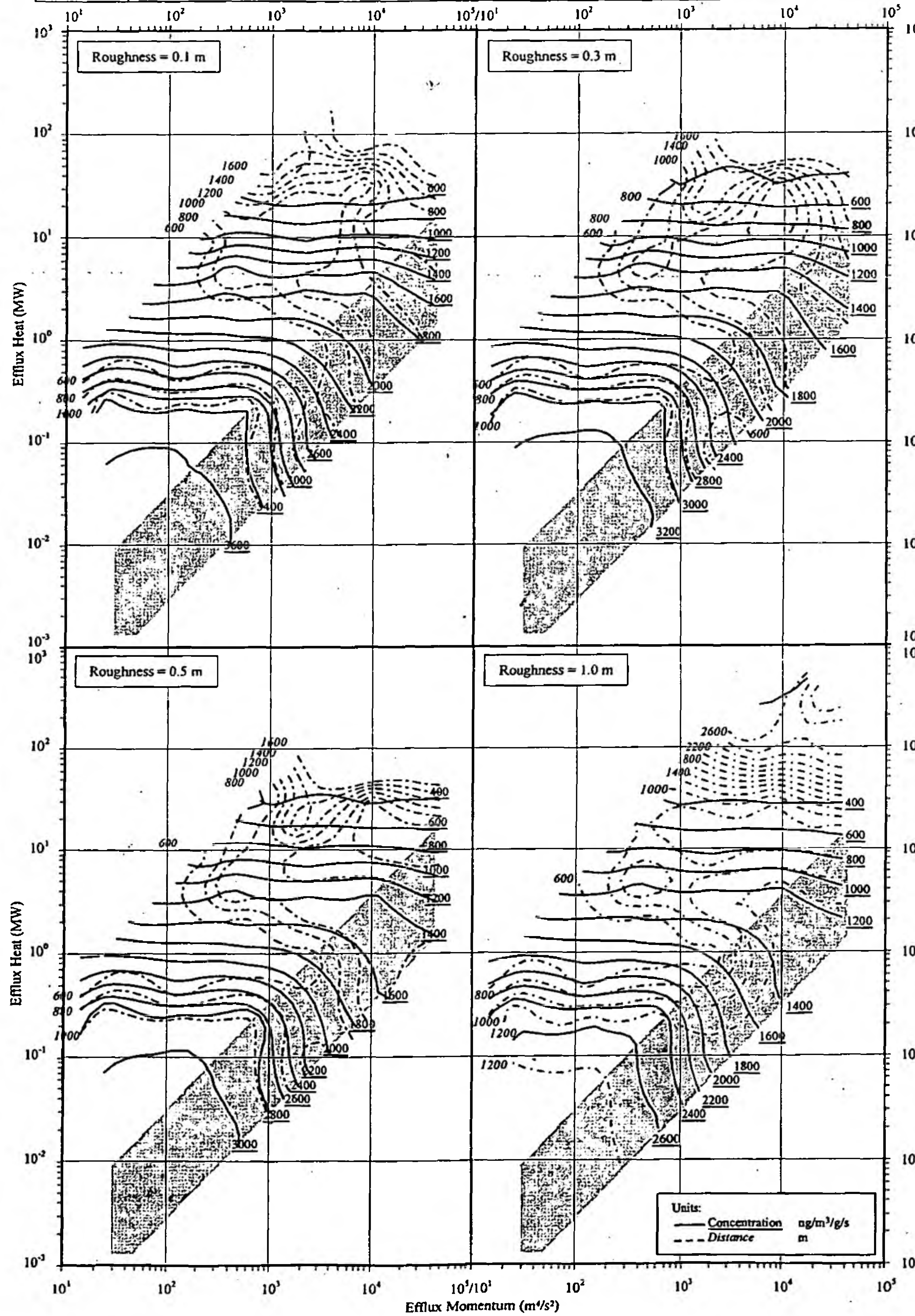


Chart 67	Maximum Ground Level Concentration	Annual Average	20m Stack	Turnhouse (Met Type 3)	ADMS2

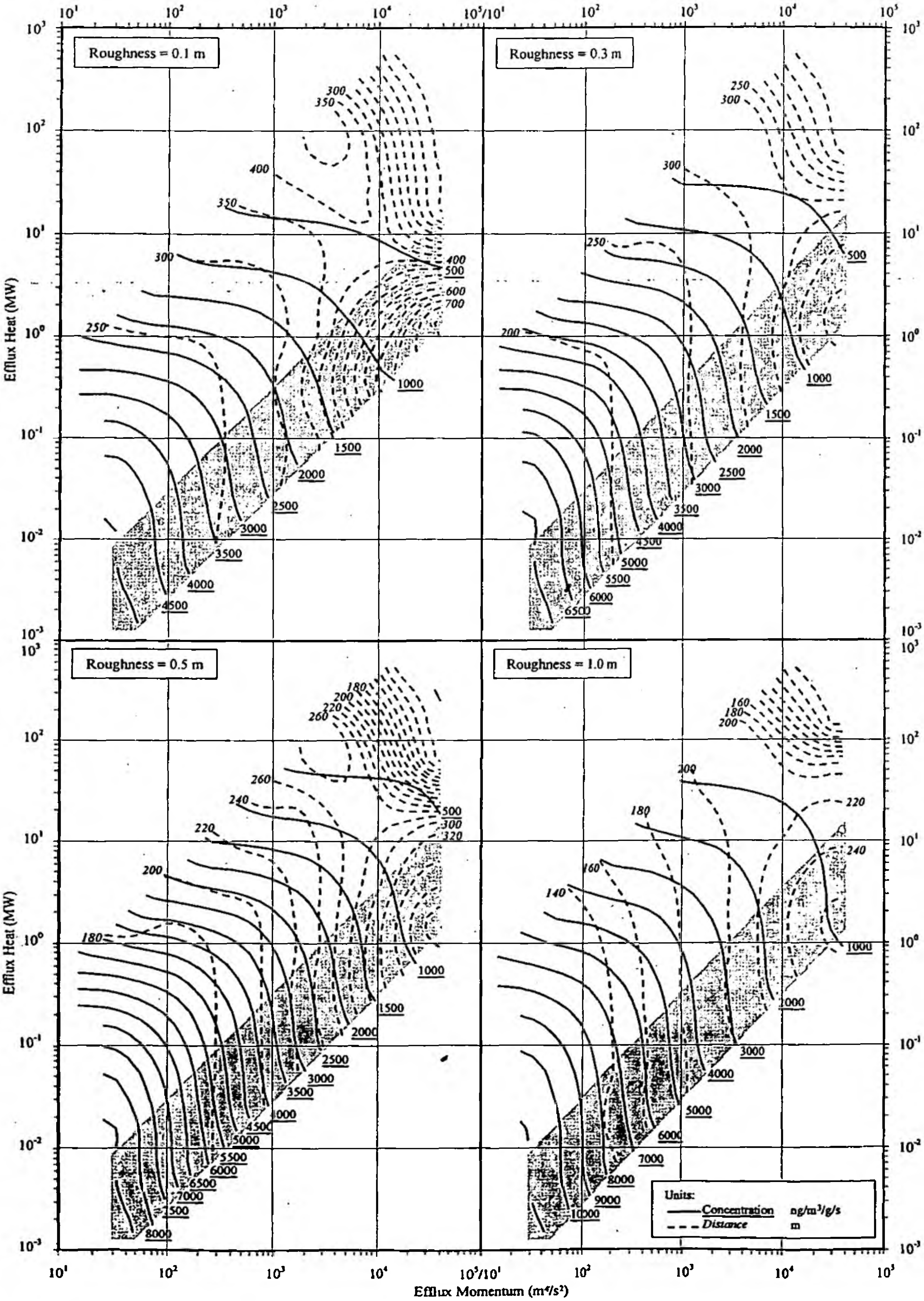


Chart 68	Maximum Ground Level Concentration	Annual Average	30m Stack	Turnhouse (Met Type 3)	ADMS2

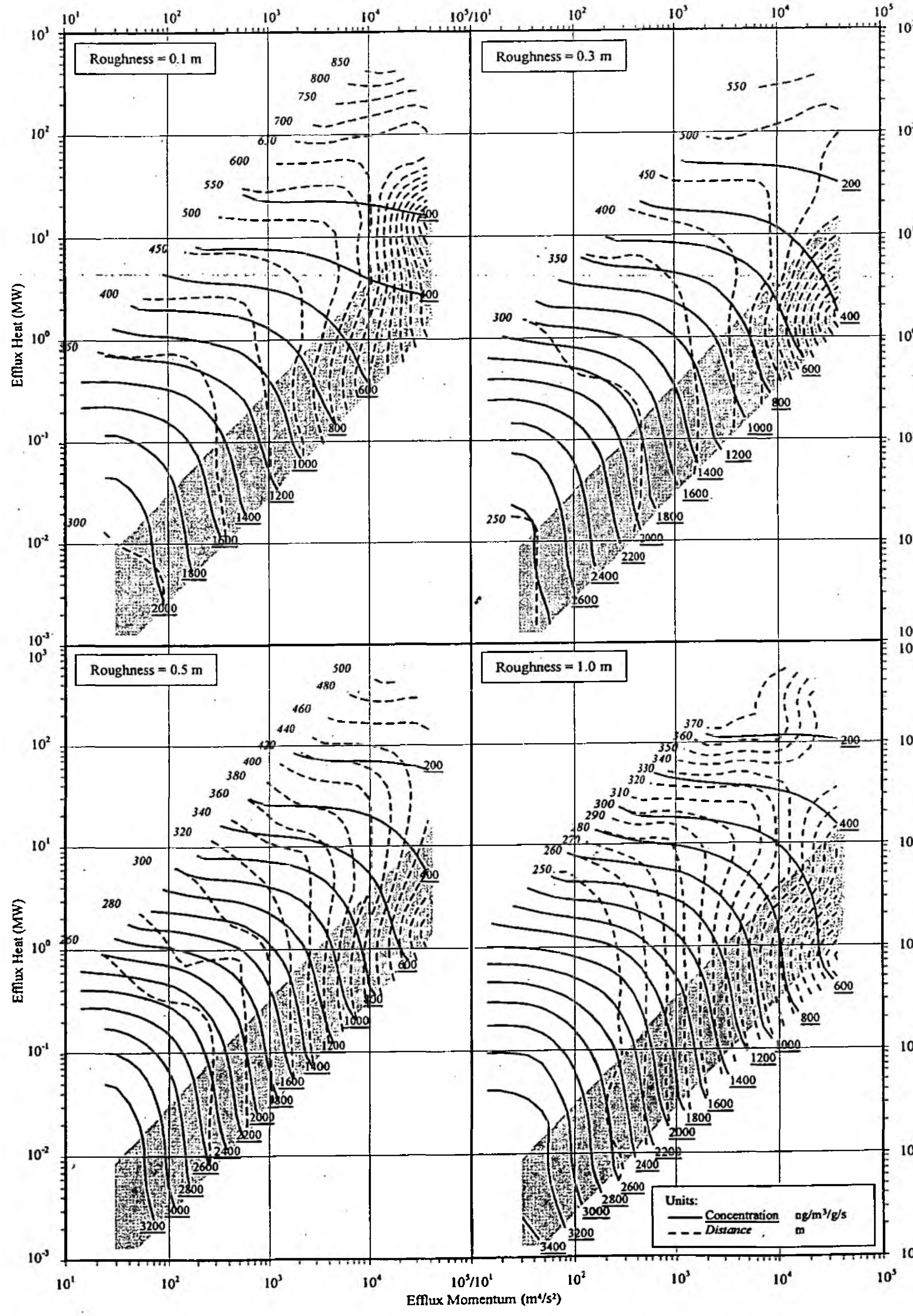


Chart 69	Maximum Ground Level Concentration	Annual Average	40m Stack	Turnhouse (Met Type 3)	ADMS2

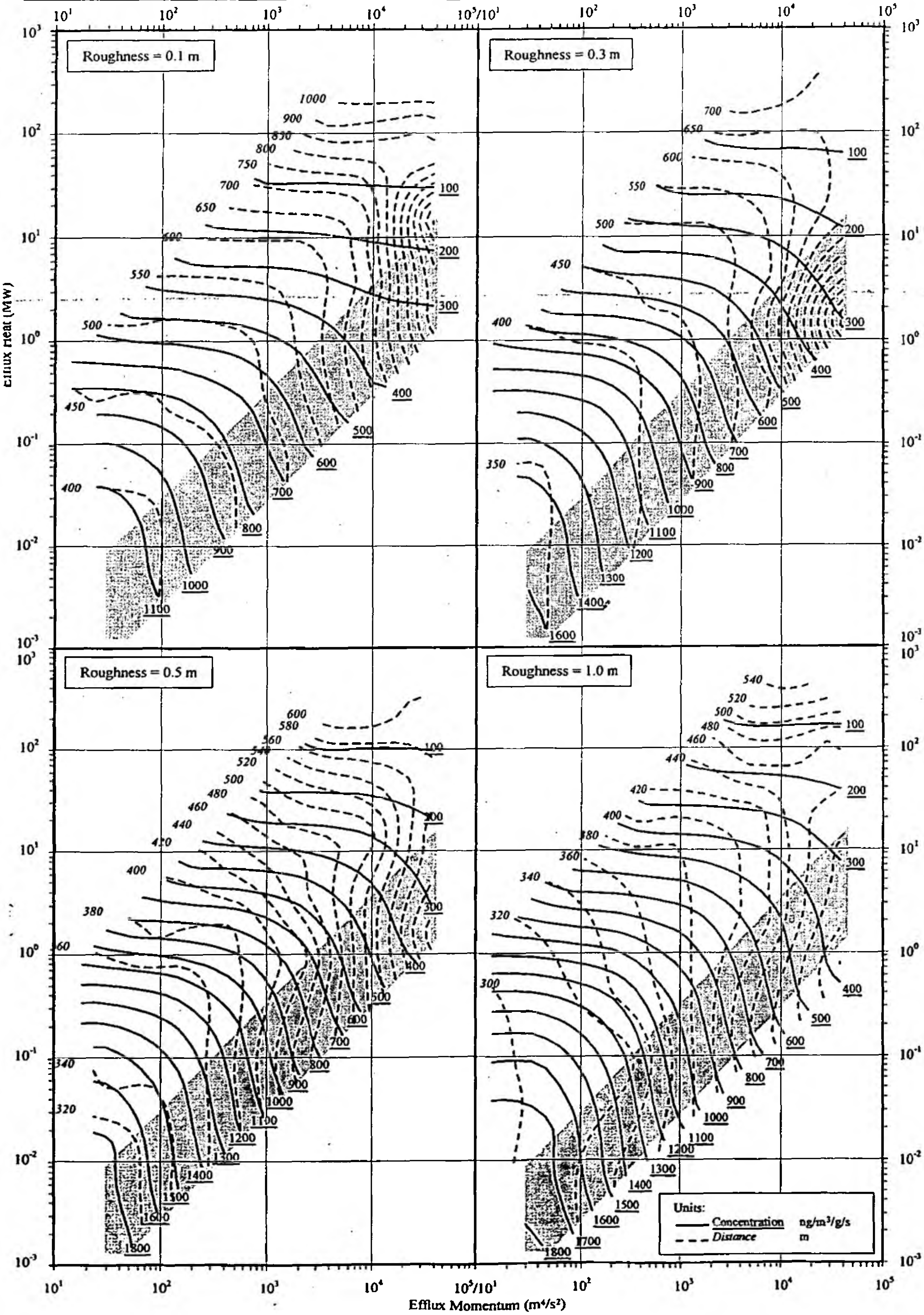


Chart 70	Maximum Ground Level Concentration	Annual Average	50m Stack	Turnhouse (Met Type 3)	ADMS2

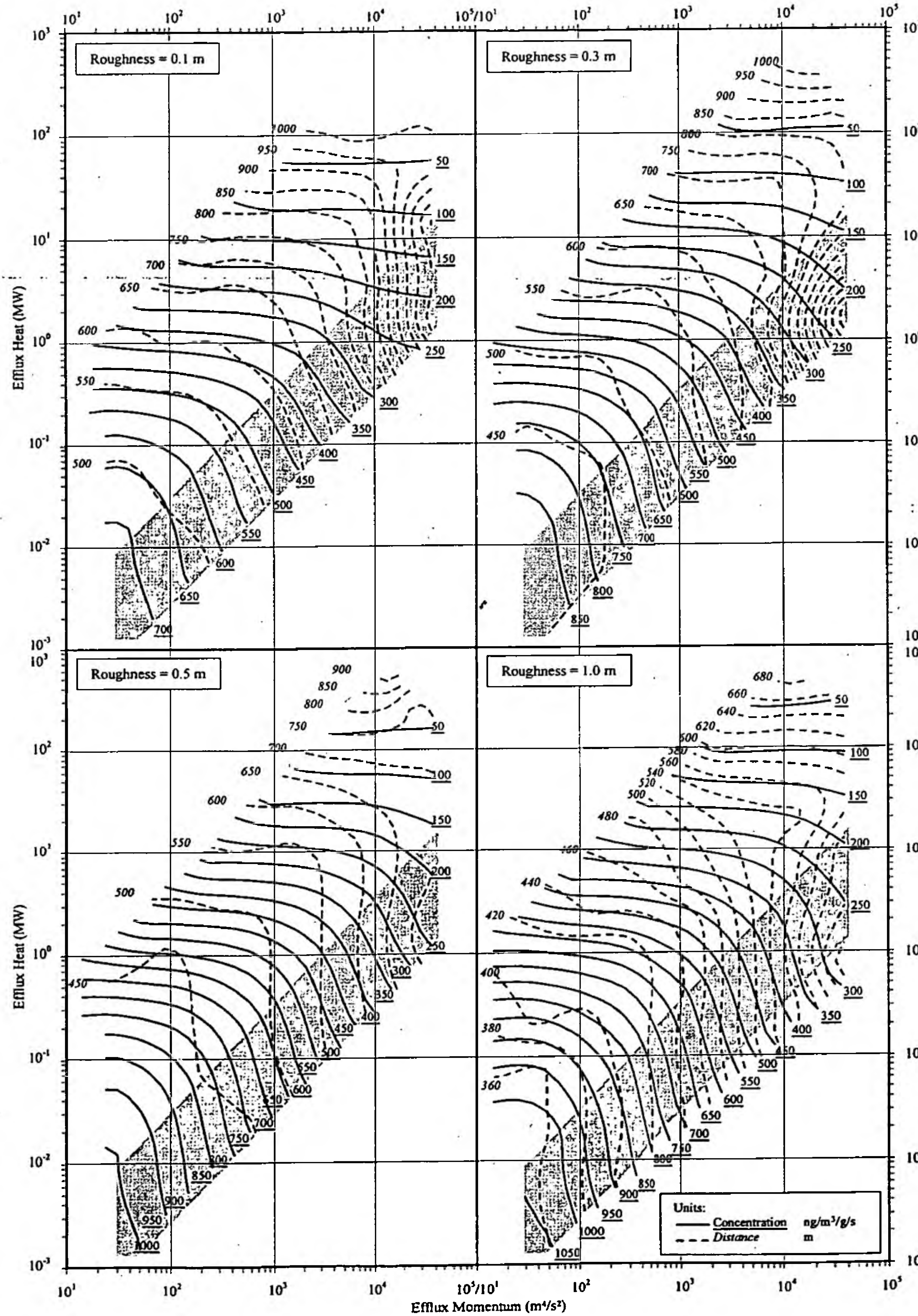


Chart 71	Maximum Ground Level Concentration	Annual Average	60m Stack	Turnhouse (Met Type 3)	ADMS2

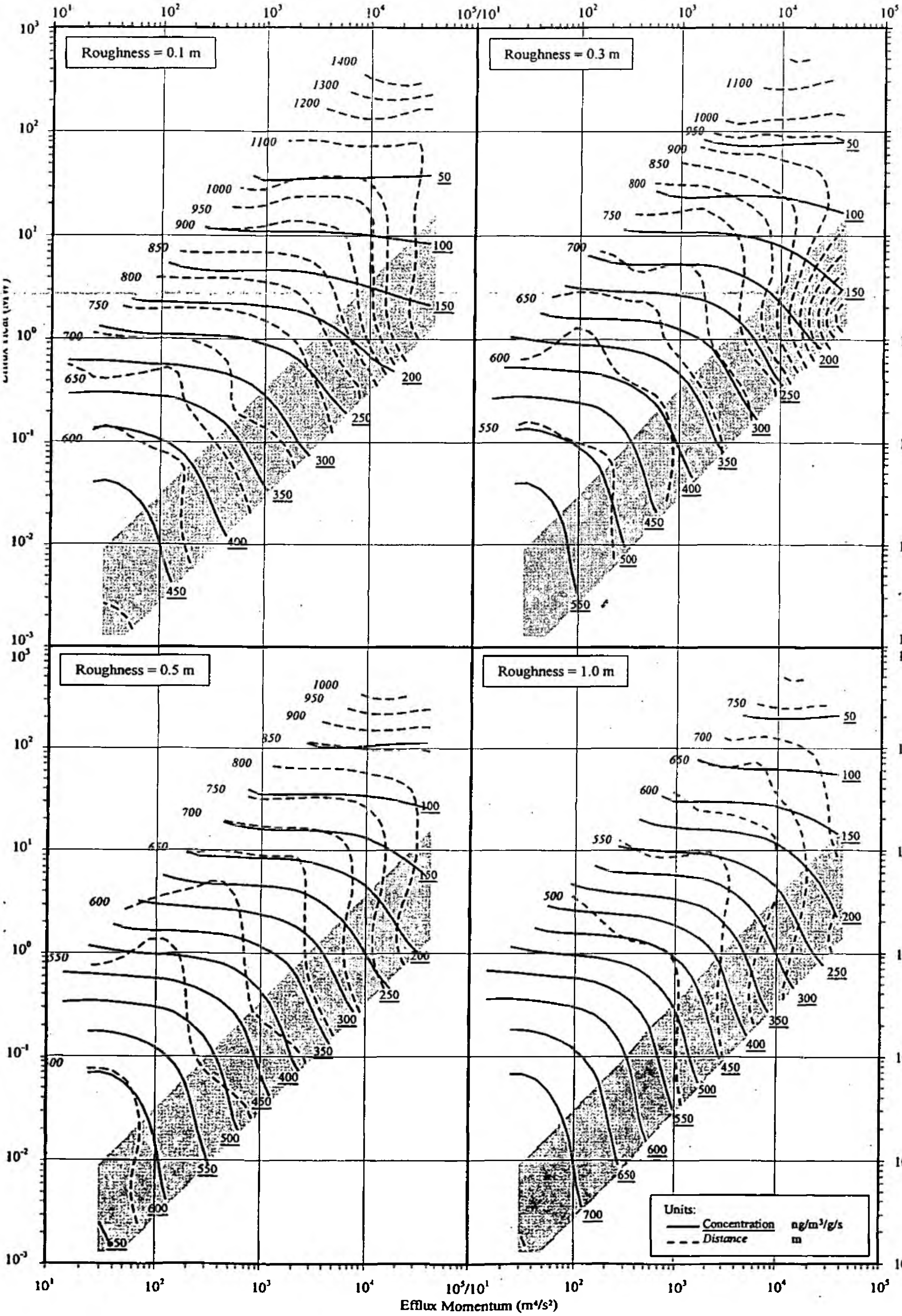


Chart 72	Maximum Ground Level Concentration	Annual Average	70m Stack	Turnhouse (Met Type 3)	ADMS2

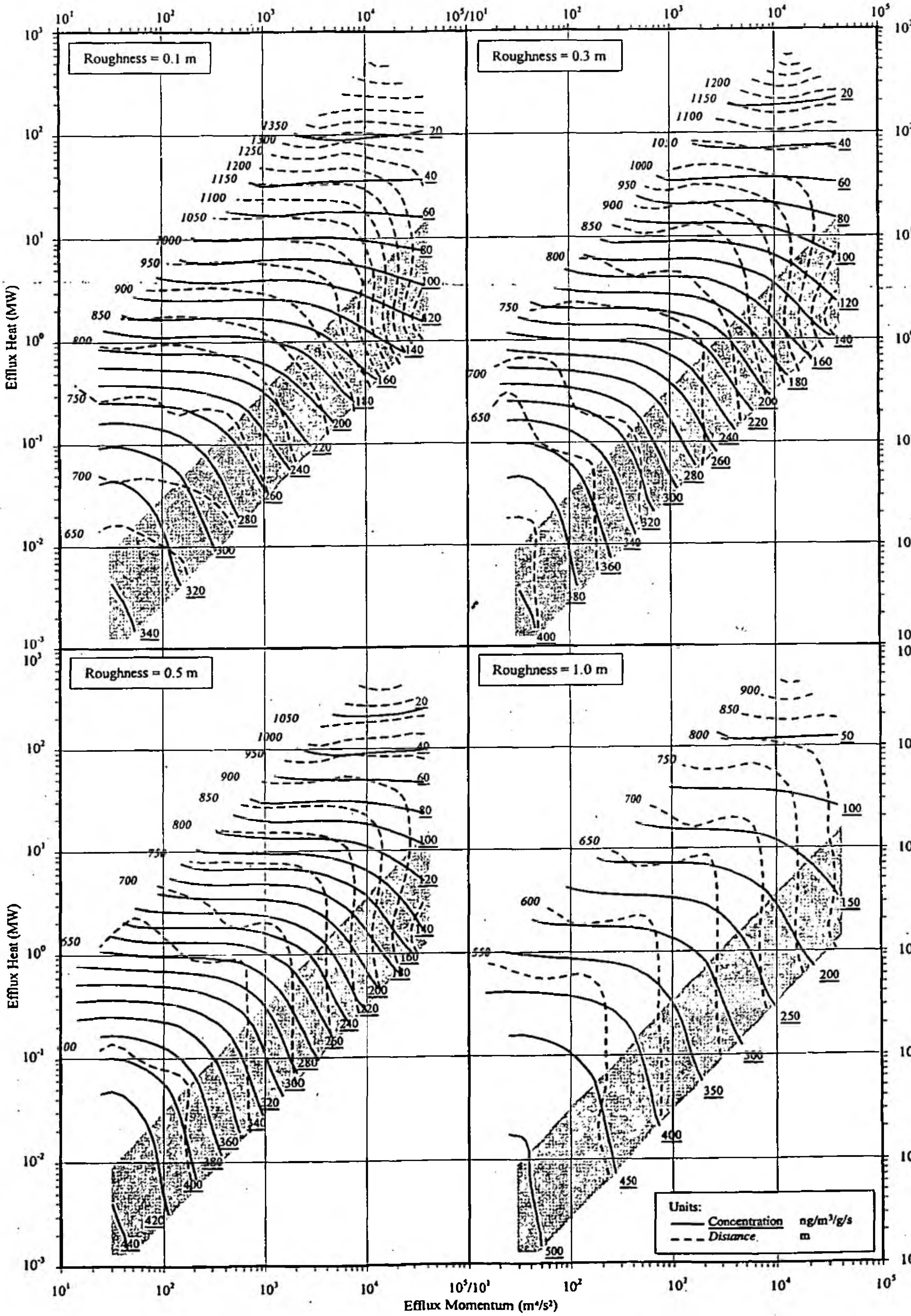


Chart 75	Maximum Ground Level Concentration	Annual Average	120m Stack	Turnhouse (Met Type 3)	ADMS2

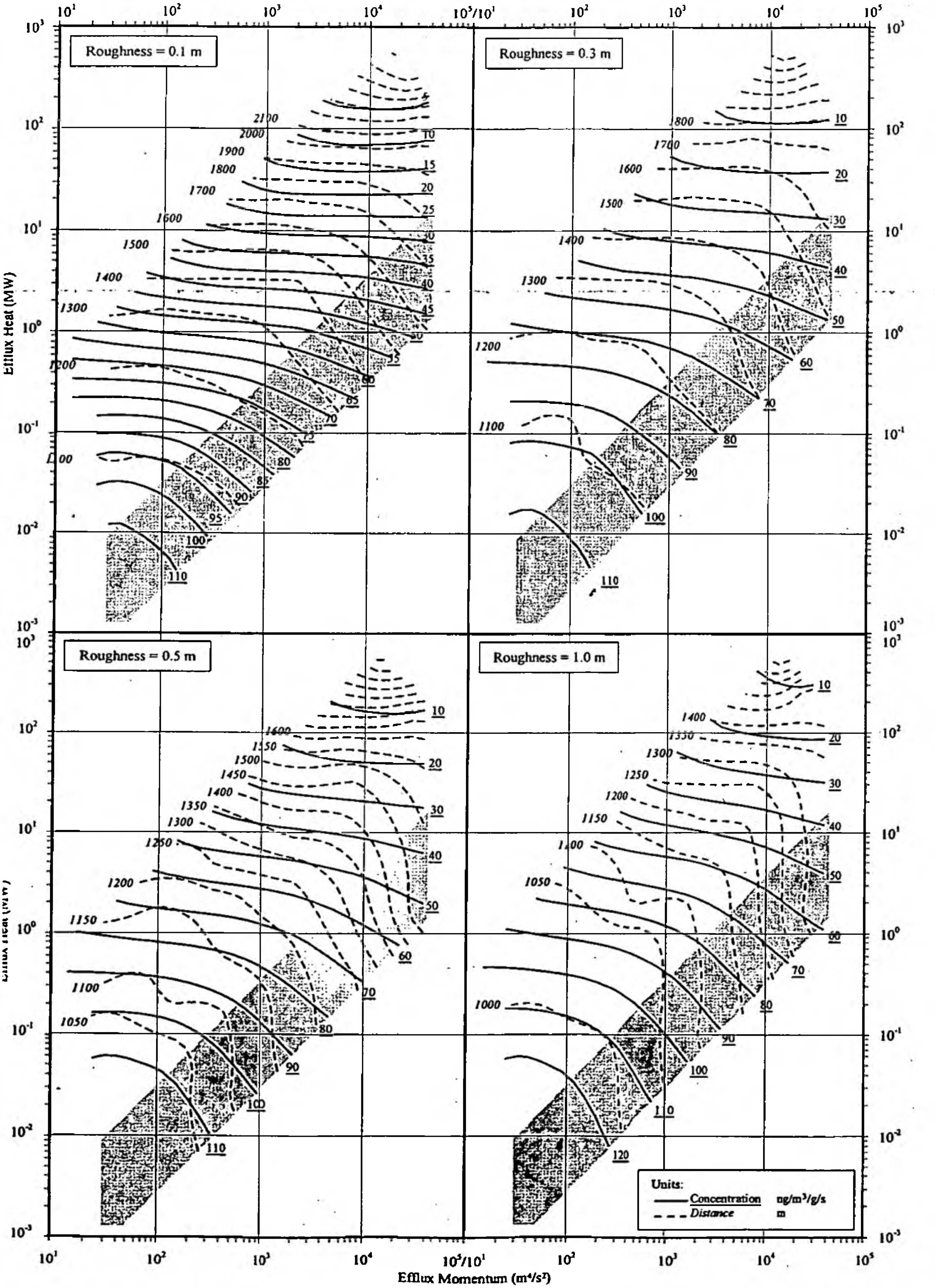


Chart 76	Maximum Ground Level Concentration	Annual Average	150m Stack	Turnhouse (Met Type 3)	ADMS2

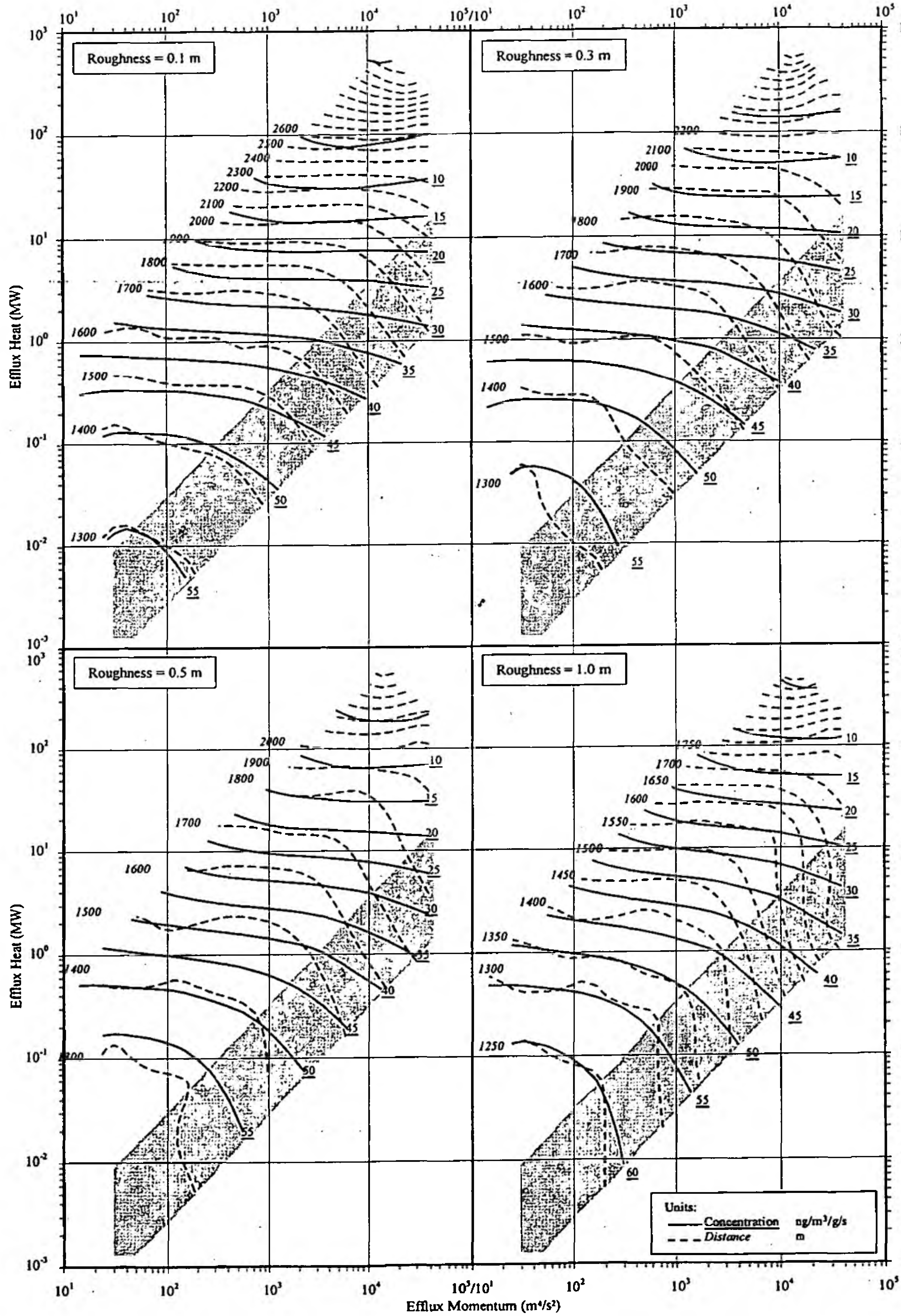


Chart 77	Maximum Ground Level Concentration	Annual Average	200m Stack	Turnhouse (Met Type 3)	ADMS2

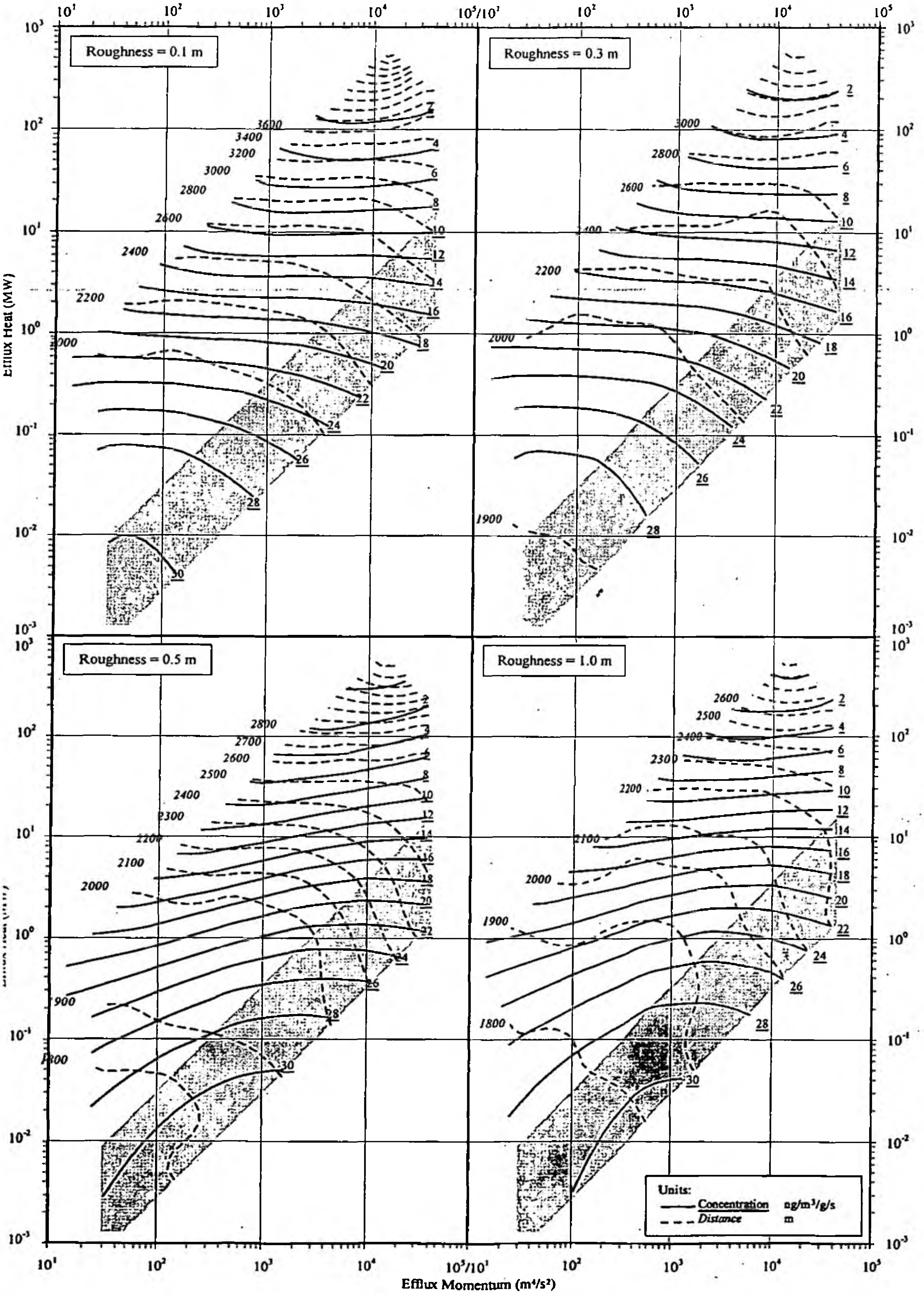


Chart 78	Maximum Ground Level Concentration	99.9th Percentile	20m Stack	Turnhouse (Met Type 3)	ADMS2

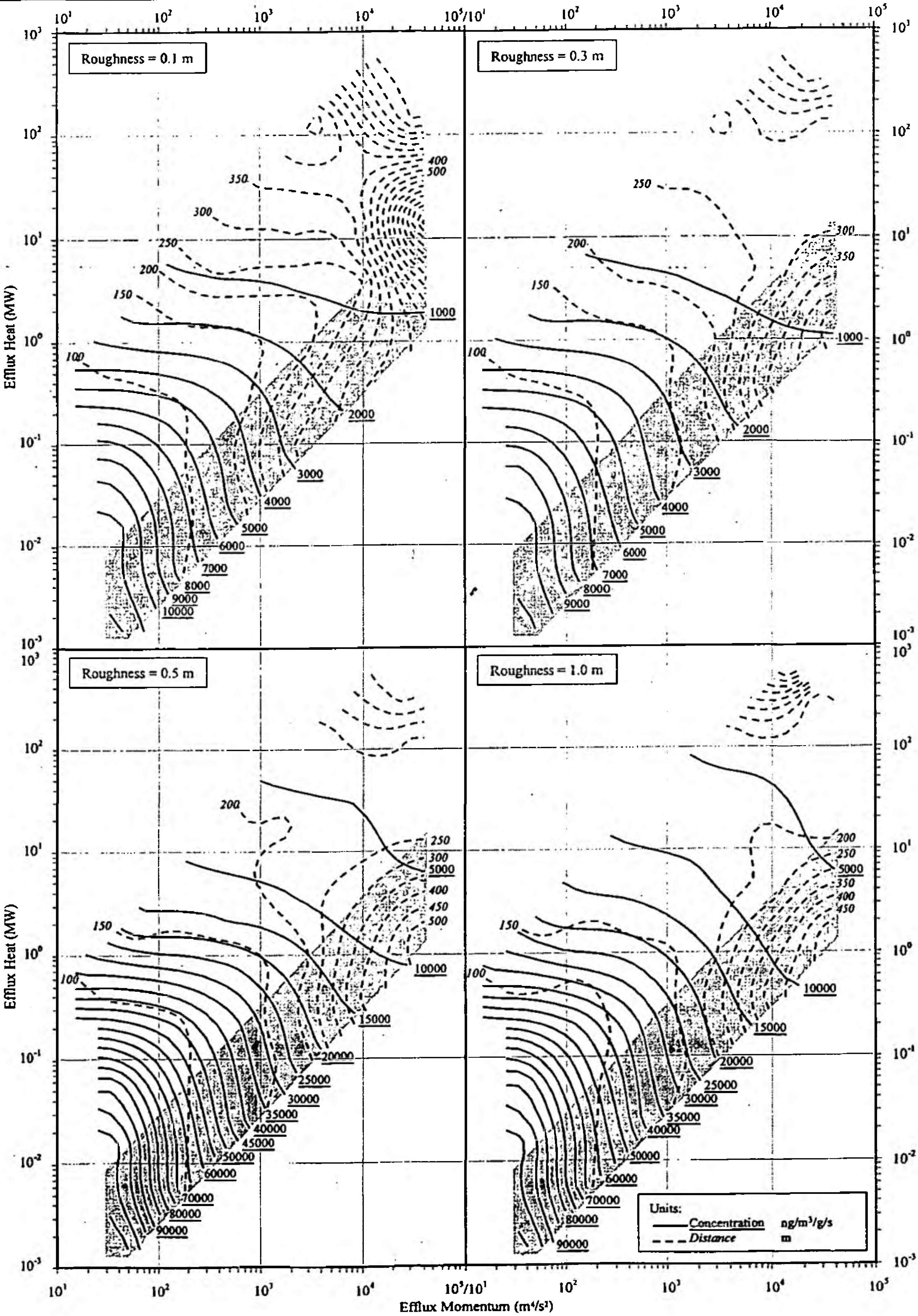


Chart 79	Maximum Ground Level Concentration	99.9th Percentile	30m Stack	Turnhouse (Met Type 3)	ADMS2

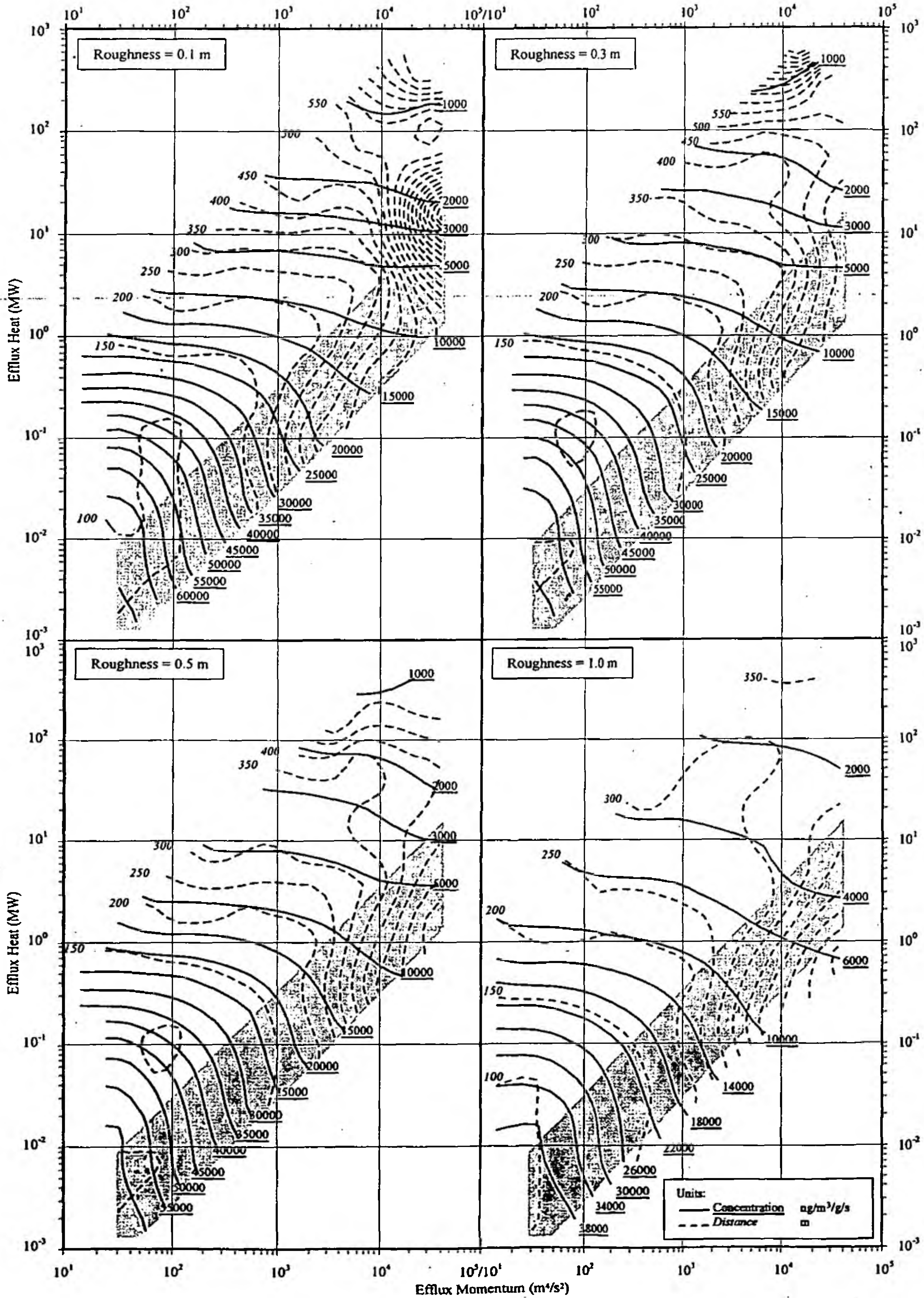


Chart 80	Maximum Ground Level Concentration	99.9th Percentile	40m Stack	Turnhouse (Met Type 3)	ADMS2

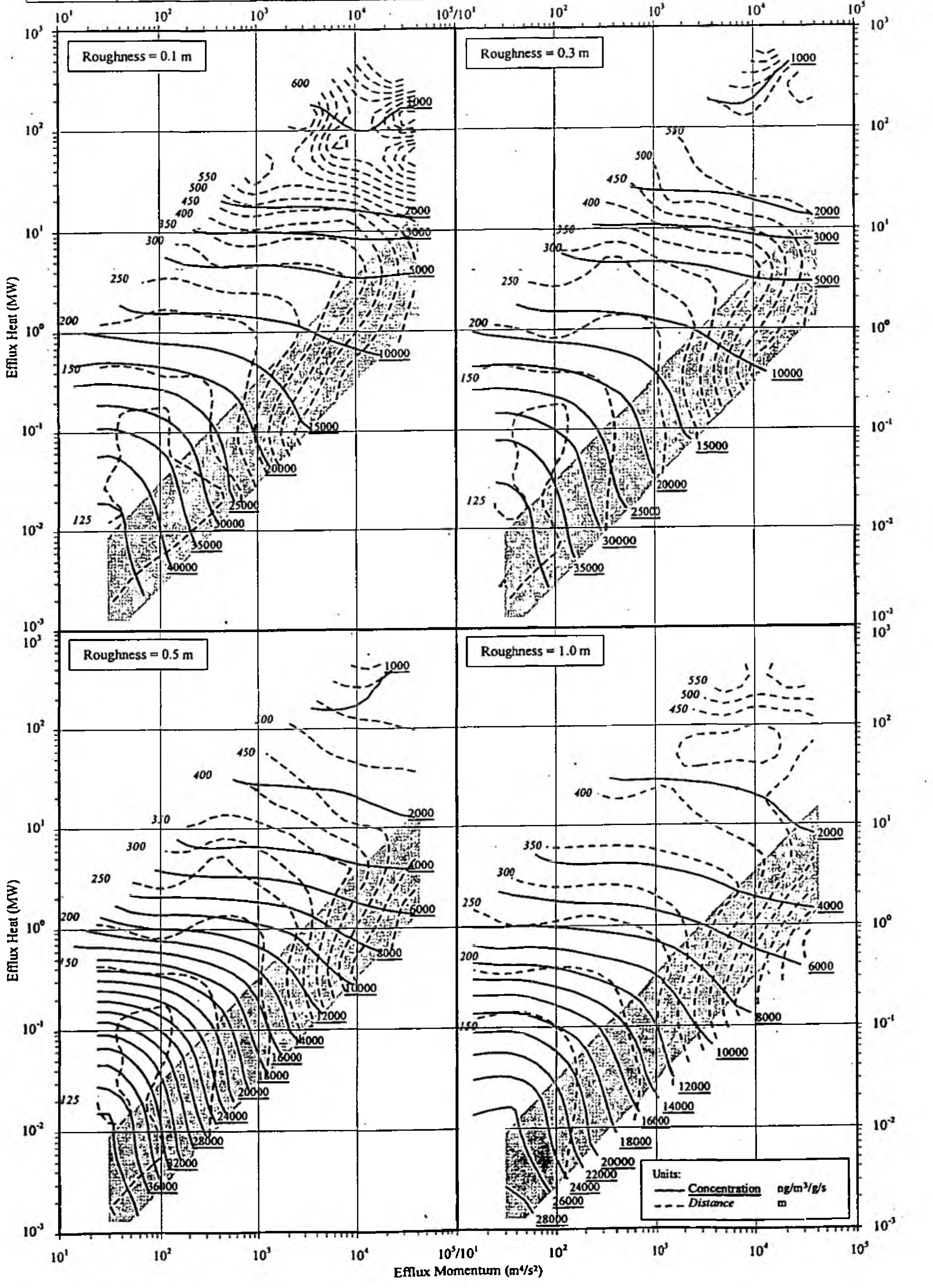


Chart 81	Maximum Ground Level Concentration	99.9th Percentile	50m Stack	Turnhouse (Met Type 3)	ADMS2

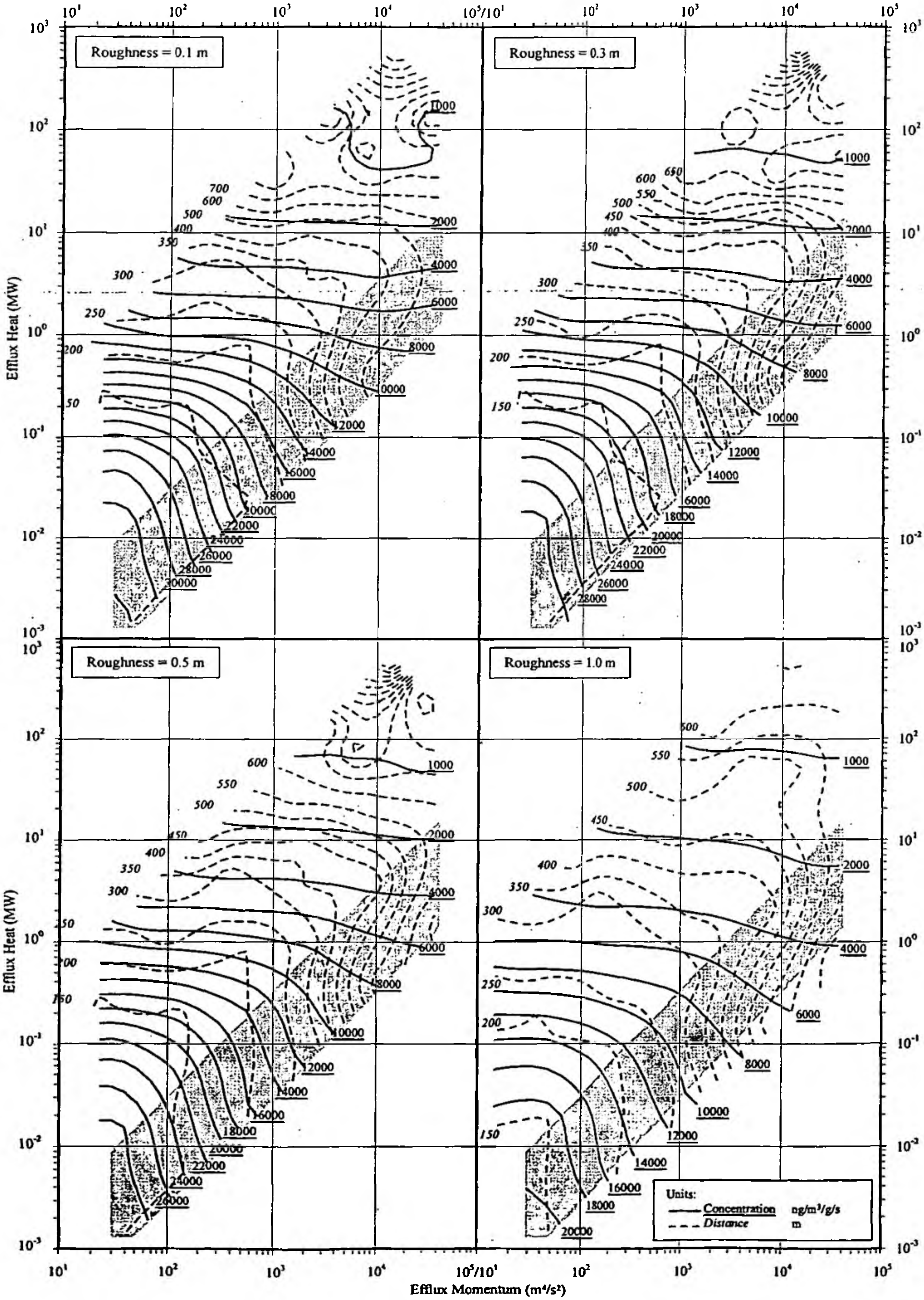


Chart 82	Maximum Ground Level Concentration	99.9th Percentile	60m Stack	Turnhouse (Met Type 3)	ADMS2

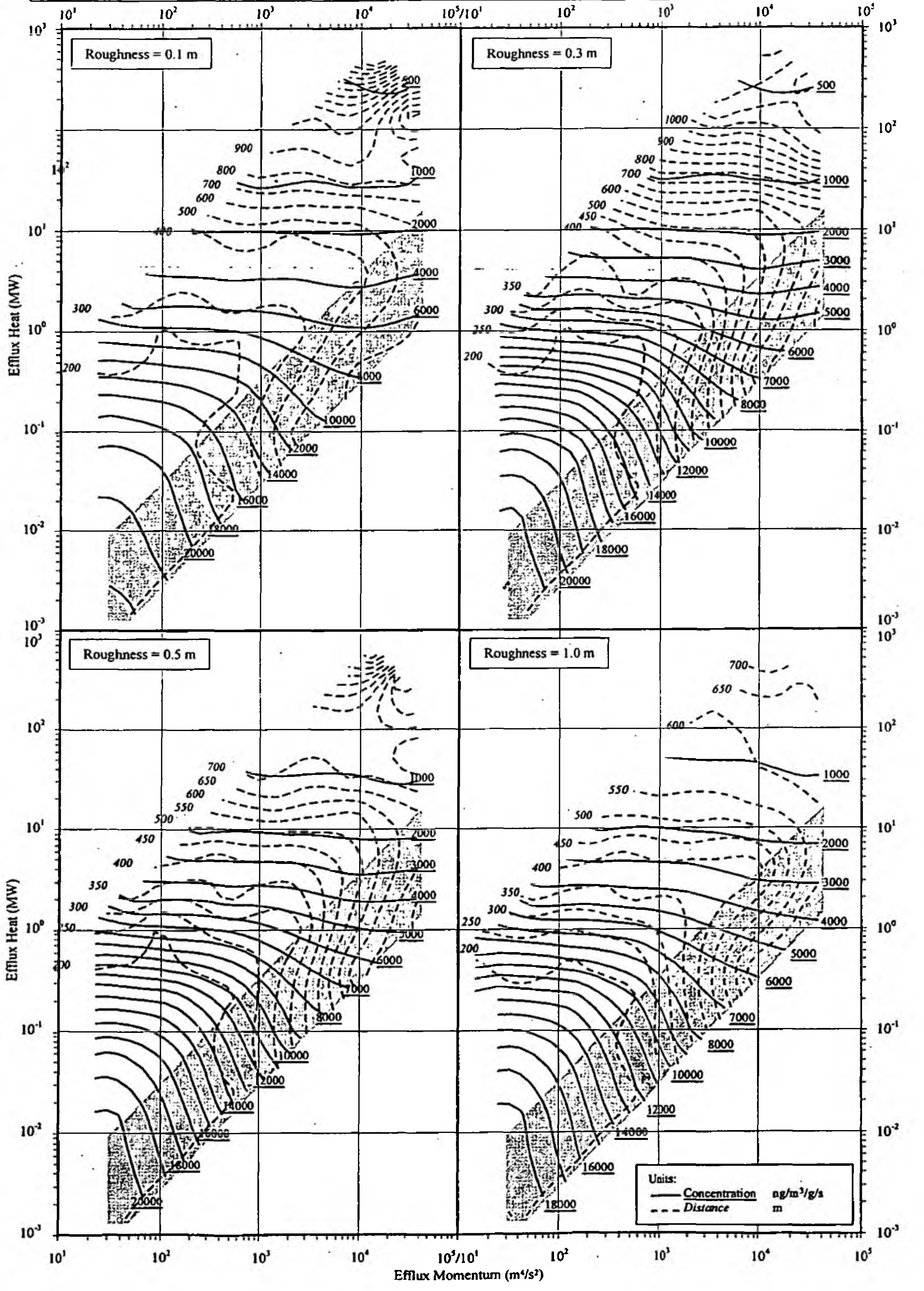


Chart 83	Maximum Ground Level Concentration	99.9th Percentile	70m Stack	Turnhouse (Met Type 3)	ADMS2

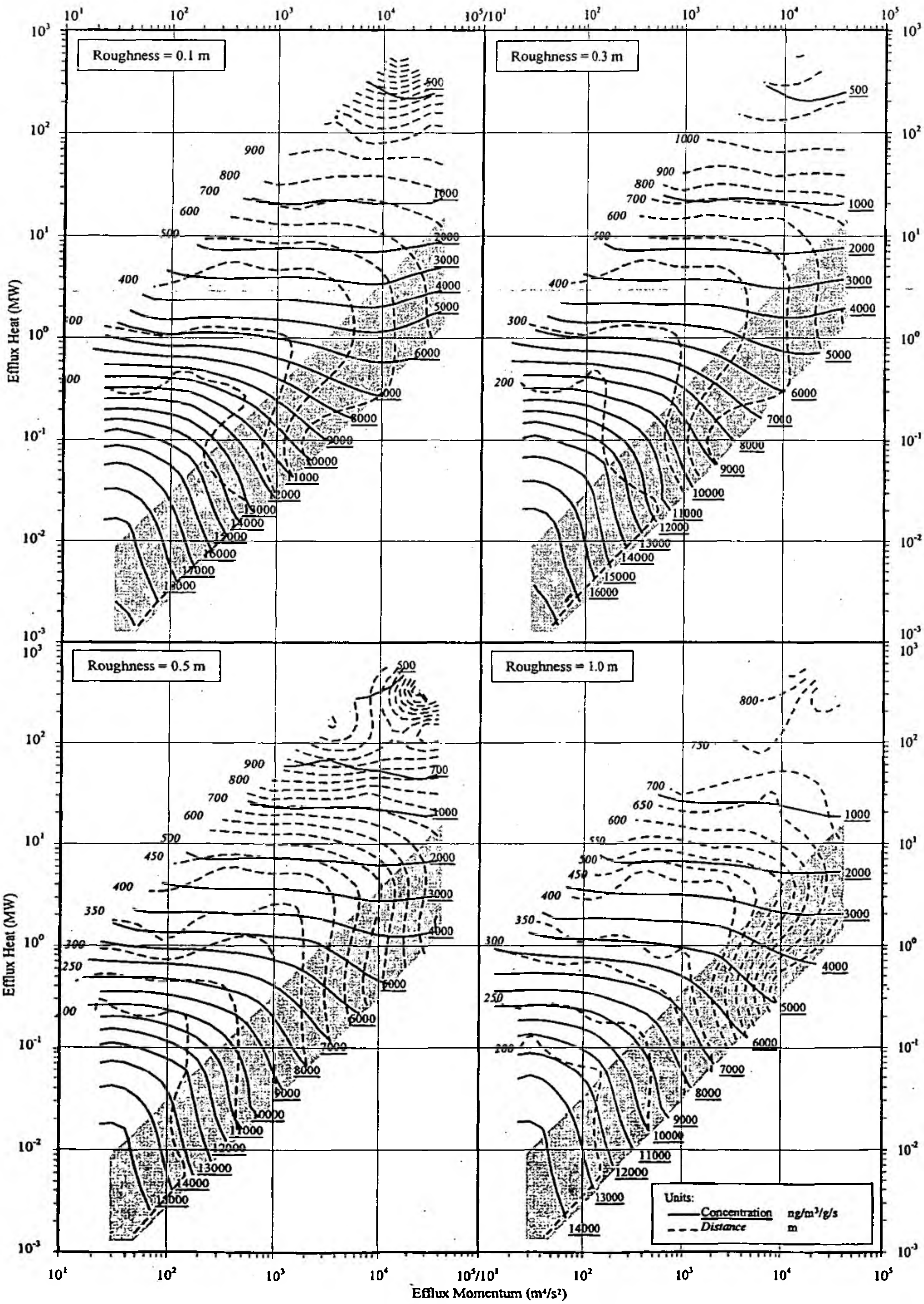


Chart 84	Maximum Ground Level Concentration	99.9th Percentile	85m Stack	Turnhouse (Met Type 3)	ADMS2

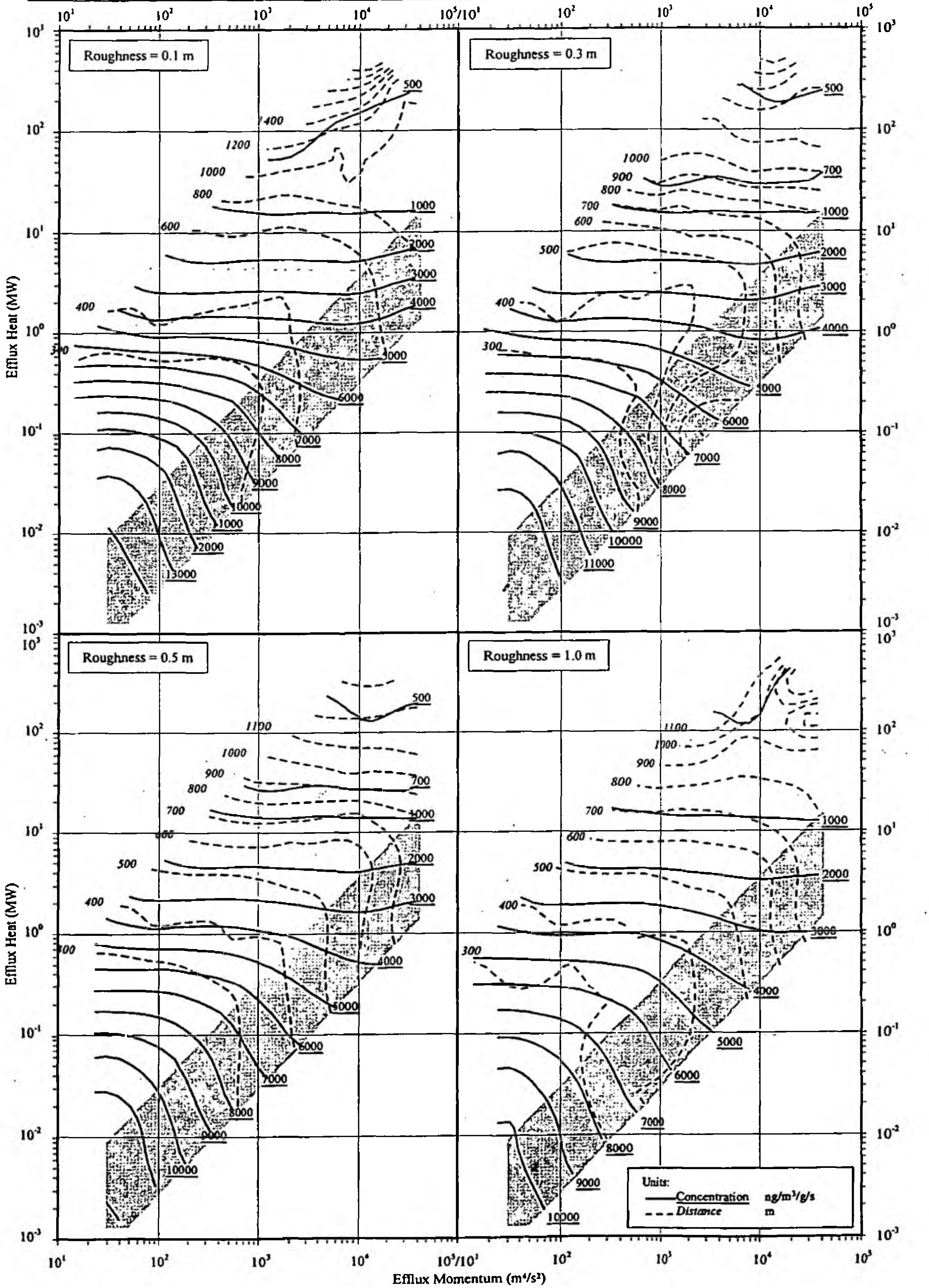


Chart 85	Maximum Ground Level Concentration	99.9th Percentile	100m Stack	Turnhouse (Met Type 3)	ADMS2

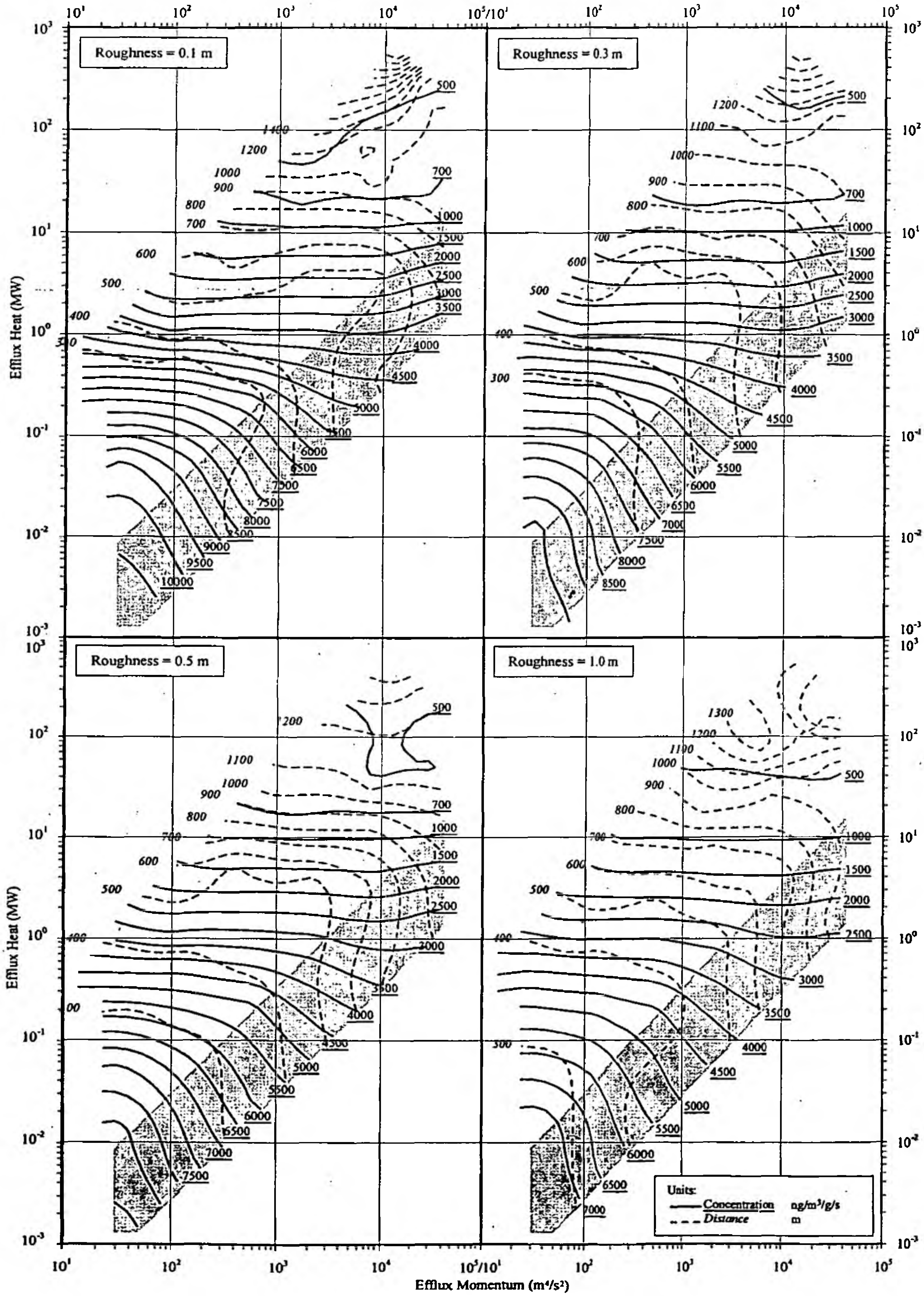


Chart 86	Maximum Ground Level Concentration	99.9th Percentile	120m Stack	Turnhouse (Met Type 3)	ADMS2

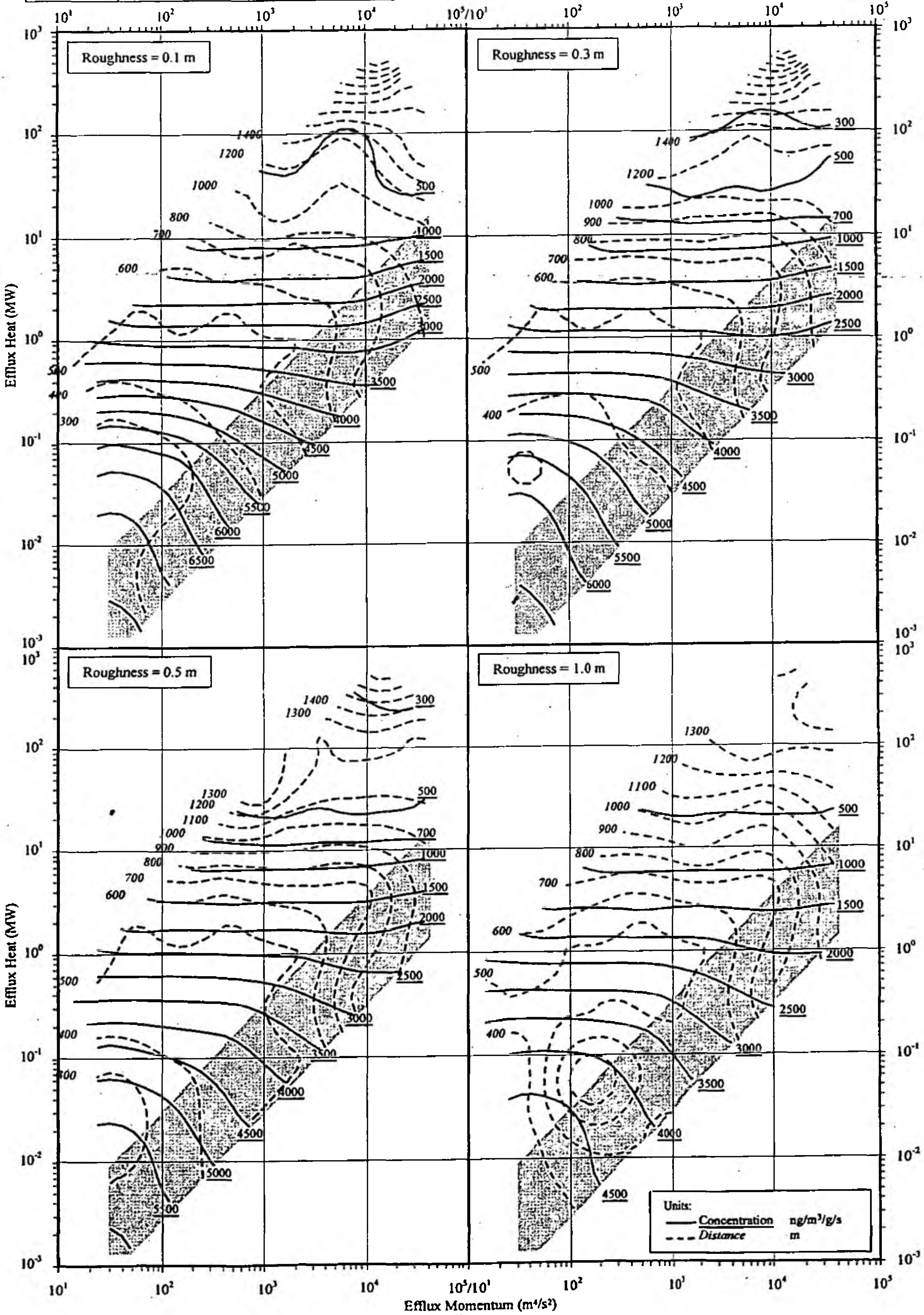


Chart 87	Maximum Ground Level Concentration	99.9th Percentile	150m Stack	Turnhouse (Met Type 3)	ADMS2

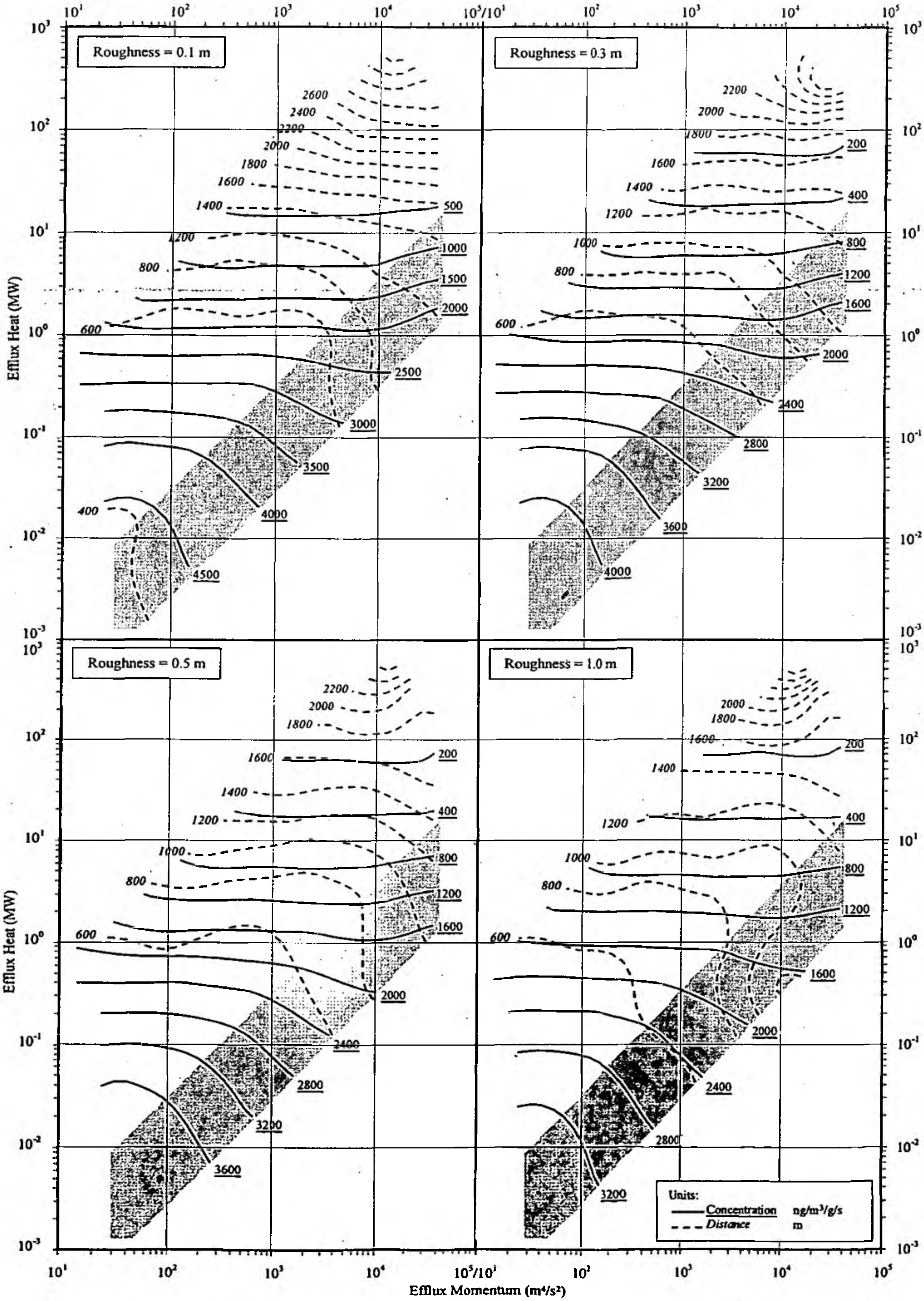


Chart 88	Maximum Ground Level Concentration	99.9th Percentile	200m Stack	Turnhouse (Met Type 3)	ADMS2

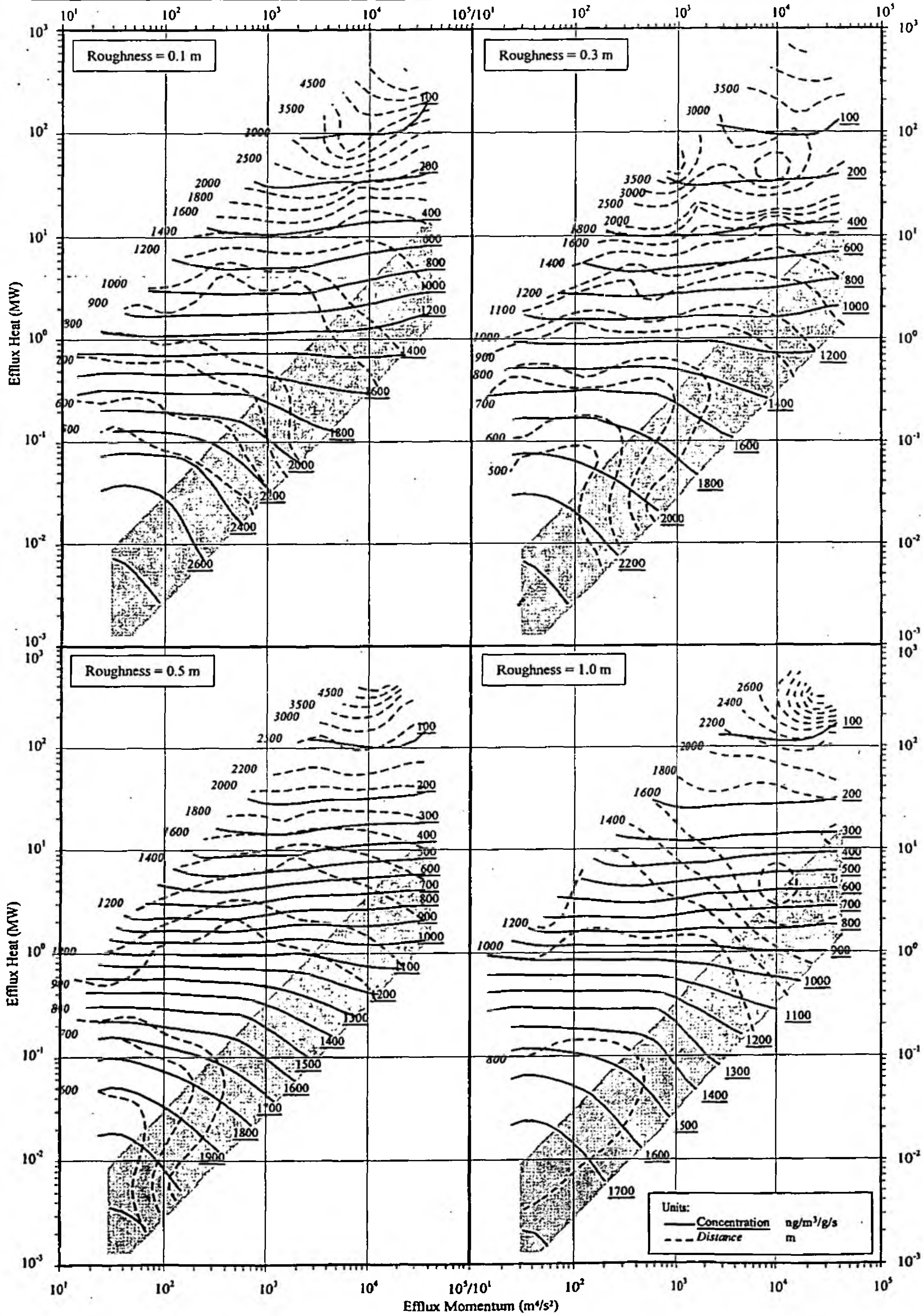


Chart 89	Maximum Ground Level Concentration	100th Percentile	20m Stack	Turnhouse (Met Type 3	ADMS2

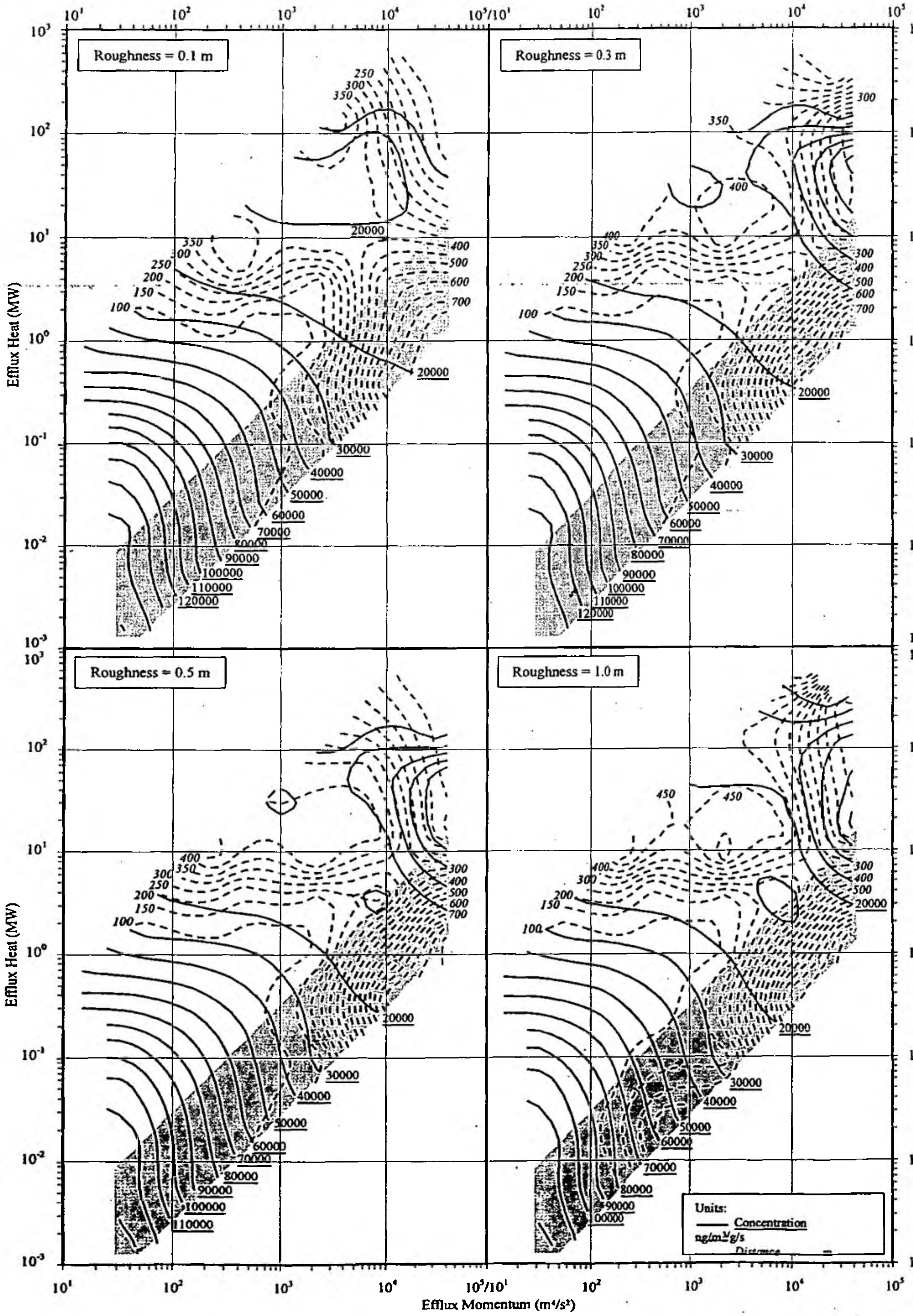


Chart 90	Maximum Ground Level Concentration	100th Percentile	30m Stack	Turnhouse (Met Type 3)	ADMS2

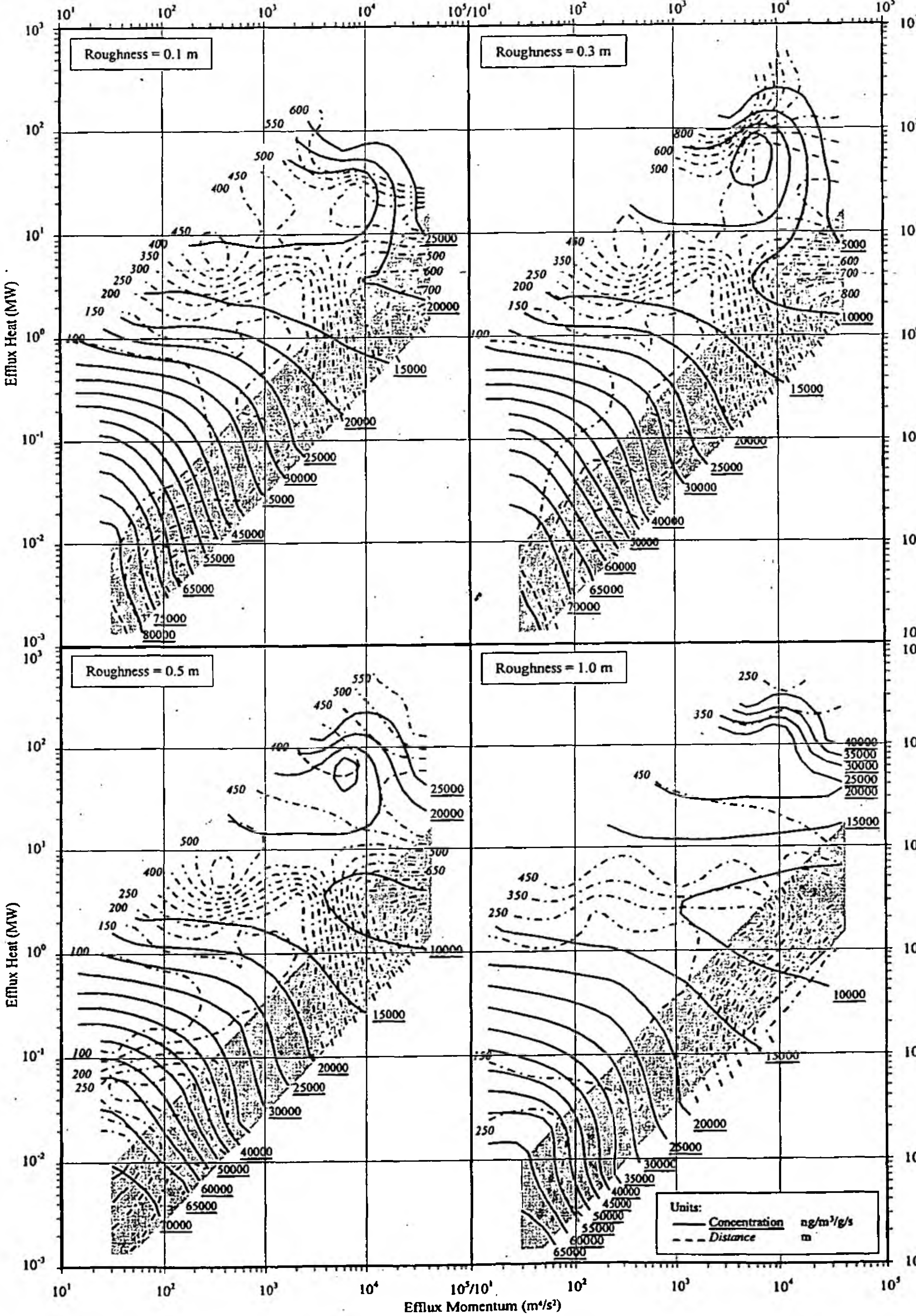


Chart 91	Maximum Ground Level Concentration	100th Percentile	40m Stack	Turnhouse (Met Type 3)	ADMS2

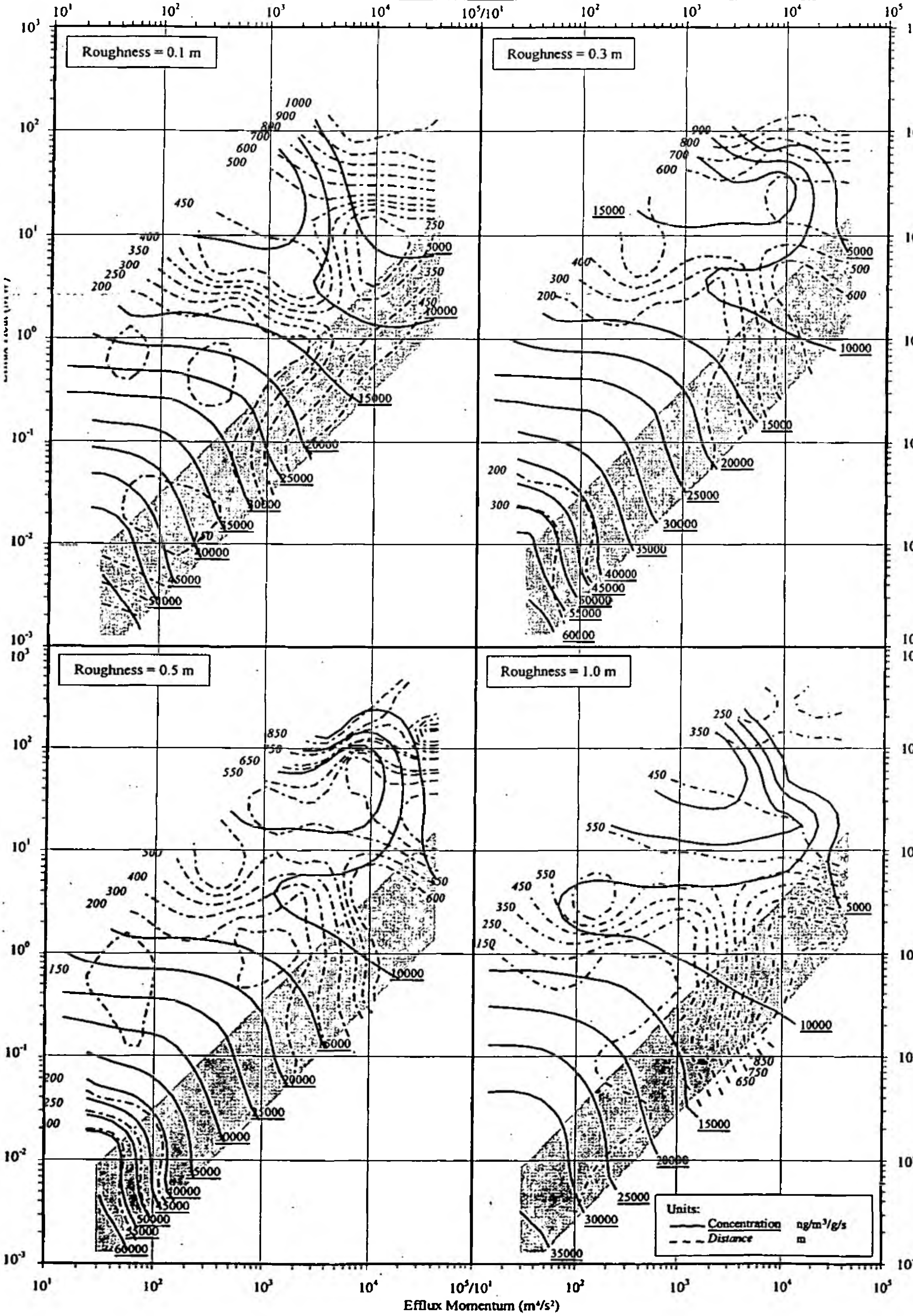


Chart 92	Maximum Ground Level Concentration	100th Percentile	50m Stack	Turnhouse (Met Type 3)	ADMS2

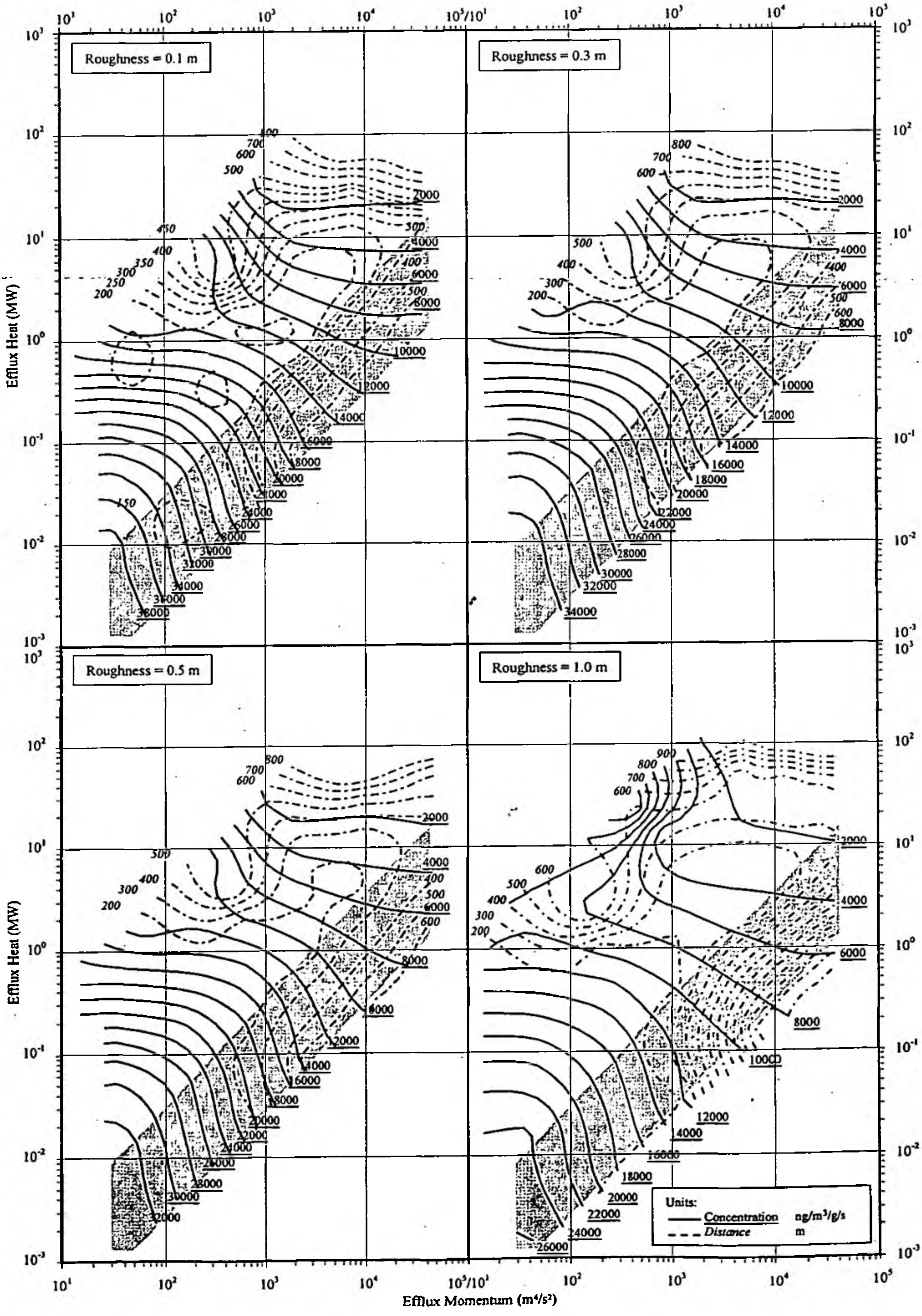


Chart 93	Maximum Ground Level Concentration	100th Percentile	60m Stack	Turnhouse (Met Type 3)	ADMS2

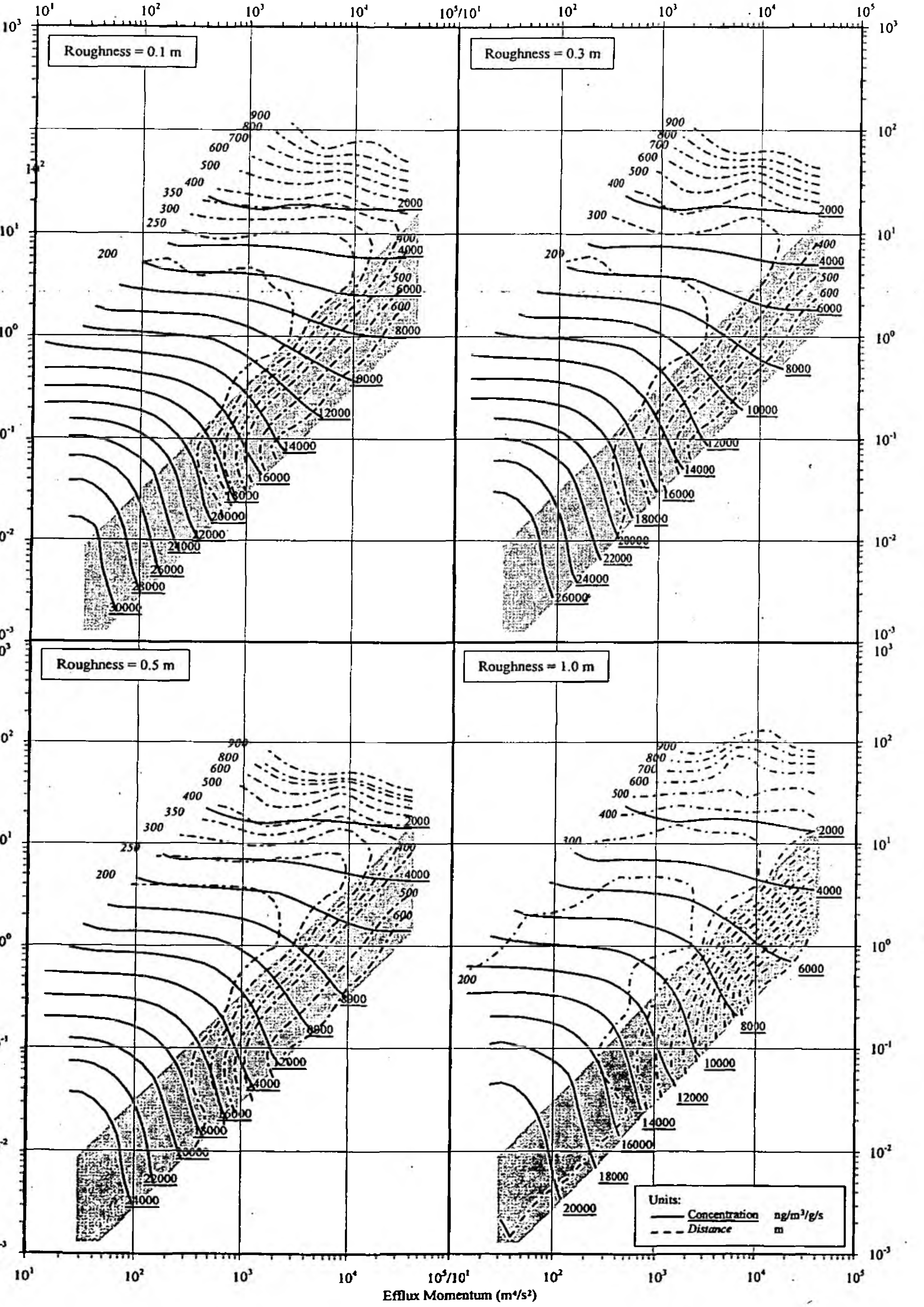


Chart 94	Maximum Ground Level Concentration	100th Percentile	70m Stack	Turnhouse (Met Type 3)	ADMS2

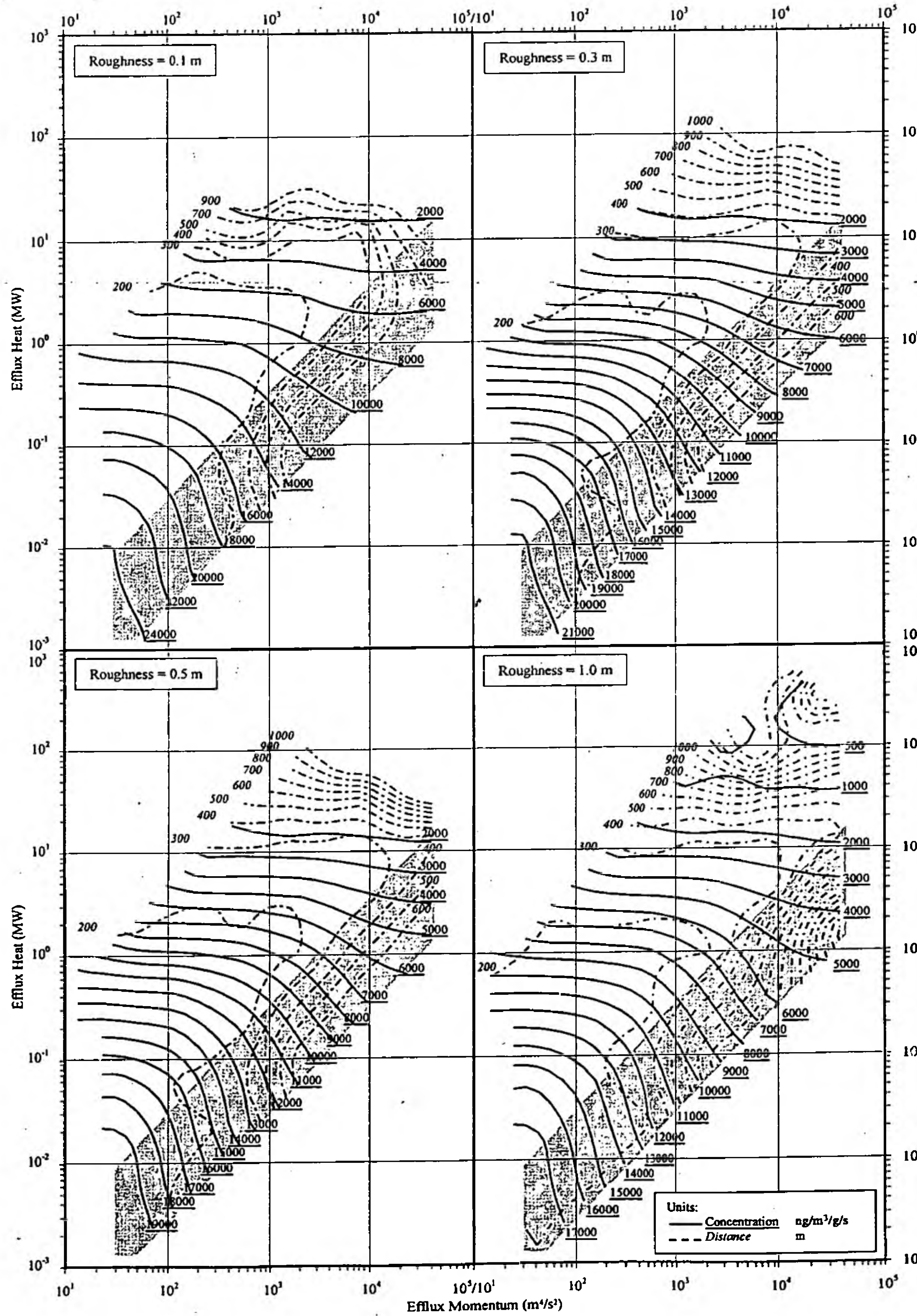


Chart 95	Maximum Ground Level Concentration	100th Percentile	85m Stack	Turnhouse (Met Type 3)	ADMS2

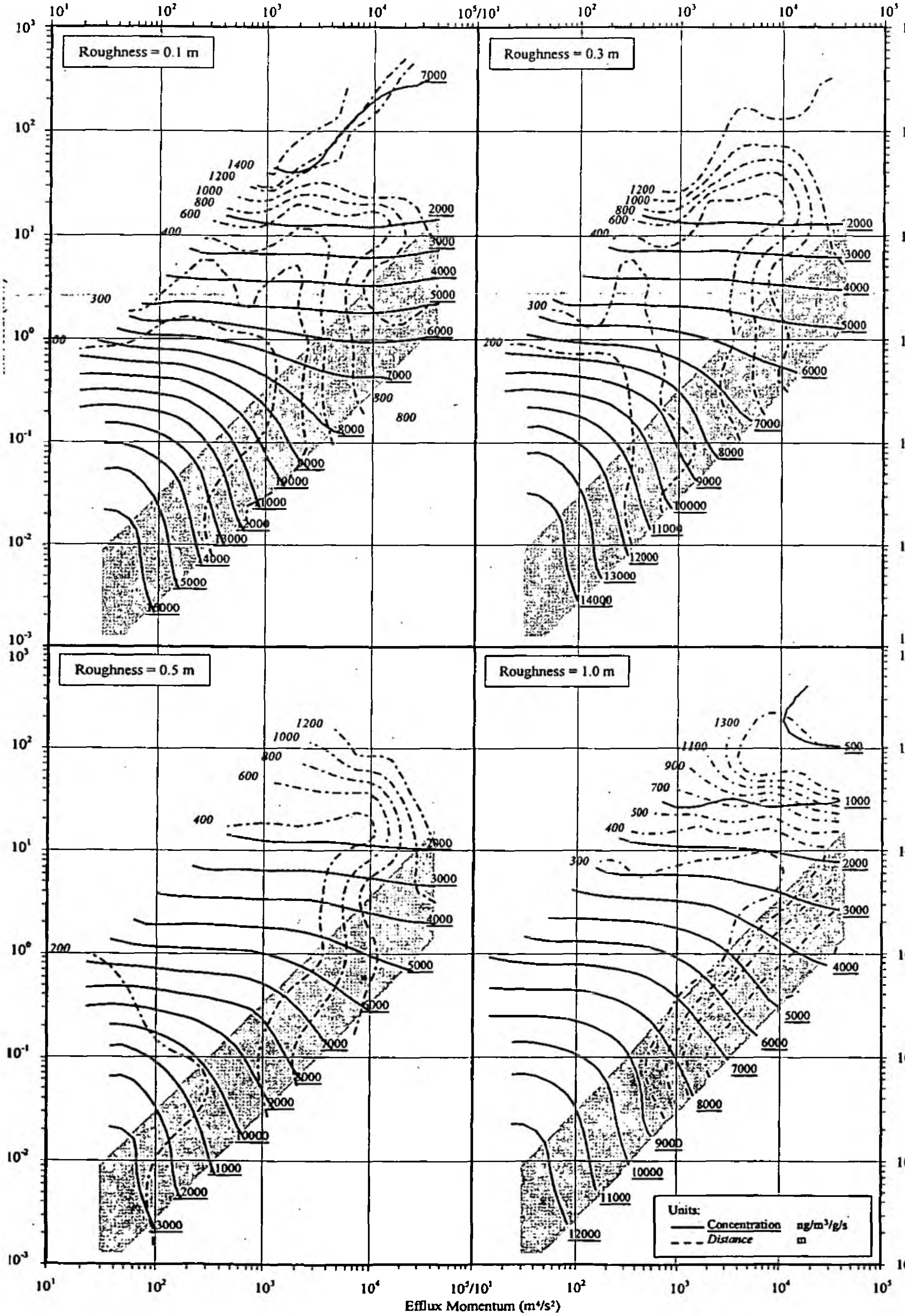


Chart 96	Maximum Ground Level Concentration	100th Percentile	100m Stack	Turnhouse (Met Type 3)	ADMS2

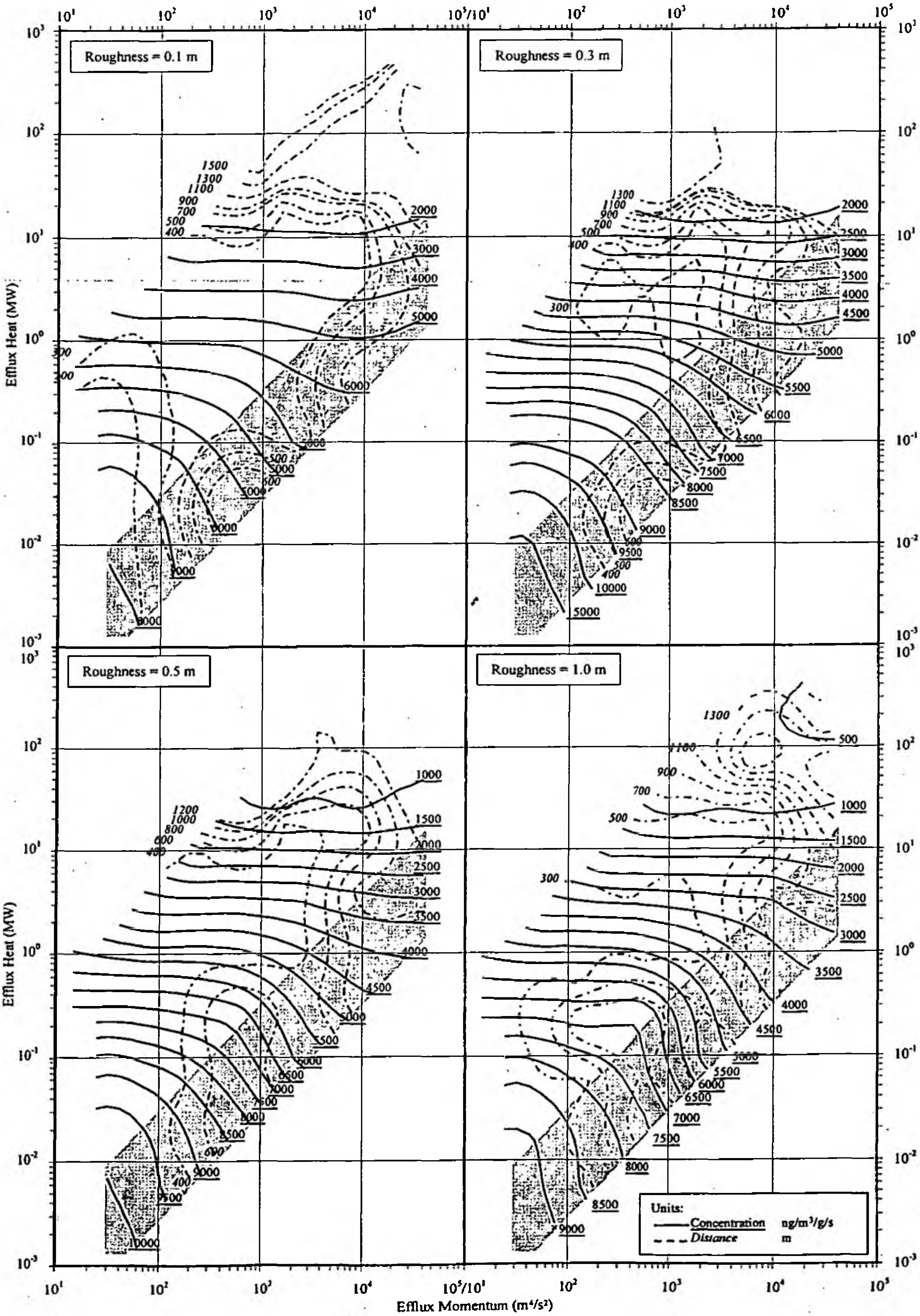


Chart 97	Maximum Ground Level Concentration	100th Percentile	120m Stack	Turnhouse (Met Type 3)	ADMS2

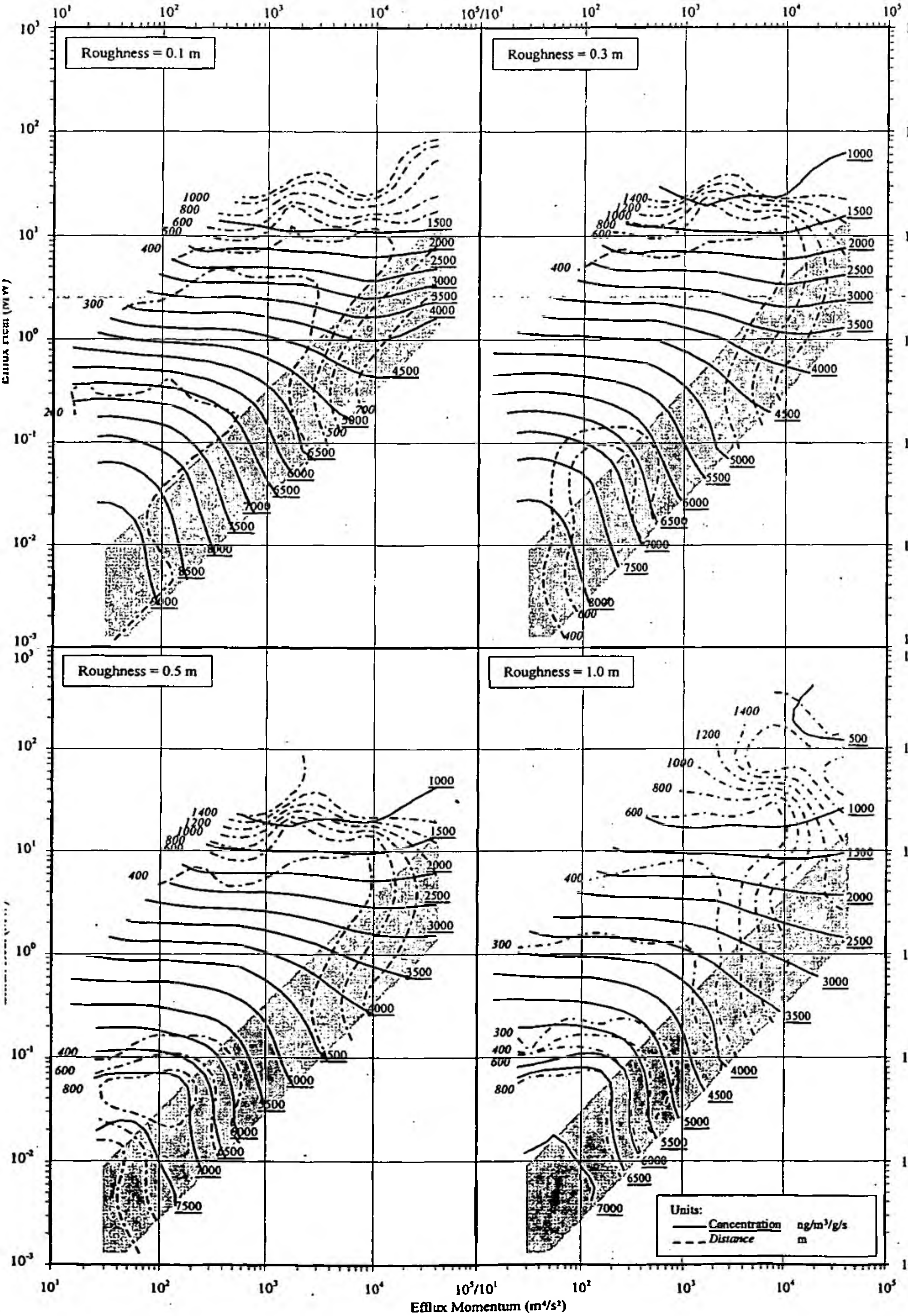


Chart 98	Maximum Ground Level Concentration	100th Percentile	150m Stack	Turnhouse (Met Type 3)	ADMS2

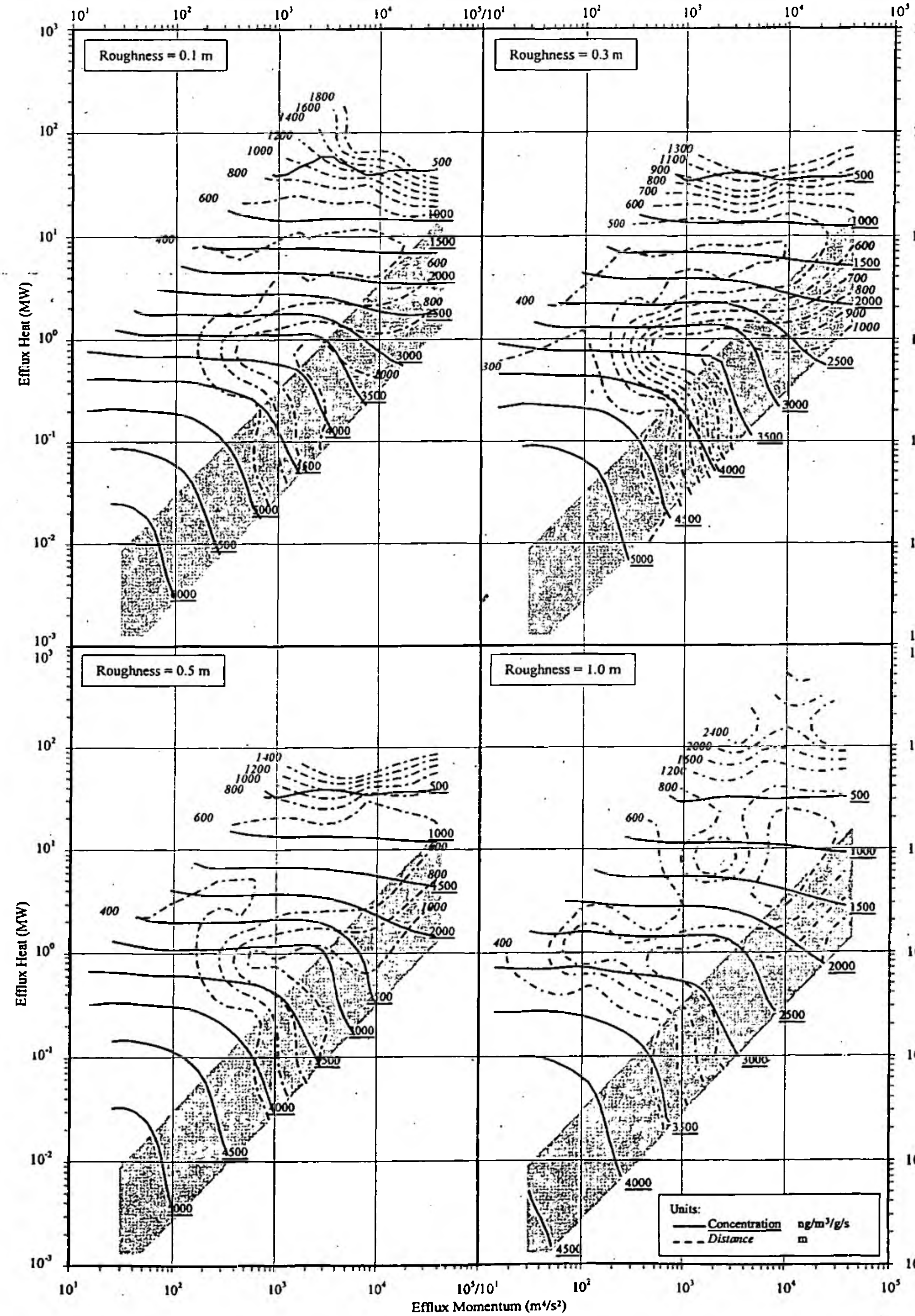
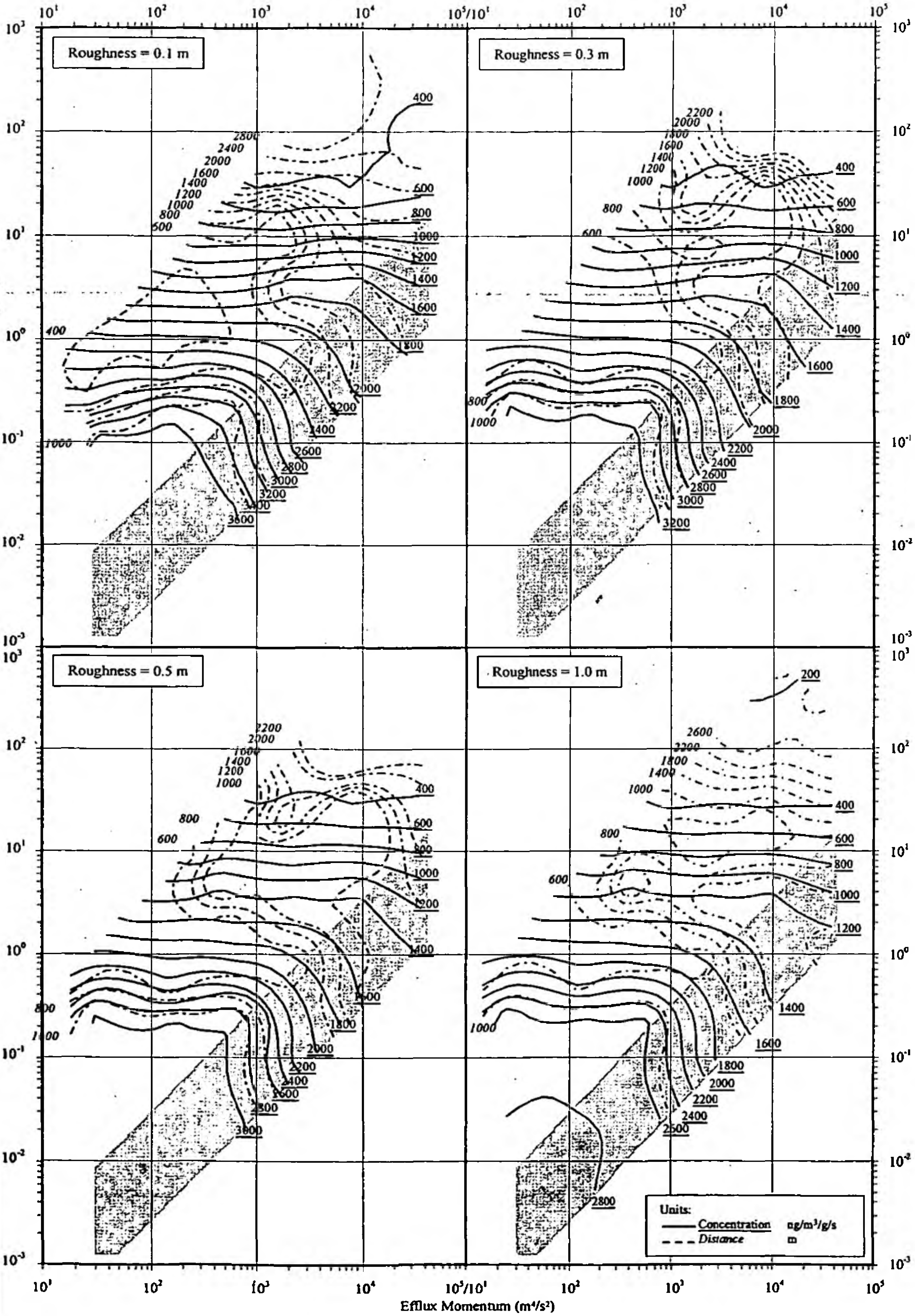


Chart 99	Maximum Ground Level Concentration	100th Percentile	200m Stack	Turnhouse (Met Type 3)	ADMS2



ANNEX IV
Further Technical Details

ANNEX IV – Further Technical Details

Contents

1. INTRODUCTION

The purpose of this annex is to add technical detail to the methods behind the results presented in the Guidance. It is not necessary to read this annex to obtain a first estimate of stack impacts but it can be consulted by users who would like more details of how the Guidance was developed.

The specific objectives of the annex are:

- To outline the method of chart production.
- To provide greater explanation of some aspects of the method, particularly those involving significant approximations and uncertainties.
- To explain the decisions and assumptions made.
- To present the results of accuracy tests that have been performed on the Guidance.
- To identify areas of further work which could be undertaken.

The objective of the Guidance was to enable a variety of users to carry out atmospheric dispersion estimates for a wide range of industrial processes throughout Great Britain. The Guidance is a paper-based system for calculating the maximum impact of pollutant releases from a process stack. It has been developed using results from a computer-based dispersion model and covers a range of geographical and discharge situations. The results of the dispersion calculations are summarised on a series of "look-up" charts from which estimates of maximum stack impacts can be derived for specific cases.

The following sections give details of :

- The model used (section 2)
- The method of chart production (section3)
- Common input data (section 4)
- Tests of the accuracy of look-up charts (section 5)
- Possible areas for further work (section6)
- References for Annex IV (Section 7)

2. MODEL DETAILS

The air dispersion model chosen to produce the charts was ADMS Version 2.02.3, which is produced by Cambridge Environmental Research Consultants (CERC) and is a widely recognised 'new generation' model. The features of this model which distinguish it from 'old generation' models, such as the NRPB R91 model (Clarke, R.H. (1979)) and the US EPA Industrial Source Complex (ISC) model, are:

- The stratification of the boundary layer is characterised by two main parameters: the height of the boundary layer and the Monin-Obukhov length, which is a length scale determined by the friction velocity and the heat flux at the surface.
- The required boundary layer parameters are calculated by the model from the input meteorological data.
- In stable and neutral conditions the distribution of pollutant concentrations is Gaussian but in convective conditions the vertical distribution of pollutant concentrations is non-Gaussian.
- Plume spread is dependent on local wind speed and turbulence, and therefore on plume height.

More detail on the technical background to the model can be found in the ADMS manual (CERC, 1995). For the production of the paper-based dispersion system, the method of running the model was modified by CERC to allow large numbers of runs to be carried out in batches.

3. CHART PRODUCTION

This section outlines the basic method used to produce a look-up chart, which is common to all of the charts. There are other variables such as roughness length, stack height, meteorology, temporal statistic, which are also explained, as they define the scope of the Guidance. However, the principles of chart production are the same regardless of these variables.

3.1 Overview of Main Variables

The following parameters were the main variables considered in the development of the look-up charts:

- Release parameters associated with the gases exiting the chimney stack:
  - Temperature, T_{rel};
  - Volume flow rate, V_{rel};
  - Velocity, w; a standard velocity of 15m/s is assumed throughout.
  - Height of release, h;
  - Internal radius of stack flue, r.

- Parameters in the locality of the release that will affect the dispersion of any emitted pollutant:
  - Meteorology; a choice of three types of dispersion climate.
  - Roughness Length; a choice of four values; 0.1, 0.3, 0.5 and 1.0m.
  - Terrain; an assumption of flat terrain has been made throughout.

- Temporal Statistics:
  - All calculations are based on hourly average dispersion.
  - Calculations have used 10 years of meteorological data.
  - Results have been summarised for different statistics:
    - –Annual average; i.e. mean of all hours in the year
    - –99.9 %ile; i.e. the eighth highest hour in the year
    - –100 %ile; i.e. the highest hour in the year

3.2 Construction of Look-up Charts

Each look-up chart has the heat and momentum of the emitted gases on the two axes. As there are three degrees of freedom for these two parameters, i.e. temperature, radius and velocity, the velocity has been fixed. A velocity of 15 m/s is recommended for processes over 1 MW (Technical Guidance Note D1), this velocity has been used as a fixed value throughout the Guidance.

The other two fundamental parameters, temperature and volume flow rate, were varied to give a range of efflux heat (Q) and efflux momentum (M) values. The following six values of T_{rel} and six values of V_{rel} were selected to encompass the variation of a sample of real processes given in '*An Assessment of the Effects of Industrial Releases of Nitrogen Oxides in the East Thames Corridor*' (HMIP, 1993):

- Temperature, 10.5°C, 15°C, 30°C, 60°C, 160°C, 460°C;
- Volume flow rate, 2.5 m^3/s, 10 m^3/s , 40 m^3/s, 160 m^3/s, 640 m^3/s, 2560 m^3/s;
- Velocity, 15 m/s.

Each combination of these values of temperature and volume flow rate was modelled for each chart giving 36 specific data points. The above values of volume flow rate were obtained by setting the radius so that the desired volume flow rate was reached with a velocity of 15 m/s, i.e. by using the following equation:

$$r = \sqrt{\frac{V_{rel}}{w\pi}} = \sqrt{\frac{V_{rel}}{15\pi}}$$

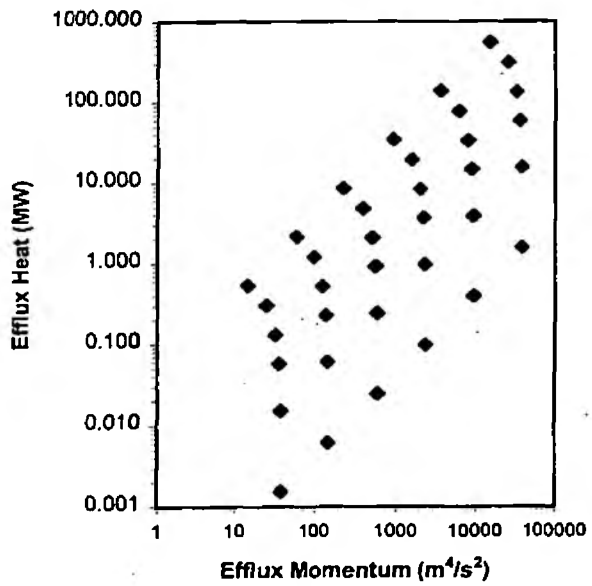
The radii are specified in Table 3.1.

Table 3.1 Radii used to achieve selected volume flow rates

	Volume flow rate (m^3/s)					
	2.5	**10**	**40**	**160**	**640**	**2560**
Radius (m)	0.23	0.46	0.92	1.84	3.69	7.37

The variation in the resulting heat and momentum for the 36 data points is indicated in Figure 3.1. Note that this has been represented on a log-log scale, in the same way as the look-up charts.

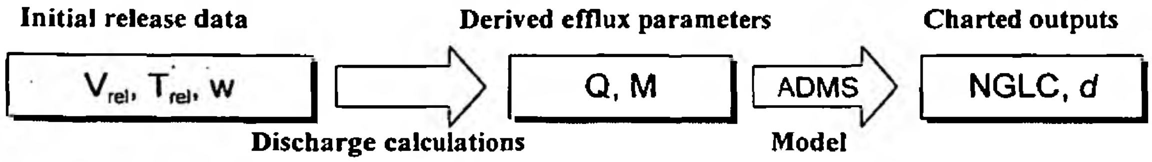
Figure 3.1 Array of input parameters



3.3 Chart Production

Each data point in Figure 3.1 is associated with a specific combination of temperature and volume flow rate, at a velocity of 15 m/s. The parameters for each data point were input into the model in order to produce the required output, i.e. maximum Normalised Ground Level Concentration (NGLC) and the distance of the maximum concentration from the stack (*d*). In other words there is a unique maximum NGLC and *d* associated with each data point in Figure 3.1. An interpolation package (Surfer for Windows version 6) was used to draw contours between these two fields of values. Separate contours were drawn for each field of values, with solid contours representing the field of maximum NGLC values and dashed contours representing the field of *d* values. Figure 3.2 summarises the key steps in chart production.

Figure 3.2 Key steps in chart production



3.4 Grid Spacing

In practice the parameters for each of the 36 data points are input into the model as a batch. ADMS allows a maximum of 32×32 locations to be modelled (CERC,. 1995). These locations are expressed as a grid in which the distance between adjacent points, *x*, can be adjusted but all values of *x* should be equal in any grid. As the value of *d* varies in a batch of runs it was important that the grid spacing specified for the batch was large enough to encompass all of the *d* values output from the batch, while remaining small enough to identify the maximum NGLC with reasonable accuracy. The value of *x* is dependent on the stack height, as this is the dominant factor governing the value of *d*. For each batch of runs the source was placed at the origin and the maximum *d* obtained. Hence *x* is increased to ensure capture of the maximum NGLC within the grid for all data points.

3.5 Meteorological Data

There is a variety of dispersion climates in Great Britain, for example ranging between inland situations, coastal situations, and situations affected by topographic channelling of the wind. Three data sets were chosen to cover this range of dispersion climates:

- Elmdon, Birmingham, representing inland situations and also south and west coast situations;
- Kilnsea, Humber Estuary, representing situations near the East Coast;
- Turnhouse, Edinburgh, representing channelled situations;

The contrast between inland, coastal, channelled and other wind regimes is clearly illustrated by Figure 1.7 (p.6) of *'The UK Environment'* (DoE, Government Statistical Service, 1992) which shows wind roses for a range of UK sites. The three locations listed above were chosen on the basis of these data; Elmdon showing minimal channelling effects; Kilnsea being influenced by its East Coast location and Turnhouse being representative of a location showing a clear case of topographic wind channelling.

The meteorological data used in the production of the look-up charts were statistically-grouped data based on 10 years of observations. This means that the data from 10 years were divided into about 2000 discrete groups (or 'bins') rather than being treated as a simple sequence. The data in each group were averaged over all the relevant hours in the 10-year period, giving a single value for each of some 2000 meteorological situations. There is some loss of precision due to this grouping process, which produces an extra uncertainty in the charts, but the use of statistically-grouped data was necessary in order to achieve reasonably fast calculations with the prevailing version of ADMS.

The magnitude of the extra uncertainty due to grouping was estimated from the difference in concentration amounts calculated using statistically-grouped and ungrouped sequential data in the ADMS model. Differences were calculated for a small sample of stack heights and temporal statistics, and it was found that:

- The differences were a few tens of percent or less in most cases, but could approach a factor of 2 in extreme cases.
- The differences tended to be larger for short-term statistics (e.g 100^{th} and 99.9^{th} percentiles of hourly values in a year) and smaller for long-term statistics (e.g annual averages).
- The sequential results tended to be higher than the statistical results, although the statistical results were higher in some cases.

It was considered from these results that the use of statistical data for the charts has introduced an extra uncertainty in estimated concentration amounts which is a few tens of percent in most cases, but which approaches a factor of 2 in extreme cases.

3.6 Temporal Statistics

The temporal statistics covered by the charts in the Guidance were chosen on the basis of the Objectives set by the National Air Quality Strategy (NAQS) for the pollutants considered most likely to be emitted from stacks. The approach taken was to select three temporal statistics which were particularly relevant to impacts from stack pollutants, and then to provide conversion factors for estimating results for other NAQs temporal statistics.

The Guidance provides approximate factors for converting between averaging times and also between percentiles. Specifically, factors are provided to convert from a) 1 hour averages to averages for 15 minutes, 8 hours and 24 hours, and b) charted percentiles to other percentiles required for comparison with NAQS objectives.

3.7 Stack Heights and Grid Spaces

A range of 11 stack heights were selected to encompass the variation in a sample of real processes (HMIP, 1993). The range of stack heights is given in Table 3.2 with the grid spacing necessary to capture all of the maximum ground level concentrations (see Section 3.4 for an explanation of how this was carried out).

Table 3.2 Grid spacing, x, for range of stack heights.

	Stack Height (m)										
	20	**30**	**40**	**50**	**60**	**70**	**85**	**100**	**120**	**150**	**200**
x (m)	45	65	80	94	125	125	140	162	170	175	300

3.8 Local parameters

The dispersion of released gases can be affected by such local parameters as the slopes(s) of nearby terrain, or by the presence of nearby buildings. However, the methodology in this Guidance is not applicable to situations involving significant effects from local terrain or buildings. The onset of significant effects is assumed to occur when terrain slopes exceed 1 in 10 (see Technical Note 1) or when the heights of buildings exceed 40% of the stack height (see Technical Note 2).

The following range of surface roughnesses was selected to cover the likely range of values occurring in different situations within Great Britain:

- 0.1 m, 0.3 m, 0.5 m and 1.0m.

The look-up charts are presented as groups of four charts, with the same variables but different surface roughnesses.

3.9 Overall Scope of Charts

The overall scope of the Guidance is shown by the matrix of chart numbers. There are 99 combinations of stack height, meteorological type and temporal statistic, giving 99 charts as summarised in Table 3.3. In addition, four surface roughnesses are available, as shown by the four plots on each chart, so that the total number of combinations covered is 396.

Table 3.3 Chart Numbers for Maximum Ground Level Concentration Charts

Met Type	Temporal Statistic	Stack Height										
		20m	30m	40m	50m	60m	70m	85m	100m	120m	150m	200m
Type 1 (Default)	Annual	1	2	3	4	5	6	7	8	9	10	11
	99.9%ile	12	13	14	15	16	17	18	19	20	21	22
	100%ile	23	24	25	26	27	28	29	30	31	32	33
Type 2 (East Coast)	Annual	34	35	36	37	38	39	40	41	42	43	44
	99.9%ile	45	46	47	48	49	50	51	52	53	54	55
	100%ile	56	57	58	59	60	61	62	63	64	65	66
Type 3 (Channelled)	Annual	67	68	69	70	71	72	73	74	75	76	77
	99.9%ile	78	79	80	81	82	83	84	85	86	87	88
	100%ile	89	90	91	92	93	94	95	96	97	98	99

4. COMMON INPUT DATA

The following input parameters were common to all model runs:

- Continuous release of gases from the source;
- Release at 52° latitude;
- Relative molecular mass of the gases was taken to be 28.96 g/mole and the density 1.225 kg/m^3;
- The specific heat capacity was set at 1000 J/°C/kg;
- A nominal pollutant mass emission rate of 1 g/s was used;

- Ambient air temperature was assumed to be 15°C;
- Dry and Wet deposition processes were not included in the modelling calculations.

5. TESTS OF ACCURACY OF LOOK-UP CHARTS

Three separate studies of the accuracy associated with the Guidance have been carried out. The purpose was to review the methodology used in the Guidance for limitations in accuracy and where possible to quantify the errors involved. Broadly, the findings of the studies support the use of the charts for estimating the effects of stationary sources, provided good care is used.

This section contains a summary of the findings of the studies. The focus of the three studies was different in each case, as illustrated below:

- **Study 1**: An assessment of the error due to the method of chart production, i.e. due to interpolating contours between 36 spot values.
- **Study 2**: An assessment of the degree of human error associated with the reading of the charts.
- **Study 3**: An assessment of the accuracy of the Guidance method in it's entirety. This involved using emission, locality and meteorological data for 7 separate stacks and comparing the results obtained from the Guidance with separate computer calculations using ADMS.

The first two accuracy studies focussed on two individual aspects of the work book methodology, which it was thought were likely sources of error, namely the production of the charts and the ability of the user to read off values of NGLC and *d* accurately. The third study examines the overall uncertainty of the Guidance method (including the effect of the errors considered in the first two studies) and gives a quantitative estimate for the overall error in the values of estimated stack impacts. However it should be noted that the third study does not include the uncertainties inherent in the air dispersion modelling from which the charts are derived. These inherent uncertainties should also be taken into account when making decisions based on the estimates.

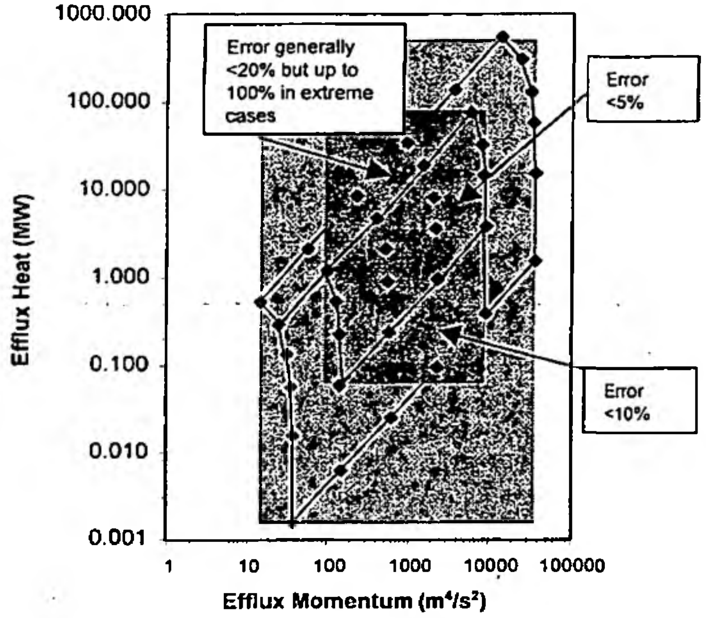
5.1 Study 1

An automated interpolation process was developed to calculate the percentage difference between the concentration and distance results obtained from ADMS and corresponding values obtained from the charts at each of the 36 control points on each chart. Examination of these results indicated that:

1. Every chart has been correctly derived and labelled.

2. The interpolation methods used for chart production mean that the central regions of the charts give more accurate results than the edges. This is summarised in Figure 5.1 which shows the positions of the 36 control points and of three areas having different errors. The tendency for errors to increase towards the margins of the charts is expected on the basis of the method used to generate the charts.

Figure 5.1 Summary of errors on chart production as shown by automated interpolation tests



5.2 Study 2

This study investigated the human error involved with plotting values of Q and M on the charts for particular cases, and with then abstracting values of NGLC and d at the plotted positions. A sample group of users was given the same values of Q and M, and asked to read values for NGLC and *d* from the charts. The values of NGLC and *d* they obtained were compared with the correct values. The tests showed that 36% of the users achieved a mean percentage deviation less than 5% for concentration, 86% achieved less than 10%, and 86% achieved less than 5% for distance. The maximum errors recorded for concentration and distance for each user range from 13-120% for concentration and 5-63% for distance. It was concluded that care is necessary in using the charts, and that errors can occur due to unfamiliarity with 'log-log' axes.

5.2 Study 3

This study involved a direct comparison between the results given by the Guidance and those given by separate calculations using ADMS for the same set of input data, including the same statistical meteorological data. Seven separate stacks were compared, in five locations with different emission and locality parameters. Tables 5.2 - 5.8 show the results of the seven case studies, in terms of process contribution (PC) and distance (*d*) values for two pollutants (NO_2 and SO_2), for both the Guidance and ADMS. Table 5.9 shows the percentage differences in the results obtained from the Guidance and ADMS.

Table 5.2 Case study 1

Case study 1	Pollutant	PC (µg/m³)	*d* (m)
Guidance	NO_2 (Annual Average)	1.11	476
	NO_2 (100%ile of 1 Hr)	39.26	190
	SO_2 (99.9%ile of 15 min)	238.67	270
ADMS	NO_2 (Annual Average)	0.83	538
	NO_2 (100%ile of 1 Hr)	38.78	200
	SO_2 (99.9%ile of 15 min)	219.24	269

Parameters:

- Stack height used: 60m
- Roughness length: 1.0m
- Efflux Momentum (M): 45.72 m^4/s^2
- Efflux Heat (Q): 1.092 MW
- Meteorology: Elmdon

Table 5.3 Case study 2

Case study 2	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	1.22	965
	NO_2 (100%ile of 1 Hr)	49.5	385
	SO_2 (99.9%ile of 15 min)	31.16	910
ADMS	NO_2 (Annual Average)	1.0	1118
	NO_2 (100%ile of 1 Hr)	28.9	1768
	SO_2 (99.9%ile of 15 min)	29.0	1250

Parameters:

- Stack height used: 85m
- Roughness length: 0.5m
- Efflux Momentum (M): 872.99 m^4/s^2
- Efflux Heat (Q): 16.26 MW
- Meteorology: Kilnsea (the Guidance); Herstmonceaux Met. Station (ADMS)

Table 5.4 Case study 3

Case study 3	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	1.80	920
	NO_2 (100%ile of 1 Hr)	161.55	245
	SO_2 (99.9%ile of 15 min)	79.52	430
ADMS	NO_2 (Annual Average)	1.37	1000
	NO_2 (100%ile of 1 Hr)	142.3	224
	SO_2 (99.9%ile of 15 min)	65.99	424.3

Parameters:

- Stack height used: 85m
- Roughness length: 0.1m
- Efflux Momentum (M): 173.53 m^4/s^2
- Efflux Heat (Q): 3.20 MW
- Meteorology: Elmdon

Table 5.5 Case study 4

Case study 4	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	9.78	1000
	NO_2 (100%ile of 1 Hr)	533.7	400
	SO_2 (99.9%ile of 15 min)	241.52	825
ADMS	NO_2 (Annual Average)	6.4	1200
	NO_2 (100%ile of 1 Hr)	417.26	361
	SO_2 (99.9%ile of 15 min)	197.60	894

Parameters:
- Stack height used: 85m
- Roughness length: 0.3m
- Efflux Momentum (M): 467.15 m^4/s^2
- Efflux Heat (Q): 16.16 MW
- Meteorology: Kilnsea

Table 5.6 Case study 5

Case study 5	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	8.09	1033
	NO_2 (100%ile of 1 Hr)	298.14	400
	SO_2 (99.9%ile of 15 min)	196.46	620
ADMS	NO_2 (Annual Average)	5.10	1208
	NO_2 (100%ile of 1 Hr)	162.50	400
	SO_2 (99.9%ile of 15 min)	111.49	781

Parameters:
- Stack height used: 100m
- Roughness length: 0.5m
- Efflux Momentum (M): 126.83 m^4/s^2
- Efflux Heat (Q): 5.71 MW
- Meteorology: Turnhouse

Table 5.7 Case study 6

Case study 6	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	39.26	248
	NO_2 (100%ile of 1 Hr)	654.4	187
	SO_2 (99.9%ile of 15 min)	469.9	184
ADMS	NO_2 (Annual Average)	30.94	282
	NO_2 (100%ile of 1 Hr)	608.98	100
	SO_2 (99.9%ile of 15 min)	393.9	200

Parameters:
- Stack height used: 30m
- Roughness length: 1.0m
- Efflux Momentum (M): 60.28 m^4/s^2
- Efflux Heat (Q): 1.99 MW
- Meteorology: Elmdon

Table 5.8 Case study 7

Case study 7	Pollutant	PC ($\mu g/m^3$)	*d* (m)
Guidance	NO_2 (Annual Average)	2.67	1847
	NO_2 (100%ile of 1 Hr)	123.36	600
	SO_2 (99.9%ile of 15 min)	58.43	1288
ADMS	NO_2 (Annual Average)	2.18	1910.5
	NO_2 (100%ile of 1 Hr)	110.41	538.5
	SO_2 (99.9%ile of 15 min)	52.45	1300

Parameters:
- Stack height used: 150m

- Roughness length: 0.3m
- Efflux Momentum (M): 703.23 m^4/s^2
- Efflux Heat (Q): 19.1 MW
- Meteorology: Turnhouse

Table 5.9 Range of percentage difference between the Guidance and ADMS results

Parameter	Averaging period	Range of percentage difference between the Guidance and ADMS results*	Average	Average across all averaging periods
PC	Annual Average	45.28 – 19.82	29.53	24.41
	100th %ile of 1Hr	58.89 – 1.23	24.01	
	99.9th %ile of 15 min	55.18 – 7.18	19.69	
d	Annual Average	18.18 – 3.38	12.18	18.24
	100th %ile of 1Hr	128.47 – 0.00	32.03	
	99.9th %ile of 15 min	31.48 – 0.37	10.49	

* Based on taking the magnitude of the difference between the Guidance and ADMS and dividing this value by the average of the Guidance and ADMS values. This value has then been multiplied by 100 to give a percentage.

It can be seen from these tables that, in general, the Guidance methodology is capable of producing values within + or – 25% of those obtained from separate calculations using ADMS. It is notable that all of the values of PC obtained with the Guidance were greater than the corresponding values obtained with separate ADMS calculations, by about 25% on average. However, the differences in the values of d were less consistent, with the Guidance values being less than the ADMS values in 14 cases, greater than in 6 cases, and the same in one case.

The Guidance was designed to enable quick first estimates of the impacts of stationary sources on local air quality, thereby reducing the need to do detailed computer modelling at an initial stage. It is unreasonable to expect the Guidance to produce identical results to ADMS, particularly as it has several conservatisms. In light of this, the levels of accuracy compared with separate ADMS calculations are acceptable for scoping purposes. The seven case studies above show that where there are differences between the Guidance and separate ADMS calculations, the Guidance is generally more conservative for concentrations, by about 25% on average. This conservatism is a useful feature of the Guidance as it tends to promote a precautionary approach in borderline cases.

6. POSSIBLE AREAS FOR FURTHER WORK

While developing the Guidance, the following possible areas for further work have been identified:

- Further Accuracy Testing. The tests of accuracy in Section 5 of Annex IV could be expanded. For example, the comparisons in Section 5.3 between results read from the charts and separate computer calculations could be expanded to cover a wider variety of stack heights, efflux heats and efflux momenta.

- Use of Sequential Meteorological Data. As mentioned in Section 3.5 of Annex IV, the meteorological data used in the preparation of the charts were statistical data i.e. data which had been divided into groups. This approach was necessary to achieve reasonably fast calculations with the prevailing version of ADMS. However, subsequent developments by CERC have enabled the model to be run with acceptable speed using ungrouped data ie sequential data. The charts could therefore be re-calculated using sequential meteorological data, thereby eliminating the extra uncertainty associated with the use of statistical data.

- Alternative Control Values. It would be useful to test the effect of using different arrays of Efflux Heat (Q) and Momentum (M) in place of the array of 36 values used to control the contouring of charts at present.

The ranges of temperature and volume flow rate from which the present control values of Q and $\dot{M}$ are derived would need to be altered, and the resulting changes to the accuracy of the charts assessed.

- Assumed Ambient Temperature. It would be useful to repeat the calculations using a fully consistent value of assumed ambient temperature. This would eliminate the 'grey areas' of greater uncertainty on the bottom of each chart due to the inconsistency between 10°C and 15°C, as explained in Technical Note 4.

- Release Velocities. It would be useful to consider the effect of using release velocities significantly different from the standard value of 15 m/s, and particularly velocities outside of the range 10-25 m/s already considered.

- Buildings. For scoping purposes it would be useful to indicate the effect of a building on maximum concentrations by repeating selected calculations with a building in place. For example, calculations could be repeated with a cuboidal building centred on each stack, with the building height set to be a fixed percentage of the stack height e.g. 50%.

- Other Models. It would be useful to prepare charts for other new-generation dispersion models in order to better understand how the choice of model effects the results of scoping calculations.

7. REFERENCES FOR ANNEX IV

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