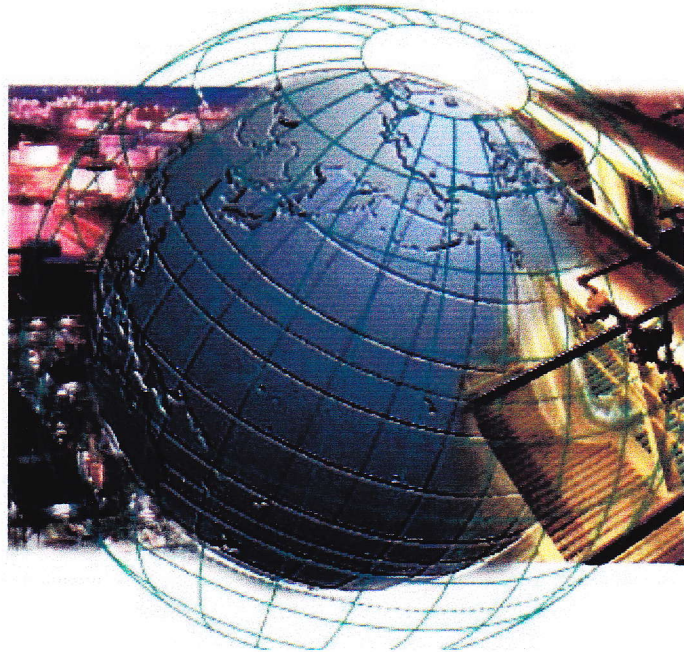**FW** **Foster Wheeler Energy Limited**
Environmental Services Group

BOC

**BOC Hydrogen Plant
North Tees Site**

Air Quality Report
7921-8151-RP-0003 Rev A1

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AIR QUALITY REPORT

1.0 Introduction

This assessment of emissions to air from the proposed BOC Hydrogen Plant at North Tees and their impact on air quality in the area has been carried out in support of the IPPC application. Air dispersion modelling of both normal and abnormal emissions has been conducted to estimate ground level concentrations of pollutants due to the Hydrogen Plant. Existing background levels have been added to these to obtain the Predicted Environmental Concentration.

Although the site is on the edge of an existing chemical site, there is a lagoon near by which is a Site of Nature Conservation Importance and the estuary foreshore, approximately a kilometre to the west of the site, is a Special Protection Area, defined under the Habitats Directive, together with Seal Sands to the north. The nearest residential areas are South Bank 2.2km to the south and Port Clarence 3km to the south west.

2.0 Releases to Atmosphere

2.1 Normal Operation

During normal operation there are two release points to atmosphere. These are the Reformer furnace stack and the steam deaerator vent.

The Reformer furnace stack emits carbon dioxide, carbon monoxide and oxides of nitrogen. Small quantities of sulphur dioxide will be emitted and there may be some particulates emitted during start-up. The stack height will be 49.5 m above ground level and the diameter 3.2 m. The stack goes up the side of the reformer and then bends across so that the top of the stack is centred on the reformer. The stack is situated at site co-ordinates 71m east, 183.5 m north. The reformer has been taken as a solid building 27 m high and 12 m wide and deep for the dispersion modelling.

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The thermal input to the burners will be approximately 120 MW and, therefore, the requirements of the Large Combustion Plant Directive (LCPD) apply. There is a proposal to tighten the emission limits under the LCPD. Current proposals are that a limit of 150 mg/Nm^3 will apply for firing of natural gas and 200 mg/Nm^3 will apply for other gases. The reformer will be firing tail gas from the hydrogen production process, supplemented with natural gas and the burners have been designed to achieve a release of 150 mg/Nm^3. This is considered to be satisfactorily below the 200 mg/Nm^3 limit for "other gases". It should be noted that the limits were quoted in an Information Note issued by the Council of the European Union in June 2000. This reflected discussions in the European Parliament.

A summary of the emissions from the reformer at full load conditions is given in Table 2.1.

Table 2.1 – Reformer Stack Emissions

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Parameter	Value
Discharge Flow Rate	60.12 Am^3/s
Discharge Velocity [1]	15 m/s
Discharge Temperature	129^{0}C
NO$_x$ Emissions	6.14 g/s
CO Emissions	8.18 g/s
SO$_2$ Emissions	0.006 g/s

[1]   A cone reducer has been fitted to the stack to increase the discharge velocity from 7.49 m/s to 15 m/s.

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Technical Guidance Note E1 from the Environment Agency was used to establish whether these emissions are significant. For sulphur dioxide with a 50m stack, emissions below 0.0198 g/s are considered insignificant. Therefore, the SO$_2$ emissions of 0.006 g/s are insignificant and are not considered further. Both NO$_x$ and CO are significant emissions and have been modelled.   The NO$_x$ was taken as initially NO$_2$.   This is an extremely conservative assumption, as NO$_2$ would be expected to contribute only part of total NO$_x$ released increasing slowly at distances measured in kilometres (see section 6.1.1).

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The use of a conical reducer to increase the velocity at point of discharge from 7.49 m/s in the main stack to 15 m/s satisfies the heat release and momentum criteria content in EA Technical Guidance Note D1 used for initial sizing of stacks.

The deaerator vent is a steam vent, contaminated with carbon dioxide, methanol, ammonia, carbon monoxide and hydrogen.   The vent release rate will be approximately 415kg/hr.   The vent will be 23m above ground and the diameter 0.076m. A summary of the emissions is given in Table 2.2.

Table 2.2 - Deaerator Vent Emissions

Parameter	Value	EA E1 Limit (20m stack)
Discharge Flow Rate	0.19m^3/s	-
Discharge Velocity	4.19m/s	-
Discharge Temperature	144^{0}C	-
Methanol Emissions	1.3g/s	0.310g/s
Ammonia Emissions	0.36g/s	0.024g/s
CO Emissions	0.14g/s	0.29g/s

Technical Guidance Note E1 from the Environment Agency was used to establish whether these emissions are significant. Figures for a 20m stack were used (see Table 2.2.). As can be seen emissions of methanol and ammonia are significant. Emissions of carbon monoxide are insignificant and are not considered further for this discharge. Both methanol and ammonia emissions have been modelled.

2.2   Start-up/Abnormal

Start-up/abnormal emissions occur through a vent stack. The vent stack is 40m high and is located near to the reformer at site co-ordinates 77.9m east, 173.15m north. The diameter of the vent stack is 0.508m, narrowing at the tip to 0.356m

During start-up the gas produced by the process is vented from the vent stack. This vent gas can contain significant quantities of carbon monoxide with hydrogen, methane and carbon dioxide. These can be vented for up to 24 hours. During the last 16 hours of this hydrogen is produced for export, reducing the volume flow rate of gases which gives the worst case for dispersion. This is the case which has been modelled. Emissions are given in Table 2.3.

Table 2.3 – Emissions During Set-Up

Parameter	Value
Discharge Flow Rate	3.18 Am^3/s
Discharge Velocity	31.0 m/s
Discharge Temperature	20^0C
CO Emissions	316g/s
CH_4 (Methane) Emissions	186 g/s

On adjusting to a different load there will be a small discharge of the Pressure Swing Adsorption (PSA) feed. Approximately once a year it may become fully blocked and trip out causing venting of the full flow rate for up to three hours. The emissions during this full flow venting are given in
Table 2.4.

Table 2.4 – Emissions Due To PSA Trip

Parameter	Value
Discharge Flow Rate	20.9 Am^3/s
Discharge Velocity	210 m/s
Discharge Temperature	37^0C
CO Emissions	907 g/s
CH_4 (Methane) Emissions	627 g/s

If the Regulator on the gas inlet to the plant fails, then the natural gas in the line will be vented to atmosphere until the shut-off valve has been closed. This is likely to be a rare event, which may occur once in the life of the plant. The majority of the gas is methane with some ethane. The emissions during this emergency scenario are given in Table 2.5.

Table 2.5 – Emissions Due to Gas Regulator Failure

Parameter	Value
Discharge Flow Rate	12.7 Am³/s
Discharge Velocity	128 m/s
Discharge Temperature	-40°C
Methane (CH_4) Emissions	5,831 g/s
Ethane (C_2H_6) Emissions	1,554 g/s

3.0   Air Quality Standards

The relevant air quality standards are those in "The Air Quality Strategy for England, Scotland, Wales and Northern Ireland", January 2000. This incorporates the requirements of the EC first Air Quality Daughter Directive and the proposed second Air Quality Daughter Directive. The air quality standards from this document for Nitrogen Dioxide and Carbon Monoxide, the main pollutants on interest are given in Table 3.1

Table 3.1 Air Quality Limits

Pollutant	Averaging Time	Limit
Nitrogen Dioxide	1 hour	200μg/m³ (105ppb) [1]
Nitrogen Dioxide	1 year	40μg/m³ (21ppb)
Carbon Monoxide	8 hour running mean	11,600μg/m³ (10,000ppb)

(1) Not to be exceeded more than 18 times per year, equivalent to a 99.8 percentile.

Additionally there will be emissions of ammonia, methanol, methane and ethane. Air quality objectives do not exist for these substances. The Environment Agency Technical Guidance Note

E4[1] gives Environmental Assessment Levels equivalent to hourly and annual average air quality limits. This gives limits for ammonia and methanol, based on occupational exposure limits (OEL). For methane and ethane no OEL is given as they are purely asphyxiants. For methane and ethane the main hazard is their flammability, so a limit of 10% of the lower explosive limit has been taken as a ground level ambient air quality limit. These limits are given in Table 3.2.

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(1) Environmental Agency Technical Guidance Note (Environmental) Best Practicable Environmental Option Assessments for Integrated Pollution Control.

Table 3.2 Air Quality Limits for other Pollutants

Pollutant	Limit	Averaging Period
Ammonia	$2400\mu g/m^3$ $170\mu g/m^3$	1 hour mean Annual average
Methanol	$31000\mu g/m^3$ $2600\mu g/m^3$	1 hour mean Annual average
Methane	4400ppm (2930 mg/m^3)	At any time
Ethane	2900ppm (3620 mg/m^3)	At any time

Nitrogen is phytotoxic (toxic to plants). At concentrations of 600 ppb ($1,150\mu g/m^3$) it inhibits photosynthesis and at 2,500 ppb ($4,750\mu g/m^3$) it causes leaf lesions. These concentrations are well above ambient air quality limits, so compliance with ambient air quality limits will ensure there is no damage to plant life within SSSIs.

4.0   Existing Air Quality

The Tees Valley Environmental Protection Group has published a summary of air quality measurements in the area[2]. There are three Automatic Urban Network (AUN) continuous monitoring stations in the area. These are sited at Breckton Hill in Middlesborough, Corporation Road in Redcar and Cleveland and Billingham at Stockton-on-Tees (measures nitrogen dioxide only). Additionally there are some local continuous monitoring stations and a mobile station used to measure concentrations of pollutants near busy roads and a network of diffusion tubes for local monitoring of nitrogen dioxide and some other pollutants. Measured pollutants of relevance are nitrogen dioxide and carbon monoxide.

Measurements of nitrogen dioxide from the AUN sites are summarised in Tables 4.1 and 4.2 and diffusion tube measurements are summarised in Table 4.3.

Table 4.1 – Annual Average Background NO₂ from AUN Monitoring Stations

AUN Station	Concentration (in ppb)		
	1999	1998	1997
Middlesborough	13	14	16
Redcar & Cleveland	12	14	14
Stockton [1]	17	18	19

Notes: [1] Sited near chemical site with nitrogen-based processes.

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[2] Air Quality in the Tees Valley 1996-1999, a comparison with National Air Quality Objectives, Tees Valley Environmental Group.

Table 4.2 – Hourly Average Background NO$_2$ from AUN Monitoring Stations

AUN Station	99.8 percentile concentration in ppb [2]		
	1999	1998	1997
Middlesborough	37 (66)	46 (63)	55 (125)
Redcar & Cleveland	39 (47)	45 (70)	40 (66)
Stockton [1]	73 (99)	77 (190)	101 (177)

Notes [1] Sited near chemical site with nitrogen-based processes.

[2] Figures in brackets are the 1 hour maximum.

Table 4.3 – Annual Average Background NO$_2$ from Diffusion Tubes

Type of Site	1999 Range of Concentrations in ppb
Kerbside (within 5m of busy road)	16-24
Intermediate (20-30m from busy road)	12-15
Background (>50m from busy road)	9-13 [1]

Notes [1] One reading at 22 ppb in Middlesborough Town Centre.

From these readings the AUN results show a drop in background nitrogen dioxide levels with time. The Stockton results are considered inapplicable to the BOC Hydrogen Plant as they are particularly high due to the nature of the nearby chemical processes. Therefore, an annual average background level for nitrogen dioxide of 13 ppb is considered appropriate. This is supported by the diffusion tube readings from background sites. Similarly, an hourly average background level for nitrogen dioxide, taken as 99.8 percentile, of 39 ppb is considered appropriate.

Concentrations of carbon monoxide are measured at two of the AUN monitoring stations and at a mobile monitoring station. Measurements of carbon monoxide from the AUN sites are summarised in Table 4.4

Table 4.4 – Maximum 8 Hour Running Mean Background Carbon Monoxide

AUN Station	Concentration (in ppm)		
	1999	1998	1997
Middlesborough	1.7	1.5	2.9
Redcar & Cleveland	2.5	3.9	3.5

From these the 1999 maximum concentration of 2.5 ppm has been taken as a background level. Measured annual average concentrations are significantly lower, ranging from 0.29 to 0.44 ppm. The mobile station, which was at roadside sites in 1999, measured maximum 8 hour running means of 0.7 to 2.6 ppm over a three month period at each location.

Table 4.5 summarises the background levels as used for the dispersion modelling.

Table 4.5 – Background Concentrations for Dispersion Modelling

Pollutant	Averaging Time	Concentration	
		ppb	$\mu g/m^3$
Nitrogen Dioxide	1 hour	39	75
	1 year	13	25
Carbon Monoxide	8 hour R.M.	2,500	2,900

There are no figures for background concentrations for the other pollutants modelled, namely methanol, ammonia, methane and ethane.

5. Dispersion Modelling

5.1 Air Dispersion Model

ADMS was used to model releases from the BOC Hydrogen Plant, except for the failure of the gas regulator, where PHAST was used. This was due to the interest in instantaneous maximum concentrations due to the flammability hazard for this case.

ADMS is a "new generation" computer model widely accepted as the industry standard in the U.K. It is capable of modelling dispersion in the atmosphere of passive, buoyant or slightly dense, continuous or finite duration releases from single or multiple sources. Cambridge Environmental Research Consultants (CERC) undertook the development of ADMS with the support of the Environment Agency and industry. The current version of the model is ADMS3, which can simultaneously take into account topography of the area and the influence of buildings on the dispersion of material released from the source.

ADMS uses the atmospheric boundary layer height and the reciprocal of the Monin-Obukhov length to characterise the atmosphere. The boundary layer is defined by measurable physical parameters obtained from meteorological data, which allows for a more realistic representation of the changing characteristics of dispersion with height and time. This results in a more soundly based prediction of the concentration of pollutants than previous generation dispersion models.

The model takes into account emissions from the source, location of nearby buildings, topography and meteorological data for the local area. The model will then provide a predicted concentration of the substance of interest at a specified point. The process is re-iterated for a large number of meteorological conditions and at a large number of receptor points to build up a prediction of the long-term mean and short-term peak concentrations over the area of interest.

Models of atmospheric dispersion are generally more reliable for long period averages and over intermediate distances (100m – 1000m). This is due to the range of experimental data that is used to compile the modules. Where emissions data is unreliable or the averaging periods are short, the results may become less reliable.

Typically the predicted hourly averages when using ADMS are accurate within a factor of two.

PHAST is a dispersion model for modelling hazardous releases for consequence analysis and risk analysis. It can model virtually instantaneous concentrations over an average of 10 seconds and hence is particularly appropriate for modelling releases of flammable gases. Dispersion of gas from a stack is initially modelled as a momentum jet until it touches down to the ground, when it is modelled as a passive plume/cloud.

5.2 Meteorological Data

Meteorological data required by ADMS includes wind speed, wind direction, temperature and cloud cover. One year of hourly sequential meteorological data has been used for the dispersion modelling. This is for Boulmer to the north of Teeside and is considered to be representative of conditions in the Teeside area and is for 1997. This is believed to be satisfactory in view of the comparatively low levels of emissions from the plant.

Meteorological data for PHAST consists of a number of specific meteorological conditions defined by Pasquil stability class and wind speed. Conditions used for this modelling are given in Table 5.1. These are considered to include worst case conditions.

Table 5.1 – Meteorological Conditions used with PHAST Modelling

Pasquil Stability Glass	Wind Speed (m/s)
A	1.0
D	3.0
D	12.0
D	24.0
F	2.0

5.3 Buildings and Topography

The dispersion of substances released from an elevated point source, such as the stack and vents on the BOC Hydrogen Plant, can be influenced by the presence of buildings close to the source. The buildings interrupt the flow of the wind and can result in higher ground level concentrations close to the source. A stack may be influence by a building if the stack is within 5 times the lesser of the height or width of the building from the nearest edge and the stack is lower than the Good Engineering Practice (GEP) stack height.

$$GEP = H + 1.5L$$

Where H = height of building and L = the lesser of the height or width of the building.

Most of the buildings and equipment in the Hydrogen Plant are either small or of open structure. The only exception to this is the Reformer, which has been input into the dispersion model for all runs. Although the main stack is taller than the GEP for this building, the vent stack could be affected. The building has been taken to be 27m high by 12m wide and 12m deep and is centred on the reformer stack at site co-ordinates 71m east, 183.5m north.

PHAST does not have the capability of modelling the effect of buildings.

A figure estimating the surface roughness is input to the model. A figure of 0.5m, typical for open suburbia or parkland, was input to the ADMS model, to allow for the nearby petrochemical works. PHAST uses a different definition of surface roughness and a figure of 0.17, typical of an industrial site, was input as the surface roughness parameter.

If the height of the surrounding area varies by more than 30% of the stack height within 1 km of the stack, then terrain heights should be input to the model. As the area around the BOC Hydrogen Plant is essentially flat, no terrain data has been input to the model.

5.4   Receptors and Contour Plotting

Predictions of pollutant concentrations for ADMS are made at user defined locations known as receptors. In this study the location of receptors have been defined by a square, cartesian grid of 6km by 6km with receptors on the intercepts of 31 uniformly spaced grid lines along each axis (north/south and east/west).

Additionally a number of specific receptors were input to the model for the reformer stack emissions case. These represent a platform on the nearby cumene plant tower and the nearest points of the nearby SSSIs/SPAs. These are Seal Sands, Tees and Hartlepool Wetlands and Tees and Hartlepool Foreshore. The co-ordinates for these specific receptors are given in Table 5.1.

Table 5.1 – Specific Receptor Co-ordinates

Receptor	Co-ordinates (in m)		
	X	Y	Z
Cumene Plant Tower	+80	0	15
Seal Sands SSSI/SPA	-290	+1075	0
Tees Wetlands SSSI/SPA	-725	-350	0
Tees Foreshore SSSI/SPA	+675	-700	0

The modelled ADMS concentrations were processed using the widely used contour plotting package Surfer (version 6.01) to produce contour plots for the model results. These are for illustrative purposes only as the assessment of the modelled results is based on the numerical results predicted by ADMS.

5.5   Other Data

Emission and source data as described is Section 2 were input to the ADMS model, together with the molecular weight and specific heat value for the gas being emitted. For the PHAST run the constituent components of the release together with the emission and source data were input to the model.

6.0 Results

6.1 Normal Operation

6.1.1 Percentage Oxidation of Nitric Oxide (NO) to Nitrogen Dioxide (NO₂)

The discharge from the reformer stack will be a mixture of oxides of nitrogen (NO_x). These are emitted to atmosphere as a result of gas combustion and will consist largely of nitric oxide (NO), a relatively innocuous substance. NO is known as "laughing gas" and is still used with oxygen as anaesthetic in hospitals. Once released into the atmosphere, nitric oxide is oxidised to nitrogen dioxide (NO_2). This is of concern with respect to health and other impacts. The proportion of nitric oxide oxidised to nitrogen dioxide depends on a number of factors and the oxidation is limited by the availability of oxidants, such as ozone (O_3).

Janssen *et al* [1] made extensive measurements of the percentage oxidation of nitric oxide to nitrogen dioxide in power station plumes and derived empirical relationships based on downwind distance, ozone concentration, wind speed and season of the year.

The fraction of nitric oxide oxidised to nitrogen dioxide in the plume is described by Janssen *et al*, by the following equation:-

$$[NO_2]/[NO_x] = a(1 - \exp(-\alpha x))$$

where x is the distance downwind (km) of the emission point and α and A are constants derived from the measurements.

The percentage oxidation to nitrogen dioxide with distance from the power station has been estimated using the data of Janssen *et al* for worst case and typical conditions, these estimates are presented in *Table 6.1*.

Table 6.1 – Estimates of the Percentage of Nitrogen Dioxide (NO₂) in Oxides of Nitrogen (NOx) for Worst Case and Typical Conditions

Downwind Distance (km)	Percentage Nitrogen Dioxide (NO₂) (%)	
	Worst Case Value	Typical Value
1	32	7
2	52	13
3	65	19
4	74	24
Notes		
The following values have been selected for the worst case and typical conditions:-		
Wind speed (ms⁻¹)	15	5
Ozone concentration (ppb)	100	25
Season	Summer	--
A (km⁻¹)	0.88	0.74
α (km⁻¹)	0.45	0.10

Based on the principles outlined above, it is expected that under typical conditions the proportion of the oxides of nitrogen in the form of nitrogen dioxide, within 2km of the stack, will be less than 15%. Under worst case conditions, approximately 50% of the oxides of nitrogen may be in the form of nitrogen dioxide.

Based on the Janssen's equations, a conservative percentage oxidation of 50% could be assumed for the maximum hourly average concentrations and 100% for annual average concentrations (long term values). Application of this approach will reduce the proportion of NO_2 in the flue gas discharge from 6.14 g/sec to 3.07 g/s. The impact of this has been discussed in Section 6.1.2.

6.1.2 Predicted NO₂ Concentrations

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Table 6.2 – Predicted Maximum Ground Level Concentrations of NO_2 ($\mu g/Nm^3$)

Averaging Time	All as NO_2	% EAL	50% as NO_s	As % EAL	EA Action Limit [1]	EAL $\mu g/Nm^3$
1 hr 99.8 percentile	36.9	18.5	18.45	9.2	20%	200
Annual average	1.03	2.6%	--	--	--	40

[1] new single source.

All modelling runs were initially undertaken using a stack discharge velocity of 7.49 m/s. The NO_2 dispersion run was repeated using a stack discharge velocity of 15 m/s.

The data presented for NO_2 in subsequent tables reflects the higher velocity. CO data is presented at 7.49 m/s.

Based on the modelling results and assessment of the NO/NO_2 ratio (see section 6.1.1 above) it is concluded that the discharge of NO_x will be substantially below the EAL under all meteorological and discharge conditions assessed For the plant design, it has been assumed that the worst situation prevails, ie, 100% NO_2 discharge.

It is difficult to attain an exact impact in relation to the prevailing background condition as the predicted concentration will decrease significantly with distances from the point of discharge. This is illustrated graphically in Pollution Contour Maps shown in Appendix A. This is also indicated in Table 6.3 below.

Table 6.3 – Comparison with Background NO_x

	Maximum	At Near Point of Seal Sands SSS1	At Salthorne Fire Station
1 hr average 99.8 percentile	36.9	10	3.0
Background	75	75	75
Total	111.9	85	78
Annual Average	1.03	0.6	0.1
Background	75	75	75
Total	76.03	75.6	75.1

Based on this data it is concluded that NO_2 emissions will not have a significant impact on populated areas.

Predicted ground level concentrations for NO_2 resulting from the reformer stack under the conditions described in Table 2.1 are presented in Table 6.2.

Table 6.4 provides a prediction of the impact of other pollutants.

Table 6.4 – Ground Level Concentrations of Other Pollutants During Normal Operations

Pollutant	Averaging Time	Predicted Process Contribution ($\mu g/m^3$)	Background ($\mu g/m^3$)	Predicted glc ($\mu g/m^3$)	Limit ($\mu g/m^3$)
CO	8 hr running mean	43.28	2,900	2,943	11,600
Ammonia	Annual	9.76	-	9.76	170
Ammonia	1 hr	48.4	-	48.4	2,400
Methanol	Annual	3.53	-	3.53	2,600
Methanol	1 hr	117	-	117	31,000

Based on ADMS modelling requests it appears that normal operation of the Hydrogen Plant will not have significant impact within or outside the plant boundary.

Attachment A contains contour plots of maximum predicted process contributions for nitrogen dioxide and carbon monoxide.

Table 6.5 presents ground level concentrations of nitrogen dioxide and carbon monoxide due to the reformer stack at the specific receptors of the cumene plant tower and nearby SSSIs. These exclude background concentrations.

Table 6.5 – Ground Level Concentrations at Specific Receptors

Receptor	Hourly Average NO_2 (based on 50% conversion)		Annual Average NO_2	8 hour running mean CO
	(99.8 percentile) ($\mu g/m^3$)	(maximum – 100% confidence) ($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)
Cumene Plant Tower [1]	3.12	23.50	0.13	24.60
Seal Sands SSSI/SPA	4.85	5.34	0.67	13.38
Tees Wetlands SSSI/SPA	4.64	5.67	0.20	10.93
Tees Foreshore SSSI/SPA	4.18	4.91	0.17	7.01
At West Fence Line	9.05	16.25	0.28	21.50

[1] Elevated, to assess exposure to nearby operations.

The fence line results shown in Table 6.5 establish that the peak ground level concentrations occur within the plant limits of the Huntsman North Tees Site. In this zone, comparison with occupational exposure limits (OEL's) should be made. OEL's have been set by the Health and Safety Executive for many chemicals to protect the health of the work force, who are exposed to chemicals on a daily basis. Two levels are set; 8 hour averages and 15 minute short term exposure levels (STEL's). Table 6.6 provides a comparison for the more significant chemicals released into the atmosphere by the operation of the Hydrogen Plant.

Table 6.6 – Occupational Exposure

Pollutant/Chemical	STEL µg/Nm³	Oel µg/Nm³	Predicted Long Term g/c (µg/Nm³)	% OEL
NO_2	9600	6700	18.5	0.32
CO	232000	35000	43.28	0.14
NH_3	25000	18000	9.8	0.05
Methanol	333000	266000	3.5	<0.01

Table 6.6 confirms that there are no significant additional risks to BOC/Huntsman staff from the operation of this plant.

6.2   Start up/Abnormal Operation

Predicted ground level concentrations during the second stage of start-up (which will lead to the highest ground level concentrations) are given in Table 6.3. Table 6.4 summarises predicted ground level concentrations during the emergency scenarios of a trip out on the Pressure Swing Adsorber (PSA) unit.

Table 6.3 – Ground Level Concentrations During Start-up

Pollutant	Averaging Time	Predicted Process Contribution (mg/m³)	Background (mg/m³)	Predicted glc (mg/m³)	Limit (mg/m³)
Carbon Monoxide	8 hr running mean	4.1	2.9	7.0	11.6
Methane	15 minutes	8.3	-	8.3	2,930

Table 6.4 – Ground Level Concentrations Due to PSA Trip

Pollutant	Averaging Time	Predicted Process Contribution (mg/m³)	Background (mg/m³)	Predicted glc (mg/m³)	Limit (mg/m³)
Carbon Monoxide	8 hr running mean	3.3 [1]	2.9	6.2	11.6
Methane	15 minutes	5.3	-	5.3	2,930

Notes: [1] As an 8 hour running mean, but emissions occur for 3 hours only.

Table 6.5 summarises the ground level concentrations predicted using the model PHAST for the emergency scenario of failure of the gas regulator.

Table 6.5 – Ground Level Concentrations Due to Failure of Gas Regulator

Pollutant	Averaging Time	Predicted glc (mg/m³)	Limit (mg/m³)
Methane	10 seconds	90	2,930
Ethane	10 seconds	17	3,620

A contour plot of maximum predicted process contributions of carbon monoxide during start up is included in Attachment A.

7.0 Discussion and Conclusion

Predicted ground level concentrations of all pollutants from the flue gas and deaerator discharges during normal operation are well within Environment Agency limits. For nitrogen dioxide the conservative assumption of 100% NO_x emissions being emitted as NO_2 has been compared with more realistic assessments based on NO reactions in the atmosphere. Concentrations at nearby Sites of Special Scientific Interest are well below levels at which damage to plants could occur, so the environmental impact at these sites is expected to be minimal.

Start up and abnormal emissions are also well within limits. The significant pollutant during these temporary conditions is carbon monoxide. Actual concentrations are likely to be lower than predicted as these occasional emissions are unlikely to coincide with worst case meteorological conditions.

From this dispersion modelling it is concluded that the BOC Hydrogen Plant at Teeside is unlikely to have a significant impact on local air quality.

APPENDIX A

POLLUTION CONTOUR MAPS

Reformer Stack NO_2 1 hour average 99.8 percentile, 7.49 m/s

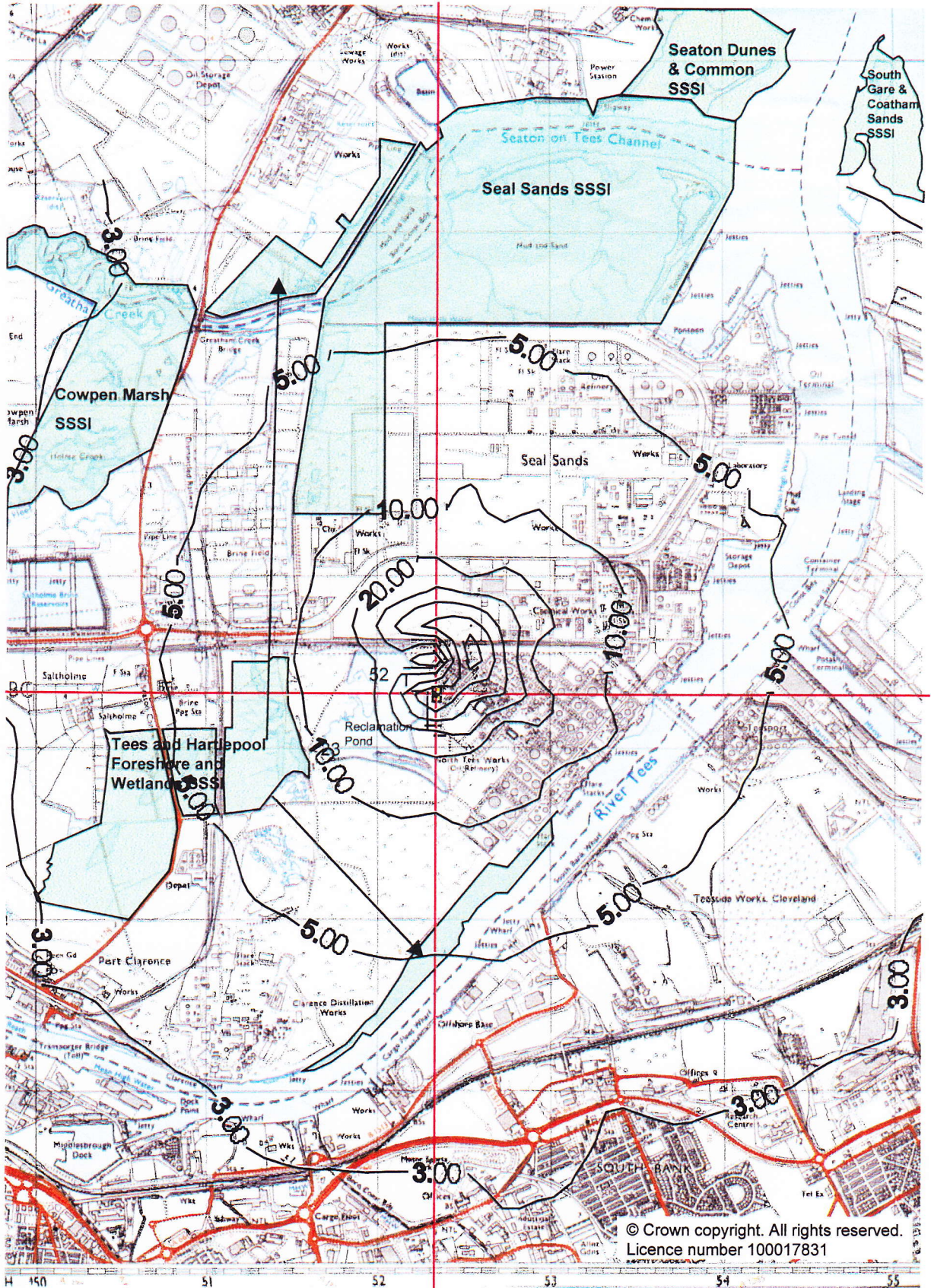Reformer Stack NO_2 1 hour average 99.8 percentile, 15 m/s

Reformer Stack NO_2 annual average

Reformer Stack CO – hour running mean

Vent Emission during start up CO 8 hour running mean

Failure of Gas Regulator Case PHAST Plume Plots

Reformer Stack NO$_2$ Concentration Isopleths ($\mu g/m^3$), 1hr average, 99.8 percentile, Peak Concentration 65$\mu g/m^3$ Excludes background levels
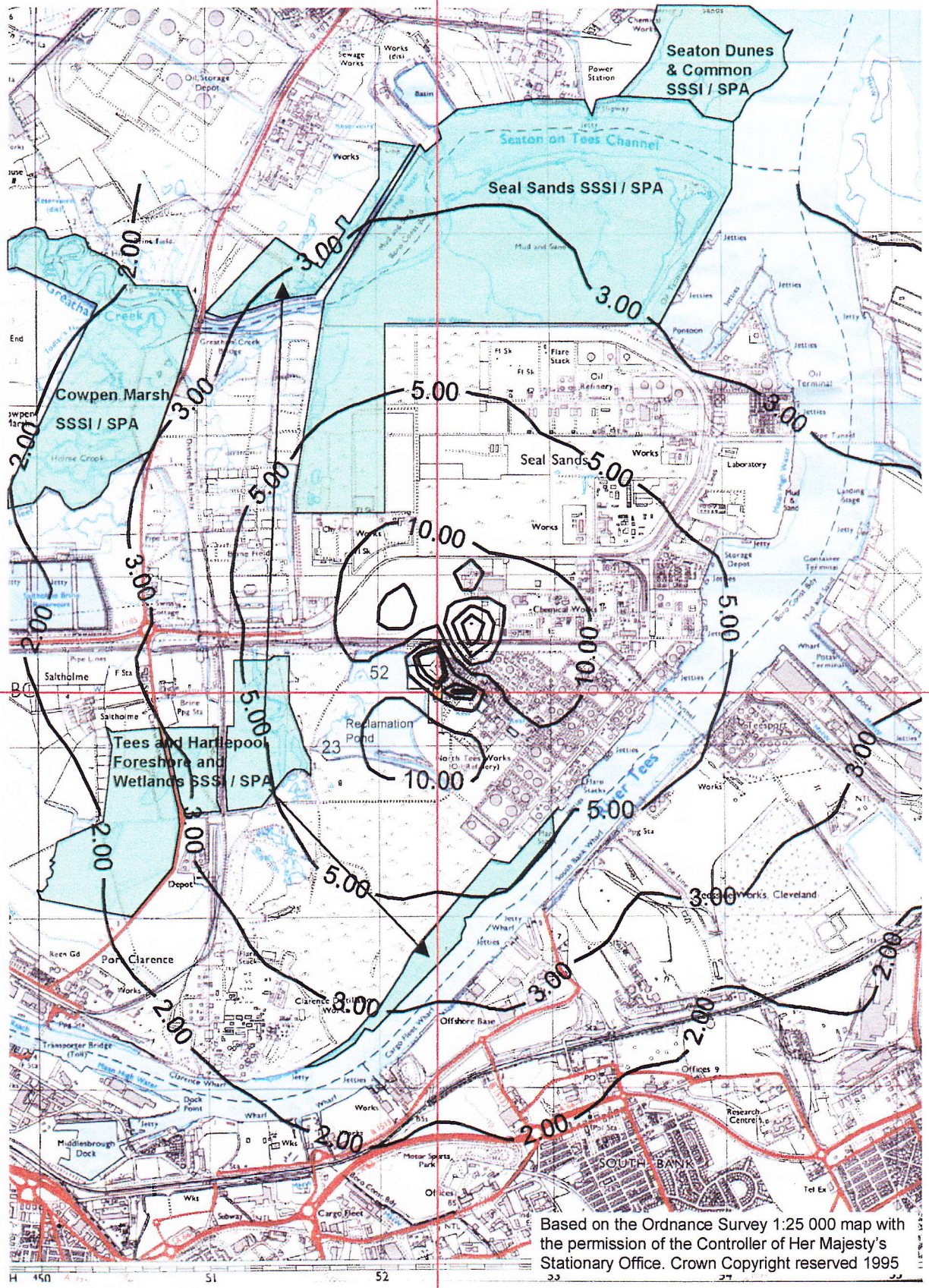

Seaton Dunes & Common SSSI

South Gare & Coatham Sands SSSI

Seal Sands SSSI

Seaton on Tees Channel

Cowpen Marsh SSSI

Cowpen Marsh

Seal Sands

Tees and Hartlepool Foreshore and Wetland SSSI

Reclamation Pond

River Tees

Teesside Works, Cleveland

Port Clarence

Clarence Distillation Works

SOUTH BANK

3.00
5.00
10.00
20.00

Hydrogen Plant -

Contours above 20$\mu g/m^3$ are at 10 $\mu g/m^3$ intervals

Reformer Stack NO$_2$ Concentration Isopleths (μg/m^3), 1hr average, 98.8 percentile, Peak Concentration 30μg/m^3 Excludes background levels

Seaton Dunes & Common SSSI / SPA

Seal Sands SSSI / SPA

Cowpen Marsh SSSI / SPA

Seal Sands
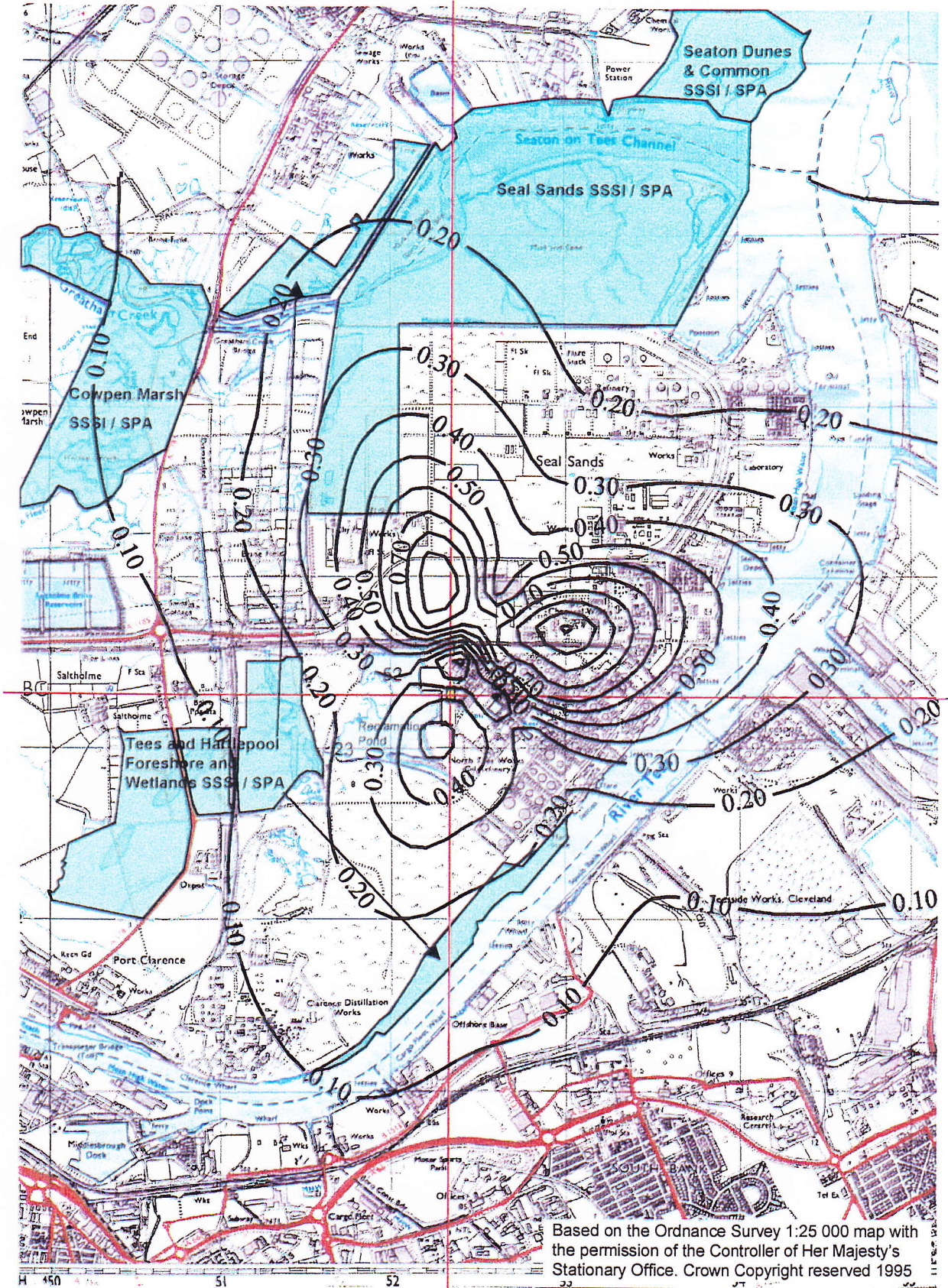
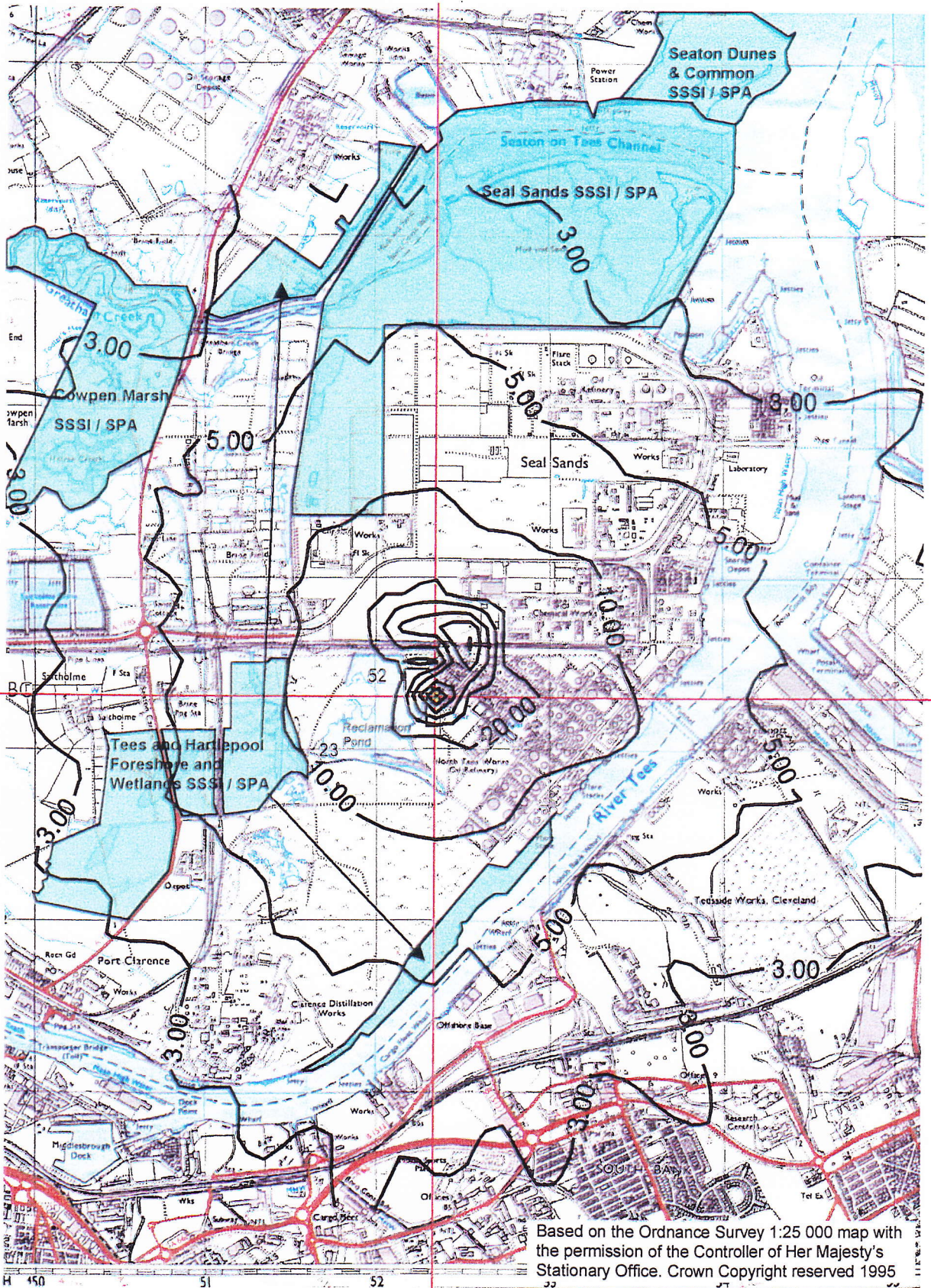Tees and Hartlepool Foreshore and Wetlands SSSI / SPA

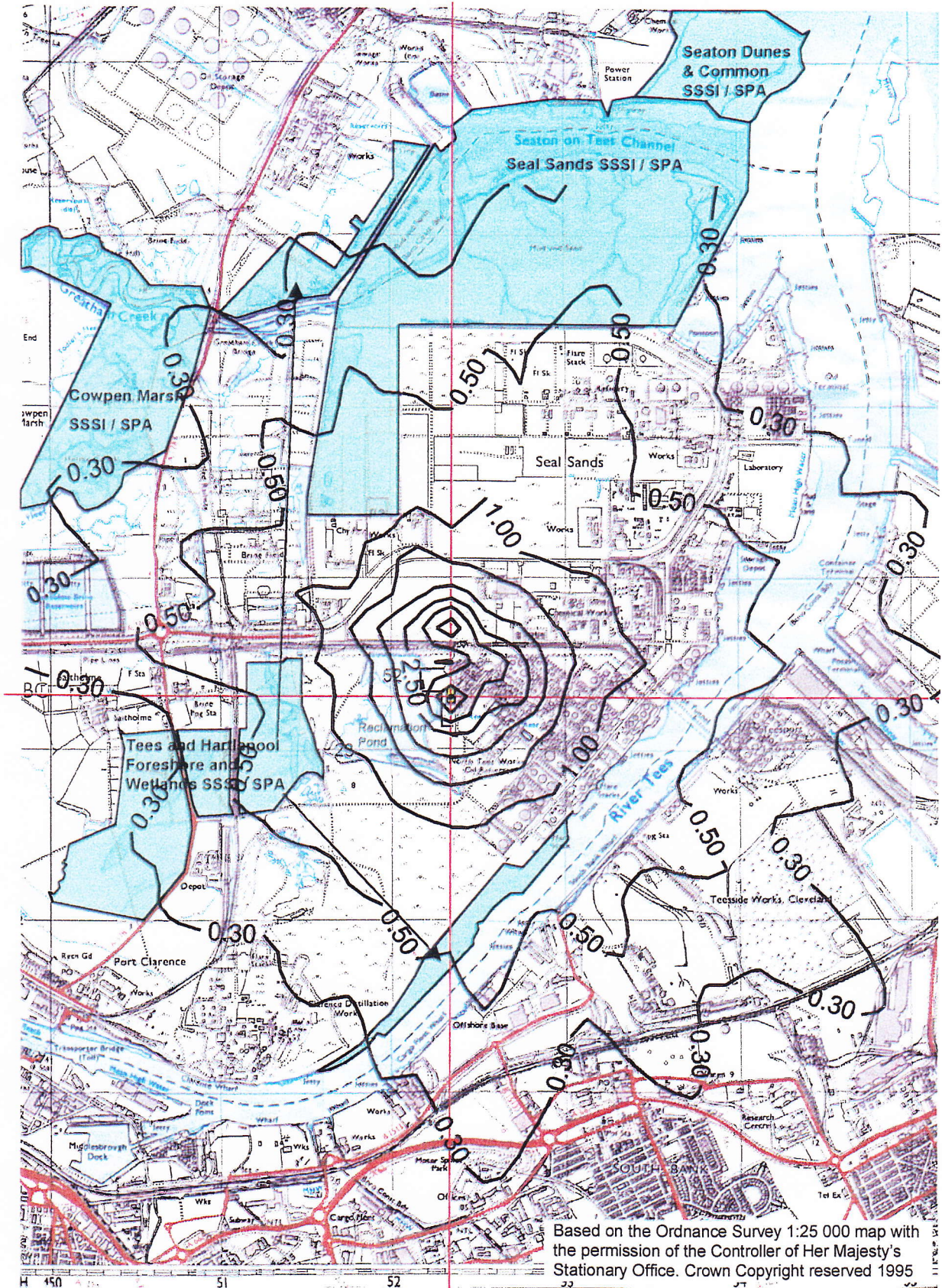Based on the Ordnance Survey 1:25 000 map with the permission of the Controller of Her Majesty's Stationary Office. Crown Copyright reserved 1995

Hydrogen Plant -

Contours above 10μg/m^3 are at 5 μg/m^3 intervals

Reformer Stack NO$_2$ Concentration Isopleths (µg/m3), Annual average, Peak Concentration 1.12µg/m^3 Excludes background levels

Hydrogen Plant -

All contours are at 0.1 µg/m^3 intervals

Reformer Stack CO Concentration Isopleths ($\mu g/m^3$), 8hr running mean, Peak Concentration 71.3 $\mu g/m^3$ Excludes background levels

Seaton Dunes & Common SSSI / SPA

Seaton on Tees Channel

Seal Sands SSSI / SPA

3.00

Greatham Creek

3.00

Cowpen Marsh SSSI / SPA

5.00

3.00

Seal Sands

3.00

5.00

10.00

52

20.00

23

Reclamation Pond

Tees and Hartlepool Foreshore and Wetlands SSSI / SPA

10.00

3.00

River Tees

5.00

5.00

3.00

3.00

3.00

Port Clarence

Clarence Distillation Works

Offshore Base

Teesside Works, Cleveland

Middlesbrough Dock

SOUTH BANK

H 450   51   52

Hydrogen Plant -

Contours above 10$\mu g/m^3$ are at 10 $\mu g/m^3$ intervals
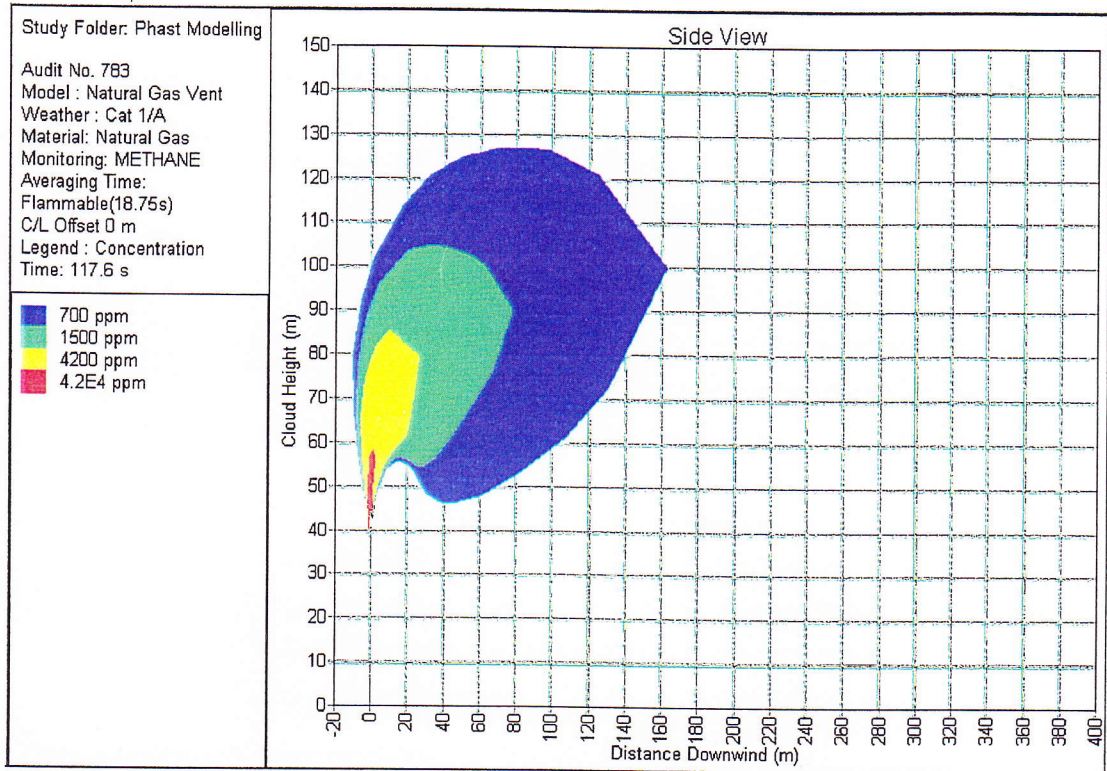
Start Up Vent Emission CO Concentrations mg/m³ 8 hour running average, Peak
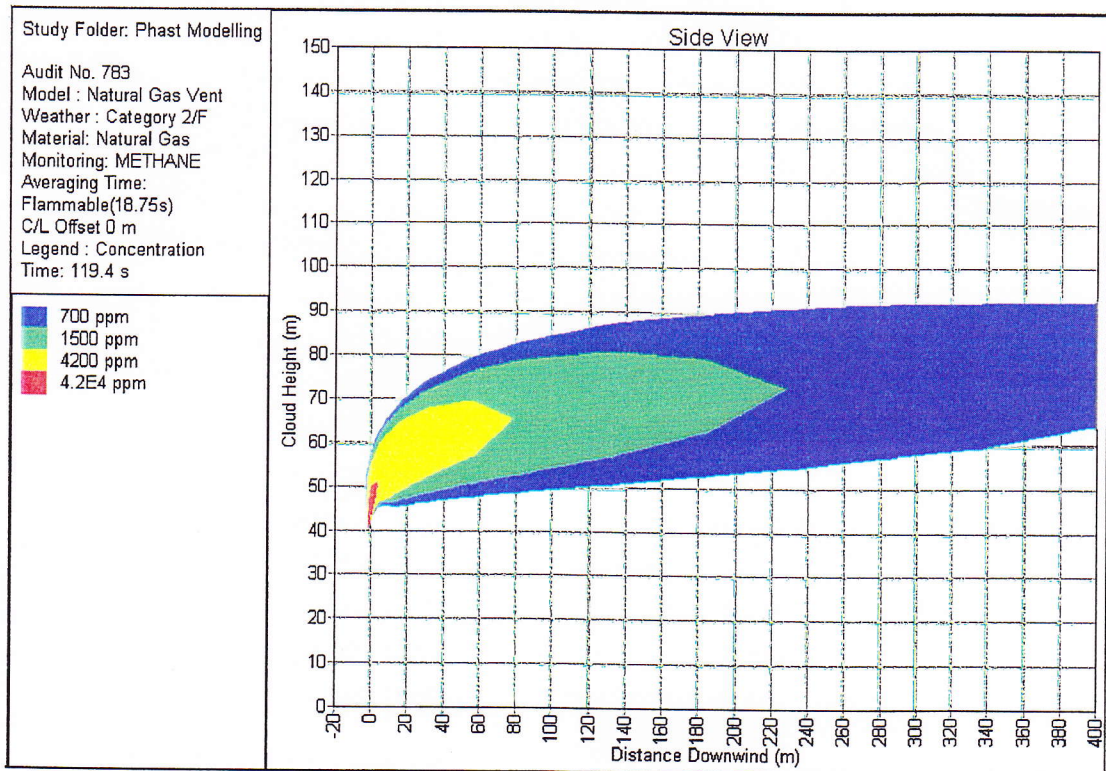Concentration 4.1 mg/m³ Excludes background levels

Hydrogen Plant - ▯

Contours above 0.5 mg/m³ are at 0.5 mg/m³ intervals

Study Folder: Phast Modelling

Audit No. 783
Model : Natural Gas Vent
Weather : Cat 1/A
Material: Natural Gas
Monitoring: METHANE
Averaging Time:
Flammable(18.75s)
C/L Offset 0 m
Legend : Concentration
Time: 117.6 s

- 700 ppm
- 1500 ppm
- 4200 ppm
- 4.2E4 ppm

Failure of gas regulator, methane plume for stability class A, wind speed 1 m/s

Study Folder: Phast Modelling

Audit No. 783
Model : Natural Gas Vent
Weather : Category 2/F
Material: Natural Gas
Monitoring: METHANE
Averaging Time:
Flammable(18.75s)
C/L Offset 0 m
Legend : Concentration
Time: 119.4 s

- 700 ppm
- 1500 ppm
- 4200 ppm
- 4.2E4 ppm

Failure of gas regulator, methane plume for stability class F, wind speed 2 m/s