



# Atmospheric Impact Report: Sasol Secunda Synfuels Operations

Project done on behalf of **Sasol South Africa (Pty) Ltd.**

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**Report No:** 16SAS03 | **Date:** January 2017



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## Report Details

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Report number	16SAS03
Status	Draft
Report Title	Atmospheric Impact Report: Sasol Secunda Synfuels Operations
Date	January 2017
Client	Sasol South Africa (Pty) Ltd
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## Revision Record

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Revision Number	Date	Reason for Revision
Rev 0	December 2016	Draft for client review
Rev 1	January 2017	Updated with client comments

## Preface

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Sasol's Secunda Synfuels Operations (SSO) is required to comply with the Minimum Emission Standards, which came into effect in terms of Section 21 of the National Environment Management: Air Quality Act (Act No 39 of 2004) on 1 April 2010, and subsequently replaced by GN893, of 22 November 2013. These standards require the operations to comply with "existing plant" limits by 1 April 2015, and with more stringent "new plant" limits by 1 April 2020. Technical investigations were conducted by SSO to establish feasibility and practicality of improving its existing process plants operations in order to comply with the standards as set out in the Minimum Emission Standards. Guided by the technical investigations, SSO requested postponement to comply with the Minimum Emission Standards in 2014. This was granted in February 2015, however for certain of the activities only a three year postponement was granted. Based on this as well as information associated with current roadmaps, the Employer intends to request an extension of the original postponement granted for the three year period to allow for the safe and complete implementation of technical solutions. In support of the submissions and to fulfil the requirements for these applications stipulated in the Air Quality Act and the Minimum Emission Standards, air quality studies are required to substantiate the motivations for the postponement application.

SSO produces synthesis gas (syngas) from coal by gasifying the coal at a temperature of 1300°C, using two types of reactors (circulating fluidised bed and Sasol Advanced Synthol™ reactors). The syngas is subsequently converted to produce components for making synthetic fuels as well as a number of downstream chemicals. Gas water and tar oil streams emanating from the gasification process are refined to produce ammonia and various grades of coke respectively.

Whilst the main air pollutants from SSO include sulfur dioxide (SO<sub>2</sub>), nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) – collectively known as NO<sub>x</sub>, other pollutants to consider include particulate matter (PM), volatile organic compounds (VOCs) (of primary importance – benzene) and metals.

Airshed Planning Professionals (Pty) Ltd (hereafter referred to as Airshed) was appointed by SSO to provide independent and competent services for the compilation of an Atmospheric Impact Report as set out in the Regulations and detailing the results of the dispersion model runs. The tasks to be undertaken consisted of:

- 1) Review of emissions inventory for the identified point sources and identification of any gaps in the emissions inventory. Where possible, it is preferable that gaps be estimated using an agreed emission estimation technique. No emission factors may be used without the written consent from Sasol that the emission factors are deemed acceptable. Should measurements be required, Sasol will source the required information.
- 2) Prepare meteorological input files for use in one or more dispersion models to cover all applicable Sasol sites. Sasol will provide surface meteorological data and ambient air quality data from the Sasol ambient air quality monitoring stations. Surface meteorological data for three years, as required by the draft Dispersion Modelling Guidelines for Level 3 Assessments, is available for ambient air quality monitoring stations situated in both Sasolburg and Secunda.
- 3) Preparation of one or more dispersion models set up with SSO's emissions inventory capable of running various scenarios for each of the point sources as specified by SSO. The intent is to model delta impacts of the various emission scenarios against an acceptable emissions baseline.
- 4) Airshed will validate the dispersion model based on an acceptable and agreed approach. The validation methodology must be agreed between the SSO and Airshed. It is anticipated that each point source identified above will require 3 scenarios per component per point source to be modelled, in order to establish the delta impacts against the baselines. i.e.:
  - a. Baseline – modelling is conducted based on the current inventory and impacts

- b. Future – modelling must be conducted based on the legislative requirement as stipulated within the Listed Activities and Minimum Emission Standards (for both 2015 and 2020 standards).
  - c. Alternative emission limits – the actual SSO proposed reductions, where applicable and different from the other 3 emission scenarios.
- 5) Comparison of dispersion modelling results with the National Ambient Air Quality Standards (NAAQS).
- 6) A report detailing the methodology used and model setup must be compiled for purposes of a peer review, which Sasol will contract independently.
- 7) Interactions with Environmental Assessment Practitioner (EAP) to provide all necessary inputs into the EAP's compilation of documentation in support of Sasol's postponement applications. Airshed will attend all Public Participation meetings scheduled by the EAP to address any queries pertaining to the dispersion model.

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## Abbreviations

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<b>AEL</b>	Atmospheric Emission Licence
<b>AIR</b>	Atmospheric Impact Report
<b>API</b>	American Petroleum Institute
<b>AQA</b>	Air quality act
<b>AQMS</b>	Air quality monitoring stations
<b>ARM</b>	Ambient Ration Method
<b>APCS</b>	Air pollution control systems
<b>As</b>	Arsenic
<b>ASG</b>	Atmospheric Studies Group
<b>BPIP</b>	Building Profile Input Program
<b>Co</b>	Cobalt
<b>CO</b>	Carbon monoxide
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>Cr</b>	Chromium
<b>CTA</b>	Crude Tar Acids
<b>CTF</b>	Coal Tar Filtration
<b>Cu</b>	Copper
<b>DEA</b>	Department of Environmental Affairs
<b>DO</b>	Decanted Oil
<b>DSC</b>	Distillate Selective Cracker
<b>DTA</b>	Depitched Tar Acids
<b>FCC</b>	Fluidised Catalytic Cracker
<b>g</b>	Gram
<b>g/s</b>	Gram per second
<b>GT</b>	Gas Turbine
<b>H<sub>2</sub></b>	Hydrogen
<b>HCl</b>	Hydrogen chloride
<b>HF</b>	Hydrogen fluoride
<b>HNO-DTA</b>	High Neutral Oil Depitcher Tar Acids
<b>HOW</b>	High Organic Waste
<b>HRSG</b>	Heat Recovery Steam Generator
<b>H<sub>2</sub>O</b>	Water
<b>H<sub>2</sub>S</b>	Hydrogen sulfide
<b>H<sub>2</sub>SO<sub>4</sub></b>	Sulfuric acid gas
<b>IP</b>	Intellectual property
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IV</b>	Inactive Vanadium
<b>LMo</b>	Monin-Obukhov length
<b>kPa</b>	Kilo pascal
<b>m</b>	Meter
<b>m<sup>2</sup></b>	Meter squared
<b>m<sup>3</sup></b>	Meter cubed
<b>MES</b>	Minimum Emission Standards
<b>m/s</b>	Meters per second
<b>Mn</b>	Manganese
<b>MRG</b>	Methane Rich Gas
<b>MTP</b>	Medium Temperature Pitch
<b>MW</b>	Mega Watt

<b>NAAQS</b>	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
<b>NEMAQA</b>	National Environmental Management Air Quality Act
<b>NH<sub>3</sub></b>	Ammonia
<b>Ni</b>	Nickel
<b>NO</b>	Nitrogen oxide
<b>NO<sub>2</sub></b>	Nitrogen dioxide
<b>NO<sub>x</sub></b>	Oxides of nitrogen
<b>O<sub>2</sub></b>	Oxygen
<b>O<sub>3</sub></b>	Ozone
<b>OCGT</b>	Open Cycle Gas Turbine
<b>OH</b>	Hydroxyl
<b>OLM</b>	Ozone Limiting Method
<b>PBL</b>	Planetary boundary layer
<b>Pb</b>	Lead
<b>PM</b>	Particulate matter
<b>PM<sub>10</sub></b>	Particulate matter with diameter of less than 10 µm
<b>PM<sub>2.5</sub></b>	Particulate matter with diameter of less than 2.5 µm
<b>ppm</b>	Parts per million
<b>Sb</b>	Antimony
<b>SCC</b>	Sasol Catalytic Converter
<b>SCS</b>	Sasol Coal Supply
<b>SLO</b>	Stabilised Light Oil
<b>SO<sub>2</sub></b>	Sulfur dioxide (1)
<b>SO<sub>3</sub></b>	Sulfur trioxide (1)
<b>TAVC</b>	Tar Acid Value Chain
<b>TVOC</b>	Total volatile organic compounds
<b>t/h</b>	Tonnes per hour
<b>US EPA</b>	United States Environmental Protection Agency
<b>USGS</b>	United States Geological Survey
<b>V</b>	Vanadium
<b>VOC</b>	Volatile organic compounds
<b>WESP</b>	Wet Electrostatic Precipitator
<b>WO</b>	Waxy Oil
<b>WSA</b>	Wet Sulfuric Acid
<b>Z<sub>o</sub></b>	Roughness length
<b>µ</b>	micro
<b>°C</b>	Degrees Celsius

**Note:**

- (1) The spelling of "sulfur" has been standardised to the American spelling throughout the report. "The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: <http://goldbook.iupac.org> (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.[doi: 10.1351/goldbook](https://doi.org/10.1351/goldbook))"

## Glossary

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Advection	Transport of pollutants by the wind
Airshed	An area, bounded by topographical features, within which airborne contaminants can be retained for an extended period
Algorithm	A mathematical process or set of rules used for calculation or problem-solving, which is usually undertaken by a computer
Assessment of environmental effects	A piece of expert advice submitted to regulators to support a claim that adverse effects will or will not occur as a result of an action, and usually developed in accordance with section 88 of the Resource Management Act 1991
Atmospheric chemistry	The chemical changes that gases and particulates undergo after they are discharged from a source
Atmospheric dispersion model	A mathematical representation of the physics governing the dispersion of pollutants in the atmosphere
Atmospheric stability	A measure of the propensity for vertical motion in the atmosphere
Building wakes	Strong turbulence and downward mixing caused by a negative pressure zone on the lee side of a building
Calm / stagnation	A period when wind speeds of less than 0.5 m/s persist
Cartesian grid	A co-ordinate system whose axes are straight lines intersecting at right angles
Causality	The relationship between cause and effect
Complex terrain	Terrain that contains features that cause deviations in direction and turbulence from larger-scale wind flows
Configuring a model	Setting the parameters within a model to perform the desired task
Convection	Vertical movement of air generated by surface heating
Convective boundary layer	The layer of the atmosphere containing convective air movements
Data assimilation	The use of observations to improve model results – commonly carried out in meteorological modelling
Default setting	The standard (sometimes recommended) operating value of a model parameter
Diagnostic wind model (DWM)	A model that extrapolates a limited amount of current wind data to a 3-D grid for the current time. It is the 'now' aspect, and makes the model 'diagnostic'.
Diffusion	Clean air mixing with contaminated air through the process of molecular motion. Diffusion is a very slow process compared to turbulent mixing.
Dispersion	The lowering of the concentration of pollutants by the combined processes of advection and diffusion
Dispersion coefficients	Variables that describe the lateral and vertical spread of a plume or a puff
Dry deposition	Removal of pollutants by deposition on the surface. Many different processes (including gravity) cause this effect.
Sasol SSO	Sasol South Africa (Proprietary) Limited operating through its Secunda Synfuels Operations (SSO), formerly Sasol Synfuels (Pty) Limited.

# Atmospheric Impact Report: Sasol Secunda Synfuels Operations

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## 1 ENTERPRISE DETAILS

### 1.1 Enterprise Details

The details of Sasol Secunda Synfuels Operations (SSO) are summarised in Table 1-1. The contact details of the responsible person, the emission control officer, are provided in Table 1-2.

**Table 1-1: Enterprise details**

Enterprise Name	Sasol Synfuels (Pty) Ltd
Trading as	Sasol Synfuels
Type of Enterprise	1979/002735/07
Company Registration Number	Synfuels Road Sasol Synfuels Secunda 2302
Registered Address	Private Bag X1000 Secunda 2302
Telephone Number (General)	017 610 2627
Fax Number (General)	
Company Website	<a href="http://www.sasol.com">www.sasol.com</a>
Industry Type/Nature of Trade	Petrochemical industry
Land Use Zoning as per Town Planning Scheme	Industrial
Land Use Rights if Outside Town Planning Scheme	n/a

**Table 1-2: Contact details of responsible person**

Responsible Person Name:	Estelle Marais
Responsible Person Post:	Senior Manager SHE: Environment – Air quality and greenhouse gas
Telephone Number:	017 610 2895
Cell Phone Number:	079 509 9011
Fax Number:	017 610 4090
E-mail Address:	Estelle.marais@sasol.com
After Hours Contact Details:	079 509 9011
Name of VP SHE Secunda Synfuels Operations:	Simon van Renssen



## 1.2 Location and Extent of the Plant

Table 1-3: Location and extent of the plant

Physical Address of the Plant	Synfuels Road Sasol Synfuels Secunda, 2302
Description of Site (Where no Street Address)	Highveld Ridge Mpumalanga
Coordinates of Approximate Centre of Operations	<b>Latitude:</b> 26.5530 S <b>Longitude:</b> 29.16484 E
Extent	24.05 km <sup>2</sup>
Elevation Above Sea Level	1 597m
Province	Mpumalanga
Metropolitan/District Municipality	Gert Sibande District Municipality
Local Municipality	Govan Mbeki Local Municipality
Designated Priority Area	Highveld Priority Area

## 1.3 Atmospheric Emission Licence and other Authorisations

The following licences related to air quality management are applicable. The License in bold text is the License applicable for the postponement application supported by this Atmospheric Impact Report (AIR).

- Atmospheric Emission License:
  - **Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd 0016/2015/F02 31 March 2015 issued to Sasol South Africa (Pty) Ltd operating through its Secunda Synfuels Operations**
  - Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd 0018/2015/F02 31 March 2015 issued to Sasol South Africa (Pty) Ltd through its Secunda Chemical Operations (LOC) (not affected)
  - Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd Sasol Oil/0019/2015/F02 31 March 2015 issued to Sasol Chemical Industries (Pty) Ltd Sasol Oil (not affected)
  - Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd 0017/2015/F02 31 March 2015 issued to Sasol South Africa (Pty) Ltd through the Secunda Chemical Operations (Solvents) (not affected)
  - Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd Sasol Nitro 0020/2014/F02 31 March 2015 issued to Sasol South Africa (Pty) Ltd Secunda Chemical Operations (Nitro) (not affected)
  - Licence no. Govan Mbeki/Sasol South Africa (Pty) Ltd 0021/2015/F02 31 March 2015 issued to Sasol South Africa (Pty) Ltd through Secunda Chemical Operations (Polymers) (not affected)
- Other: None

## 2 NATURE OF THE PROCESS

### 2.1 Listed Activities

A summary of listed activities currently undertaken at SSO is provided in Table 2-1. The listed activities in bold text is applicable for the postponement application supported by this AIR.

**Table 2-1: Listed activities**

Category of Listed Activity	Sub-category of the Listed Activity	Listed Activity name	Description of the Listed Activity
1	1.1	Solid Fuel Combustion installations	Solid fuels combustion installations used primarily for steam raising or electricity generation
	1.4	Gas Combustion Installations	Gas combustion (including gas turbines burning natural gas) used primarily for steam raising or electricity generation
2	2.1	Combustion installation	Combustion installation not used primarily for steam raising or electricity generation (furnaces and heaters)
	2.2	Catalytic cracking	Refinery catalytic cracking units
3	3.3	Tar processes	Processes in which tar, creosote or any other product of distillation of tar is distilled or is heated in any manufacturing process
	3.6	<b>Synthetic gas production and clean up</b>	<b>The production and clean-up of a gaseous stream derived from coal gasification and includes gasification, separation and clean-up of a raw gas stream through a process that involves sulfur removal and Rectisol as well as the stripping of a liquid tar stream derived from the gasification process</b>
4	4.2	Combustion installation	Combustion installation not used primarily for steam raising and electricity generation (except drying)
	4.7	Electric Arc Furnaces	Electric arc furnaces in the steel making industry
5	5.1	Storage and handling of ore and coal	Storage and handling of ore and coal not situated on the premises of a mine or works as defined in the Mines Health and Safety Act 29/1996
6	6	Organic Chemical Industry	The production or use in production of organic chemicals not specified elsewhere including acetylene, acetic, maleic or phthalic anhydride or their acids, carbon disulphide, pyridine, formaldehyde, acetaldehyde, acrolein and its derivatives, amines and synthetic rubber.
7	7.1	Production and or use in manufacturing of ammonia, fluorine, fluorine compounds, chlorine and hydrogen cyanide	Production and or use in manufacturing of ammonia, fluorine, fluorine compounds, chlorine and hydrogen cyanide and chlorine gas (excluding metallurgical processes related activities regulated under category 4)
	7.2	Production of acids	Production, bulk handling and or use of Sulfuric acid in concentration exceeding 10 %
8	8.1	<b>Thermal treatment of General and Hazardous Waste</b>	<b>Facilities where general and hazardous waste are treated by the application of heat</b>

## 2.2 Process Description

A description on the process units operating at SSO is provided below.

### 2.2.1 Utilities

#### 2.2.1.1 Steam Plant

Steam is used in various processes throughout the factory and for generating electricity. The Steam plant generates steam from 17 boilers using fine coal and boiler feed water. Electricity is generated by means of 10 steam driven turbine generators.

Steam Plant (Unit 43 /243) supplies process steam for the Gasification process, as well as drive steam for the turbines at Synthol and Oxygen East. Make-up steam is let down to satisfy deficits on the MP and LP factory steam headers. The balance of the steam produced is used to generate electricity.

U43 and 243 both have eight Babcock boilers, while U243 has a ninth boiler built by ICAL. Electricity is generated in turbo-generator sets rated at 60 MWe. There are 6 and 4 turbo-generators at both Unit 43 and Unit 243 respectively, resulting in combined generation capacity of 600 MWe.

The operating philosophy of steam plant is such that the steam header pressure control is done by manipulating the boilers and turbo generator load.

#### 2.2.1.2 Gas Turbines

Two gas turbines provide additional electricity generating capacity. Natural gas from Mozambique and Methane Rich Gas (MRG) from Cold Separation (Gas Circuit) are used as the feed streams.

The open cycle gas turbine (OCGT) power plant consists of 2 x GE PG9171 (E) gas turbine generators and associated plant. The nominal output from each gas turbine is approximately 104MW. The gas turbines utilise natural gas as fuel. The exhaust gas from the gas turbines is used to generate high pressure steam in Heat Recovery Steam Generator (HRSG). Each gas turbine has its own boiler with supporting boiler feed water pre-conditioning equipment as well as own blow down equipment. Each HRSG is at 163 t/h MCR 40 bar (g) steam production.

There are two gas turbine (GT) trains which are operated independently in parallel. Each GT train has a maximum operating generation capacity of 104 MW during summer months and 110 – 118 MW during winter months. The GTs has a design generation capacity of 118 MW. The Gas Turbines supply electricity into the Eskom grid.

### 2.2.2 Gas Production

#### 2.2.2.1 Coal processing

Coal is conveyed from Sasol Coal Supply (SCS) to Coal Processing (Unit 01 / 201) where it gets screened. The coarse fraction (oversize material) is conveyed to Coal Distribution (Unit 02 / 202) from where it is transferred via conveyer belts to tripper cars to fill the different bunkers of the gasifiers. The smaller fraction (undersized material) is transferred by means of gravity for dewatering purposes. The oversized material from the screens is transferred to a centrifuge where further

dewatering takes place. The undersized material from the screens are transferred in a slurry launder to the thickener system where flocculent is added to aid in the settling of the coal particles. The underflow of the thickeners is pumped to the filter section where the slurry is dewatered by means of vacuum filtration. The filter cake is removed from the filter cloth with the aid of a compressed air cycle. The filter cake and centrifuge product combine to be used as feed to the Steam Plant (Unit 43 / 243).

#### *2.2.2.2 Gasification and Raw Gas Cooling*

84 Sasol® FBDB™ gasifiers (42 gasifiers at each unit, 10 and 210), are used to gasify coarse coal using high pressure superheated steam and oxygen. The Sasol® FBDB™ gasifier is a commercially proven process for the conversion of coal feedstock into synthesis gas. In this process, the following streams are formed:

- Raw gas which is transferred to Raw Gas Cooling and then to Rectisol for further purification
- Ash as a waste stream that is processed by the Inside Ash
- Gas Liquor (a water stream) is transferred to Gas Liquor Separation to separate tars, oils and solids from the aqueous phase.

Wet gasification coal (the coarse fraction) is sent to the coal storage at the top of each gasifier. Coal is loaded to each gasifier using batch operated coal locks. Inside the gasifiers, coal reacts with steam and oxygen mixture producing crude (raw) gas containing hydrogen, carbon dioxide, carbon monoxide, methane, steam, as well as small concentrations of hydrocarbons, tars, oils, phenols, ammonia and many more.

Hot gas leaving the gasifiers is quenched to remove solids and heavy tars and then cooled in heat exchangers at Raw Gas Cooling (units 11 & 211) before it is sent to Rectisol for further purification.

During gasification process, mineral matter contained in coal is oxidised and ash is produced. The ash is intermittently removed from the bottom of the gasifier via an automatically operated ash lock hopper, quenched with water and sent to Inside Ash unit for processing and disposal.

The gas liquor containing dissolved oil, phenols, tar acids, organic acids and ammonia, is worked-up in the Gas Liquor Separation, Phenosolvan, Ammonia Recovery and biological Water Recovery effluent treatment plants, before it is used as make-up water to the process cooling towers.

#### *2.2.2.3 Rectisol*

The main function of Rectisol is to remove acid gases, such as carbon dioxide (CO<sub>2</sub>) and hydrogen sulfide (H<sub>2</sub>S), together with other impurities from the raw gas produced by Gasification. The resulting cleaned gas, called pure gas, is the feedstock to the Synthol plant.

The CO<sub>2</sub> and H<sub>2</sub>S-containing off gas streams are routed to Sulfur plant and Wet Sulfuric Acid for further processing.

## 2.2.3 Gas Circuit

### 2.2.3.1 Benfield

Tail Gas from Synthol (gas synthesis section) passes through a knock-out drum and a filter coalescer to remove any liquid droplets from the feed gas. The gas is then heated by heat exchange with hot potassium carbonate solution and enters the absorber column. CO<sub>2</sub> is absorbed from the gas stream into the potassium carbonate absorption medium. The cleaned gas then passes through a knock-out drum into the DEA system, which acts as a CO<sub>2</sub> removal polishing unit. The sweetened gas then passes through a cryogenic separation unit called Cold Separation.

The rich (loaded with CO<sub>2</sub>) potassium carbonate solution is regenerated by flashing the solution and by reboil in the regeneration column. The CO<sub>2</sub> and steam mixture is released to atmosphere and the lean potassium carbonate is re-circulated to the absorber column. A similar recycle and regeneration process is used in the DEA system. The CO<sub>2</sub> and steam stripped from the DEA solution, joins the carbonate regeneration column and is released to atmosphere. Condensate is added to both regeneration columns (carbonate and DEA) to make up for the water lost to atmosphere.

### 2.2.3.2 Catalyst Manufacturing and Catalyst Reduction

The Synthol (SAS) reactors are based on high temperature Fischer – Tropsch technology and uses catalyst. The catalyst is manufactured at the Catalyst Manufacturing units.

## 2.2.4 Refining

### 2.2.4.1 Tar Distillation Units (UNIT 14/214)

The purpose of this unit is to fractionate crude tar, originating from Gasification, into different fractions, which is then used as feed for downstream units. These fractions (from low to high boiling point) include light naphtha, heavy naphtha, medium creosote, heavy creosote, residue oil and pitch.

### 2.2.4.2 Unit 27A

The purpose of Unit 27A is to remove the neutral oils contained in the HNO-DTA (high neutral oil depitched tar acids) feed, producing LNO-DTA (low neutral oil depitched tar acids). Unit 27A is the final processing step in the Tar Acid Value Chain (TAVC) on the Secunda site. The LNO-DTA consists mainly of phenols, cresols and xylenols) that are extracted from the gas liquor stream at Phenosolvan into crude tar acids (CTA), from where the majority of pitch is removed in the Primary Depitchers where the distillate product HNO-DTA is sent to Unit 27A.

### 2.2.4.3 Unit 74

The CTA feed stream to the Primary Depitcher at Phenosolvan is split into the side draw, HNO-DTA stream going to Unit 27A and the phenolic pitch bottoms stream that is fed to Unit 74. A secondary depitcher recovers the remaining PCX's from the phenolic pitch stream.

#### 2.2.4.4 Coal tar Naphtha Hydrogenation (Unit 15/215)

The purpose of this unit is to hydro treat a combined feed of Rectisol naphtha, light naphtha and heavy naphtha from Unit 14/214 to remove phenolic and nitrogen compounds. Olefin saturation and sulfur removal also takes place to produce a product acceptable for utilisation in the petrol pool. The liquid product is fed to a H<sub>2</sub>S stripper where the sour water is removed from the product stream. The final product goes to storage to be used as blending component in petrol.

#### 2.2.4.5 Creosote Hydrogenation Unit (Unit 228)

The purpose of this unit is to hydrotreat heavy tar derived cuts to produce creosote, naphtha and diesel. The plant receives medium creosote, heavy creosote and residue oil from units 14/214. The unit also receives MTP, FFC, coker gas oil and waxy oil transfer material from unit 39 and this is fed to the unit as a percentage of the U2/14's feed streams. The one product stream containing high naphthene and aromatic content is routed to the platformer, while the other stream (creosote diesel) is a final diesel blending component.

#### 2.2.4.6 Naphtha Hydrotreater, Platformer and CCR (Unit 30/230 and Unit 31/231)

The naphtha hydrotreater is a catalytic refining process used to saturate olefins and remove oxygenates. The feed for the naphtha hydrotreater is naphtha cut originating from Synthol light oil, distillate naphtha from the distillate hydrotreater (Unit 35/235) and creosote naphtha from U228. After the hydrotreating reactors a high concentration hydrogen gas stream, hydrogen sulphide (produced) rich gas stream and sour water (produces and added) is separated from the hydrocarbon stream at various points. The hydrocarbon stream is separated into an IP and platformer feed stream.

Platforming is a catalytic refining process employing a selected catalyst to convert low quality naphtha into an aromatic rich, high octane product while also yielding a LPG stream. The LPG stream is routed to U32/232 or to a petrol component tank depending on season. The hydrocarbon stream is routed to the petrol component tanks.

During a normal operating cycle, platforming catalyst deactivates due to excessive carbon build-up. The catalyst is continuously removed from the platforming reactors and sent to the CCR unit, where the carbon is burnt off the catalyst restoring the activity of the catalyst.

#### 2.2.4.7 Catalytic Distillation Hydrotreater (Unit 78)

The U78 CD Hydro Unit is designed to individually hydro-isomerize C5 and C6+ hydrocarbons produce a diene-free C5 feedstock to the Skeletal Isomerization unit (U90) and eventually the TAME unit.

The C5 CDHydro product from the column's bottoms is routed to the Skeletal Isomerization unit, and eventually to the CDTame unit for TAME (tertiary amyl methyl ether) production. The C5 product can also be routed either to storage, directly to U79 or in combination of the mentioned scenarios.

#### 2.2.4.8 CDTame Unit (Unit 79)

The CDTame Unit 79 converts a C5 product from the C5 CDHydro column via the Skeletal Isomerization Unit 90, to produce TAME. This C5 stream from U90 is fed to U79 reactors to recover TAME product.

#### 2.2.4.9 C5 Isomerisation (Unit 90)

The C5 Skeletal Isomerisation Unit (Unit 90) produces branched chained iso-amylenes from the C5 olefinic feed from the C5 CD-Hydro Unit (Unit 78) which are required as feed to the CD-TAME Unit (Unit 79).

The C5 olefinic feed is sent to a reactor from where the heavy ends of C6 and higher are sent to the C6 storage facilities in Tank Farm and the light ends are sent to the Catalytic Polymerisation Unit (Unit 32). The bottoms product from the Debutaniser column is the C5 iso-amylenes product that is sent to Unit 79.

#### 2.2.4.10 Vacuum distillation (Unit 34/234)

The vacuum distillation unit (U34/234) separates the decanted oil (DO) stream from Synthol as well as the heavy components produced in U2/29. The products from this unit are light vacuum gas oil and heavy gas oil for unit 235 Diesel Hydrotreaters and a minimum amount of heavy fuel oil for U39 Carbo Tar.

#### 2.2.4.11 Distillate Hydrotreater (U35/235)

The purpose of this unit is hydrotreating. The plant receives heavy components from stabilised light oil (SLO) and the lighter components from the vacuum distillation units (2/34). The hydrocarbon stream is separated into a naphtha, light diesel and a heavy stream. The naphtha stream is sent to the naphtha hydrotreaters (2/30), the distillate selective cracker (35DSC) and the light diesel is sent to the diesel component tanks.

#### 2.2.4.12 Distillate Selective Cracker (U35)

The Distillate Selective Cracker (DSC) unit consists of two main sections- the cracking/dewaxing reactor reaction and the fractionation section. The main function of the reactor is to crack the heavy feed material into diesel range boiling material and to isomerize n-paraffin into iso-paraffin. The DSC fractionation section main purpose is to separate reactor effluent material into very light gasoline boiling range material, a heavy diesel cut and a fuel oil cut.

#### 2.2.4.13 Light Oil Fractionation (Unit 29/229)

The purpose of this unit is to perform the primary fractionation for the Refinery facilities. The feed to the unit is SLO from Synthol. The unit produces a light C5/C6 stream for CD Hydro unit (U78), a naphtha product that feeds Octene and the Naphtha Hydro-treatment units (U2/30), a distillate stream that feeds Safol and Diesel Hydrotreaters (U2/35), a heavy product that feeds the vacuum distillation unit (U2/34).

#### 2.2.4.14 Polymer Hydrotreater (Unit 33/233)

The purpose of this unit is to convert olefins to the corresponding paraffins. The feed to the unit comes from U2/32. The hydrocarbon stream is separated into petrol and diesel component stream.

#### 2.2.4.15 Catalytic Polymerisation and LPG Recovery (Unit 32 / 232)

The purpose of this unit is to produce motor fuels namely petrol, diesel and jet fuel from a stream of C3/C4. Saturated C3's and C4's are sold as LPG.

#### 2.2.4.16 Sasol Catalytic Converter (Unit 293)

The Sasol Catalytic Converter (SCC) Process is a Fluidized Catalytic Cracking (FCC) process, similar in configuration to a refinery FCC unit. Low molecular weight olefins and paraffins are converted to ethylene and propylene in a reactor. High octane gasoline is also produced.

### 2.2.5 Tar, Phenosolvan and Sulfur

#### 2.2.5.1 Gas Liquor Separation

The purpose of the gas liquor separation unit is to separate various gaseous, liquid and solid components from the gas liquor streams. Dissolved gases are removed from the gas liquor by expansion to almost atmospheric pressure. The different liquids and solids are separated in separators by means of physical methods based on settling time and different densities.

Separation takes place by gravity at controlled temperatures and atmospheric pressure. The feed to the gas liquor separation unit originates from the cooling and washing of the raw gas from coal gasification. The raw gas contains large amounts of water vapours (steam, carbonization water and coal moistures) and by-products from carbonization such as tar, oil, naphtha, phenols, chlorine, fluorine and fatty acids. It also contains dissolved gases (mostly ammonia (NH<sub>3</sub>), CO<sub>2</sub>, and hydrogen (H<sub>2</sub>)) and small amounts of combustible gases and coal dust as well as inorganic salts.

Feed streams originate in:

- Gasification (unit 10/210);
- Gas cooling (unit 11/211);
- Rectisol (unit 12/212);
- Phenosolvan (unit 16/216);
- Coal Tar Filtration (CTF) (on the Western site only);
- Refinery Unit 14 and 74;
- Carbo Tar.

#### 2.2.5.2 Phenosolvan

The Phenosolvan (Unit 16 / 216) and Ammonia Recovery (Unit 17 / 217) plants are mainly water purification plants with the purpose to remove impurities such as suspended solids and oil as well as to recover pitch, phenols, organic waste, CO<sub>2</sub>, H<sub>2</sub>S and NH<sub>3</sub> from the gas liquor before pumping the stripped gas liquor to Water Recovery (Unit 52 / 252) for re-use in the Synfuels factory as cooling water. Only phenols and ammonia are marketable products.

Unit 16 / 216 serves the purpose for gas liquor filtration, phenol and pitch extraction, solvent recovery and depitching of crude tar acids to produce depitched tar acids (DTA). Unit 17 / 217 serves the purpose for solvent recovery, acid gas removal, organic contaminants removal, ammonia recovery as well as purification and liquefaction of ammonia.



#### 2.2.5.3 Sulfur Recovery

The plants receive the feed-gas from Rectisol for the absorption and conversion of  $\text{H}_2\text{S}$  prior to routing the  $\text{H}_2\text{S}$  lean gas to the stack. The off-gas from Sulfur plant is combined with the off-gas from Rectisol before being routed to the stack. The  $\text{H}_2\text{S}$  in the feed-gas from Rectisol is absorbed into the sulpholin liquor by means of venturi absorbers.

From the absorbers the liquor with absorbed  $\text{H}_2\text{S}$  goes into the reaction tanks where elemental sulfur is produced. In the reaction tanks vanadium (V) is an active oxidizing agent that oxidizes  $\text{HS}^-$  to elemental Sulfur. During this process vanadium is reduced to inactive vanadium (IV), which needs to be re-activated. The slurry from the reaction tanks is sent to two oxidizers arranged in series.

The sulfur slurry in the oxidizers is separated from the liquor by means of weirs in the last oxidizer. The Sulfur slurry from the last oxidizer falls directly into three (3) slurry tanks. From the slurry tanks, the slurry is pumped to decanters for the removal of the entrained liquor. The liquor is routed back to the process via the balance tank. The Sulfur rich cake from the decanters is re-pulped using wash condensate before it is pumped to the sulfur separator.

In the separator, the liquid sulfur is separated from water and sent down to the sulfur pit. From the pit, the liquid sulfur is transported by road trucks to the granulation plant for filtering and formation of sulfur granules.

During the conversion of  $\text{HS}^-$  to elemental sulfur and the re-oxidation of vanadium, salts such as  $\text{NaSCN}$ ,  $\text{NaHCO}_3$  and  $\text{Na}_2\text{SO}_4$  are formed. A bleed stream from the discharge side of the circulation pump is routed to the sulphate plant to produce Sodium Sulphate as a by-product, thereby reducing the salt concentration of the circulation liquid.

#### 2.2.5.4 Wet Sulfuric Acid Plant

The feed gas to Wet Sulfuric Acid (WSA) is sourced from Rectisol east (phase 3 and phase 4), which are routed to a knock out drum (per phase). The outlets of the knockout drums combine before Phenosan off gas joins the feed header into the WSA combustor where the feed gas is burned with fuel gas and hot air to form sulfur dioxide ( $\text{SO}_2$ ) containing process gas.

After combustion the process gas is cooled in a waste heat boiler. The formed process gas, after being cooled down, leaves the waste heat boiler and dilution air is introduced to ensure sufficient oxygen content before entering a oxides of nitrogen ( $\text{NO}_x$ ) converter. In the  $\text{NO}_x$  converter the nitrogen oxides are removed from the process gas. The reduction of the nitrogen oxides is carried out by the injection of ammonia into the process gas and subsequently passing the gas mixture over a catalyst where the nitrogen oxides react with the ammonia and are converted to nitrogen and water vapour.

From the  $\text{NO}_x$  converter the process gas is further processed in the  $\text{SO}_2$  converter. The  $\text{SO}_2$  in the process gas is oxidized catalytically. The  $\text{SO}_2$  gas reacts with oxygen ( $\text{O}_2$ ) to form  $\text{SO}_3$  gas. The formed  $\text{SO}_3$  gas reacts with the water vapour present in the process gas through exothermic hydration reaction, resulting in the formation of the sulfuric acid gas ( $\text{H}_2\text{SO}_4$ ).

The process gas then enters the WSA condenser where it is further cooled by means of air in a glass tube heat exchanger, and the remaining part of the hydration reaction and the condensation of sulfuric acid take place. The produced sulfuric acid has a concentration of 96.5 wt%, with a maximum acid mist content of 20 ppm (by volume) when leaving the top of the WSA condenser. The hot sulfuric acid product will leave the bottom of the WSA condenser.

Normally, if no special precautions are taken, condensations of sulfuric acid vapour will result in a mist of very small acid droplets. These very small droplets cannot be separated from the process gas in the WSA condenser. Thus to overcome this problem four mist control units are installed. The cleaned gas leaves the top of the WSA condenser. Even though all four mist control units are well in operation, the clean gas will contain a small amount of remaining acid mist which is reduced by the Wet Electrostatic Precipitator (WESP). The WESP consists of an empty column scrubber part, where the cleaned gas sprayed with weak acid and the precipitator part where the mist particles form a liquid film on the vertical collecting electrodes due to the strong electric field. The liquid film then runs down the electrodes to the scrubber sump and the cleaned gas proceeds to the stack where it's lead to the atmosphere.

#### 2.2.5.5 Carbo Tar and Coal Tar Filtration

##### 2.2.5.5.1 Coker (Unit 39)

The Delayed Coker Plant receives the so called bottom of the barrel products from upstream units to produce coke. The plant mainly operates in three different modes to produce three different types of coke. These modes are the normal MTP (medium temperature pitch) mode, Waxy Oil (WO) mode and the hybrid mode, which is a 70:30% blend between MTP and FCC (fluidised catalytic cracker) slurry.

##### Reactions and Catalyst

The Coker Plant produces green coke using a delayed coking process, which involves thermal cracking of the feedstock (pitch, WO or FCC slurry) at elevated temperatures and long residence time at specific conditions. The basic reaction that takes place is:  $HC + \text{Impurities} = C + \text{Impurities} + \text{Vapour (H}_2\text{O \& Volatile material)}$ .

##### 2.2.5.5.2 Calciner (Unit 75)

The coke calcining unit, (U75) receives green Coke from the Delayed Coker plant (U39) and thermally upgrades the green coke to produce calcined Coke. U39 processes three basic types of feed: WO, MTP and Hybrid (70%-30% MTP-FCC slurry blend) green coke. From these feed stocks, U39 produce seven different grades of green coke, of which five are calcined and sent to the market.

##### 2.2.5.5.3 Coal Tar Filtration (Unit 96)

At Unit 096 tar is received from the Gas Liquor Separation units (Unit 13 and 213). Solids and water is removed from the tar. The solids get removed by means of decanters and filters while water gets removed by means of a force feed evaporator. The solids get trucked to the Mixing plant where it is mixed with fine coal and fed to the boilers. The final tar product is pumped to tank farm as feed for the Tar distillation units (Unit 14 and Unit 214).

##### 2.2.5.5.4 Feed Preparation (Unit 86)

The purpose of the Feed Preparation Plant (U86) is to clean-up heavy residue streams from tanks and dams containing solids and water; the feed streams can vary depending on availability. The plant consists of two Trains; Train 1 processes WO related product, which is obtained from the American Petroleum Institute (API) dams; and Train 2 processes the crude tar from various sources and also serves as a Coal Tar Filtration (CTF) contingency.

Train 1 can also be utilised to process tar when there are very high tank levels from Tank Farm (256TK 1401/2). Through the series of processes, water and solids are removed from the contaminated feed streams and made available to customers such as heating fuels and Tar Distillation Units (U(2)14).

#### 2.2.5.5.5 Calciner (Unit 76)

This unit is a storage facility for final products from the calciner Unit 075 and distribution via rail and road trucks of different sizes, quantities and products.

### 2.2.6 Water and Ash

#### 2.2.6.1 Multi hearth sludge incinerator

Waste activated sludge is burned in 4 twelve bed multi hearth type incinerators (2 per unit). Each incinerator has two burner chambers designed such that each chamber can be supplied with fuel gas. Combustion and cooling air is also introduced to the incinerator. Thickened waste activated sludge is fed into the incinerators. Off-gas, slurry and ash exit the incinerator.

#### 2.2.6.2 HOW Incinerator

The purpose of the HOW incinerator is to burn concentrated high organic waste (HOW) and gas fumes from Phenosolvan and Ammonia recovery (U17/217).

The interior of the incinerator consists of a horizontal combustion chamber that has been lined with fireproof bricks out of a kind of ceramic that is extremely heatproof. The burner is a combination burner for optional or simultaneous combustion of fuel gas and HOW and is mounted to the front of the combustion chamber. The product is atomized with steam in the burner. Fuel gas serves as the pilot flame to ignite the HOW. For this reason, the fuel gas flame must be kept burning permanently. Oxygen is required for combustion. In this case, a controlled quantity of air is provided to the burner called primary air (combustion air). Warm air containing combustion gases is let out to the atmosphere through the chimney.

#### 2.2.6.3 Sewage Incinerator

The purpose of the domestic sewage plant is to treat all sewage from Secunda town and ablution facilities from Sasol Secunda site, upgrading it to render it suitable to discharge to the river. The process can be divided into the following sections:

- Inlet works (primary treatment section)
- Biological Section (secondary treatment section)
- Polishing section (tertiary treatment section)

Untreated sewage enters the inlet works where screening and removal of grit takes place. The flow then moves to the biological section where the removal of soluble and particulate organic material is removed from raw sewage. The last section (polishing section) is where further removal of suspended solids takes place, as well as and the sanitation of effluent before the effluent is released to the river. The function of the sewage incinerator is to burn waste screenings from the primary treatment section. The products are ash and combustion gases.

#### 2.2.6.4 Thermal Oxidizer

In order to prevent atmospheric pollution from the storage tanks and vessels that contain volatile organic compounds (VOC's), it gets vented to a thermal oxidizer. It consists of a piping/ducting system to draw vapours from the following tanks:

- Oily Waste Tanks (TK2005/11/12)
- Phenolic Waste Tanks (TK2002/4)
- Organic Waste Tanks (TK2006)
- Flare knock out water (TK2003)
- Quarantine Waste Tank (TK2016)
- Recovered oil Tank (TK2009)
- APS storage tank (TK2512)
- Hydrocarbon Equalization Tank (TK2501)
- API Separator (TK2505)
- Recovered Oil Tank (TK2510)
- DAF Separator (DAF 2501)
- Area 10 Loading Arms (ME 1010/1011/1013)

### 2.3 Unit Processes

Unit process considered listed activities under the National Environmental Management Air Quality Act (NEMAQA) are summarised in Table 2-2. The listed activity for which the postponement is applied is indicated as bold text.

**Table 2-2: List of unit processes considered listed activities under NEMAQA**

Name of the Unit Process	Unit Process Function	Batch or Continuous Process	Listed Activity Sub-category
Steam Plant	Produces steam for process units	Continuous	1.1
Gas Turbines	Electricity generation and raising steam	Continuous	1.4
Gasification	Gasification of coal	Continuous	3.6
Gas cooling	Cooling of the gasification products, separation of the condensable products of gasification	Continuous	3.6
Tar Value Chain	Separation of the gasification tar stream	Continuous	3.3
Rectisol	Cleaning of the Gasification gas	Continuous	3.6
<b>Phenosolvan</b>	<b>Processing of the Gasification water stream</b>	<b>Continuous</b>	<b>3.6</b>
Sulfur Processing	Removal of H <sub>2</sub> S from gas exiting the factory	Continuous	3.6
Wet Sulfuric acid	Removal of H <sub>2</sub> S from gas exiting the factory, production of sulfuric acid	Continuous	7.2
Catalyst manufacturing	Catalyst preparation for SAS reactors	Continuous and semi-batch	4.2 4.7
Refinery	Production of synthetic fuels and products	Continuous	2

Name of the Unit Process	Unit Process Function	Batch or Continuous Process	Listed Activity Sub-category
Benfield	Remove carbon dioxide from tail gas entering Cold Separation process, thereby preventing freeze blockages	Continuous	6
Incineration	Incineration of waste products	Continuous	8.1

For completeness, all unit processes for the SSO are listed in Table 2-3.

**Table 2-3: Unit processes at SSO**

Unit Process	Function of Unit Process	Batch or Continuous Process
<b>Utilities</b>		
Coal milling process	There are 4 mills per boiler. The mill grinds the course coal to fine coal, which is known as pulverized fuel (PF). Primary air dries the coal and then transports the PF into the boiler furnace for combustion.	Continuous
De-aeration process	The feed water de-aerators make use of low pressure steam to heat up the feed water as well as to remove the oxygen from the feed water. Oxygen causes corrosion inside the boiler tubes if it is present. Chemical dosing into the de-aerator discharge line also helps to remove the oxygen.	Continuous
Combustion process	The PF is combusted in the 17 boilers and the hot flue gases are used to heat up the water in the water wall tubes. The hot flue gases containing ash and other gases are used to heat up the primary air while being extracted from the boiler furnace via the induced draught fans. The heated water is separated in the steam-water drum and reintroduced into the boiler to be superheated before supplied to the factory as superheated steam.	Continuous
Flashing process	Blow down from the steam/water and mud drum as well as drains are flashed in the blow down vessel to 4bar steam.	Continuous
Ash capture and handling process	The flue gas contains fly ash and coarse ash. The fly ash is separated from the flue gas using electrostatic precipitators. The ash which is not captured by the electrostatic precipitators is sent up the stack. The coarse ash falls from the furnace section into drag chains. Both the coarse and fly ash is mixed with water and pumped to the ash system.	Continuous
Electricity generation process	Excess superheated steam not used in the process is used to generate electricity in turbo-generators. There are 10 turbo generators with a capacity of 60MW.	Continuous
Burner oil for start-up process	Burner oil is used during start up and shutdown of boilers. Burner oil is also used when coal milling is stopped for maintenance.	Intermittent
Gas turbine	Power generation by burning natural gas	Continuous
Heat Recovery Steam Generator (HRSG)	Steam is generated using the hot off gas from the gas turbines. The steam generation includes a boiler, economisers, evaporators, and super heaters. Superheated steam is generated from this process at 425°C and 4300kPag with a maximum flow of 163t/h per boiler.	Continuous
<b>Gas Production</b>		
<u>Coal Processing</u>		
Separation	Separation of fine and course coal	Continuous
<u>Gasification</u>		
Gasification and Raw Gas Cooling	Sasol® FBDB™ Gasification Process	Continuous
<u>Rectisol</u>		

Unit Process	Function of Unit Process	Batch or Continuous Process
Absorption	Washes the raw gas in order to remove CO <sub>2</sub> , H <sub>2</sub> S, BTEX's and other organic and inorganic compounds	Continuous
Regeneration	Purification of methanol	Continuous
<b>Gas Circuit</b>		
<u>Benfield</u>		
Benfield	The purpose of the Benfield Process is to remove Carbon Dioxide from the tail gas entering the Cold Separation thereby preventing freeze blockages.	Continuous
<u>Catalyst preparation</u>		
Catalyst Manufacturing	Manufacturing of catalyst for the Synthol process.	Continuous (Arc furnace is semi-batch process)
Catalyst Reduction	The purpose of this system is to activate the catalyst before it is fed to the reactors.	Batch
<b>Refinery</b>		
<u>Generic Refinery Unit Processes</u>		
Tank	The feed tank serves as feed reserve tank. This is for a holdup for the polymerisation of the mixed feed components and for the separation of entering water.	Continuous
Vaporiser	The vaporizer separates the light ends from the heavy ends. Saturated high pressure (HP) steam is used to vapourise the feed.	Continuous
Distillation column	The purpose of the columns is to purify hydrocarbon streams as well as separation of the hydrocarbon streams into various components.	Continuous
CD Hydro Hydrogenation Columns	To hydrotreat and separate hydrocarbons.	Continuous
Separation and collection drums	It's used to separate streams into lighter and heavier components.	Continuous
Hydrotreating reactors	The reactors are used to saturate olefins and oxygenates. To remove nitrogen and sulfide components as well as removing other impurities in the presence of hydrogen.	Continuous
Platforming reactors	The reactors convert low quality naphtha in the presence of hydrogen, into an aromatic rich, high octane product.	Continuous
U90-Skeletal isomerisation reactor	The purpose of the skeletal isomerization unit is to convert the C5 feed from the CD-Hydro unit to isoamylenes as feed to the CD-TAME unit	Continuous
Catalytic polymerisation	The purpose of this unit is to produce motor fuels namely petrol, diesel and jet fuel from a stream of C3/C4.	Continuous
Heat exchangers	There are a large number of heat exchangers that is used to heat up, cool down, vaporise and condense the hydrocarbon streams. There is a combination of product, product exchangers (two process exchangers exchanging energy) as well as product utility exchangers.	Continuous
Air coolers	The air coolers are used to cool down and condense hydrocarbon streams	Continuous
Ejectors	The equipment is used to generate a negative gauge pressure (vacuum). There are a number of plants in the refinery that utilises vacuum conditions for the separation of hydrocarbon streams	Continuous
Compressors	The compressors are used to increase and or maintain the high operating pressures of the refinery processes. There are reciprocal, centrifugal and turbine compressors used in the refinery environment	Continuous
Pumps	The pumps used in the refinery are centrifugal, multi stage and positive displacement pumps	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Electrical heaters	The electrically heater is normally not in operation. The heater is primarily provided for catalyst regeneration and is also used to heat up the main reactor for start-up.	Start-up and as required
Heaters	The heaters are used to heat up hydrocarbon and gas streams	Continuous
Superflex Catalytic Cracker	Low molecular weight olefins and paraffins are converted to ethylene and propylene in a reactor. High octane gasoline is also produced.	Continuous
Catalyst Fines system and Waste Heat Boiler	The purpose of the unit is to recover catalyst fines from the flue gas. The waste heat boiler cools the flue gas against boiler feed water to produce high pressure steam.	Continuous
<u>Gas Clean-up equipment</u>		
Reactors	The purpose of the unit is to remove oxygen, acid gasses and moisture from the process gas.	Continuous
DEA and Caustic sections		
Gas Dryers		
Liquid Dryers	The purpose of the unit is to remove water from the C3 stream.	Continuous
Propylene Refrigerant system	The propylene refrigeration system is a closed-loop system providing three levels of refrigeration, -39°C, -22°C and 4°C.	Continuous
<u>Tar distillation units</u>		
Water Stripper (14VL101/201; 214VL101/201)	The crude tar that is fed to the stripper is heated in a number of heat exchangers. This feed is then stripped of water in VL101. The overhead vapours of the stripper are then condensed and the water free crude tar is sent to VL102.	Continuous
Distillation Column (14VL102/202; 214VL102/202)	This column is operated at atmospheric pressure and superheated stripping steam is fed to the bottom section to control the temperature. The distillation tower is heated up by the tar furnace 14HT-101. The overhead vapours being mainly water and light naphtha are condensed. In the distillation tower 14VL-102 heavy naphtha, medium creosote and heavy creosote are recovered as side streams of the tower.	Continuous
Reflux Drum (14DM102/202; 214DM102/202)	The condensed vapours of both VL101 and VL102 are fed to this drum where the water is separated from the light naphtha. The water overflows into the sewer, the hydrocarbons are partly sent as reflux to 14 VL101 and 14 VL102, and partly routed as light naphtha product to the tank.	Continuous
Flash Drum (14DM104/204; 214DM104/204)	The net bottom product of the distillation tower is withdrawn from the tar furnace (14HT-101) circulation stream and sent to the flash drum 14DM-104. In this drum, operating under vacuum, separation between pitch and residue oil is achieved by one stage flash evaporation.	Continuous
Heavy Creosote Process Vessel (14DM106/206; 214DM106/206)	This vessel stores heavy creosote which is a side draw from VL102 before it is pumped to tank farm.	Continuous
Medium Creosote Process Vessel (14DM107/207; 214DM107/207)	This vessel stores medium creosote which is a side draw from VL102 before it is pumped to tank farm.	Continuous
Heavy Naphtha Process Vessel (14DM108/208; 214DM108/208)	This vessel stores heavy naphtha which is a side draw from VL102 before it is pumped to tank farm.	Continuous
Pitch Drum (14DM109/209; 214DM109/209)	The bottoms product of 14DM104 is pitch, which passes via a barometric pipe to pitch cooler 14 ES114 and to the pitch drum 14DM109, from where it is pumped to Carbo Tar, unit 39 or Tank Farm.	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Residue oil Drum (14DM110/210; 214DM110/210)	The top product of the flash drum 14DM104 is residue oil, which is condensed in 14ES115, a steam producing heat exchanger, and then travels via 14DM111 along a barometric pipe to the residue oil drum 14DM110 from where it is pumped by 14PC108 to battery limit.	Continuous
Heaters (14HT101/201; 214HT101/201)	This furnace is used to heat a high circulating bottoms product from 14VL102 and thus control the temperature of the column.	Continuous
<u>Unit 27A</u>		
Neutral oil stripper (27VL101)	The purpose of this stripper is to remove the neutral oils contained in the HNO-DTA (high neutral oil depitched tar acids) feed, producing LNO-DTA (low neutral oil depitched tar acids).	Continuous
Flash Drum (27DM103)	This drum flashes the neutral oil from the water and the neutral oil rich stream goes to 27DM1 and the water rich stream is recycled back to the column.	Continuous
Separator Drum (27DM1)	The stream from 27DM103 that is rich in neutral oil is cooled and sent to 27DM1 for separation.	Continuous
<u>Unit 74</u>		
Vacuum Distillation (74VL101)	This is a secondary depitcher column that flashes phenolic pitch and fractionate the stream to recover as much phenolic material possible in the side draw, without entraining catechol or any heavy ends. The column operates under a vacuum. The depitched tar acids are drawn off from the top of the column and are the product and the pitch at the bottom is sent to unit 14/214 and CarboTar.	Continuous
<u>Coal tar naphtha hydrogenation</u>		
Feed Tank (15TK-101)	The feed tank serves as feed reserve tank. This is for a holdup for the polymerisation of the mixed feed components and for the separation of entering water.	Continuous
Vaporizer (15EX-101)	The vaporizer separates the light ends (Naphtha) from the heavy ends (residue oil). Saturated HP steam is used to vaporise the feed.	Continuous
Residue Stripper (15VL-101)	The purpose of the residue stripper is to strip the remaining low boiling components by means of super-heated recycle gas.	Continuous
Residue Oil Collection Drum (15DM-102)	Residue oil from the residue stripper is collected in the residue oil collect drum and is continuously pumped to tank farm.	Continuous
Pre-reactor (15RE-101)	The bottom of the pre-reactor accommodates a separator, which retains any entrained liquid droplets, before the hydrocarbon vapor mixture enters the pre-reactor. The pre-reactor is filled with catalyst.	Continuous
Main Reactor (15RE-102)	Recycle gas and a hydrocarbon vapour mixture passes through the main reactor. A quench stream of cold recycle gas is used between the two main reactor beds to prevent H <sub>2</sub> S from reacting back to mercaptans or thiophenes and to prevent severe hydrogenation.	Continuous
HP separator (15DM-106)	Separates the raffinate from the gas.	Continuous
Medium Pressure Naphtha Water Separator (15DM-107)	The medium pressure naphtha water separator is a three phase separator, firstly to separate the gas liquid mixture and secondly to separate the organic aqueous liquid mixture. The gas/raffinate and condensate are separated under gravity, due to their density difference. The water and product is separated by a gooseneck. The entrained injection and reaction water separated is discharged from the bottom of the separator's water compartment directly to unit 16/216 as waste water, or to the oily water sewer during upset conditions	Continuous



Unit Process	Function of Unit Process	Batch or Continuous Process
H <sub>2</sub> S Stripper (15VL-102)	The hydrogenated naphtha product is stripped of water, H <sub>2</sub> S, NH <sub>3</sub> and other dissolved gases.	Continuous
<u>Naphtha hydrotreater, platformer and CCR</u>		
Naphtha reactors System	Saturation of olefins	Continuous
NHT Charge Heater	Heating of NHT reactor feed	Continuous
Separation drums	Hydrogen, uncondensed hydrocarbon gases and water are separated from the condensed reactor products.	Continuous
Stripper System	Removing of light ends (H <sub>2</sub> S and water)	Continuous
Stripper Reboiler (Fired Heater)	Heating Stripper bottoms	Continuous
Splitter System	Splits between C <sub>5</sub> + and C <sub>5</sub> -	Continuous
Splitter Reboiler (Fired Heater)	Heating Splitter bottoms	Continuous
Platformer Charge Heater	Heating Platformer reactor feed	Continuous
Platforming Reactors	Produces aromatics from paraffins and naphthenes	Continuous
Continuous Catalyst regeneration system	Regenerates Platformer catalyst on continuous basis	Continuous
Product Separator	H <sub>2</sub> is separated from the condensed Platformer product	Continuous
Debutanizer	Removes C <sub>4</sub> - from final product	Continuous
Debutanizer Reboiler (Fired Heater)	Heating Debutanizer bottoms	Continuous
<u>Catalytic distillation hydrotreater</u>		
78VL-101 (Depentaniser)	Splits a liquid feed stream into C <sub>5</sub> and C <sub>6</sub> + streams. The C <sub>6</sub> + stream is sent to the Alpha Olefin plants for Hexene extraction. The C <sub>5</sub> stream is sent to 78VL-102 (CD Hydro Column)	Continuous
78VL-102 (CD Hydro Column)	Hydro-treats the C <sub>5</sub> hydrocarbons to produce a diene-free feed to U90.	Continuous
<u>CD Tame</u>		
79RE-101 (Primary reactor)	79RE-101 (Primary reactor) – The first reaction between isoamylenes and methanol takes place in this reactor.	Continuous
79RE-103 (Secondary reactor)	The second reaction between isoamylenes and methanol takes place in this reactor.	Continuous
79VL-101 (CD TAME Column)	The last phase of reaction takes place in this column. This column also serves to separate the TAME product from the unreacted reactants.	Continuous
79VL-102 (Methanol Extraction Column)	Uses a water stream to extract methanol from the C <sub>5</sub> Hydrocarbons. The C <sub>5</sub> hydrocarbons are sent to storage, and the methanol-water stream is sent to 79VL-103.	Continuous
79VL-103 (Methanol recovery column)	The water-methanol stream from 79VL-101 is split into methanol and water streams. The methanol is recycled to the front end of the process, and the water is recycled to 79VL-102 where it is used to extract the methanol.	Continuous
<u>C5 Isomerisation</u>		
U90-Skeletal isomerisation unit	The purpose of the skeletal isomerization unit is to convert the C <sub>5</sub> feed from the CD-Hydro unit to isoamylenes as feed to the CD-TAME unit	Continuous
<u>Vacuum distillation</u>		

Unit Process	Function of Unit Process	Batch or Continuous Process
Vacuum Distillation	The aim is to fractionate high boiling point hydrocarbons at low temperatures by lowering the pressure to $\pm 2.5$ kPag using Decanted Oil from U20 and the heaviest fraction from U29 is fractionated to a Heavy and Light Gas Oil and Waxy Oil.	Continuous
<u>Distillate hydrotreater</u>		
Distillation	The fractionation of the feed oil material into components of similar boiling range.	Continuous
Light diesel stripping	Separation of diesel (medium cut material) range boiling material from the feed stream using distillation.	Continuous
Naphtha stripping	Separation of naphtha (light material) range boiling material from the feed stream using distillation.	Continuous
Hydrogenation	The conversion of oxygenates and olefins into paraffins.	Continuous
Catalyst Sulfiding	This is to regulate catalyst activity	Continuous
Water removal	Removal of water from the feed oil stream in a drum operated such that water settles in the drum's water boot.	Continuous
High temperature Separation	Separate a feed stream into a liquid and vapour streams in a drum at a high temperature.	Continuous
Low Temperature separation	Separate a feed stream into a liquid and gas streams in a drum at a low temperature.	Continuous
Hydrogen recycle	To reuse the hydrogen rich off gases leaving the cold separation drum.	Continuous
Heating	This is to preheat feed streams and cool down product streams.	Continuous
<u>Distillate selective cracker</u>		
Cracking reaction system	To selectively crack high-pour point components (predominately paraffins)	Continuous
Distillation	Fractionation of the heavy oil material	Continuous
Vacuum distillation	Separate the heavy distillate material mainly heavy diesel.	Continuous
Heating and Cooling	Preheat feed material and cool down product streams	Continuous
Water removal	Separate entrained water from feed stream	Continuous
Hot Temperature separation	Separate reactor product stream into a liquid and vapour stream.	Continuous
Hydrogen recycle	Recycle the off gas rich stream separate from the reactor liquid stream	Continuous
Catalyst sulfiding	To regulate the catalyst activity	Continuous
<u>Light Oil Fractionation</u>		
Atmospheric Distillation	The purpose of the unit is to fractionate the Stabilized Light Oil into different fractions of molecules used in downstream processes. The different fractions are C5/C6 to the CD Tame unit, Naphtha to Octene (and U30NHT), Light Diesel to Safol (and U35DHT) and a Heavy fraction to U34.	Continuous
<u>Polymer Hydrotreater</u>		
Polymer Hydrotreater	The purpose of the unit is to hydrotreat the polymer produced in the catalytic polymerisation unit to a paraffinic petrol and diesel/jet fuel fractions.	Continuous
<u>Catalytic polymerisation and LPG recovery</u>		
Catalytic polymerisation	The purpose of this unit is to produce motor fuels namely petrol, diesel and jet fuel from a stream of C3/C4.	Continuous
LPG recovery	The purpose of this section is to recover unreacted paraffinic C3 and C4 material for LPG production.	Continuous
<u>Sasol Catalytic Converter</u>		
Pre-heat furnace	The purpose of this section is to vaporise the low molecule olefin and paraffin feed	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Superflex Catalytic Cracker	Low molecular weight olefins and paraffins are converted to ethylene and propylene in a reactor. High octane gasoline is also produced.	Continuous
Quench Column and Strippers Towers	The purpose of this unit is to remove heavy oil and separate the process gas from the gasoline phase.	Continuous
C4 and C5 CD Hydro Hydrogenation Columns	The purpose of this unit is to saturate olefins.	Continuous
Catalyst Fines system and Waste Heat Boiler	The purpose of the unit is to recover catalyst fines from the flue gas. The waste heat boiler cools the flue gas against boiler feed water to produced high pressure steam.	Continuous
Process Gas Compression (KC2501 – PGC)	The purpose of the unit is to compress the process gas.	Continuous
<u>Gas Clean-up equipment</u>		
Reactors	The purpose of the unit is to remove oxygen, acid gasses and moisture from the process gas.	Continuous
DEA and Caustic sections		
Gas Dryers		
SCC De-Propanizer (VL4001)	The purpose of the unit is to separate C4 molecules from the process gas.	Continuous
Chill Train, De-Methanizer and Cold Box	The purpose of the unit is to cool down the process gas and remove methane.	Continuous
C2 System which can be divided into the De-Ethanizer and C2 Splitter	The purpose of the unit is to separate C3 molecules from C2 molecules and to separate the C2 molecules into ethane and ethylene.	Continuous
PPU 5 which comprises of the FT De-Propanizer and C3 Splitter	The purpose of the unit is to separate C3 from C4 molecules and to separate the C3 molecules into propane and propylene.	Continuous
Liquid Dryers	The purpose of the unit is to remove water from the C3 stream.	Continuous
Propylene Refrigerant system	The propylene refrigeration system is a closed-loop system providing three levels of refrigeration, -39°C, -22°C and 4°C.	Continuous
<b>Tar, Phenosolvan and Sulphur (TPS)</b>		
<u>Gas Liquor Separation</u>		
Gas Liquor Separation	The purpose of the gas liquor separation unit is to separate various gaseous, liquid and solid components from the gas liquor streams. Dissolved gases are removed from the gas liquor by expansion to almost atmospheric pressure. The different liquids and solids are separated in separators by means of physical methods based on settling time and different densities.	Continuous
<u>Phenosolvan</u>		
Water Purification	The purpose of this system is to filter out any oil, tar and suspended solids.	Continuous
The extraction process	The purpose of the extraction system is to remove phenols from gas liquor by mixing gas liquor with di-isopropyl-ether (DIPE) to extract the phenols.	Continuous
DIPE recovery and Phenol production	The DIPE and phenols are then separated through several distillation processes.	Continuous
Ammonia Recovery (Unit17)	Recovering of ammonia from the gas liquor. The raffinate from Unit 16 / 216, with about 1% DIPE, is first sent to the de-acidifier to remove acid gases.	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Acid Gas Scrubber	The purpose of this system is to remove final traces of CO <sub>2</sub> from the ammonia.	Continuous
Fractionation system	The ammonia leaving the Acid Gas Scrubber overhead is firstly compressed prior to the fraction process to improve ammonia recovery. The distillate product of the fractionator (2)17VL-105 is NH <sub>3</sub> and the bottoms product is organics. The ammonia is cooled down to form a liquid and expanded and the final ammonia product is sent to Tank Farm.	Continuous
<u>Sulfur recovery</u>		
Sulfur recovery	The purpose of the Sulfur Recovery unit is to reduce the amount of sulfur released into the atmosphere as hydrogen sulfide (H <sub>2</sub> S) gas by producing elemental sulfur as a saleable product.	Continuous
<u>Wet Acid</u>		
Wet Sulfuric Acid	The purpose of the Wet Sulfuric Acid (WSA) unit is to reduce the amount of sulfur released into the atmosphere as hydrogen sulfide (H <sub>2</sub> S) gas by producing sulfuric acid as a saleable product.	Continuous
<u>Carbo Tar</u>		
Coker	The Delayed Coker Plant receives bottom of the barrel products from upstream units to produce coke.	Continuous
Calcliner	The coke calcining process is used to thermally upgrade green coke in order to remove associated moisture and combustible volatile matter (VCM) and to otherwise improve critical physical properties like the electrical conductivity, real density, etc.	Continuous
Coal Tar filtration	CTF utilises three solids removal processes and one water removal process.  Solids are removed by means of gravity separation in the feed receiving dump bins, followed by solids removal by means of centrifugal separation in the decanter and lastly the final solids are removed by the pressure leaf filters. The water is removed by means of a forced feed evaporator system	Dump bins, decanters, force feed evaporator – continuous  Filters - batch
Unit 86	The main unit processes for U86 Train 1 is heat exchange, centrifugation and distillation while the main processed for U86 Train 2 is heat exchange, distillation and then filtration. Tankage of product happens before and after processing.	All processes are continuous except for the batch filtration processes
Unit 76	The unit consists mainly of conveyors systems combined with storage silos. Loading and weighting facilities are also on site.	Continuous
<u>Water and Ash</u>		
Multi hearth sludge incinerators	The purpose of this system is to incinerate waste activated sludge from the biological treatment systems which treat industrial and domestic effluent respectively. The systems has 4 centrifuges per side to dry the sludge, which is then incinerated in 1 of 2 multiple stage hearth incinerators per side, with a temperature of around 780°C in the burning zone. The off-gas is sent to an emission treatment system before it passes into the atmosphere, while the coarse ash is sent to Outside ash for disposal.	Continuous
HOW incinerators	The purpose of this system is to incinerate high organic waste (HOW). The HOW, which is pumped from U17/217 to the HOW storage tank, is ignited by means of a fuel gas pilot flame inside a single chamber, refractory brick-lined incinerator. The combustion temperature is controlled at 950°C, and there are two burners. Steam is used to atomize the HOW. The only combustion product is off-gas.	Continuous

Unit Process	Function of Unit Process	Batch or Continuous Process
Sewage incinerator	The purpose of this incinerator is to burn screenings from primary treatment. It is a single chamber, furnace-type incinerator. The incinerator is manually filled with screenings. Diesel is used as a fuel, and the incinerator has two burners and one fan per burner. The combustion is automated. The products are off-gas and ash.	Batch
Waste Recycling Facility Thermal Oxidizer	Some of the enclosed storage and treatment tanks at WRF do not vent to the atmosphere but rather to the thermal oxidiser. It is introduced to the burners (which are kept burning with fuel gas) with air for combustion.	Continuous
<b>Market and Process Integration (MPI)</b>		
<u>Flares</u>		
Central corridor flares	A system consisting of 2 flare stacks, 2 relief headers and other associated equipment to collect and completely incinerate off-gases, off-specification gases and emergency venting.	As required

### 3 TECHNICAL INFORMATION

Raw material consumption for the listed activities applying for Minimum Emission Standards (MES) postponement is tabulated in Table 3-1. For completeness, the raw materials used by all process are included in Appendix C1 (Table C-1), unless the information is intellectual property (IP) or otherwise sensitive due to competition law. Pollution abatement technologies employed at SSO for the listed activities applying for MES postponement are provided in Table 3-2 (all appliance and abatement equipment in use at SSO provided in Appendix C; Table C-2).

#### 3.1 Raw Materials Used and Production Rates

**Table 3-1: Raw materials used in listed activities seeking postponements**

Raw Material Type	Design Consumption Rate	Rate Unit
<b>Phenosolvan</b>		
Gas Liquor	(a)	m <sup>3</sup> /h per factory
<b>Water and Ash</b>		
Multi hearth sludge incinerator		
Thickened waste activated sludge	508	m <sup>3</sup> /day
HOW incinerator		
High organic waste	48	m <sup>3</sup> /day

(a) Raw material rate for Phenosolvan not included as information sensitive

#### 3.2 Appliances and Abatement Equipment Control Technology

Abatement equipment fitted to process units at SSO is listed in Table 3-2. The postponement application for which this AIR provides support applies to abatement equipment required on the incinerators.

**Table 3-2: Appliances and abatement equipment control technology**

Appliance Name	Abatement Appliance Type	Appliance function / purpose
<b>Multi hearth biosludge incinerators</b>		
Scrubber	Venturi Scrubber	Removal of particulate and gaseous emissions

## 4 ATMOSPHERIC EMISSIONS

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from SSO on the receiving environment.

Point source parameters and emissions for stacks and tanks are provided in Section 4.1 and Section 4.2 respectively. A locality map indicating the position of SSO in relation to surrounding residential areas is provided in Figure 4-1.



**Figure 4-1: Locality map of SSO in relation to surrounding residential areas**



## 4.1 Point Source Stack Emissions

### 4.1.1 Point Source Stack Parameters

The point source parameters all point sources at SSO are included in Table 4-1.

**Table 4-1: Point source parameters**

Point source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Exit Velocity (m/s)	Type of Emission (Continuous /Batch)
<i>Baseline point sources</i>								
S1	B1 (U43): Main Stack West	-26.5575	29.14993	250.0	13.60	185	23.00	Continuous
S2	B2 (U243): Main Stack East	-26.5601	29.16841	301.0	14.40	185	23.00	Continuous
S3	GT1	-26.5642	29.165	40.0	5.30	210	40.00	Continuous
S4	GT2	-26.5642	29.16444	40.0	5.30	210	40.00	Continuous
S5	CM1 (West Kiln Stack)	-26.555	29.15655	25.0	0.91	170	28.70	Semi-batch
S6	CM2 (West Arc Furnace Stack)	-26.5551	29.15655	25.0	1.50	35	34.30	Semi-batch
S7	CM3 (East Kiln A Stack)	-26.5574	29.17548	25.0	0.90	205	12.00	Semi-batch
S8	CM4 (East Arc Furnace Stack)	-26.5577	29.17531	25.0	1.50	73	5.35	Continuous
S9	CM5 (East Kiln B Stack)	-26.5569	29.17537	25.0	0.90	192	11.90	Continuous
S10	SCC 1 Stack	-26.556	29.1639	80.0	3.60	232	12.50	Continuous
S11	WSA 1 Stack	-26.5593	29.16764	75.0	2.75	41	9.73	Continuous
S16	SW1 (353IN101)	-26.5388	29.14611	10.0	0.60	231	4.40	Continuous
S19	WRF_TO (Unit 555)	-26.5509	29.1434	20.0	1.25	815	0.44	Continuous
S20	Polymer Furnace A	-26.5428	29.154	34.0	1.25	300	0.70	Continuous
S21	Polymer Furnace B	-26.5428	29.154	34.0	1.25	300	0.70	Continuous
S22	Polymer Furnace C	-26.5428	29.154	34.0	1.25	300	0.70	Continuous
S23	Polymer Furnace D	-26.5428	29.154	34.0	1.25	300	0.70	Continuous
S24	Polymer Furnace E	-26.5428	29.154	34.0	1.25	300	0.70	Continuous



Point source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Exit Velocity (m/s)	Type of Emission (Continuous /Batch)
S25	Solvents HT 1901/1902	-26.5544	29.18062	58.0	1.00	350	9.60	Continuous
S26	Solvents Regenerator Stack	-26.5534	29.17881	66.0	1.20	88	16.93	Continuous
S27	Nitro: Nitric Acid Stack	-26.5918	29.18227	61.0	1.52	100	18.36	Continuous
S28	Nitro: Ammonium Nitrate Stack	-26.5899	29.18286	45.3	0.80	77	11.28	Continuous
S29	Nitro: LAN Stack	-26.9775	29.4086	64.0	2.24	40	12.38	Continuous
S30	Nitro: Ammonium Sulphate Stack	-26.7142	29.4147	21.0	1.02	22	17.25	Continuous
S31	R1 (14HT101)	-26.5492	29.18306	51.9	0.89	440	3.27	Continuous
S32	R2 (14HT201)	-26.5492	29.15083	51.9	0.89	440	3.27	Continuous
S33	R3 (214HT101)	-26.5492	29.13417	51.9	0.89	440	3.27	Continuous
S34	R4 (214HT201)	-26.5492	29.1175	51.9	0.89	440	3.27	Continuous
S35	R6 (30HT101)	-26.9197	29.28278	51.9	1.22	298	1.48	Continuous
S36	R7 (30HT102)	-26.5503	29.14972	38.4	0.99	304	4.16	Continuous
S37	R8 (30HT103)	-26.5503	29.14972	51.7	2.36	177	2.39	Continuous
S38	R9 (30HT104)	-26.5503	29.14972	43.0	1.28	360	1.79	Continuous
S39	R10 (30HT105)	-26.5503	29.14972	38.4	0.99	313	2.47	Continuous
S40	R17 (34HT101)	-26.5503	29.14972	32.0	1.27	321	2.35	Continuous
S41	R19 (35HT101)	-26.9242	29.28278	41.3	0.99	299	2.84	Continuous
S42	R20 (35HT102)	-26.9236	29.28278	44.2	1.35	345	2.16	Continuous
S43	R24 (35HT103)	-26.9222	29.28306	31.4	0.87	388	1.63	Continuous
S44	R25 (35HT104)	-26.9231	29.28306	35.0	0.99	221	1.13	Continuous
S45	R26 (35HT105)	-26.9236	29.28306	31.0	0.68	340	2.82	Continuous
S46	R27 (29HT101)	-26.5506	29.15028	48.0	1.81	280	2.31	Continuous
S47	R28 (29HT102)	-26.9247	29.28306	42.6	1.20	267	3.37	Continuous
S48	R30 (33HT101)	-26.3825	29.14306	34.9	1.53	300	2.31	Continuous
S49	R31 (33HT102)	-26.3825	29.14306	38.7	1.40	274	2.90	Continuous
S50	R32 (33HT105)	-26.9211	29.28278	46.0	1.37	320	5.06	Continuous

Point source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Exit Velocity (m/s)	Type of Emission (Continuous /Batch)
S51	R36 (32HT101)	-26.9211	29.28278	37.2	1.24	267	3.80	Continuous
S52	R37 (32HT201)	-26.3825	29.14306	37.2	1.24	226	3.51	Continuous
S53	R38 (32HT102)	-26.3825	29.14306	51.5	2.13	309	6.75	Continuous
S54	R5 (228HT101)	-26.3825	29.14306	41.3	0.91	318	3.90	Continuous
S55	R11 (230HT101)	-26.5508	29.15056	51.9	1.22	298	2.30	Continuous
S56	R12 (230HT102)	-26.5514	29.15111	38.4	0.99	304	3.09	Continuous
S57	R13 (230HT103)	-26.9247	29.28306	51.7	2.36	177	2.59	Continuous
S58	R14 (230HT104)	-26.5511	29.14972	43.0	1.28	360	0.71	Continuous
S59	R15 (230HT105)	-26.5508	29.14972	38.4	0.99	313	2.57	Continuous
S60	R18 (234HT101)	-26.5508	29.14972	32.0	1.27	321	2.35	Continuous
S61	R22 (235HT101)	-26.9256	29.2825	41.3	1.31	299	1.41	Continuous
S62	R23 (235HT102)	-26.9256	29.2825	44.2	1.35	310	2.45	Continuous
S63	R29 (229HT101)	-26.9256	29.2825	47.7	1.73	367	4.28	Continuous
S64	R33 (233HT101)	-26.9256	29.15028	34.9	1.53	300	2.31	Continuous
S65	R34 (233HT102)	-26.5517	29.15028	38.7	1.40	274	2.90	Continuous
S66	R35 (233HT105)	-26.5517	29.15028	46.0	1.37	320	5.06	Continuous
S67	R39 (232HT101)	-26.9281	29.28167	37.2	1.24	267	4.03	Continuous
S68	R40 (232HT201)	-26.9281	29.28167	37.2	1.24	226	4.31	Continuous
S69	R41 (232HT102)	-26.9281	29.28167	51.5	2.13	309	6.60	Continuous
S79 (S1)	Rectisol West	-26.5575	29.14993	250.0	13.60	185	23.00	Continuous
S80 (S2)	Rectisol East	-26.5601	29.16841	301.0	14.40	185	23.00	Continuous
<i>Point sources applying for postponement</i>								
S12	WA1 (052WK-2102)	-26.5462	29.1422	30	1.40	80	10.08	Continuous
S13	WA2 (052WK-2202)	-26.546	29.14155	30	1.40	80	10.08	Continuous
S14	WA3 (252WK-2102)	-26.541	29.14283	30	1.40	80	9.89	Continuous
S15	WA4 (252WK-2202)	-26.5411	29.14226	30	1.40	80	9.89	Continuous
S17	HOW1 (052CI-101)	-26.5481	29.14257	15	1.95	400	8.15	Continuous

Point source number	Source name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Exit Velocity (m/s)	Type of Emission (Continuous /Batch)
S18	HOW1 (252CI-101)	-26.5432	29.14331	15	1.95	400	6.55	Continuous
S75	016VL101 (Phenosolvan Saturation Column)	-26.55550	29.15040	33.5	0.15	33	1.70	Continuous
S76	016VL401 (Phenosolvan Saturation Column)	-26.55610	29.15040	33.5	0.15	33	1.70	Continuous
S77	216VL101 (Phenosolvan Saturation Column)	-26.55760	29.16940	33.5	0.15	33	1.70	Continuous
S78	216VL401 (Phenosolvan Saturation Column)	-26.55830	29.16930	33.5	0.15	33	1.70	Continuous

#### 4.1.2 Point Source Stack Emission Rates During Normal Operating Conditions

In cases where periodic compliance measurements are conducted, these are measured in accordance with the methods prescribed in Annexure A of the MES, and aligned with what is prescribed in the Atmospheric Emission Licence (AEL). These reflect the average of three test runs conducted during normal operating conditions.

Table 4-2: Point source emission rates (units: g/s) (Point source numbers match numbers and names in Table 4-1)

Point source number	SO <sub>2</sub>	NO <sub>x</sub> as NO <sub>2</sub>	PM	CO	H <sub>2</sub> S	HCl	HF	TOC	NH <sub>3</sub>	Dioxins & Furans	Sum of Metals	Hg	Cd & Tl	VOCs	Benzene
<i>Baseline point sources</i>															
S1	2795.08	2059.86	199.38		725.5										
S2	3006.77	2234.83	222.84		974.8										
S3	0.92	16.27	2.42												
S4	0.83	16.87	2.31												
S5	0.43	1.05	0.47												
S6	0.34	1.26	1.47												
S7	0.21	1.07	0.26												
S8	0.16	7.31	0.91												
S9	1.37	1.53	1.58												
S10	0.11	0.44	9.44												
S11	12.00	1.06	0.00												
S16	0.00	0.29	0.01	0.21		7.85E-04	4.62E-04	1.13E-02	4.62E-04	8.46E-12	4.64E-05	3.02E-06	9.59E-07		
S19	0.02	0.05	0.01	0.02		7.40E-05	2.22E-05	1.25E-03	7.40E-05	5.02E-12	2.58E-05	5.33E-07	5.60E-07		
S20	0.02	0.49	0.08												
S21	0.02	0.54	0.07												
S22	0.02	0.31	0.22												
S23	0.01	0.39	0.07												
S24	0.03	0.37	0.30												
S25	0.57	0.16	0.14												
S26	0.19	1.25	0.16												
S27	0.15	9.54	0.00												
S28	0.00	0.21	0.00												
S29	0.18	0.11	1.18												
S30	0.02	0.02	0.10												
S31	0.02	0.00	0.00												
S32	0.02	0.00	0.00												

Point source number	SO <sub>2</sub>	NO <sub>x</sub> as NO <sub>2</sub>	PM	CO	H <sub>2</sub> S	HCl	HF	TOC	NH <sub>3</sub>	Dioxins & Furans	Sum of Metals	Hg	Cd & Tl	VOCs	Benzene
S33	0.01	0.00	0.00												
S34	0.01	0.00	0.00												
S35	0.20	0.03	0.02												
S36	0.35	0.06	0.03												
S37	1.85	0.30	0.15												
S38	0.28	0.05	0.02												
S39	0.24	0.04	0.02												
S40	0.67	0.11	0.06												
S41	0.16	0.03	0.01												
S42	0.41	0.07	0.03												
S43	0.09	0.02	0.01												
S44	0.10	0.02	0.01												
S45	0.09	0.01	0.01												
S46	1.76	0.29	0.15												
S47	0.46	0.08	0.04												
S48	0.38	0.06	0.03												
S49	0.36	0.06	0.03												
S50	0.77	0.13	0.06												
S51	0.54	0.09	0.05												
S52	0.51	0.08	0.04												
S53	1.42	0.23	0.12												
S54	0.53	0.09	0.04												
S55	0.30	0.05	0.03												
S56	0.46	0.08	0.04												
S57	2.45	0.40	0.21												
S58	0.16	0.03	0.01												
S59	0.29	0.05	0.02												
S60	0.67	0.11	0.06												

Point source number	SO <sub>2</sub>	NO <sub>x</sub> as NO <sub>2</sub>	PM	CO	H <sub>2</sub> S	HCl	HF	TOC	NH <sub>3</sub>	Dioxins & Furans	Sum of Metals	Hg	Cd & Tl	VOCs	Benzene
S61	0.29	0.05	0.02												
S62	0.70	0.11	0.06												
S63	1.97	0.32	0.16												
S64	0.40	0.07	0.03												
S65	0.33	0.06	0.03												
S66	0.71	0.12	0.06												
S67	0.47	0.08	0.04												
S68	0.48	0.08	0.04												
S69	1.22	0.20	0.10												
S79 (S1)														20.80	18.24
S80 (S2)														11.20	9.84
<i>Point sources applying for postponement</i>															
S12	0.23	0.97	0.51	12.50		2.08E-02	1.59E-02	1.81E+00	7.12E-02	3.11E-10	7.62E-03	1.70E-03	4.41E-05		
S13	0.16	2.30	0.93	12.40		3.96E-02	9.13E-03	8.14E+00	4.07E-02	7.70E-10	2.88E-03	2.71E-03	3.58E-05		
S14	0.42	2.64	1.24	15.60		5.91E-01	3.39E-02	9.61E+00	8.07E-02	1.12E-10	4.14E-03	9.49E-04	5.32E-05		
S15	0.08	1.60	1.04	8.29		6.23E-02	2.78E-02	2.24E+00	7.09E-02	6.49E-11	3.64E-03	1.21E-03	3.56E-05		
S17	1.58	11.61	2.22	0.19		1.27E-01	2.90E-02	1.27E-01	1.94E-02	3.18E-09	5.10E-02	2.78E-04	1.03E-04		
S18	0.53	10.94	3.06	1.32		8.49E-02	2.64E-02	1.20E-01	1.55E-02	9.31E-09	1.27E-02	7.76E-05	4.82E-05		
S75														0.42	0.21
S76														0.42	0.21
S77														0.42	0.21
S78														0.42	0.21

#### 4.2 Point Source VOC Emissions from Fixed-Roof Tanks

Parameters and emission rates for the point source VOC emissions from the fixed-roof tanks of concern at the SSO are given in Table 4-3, Table 4-4, and Table 4-5.

**Table 4-3: Tank point source parameters**

Unique Source ID	Source Name	Source Description	Latitude (decimal degrees)*	Longitude (decimal degrees)*	Tank wall height (m)	Tank roof height (m)	Tank diameter (m)	Vent diameter (m)	Vent height (m)
1	56TK1401	Crude tar storage tank	-26.5473	29.1520	10.74	1.146	27.5	0.152	11.9
2	56TK1402	Crude tar storage tank	-26.5476	29.1519	10.74	1.146	27.5	0.152	11.9
3	256TK1401	Crude tar storage tank	-26.5475	29.1533	10.74	1.146	27.5	0.152	11.9
4	256TK1402	Crude tar storage tank	-26.5478	29.1535	10.74	1.146	27.5	0.152	11.9
5	39TK103	Pitch – MTP storage tank	-26.54899	29.14762	12.20	0.763	18.3	0.254	13.6
6	39TK104	Pitch – MTP storage tank	-26.54887	29.14746	12.20	0.763	18.3		
7	39TK105	Pitch – MTP storage tank	-26.54875	29.14714	12.20	1.359	21.75		

**Table 4-4: Tank parameters provided by SSO for the quantification of tank VOC emissions**

Tank name	Annual throughput (m³)	Compound stored	Tank type	Roof type	Tank roof height (m)	Tank height (m)	Tank diameter (m)	Tank volume (m³)	Working volume (m³)	Heated tank	Vapour pressure (kPa)	Tank colour	Vent diameter (m)
56TK1401	200 000	Crude tar	Vertical fixed-roof	Cone	1.146	10.74	27.5	5 916	5 292	Yes	60	Grey	0.1524
56TK1402	200 000	Crude tar	Vertical fixed-roof	Cone	1.146	10.74	27.5	5 916	5 292	Yes	60	Grey	0.1524
256TK1401	66 570	Crude tar	Vertical fixed-roof	Cone	1.146	10.74	27.5	5 916	5 292	Yes	60	Grey	0.1524
256TK1402	66 570	Crude tar	Vertical fixed-roof	Cone	1.146	10.74	27.5	5 916	5 292	Yes	60	Grey	0.1524
39TK103	97 000	Pitch – MTP	Vertical fixed-roof	Cone	0.763	12.20	18.3	3 209	3 021	No	>23	Aluminium	0.254
39TK104	97 000	Pitch – MTP	Vertical fixed-roof	Cone	0.763	12.20	18.3	3 209	3 021	No	>23	Aluminium	
39TK105	97 000	Pitch – MTP	Vertical fixed-roof	Cone	1.359	12.20	21.75	4 533	4 226	No	>23	Aluminium	

**Table 4-5: Tank point source emissions during normal operating conditions for tanks calculated using the US EPA TANKS model**

Tank source	Pollutant Name	Maximum Release Rate (grams per second)	Average Annual Release Rate (tonnes per annum)	Emission Hours	Type of Emission (Continuous / Intermittent)	Wind Dependent (Yes / No)
1	Total VOC	0.49	15.61	24 hours	Continuous	Yes
1	Benzene	5.05X10 <sup>-3</sup>	0.16	24 hours	Continuous	Yes
2	Total VOC	1.33	41.85	24 hours	Continuous	Yes

Tank source	Pollutant Name	Maximum Release Rate (grams per second)	Average Annual Release Rate (tonnes per annum)	Emission Hours	Type of Emission (Continuous / Intermittent)	Wind Dependent (Yes / No)
2	Benzene	1.35X10 <sup>-2</sup>	0.43	24 hours	Continuous	Yes
3	Total VOC	0.46	14.5	24 hours	Continuous	Yes
3	Benzene	4.69X10 <sup>-3</sup>	0.15	24 hours	Continuous	Yes
4	Total VOC	0.46	14.5	24 hours	Continuous	Yes
4	Benzene	4.69X10 <sup>-3</sup>	0.15	24 hours	Continuous	Yes
5	Total VOC	4.83	152.44	24 hours	Continuous	Yes
5	Benzene	2.45	77.12	24 hours	Continuous	Yes
6	Total VOC	4.83	152.44	24 hours	Continuous	Yes
6	Benzene	2.45	77.12	24 hours	Continuous	Yes
7	Total VOC	5.26	165.93	24 hours	Continuous	Yes
7	Benzene	2.66	83.95	24 hours	Continuous	Yes

**Table 4-6: Tank point source emission estimation information**

Area Source	Basis for Emission Rates
All tanks	US EPA AP-42 TANKS Software, based on AP-42 Section 7.1, Organic Liquid Storage Tanks



### 4.3 Fugitive Emissions

Fugitive emissions from SSO are managed and quantified through two fugitive emissions monitoring programs.

#### 4.3.1 Fugitive VOC emissions

The first monitoring program is associated with fugitive VOC emissions. These emissions originate from various sumps, drains and from process equipment, such as product storage tanks, valves and pumps. The on-site monitoring of fugitive process emissions is associated with Leak Detection and Repair. A third party contractor is contracted to conduct leak detection, with the help of a “sniffer” device and infrared camera, to identify and quantify the leaks associated with various process emissions. The report results are then included in a maintenance plan and the leaking process units are repaired per schedule. This process has been implemented for a period exceeding five years.

As a last resort, all VOC emissions, where arising from point sources, are detected by the monitoring stations surrounding SSO. These measurements reflect the total, combined effect of VOC emissions from across the entire Sasol Secunda complex, and Sasol conservatively assumes all ambient VOCs are attributable to the Secunda complex.

#### 4.3.2 Dustfall monitoring

Fallout dust is governed by the fallout dust regulations; Government Gazette No. 36974, No. R. 827; 1 November 2013). SSO has a number of fallout dust monitoring stations measuring the dust fallout on site. The dust fallout buckets are placed in locations where fallout of dust from coal stockpiles, fine ash dams and construction activities will occur, to ensure adequate control of most probable dust sources is in place. The Safety, Health and Environmental function at SSO is responsible for the measurement and management of dust in accordance with the fallout dust regulations and an accredited third party is responsible for replacing and analysing the buckets on a monthly basis. The position of the buckets was determined by dispersion modelling conducted by an independent consultant.

The 2014 and 2015 dustfall sampling campaign reports are attached at the end of the report (Annexure C). These reports show that the 99% of measured dustfall rates, in both 2014 and 2015, are below the residential standard, despite being an industrial site. Sasol inherently does not operate a process with large amounts of dust or large stock piles of possible fugitive dust emissions, with the exception of some coal stock piles, coarse ash heaps and fine ash dams. The operational fine ash dam is wet and therefore wind-blown fugitive particulate emissions are limited. The non-operational fine ash dam has natural vegetation on the sides, but the fine ash from this non-operational fine ash dam is harvested for rehabilitation purposes of other sites within the ash storage area.

The monitoring plan philosophy is that Sasol conduct monitoring and investigate spikes in the monitoring results. In the event that a spike is observed, the problem will be addressed to ensure fugitive fallout dust is maintained within the standard.

### 4.4 Emergency Incidents

Unplanned downtime events such as upset conditions are undesirable from a production perspective as well as an environmental perspective and Sasol endeavours to minimise unplanned downtime by conducting regular and pro-active maintenance and ensuring control of the process within their designed operating parameters. While unplanned downtime cannot be completely eliminated, it is minimised as far as practicably possible, and rectified with high priority.

The MES prescribes that start-up, shut-down, upset and maintenance events should not exceed 48 hours – and if they do, a Section 30 NEMA incident is incurred (as also indicated in the AEL). SSO can confirm that, in the preceding two years, its facility has not exceeded the 48 hour window during start up, maintenance, upset and shutdown conditions, which has ensured that ambient impacts are limited in duration.

Sasol owns and operates accredited ambient air quality monitoring stations in the vicinity of SSO. The real-time ambient air quality monitoring data is closely followed during upset conditions at the plant, to ensure that air quality does not exceed the national ambient air quality standards as a consequence of SSO's activities. These activities are also communicated to the Licensing Authority.

## 5 IMPACT OF ENTERPRISE ON THE RECEIVING ENVIRONMENT

### 5.1 Analysis of Emissions' Impact on Human Health

The report includes the results for three emission scenarios per pollutant, in order to establish the delta impacts against air quality limit values. The scenarios are as follows:

- *Baseline Emissions* – modelling conducted based on the current routine inventory and impacts
- *Minimum Emissions Standards* – modelling conducted based on plants theoretically complying with:
  - Existing Plant Standards, and;
  - New Plant Standards
- *Alternative Emission Limits* – the emission reductions as proposed by SSO, where applicable and different from the scenarios above.

#### 5.1.1 Study Methodology

##### 5.1.1.1 Study Plan

The study methodology may conveniently be divided into a “preparatory phase” and an “execution phase”. The basic methodology followed in this assessment is provided in Figure 5-1.

The preparatory phase included the following basic steps prior to performing the actual dispersion modelling and analyses:

1. Understand Scope of Work
2. Assign Appropriate Specialists
3. Review of legal requirements (e.g. dispersion modelling guideline)
4. Prepare a Plan of Study for Peer Review
5. Decide on Dispersion Model

The Regulations Regarding Air Dispersion Modelling (Gazette No 37804 published 11 July 2014) was referenced for the dispersion model selection (Appendix B).

Three Levels of Assessment are defined in the Regulations Regarding Air Dispersion Modelling:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
  - where a detailed understanding of air quality impacts, in time and space, is required;
  - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
  - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an airshed; or,
  - when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level O<sub>3</sub>, particulate formation, visibility)

The models recommended for Level 3 assessments are CALPUFF or SCIPUFF. In this study, CALPUFF was selected for the following reasons (as referenced in Figure 5-1 - Model Aspects to Consider and Dispersion Models):

- This Lagrangian Gaussian Puff model is also well suited to simulate low or calm wind speed conditions. Alternative regulatory models such as the US EPA AERMOD model treats all plumes as straight-line trajectories, which under calm wind conditions over-estimates the plume travel distance (Busini *et al.*, 2012; Gulia *et al.* 2015; Lakes Environmental, 2017).
- CALPUFF is able to perform chemical transformations. In this study the conversion of NO to NO<sub>2</sub> and the secondary formation of particulate matter was a concern.

The execution phase (i.e. dispersion modelling and analyses) firstly involves gathering specific information in relation to the emission source(s) and site(s) to be assessed. This includes:

- Source information: Emission rate, exit temperature, volume flow, exit velocity, etc.;
- Site information: Site building layout, terrain information, land use data;
- Meteorological data: Wind speed, wind direction, temperature, cloud cover, mixing height;
- Receptor information: Locations using discrete receptors and/or gridded receptors.

The model uses this specific input data to run various algorithms to estimate the dispersion of pollutants between the source and receptor. The model output is in the form of a predicted time-averaged concentration at the receptor. These predicted concentrations are compared with the relevant ambient air quality standard or guideline. Post-processing can be carried out to produce percentile concentrations or contour plots that can be prepared for reporting purposes.

The following steps were followed for the execution phase of the assessment:

- Decide on meteorological data input (Figure 5-1 - CALMET). A summary of the model control options for CALMET is provided in Appendix D. Refer to Section 5.1.4.6.
- Prepare all meteorological model input files (Figure 5-1 - CALMET)
  - Surface meteorological files
  - WRF meteorological files
  - Topography
  - Land Use
- Select control options in meteorological model (Figure 5-1 - CALMET)
  - Dispersion coefficients
  - Vertical levels
  - Receptor grid
- *Feedback to Project Team and revise where necessary*
- Review emissions inventory and ambient measurements
- *Feedback to Project Team and revise where necessary*
- Decide on dispersion model controls and module options (Figure 5-1 - CALPUFF). A summary of the model control options for CALPUFF is provided in Appendix E. Refer to Section 5.1.4.2
- Decide on dispersion module options (Figure 5-1 - CALPUFF).
  - Sulfate and nitrate formation module (MESOPUFF or RiVAD)
  - Nitrogen dioxide (NO<sub>2</sub>) formation (MESOPUFF or RiVAD)
  - Model resolution
- *Feedback to Project Team and revise where necessary*

- Decide on modelling domain and receptor locations (Figure 5-1 – CALPUFF and Simulations)
- *Feedback to Project Team and revise where necessary*
- Prepare all dispersion model input files (Figure 5-1 - CALPUFF)
  - Control options
  - Measured ambient ozone (O<sub>3</sub>) and NH<sub>3</sub> for chemical transformation module
  - Meteorology
  - Source data
  - Receptor grid and discrete receptors
- Review all modelling input data files and fix where necessary
- Simulate source groups per pollutant and calculate air concentration levels for regular and discrete grid locations for the following scenarios (Figure 5-1 – Simulations):
  - Baseline (current) air emissions
  - Change Baseline sources to reflect theoretical compliance with “Existing Plant” standards
  - Change Baseline sources to reflect theoretical compliance with “New Plant” standards
  - Change Baseline sources to reflect “Alternative Emissions Limits”, where applicable
- Compare against National Ambient Air Quality Standards (NAAQS)
- Preparation of draft AIR
- *Present AIR to Project Team*
- Preparation of final AIR.

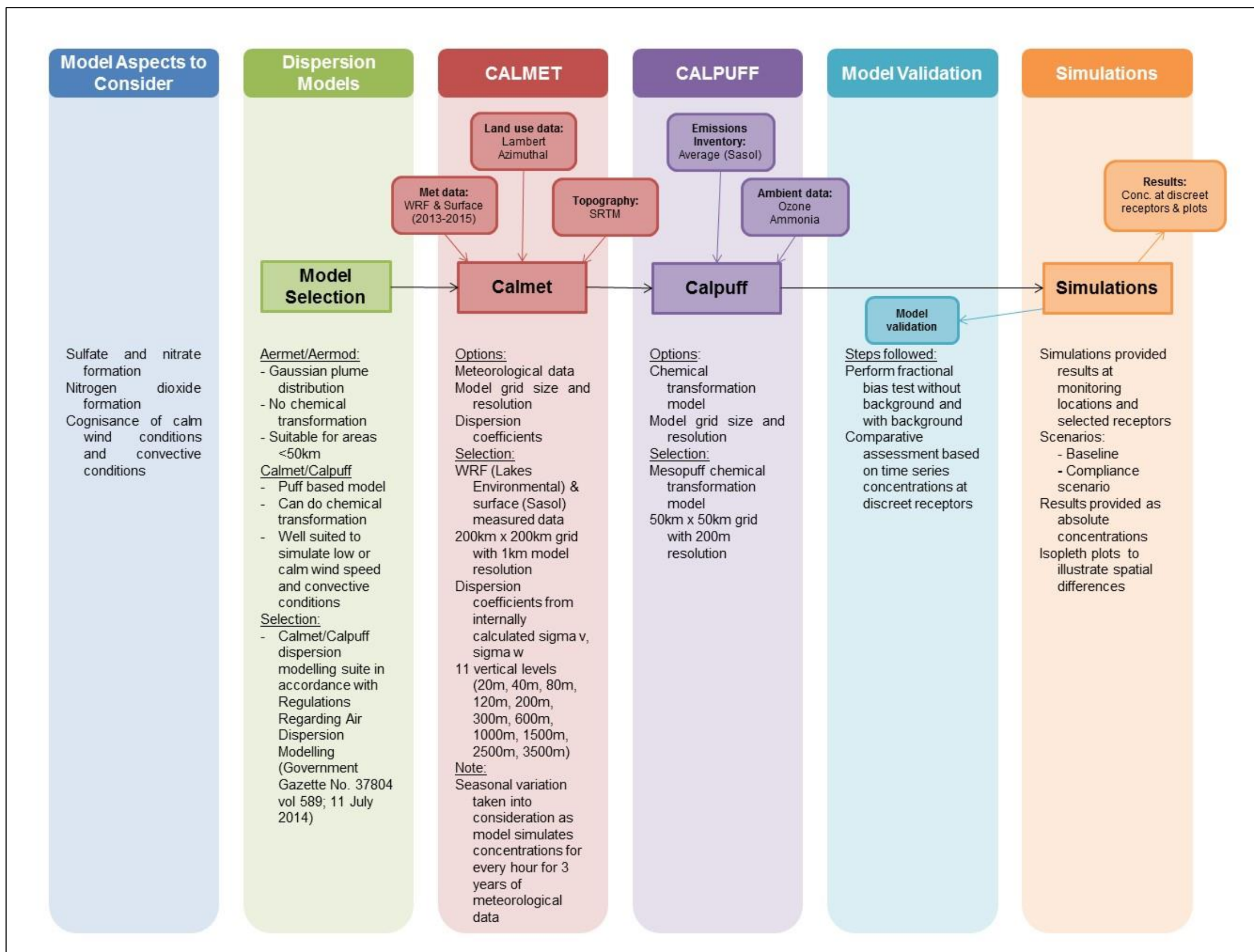


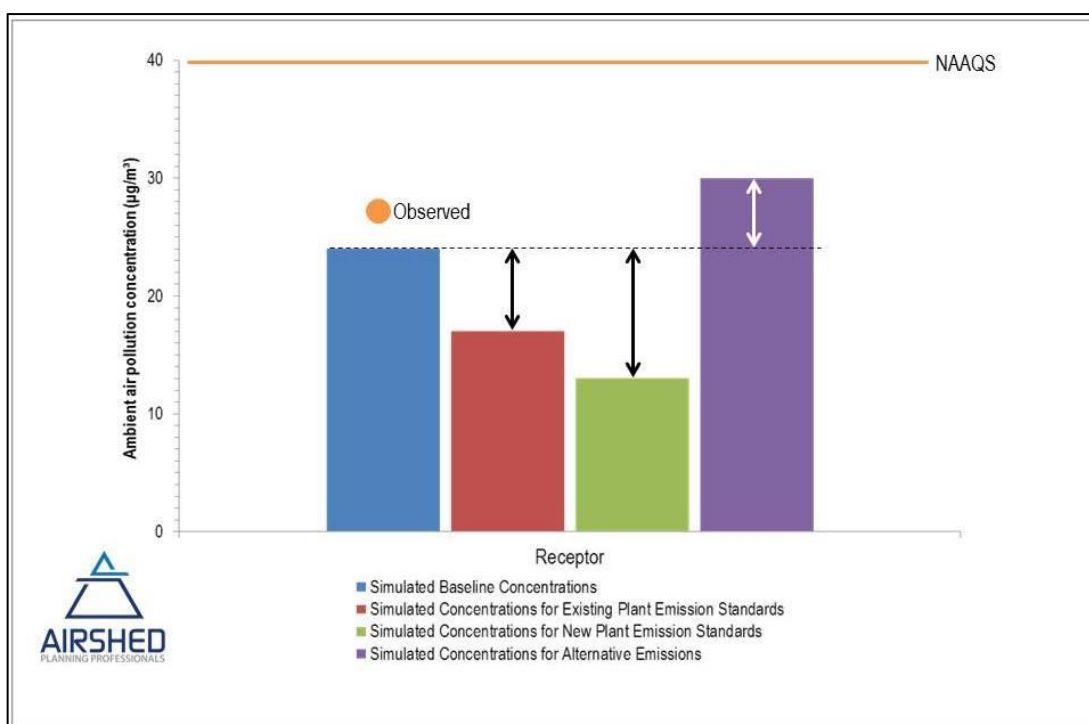
Figure 5-1: The basic study methodology followed for the assessment

In order to assess the impact of the postponements for which SSO is applying, four emissions scenarios were modelled, with the results throughout the AIR presented as illustrated in Figure 5-2.

1. **Current baseline emissions**, reflective of the impacts of present operations, which are modelled as averages of measurements taken from periodic emission monitoring. This scenario is represented by the first column in the presentation of all AIR graphs (shown in blue in Figure 5-2). Baseline emissions were derived from 3rd parties and accredited (ISO/IEC17025) laboratories. Emissions measurements follow the requirements prescribed in Schedule A of GN 893. The reason baseline emissions were modelled as averages of measured point source emissions was to obtain a picture of long-term average impacts of SSO's emissions on ambient air concentrations, which could be reasonably compared with monitored ambient concentrations, as a means of assessing the representativeness of the dispersion model's predictions. Modelling baseline emissions at a ceiling level, which is seldom reflective of actual emissions, would over-predict ambient impacts, and therefore not allow for reasonable assessment of the model's representativeness.

The following three scenarios are modelled to reflect the administrative basis of the Minimum Emission Standards (MES), being ceiling emission levels. These scenarios are therefore theoretical cases where the point source is constantly emitting at the highest expected emission level possible under normal operating conditions, for the given scenario (i.e. the 100<sup>th</sup> percentile emission concentration).

2. **Compliance with the 2015 existing plant standards**. This is modelled as a ceiling emissions limit (i.e. maximum emission concentration) aligned with the prescribed standard, and reflects a scenario where abatement equipment is introduced to theoretically reduce emissions to conform to the standards. This scenario is the represented by the second column in the presentation of all AIR graphs (shown in red in Figure 5-2).
3. **Compliance with the 2020 new plant standards**. This is modelled as a ceiling emissions limit (i.e. maximum emission concentration) aligned with the prescribed standard, and reflects a scenario where abatement equipment is introduced to theoretically reduce emissions to conform to the standards. This scenario is then represented by the third column in the presentation of all AIR graphs (shown in green in Figure 5-2).
4. **A worst-case scenario of operating constantly at the requested alternative emissions limits**, which have been specified as ceiling emissions limits (i.e. maximum emission concentrations). This scenario is represented by the fourth column in the presentation of all AIR graphs (shown in purple in Figure 5-2). It is re-emphasised that SSO will not physically increase its current baseline emissions (expressed as an average). SSO seeks alternative emissions limits which are aligned with the manner in which the MES are stated and which accommodate the natural variability inherent in emissions under different operating conditions, and hence must request a ceiling emissions limit rather than an average emissions limit. The alternative emission limit is hence simply a different way of expressing current baseline emissions (in cases where further abatement is not possible), or may even reflect a reduction in average baseline emissions (in cases where further abatement is possible, but not to a level which achieves compliance with the MES ceiling emissions limits).



**Figure 5-2: Schematic displaying how the dispersion modelling scenarios are presented, for each monitoring station receptor in the modelling domain**

In Figure 5-2, the black arrows above the red and green bars reflect the predicted delta (change) in ambient impacts of SSO's baseline emissions versus the given compliance scenario. At a practical level, the white arrow on the purple bar represents the theoretical delta increase in short-term ambient impacts, where 100<sup>th</sup> percentile emissions occur, compared with the predicted impact of average current baseline emissions. The orange dot in Figure 5-2 represents physically measured ambient air quality, reflective of the total impact of all sources in the vicinity, as the 99<sup>th</sup> percentile recorded value over the averaging period. On a given day, there is a 99% chance that the actual measured ambient air quality would be lower than this value, but this value is reflected for the purpose of aligning with modelling requirements. The orange line represents the applicable NAAQS.

#### 5.1.1.3 CALPUFF/CALMET Modelling Suite

As discussed in the previous section, the CALPUFF model was selected for use in the current investigation to predict maximum short-term (1 and 24-hour) and annual average ground-level concentrations at various receptor locations within the computational domains. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal (Scire *et al.*, 2000a). It can accommodate arbitrarily varying point source, area source, volume source, and line source emissions. The CALPUFF code includes algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub grid scale terrain interactions as well as longer range effects such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, vertical wind shear, overwater transport and coastal interaction effects.

It is intended for use on scales from tens of metres to hundreds of kilometres from a source (US EPA 1998). A number of dispersion coefficients options are accommodated, including



- stability-based empirical relationships such as the Pasquill-Gifford or McElroy-Pooler dispersion coefficients;
- turbulence-based dispersion coefficients (based on measured standard deviations of the vertical and crosswind horizontal components of the wind); and
- similarity theory to estimate the turbulent quantities using the micrometeorological variables calculated by CALMET

The most desirable approach is to use turbulence-based dispersion coefficients using measured turbulent velocity variances or intensity components, if such data are readily available and they are of good quality. However, since reliable turbulent measurements are generally not available, the next best recommendation is to use the similarity approach.

CALPUFF also has the capability to model the effects of vertical wind shear by explicitly allowing different puffs to be independently advected by their local average wind speed and direction, as well as by optionally allowing well-mixed puffs to split into two or more puffs when across-puff shear becomes important. Another refinement is an option to use a probability density function (pdf) model to simulate vertical dispersion during convective conditions.

CALPUFF includes parameterized chemistry modules for the formation of secondary sulfate and nitrate from the oxidation of the emitted primary pollutants, SO<sub>2</sub> and NO<sub>x</sub>. The conversion processes are assumed to be linearly dependent (first-order) on the relevant primary species concentrations. Two options are included, namely the MESOPUFF II and RIVAD/ARM3 chemistry options. In both options, a fairly simple stoichiometric thermodynamic model is used to estimate the partitioning of total inorganic nitrate between gas-phase nitric acid and particle-phase ammonium nitrate. Ammonia and ozone concentrations are required as background values to the model.

CALPUFF uses dry deposition velocities to calculate the dry deposition of gaseous and particulate pollutants to the surface. These dry deposition velocities can either be user-specified or calculated internally in CALPUFF. A resistance-based model is used for the latter option. For gaseous pollutants, the resistances that are considered are the atmospheric resistance, the deposition layer resistance, and the canopy resistance. For particles, a gravitational settling term is included and the canopy resistance is assumed to be negligible. CALPUFF uses the scavenging coefficient approach to parameterize wet deposition of gases and particles. The scavenging coefficient depends on pollutant characteristics (e.g., solubility and reactivity), as well as the precipitation rate and type of precipitation. The model provides default values for the scavenging coefficient for various species and two types of precipitation (liquid and frozen). These values may be overridden by the user.

The CALPUFF modelling system consists of a number of components, as summarised in Table 5-1, however only CALMET and CALPUFF contain the simulation engines to calculate the three-dimensional atmospheric boundary layer conditions and the dispersion and removal mechanisms of pollutants released into this boundary layer. The other codes are mainly used to assist with the preparation of input and output data. Table 5-1 also includes the development versions of each of the codes used in the investigation.

**Table 5-1: Summary description of CALPUFF/CALMET model suite with versions used in the investigation**

Module	Version	Description
<b>CALPUFF/CALMET model suite</b>		
CALMET	v6.334	Three-dimensional, diagnostic meteorological model
CALPUFF	v6.42	Non-steady-state Gaussian puff dispersion model with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation and other effects.
CALPOST	V6.292	A post-processing program for the output fields of meteorological data, concentrations and deposition fluxes.
CALSUM	v1.4 <sup>(1)</sup>	Sums and scales concentrations or wet/dry fluxes from two or more source groups from different CALPUFF runs
PRTMET	v 4.495 <sup>(1)</sup>	Lists selected meteorological data from CALMET and creates plot files
POSTUTIL	v1.641 <sup>(1)</sup>	Processes CALPUFF concentration and wet/dry flux files. Creates new species as weighted combinations of modelled species; merges species from different runs into a single output file; sums and scales results from different runs; repartitions nitric acid/nitrate based on total available sulfate and ammonia.
TERREL	v3.69 <sup>(1)</sup>	Combines and grids terrain data
CTGPROC	v3.5 <sup>(1)</sup>	processes and grids land use data
MAKEGEO	v3.2 <sup>(1)</sup>	merges land use and terrain data to produce the geophysical data file for CALMET

Note <sup>(1)</sup>: These modules indicate version number as listed on [http://www.src.com/calpuff/download/mod6\\_codes.htm](http://www.src.com/calpuff/download/mod6_codes.htm) (for CALPro Plus v6) [version number not given in GUI interface or 'About' information].

A summary of the main CALMET and CALPUFF control options are given in Appendices D and E, respectively.

### 5.1.2 Legal Requirements

#### 5.1.2.1 Atmospheric Impact Report

In the event where an application for postponement is being made, Section 21 of NEM: Air Quality Act (AQA), Regulations 11 and 12 state:

1. An application for postponement may be made to the National Air Quality Officer
2. The application contemplated in Regulation 11 must include, amongst others, an Atmospheric Impact Report

The format of the Atmospheric Impact Report is stipulated in the Regulations Prescribing the Format of the Atmospheric Impact Report, Government Gazette No. 36904, Notice Number 747 of 2013 (11 October 2013) (Appendix B; Table B-1).

Sasol appointed Airshed to compile this AIR to meet the requirements of Regulation 12 (Postponement of compliance time frames) of the Listed Activities and Associated Minimum Emissions Standards (Government Gazette No. 37054, 22 November 2013) (Appendix B; Table B-2).

#### 5.1.2.2 National Ambient Air Quality Standards (NAAQS)

Modelled concentrations will be assessed against NAAQS (Table 5-2), where they are prescribed by South African legislation. Where no NAAQS exists for a relevant non-criteria pollutant, health screening effect levels based on international guidelines are used. These are discussed with the results of dispersion modelling in Section 5.1.8.2.

**Table 5-2: National Ambient Air Quality Standards (bold text indicates pollutant of interest)**

Pollutant	Averaging Period	Concentration ( $\mu\text{g}/\text{m}^3$ )	Permitted Frequency of Exceedance	Compliance Date
Benzene ( $\text{C}_6\text{H}_6$ )	1 year	5	0	1 January 2015
Carbon Monoxide (CO)	1 hour	30000	88	Immediate
	8 hour <sup>(a)</sup>	10000	11	Immediate
Lead (Pb)	1 year	0.5	0	Immediate
Nitrogen Dioxide ( $\text{NO}_2$ )	1 hour	200	88	Immediate
	1 year	40	0	Immediate
Ozone ( $\text{O}_3$ )	8 hour <sup>(b)</sup>	120	11	Immediate
Inhalable particulate matter less than $2.5\ \mu\text{m}$ in diameter ( $\text{PM}_{2.5}$ )	24 hour	40	4	Immediate until 31 December 2029
	24 hour	25	4	1 January 2030
	1 year	20	0	Immediate until 31 December 2029
	1 year	15	0	1 January 2030
Inhalable particulate matter less than $10\ \mu\text{m}$ in diameter ( $\text{PM}_{10}$ )	24 hour	75	4	Immediate
	1 year	40	0	Immediate
Sulfur Dioxide ( $\text{SO}_2$ )	10 minutes	500	526	Immediate
	1 hour	350	88	Immediate
	24 hour	125	4	Immediate
	1 year	50	0	Immediate

#### 5.1.2.3 National Dust Control Regulations

South Africa's Draft National Dust Control Regulations were published on 27 May 2011 with the dust fallout standards passed and subsequently published on 1 November 2013 (Government Gazette No. 36974). These are called the National Dust Control Regulations (NDCR). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Acceptable dustfall rates according to the regulations are summarised in Table 5-3.

**Table 5-3: Acceptable dustfall rates**

Restriction areas	Dustfall rate (D) in $\text{mg}/\text{m}^2\text{-day}$ over a 30 day average	Permitted frequency of exceedance
Residential areas	$D < 600$	Two within a year, not sequential months.

Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.
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The regulations also specify that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. It is important to note that dustfall is assessed for nuisance impact and not inhalation health impact.

### 5.1.3 Regulations Regarding Air Dispersion Modelling

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Regulations regarding Air Dispersion Modelling were promulgated in Government Gazette No. 37804 vol. 589; 11 July 2014, and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

- (a) in the development of an air quality management plan, as contemplated in Chapter 3 of the AQA;
- (b) in the development of a priority area air quality management plan, as contemplated in section 19 of the AQA;
- (c) in the development of an atmospheric impact report, as contemplated in section 30 of the AQA; and,
- (d) in the development of a specialist air quality impact assessment study, as contemplated in Chapter 5 of the AQA.

The Regulations have been applied to the development of this report. The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Chapter 2 of the Regulations present the typical levels of assessments, technical summaries of the prescribed models (SCREEN3, AERSCREEN, AERMOD, SCIPUFF, and CALPUFF) and good practice steps to be taken for modelling applications.

Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Chapter 3 of the Regulations prescribe the source data input to be used in the models. Dispersion modelling can typically be used in the:

- Apportionment of individual sources for installations with multiple sources. In this way, the individual contribution of each source to the maximum ambient simulated concentration can be determined. This may be extended to the study of cumulative impact assessments where modelling can be used to model numerous installations and to investigate the impact of individual installations and sources on the maximum ambient pollutant concentrations.
- Analysis of ground level concentration changes as a result of different release conditions (e.g. by changing stack heights, diameters and operating conditions such as exit gas velocity and temperatures).
- Assessment of variable emissions as a result of process variations, start-up, shut-down or abnormal operations.
- Specification and planning of ambient air monitoring programs which, in addition to the location of sensitive receptors, are often based on the prediction of air quality hotspots.

The above options can be used to determine the most cost-effective strategy for compliance with the NAAQS. Dispersion models are particularly useful under circumstances where the maximum ambient concentration approaches the ambient air quality limit value and provide a means for establishing the preferred combination of mitigation measures that may be required including:

- Stack height increases;

- Reduction in pollutant emissions through the use of air pollution control systems (APCS) or process variations;
- Switching from continuous to non-continuous process operations or from full to partial load.

Chapter 4 of the Regulations prescribe meteorological data input from onsite observations to simulated meteorological data. The chapter also gives information on how missing data and calm conditions are to be treated in modelling applications. Meteorology is fundamental for the dispersion of pollutants because it is the primary factor determining the diluting effect of the atmosphere. Therefore, it is important that meteorology is carefully considered when modelling.

New generation dispersion models, including models such as AERMOD and CALPUFF<sup>1</sup>, simulate the dispersion process using planetary boundary layer (PBL) scaling theory. PBL depth and the dispersion of pollutants within this layer are influenced by specific surface characteristics such as surface roughness, albedo and the availability of surface moisture:

- Roughness length ( $z_0$ ) is a measure of the aerodynamic roughness of a surface and is related to the height, shape and density of the surface as well as the wind speed.
- Albedo is a measure of the reflectivity of the Earth's surface. This parameter provides a measure of the amount of incident solar radiation that is absorbed by the Earth/atmosphere system. It is an important parameter since absorbed solar radiation is one of the driving forces for local, regional, and global atmospheric dynamics.
- The Bowen ratio provides measures of the availability of surface moisture injected into the atmosphere and is defined as the ratio of the vertical flux of sensible heat to latent heat, where sensible heat is the transfer of heat from the surface to the atmosphere via convection and latent heat is the transfer of heat required to evaporate liquid water from the surface to the atmosphere.

Topography is also an important geophysical parameter. The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus the accurate determination of terrain elevations in air dispersion models is very important.

The modelling domain would normally be decided on the expected zone of influence; the latter extent being defined by the simulated ground level concentrations from initial model runs. The modelling domain must include all areas where the ground level concentration is significant when compared to the air quality limit value (or other guideline). Air dispersion models require a receptor grid at which ground-level concentrations can be calculated. The receptor grid size should include the entire modelling domain to ensure that the maximum ground-level concentration is captured and the grid resolution (distance between grid points) sufficiently small to ensure that areas of maximum impact adequately covered. No receptors however should be located within the property line as health and safety legislation (rather than ambient air quality standards) is applicable within the site.

Chapter 5 provides general guidance on geophysical data, model domain and coordinates system required in dispersion modelling, whereas Chapter 6 elaborates more on these parameters as well as the inclusion of background air concentration data. The chapter also provides guidance on the treatment of NO<sub>2</sub> formation from NO<sub>x</sub> emissions, chemical transformation of sulfur dioxide into sulfates and deposition processes.

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<sup>1</sup> The CALMET modelling system require further geophysical parameters including surface heat flux, anthropogenic heat flux and leaf area index (LAI).

Chapter 7 of the Regulations outline how the plan of study and modelling assessment reports are to be presented to authorities. A comparison of how this study met the requirements of the Regulations is provided in Appendix B.

#### *5.1.4 Atmospheric Dispersion Processes*

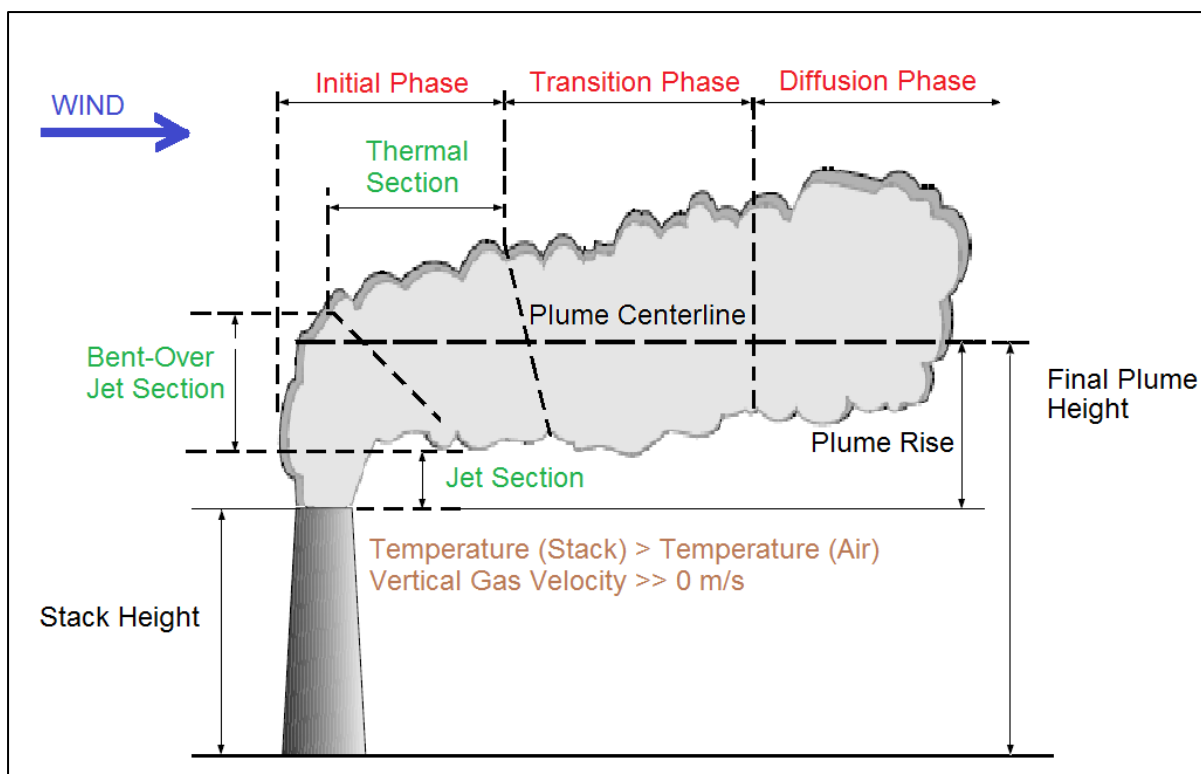
CALPUFF initiates the simulation of point source plumes with a calculation of buoyant plume rise as discussed below in Section 5.1.4.1. Transport winds are extracted from the meteorological data file at the location of the stack and at the effective plume height (stack height plus plume rise). For near-field effects, the height of the plume in transition to the final plume height is taken into account. The puff release rate is calculated internally, based on the transport speed and the distance to the closest receptor.

As the puff is transported downwind, it grows due to dispersion and wind shear, and the trajectory is determined by advection winds at the puff location and height at each time step. The pollutant mass within each puff is initially a function of the emission rate from the original source. The pollutant mass is also subject to chemical transformation, washout by rain and dry deposition, when these options are selected, as is the case in this application. Chemical transformation and removal are calculated based on a one-hour time step.

Both wet and dry deposition fluxes are calculated by CALPUFF, based on a full resistance model for dry deposition and the use of precipitation rate-dependent scavenging coefficients for wet deposition. Pollutant mass is removed from the puff due to deposition at each time step. For the present modelling analyses, most options were set at “default” values, including the treatment of terrain.

##### *5.1.4.1 Plume Buoyancy*

Gases leaving a stack mix with ambient air and undergo three phases namely the initial phase, the transition phase and the diffusion phase (Figure 5-3). The initial phase is greatly determined by the physical properties of the emitted gases. These gases may have momentum as they enter the atmosphere and are often heated and are therefore warmer than the ambient air. Warmer gases are less dense than the ambient air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise (vertical jet section, in Figure 5-3). In the Bent-Over Jet Section, entrainment of the cross flow is rapid because, by this time, appreciable growth of vortices has taken place. The self-generated turbulence causes mixing and determines the growth of plume in the thermal section. This is referred to as plume rise and allows air pollutants emitted in this gas stream to be lifted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches ground level. With greater volumetric flow and increased exit gas temperatures, the plume centreline would be higher than if either the volumetric flow or the exit gas temperature is reduced. The subsequent ground level concentrations would therefore be lower.



**Figure 5-3: Plume buoyancy**

This is particularly important in understanding some of the dispersion model results in Section 5.1.8. As an example, consider the emissions from a boiler. With the introduction of retrofitted emission controls (e.g. wet scrubber or bag filters), the exit gas temperature and perhaps the volumetric flow would be lower than the original values. Thus it is quite possible that the resultant decrease in plume momentum and buoyancy may actually result in higher ground level concentrations despite the reduction in point source emission concentrations, due to the lower plume centreline.

#### 5.1.4.2 Urban and Rural Conditions

Land use information is important to air dispersion modelling, firstly to ensure that the appropriate dispersion coefficients and wind profiles (specified as surface roughness) are used, and secondly, that the most appropriate chemical transformation models are employed. Urban conditions result in different dispersion conditions than in rural areas, as well as changing the vertical wind profiles. Urban conditions are also generally associated with increased levels of volatile organic compounds (VOCs), thereby influencing chemical equilibria between the photochemical reactions of  $\text{NO}_x$ , CO and  $\text{O}_3$ .

It can be appreciated that the definition of urban and rural conditions for the dispersion coefficients and wind profiles, on the one hand, and chemical reactions on the other, may not be the same. Nonetheless, it was decided to use the US Environmental Protection Agency's (US EPA) guideline on air dispersion models (US EPA 2005), to classify the surrounding land-use as rural or urban based on the Auer method, which is strictly recommended for selecting dispersion coefficients.

The classification scheme is based on the activities within a 3 km radius of the emitting source. Areas typically defined as rural include residences with grass lawns and trees, large estates, metropolitan parks and golf courses, agricultural areas, undeveloped land and water surfaces. An area is defined as urban if it has less than 35% vegetation coverage or the area falls into one of the use types in Table 5-4.

**Table 5-4: Definition of vegetation cover for different developments (US EPA 2005)**

Urban Land-Use		
Type	Development Type	Vegetation Cover
I1	Heavy industrial	Less than 5%
I2	Light/moderate industrial	Less than 10%
C1	Commercial	Less than 15%
R2	Dense/multi-family	Less than 30%
R3	Multi-family, two storey	Less than 35%

According to this classification scheme, the study area is classified as urban.

#### 5.1.4.3 Nitrogen Dioxide Formation

Of the several species of nitrogen oxides, only NO<sub>2</sub> is specified in the NAAQS. Since most sources emit uncertain ratios of these species and these ratios change further in the atmosphere due to chemical reactions, a method for determining the amount of NO<sub>2</sub> in the plume must be selected.

Estimation of this conversion normally follows a tiered approach, as discussed in the Regulations Regarding Air Dispersion Modelling (Government Gazette No. 37804, published 11 July 2014), which presents a scheme for annual averages:

##### Tier 1: Total Conversion Method

*Use any of the appropriate models recommended to estimate the maximum annual average NO<sub>2</sub> concentrations by assuming a total conversion of NO to NO<sub>2</sub>. If the maximum NO<sub>x</sub> concentrations are less than the NAAQS for NO<sub>2</sub>, then no further refinement of the conversion factor is required. If the maximum NO<sub>x</sub> concentrations are greater than the NAAQS for NO<sub>2</sub>, or if a more "realistic" estimate of NO<sub>2</sub> is desired, proceed to the second tier level.*

##### Tier 2: Ambient Ratio Method (ARM) - Multiply NO<sub>x</sub> by a national ratio of NO<sub>2</sub>/NO<sub>x</sub> = 0.80

*Assume a wide area quasi-equilibrium state and multiply the Tier 1 empirical estimate NO<sub>x</sub> by a ratio of NO<sub>2</sub>/NO<sub>x</sub> = 0.80. The ratio is recommended for South Africa as the conservative ratio based on a review of ambient air quality monitoring data from the country. If representative ambient NO and NO<sub>2</sub> monitoring data is available (for at least one year of monitoring), and the data is considered to represent a quasi-equilibrium condition where further significant changes of the NO/NO<sub>2</sub> ratio is not expected, then the NO/NO<sub>2</sub> ratio based on the monitoring data can be applied to derive NO<sub>2</sub> as an alternative to the national ratio of 0.80.*

In the Total Conversion Method, the emission rate of all NO<sub>x</sub> species is used in the dispersion model to predict ground-level concentrations of total NO<sub>x</sub>. These levels of NO<sub>x</sub> are assumed to exist as 100% NO<sub>2</sub>, and are directly compared to the NAAQS for NO<sub>2</sub>. If the NAAQS are met, the Tier 2 methods are not necessary.

Although not provided in the Regulations (Section 5.1.3), the conversion of NO to NO<sub>2</sub> may also be based on the amount of ozone available within the volume of the plume. The NO<sub>2</sub>/NO<sub>x</sub> conversion ratio is therefore coupled with the dispersion of the plume. This is known as the Ozone Limiting Method (OLM). Use of onsite ozone data is always preferred for the OLM method.

Ideally, the NO<sub>2</sub> formation should be dealt with in the dispersion model. CALPUFF has one such a module, known as the RIVAD / ARM3 chemical formulations. The RIVAD / ARM3 chemical formulations option in the CALPUFF model can be



used to calculate NO<sub>2</sub> concentrations directly in rural (non-urban) areas (Morris et al., 1988). The RIVAD / ARM3 option incorporates the effect of chemical and photochemical reactions on the formation of nitrates and other deposition chemicals. However, since the study area could be classified as urban (Section 5.1.4.2), the RIVAD / ARM3 chemical formulations should not be used.

Whilst the MESOPUFF II chemical transformation scheme, which is also included in the CALPUFF model accommodates NO<sub>x</sub> reactions, these are only considering the formation of nitrates and not the NO /NO<sub>2</sub> reactions.

Given all of the above limitations, it was decided to employ the Ambient Ratio Method (ARM), i.e. the second version of the DEA Tier 2 option. The ARM ambient ratio method is based upon the premise that the NO<sub>2</sub>/NO<sub>x</sub> ratio in a plume changes as it is transported but attains an equilibrium value some distance away from the source (Scire and Borissova, 2011). In their study, Scire and Borissova analysed hourly monitored NO<sub>2</sub> and NO<sub>x</sub> data for 2006 at 325 monitoring sites throughout USA, which amounted to approximately 2.8 million data points for each species. These observations were grouped into a number of concentration ranges (bins), and the binned data were used to compute bin maximums and bin average curves. Short-term (1-hr) NO<sub>2</sub>/NO<sub>x</sub> ratios were subsequently developed based on bin-maximum data. Similarly, long-term (annual average) NO<sub>2</sub>/NO<sub>x</sub> ratios were based on bin-averaged data. The method was tested using the NO<sub>2</sub>/NO<sub>x</sub> ratios applied to the observed NO<sub>x</sub> at selected stations to predict NO<sub>2</sub>, and then compared to observed NO<sub>2</sub> concentrations at that station. The comparison of NO<sub>2</sub> derived from observed NO<sub>x</sub> using these empirical curves was shown to be a conservative estimate of observed NO<sub>2</sub>, whilst at the same time arriving at a more realistic approximation than if simply assuming a 100% conversion rate. More details of the adopted conversion factors are given in Appendix F.

#### 5.1.4.4 *Particulate Formation*

CALPUFF includes two chemical transformation schemes for the calculation of sulfate and nitrate formation from SO<sub>2</sub> and NO<sub>x</sub> emissions. These are the MESOPUFF II and the RIVAD / ARM3 chemical formulations. Whilst the former scheme is not specifically restricted to urban or rural conditions; the latter was developed for use in rural conditions. Since the study area could be classified as urban (Section 5.1.5), the RIVAD / ARM3 chemical formulations should not be used. The chemical transformation scheme chosen for this analysis was therefore the MESOPUFF II scheme. As described in the CALPUFF User Guide it is a “pseudo first-order chemical reaction mechanism” and involves five pollutant species namely SO<sub>2</sub>, sulfates (SO<sub>4</sub>), NO<sub>x</sub>, nitric acid (HNO<sub>3</sub>) and particulate nitrate. CALPUFF calculates the rate of transformation of SO<sub>2</sub> to SO<sub>4</sub>, and the rate of transformation of NO<sub>x</sub> to NO<sub>3</sub>, based on environmental conditions including the ozone concentration, atmospheric stability, solar radiation, relative humidity, and the plume NO<sub>x</sub> concentration. The daytime reaction formulation depends on solar radiation and the transformation increases non-linearly with the solar radiation (see the SO<sub>2</sub> to SO<sub>4</sub> transformation rate equation (equation 2-253 in the CALPUFF User Guide). At night, the transformation rate defaults to a constant value of 0.2% per hour. Calculations based on these formulas show that the transformation rate can reach about 3 per cent per hour at noon on a cloudless day with 100 ppb of ozone.

With the MESOPUFF-II mechanism, NO<sub>x</sub> transformation rates depend on the concentration levels of NO<sub>x</sub> and O<sub>3</sub> (equations 2-254 and 2-255 in the CALPUFF User Guide) and both organic nitrates (RNO<sub>3</sub>) and HNO<sub>3</sub> are formed. According to the scheme, the formation of RNO<sub>3</sub> is irreversible and is not subject to wet or dry deposition. The formation of HNO<sub>3</sub>, however, is reversible and is a function of temperature and relative humidity. The formation of particulate nitrate is further determined through the reaction of HNO<sub>3</sub> and NH<sub>3</sub>. Background NH<sub>3</sub> concentrations are therefore required as input to calculate the equilibrium between HNO<sub>3</sub> and particulate nitrate. At night, the NO<sub>x</sub> transformation rate defaults to a constant value of 2.0% per hour. Hourly average ozone and ammonia concentrations were included as input in the CALPUFF model to facilitate these sulfate and nitrate formation calculations.

The limitation of the CALPUFF model is that each puff is treated in isolation, i.e. any interaction between puffs from the same or different points of emission is not accounted for in these transformation schemes. CALPUFF first assumes that ammonia reacts preferentially with sulfate, and that there is always sufficient ammonia to react with the entire sulfate present within a single puff. The CALPUFF model performs a calculation to determine how much  $\text{NH}_3$  remains after the particulate sulfate has been formed and the balance would then be available for reaction with  $\text{NO}_3$  within the puff. The formation of particulate nitrate is subsequently limited by the amount of available  $\text{NH}_3$ . Although this may be regarded a limitation, in this application the particulate formation is considered as a group and not necessarily per species.

#### 5.1.4.5 Ozone Formation

Similar to sulfate, nitrate and nitrogen dioxide,  $\text{O}_3$  can also be formed through chemical reactions between pollutants released into the atmosphere. As a secondary pollutant,  $\text{O}_3$  is formed in the lower part of the atmosphere, from complex photochemical reactions following emissions of precursor gases such as  $\text{NO}_x$  and VOCs (Seinfeld and Pandis, 1998).  $\text{O}_3$  is produced during the oxidation of carbon monoxide (CO) and hydrocarbons by hydroxyls (OH) in the presence of  $\text{NO}_x$  and sunlight (Seinfeld and Pandis, 1998). The rate of ozone production can therefore be limited by CO, VOCs or  $\text{NO}_x$ . In densely populated regions with high emissions of  $\text{NO}_x$  and hydrocarbons, rapid  $\text{O}_3$  production can take place and result in a surface air pollution problem. In these urban areas  $\text{O}_3$  formation is often VOC-limited.  $\text{O}_3$  is generally  $\text{NO}_x$ -limited in rural areas and downwind suburban areas.

$\text{O}_3$  concentration levels have the potential to become particularly high in areas where considerable  $\text{O}_3$  precursor emissions combine with stagnant wind conditions during the summer, when high insolation and temperatures occur (Seinfeld and Pandis, 1998). The effects of sunlight on  $\text{O}_3$  formation depend on its intensity and its spectral distribution.

The main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution. In many urban areas,  $\text{O}_3$  nonattainment is not caused by emissions from the local area alone. Due to atmospheric transport, contributions of precursors from the surrounding region can also be important. The transport of  $\text{O}_3$  is determined by meteorological and chemical processes which typically extend over spatial scales of several hundred kilometres. Thus, in an attempt to study  $\text{O}_3$  concentrations in a local area, it is necessary to include regional emissions and transport. This requires a significantly larger study domain with the inclusion of a significantly more comprehensive emissions inventory of  $\text{NO}_x$  and VOCs sources (e.g. vehicle emissions in Gauteng). Such a collaborative study was not within the scope of this report.

#### 5.1.4.6 Model Input

##### 5.1.4.6.1 Meteorological Input Data

The option of Partial Observations was selected for the CALMET wind field model which used both simulated and observed meteorological data (refer to Appendix D for all CALMET control options). For simulated data, the Weather Research and Forecasting mesoscale model (known as WRF) was used.

The WRF Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It features two dynamical cores, a data assimilation system, and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres. WRF can generate atmospheric simulations using real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and

computationally-efficient platform, while providing recent advances in physics, numeric, and data assimilation contributed by developers across the very broad research community.

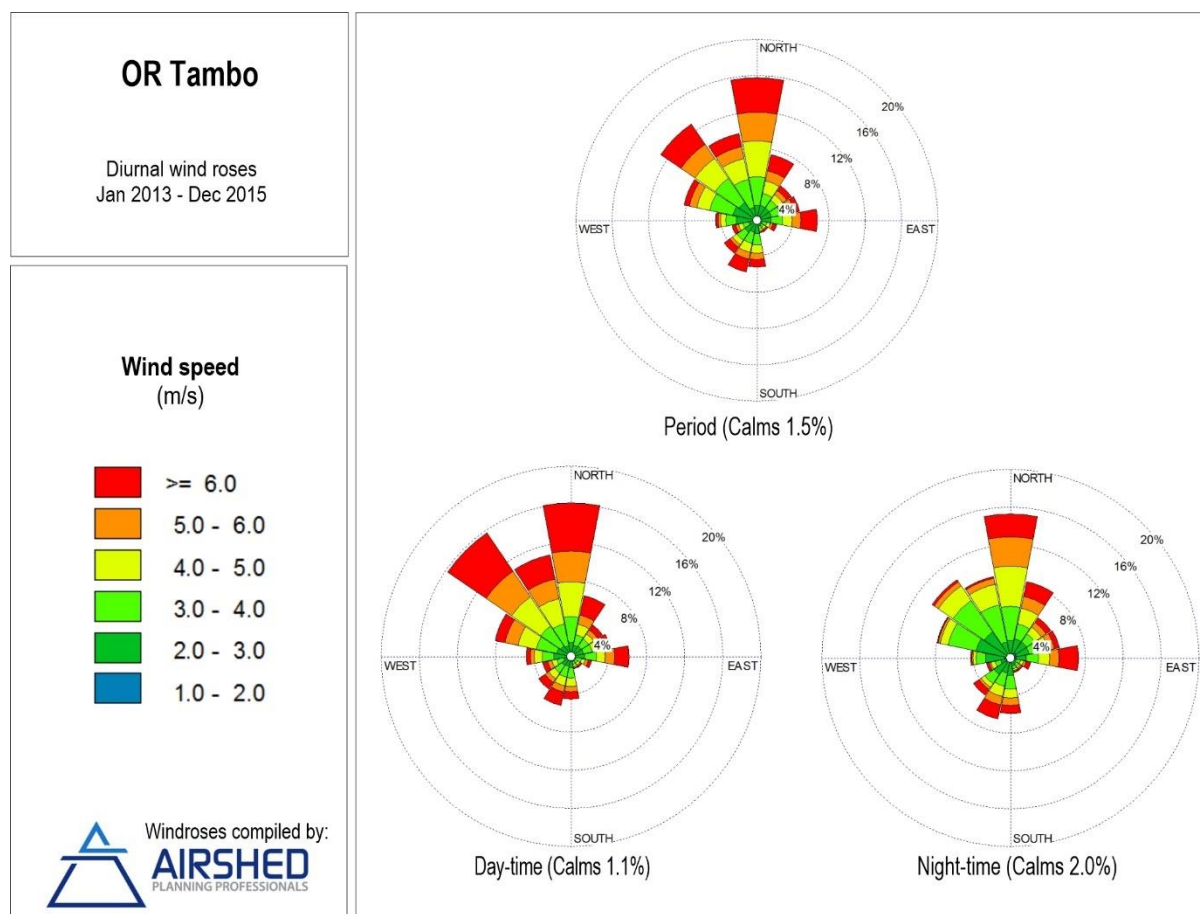
WRF data for the period 2013 to 2015 on a 4 km horizontal resolution for a 200 km by 200 km was used. An evaluation of the WRF data is provided in Table 5-5 with the benchmark for the WRF data provided in Table 5-4. This evaluation was undertaken for a point extracted at OR Tambo (see Figure 5-8). OR Tambo was selected for the evaluation as it is expected that the data quality at this weather station is of high standard. From the evaluation, the daily average WRF results for the period 2013 to 2015 were within the benchmarks for model evaluation, with the exception of the gross error for the wind direction (WRF providing value of 35 degrees where benchmark is at  $\leq 30$  degrees) and index of agreement for humidity (WRF providing value of 0.55 where benchmark is at  $\geq 0.6$ ). A comparison of wind roses from measured meteorological data at OR Tambo (Figure 5-4) to CALMET data (extracted at OR Tambo) (Figure 5-5) is provided below. The measured wind direction at OR Tambo has a higher frequency of winds from the north than the WRF data. The gross error for wind direction could influence the CALPUFF simulated pollutant concentrations by up to 35 degrees. This is limited by the inclusion of measured wind speed and direction at surface stations near SO.

**Table 5-5: Benchmarks for WRF Model Evaluation**

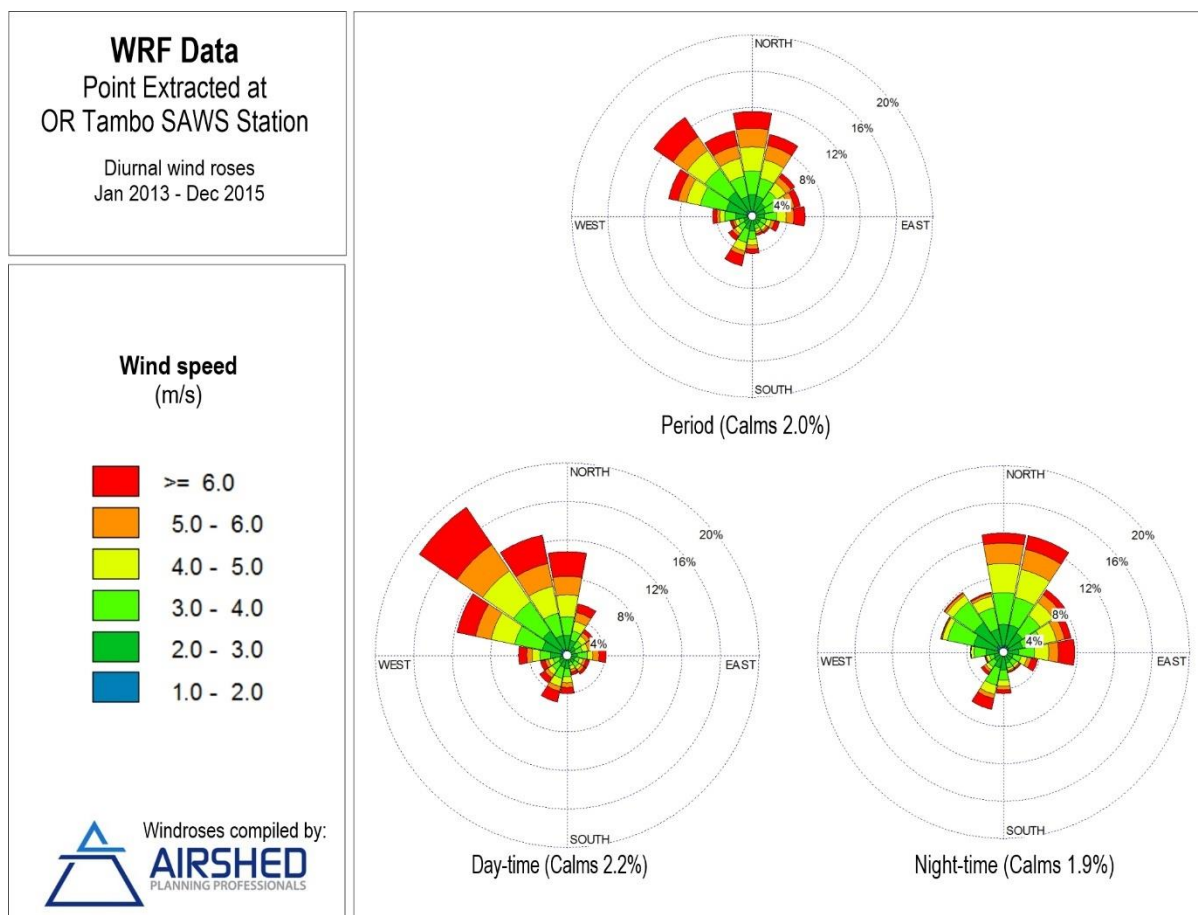
	Wind Speed	Wind Direction	Temperature	Humidity
IOA	$\geq 0.6$		$\geq 0.8$	$\geq 0.6$
RMSE	$\leq 2$ m/s			
Mean Bias	$\leq \pm 0.5$ m/s	$\leq \pm 10$ deg	$\leq \pm 0.5$ K	$\leq \pm 1$ g/kg
Gross Error		$\leq 30$ deg	$\leq 2$ K	$\leq 2$ g/kg

**Table 5-6: Daily evaluation results for the WRF simulations for the 2013-2015 extracted at OR Tambo**

	Wind Speed	Wind Direction	Temperature	Humidity
IOA	0.61		0.91	0.55
RMSE	1.54			
Mean Bias	-0.09	-1.48	-0.46	-0.14
Gross Error		34.97	1.60	1.01



**Figure 5-4: Period, day- and night-time wind rose for OR Tambo for the period 2013 - 2015**



**Figure 5-5: Period, day- and night-time wind rose for WRF data as extracted at OR Tambo for the period 2013 - 2015**

WRF data was supplemented with surface field observations from four monitoring stations operated by Sasol in the Sasolburg area and three monitoring stations operated by Sasol in the Secunda area. Meteorological parameters provided for the Sasol monitoring stations in the Secunda area are provided in Table 5-7.

**Table 5-7: Meteorological parameters provided for the Sasol monitoring stations in the Secunda area**

Monitoring Station	Latitude	Longitude	Closest Residential Area	Meteorology						
				WD	WS	Temp	RH	Press	SR	Rain
Secunda Club	-26.52333	29.1897	Secunda	✓	✓	✓				
Embalenhle	-26.55166	29.1125	Secunda	✓	✓	✓				
Bosjesspruit	-26.60583	29.2108	Secunda	✓	✓	✓				

WD: Wind direction

WS: Wind speed

Temp: Temperature

RH: Relative humidity

Press: Surface pressure

SR: Solar radiation

Figure 5-6 and Figure 5-7 provides examples of the CALMET layer 1 (up to 20 m above surface) wind vector plots from the CALMET data for 15 May 2013 at 05:00 and 2 February 2014 at 05:00 respectively. The spatial variations in the wind field over parts of the domain are due to terrain effects which are to be expected during this part of the diurnal cycle.



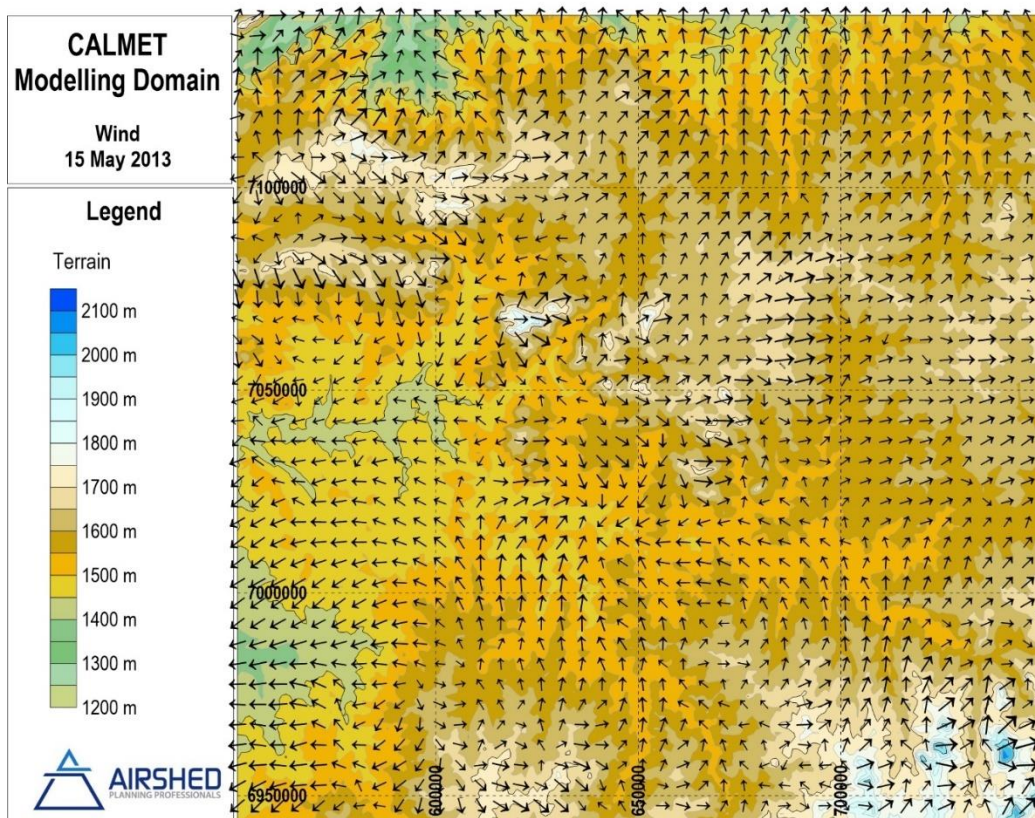


Figure 5-6: CALMET Layer 1 wind vector plot for 15 May 2013 at 05:00

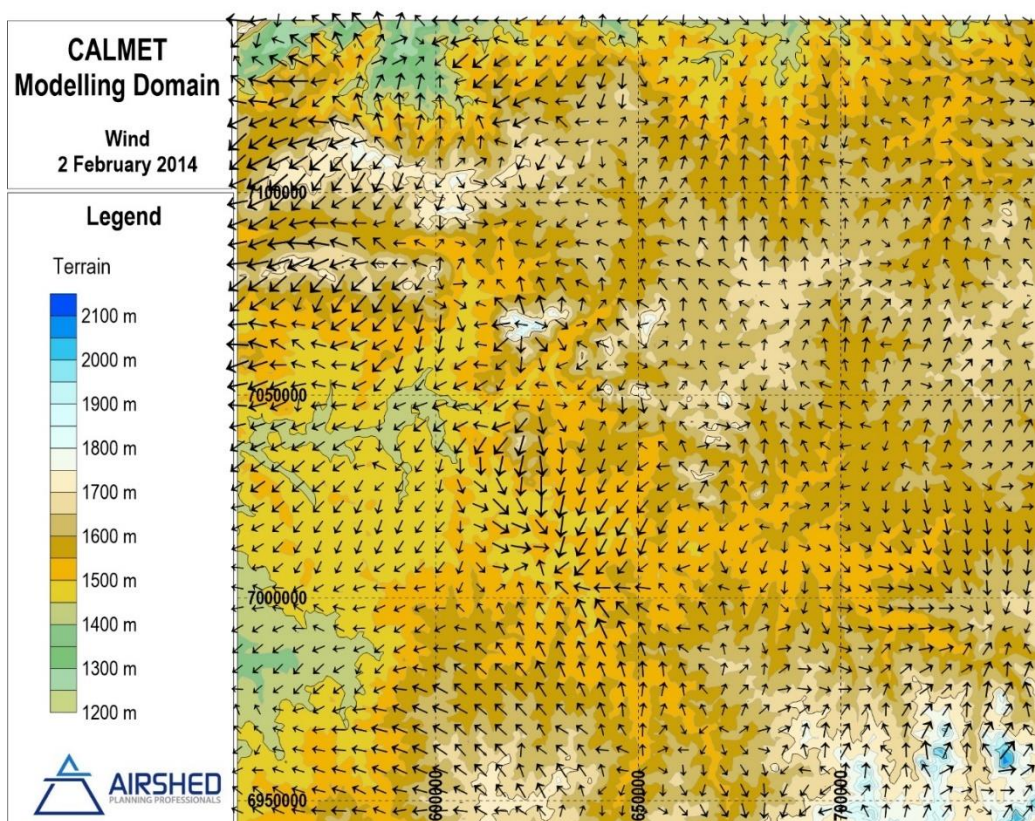


Figure 5-7: CALMET Layer 1 wind vector plot for 2 February 2014 at 05:00



#### 5.1.4.6.2 Land Use and Topographical Data

Readily available terrain and land cover data for use in CALMET was obtained from the Atmospheric Studies Group (ASG) via the United States Geological Survey (USGS) web site at ASG. Use was made of Shuttle Radar Topography Mission (SRTM) (90 m, 3 arc-sec) data and Lambert Azimuthal land use data for Africa.

Figure 5-8 provides the terrain contours and landuse categories over the entire CALMET domain and the location of the CALPUFF computational domain.

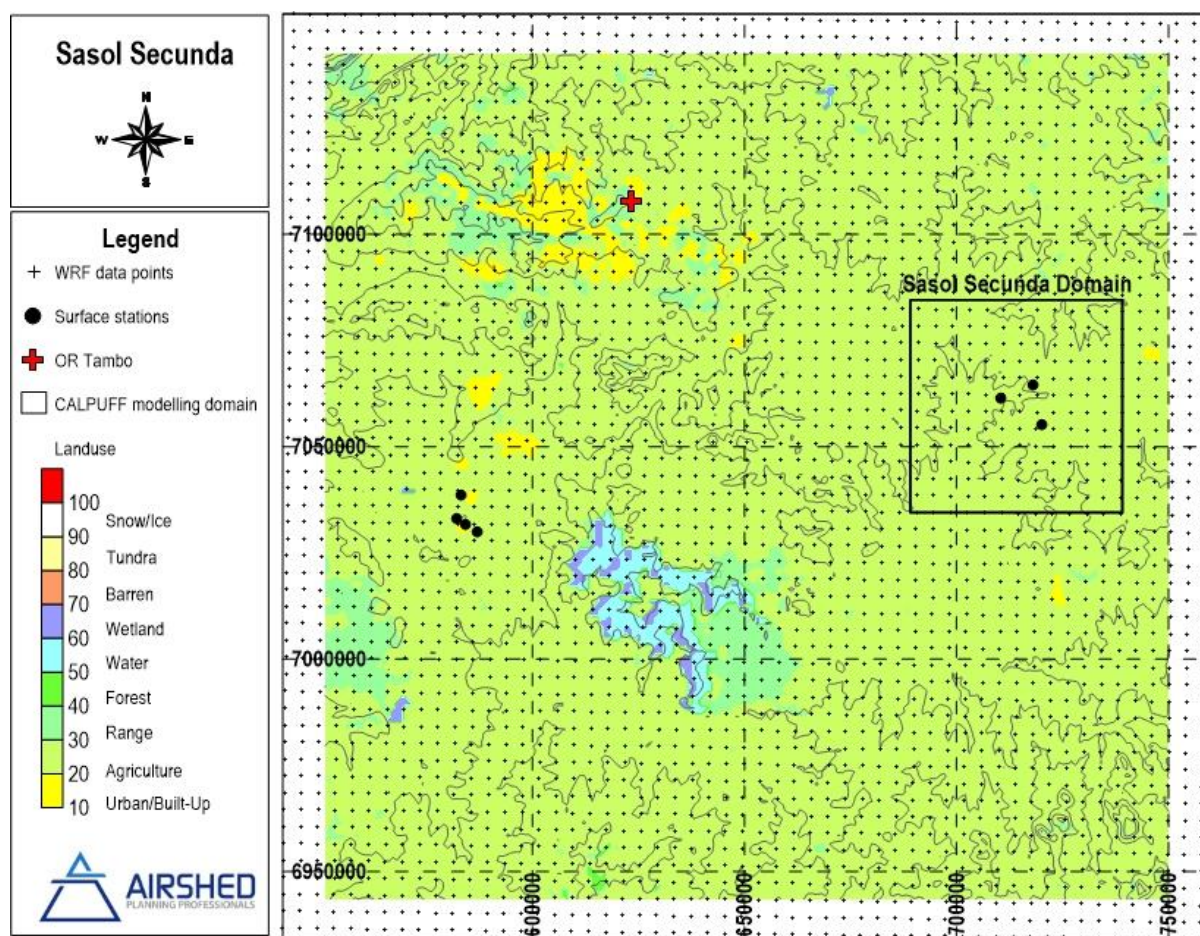


Figure 5-8: Land use categories, terrain contours, meteorological WRF grid points and surface station locations displayed on 200 x 200 km CALMET domain (1 km resolution)

#### 5.1.4.6.3 Dispersion Coefficients

The option of dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables ( $u^*$ ,  $w^*$ ,  $L$ , etc.) was selected (refer to Appendix E for all CALPUFF control options).

#### 5.1.4.6.4 Grid Resolution and Model Domain

The CALMET modelling domain included an area of 200 km by 200 km with a grid resolution of 1 km. The vertical profile included 11 vertical levels up to a height of 3 500 m. The CALPUFF model domain selected for the sources at the Sasol Secunda facility included an area of 50 km by 50 km with a grid resolution of 200 m. This area was selected based on the predicted area of impact around Secunda.

#### 5.1.4.6.5 Building downwash

The impact of building downwash on ground-level pollutant concentrations was evaluated using "ScreenView" - a Tier 1 screening model which includes the same building downwash scheme as CALPUFF. For the most conservative simulation of downwind concentrations "ScreenView" was used with a full meteorological set. The screening exercise assessed the individual impact of three sources selected based on location; stack height; proximity to nearby buildings (excluding complex pipework structures); and, proximity to receptors. The baseline emission parameters (temperature, release height, exit velocities, etc.) were used in combination with three theoretical building heights (10, 15, and 20 m). A single emission rate (1 m/s) was used to simulate the ground-level concentrations at automated distances between 1 m and 5 000 m from the sources, at 100 m intervals.

The screening assessment indicated that building downwash did not affect downwind concentration as a result of the emissions from tall stacks (75 m). Sources with lower release heights (15 m and 20 m) were found to increase ground-level concentrations downwind of the source where the scale of increase was dependent on the height of the near-by building. The distance after which simulated ground-level concentrations matched levels for comparative simulations where building downwash was not included was a minimum of 1 800 m.

Building downwash was not accounted for in the dispersion modelling of stack emission sources, based on the findings from the screening evaluation, and on the basis that the nearest receptor is approximately 4 500 m away from the SSO facility.

Building downwash was, however, accounted for in the dispersion modelling of crude tar and pitch (MTP) storage tanks. Tank locations and dimensions were provided by Sasol and the AERMOD Building Profile Input Program (BPIP) module was used to generate a building downwash input file for CALPUFF.

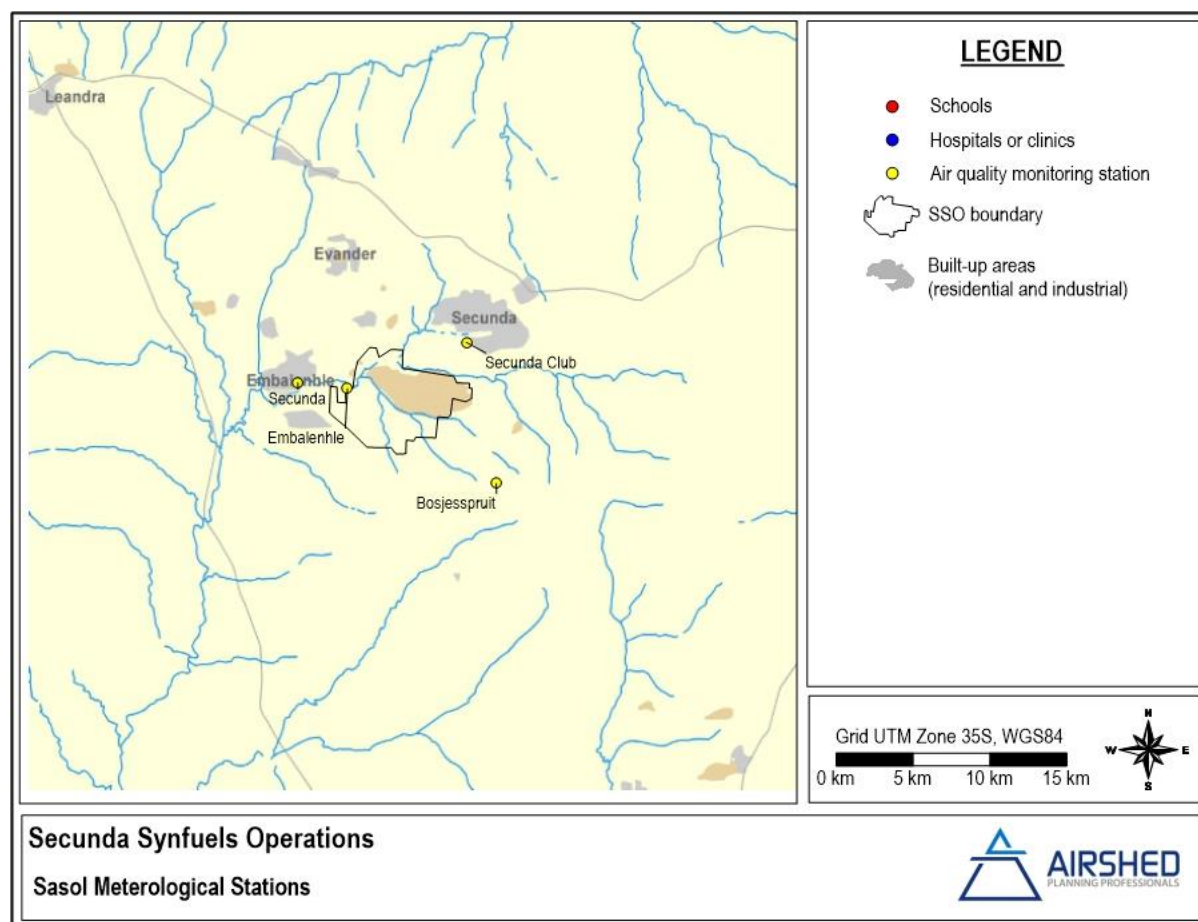
#### 5.1.5 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. The horizontal dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. A summary of the measured meteorological data is given in Appendix F.

Sasol currently operates three meteorological stations in the Secunda area (viz. Secunda Club, Embalenhle and Bosjesspruit - Figure 5-9). For this assessment, data from the Sasol operated meteorological stations was provided for the



period 2013 to 2015. Parameters useful in describing the dispersion and dilution potential of the site (i.e. wind speed, wind direction, temperature and atmospheric stability) are subsequently discussed.



**Figure 5-9: Sasol meteorological stations in relation to SSO**

#### 5.1.5.1 Surface Wind Field

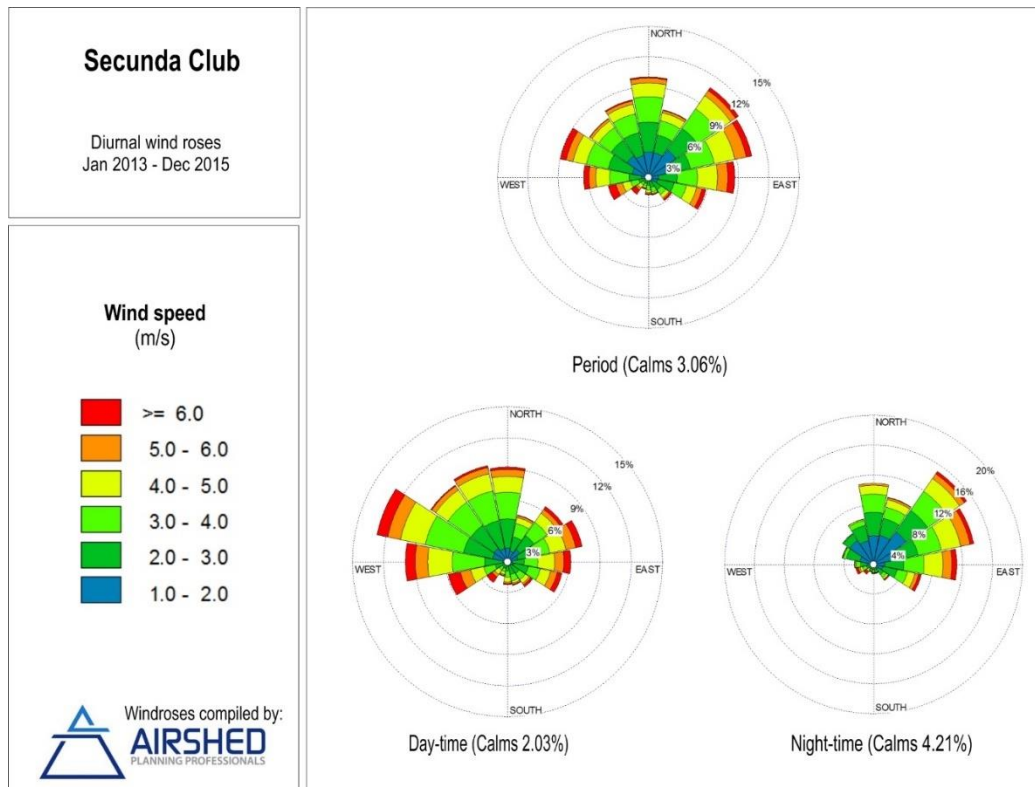
Wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the red area, for example, representing winds >6m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability for the three Sasol operated meteorological stations in the Secunda area, for the period 2013 to 2015, is provided in Figure 5-9 to Figure 5-11.

The predominant flow field at Secunda Club is from the northeasterly and northwesterly sectors with the highest frequency of winds from the northeast (~11%). During day-time conditions winds from the northwestern sector increase while winds from the northeastern sector are more frequent during night-time conditions (Figure 5-9).

The predominant flow field at Embalenhle is from the east-northeast (~15%). During day-time conditions winds from the western and north-western sector increases while winds from the east-northeast are more frequent during night-time conditions (Figure 5-10).

The predominant wind direction at Bosjesspruit is from the northeast (~10% frequency of occurrence) (Figure 5-11). Very little wind is measured from the south. During day-time conditions winds from the western sector increase while winds from the northeast are more frequent during night-time conditions.



**Figure 5-10: Period, day- and night-time wind rose for Secunda Club for the period 2013 - 2015**

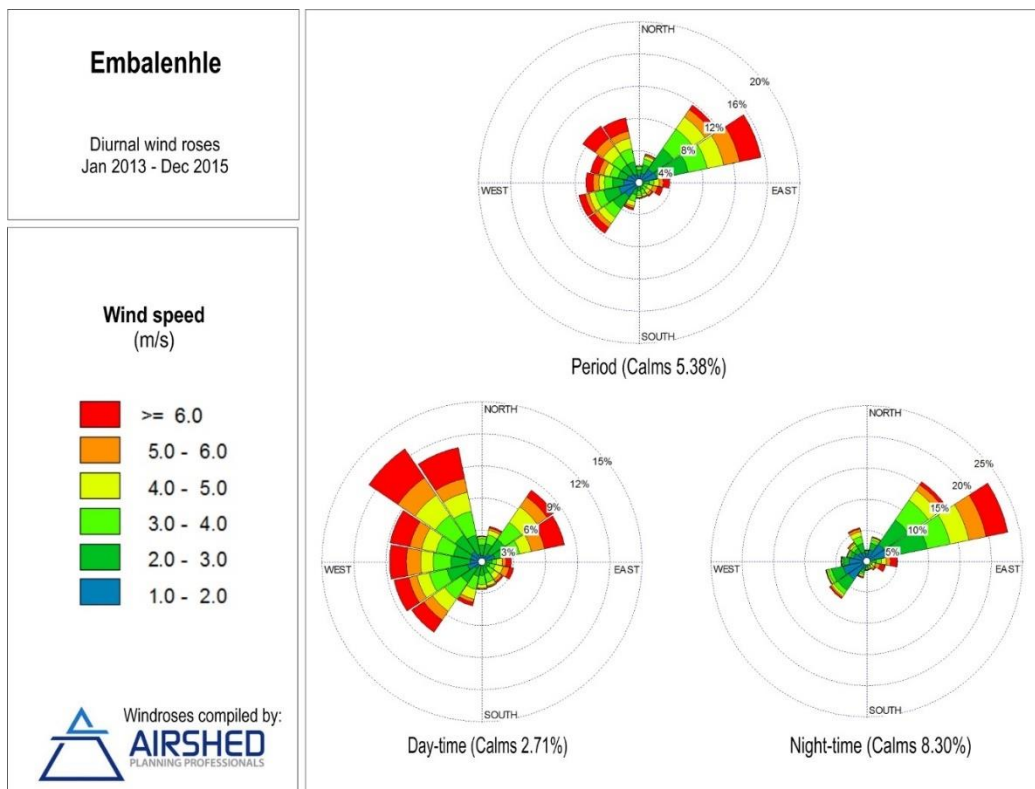


Figure 5-11: Period, day- and night-time wind rose for Embalenhle for the period 2013 - 2015

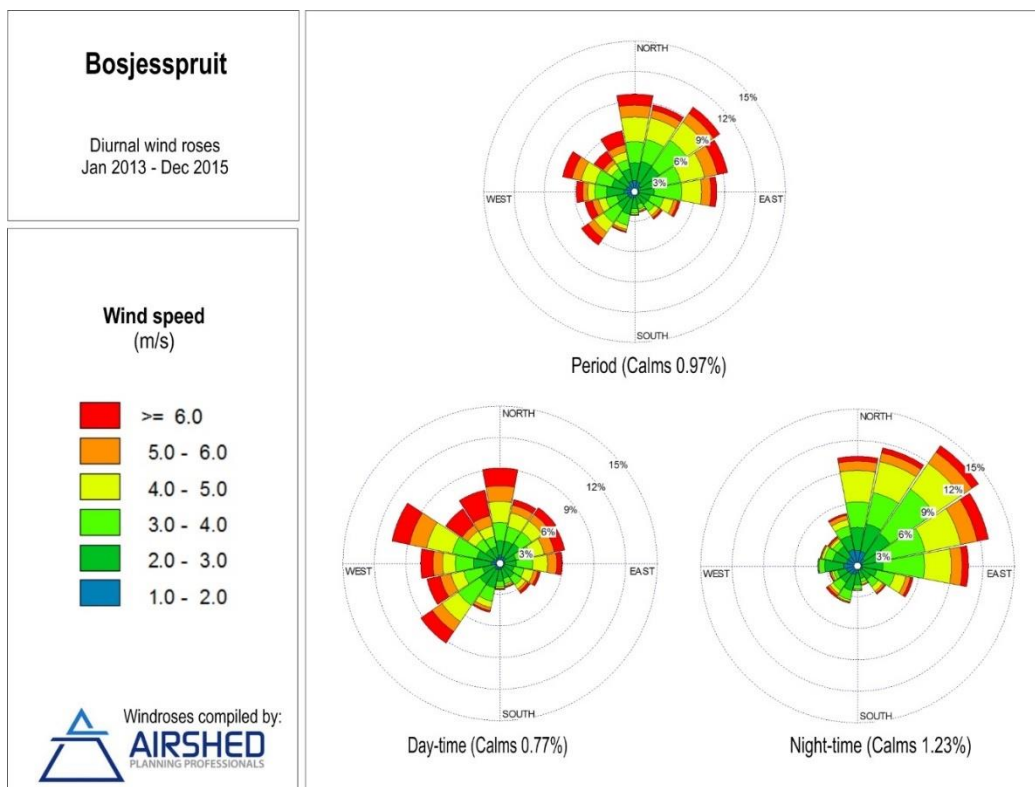


Figure 5-12: Period, day- and night-time wind rose for Bosjesspruit for the period 2013 - 2015

### 5.1.5.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the emission plume and the ambient air, the higher the plume can rise), and determining the development of the mixing and inversion layers.

The average monthly temperature trends are presented in Figure 5-12, Figure 5-13 and Figure 5-14 for Secunda Club, Embalenhle and Bosjesspruit respectively. Monthly mean and hourly maximum and minimum temperatures are given in Table 5-7. Average temperatures ranged between 7.9 °C and 20.3 °C. The highest temperatures occurred in January and the lowest in June/July. During the day, temperatures increase to reach maximum at around 15:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 07:00 i.e. just before sunrise.

**Table 5-8: Monthly temperature summary (2013 - 2015)**

Hourly Minimum, Hourly Maximum and Monthly Average Temperatures (°C) (2013 - 2015)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Secunda Club</b>												
Minimum	14.7	14.3	13.2	8.8	5.8	2.4	2.5	4.5	9.1	10.6	12.7	14.9
Maximum	25.6	27.0	24.2	22.5	22.8	19.8	19.2	22.1	25.3	25.7	25.0	25.2
Average	19.9	19.9	18.0	14.9	13.4	10.0	10.0	12.8	16.8	17.7	18.6	19.7
<b>Embalenhle</b>												
Minimum	15.0	14.1	13.0	7.9	3.1	-0.7	0.2	2.7	7.8	10.7	12.7	15.1
Maximum	26.2	26.8	24.4	22.1	22.4	19.2	18.9	21.7	25.3	26.2	25.5	25.5
Average	20.3	19.9	18.0	14.2	11.6	7.9	8.4	11.5	16.2	18.1	18.8	20.0
<b>Bosjesspruit</b>												
Minimum	14.1	13.7	13.0	9.2	6.7	3.3	2.7	5.1	9.5	10.5	12.2	14.4
Maximum	25.4	25.8	23.4	21.8	22.0	19.0	18.2	21.4	25.1	25.9	24.7	24.6
Average	19.3	19.1	17.6	14.6	13.4	10.0	9.5	12.4	16.6	17.5	18.1	19.2

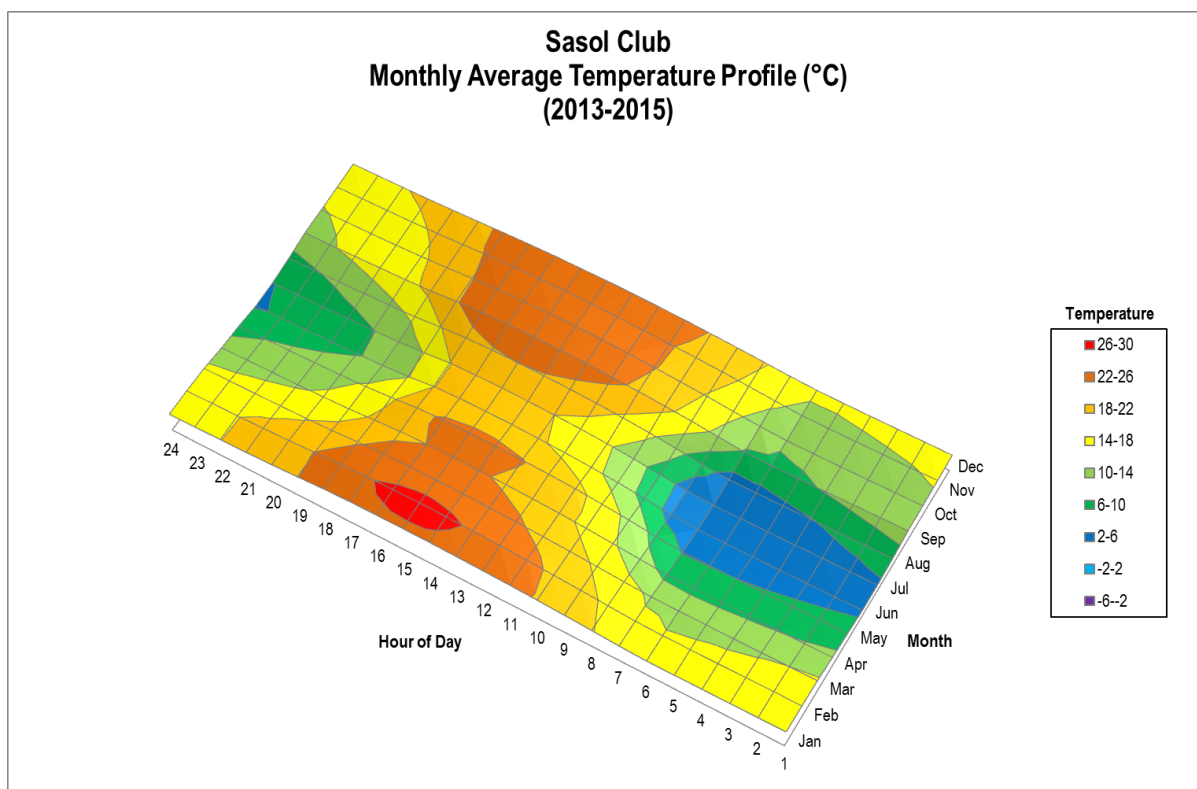


Figure 5-13: Monthly average temperature profile for Secunda Club (2013 – 2015)

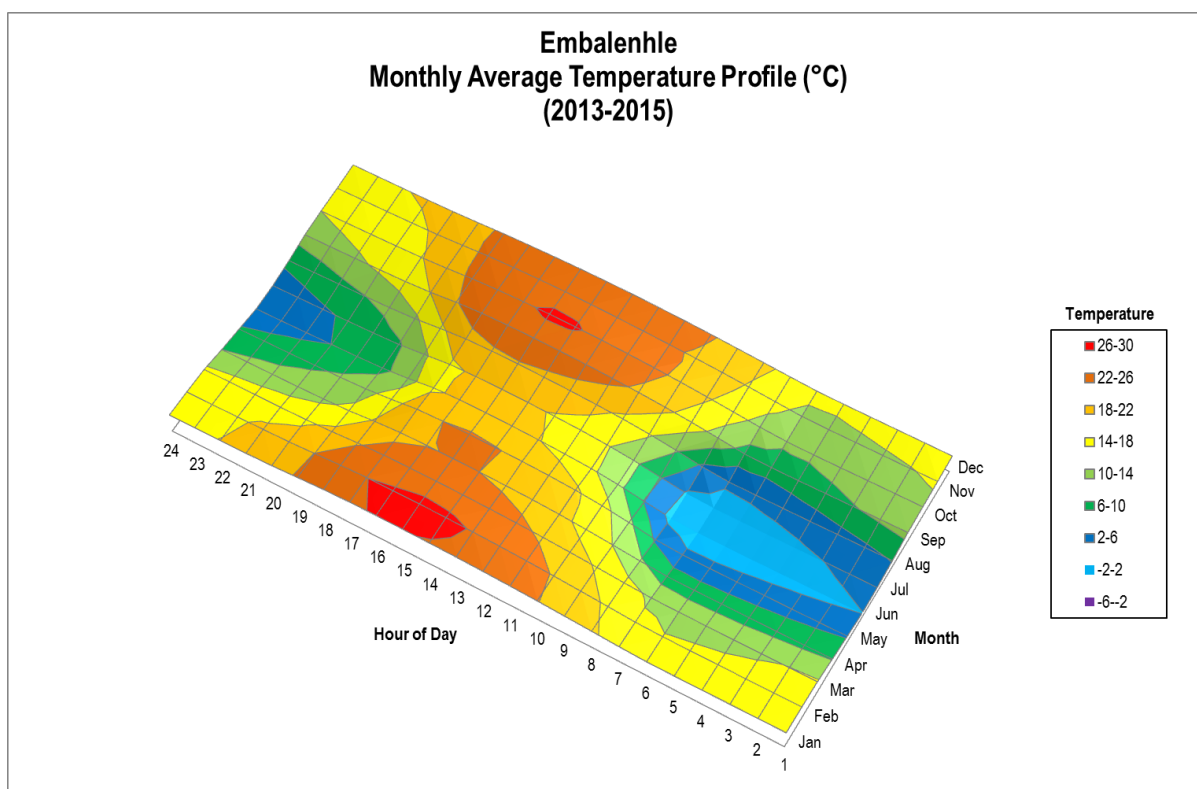
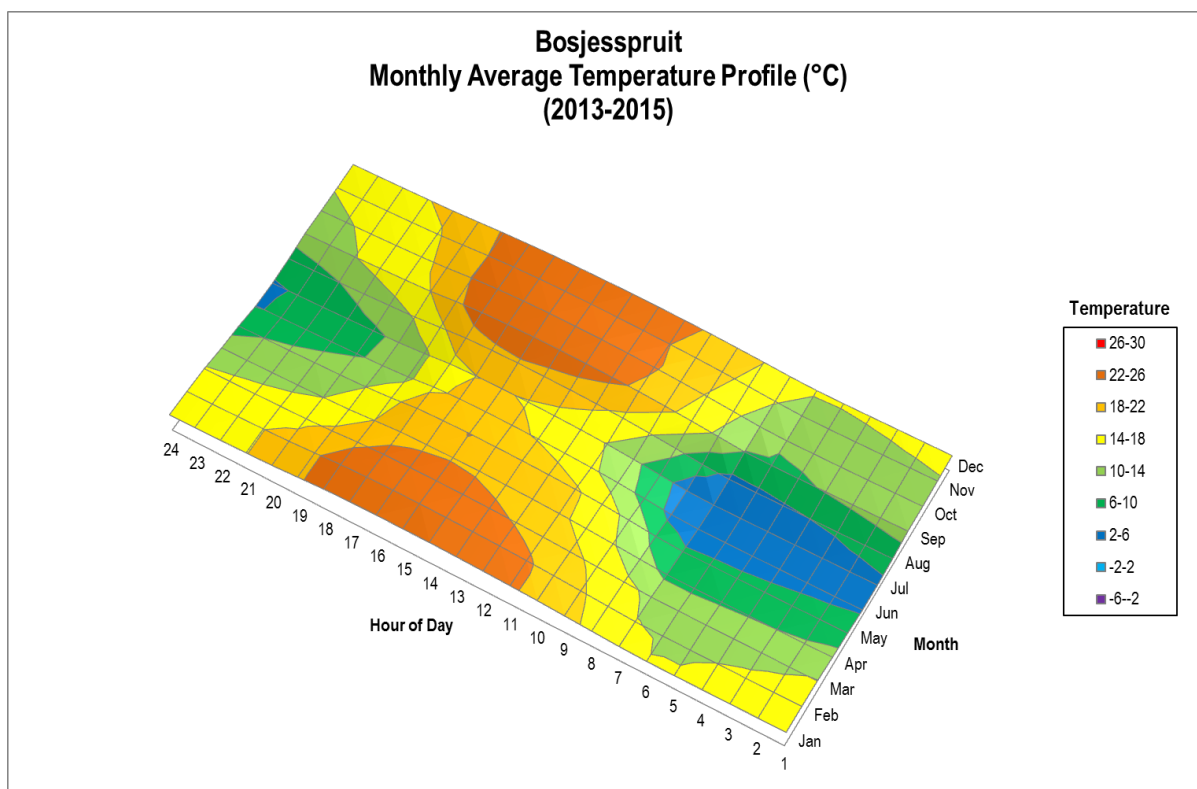


Figure 5-14: Monthly average temperature profile for Embalenhle (2013 – 2015)



**Figure 5-15: Monthly average temperature profile for Bosjesspruit (2013 – 2015)**

#### 5.1.5.3 Atmospheric Stability

The atmospheric boundary layer properties are described by two parameters; the boundary layer depth and the Monin-Obukhov length.

The Monin-Obukhov length (L<sub>Mo</sub>) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

Diurnal variation in atmospheric stability, as calculated from on-site data (Tiwary and Colls, 2010), and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 5-16. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions.

For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called looping (Figure 5-16 (c)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as coning (Figure 5-16 (b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called fanning (Figure 5-16 (a)) (Tiwary & Colls, 2010).

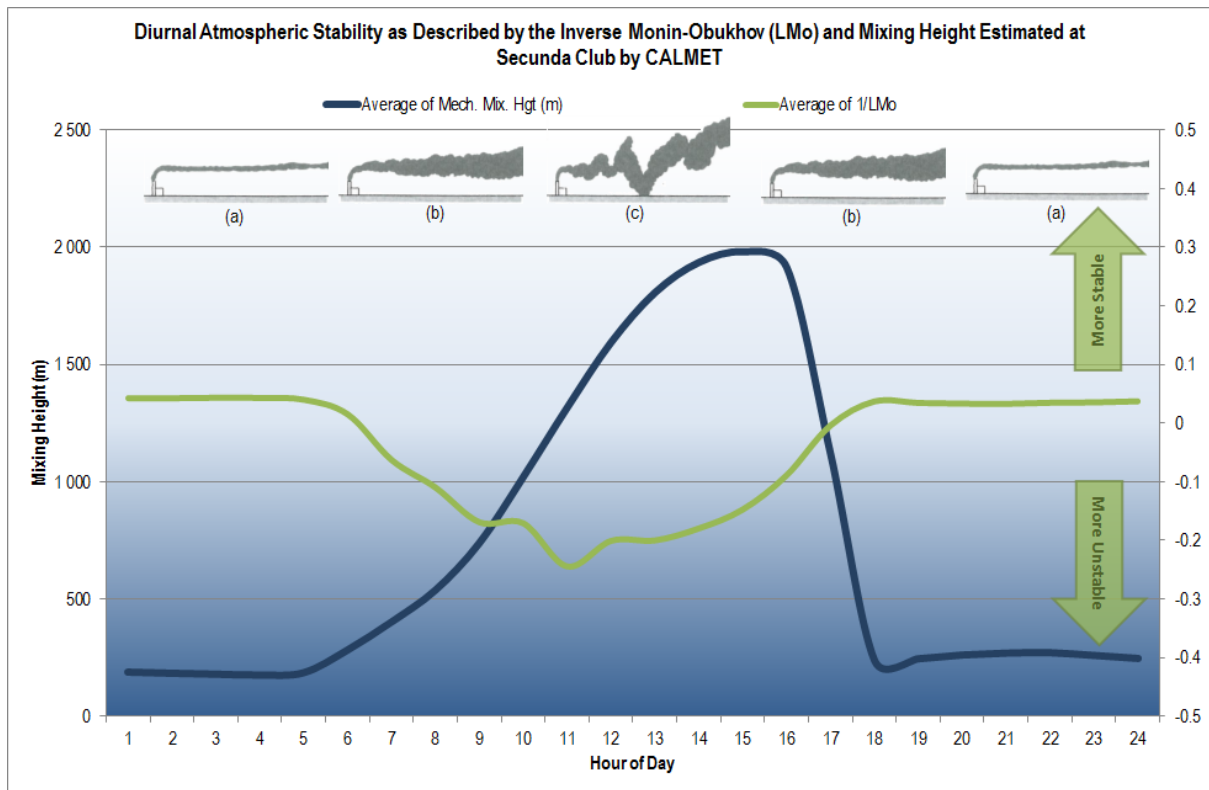


Figure 5-16: Diurnal atmospheric stability (extracted from CALMET at the Secunda Club monitoring point)

#### 5.1.5.4 Air Quality Monitoring data

Time series of the measured ambient air quality data is provided in Appendix F. A summary of ambient data measured at Secunda Club, Embalenhle, Bosjesspruit by Sasol, and at the Department of Environmental Affairs (DEA)-managed Secunda station for the period 2013 – 2015 is provided in Table 5-9, Table 5-10, Table 5-11 and Table 5-12 respectively.



**Table 5-9: Summary of the ambient measurements at Secunda Club for the period 2013-2015 (units: µg/m³)**

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
NO <sub>2</sub>							
2013	64%	160.2	90.8	52.2	18.4	24.3	3
2014	93%	229.0	97.1	49.6	20.3	25.7	
2015	93%	185.8	83.4	41.7	17.1	22.0	
Average			90.4	47.8	18.6	24.0	
SO <sub>2</sub>							
2013	100%	426.3	160.6	47.7	8.9	19.6	1
2014	97%	474.4	190.9	54.5	12.9	23.7	11
2015	100%	426.3	166.1	46.0	7.4	18.4	7
Average			172.5	49.4	9.7	20.5	
CO							
2013	100%	1.9	0.8	0.5	0.2	0.2	
2014	99%	2.2	1.0	0.6	0.3	0.3	
2015	100%	1.2	0.9	0.5	0.2	0.2	
Average			0.9	0.5	0.2	0.3	
Period	Availability	Daily				Annual Average	No of recorded daily exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
SO <sub>2</sub>							
2013	100%	84.5	68.8	36.4	16.9	19.6	
2014	97%	102.1	86.2	45.6	20.6	23.8	
2015	100%	114.6	62.3	37.4	14.7	18.4	
Average			72.4	39.8	17.4	20.6	
PM <sub>10</sub>							
2013	97%	174.0	91.2	61.6	31.0	34.4	17
2014	95%	201.0	146.0	84.0	40.0	45.6	54
2015	24%	52.0	45.8	38.0	20.0	21.9	
Average			94.4	61.2	30.3	37.9	
PM <sub>2.5</sub>							
2013	98%	40.0	35.4	23.0	11.0	12.9	
2014	96%	43.0	37.5	27.0	14.0	15.3	
2015	32%	25.0	23.0	17.3	8.0	9.8	
Average			32.0	22.4	11.0	6.0	
O <sub>3</sub>							
2013	82%	171.8	140.7	91.0	56.6	61.8	12
2014	88%	140.5	125.6	94.7	56.0	61.9	5
2015	92%	130.9	118.3	97.4	68.9	69.9	2
Average			128.2	94.4	60.5	64.6	



**Table 5-10: Summary of the ambient measurements at Embaleh for the period 2013-2015 (units: µg/m³)**

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
NO <sub>2</sub>							
2013	74%	169.2	85.5	40.7	9.2	15.5	0
2014	86%	162.6	68.2	34.4	10.9	14.8	0
2015	72%	118.9	80.5	47.4	14.5	20.3	0
Average			78.1	40.8	11.6	16.8	
SO <sub>2</sub>							
2013	92%	557.4	180.1	56.2	15.1	25.3	13
2014	95%	433.5	188.1	49.8	12.3	22.9	8
2015	97%	397.5	142.9	43.8	10.4	19.5	4
Average			170.4	49.9	12.6	22.5	
Benzene							
2013	80%	224.2	12.9	3.7	0.3	1.4	
2014	0%						
2015	0%						
Average			12.9	3.7	0.3	22.5	
Period	Availability	Daily				Annual Average	No of recorded daily exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
SO <sub>2</sub>							
2013	92%	126.8	80.4	48.7	21.7	25.2	1
2014	95%	100.9	92.2	42.1	18.9	22.8	0
2015	97%	89.5	62.2	36.2	15.8	19.3	0
Average			78.3	42.3	18.8	22.4	
PM <sub>10</sub>							
2013	56%	194.0	146.8	99.2	42.0	53.0	47
2014	87%	289.0	182.0	122.0	60.0	67.9	119
2015	24%	68.0	67.1	57.8	34.0	36.3	0
Average			132.0	93.0	45.3	52.4	
PM <sub>2.5</sub>							
2013	56%	52.0	43.0	31.0	14.0	16.0	0
2014	88%	66.0	45.8	34.9	17.0	19.0	1
2015	47%	31.0	26.3	18.8	12.0	12.2	0
Average			36.0	26.9	14.5	15.6	

**Table 5-11: Summary of the ambient measurements at Bosjesspruit for the period 2013-2015 (units: µg/m³)**

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
NO <sub>2</sub>							
2013	91%	142.0	64.4	31.0	7.0	12.1	
2014	94%	170.2	71.7	34.9	11.4	15.9	
2015	72%	129.7	61.5	28.4	10.7	13.9	
Average			65.9	31.4	9.7	14.0	
SO <sub>2</sub>							
2013	95%	459.6	184.7	52.0	5.3	18.6	10
2014	95%	555.5	194.0	50.6	6.7	19.8	27
2015	93%	459.6	203.2	48.5	7.4	19.9	8
Average			194.0	50.4	6.5	19.4	
H <sub>2</sub> S							
2013	84%	359.4	77.5	7.7	1.4	5.0	24
2014	96%	319.9	70.1	7.4	1.7	4.7	19
2015	92%	202.1	84.1	10.1	3.1	6.6	20
Average			77.2	8.4	2.0	19.4	
Period	Availability	Daily				Annual Average	No of recorded hourly exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
SO <sub>2</sub>							
2013	95%	81.9	68.2	40.7	14.7	18.6	0
2014	95%	233.4	82.3	42.0	15.3	19.8	1
2015	93%	90.4	77.8	40.6	16.8	19.9	0
Average			76.1	41.1	15.6	19.4	
<b>Note:</b> Hourly H <sub>2</sub> S exceedances calculated based on the recommended 4-hour acute exposure limit proposed by Haahtele <i>et al.</i> , (1992)							

**Table 5-12: Summary of the ambient measurements at Secunda for the period 2013-2015 (units:  $\mu\text{g}/\text{m}^3$ )**

Period	Availability	Hourly				Annual Average	No of recorded hourly exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
NO <sub>2</sub>							
2013	99%	169.0	69.4	44.2	21.2	23.5	
2014	77%	119.7	77.2	50.3	26.1	27.9	
2015	49%	239.3	154.0	74.5	23.8	34.2	4
Average			100.2	56.4	23.7	27.4	
SO <sub>2</sub>							
2013	80%	634.4	167.6	56.3	16.9	26.4	12
2014	77%	484.7	195.7	61.2	17.4	28.5	6
2015	53%	322.9	126.0	36.9	6.8	15.2	
Average			163.1	51.5	13.7	24.2	
Benzene							
2013	69%	231.5	56.8	6.2	0.3	3.4	
2014	37%	111.5	17.3	4.3	0.4	1.8	
2015	8%	1.4	1.4	1.4	1.4	1.4	
Average			25.2	4.0	0.7	2.7	
Period	Availability	Daily				Annual Average	No of recorded daily exceedances
		Max	99 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile		
SO <sub>2</sub>							
2013	80%	48.5	34.4	17.9	7.9	26.4	0
2014	77%	47.2	36.4	20.7	8.7	28.5	0
2015	53%	39.7	21.8	10.9	4.2	15.2	0
Average			30.9	16.5	6.9	24.2	
PM <sub>10</sub>							
2013	99%	496.9	310.1	167.4	48.8	71.8	134
2014	75%	278.7	219.0	140.6	29.3	54.1	75
2015	49%	111.5	98.7	37.0	3.3	11.8	6
Average						52.0	
PM <sub>2.5</sub>							
2013	99%	131.4	107.5	71.8	18.1	29.5	47
2014	75%	117.7	109.1	66.4	14.8	25.8	31
2015	49%	62.7	37.4	18.5	2.5	6.7	0
Average			84.7	52.2	11.8	23.0	
O <sub>3</sub>							
2013	13%	48.7	46.2	36.3	0.0	11.9	
2014	80%	52.1	48.7	35.1	20.7	22.0	
2015	55%	89.4	71.0	50.1	29.4	30.9	
Average			55.3	40.5	16.7	24.4	

The following graphs summarise the observed concentrations of SO<sub>2</sub>, NO<sub>2</sub> and PM<sub>10</sub> at Secunda Club, Embalenhle, Bosjesspruit, and, Secunda monitoring stations for the years 2013 to 2015. The NAAQS have been included in the graphs for:

- SO<sub>2</sub> hourly (permitted 88 hourly exceedances of 350  $\mu\text{g}/\text{m}^3$ ) and daily average (permitted 4 daily exceedances of 125  $\mu\text{g}/\text{m}^3$ )
- NO<sub>2</sub> hourly average (permitted 88 hourly exceedances of 200  $\mu\text{g}/\text{m}^3$ ); and,
- PM<sub>10</sub> daily average (permitted 4 daily exceedances of 75  $\mu\text{g}/\text{m}^3$ ; 2015 standards).

The hourly 99<sup>th</sup> percentiles for SO<sub>2</sub> were below the limit value of 350  $\mu\text{g}/\text{m}^3$  at all four stations for all three years (Figure 5-17, Figure 5-19, Figure 5-21 and Figure 5-23). The daily 99<sup>th</sup> percentiles for SO<sub>2</sub> were below the limit value (125  $\mu\text{g}/\text{m}^3$ ) at

all the stations: Secunda Club (Figure 5-18), Embalenhle (Figure 5-20), Bosjesspruit (Figure 5-22), and Secunda (DEA) (Figure 5-24).

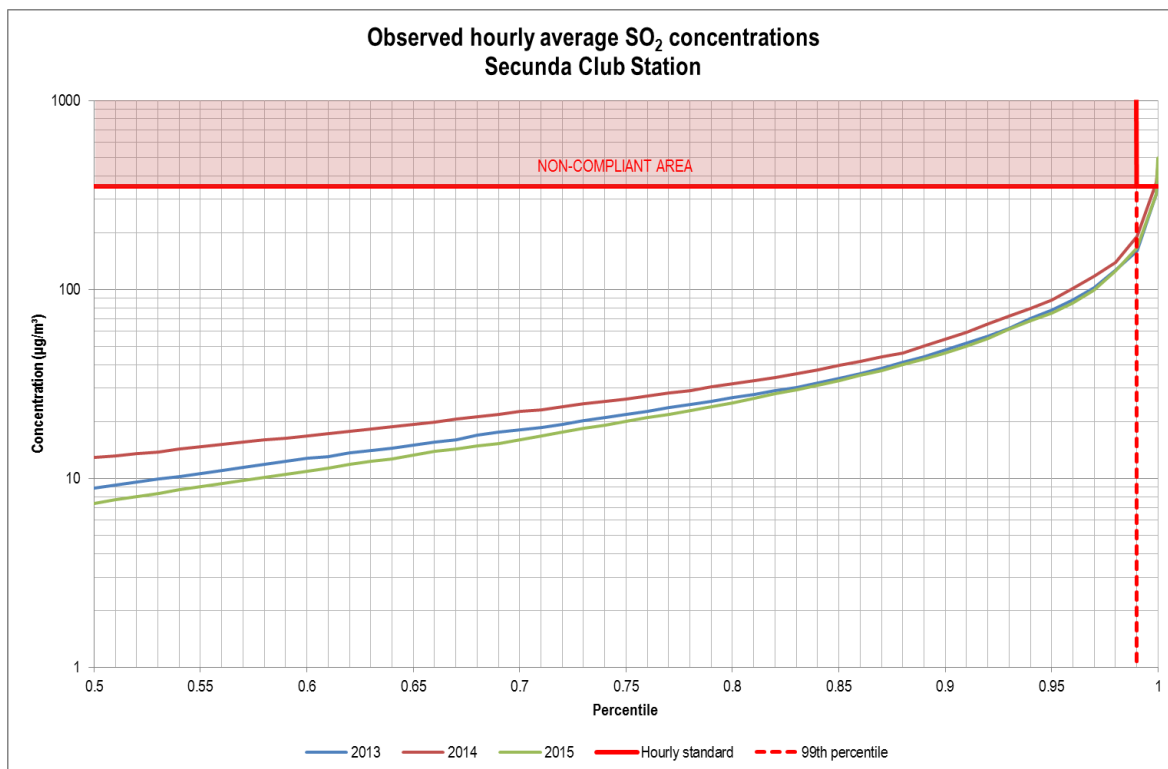


Figure 5-17: Observed hourly average SO<sub>2</sub> concentrations at Secunda Club

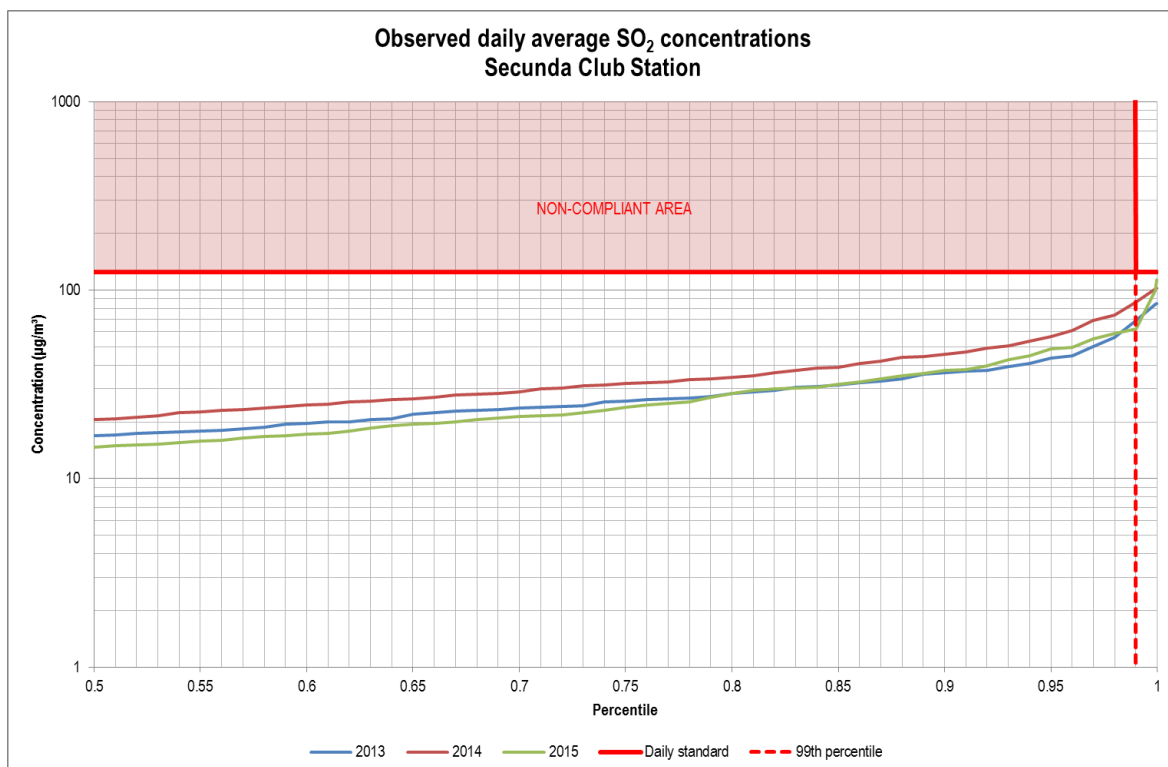


Figure 5-18: Observed daily average SO<sub>2</sub> concentrations at Secunda Club

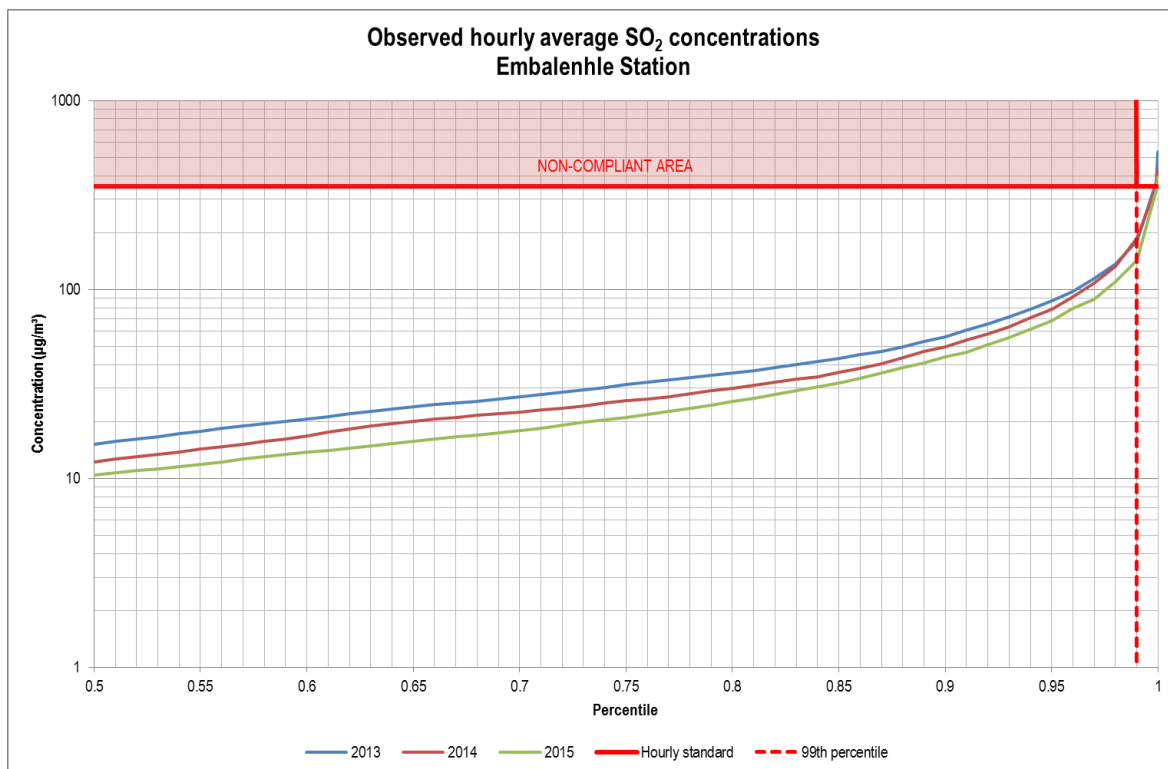


Figure 5-19: Observed hourly average SO<sub>2</sub> concentrations at Embalenhle

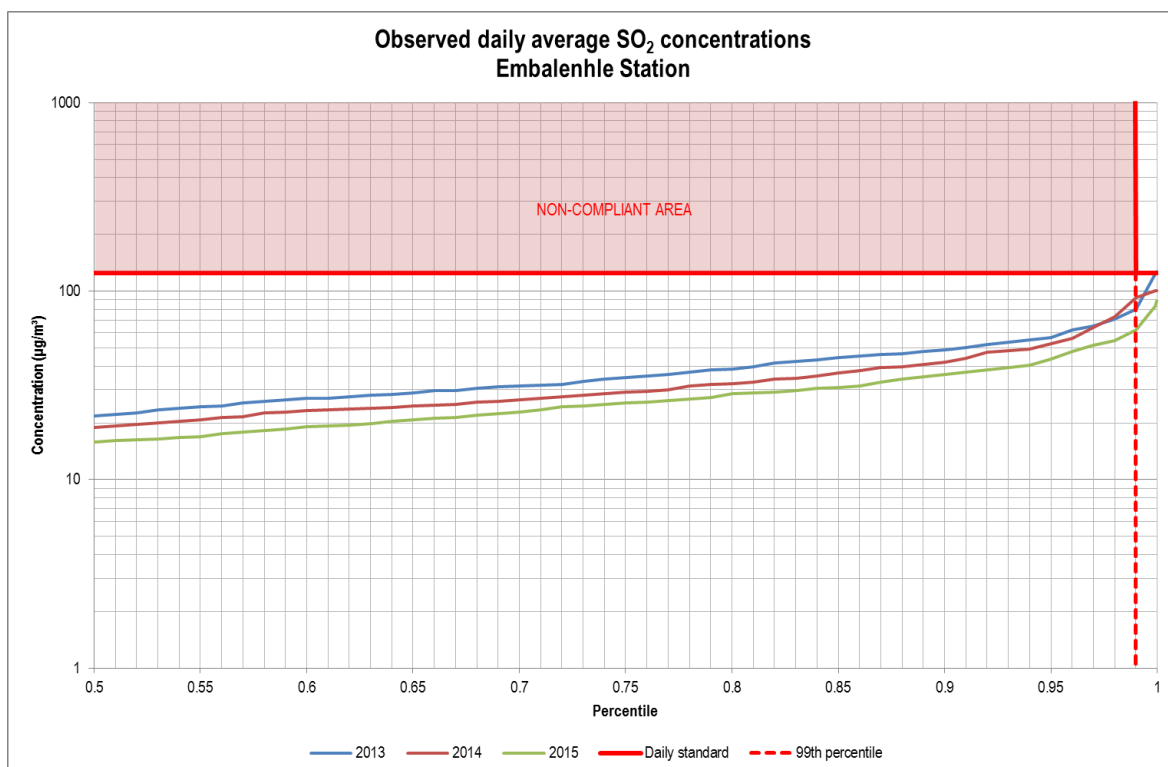


Figure 5-20: Observed daily average SO<sub>2</sub> concentrations at Embalenhle

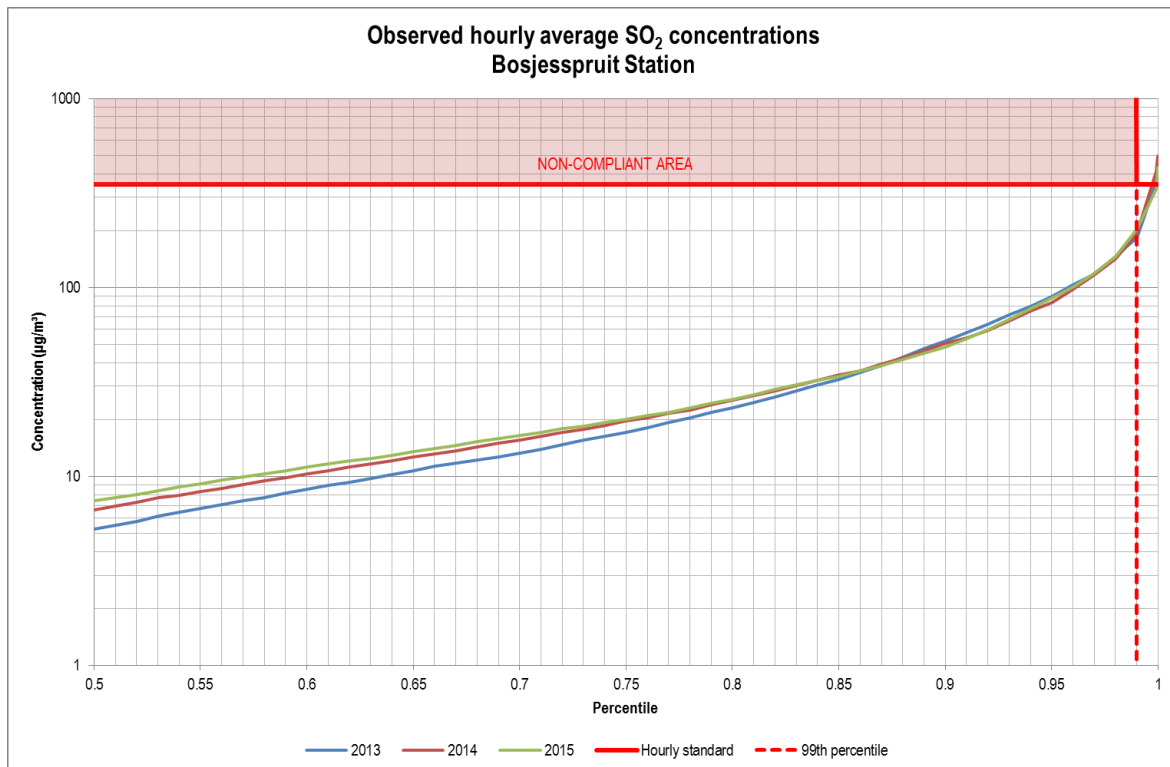


Figure 5-21: Observed hourly average SO<sub>2</sub> concentrations at Bosjesspruit

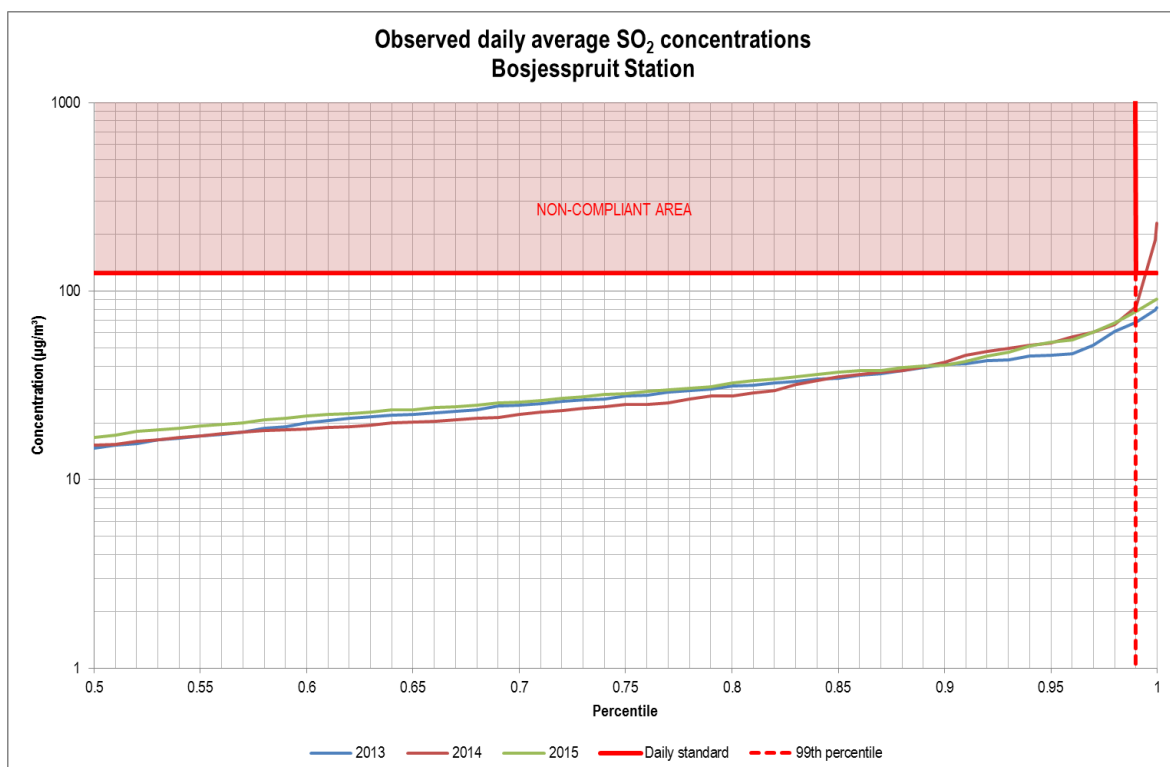


Figure 5-22: Observed daily average SO<sub>2</sub> concentrations at Bosjesspruit

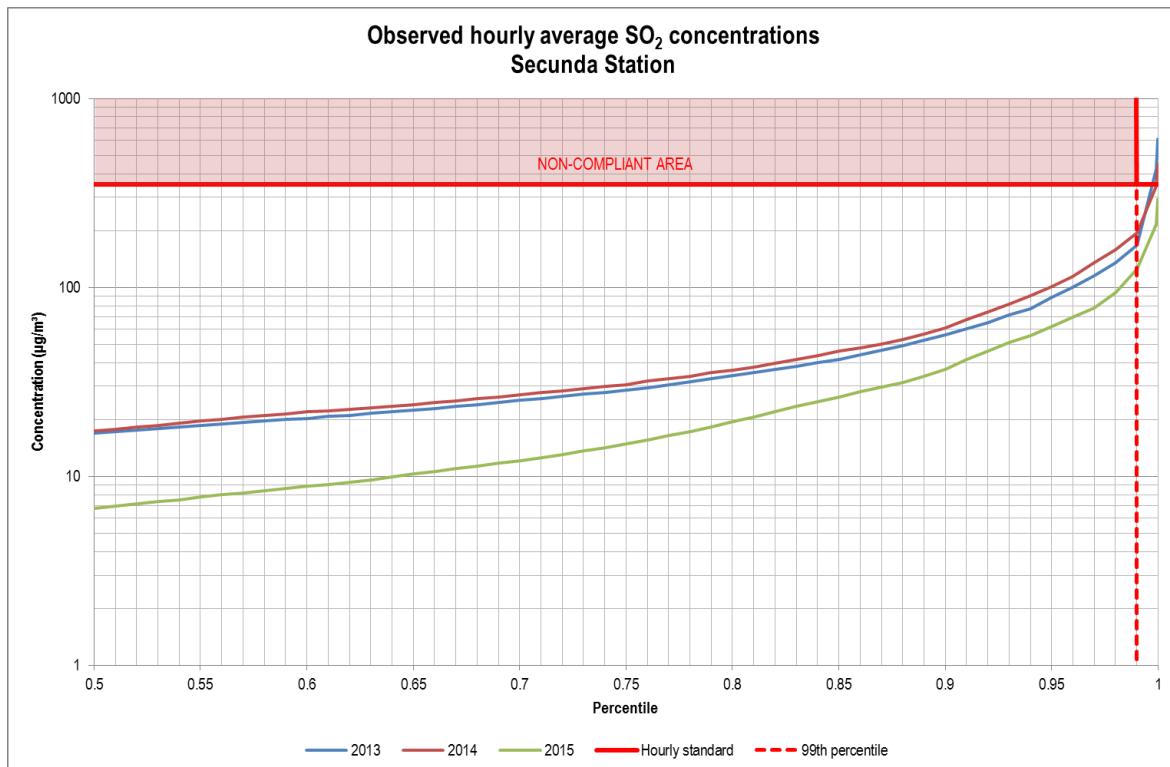


Figure 5-23: Observed hourly average SO<sub>2</sub> concentrations at Secunda (DEA)

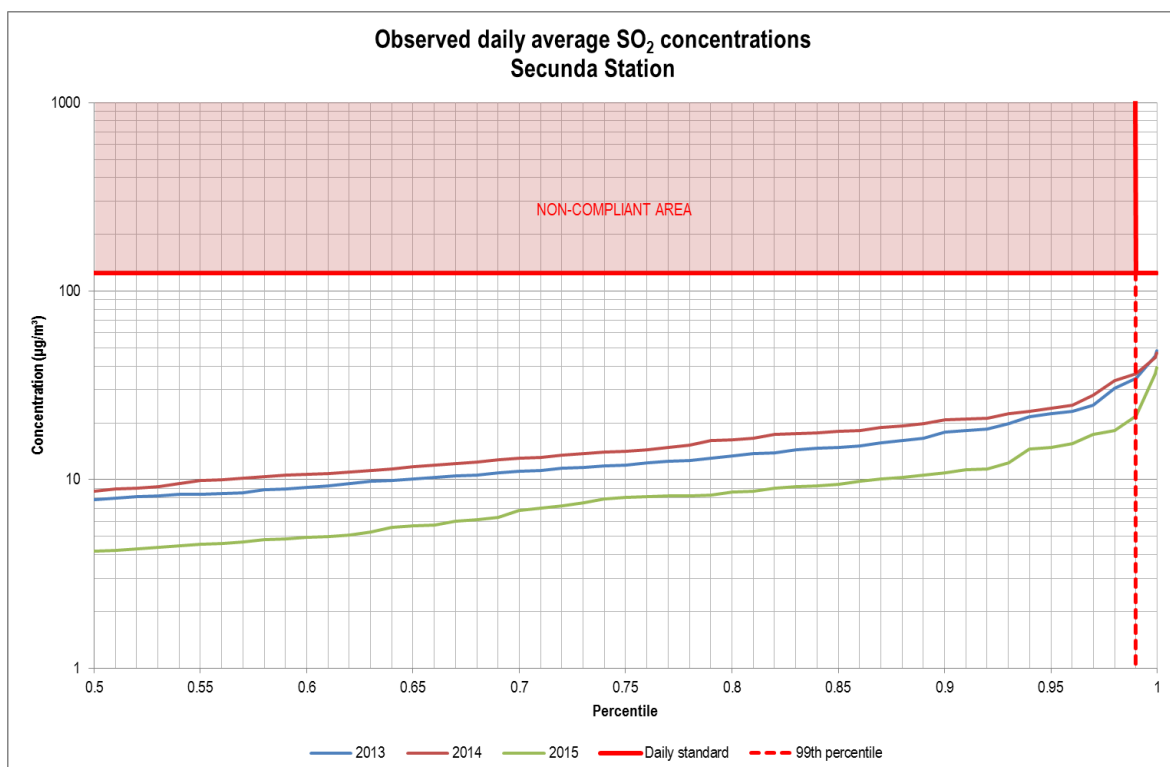


Figure 5-24: Observed daily average SO<sub>2</sub> concentrations at Secunda (DEA)

The hourly 99<sup>th</sup> percentiles for NO<sub>2</sub> were below the limit value (200 µg/m<sup>3</sup>) at all stations and for all three years (Figure 5-25, Figure 5-26, Figure 5-27, and Figure 5-28).

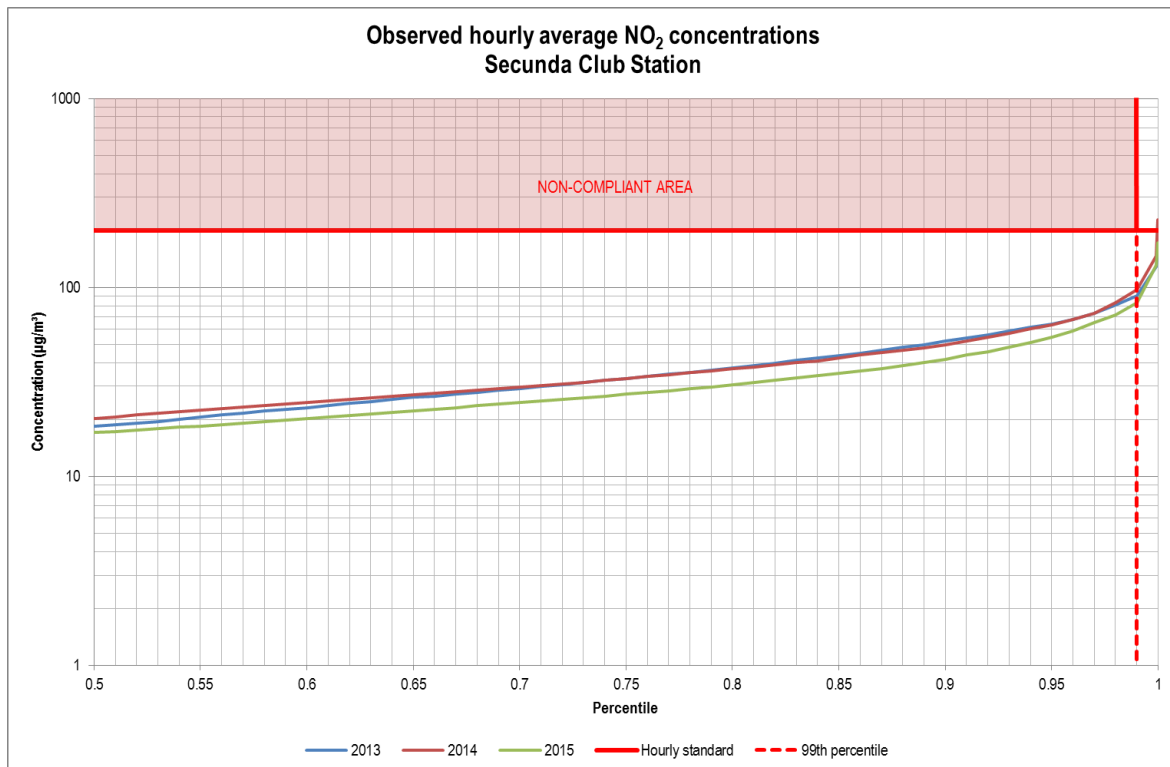


Figure 5-25: Observed hourly average NO<sub>2</sub> concentrations at Secunda Club

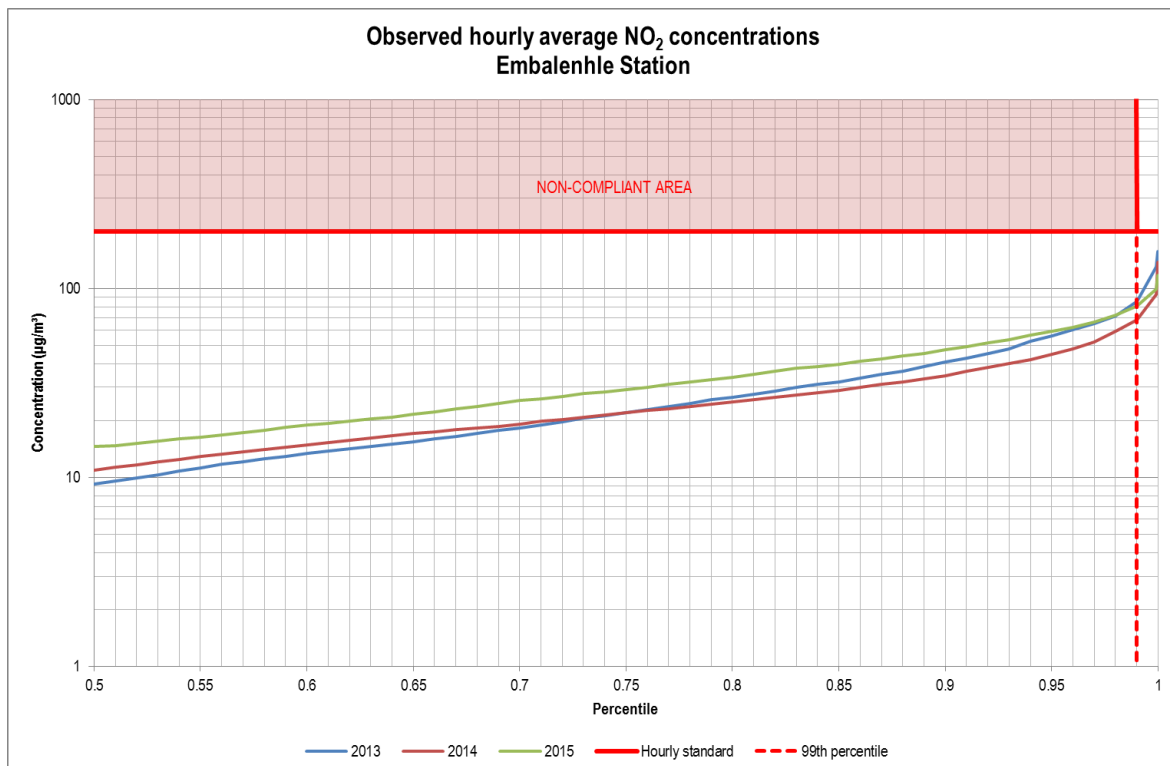


Figure 5-26: Observed hourly average NO<sub>2</sub> concentrations at Embalenhle



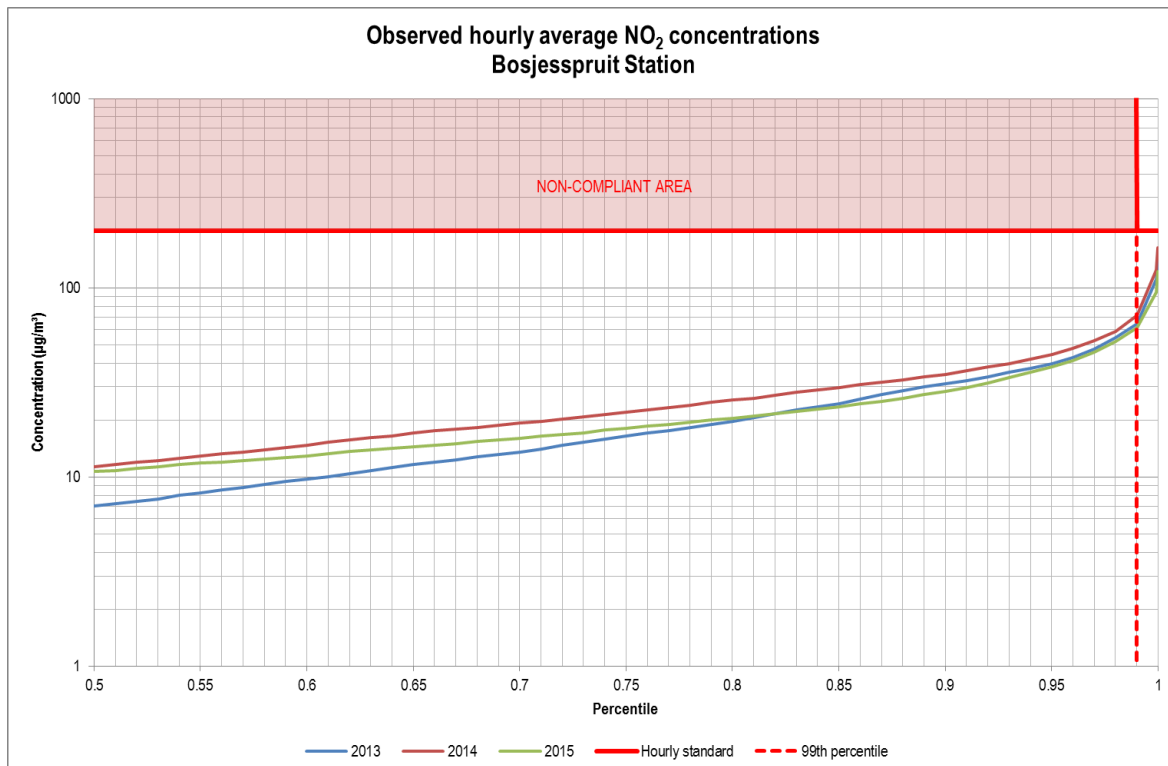


Figure 5-27: Observed hourly average NO<sub>2</sub> concentrations at Bosjesspruit

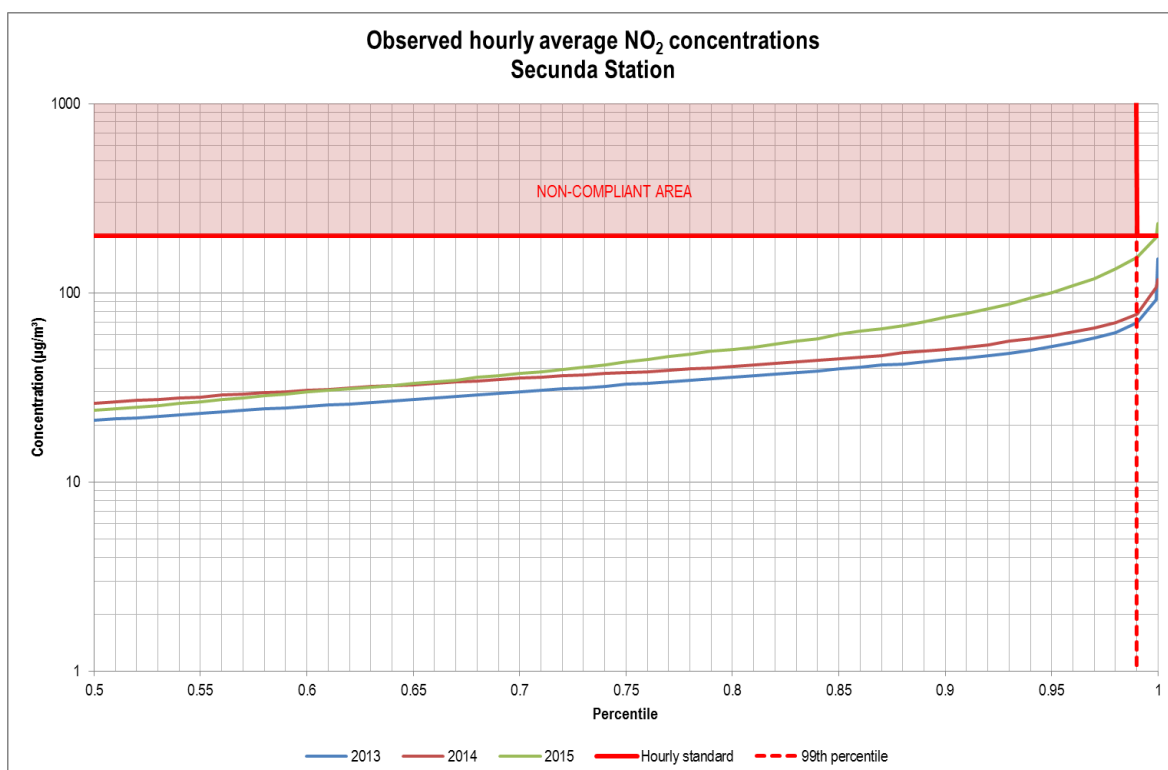


Figure 5-28: Observed hourly average NO<sub>2</sub> concentrations at Secunda (DEA)

The daily 99<sup>th</sup> percentiles for PM<sub>10</sub> exceeded the limit value (75 µg/m<sup>3</sup>; 2015 standard) at the Secunda Club (Figure 5-29) and Embalenhle stations (Figure 5-30) in 2013 and 2014. At the Secunda (DEA) station, daily 99<sup>th</sup> percentile PM<sub>10</sub> exceeded

the limit value for all three years. While the SO<sub>2</sub> and NO<sub>2</sub> annual averages were below the NAAQS, the PM<sub>10</sub> annual averages exceeded the 2015 limit value of 40 µg/m<sup>3</sup> for 2013 and 2014 at Embalenhle and Secunda (DEA) stations.

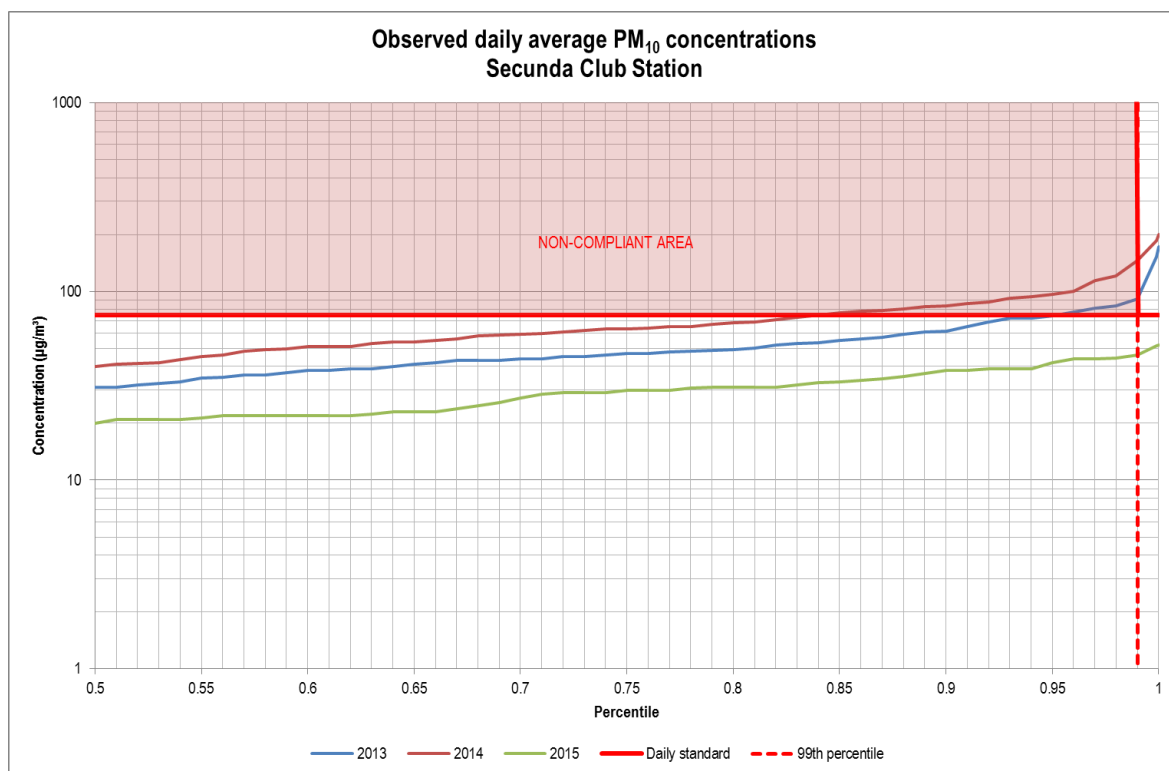


Figure 5-29: Observed daily average PM<sub>10</sub> concentrations at Secunda Club

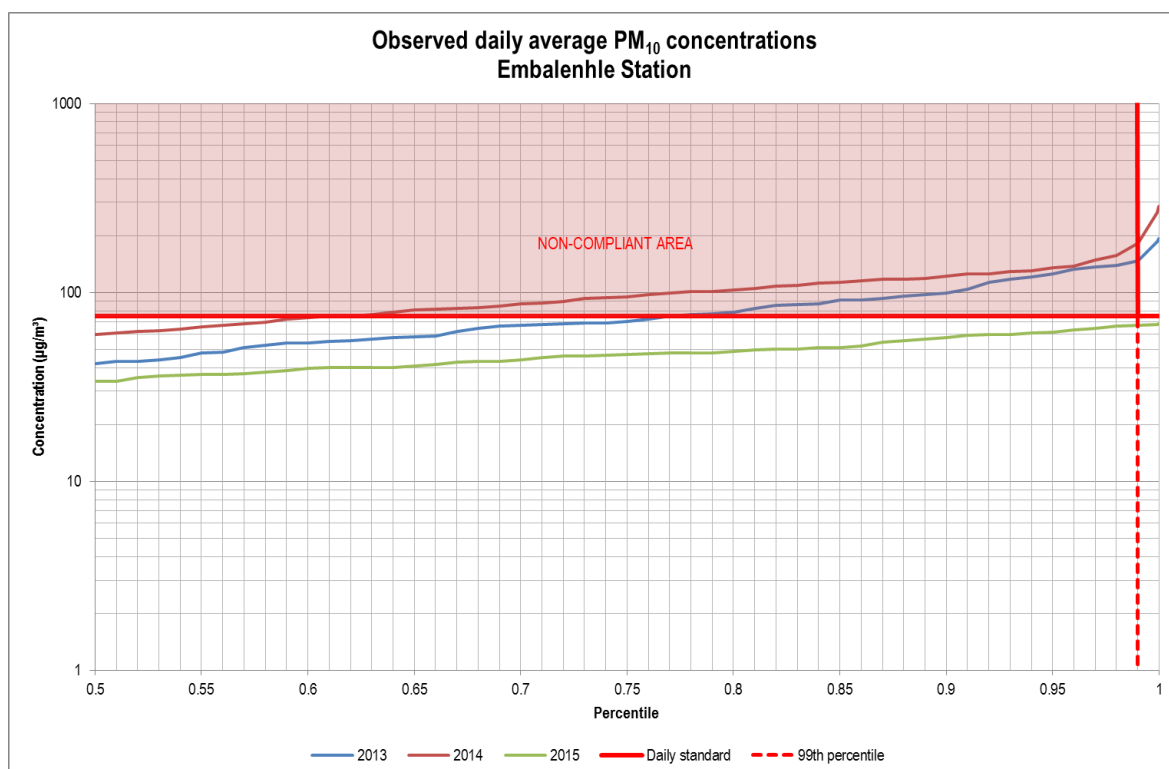
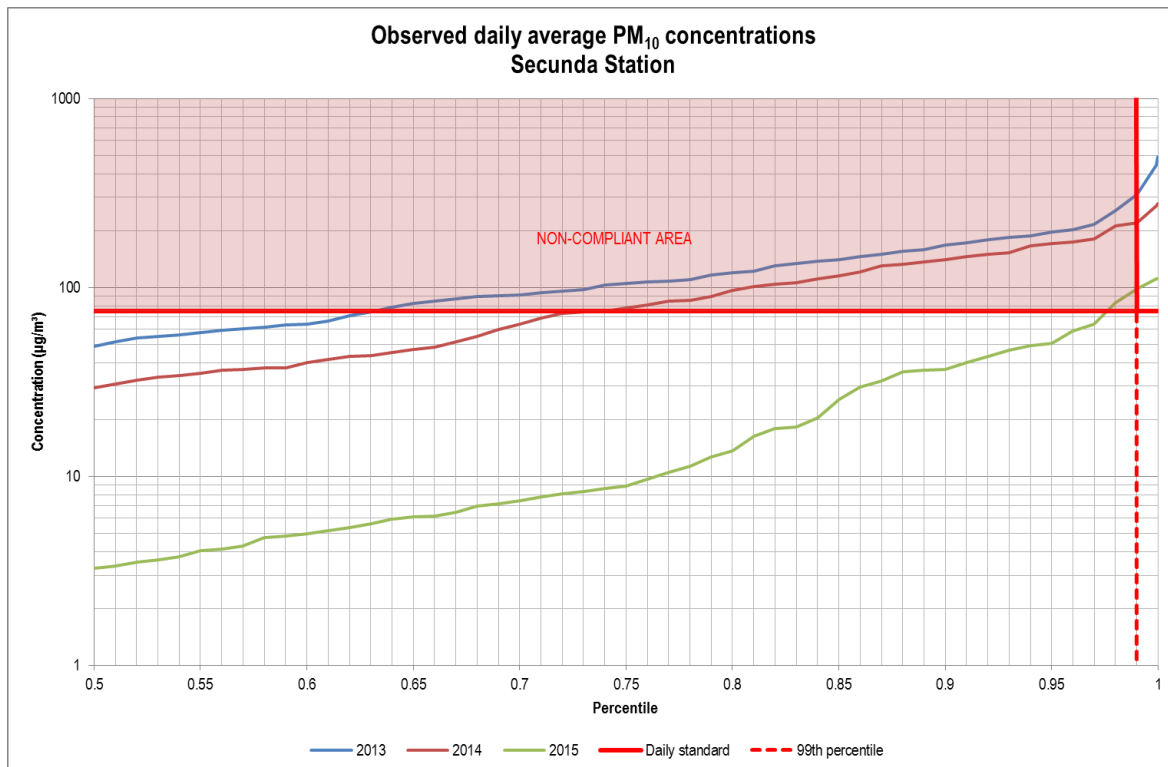


Figure 5-30: Observed daily average PM<sub>10</sub> concentrations at Embalenhle



**Figure 5-31: Observed daily average PM<sub>10</sub> concentrations at Secunda (DEA)**

Time series plots (mean with 95% confidence interval) of ambient SO<sub>2</sub>, NO<sub>2</sub>, H<sub>2</sub>S, PM<sub>10</sub>, and benzene concentrations measured at Secunda Club (Figure 5-32 and Figure 5-33), and Embalenhle (Figure 5-34 to Figure 5-36) Bosjesspruit (Figure 5-37 and Figure 5-38), and Secunda (DEA) (Figure 5-39 to Figure 5-41) show the variation of these pollutants over daily, weekly and annual cycles.

The daily SO<sub>2</sub> show a typically industrial signature with increased SO<sub>2</sub> concentrations as just before midday due to the break-up of an elevated inversion layer, in addition to the development of daytime convective conditions causing the plume to be brought down to ground level relatively close to the point of release from tall stacks. Increased NO<sub>2</sub> concentrations during peak traffic times (07:00 to 08:00 and 16:00 to 18:00) illustrate the contribution of vehicle emissions to the ambient NO<sub>2</sub> concentrations. The winter (June, July and August) elevation of SO<sub>2</sub> and NO<sub>2</sub> shows the contribution of residential fuel burning to the ambient SO<sub>2</sub> and NO<sub>2</sub> concentrations.

Monthly variation of PM<sub>10</sub> shows a typical Highveld signature of elevated concentrations during winter months due to the greater contribution from domestic fuel burning, dust from uncovered soil and the lack of the settling influence of rainfall.

Large temporal variation is evident in H<sub>2</sub>S with different time-period patterns evident at each of the monitoring stations. Benzene shows a strong daily periodicity with elevated concentrations at 06:00 and 18:00. Benzene concentrations at both monitoring stations were elevated during late winter.

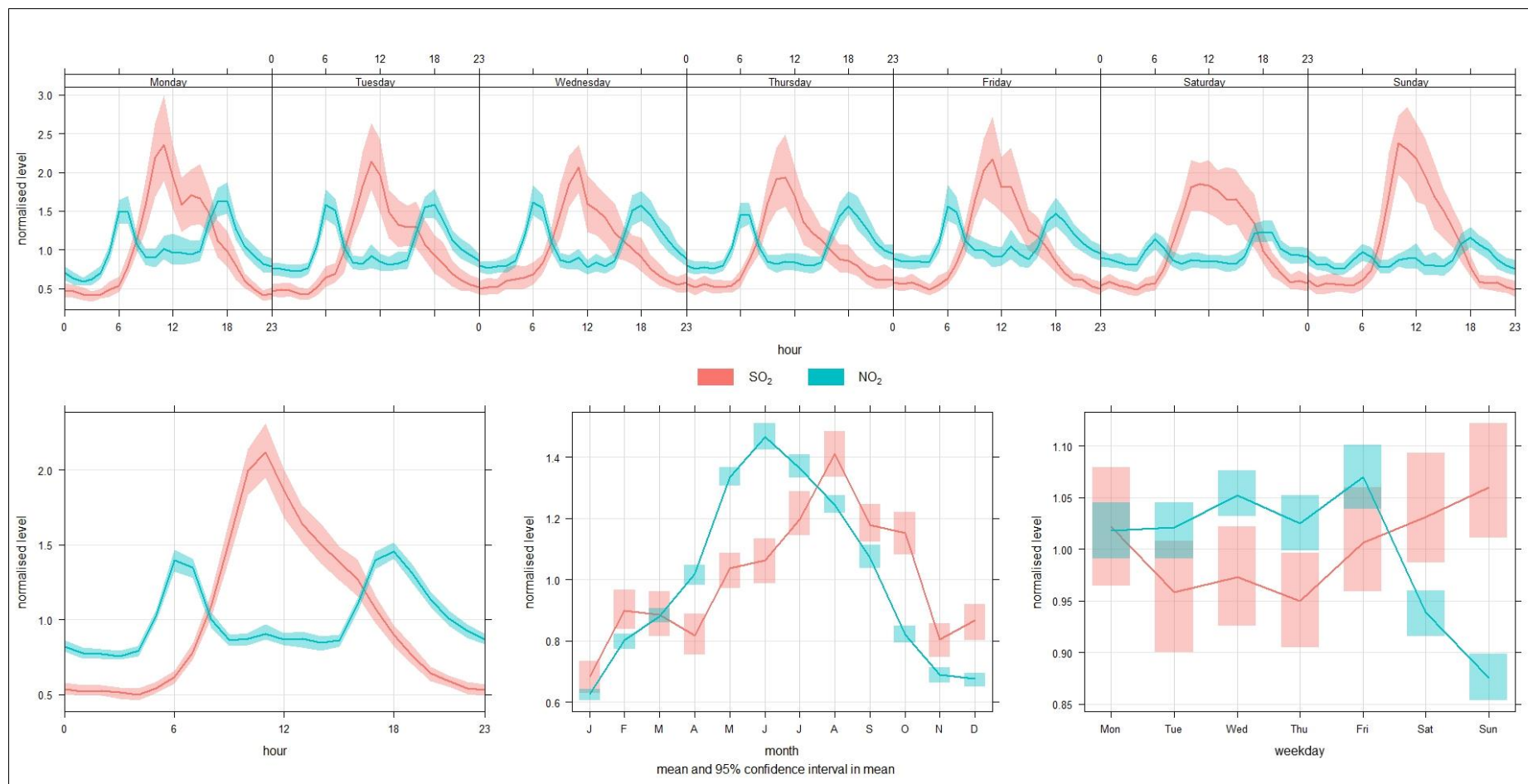


Figure 5-32: Time series plot of normalised observed SO<sub>2</sub> and NO<sub>2</sub> concentrations at Secunda Club (shaded area indicates 95<sup>th</sup> percentile confidence interval)

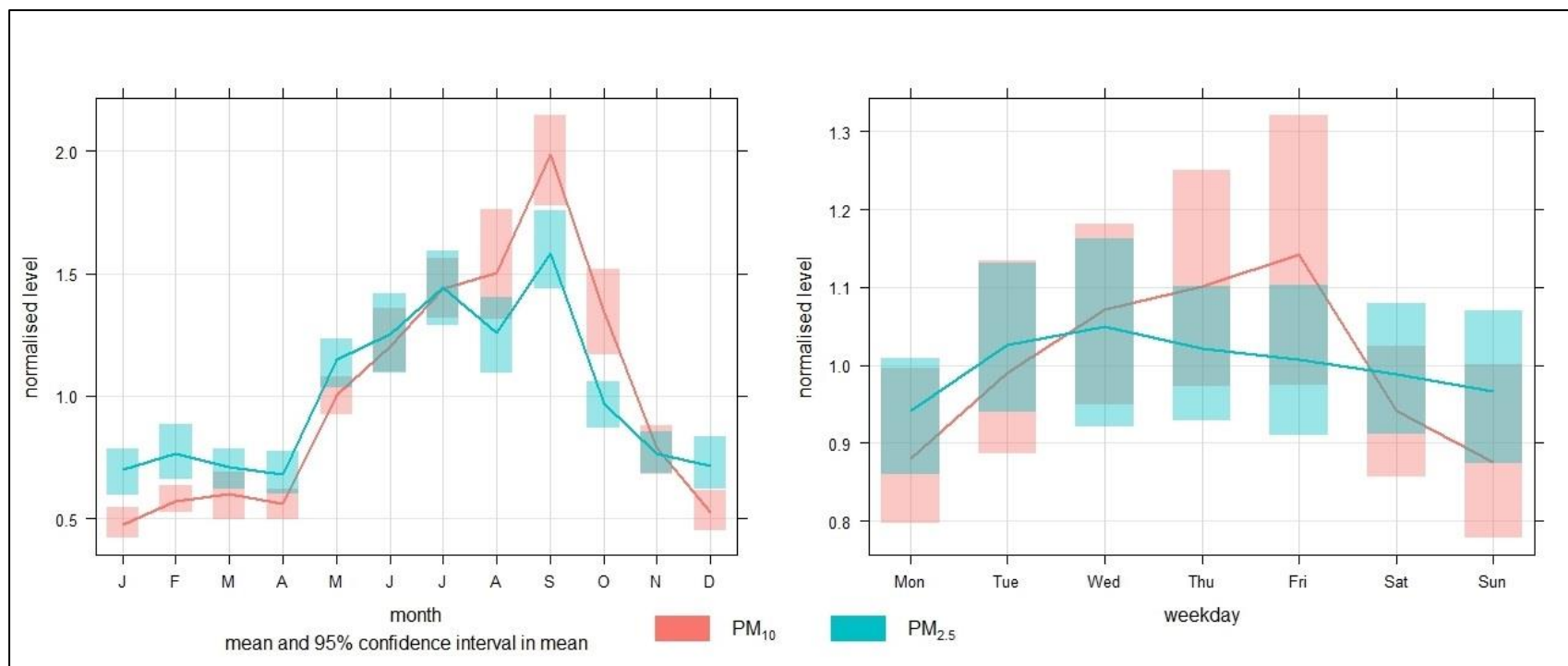


Figure 5-33: Time series plot of normalised observed PM<sub>10</sub> and PM<sub>2.5</sub> concentrations at Secunda Club (shaded area indicates 95<sup>th</sup> percentile confidence interval)

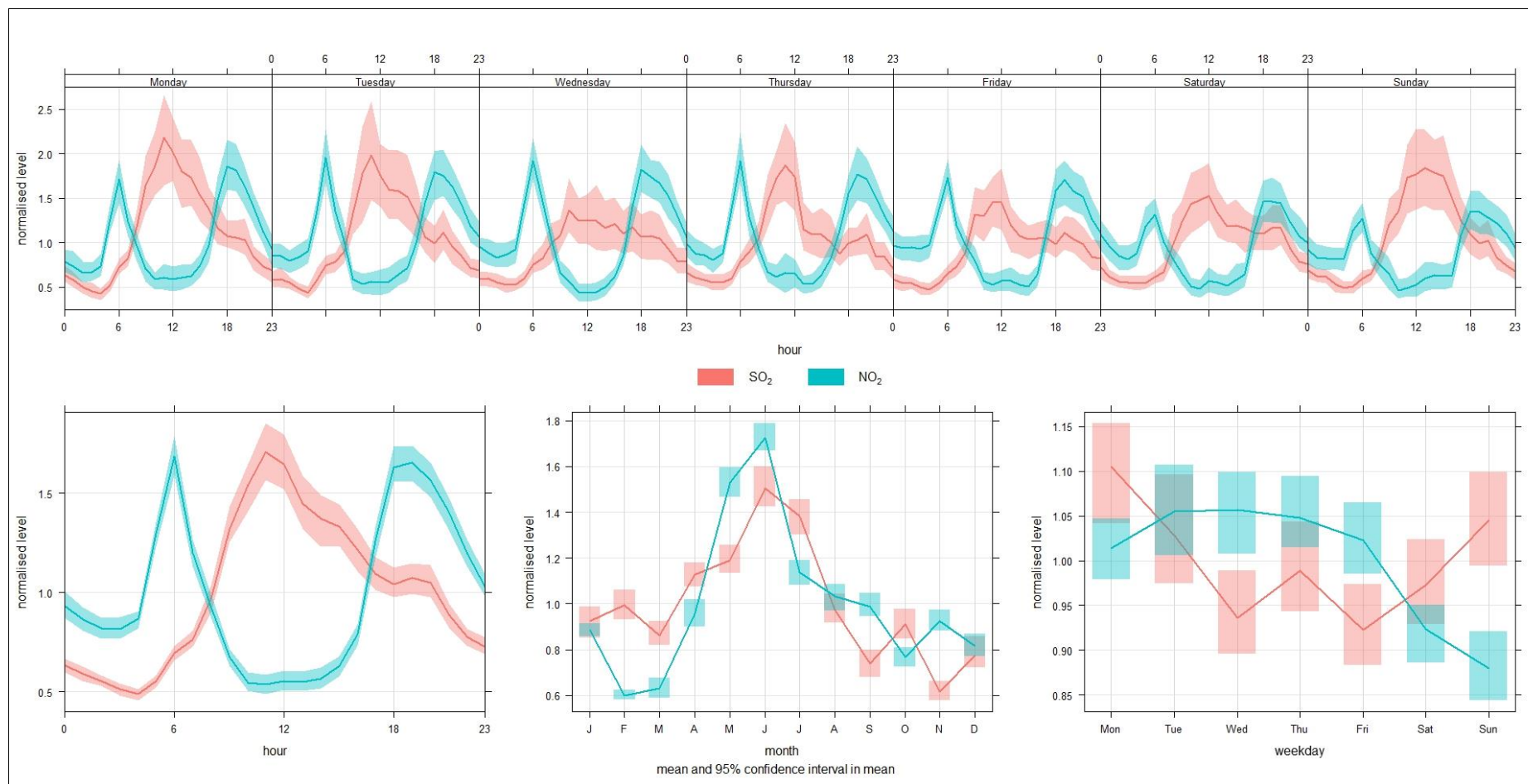


Figure 5-34: Time series plot of normalised observed SO<sub>2</sub> and NO<sub>2</sub> concentrations at Embalenhle (shaded area indicates 95<sup>th</sup> percentile confidence interval)

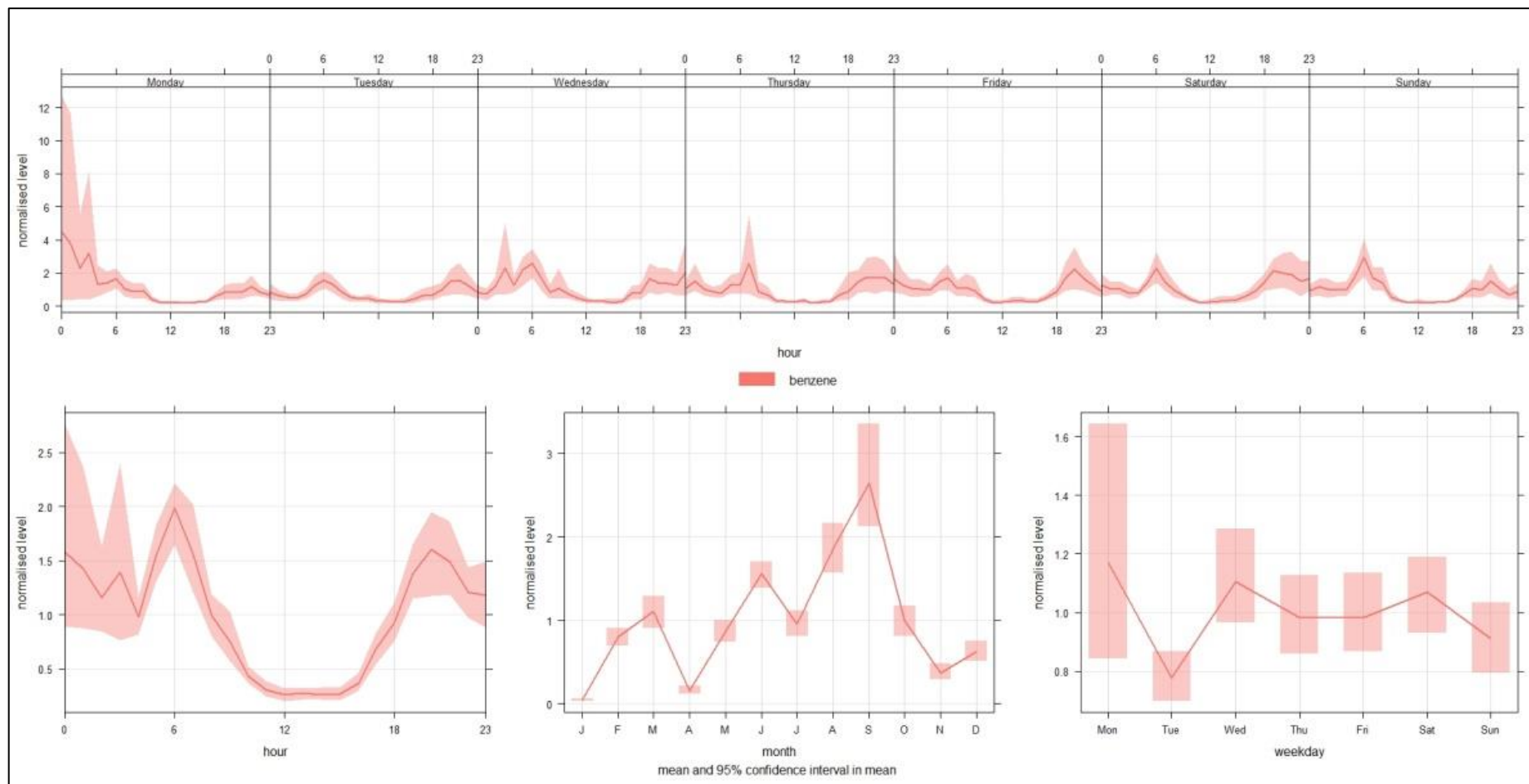


Figure 5-35: Time series plot of normalised observed benzene concentrations at Embalenhle (shaded area indicates 95<sup>th</sup> percentile confidence interval)

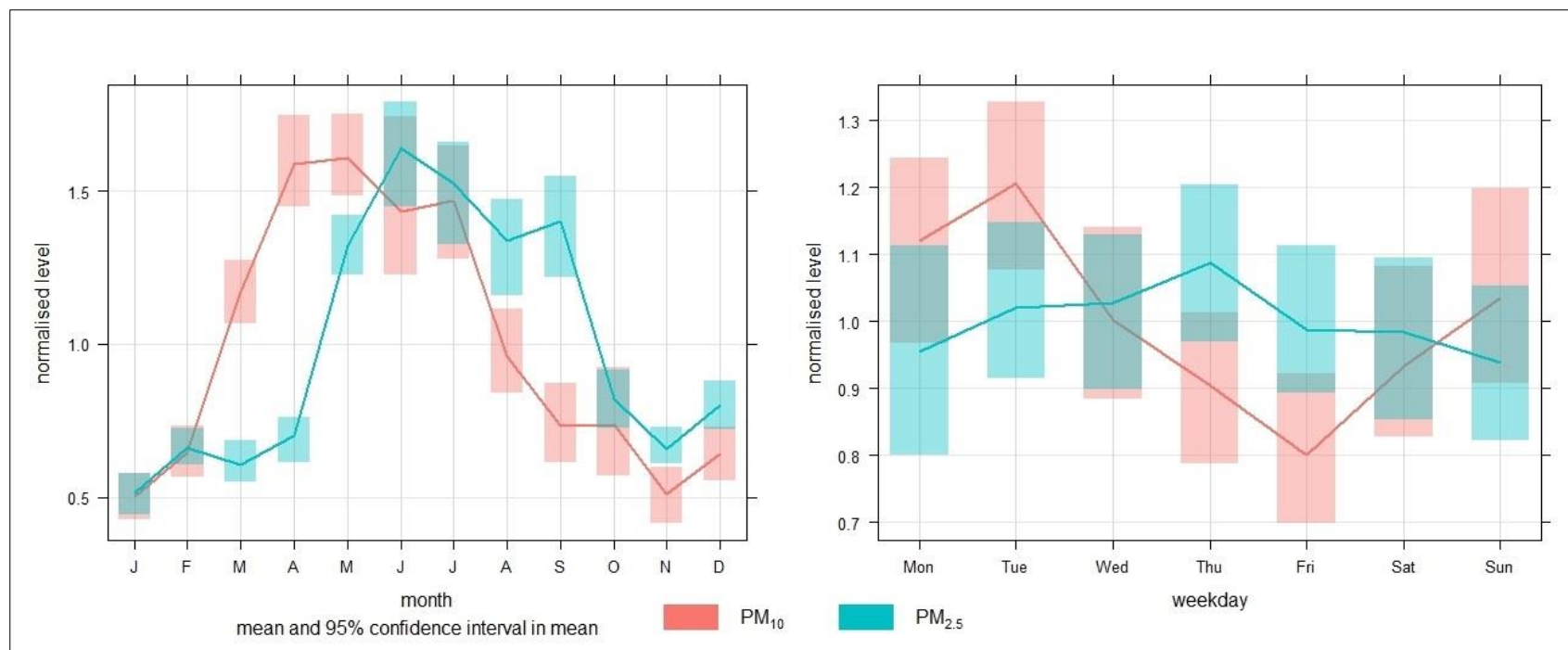


Figure 5-36: Time series plot of normalised observed PM<sub>10</sub> and PM<sub>2.5</sub> concentrations at Embalenhle (shaded area indicates 95<sup>th</sup> percentile confidence interval)



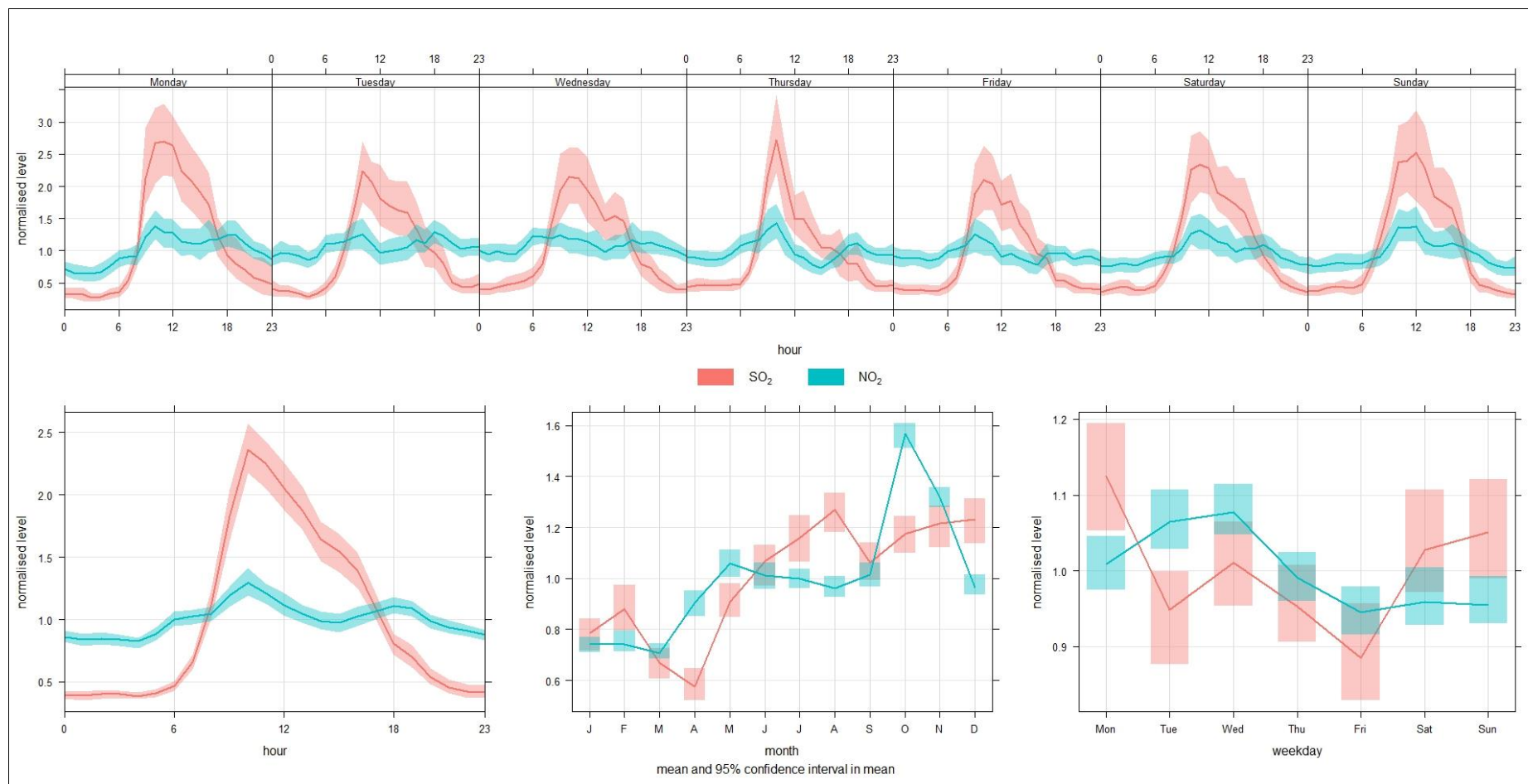


Figure 5-37: Time series plot of observed SO<sub>2</sub> and NO<sub>2</sub> concentrations at Bosjesspruit (shaded area indicates 95<sup>th</sup> percentile confidence interval)

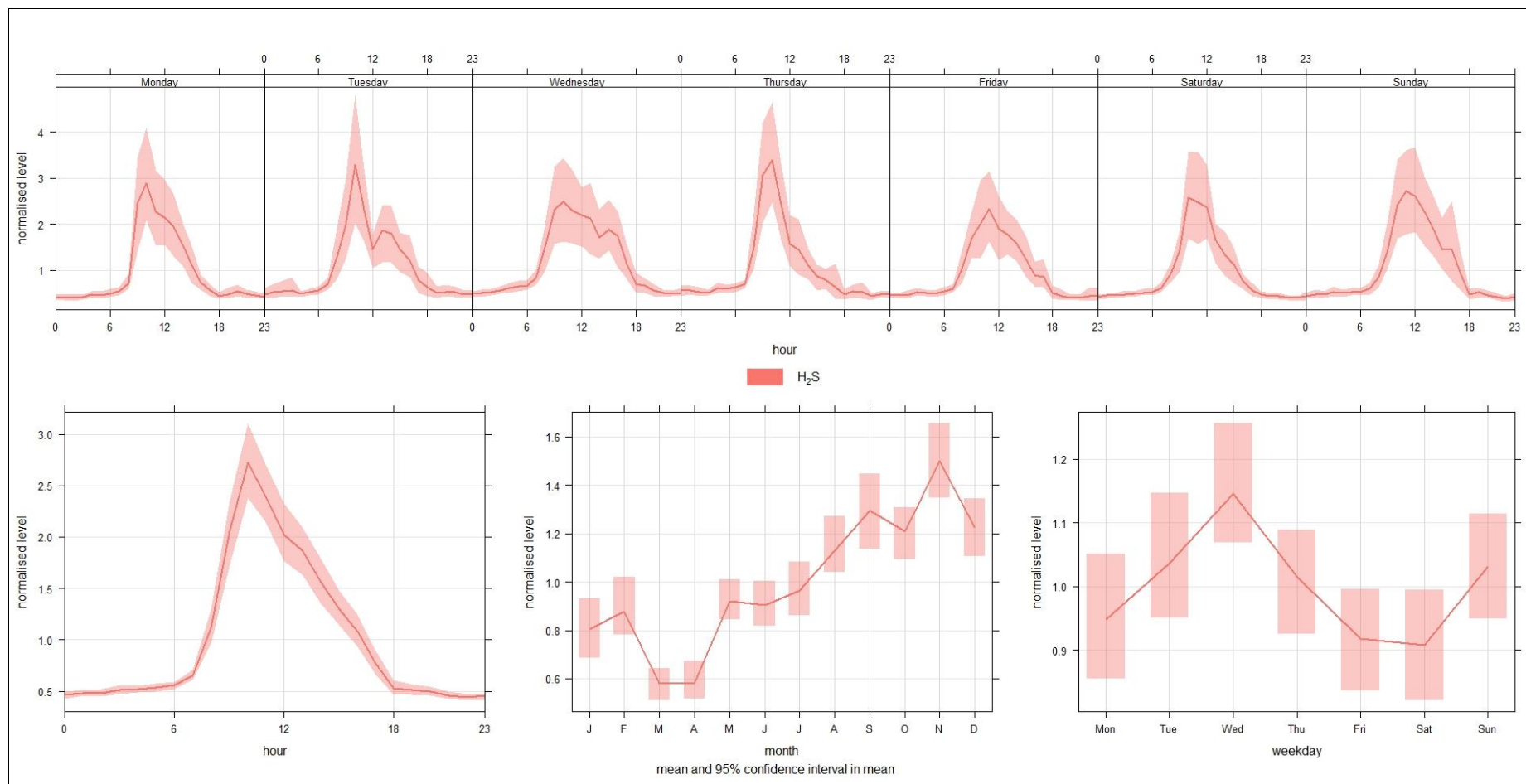


Figure 5-38: Time series plot of normalised observed  $H_2S$  concentrations at Bosjesspruit (shaded area indicates 95<sup>th</sup> percentile confidence interval)

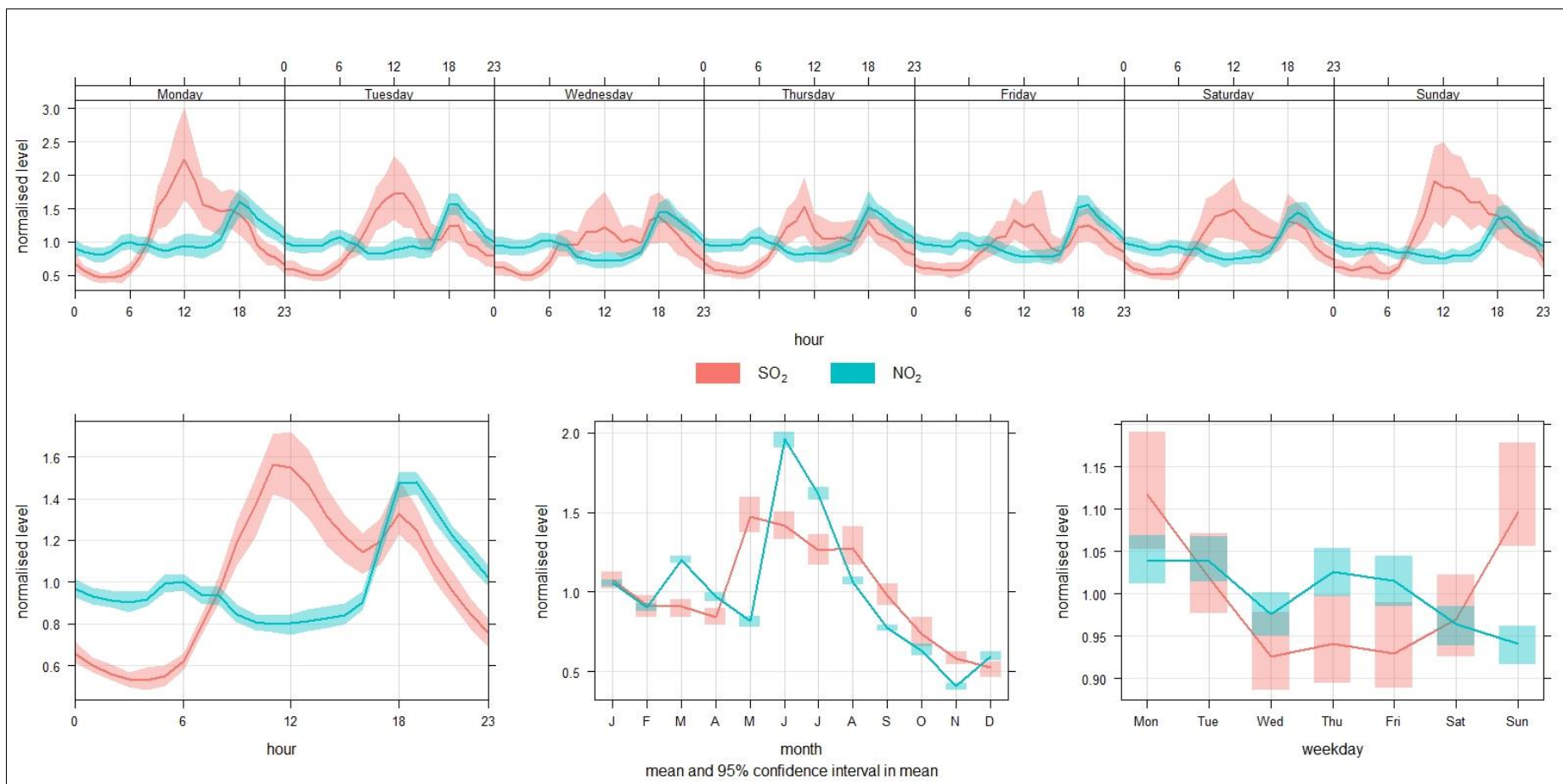


Figure 5-39: Time series plot of normalised observed SO<sub>2</sub> and NO<sub>2</sub> concentrations at Secunda (DEA) (shaded area indicates 95<sup>th</sup> percentile confidence interval)

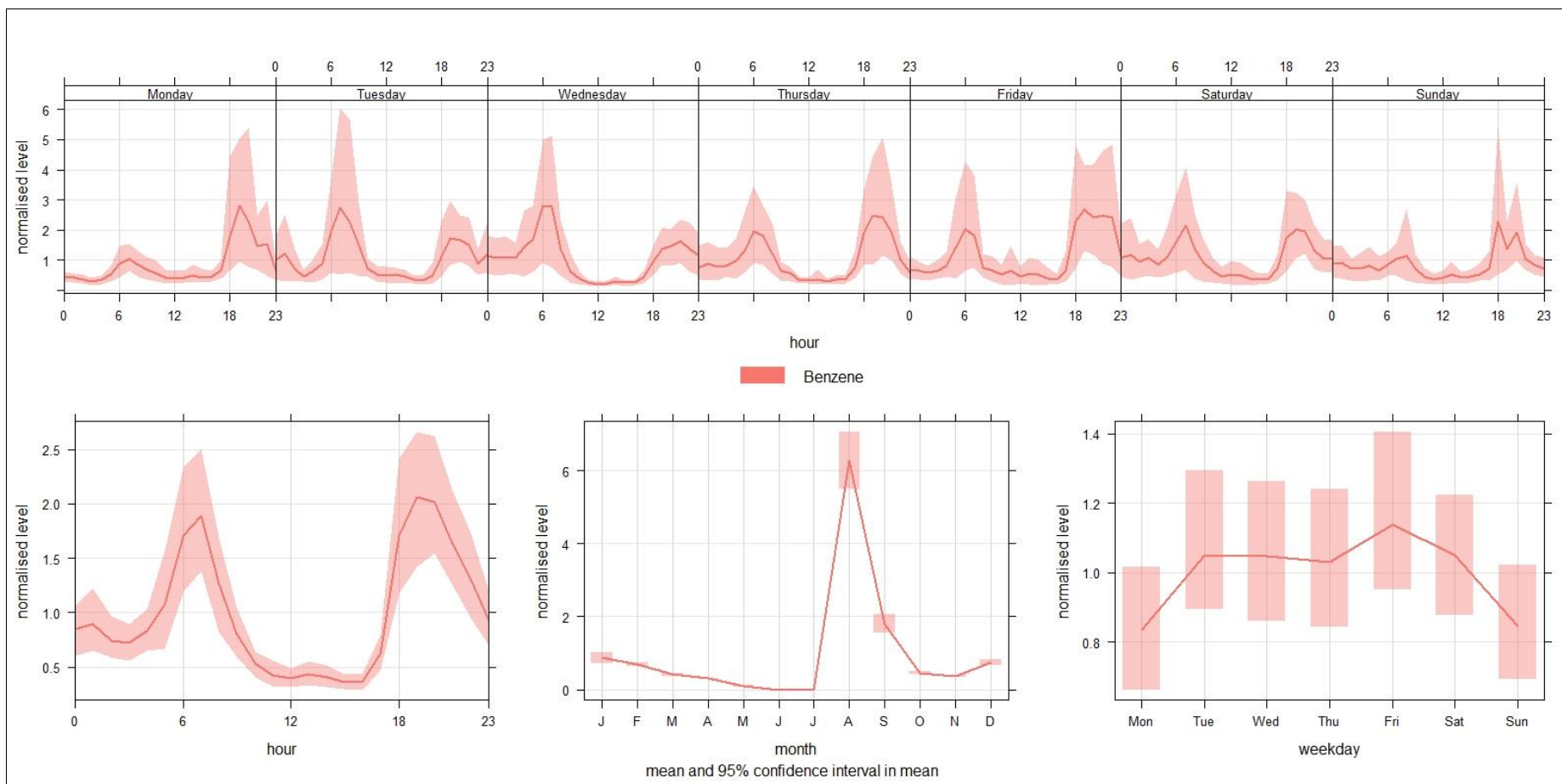


Figure 5-40: Time series plot of normalised observed benzene concentrations at Secunda (DEA) (shaded area indicates 95<sup>th</sup> percentile confidence interval)

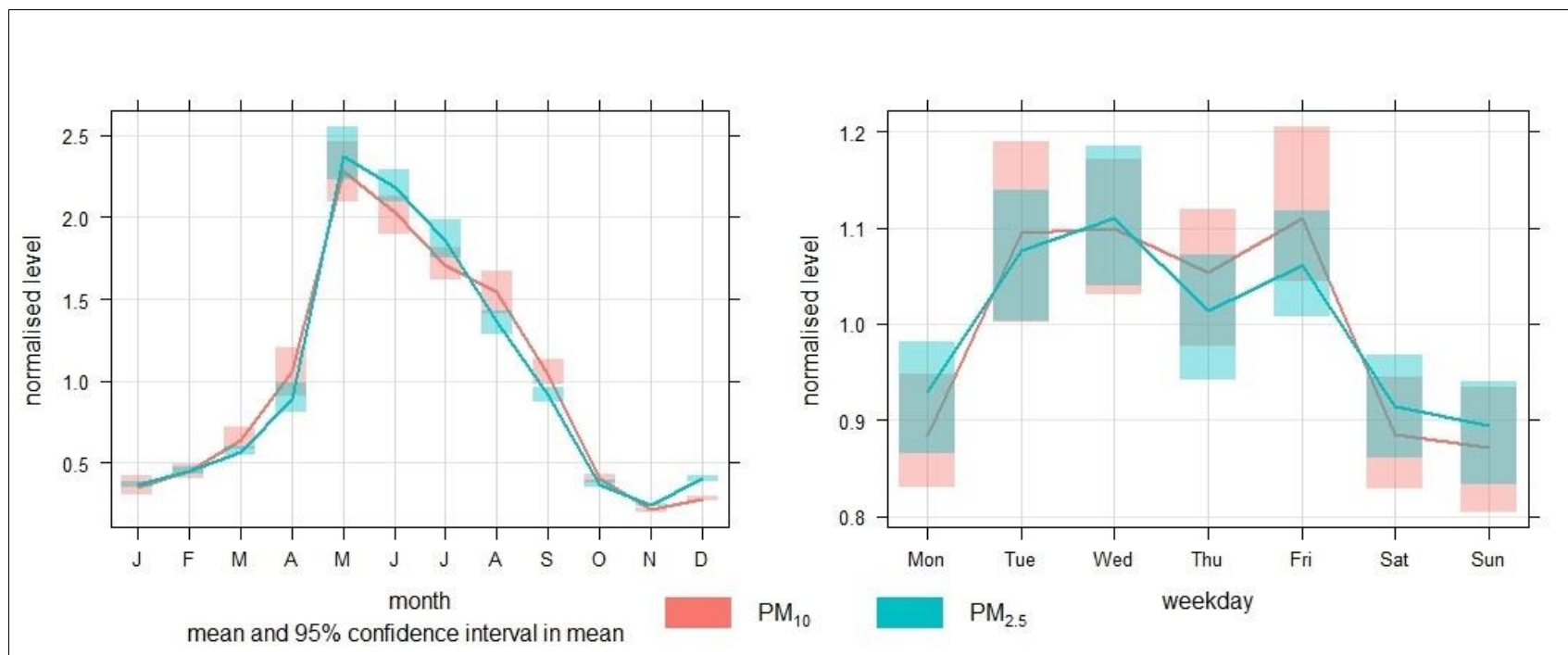


Figure 5-41: Time series plot of normalised observed PM<sub>10</sub> and PM<sub>2.5</sub> concentrations at Secunda (DEA) (shaded area indicates 95<sup>th</sup> percentile confidence interval)