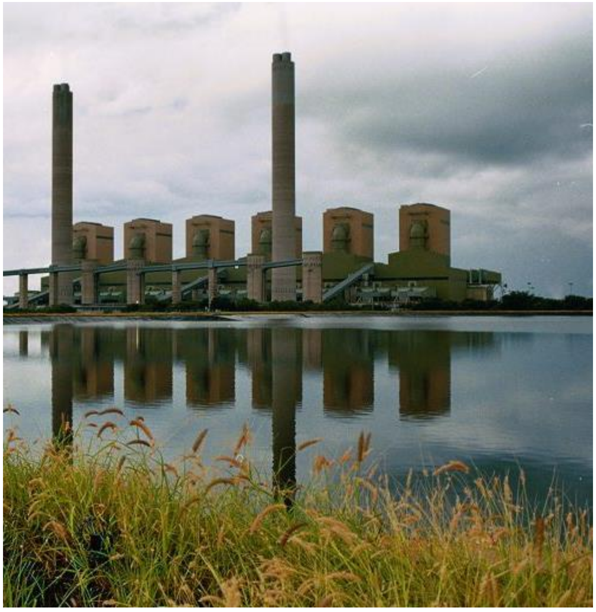
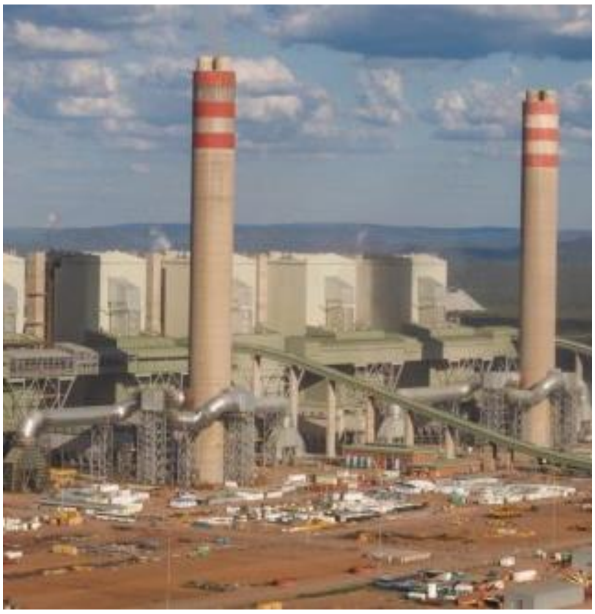
Appendix B

CUMULATIVE AIRSHED STACK PM EMISSIONS ONLY

ADDENDUM TO:
ATMOSPHERIC IMPACT REPORT IN SUPPORT OF THE APPLICATION FOR EXEMPTION FROM THE MINIMUM EMISSION STANDARDS FOR ESKOM's COAL-FIRED POWER STATIONS IN THE WATERBERG (A CUMULATIVE ASSESSMENT)





9 December 2024

uMOYA-NILU

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Report Details

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GLOSSARY OF TERMS AND ACRONYMS

AEL	Atmospheric Emission Licence
AIR	Atmospheric Impact Report
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DSI	Dry Sorbent Injection
EIA	Environmental Impact Assessment
FGD	Flue-gas desulfurisation
g/s	Grams per second
kPa	Kilo Pascal
LNB	Low NO_X burner
MES	Minimum Emission Standards
mg/Nm^3	Milligrams per normal cubic meter refers to emission concentration, i.e. mass per volume at normal temperature and pressure, defined as air at 20^oC (293.15 K) and 1 atm (101.325 kPa)
NAAQS	National Ambient Air Quality Standards
NAQO	National Air Quality Officer
NECA	National Environmental Consultative and Advisory
NEM-AQA	National Environment Management: Air Quality Act, 2004 (Act No. 39 of 2004)
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
USEPA	United States Environmental Protection Agency
µm	1 µm = Micro meter 1 µm = 10^{-6} m

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1. INTRODUCTION

On 22 May 2024, the Minister directed Eskom to submit an application in terms of Section 59 of the National Environmental Management: Air Quality Act for exemption of the MES for eight (8) power stations that will continue to operate post 2030. These are Duvha, Kendal, Majuba, Matla and Tutuka in the Highveld Priority Area; Lethabo in the Vaal Triangle Airshed Priority Area; and Medupi and Matimba in the Waterberg-Bojanala Priority Area.

In terms the Minister's ruling Eskom Holdings SOC Ltd appointed WSP Group Africa (Pty) Ltd to prepare the necessary applications. WSP Group Africa (Pty) Ltd sub-contracted uMoya-NILU Consulting (Pty) Ltd to prepare the associated Atmospheric Impact Reports (AIRs) to support the applications. AIRs were duly prepared to support the respective exemption applications for the individual power stations. Furthermore, two cumulative AIRs were prepared, for the suite of power stations on the Highveld and the Vaal Triangle, and for the two coal-fired power stations in the Waterberg-Bojanala Priority Area, i.e. Medupi and Matimba (uMoya-NILU, 2024). In so doing, 5 emission scenarios were assessed, which included SO_2, NO_X and PM emissions from the stacks as well as fugitive PM emissions from the coal stockyard and ash dumps. The intention was to provide an understanding of the power stations total contribution to ambient concentrations.

The stack emission data were provided by Eskom for the five scenarios based firstly on actual emissions, followed by emissions representing anticipated station performance in different years. Fugitive emissions were estimated based on a worst-case scenario, with little dust control implemented on the ash dumps. Specifically, 60-80% of the entire area of the ash dumps was assumed to be exposed and available for entrainment of particulates. It was assumed that the sides of the ash dumps are in fact partially vegetated, and the tops are partially wet.

To provide an absolute worst-case, it was assumed that the total PM emission from the stacks into the respective PM_{10} and $PM_{2.5}$ fractions. Therefore, the total PM emission was firstly assumed to be PM_{10}, then was assumed to be $PM_{2.5}$. For consistency in the modelling, the total PM emission from the fugitive sources was also assumed to be PM_{10}, then $PM_{2.5}$. The modelled outputs were then compared against the respective National Ambient Air Quality Standards (NAAQS).

The modelled PM_{10} and $PM_{2.5}$ concentrations were high close to the respective power stations and exceeded the NAAQS. Further away from the power stations, the predicted concentrations were relatively low and complied with the NAAQS. From the results it was however impossible to distinguish between the contribution of the fugitive sources and the stack emissions to ambient concentrations, although the results indicated that the high concentrations were due to the fugitive sources rather than the stack emissions themselves.

As Eskom's request to the Minister concerns stack emissions, it was decided to prepare an addendum to the cumulative assessment for the Waterberg power stations and to assess the contribution of stack PM emissions only to the ambient PM_{10} and $PM_{2.5}$ concentrations. The same dispersion model, stack parameterisation and model setup are used. In this

Addendum to the AIR (uMoya-NILU, 2024), the focus is specifically on stack emissions for PM and the modelled results for PM_{10} and $PM_{2.5}$.

2. STACK EMISSIONS

In this Addendum to the AIR (uMoya-NILU, 2024), the cumulative effect of stack emissions from 2 coal-fired power stations comprising the Waterberg fleet are assessed, i.e. Medupi and Matimba.

2.1 Operational Scenarios

The five operational scenarios anticipated by Eskom for the Waterberg power station fleet in the coming years are:

Scenario 1 (Current): The baseline scenario using actual monthly stack emissions for 2021-2023 (No FGD installed).

Scenario A (2025): Eskom's planned 2025 stack emissions, representing anticipated station performance between 2025 – 2030 (No FGD installed).

Scenario B (2031): Eskom's planned 2031 stack emissions, representing anticipated station performance between 2031 – 2035 (No FGD installed but load reduction).

Scenario C (2036): Eskom's planned 2036 stack emissions, representing anticipated station performance from 2036 onwards (FGD installed at Medupi).

Scenario D (MES): Full compliance with the MES (FGD installed at Medupi and Matimba).

The estimated emission rates for SO_2, NO_X and PM_{10} and equivalent emission concentrations that are used in the dispersion modelling for the power stations are shown in **Error! Reference source not found.**. A reminder that the total PM emission is assumed to be PM_{10}. The estimated emission rates and equivalent emission concentrations that are used in the dispersion modelling for the two power stations are shown in Table 2-1. The maximum anticipated emissions during each period are used for simulation in the model. The boiler units are assumed to operate continuously, i.e. 24 hours a day. Since each future scenario is a snapshot of the period of operation (e.g. Scenario A = 2025 to 2030), the maximum anticipated emissions during that period, in a single year was selected for simulation in the model.

Table 2-1: Annual emissions from the Medupi and Matimba Power Stations and the corresponding emission concentrations

Scenario	Stack	Emission rate (tonnes/annum)			Emission concentration @ 10% O_2 and average load (mg/Nm^3)		
		NO_x	SO_2	PM	NO_x	SO_2	PM
		Medupi Power Station					
1[a]	Stack 1	25 577	123 502	1 314	257	1 343	13
	Stack 2	25 577	123 502	1 314	257	1 343	13
A	Stack 1	34 716	134 340	1 663	522	2 020	25
	Stack 2	34 716	134 340	1 663	522	2 020	25
B	Stack 1	20 770	80 374	1 273	522	2 020	32
	Stack 2	20 770	80 374	1 273	522	2 020	32
C	Stack 1	23 447	31 263	1 438	375	500	23
	Stack 2	23 447	31 263	1 438	375	500	23
D	Stack 1	23 447	31 263	1 438	375	500	23
	Stack 2	23 447	31 263	1 438	375	500	23
		Matimba Power Station					
1[a]	Stack 1	28 921	150 457	2 648	291	1 514	27
	Stack 2	28 921	150 457	2 648	291	1 514	27
A	Stack 1	28 346	150 830	1 820	545	2 900	35
	Stack 2	28 346	150 830	1 820	545	2 900	35
B	Stack 1	18 118	103 026	1 243	510	2 900	35
	Stack 2	18 118	103 026	1 243	510	2 900	35
C	Stack 1	20 872	112 752	1 432	510	2 755	35
	Stack 2	20 872	112 752	1 432	510	2 755	35
D	Stack 1	20 872	33 825	1 432	510	827	35
	Stack 2	20 872	33 825	1 432	510	827	35
MES					**750**	**1000**	**50**

(a): Average from actual monthly emissions

2.2 Methodology for determining $PM_{2.5}$ emissions

In terms of the determination of fine particulate matter emissions ($PM_{2.5}$), it is noted that Eskom utilises the dry bottom boiler emission factors from the United States Environmental Protection Agency (US EPA AP42) (US EPA, 1995) to determine the fine particulate matter emissions ($PM_{2.5}$). The ratio of the $PM_{2.5}$ to PM_{10} is used to calculate $PM_{2.5}$ from the total PM measured from the Continuous Emission Monitoring System (CEMS) equipment at the respective stacks. The utilisation of CEMS equipment is a more accurate representation of site-specific PM and therefore constitutes a Tier 3 method of reporting.

The US EPA defines dry bottom boilers as those burning coals with high fusion temperatures resulting in dry ash. In wet bottom boilers, coal with low fusion temperatures is used, resulting in molten ash or slag. Eskom coal fired power stations are therefore considered to have dry bottom boilers. Eskom has either Electrostatic Precipitators (ESPs) or Fabric Filter Plants (FFPs) installed as air pollution control devices in all its coal fired units. The following ratios determined from dry bottom emission factors in the US EPA AP42 are used:

- ESP controlled - 0.024 lb/ton for $PM_{2.5}$ and 0.054 lb/ton for PM_{10} [ratio = 0.44]
- FFP controlled - 0.01 lb/ton for $PM_{2.5}$ and 0.02 lb/ton for PM_{10} [ratio = 0.5]

The above ratios for PM_{10}:$PM_{2.5}$ have been applied accordingly at the power stations as follows:

- Medupi has FFPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.50
- Matimba has ESPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.44

3. DISPERSION MODELLING RESULTS

The CALPUFF modelling suite provides for the chemical conversion of SO_2 and NO_X to secondary particulates, i.e. sulphates and nitrates in the modelling results. For PM_{10} and $PM_{2.5}$, the predicted concentrations presented are therefore attributed to stack emissions and the contribution from secondary particulate formation.

The DEA (2014) recommends the 99th percentile concentrations for short-term assessment with the NAAQS since the highest predicted ground-level concentrations can be considered outliers due to complex variability of meteorological processes. In addition, the limit value in the NAAQS is the 99th percentile. The impact assessment therefore compares the predicted 99th percentile concentrations with the respective NAAQS limit values and the permitted frequency of exceedance for the five scenarios.

3.1 Maximum predicted ambient concentrations

The maximum predicted annual PM_{10} and $PM_{2.5}$ concentrations and the 99th percentile of the 24-hour predicted concentrations are discussed here and are listed in Table 3-1 for the 5 scenarios.

Changes in the predicted annual average and 24-hour PM_{10} and $PM_{2.5}$ concentrations from one scenario to the next are strongly influenced by changes in PM_{10} and $PM_{2.5}$ emissions, the contribution from secondary particulate formation and stack exit velocity.

In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS. In other words, here are no predicted exceedances of the 24-hour limit value of the respective NAAQS for PM_{10} and for $PM_{2.5}$.

The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted PM_{10} and $PM_{2.5}$ ambient concentrations. Although there is a decrease in PM_{10} and $PM_{2.5}$ emissions at Matimba, the reduced exit velocity in the stacks reduces the dispersion potential.

The maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations decrease significantly from Scenario A (2025) to Scenario B (2031) due to the substantial decrease in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and Matimba.

Although there is an increase in NO_X, PM_{10} and $PM_{2.5}$ emissions, and a reduction in exit velocity in the stacks at Medupi and Matimba from Scenario B (2031) to Scenario C (2036), the substantial decrease in SO_2 emissions at Medupi is responsible for a slight decrease in PM_{10} and $PM_{2.5}$ ambient concentrations, as this reduces the formation of secondary particulates.

Although NO_X, PM_{10} and $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), it is noted that the maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations show a fairly large decrease between the two scenarios. This decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions at Matimba.

Table 3-1: Maximum predicted ambient annual PM_{10}, and $PM_{2.5}$ concentrations in µg/m³ and the predicted 99th percentile concentrations for 24-hour averaging periods, with the South African NAAQS

Scenario and Pollutant	Averaging time	
Predicted maximum PM_{10}	**Annual**	**24-hour**
Scenario 1 (Current)	1.2	15.4
Scenario A (2025)	1.7	17.9
Scenario B (2031)	1.3	13.8
Scenario C (2035)	1.0	10.8
Scenario D (MES)	0.6	6.0
NAAQS	**40**	**75**
Predicted maximum $PM_{2.5}$	**Annual**	**24-hour**
Scenario 1 (Current)	1.1	14.3
Scenario A (2025)	1.5	16.8
Scenario B (2031)	1.2	12.8
Scenario C (2035)	0.9	10.0
Scenario D (MES)	0.5	4.9
NAAQS (up to 31 Dec 2029)	**20**	**40**
NAAQS (from 01 Jan 2030)	**15**	**25**

3.2 Predicted concentrations at the AQMSs

The predicted annual PM_{10} and $PM_{2.5}$ concentrations are compared with the measured annual averages in 2021, 2022 and 2023 at three Air Quality Monitoring Stations (AQMS) in the Waterberg modelling domain for Scenario 1 (Current) in Table 3-2 and Table 3-3, respectively.

For PM_{10} and $PM_{2.5}$ the predicted ambient concentrations result from the respective power station stack emissions. At all AQMSs, the modelled concentrations are considerably lower than the monitored concentrations. This is to be expected since the here are exposed to all sources of PM_{10} and $PM_{2.5}$. The difference between the predicted concentrations and the measured concentrations provides an indication of the contribution of the power station stack emissions at the respective AQMSs.

Table 3-2: Measured annual average PM_{10} concentration at the Waterberg AQMSs compared with predicted concentrations in µg/m³ for Scenario 1 (Current)

Receptor	2021	2022	2023	Modelled
Marapong AQMS	47.0	-	-	**0.7**
Medupi AQMS	28.8	28.4	37.5	**0.8**
Lephalale AQMS	37.3	-	17.4	**0.7**

Table 3-3: Measured annual average $PM_{2.5}$ concentration at the Waterberg AQMSs compared with predicted concentrations in µg/m^3 for Scenario 1 (Current)

Receptor	2021	2022	2023	Modelled
Marapong AQMS	25.8	30.2	-	**0.6**
Medupi AQMS	15.2	-	-	**0.7**
Lephalale AQMS	-	-	12.2	**0.6**

3.3 Predicted concentrations at sensitive receptors

In the Waterberg study area, 51 sensitive receptors were identified. These are listed in Annexure 1. Predicted ambient concentrations for PM_{10} and $PM_{2.5}$ for the five scenarios are presented in Annexure 2.

At all identified sensitive receptors, the predicted PM_{10} and $PM_{2.5}$ concentrations are low and well below the limit value of the respective NAAQS for all five scenarios. The highest predicted concentrations occur for Scenario A (2025) and the lowest predicted concentrations occur for Scenario D (MES).

Noteworthy is the systematic decrease in predicted PM_{10} and $PM_{2.5}$ concentrations from 2025 to 2036 at all sensitive receptors.

3.4 Isopleth maps

Isopleth maps of predicted ambient PM_{10} and $PM_{2.5}$ concentrations are presented in the following sections. The predicted concentrations are shown as isopleths, lines of equal concentration, in µg/m^3 for the respective NAAQS averaging periods. The isopleths are depicted as coloured lines on the various maps, corresponding to a particular predicted ambient concentration. Sensitive receptors are represented by green squares and AQMSs are represented by white dots.

The South African NAAQS permits 4 exceedances of the 24-hour or daily limit value per annum, implying 12 permitted exceedances in a three-year modelling period. In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS. The predicted 24-hour PM_{10} and $PM_{2.5}$ concentrations therefore comply with the NAAQS for all five scenarios. As discussed above, changes in the predicted concentrations are strongly influenced by changes in emissions, the contribution from secondary particulate formation and stack exit velocity.

3.4.1 Particulates (PM_{10})

In Scenario 1 (Current), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur up to 20 km around the Medupi and Matimba Power Stations.

The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted concentrations. In Scenario A (2025), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 20 km to the southwest of the Medupi Power Station, and approximately 10 km to the east of the Matimba Power Station.

Noticeable is the dramatic decrease in ambient concentrations on the isopleths for Scenario B (2031), where the biggest reductions are seen, due to the substantial decrease in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and Matimba. In Scenario B (2031), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur up to 20 km around the Medupi and Matimba Power Stations.

The effect of the reduced formation of secondary particulates brought about by the substantial decrease in SO_2 emissions at Medupi are also noticeable on the isopleths for Scenario C (2036). In Scenario C (2036), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 10 km to the west of the Medupi Power Station, and approximately 5 km to the east of the Matimba Power Station.

Although PM_{10} emissions remain the same for Scenario C (2036) and Scenario D (MES), the predicted PM_{10} concentrations show a fairly large decrease on the isopleths for Scenario D (MES) (as discussed previously, this decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios at Matimba). In Scenario D (MES), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 20 km to the southwest of the Medupi Power Station, and approximately 10 km to the west of the Matimba Power Station.

Isopleth maps of the predicted annual average and 99^{th} percentile of the 24-hour PM_{10} concentrations are presented in Figure 3-1 to Figure 3-10.

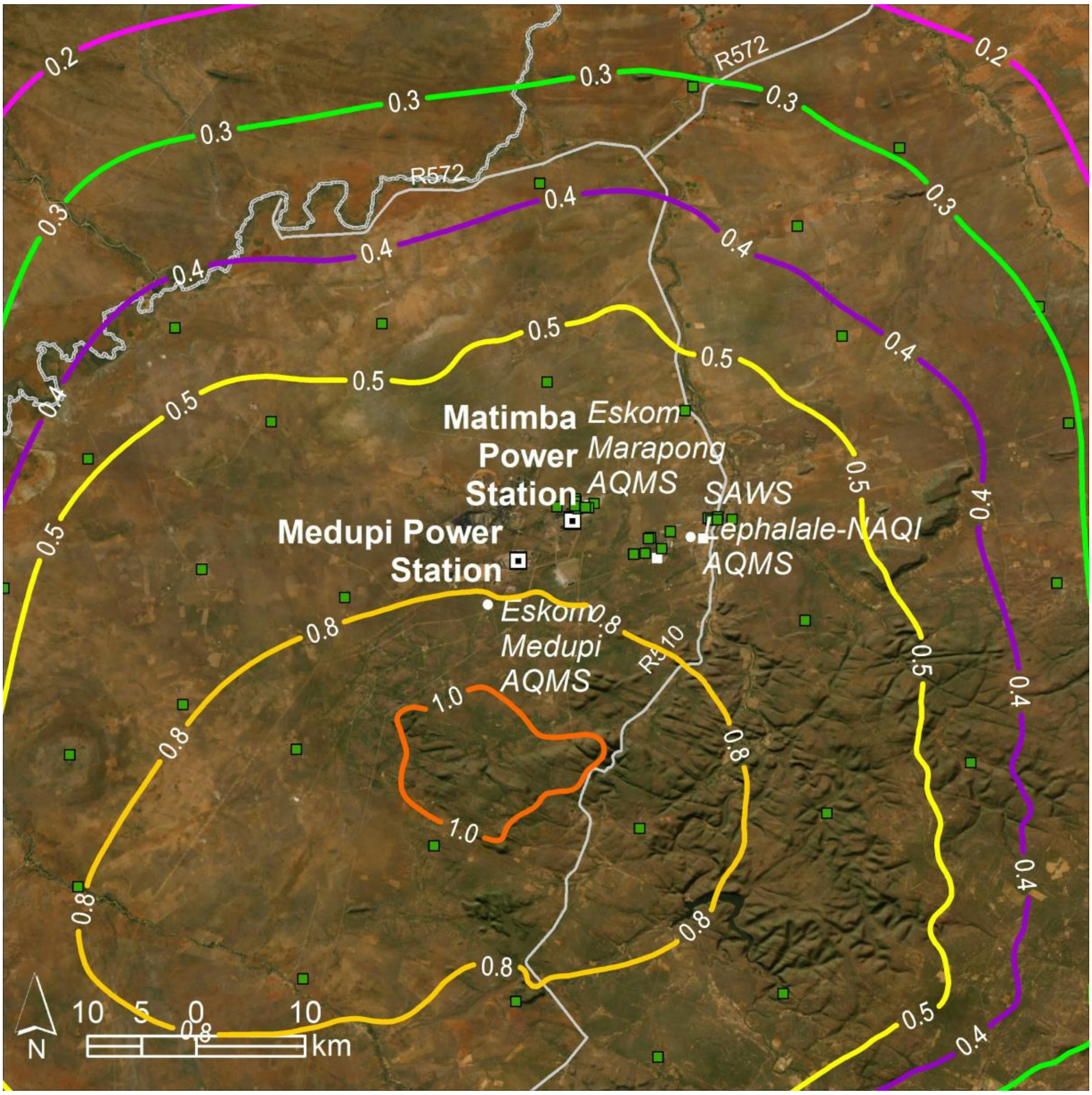

Figure 3-1: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario 1 (Current) (NAAQS Limit is 40 µg/m³)

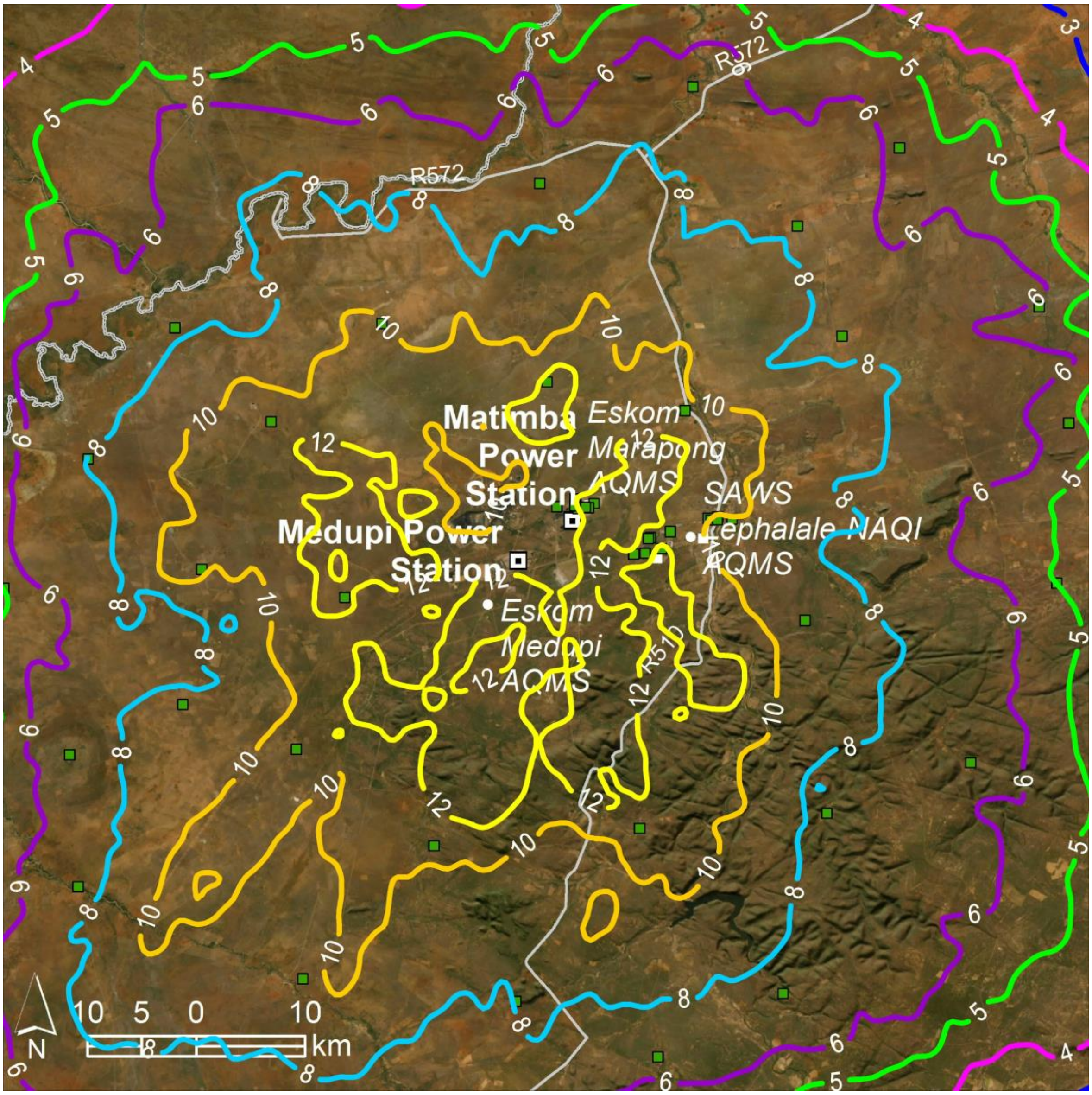

Figure 3-2: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario 1 (Current) (NAAQS Limit is 75 µg/m³)

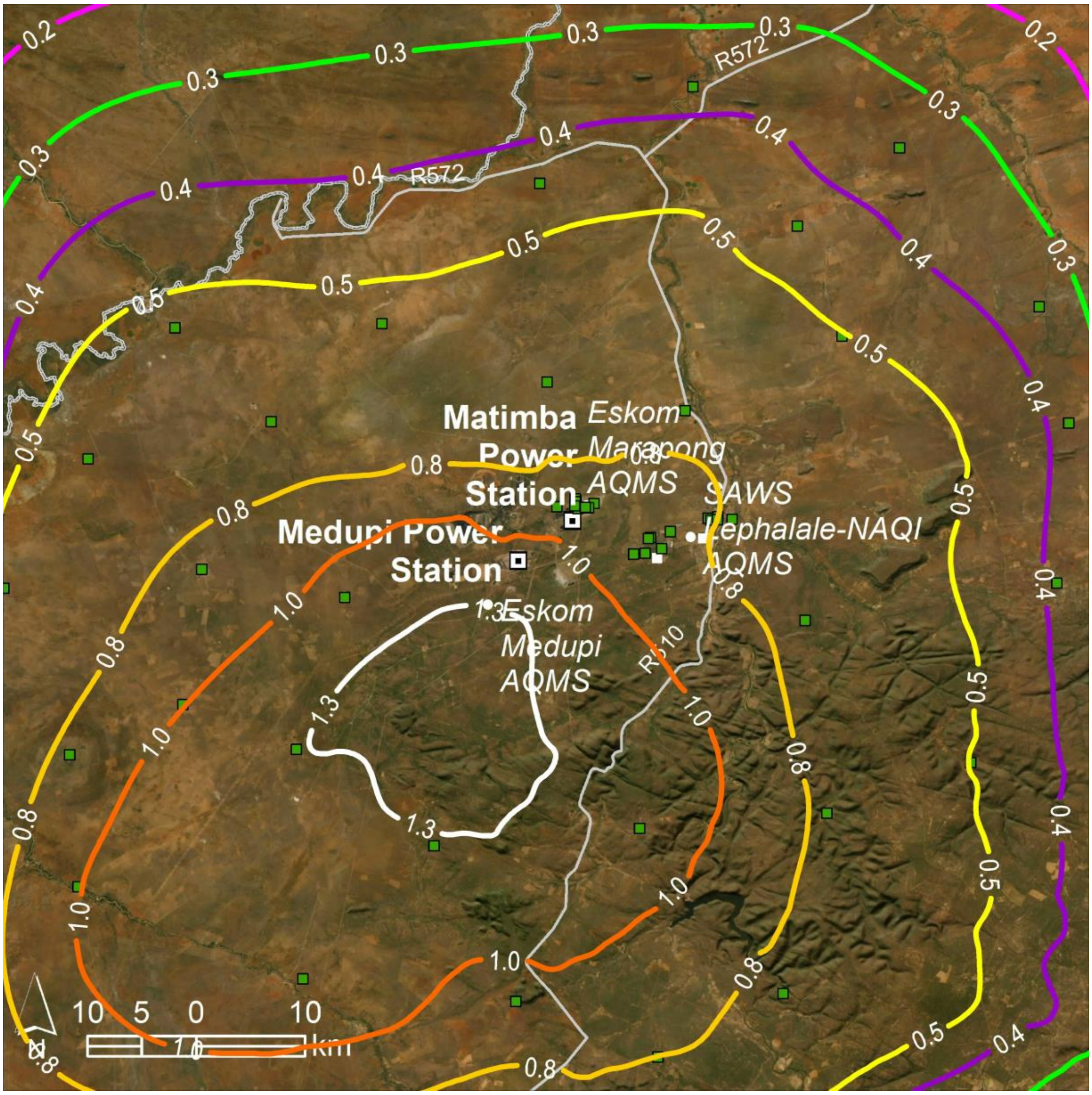

Figure 3-3: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 40 µg/m³)

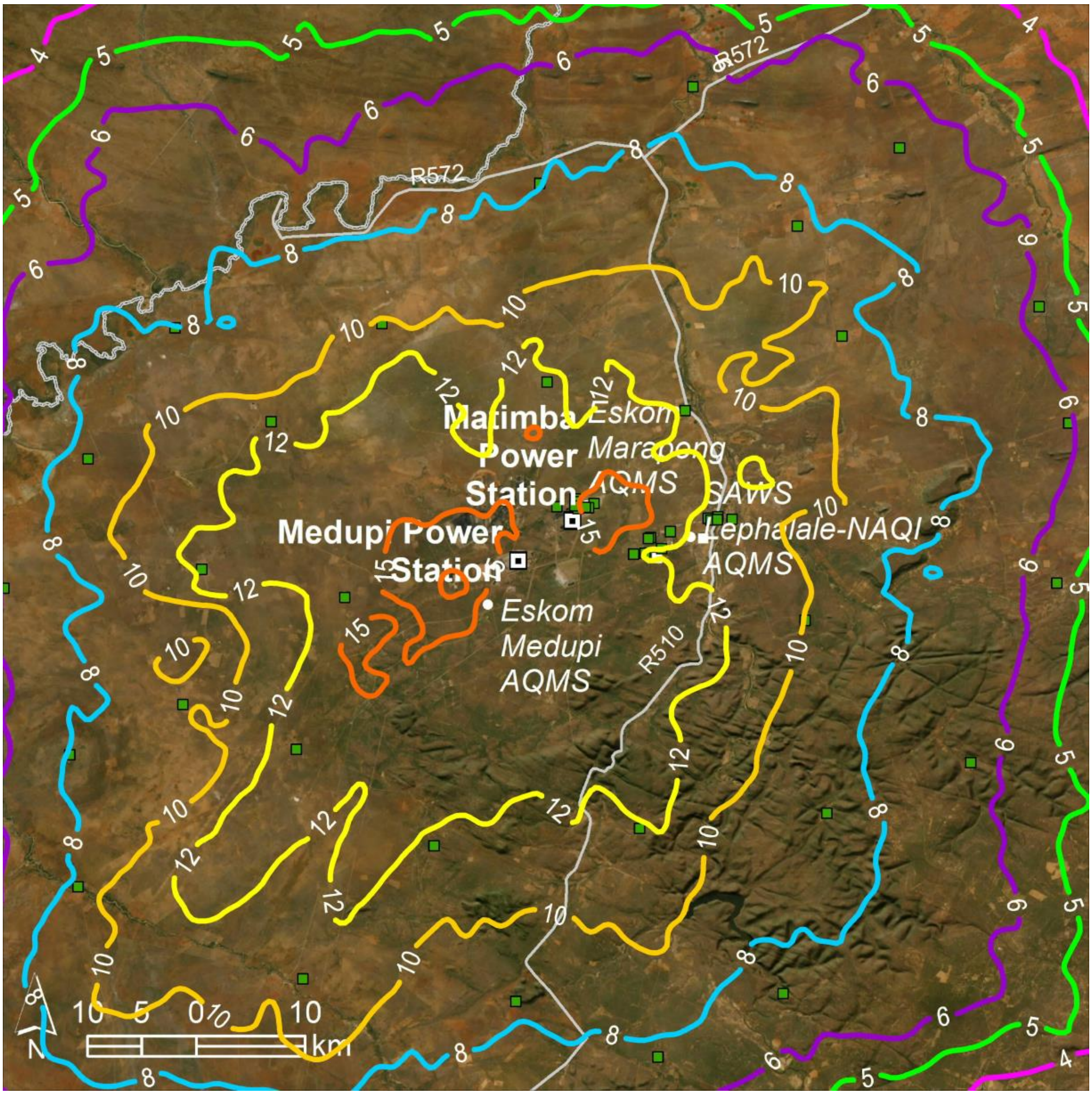

Figure 3-4: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 75 µg/m³)

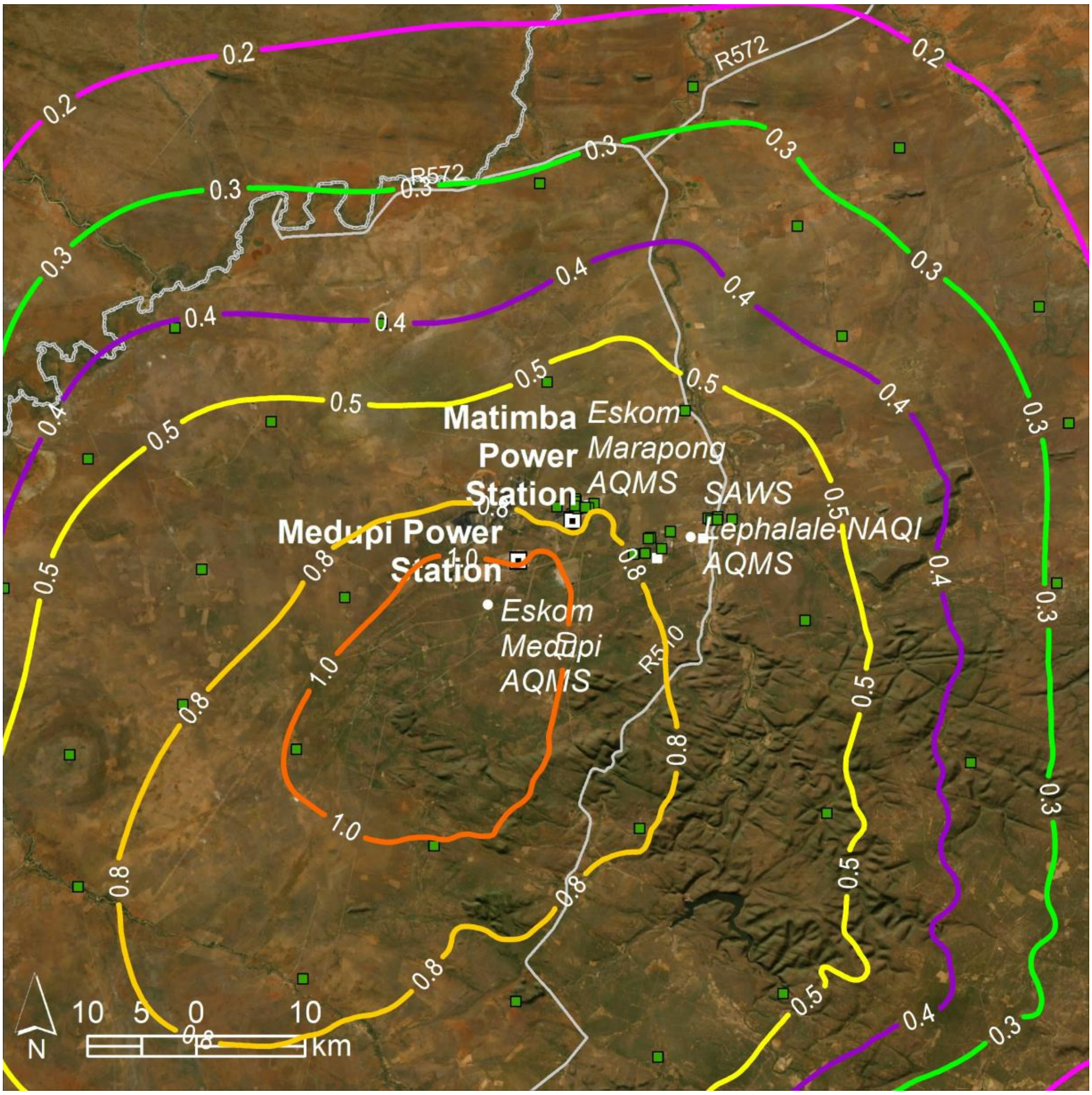

Figure 3-5: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario B (2031) (NAAQS Limit is 40 µg/m³)

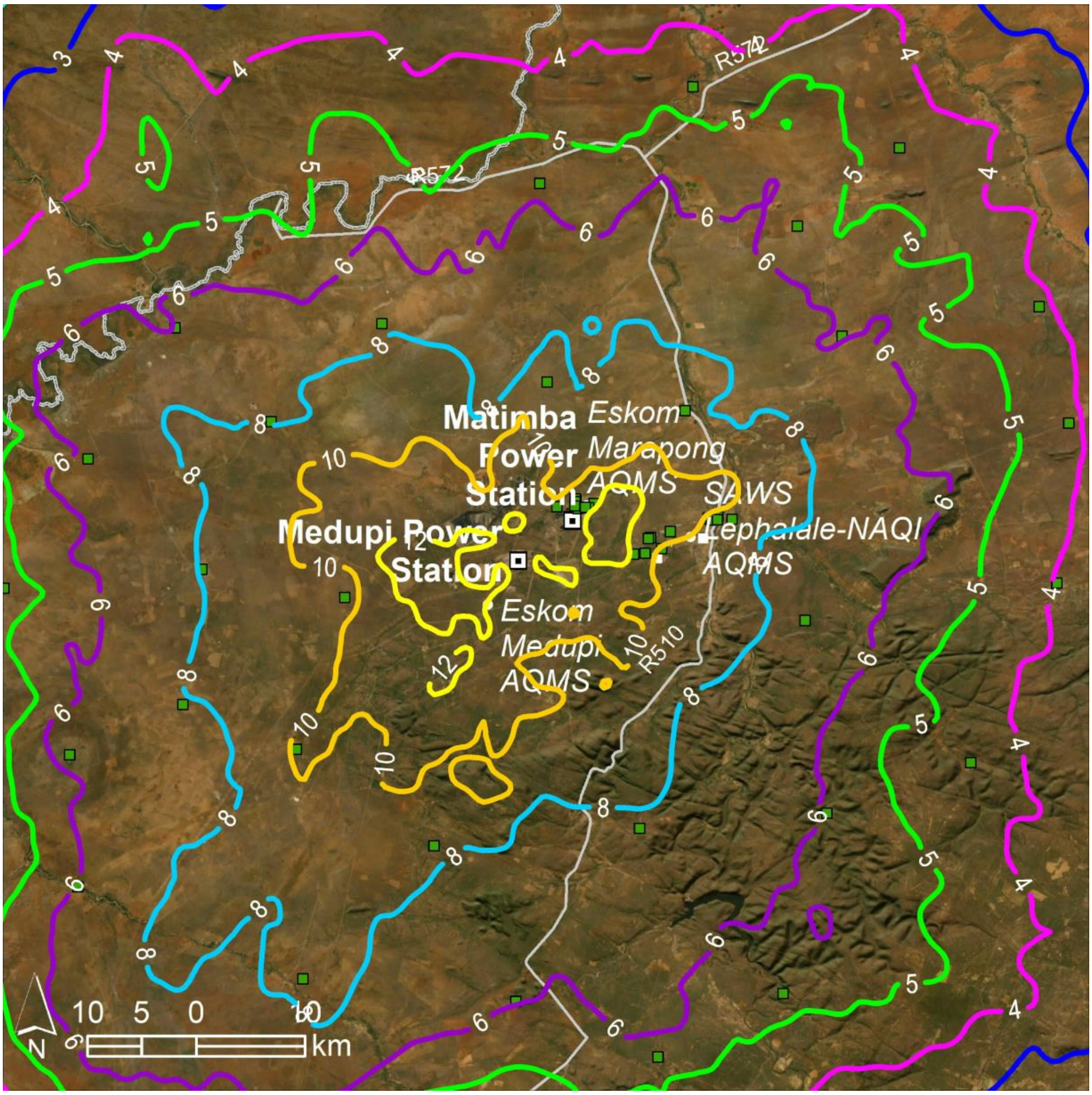

Figure 3-6: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m^3 for Scenario B (2031) (NAAQS Limit is 75 µg/m^3)

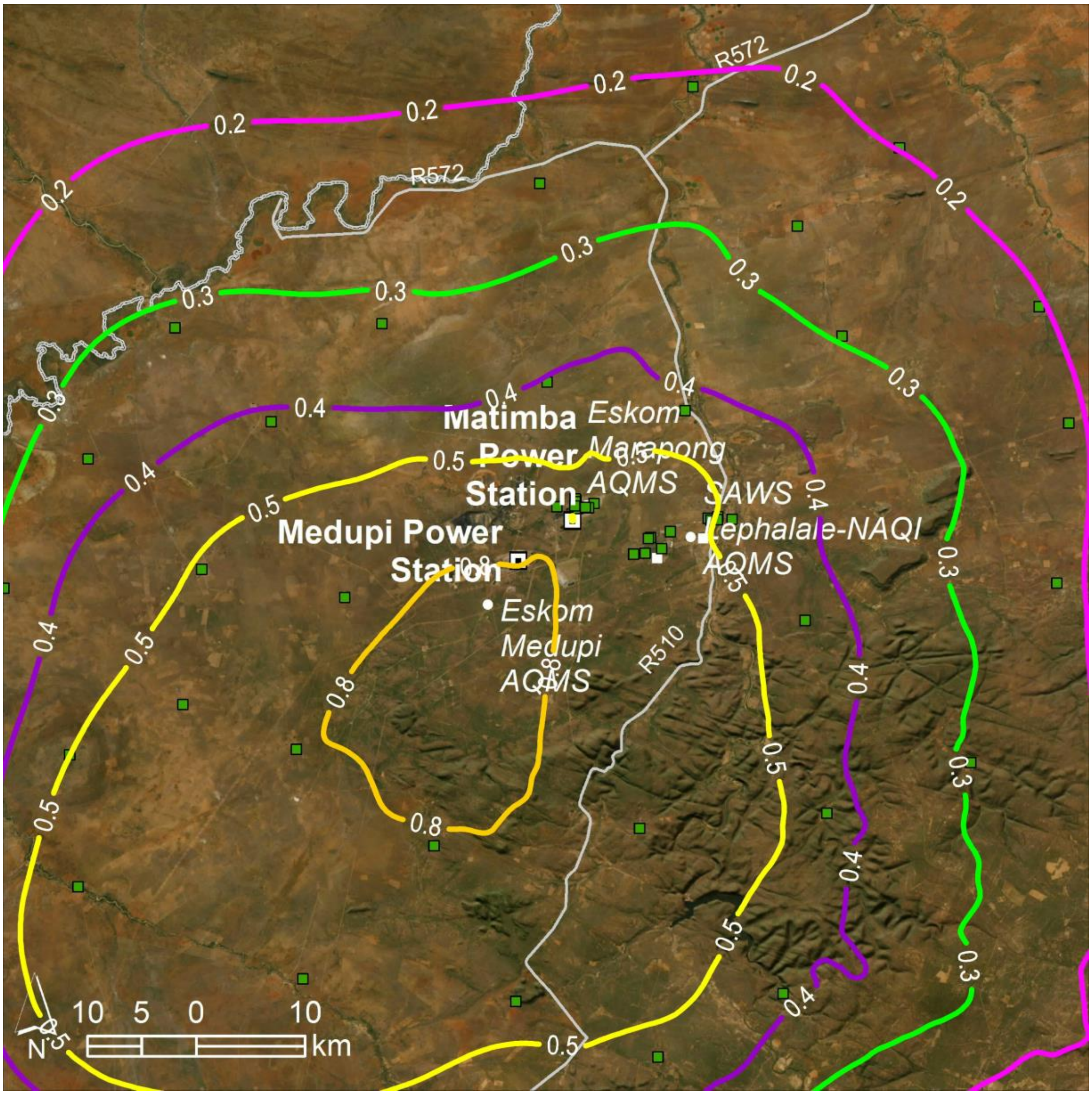

Figure 3-7: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 40 µg/m³)

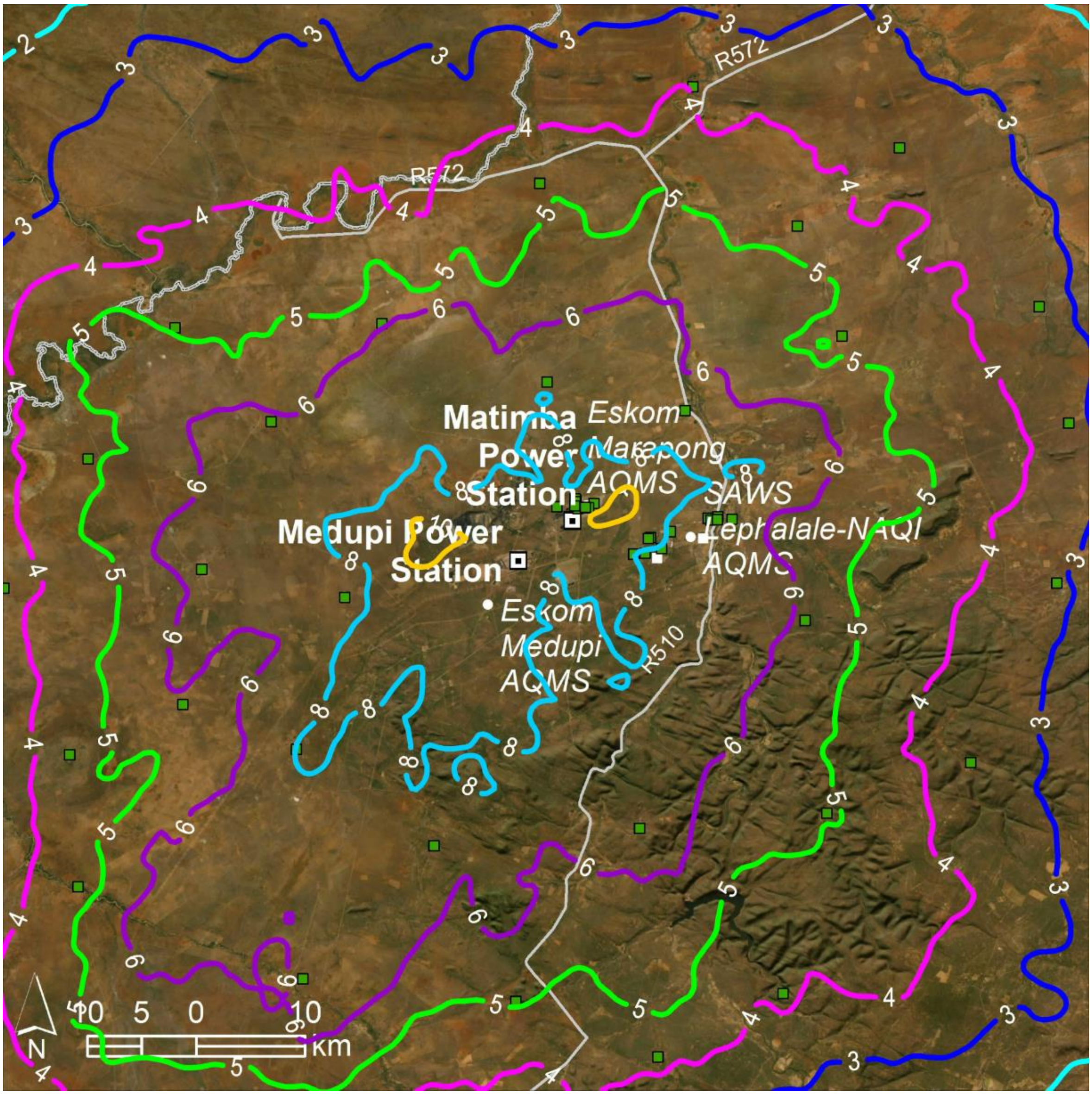

Figure 3-8: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 75 µg/m³)

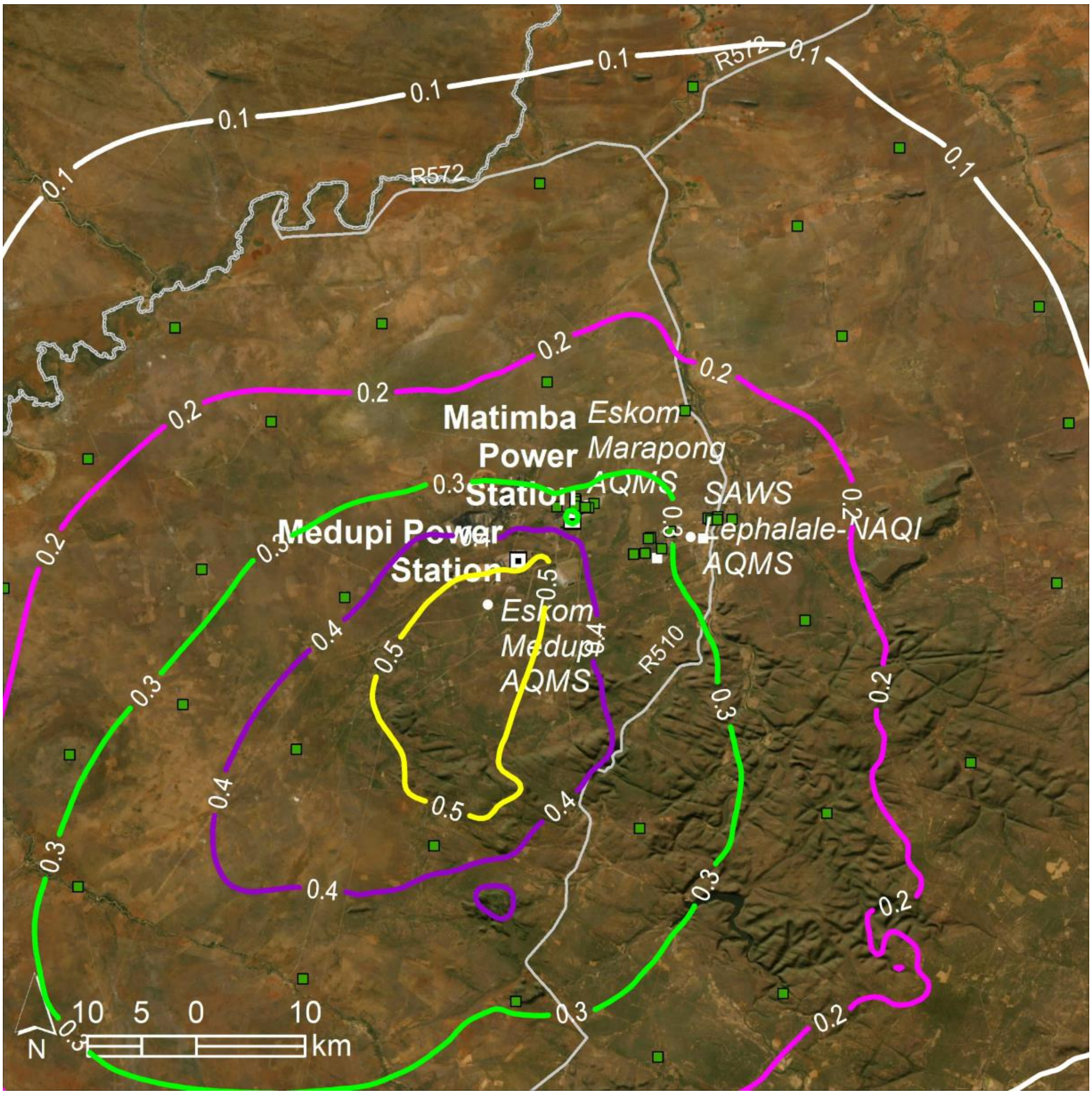

Figure 3-9: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 40 µg/m³)

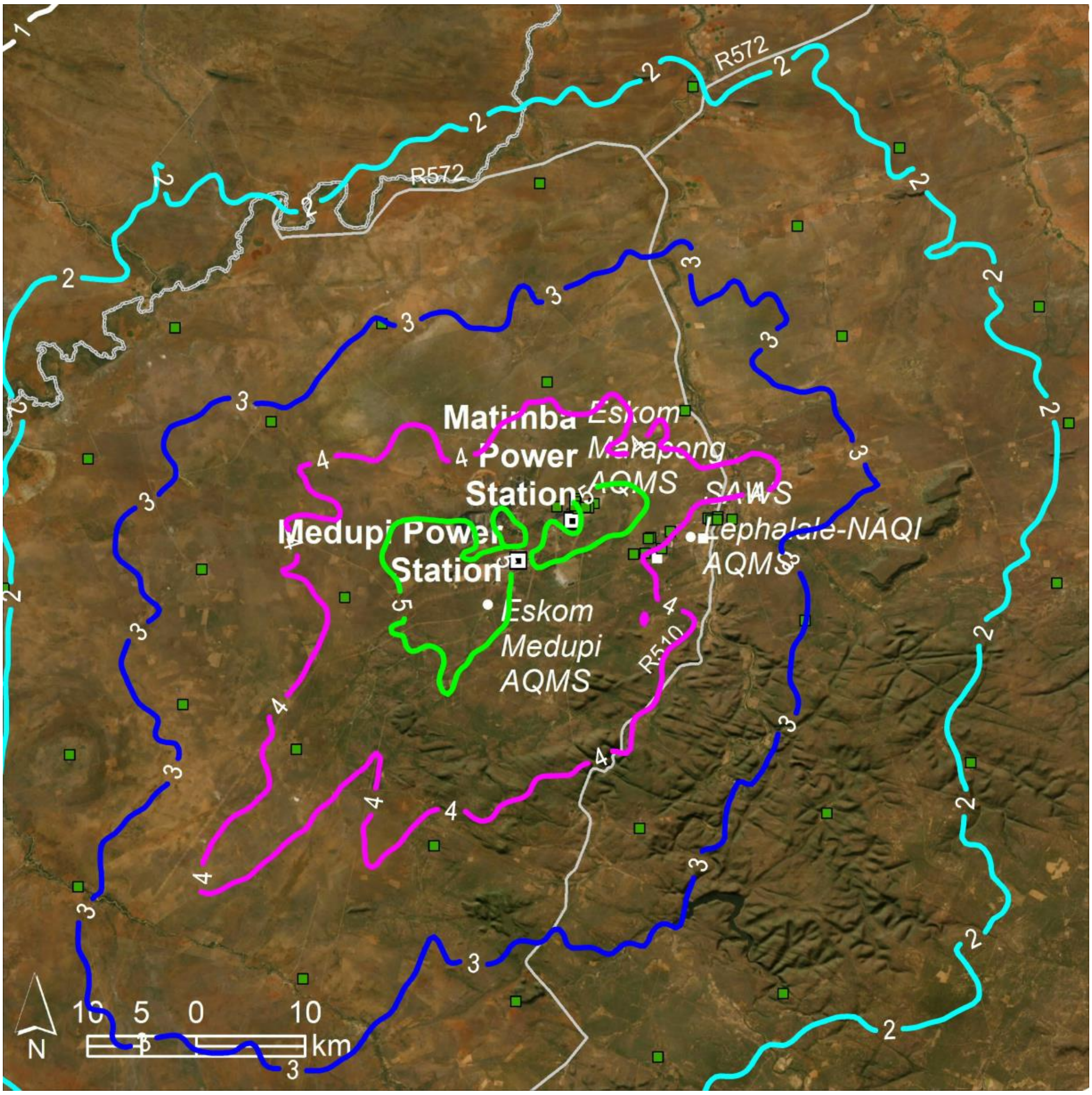

Figure 3-10: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 75 µg/m³)

3.4.2 Particulates ($PM_{2.5}$)

In Scenario 1 (Current), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur up to 20 km around the Medupi and Matimba Power Stations.

The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted concentrations. In Scenario A (2025), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 20 km to the southwest of the Medupi Power Station, and approximately 10 km to the east of the Matimba Power Station.

Noticeable is the dramatic decrease in ambient concentrations on the isopleths for Scenario B (2031), where the biggest reductions are seen, due to the substantial decrease in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and Matimba. In Scenario B (2031), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur up to 20 km around the Medupi and Matimba Power Stations.

The effect of the reduced formation of secondary particulates brought about by the substantial decrease in SO_2 emissions at Medupi are also noticeable on the isopleths for Scenario C (2036). In Scenario C (2036), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 10 km to the west of the Medupi Power Station, and approximately 5 km to the east of the Matimba Power Station.

Although $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), the predicted $PM_{2.5}$ concentrations show a fairly large decrease on the isopleths for Scenario D (MES) (as discussed previously, this decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios at Matimba). In Scenario D (MES), the highest predicted annual concentrations occur approximately 20 km to the south-southwest of the Medupi Power Station. The highest predicted 24-hour concentrations occur approximately 20 km to the southwest of the Medupi Power Station, and approximately 10 km to the west of the Matimba Power Station.

Isopleth maps of the predicted annual average and 99^{th} percentile of the 24-hour $PM_{2.5}$ concentrations are presented in Figure 3-11 to Figure 3-20.

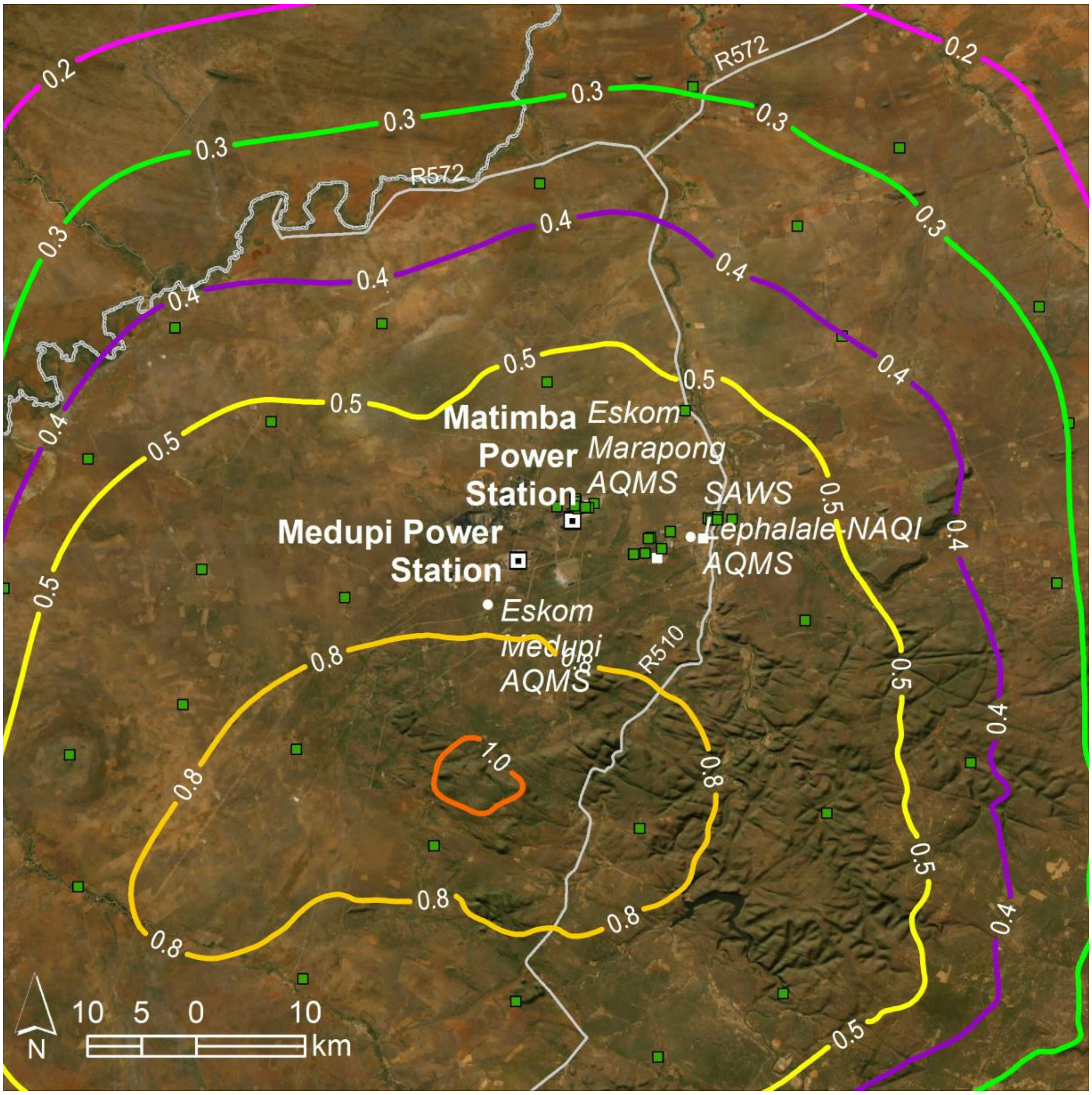

Figure 3-11: Predicted annual average $PM_{2.5}$ concentrations in µg/m^3 for Scenario 1 (Current) (NAAQS Limit is 20 µg/m^3)

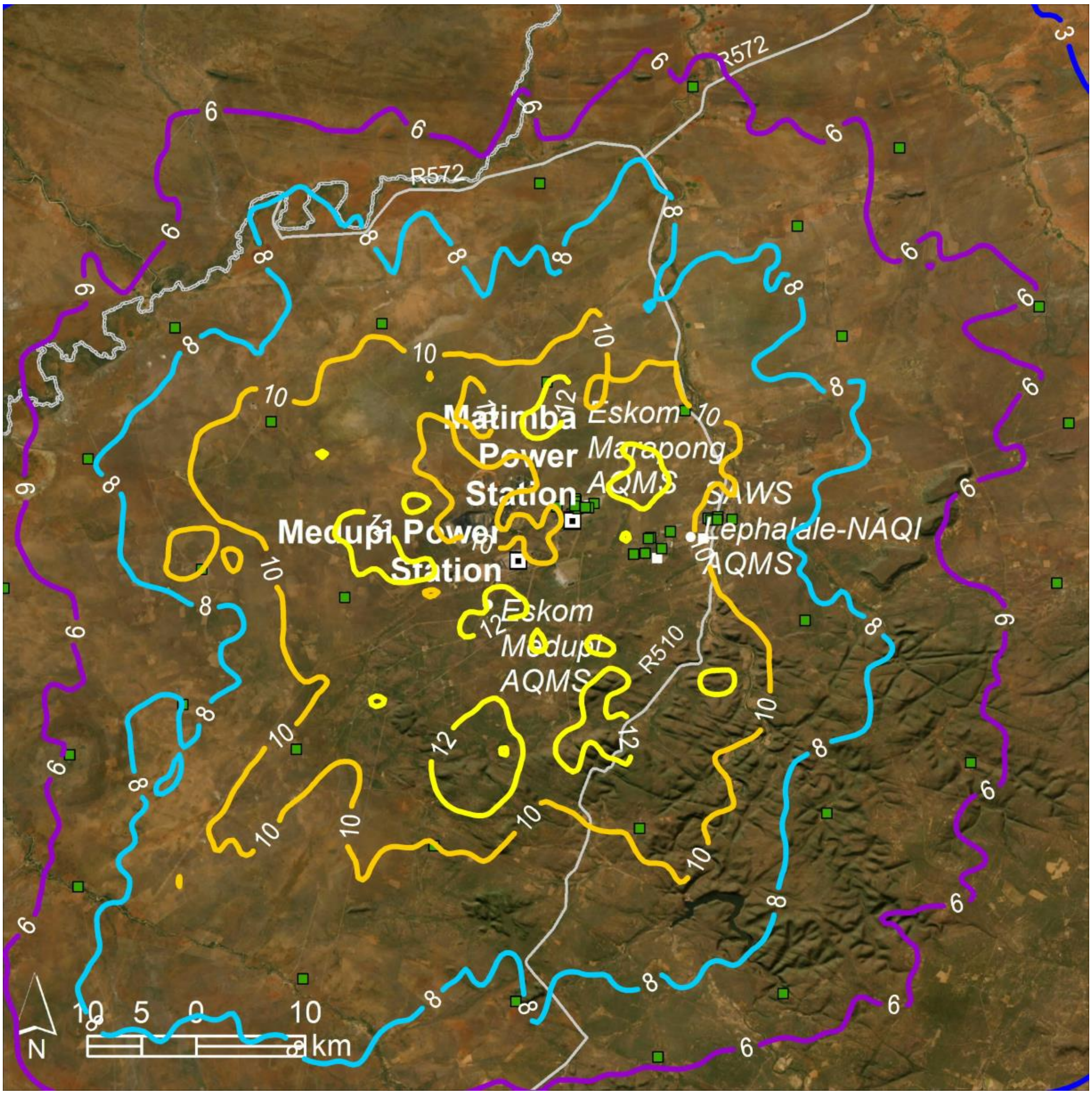

Figure 3-12: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario 1 (Current) (NAAQS Limit is 40 µg/m³)

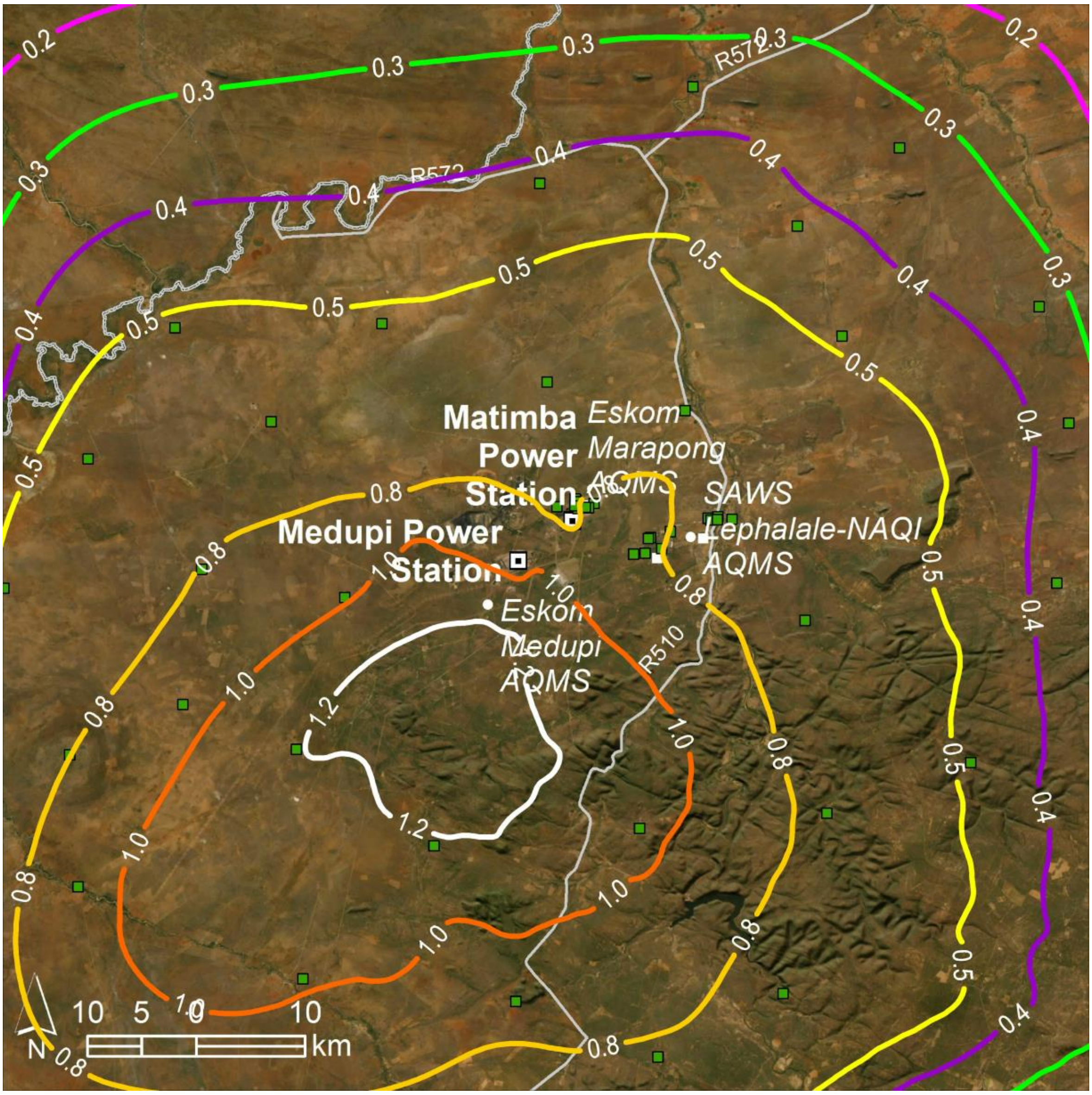

Figure 3-13: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 20 µg/m³)

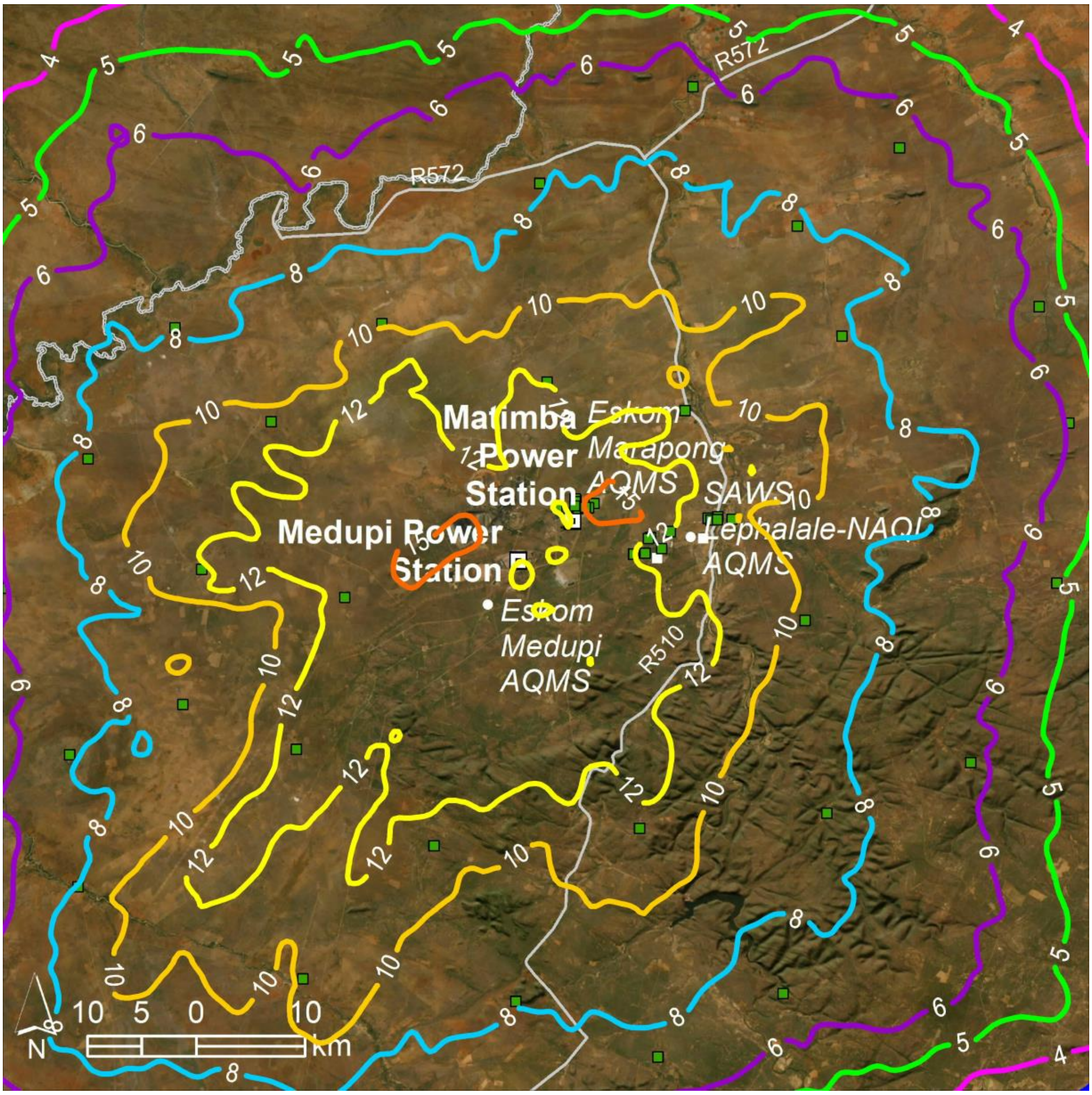

Figure 3-14: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in $\mu g/m^3$ for Scenario A (2025) (NAAQS Limit is 40 $\mu g/m^3$)

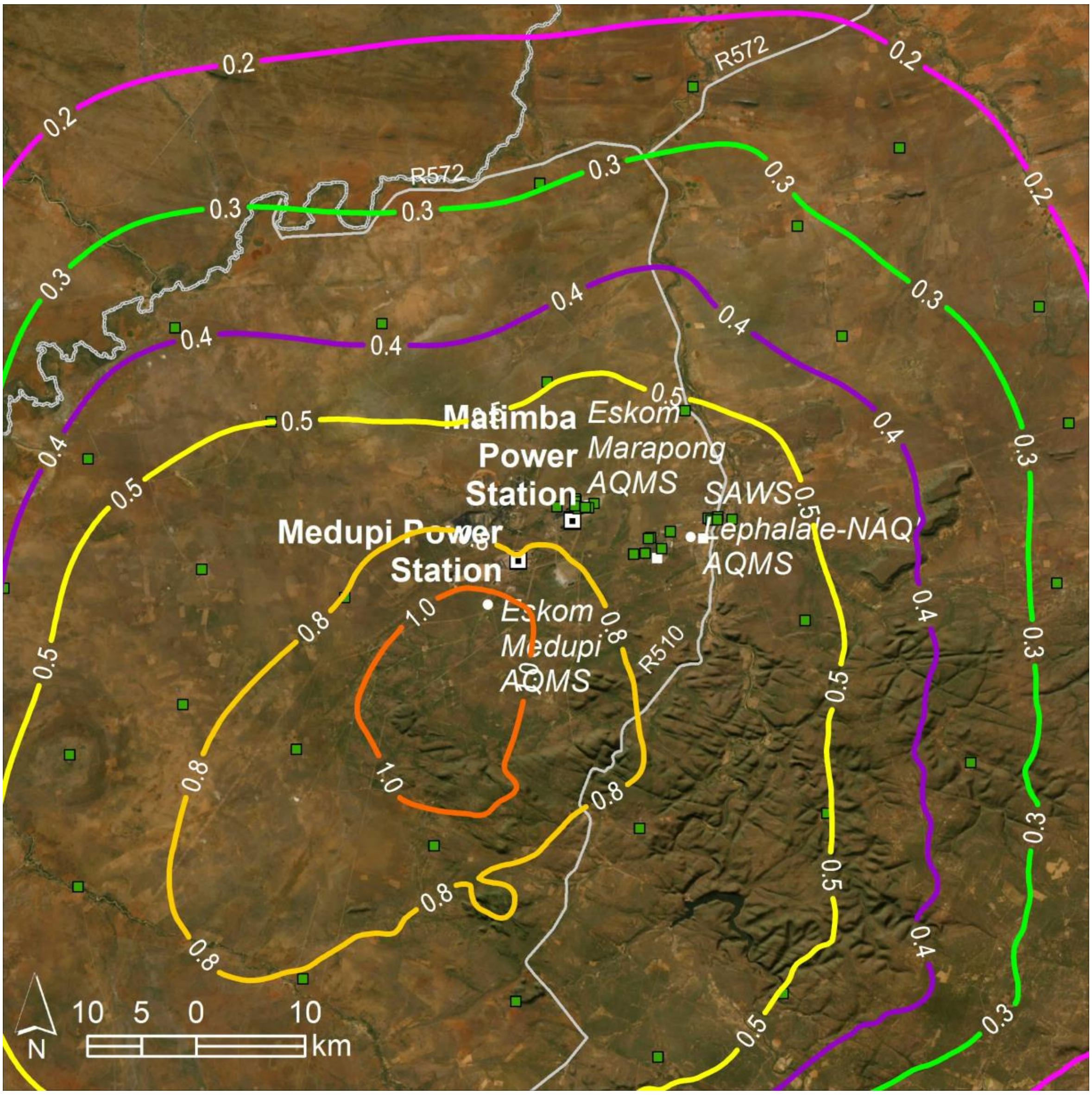

Figure 3-15: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario B (2031) (NAAQS Limit is 15 µg/m³)

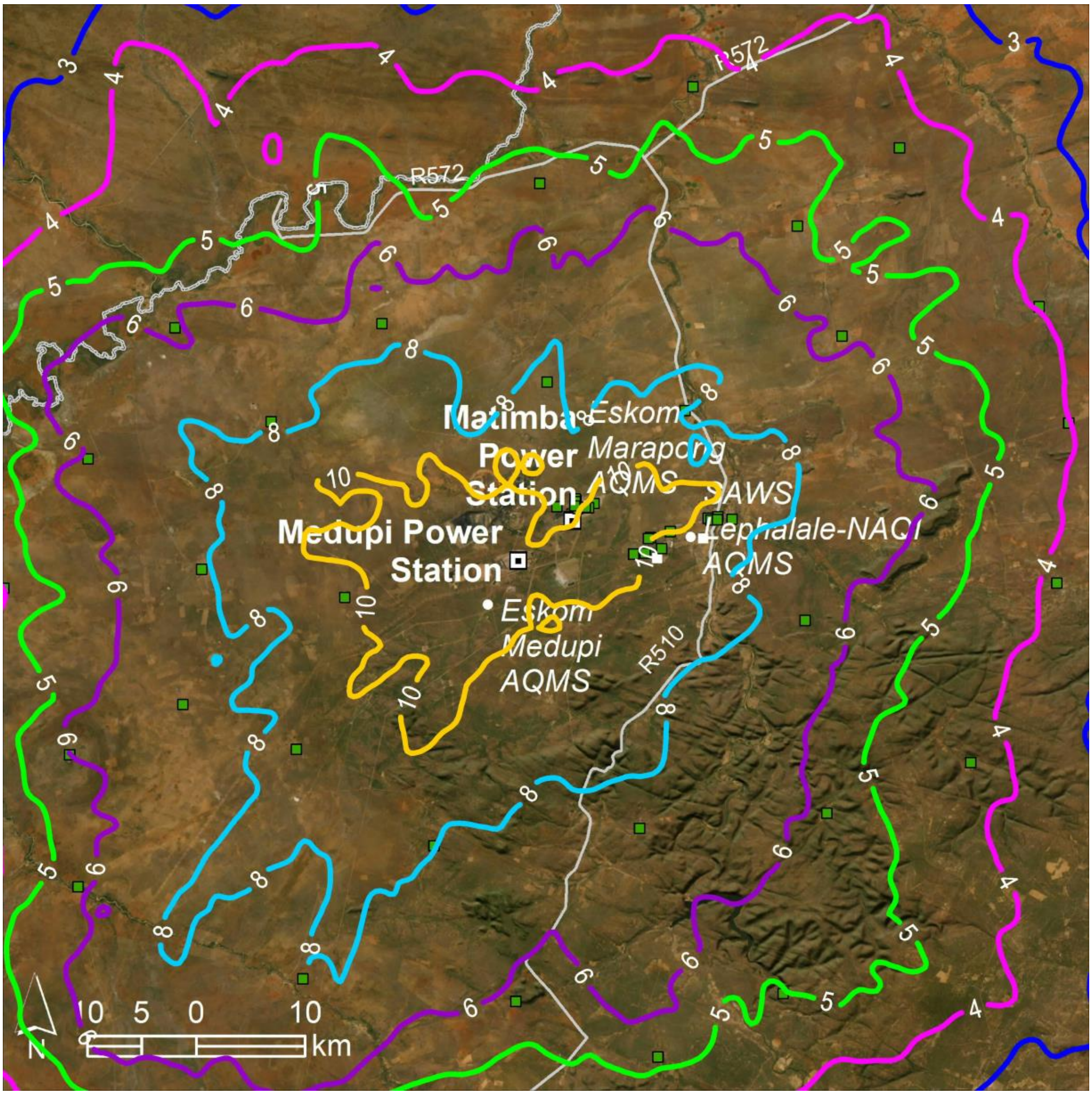

Figure 3-16: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario B (2031) (NAAQS Limit is 25 µg/m³)

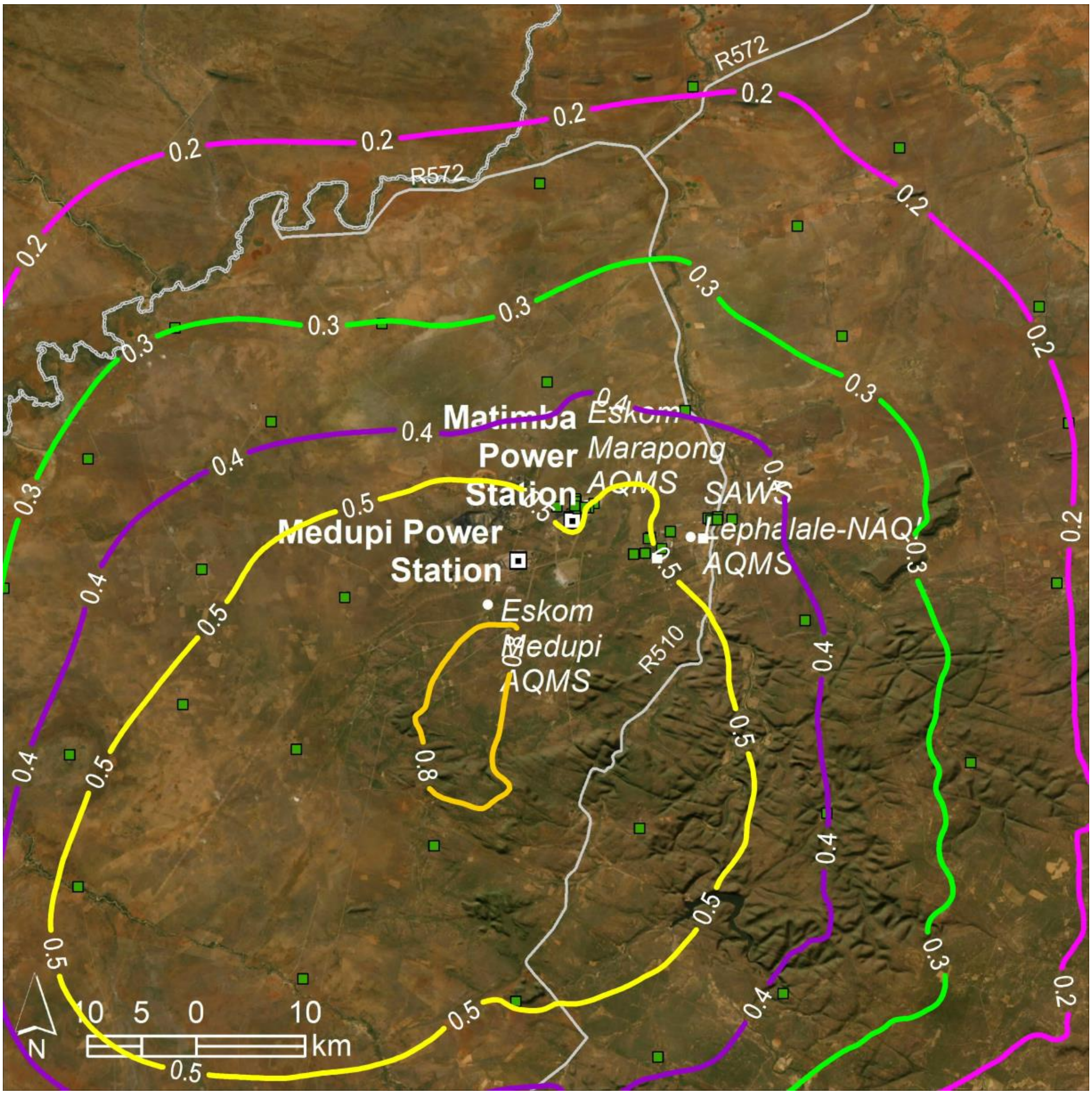

Figure 3-17: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 15 µg/m³)

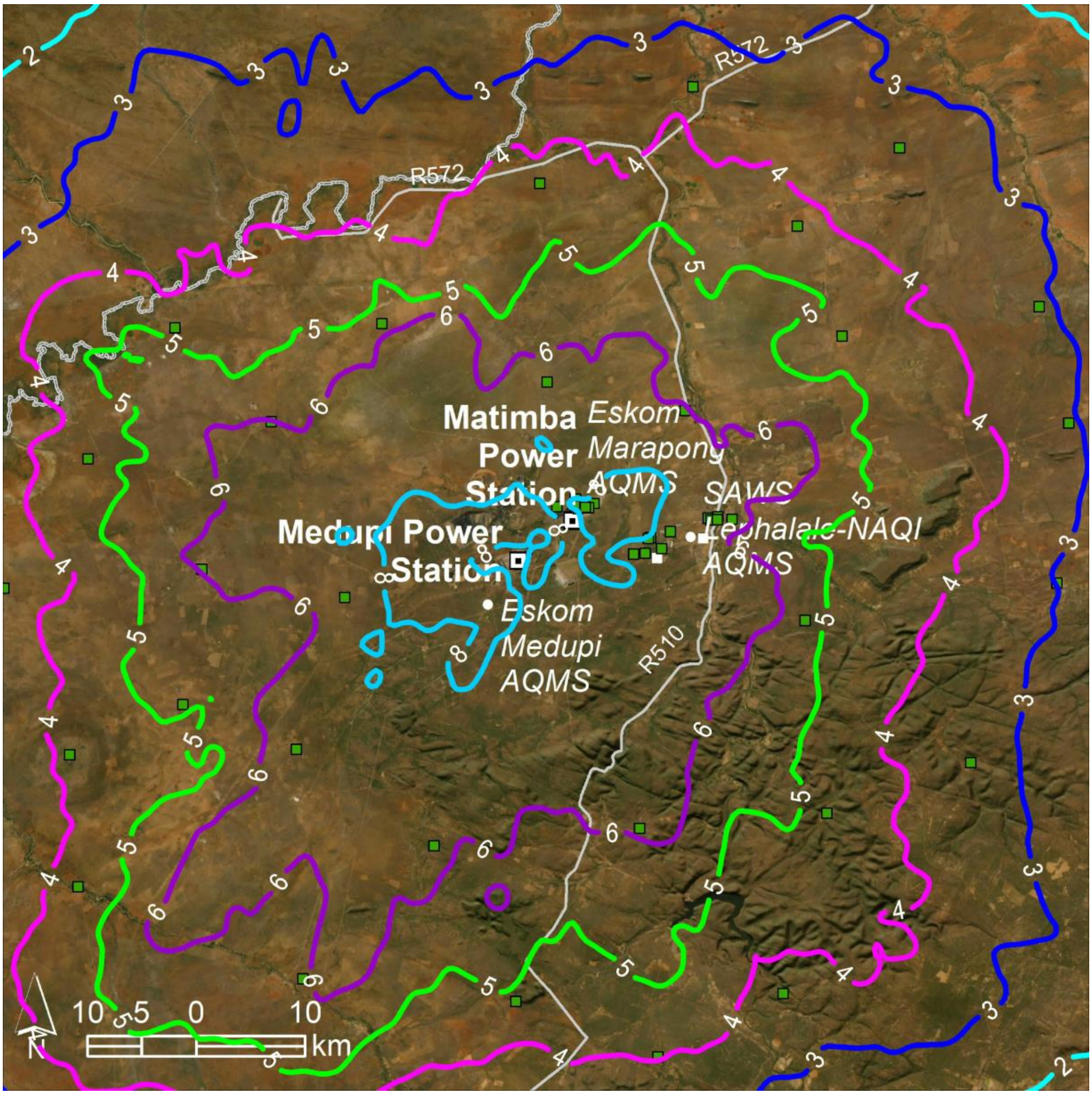

Figure 3-18: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 25 µg/m³)

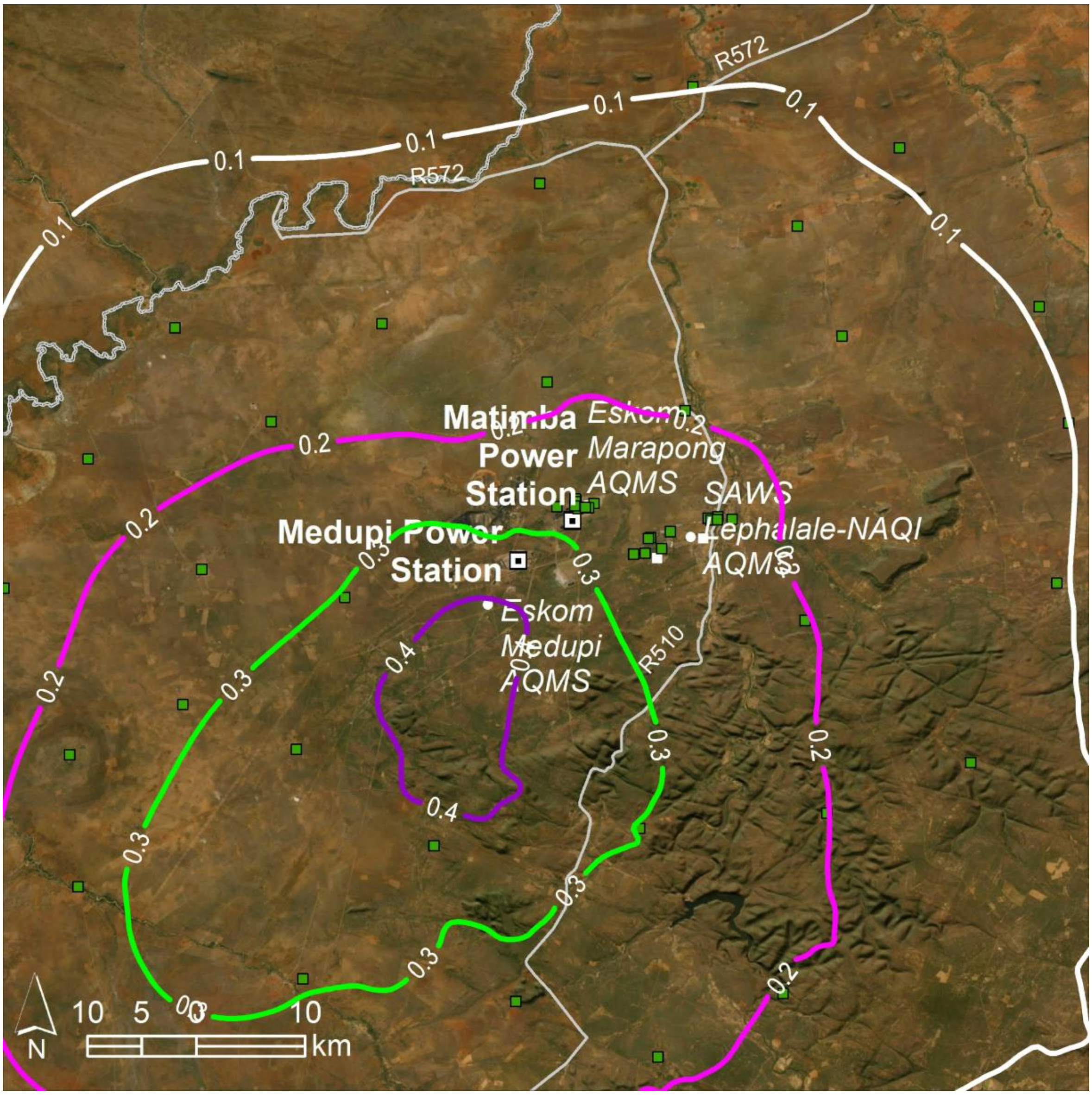

Figure 3-19: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 15 µg/m³)

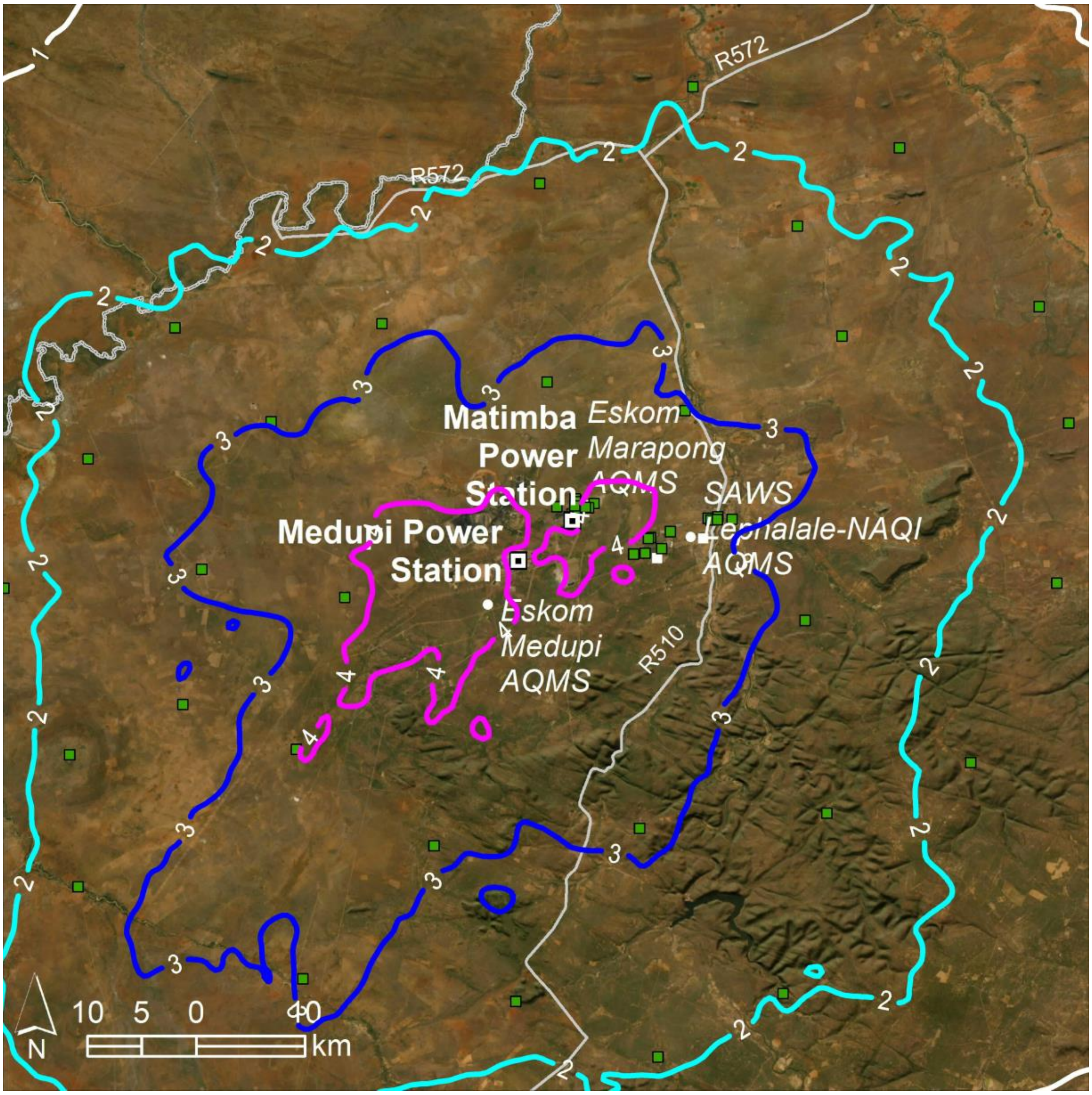

Figure 3-20: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 25 µg/m³)

4. SUMMARY AND CONCLUSION

In this Addendum to the AIR (uMoya-NILU, 2024), the focus is specifically on stack emissions for PM and the modelled results for PM_{10} and $PM_{2.5}$. In this Addendum, the cumulative effect of stack emissions from the 2 coal-fired power stations comprising the Waterberg power station fleet are assessed, i.e. Medupi and Matimba in the Waterberg-Bojanala Priority Area.

Dispersion modelling is used to demonstrate the effect of Eskom's emission reduction strategy by assessing 5 sequential emission scenarios. These are from Scenario 1 using actual emissions from 2021 to 2023, Scenario A using proposed 2025 emissions, Scenario B using proposed 2031 emissions and Scenario C using proposed 2036 emissions. Scenario D uses emissions that comply with the MES to demonstrate the relative effect of compliance.

Noteworthy findings from the modelling results may be summarised as follows:

i) Changes in the predicted annual average and 24-hour PM_{10} and $PM_{2.5}$ concentrations from one scenario to the next are strongly influenced by changes in PM_{10} and $PM_{2.5}$ emissions, the contribution from secondary particulate formation and stack exit velocity.

ii) In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS.

iii) The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted PM_{10} and $PM_{2.5}$ ambient concentrations. Although there is a decrease in PM_{10} and $PM_{2.5}$ emissions at Matimba, the reduced exit velocity in the stacks reduces the dispersion potential.

iv) The maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations decrease significantly from Scenario A (2025) to Scenario B (2031) due to the substantial decrease in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions at Medupi and Matimba.

v) Although there is an increase in NO_X, PM_{10} and $PM_{2.5}$ emissions, and a reduction in exit velocity in the stacks at Medupi and Matimba from Scenario B (2031) to Scenario C (2036), the substantial decrease in SO_2 emissions at Medupi is responsible for a slight decrease in PM_{10} and $PM_{2.5}$ ambient concentrations, as this reduces the formation of secondary particulates.

vi) Although NO_X, PM_{10} and $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), it is noted that the maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations show a fairly large decrease between the two scenarios. This decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions at Matimba.

vii) At all AQMSs, the modelled PM_{10} and $PM_{2.5}$ concentrations are considerably lower than the monitored concentrations. This is to be expected since the AQMSs are exposed to all sources of PM_{10} and $PM_{2.5}$. The difference between the predicted concentrations and the measured concentrations provides an indication of the contribution of the power station stack emissions at the respective AQMSs.

viii) At all identified sensitive receptors, the predicted PM_{10} and $PM_{2.5}$ concentrations are low and well below the limit value of the respective NAAQS for all five scenarios. Noteworthy is the systematic decrease in predicted PM_{10} and $PM_{2.5}$ concentrations from 2025 to 2036 at all sensitive receptors.

5. REFERENCES

DEA (2014): Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa, Government Notice R.533, Government Gazette, no. 37804, 11 July 2014.

uMoya-NILU (2024): Atmospheric Impact Report in Support of the Application for Exemption from the Minimum Emission Standards for Eskom's Coal-Fired Power Stations in the Waterberg (A Cumulative Assessment), Report No.: uMN219-24, November 2024.

USEPA (1995): Compilation of air pollutant emission factors. Volume 1: Stationary point and area sources. AP-42 fifth edition January 1995. US EPA

6. FORMAL DECLARATIONS

A declaration of the accuracy of the information contained in this Atmospheric Impact Report is included here. A declaration of the independence of the practitioners in the uMoya-NILU consultancy team that compiled this AIR is also included.

DECLARATION OF ACCURACY OF INFORMATION – APPLICANT

Name of Enterprise: uMoya-NILU Consulting (Pty) Ltd

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act

I, Mark Zunckel [duly authorised], declare that the information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality office is a criminal office in terms of section 51(1)(g) of this Act.

Signed at Durban on this 9th day of December 2024.

SIGNATURE

Managing Director – uMoya-NILU Consulting
CAPACITY OF SIGNATORY

DECLARATION OF INDEPENDENCE – PRACTITIONER

Name of Practitioner: Mark Zunckel

Name of Registered Body: South African Council for Natural Scientific Professionals

Professional Registration Number: 400449/04

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act

I, Mark Zunckel declare that I am independent of the applicant. I have the necessary expertise to conduct the assessment required for the report and will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The information provided in the atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality office is a criminal office in terms of section 51(1)(g) of this Act.

Signed at Durban on this 9th day of December 2024.

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SIGNATURE

Managing Director – uMoya-NILU Consulting
CAPACITY OF SIGNATORY

ANNEXURE 1: WATERBERG SENSITIVE RECEPTORS

Area	Sensitive Receptors	Latitude	Longitude
Marapong	Phegelelo Senior Secondary	-23.651888°	27.618334°
	Contractors Village	-23.657320°	27.601031°
	Ditheku Primary School	-23.651003°	27.617502°
	Ditheko pramary School	-23.654704°	27.634336°
	Marapong Training Centre	-23.658318°	27.618626°
	Marapong Clinic	-23.658287°	27.629470°
	Tielelo Secondary School	-23.653177°	27.617447°
	Grootegeluk Medical Centre - Community center	-23.658717°	27.619834°
Lephalale	Lephalale College	-23.682740°	27.685668°
	Nelsonskop Primary School	-23.657586°	27.626724°
	Hansie En Grietjie Pre-Primary School	-23.683331°	27.683339°
	Sedibeng Special School for the Deaf and Disabilities	-23.691657°	27.695709°
	Kings College	-23.696561°	27.670262°
	Bosveld Primary School	-23.695608°	27.680724°
	Lephalale Medical Hospital	-23.656805°	27.617153°
	Ellisras Hospital	-23.677758°	27.703310°
	Laerskool Ellisras Primary School	-23.665398°	27.745938°
	Hoerskool Ellisras Secondary School	-23.666541°	27.737342°
	Marlothii Learning Academy	-23.667777°	27.739952°
	Hardekool Akademie vir C.V.O	-23.667215°	27.758752°
	Lephalale Clinic	-23.667615°	27.745728°
Ons Hoop	Ons Hoop	-23.577123°	27.716123°
Woudend	Woudend	-23.308433°	27.721479°
Ramabara's	Ramabara's	-23.750848°	27.825234°
Shongoane	Ga-Shongoane	-23.585319°	28.061576°
Bulge River	Bulge River	-24.113815°	27.694438°
	Kaingo Mountain Lodge	-24.060357°	27.807197°
	Community	-24.067953°	27.565793°
Kiesel	Kiesel	-23.974023°	27.169620°
	Kremetartpan	-23.859326°	27.366887°
	Mbala Private Camp	-23.939199°	27.491076°
Steenbokpan	Steenbokpan	-23.733401°	27.409802°
	Receptor	-23.587405°	27.343032°
Sandbult	Sandbult	-23.710158°	27.280718°
Hardekraaltjie	Hardekraaltjie	-23.509997°	27.256399°
	Receptor	-23.554188°	27.591804°
	Receptor	-23.506063°	27.442803°
	Receptor	-23.388962°	27.584125°
	Receptor	-23.423577°	27.816176°
	Receptor	-23.514728°	27.856760°
Ditaung	Ditaung	-23.489060°	28.034173°
Letlora	Letlora	-23.358262°	27.907715°
	Receptor	-23.822555°	27.264099°
	Glenover	-23.864360°	27.162054°

Area	Sensitive Receptors	Latitude	Longitude
	Oxford Safaris	-23.726164°	27.102742°
	Receptor	-23.618685°	27.178320°
Tholo Bush Estate	Tholo Bush Estate	-23.910668°	27.845646°
	Receptor	-23.924018°	27.676686°
	Receptor	-23.867661°	27.975574°
Thabazimbi	Cheetah Safaris	-24.049921°	27.373278°
	Rhinoland Safaris	-23.718286°	28.051922°

ANNEXURE 2: PREDICTED CONCENTRATIONS AT SENSIIVE RECEPTORS

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario 1 (Current), together with the limit value of the NAAQS

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Phegelelo Senior Secondary	12.6	0.6	11.9	0.6
Contractors Village	10.5	0.6	9.9	0.6
Ditheku Primary School	12.5	0.6	11.8	0.6
Ditheko Primary School	12.6	0.7	11.8	0.6
Marapong Training Centre	11.7	0.6	10.9	0.6
Marapong Clinic	12.4	0.7	11.6	0.6
Tielelo Secondary School	12.1	0.6	11.4	0.6
Grootegeluk Medical Centre - Community Center	11.7	0.7	10.9	0.6
Lephalale College	11.4	0.7	10.8	0.6
Nelsonskop Primary School	12.1	0.7	11.3	0.6
Hansie en Grietjie Pre-Primary School	11.5	0.7	10.9	0.6
Sedibeng Special School for the Deaf and Disabilities	12.4	0.7	11.9	0.6
Kings College	11.0	0.7	10.4	0.7
Bosveld Primary School	11.6	0.7	11.0	0.7
Lephalale Medical Hospital	11.6	0.6	10.8	0.6
Ellisras Hospital	10.9	0.7	10.4	0.6
Laerskool Ellisras Primary School	9.9	0.6	9.4	0.6
Hoerskool Ellisras Secondary School	10.2	0.6	9.8	0.6
Marlothii Learning Academy	10.1	0.6	9.6	0.6
Hardekool Akademie vir C.V.O	9.9	0.6	9.4	0.6
Lephalale Clinic	9.9	0.6	9.4	0.6
Ons Hoop	10.7	0.6	10.2	0.5
Woudend	6.6	0.3	6.3	0.3
Ramabara's	9.1	0.6	8.6	0.6
Ga-Shongoane	5.3	0.3	5.1	0.3
Bulge River	7.1	0.7	6.7	0.6
Kaingo Mountain Lodge	7.4	0.6	7.1	0.6
Community	8.1	0.8	7.7	0.7
Kiesel	7.6	0.8	7.2	0.7
Kremetartpan	11.2	1.0	10.5	0.9
Mbala Private Camp	10.6	0.9	10.0	0.9
Steenbokpan	12.2	0.8	11.6	0.7
Receptor	11.1	0.5	10.7	0.5
Sandbult	10.4	0.7	10.0	0.6
Hardekraaltjie	7.4	0.4	7.1	0.4
Receptor	12.0	0.6	11.5	0.5
Receptor	10.2	0.4	9.8	0.4
Receptor	7.2	0.4	6.9	0.4
Receptor	7.6	0.4	7.3	0.4
Receptor	7.2	0.4	6.9	0.4
Ditaung	5.7	0.3	5.5	0.3
Letlora	5.6	0.3	5.4	0.3
Receptor	8.3	0.8	7.9	0.7
Glenover	6.5	0.7	6.1	0.6
Oxford Safaris	5.1	0.5	4.8	0.4
Receptor	8.0	0.5	7.7	0.5
Tholo Bush Estate	7.7	0.6	7.3	0.6

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**40**	**20**
Receptor	11.1	0.9	10.6	0.9
Receptor	6.5	0.4	6.2	0.4
Cheetah Safaris	9.3	0.8	8.9	0.8
Rhinoland Safaris	5.0	0.3	4.7	0.3

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario A (2025), together with the limit value of the NAAQS

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	40	20
Phegelelo Senior Secondary	13.9	0.9	12.7	0.8
Contractors Village	12.3	0.8	11.3	0.8
Ditheku Primary School	14.1	0.9	13.0	0.8
Ditheko Primary School	17.9	0.9	16.8	0.8
Marapong Training Centre	15.6	0.9	14.3	0.8
Marapong Clinic	17.3	0.9	16.1	0.8
Tielelo Secondary School	14.0	0.9	12.8	0.8
Grootegeluk Medical Centre - Community Center	15.5	0.9	14.3	0.8
Lephalale College	12.9	0.9	12.3	0.8
Nelsonskop Primary School	17.1	0.9	15.9	0.8
Hansie en Grietjie Pre-Primary School	12.8	0.9	12.2	0.8
Sedibeng Special School for the Deaf and Disabilities	11.6	0.9	11.0	0.8
Kings College	12.6	0.9	12.0	0.8
Bosveld Primary School	11.7	0.9	11.1	0.8
Lephalale Medical Hospital	13.9	0.9	12.8	0.8
Ellisras Hospital	12.3	0.9	11.7	0.8
Laerskool Ellisras Primary School	11.1	0.8	10.5	0.8
Hoerskool Ellisras Secondary School	11.6	0.8	11.0	0.8
Marlothii Learning Academy	11.4	0.8	10.8	0.8
Hardekool Akademie vir C.V.O	10.5	0.8	9.9	0.7
Lephalale Clinic	11.0	0.8	10.5	0.8
Ons Hoop	11.4	0.7	10.8	0.7
Woudend	6.7	0.4	6.4	0.4
Ramabara's	10.0	0.7	9.5	0.7
Ga-Shongoane	6.2	0.4	6.0	0.4
Bulge River	7.4	0.8	7.1	0.8
Kaingo Mountain Lodge	7.0	0.7	6.8	0.7
Community	8.6	0.9	8.2	0.9
Kiesel	8.8	1.0	8.3	0.9
Kremetartpan	13.6	1.3	12.9	1.2
Mbala Private Camp	11.6	1.3	11.0	1.2
Steenbokpan	13.9	1.1	13.2	1.0
Receptor	10.8	0.7	10.4	0.6
Sandbult	12.5	0.9	11.9	0.8
Hardekraaltjie	8.0	0.5	7.7	0.5
Receptor	12.9	0.7	12.2	0.6
Receptor	10.5	0.5	10.1	0.5
Receptor	7.7	0.4	7.4	0.4
Receptor	8.7	0.4	8.4	0.4
Receptor	8.7	0.5	8.3	0.5
Ditaung	5.7	0.4	5.4	0.3
Letlora	6.6	0.3	6.4	0.3
Receptor	9.6	1.0	9.1	0.9
Glenover	8.0	0.8	7.6	0.8
Oxford Safaris	6.2	0.6	5.9	0.5
Receptor	8.8	0.6	8.5	0.6
Tholo Bush Estate	9.0	0.8	8.7	0.7

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**40**	**20**
Receptor	11.9	1.1	11.4	1.0
Receptor	6.4	0.5	6.2	0.5
Cheetah Safaris	10.5	1.1	10.1	1.0
Rhinoland Safaris	5.4	0.4	5.2	0.4

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario B (2031), together with the limit value of the NAAQS

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	25	15
Phegelelo Senior Secondary	10.8	0.7	9.7	0.6
Contractors Village	10.4	0.7	9.4	0.7
Ditheku Primary School	10.7	0.7	9.6	0.6
Ditheko Primary School	11.4	0.8	10.3	0.7
Marapong Training Centre	11.3	0.7	10.0	0.7
Marapong Clinic	11.5	0.8	10.3	0.7
Tielelo Secondary School	10.9	0.7	9.8	0.7
Grootegeluk Medical Centre - Community Center	11.6	0.8	10.3	0.7
Lephalale College	10.7	0.8	10.1	0.7
Nelsonskop Primary School	11.4	0.8	10.2	0.7
Hansie en Grietjie Pre-Primary School	10.7	0.8	10.0	0.7
Sedibeng Special School for the Deaf and Disabilities	9.7	0.7	9.1	0.7
Kings College	11.6	0.8	10.9	0.7
Bosveld Primary School	10.7	0.8	10.1	0.7
Lephalale Medical Hospital	11.1	0.7	9.8	0.7
Ellisras Hospital	10.9	0.7	10.4	0.7
Laerskool Ellisras Primary School	9.4	0.7	8.8	0.6
Hoerskool Ellisras Secondary School	9.7	0.7	9.2	0.6
Marlothii Learning Academy	9.6	0.7	9.1	0.6
Hardekool Akademie vir C.V.O	9.5	0.6	9.0	0.6
Lephalale Clinic	9.4	0.7	8.8	0.6
Ons Hoop	8.7	0.6	8.2	0.5
Woudend	4.7	0.3	4.4	0.3
Ramabara's	7.2	0.6	6.8	0.5
Ga-Shongoane	4.3	0.3	4.0	0.3
Bulge River	5.6	0.6	5.3	0.6
Kaingo Mountain Lodge	5.1	0.5	4.9	0.5
Community	6.1	0.7	5.8	0.7
Kiesel	6.1	0.8	5.7	0.7
Kremetartpan	10.1	1.0	9.5	0.9
Mbala Private Camp	8.5	1.0	8.1	0.9
Steenbokpan	9.5	0.9	8.9	0.8
Receptor	7.7	0.5	7.3	0.5
Sandbult	8.1	0.7	7.7	0.6
Hardekraaltjie	6.0	0.4	5.8	0.4
Receptor	9.4	0.5	8.8	0.5
Receptor	7.5	0.4	7.2	0.4
Receptor	5.8	0.3	5.5	0.3
Receptor	5.4	0.3	5.1	0.3
Receptor	5.8	0.4	5.5	0.4
Ditaung	4.2	0.3	4.0	0.2
Letlora	4.6	0.3	4.4	0.2
Receptor	7.9	0.8	7.4	0.7
Glenover	6.4	0.6	6.0	0.6
Oxford Safaris	4.3	0.4	4.0	0.4
Receptor	6.2	0.5	5.9	0.4
Tholo Bush Estate	5.9	0.5	5.6	0.5

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**25**	**15**
Receptor	7.8	0.8	7.4	0.8
Receptor	4.5	0.4	4.3	0.3
Cheetah Safaris	8.3	0.9	7.9	0.8
Rhinoland Safaris	4.0	0.3	3.8	0.3

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario C (2036), together with the limit value of the NAAQS

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Phegelelo Senior Secondary	9.4	0.5	8.2	0.5
Contractors Village	8.6	0.5	7.6	0.5
Ditheku Primary School	9.1	0.5	8.0	0.5
Ditheko Primary School	9.1	0.6	8.1	0.5
Marapong Training Centre	9.5	0.6	8.3	0.5
Marapong Clinic	9.8	0.6	8.6	0.5
Tielelo Secondary School	9.4	0.5	8.2	0.5
Grootegeluk Medical Centre - Community Center	9.2	0.6	8.1	0.5
Lephalale College	8.6	0.6	8.0	0.5
Nelsonskop Primary School	9.8	0.6	8.6	0.5
Hansie en Grietjie Pre-Primary School	8.6	0.6	8.0	0.5
Sedibeng Special School for the Deaf and Disabilities	8.0	0.6	7.5	0.5
Kings College	8.0	0.6	7.4	0.5
Bosveld Primary School	7.9	0.6	7.4	0.5
Lephalale Medical Hospital	9.7	0.6	8.4	0.5
Ellisras Hospital	7.8	0.5	7.2	0.5
Laerskool Ellisras Primary School	7.0	0.5	6.5	0.5
Hoerskool Ellisras Secondary School	7.3	0.5	6.8	0.5
Marlothii Learning Academy	7.0	0.5	6.5	0.5
Hardekool Akademie vir C.V.O	7.2	0.5	6.7	0.4
Lephalale Clinic	6.9	0.5	6.4	0.5
Ons Hoop	6.7	0.4	6.2	0.4
Woudend	3.9	0.2	3.7	0.2
Ramabara's	5.6	0.4	5.2	0.4
Ga-Shongoane	3.4	0.2	3.2	0.2
Bulge River	4.4	0.5	4.1	0.4
Kaingo Mountain Lodge	4.1	0.4	3.8	0.4
Community	5.2	0.6	4.8	0.5
Kiesel	4.7	0.6	4.3	0.5
Kremetartpan	7.9	0.8	7.3	0.7
Mbala Private Camp	6.9	0.8	6.4	0.7
Steenbokpan	7.5	0.7	6.9	0.6
Receptor	6.4	0.4	6.0	0.4
Sandbult	6.7	0.5	6.3	0.5
Hardekraaltjie	4.7	0.3	4.5	0.3
Receptor	7.4	0.4	6.9	0.4
Receptor	5.9	0.3	5.5	0.3
Receptor	4.5	0.2	4.3	0.2
Receptor	4.8	0.3	4.5	0.2
Receptor	5.0	0.3	4.7	0.3
Ditaung	3.4	0.2	3.2	0.2
Letlora	3.7	0.2	3.5	0.2
Receptor	5.6	0.6	5.2	0.5
Glenover	4.6	0.5	4.2	0.5
Oxford Safaris	3.4	0.3	3.2	0.3
Receptor	4.9	0.4	4.7	0.3
Tholo Bush Estate	5.1	0.4	4.8	0.4

Scenario C (2036)	**PM_{10} Total**		**$PM_{2.5}$ Total**	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**25**	**15**
Receptor	6.5	0.6	6.1	0.6
Receptor	3.5	0.3	3.3	0.3
Cheetah Safaris	6.2	0.6	5.8	0.6
Rhinoland Safaris	3.2	0.2	3.0	0.2

Predicted concentrations in μg/m³ at the sensitive receptors for Scenario D (MES), together with the limit value of the NAAQS

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Phegelelo Senior Secondary	4.9	0.3	3.8	0.2
Contractors Village	4.9	0.3	4.0	0.2
Ditheku Primary School	5.0	0.3	3.9	0.2
Ditheko Primary School	5.2	0.3	4.2	0.3
Marapong Training Centre	5.3	0.3	4.1	0.3
Marapong Clinic	5.6	0.3	4.5	0.3
Tielelo Secondary School	5.0	0.3	3.8	0.2
Grootegeluk Medical Centre - Community Center	5.5	0.3	4.3	0.3
Lephalale College	4.5	0.3	3.9	0.3
Nelsonskop Primary School	5.5	0.3	4.3	0.3
Hansie en Grietjie Pre-Primary School	4.4	0.3	3.8	0.3
Sedibeng Special School for the Deaf and Disabilities	3.9	0.3	3.4	0.2
Kings College	4.2	0.3	3.6	0.3
Bosveld Primary School	4.0	0.3	3.5	0.3
Lephalale Medical Hospital	5.2	0.3	4.0	0.3
Ellisras Hospital	4.1	0.3	3.6	0.2
Laerskool Ellisras Primary School	3.6	0.3	3.1	0.2
Hoerskool Ellisras Secondary School	3.8	0.3	3.3	0.2
Marlothii Learning Academy	3.7	0.3	3.2	0.2
Hardekool Akademie vir C.V.O	3.7	0.3	3.2	0.2
Lephalale Clinic	3.6	0.3	3.1	0.2
Ons Hoop	3.6	0.2	3.0	0.2
Woudend	2.1	0.1	1.8	0.1
Ramabara's	3.0	0.2	2.6	0.2
Ga-Shongoane	1.9	0.1	1.7	0.1
Bulge River	2.4	0.3	2.2	0.2
Kaingo Mountain Lodge	2.2	0.2	2.0	0.2
Community	2.7	0.3	2.4	0.3
Kiesel	2.8	0.3	2.4	0.3
Kremetartpan	4.5	0.5	3.9	0.4
Mbala Private Camp	3.7	0.4	3.2	0.4
Steenbokpan	4.2	0.4	3.7	0.3
Receptor	3.2	0.2	2.9	0.2
Sandbult	3.7	0.3	3.2	0.2
Hardekraaltjie	2.4	0.2	2.2	0.1
Receptor	3.8	0.2	3.3	0.2
Receptor	3.1	0.2	2.7	0.1
Receptor	2.4	0.1	2.1	0.1
Receptor	2.5	0.1	2.2	0.1
Receptor	2.7	0.2	2.4	0.1
Ditaung	1.8	0.1	1.6	0.1
Letlora	2.0	0.1	1.8	0.1
Receptor	3.3	0.3	2.9	0.3
Glenover	2.7	0.3	2.3	0.2
Oxford Safaris	1.9	0.2	1.7	0.2
Receptor	2.5	0.2	2.2	0.2
Tholo Bush Estate	2.7	0.2	2.5	0.2

Scenario D (MES)	**PM_{10} Total**		**$PM_{2.5}$ Total**	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**25**	**15**
Receptor	3.6	0.4	3.2	0.3
Receptor	1.9	0.2	1.7	0.1
Cheetah Safaris	3.5	0.4	3.1	0.3
Rhinoland Safaris	1.7	0.1	1.5	0.1

ADDENDUM TO:
ATMOSPHERIC IMPACT REPORT IN SUPPORT OF THE APPLICATION FOR EXEMPTION FROM THE MINIMUM EMISSION STANDARDS FOR ESKOM's COAL-FIRED POWER STATIONS ON THE HIGHVELD AND IN THE VAAL TRIANGLE
(A CUMULATIVE ASSESSMENT)

9 December 2024

Report issued by:

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Report issued to:

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GLOSSARY OF TERMS AND ACRONYMS

AEL	Atmospheric Emission Licence
AIR	Atmospheric Impact Report
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DSI	Dry Sorbent Injection
EIA	Environmental Impact Assessment
FGD	Flue-gas desulfurisation
g/s	Grams per second
kPa	Kilo Pascal
LNB	Low NO_X burner
MES	Minimum Emission Standards
mg/Nm^3	Milligrams per normal cubic meter refers to emission concentration, i.e. mass per volume at normal temperature and pressure, defined as air at 20^{o}C (293.15 K) and 1 atm (101.325 kPa)
NAAQS	National Ambient Air Quality Standards
NAQO	National Air Quality Officer
NECA	National Environmental Consultative and Advisory
NEM-AQA	National Environment Management: Air Quality Act, 2004 (Act No. 39 of 2004)
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
USEPA	United States Environmental Protection Agency
µm	1 µm = Micro meter 1 µm = 10^{-6} m

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1. INTRODUCTION

On 22 May 2024, the Minister directed Eskom to submit an application in terms of Section 59 of the National Environmental Management: Air Quality Act for exemption of the MES for eight (8) power stations that will continue to operate post 2030. These are Duvha, Kendal, Majuba, Matla and Tutuka in the Highveld Priority Area; Lethabo in the Vaal Triangle Airshed Priority Area; and Medupi and Matimba in the Waterberg-Bojanala Priority Area.

In terms of the Minister's ruling, Eskom Holdings SOC Ltd appointed WSP Group Africa (Pty) Ltd to prepare the necessary applications. WSP Group Africa (Pty) Ltd sub-contracted uMoya-NILU Consulting (Pty) Ltd to prepare the associated Atmospheric Impact Reports (AIRs) to support these applications. AIRs were duly prepared to support the respective exemption applications for the individual power stations. Furthermore, two cumulative AIRs were prepared, for the suite of power stations on the Highveld and the Vaal Triangle, and for the two coal-fired power stations in the Waterberg-Bojanala Priority Area, i.e. Medupi and Matimba (uMoya-NILU, 2024). In so doing, 5 emission scenarios were assessed, which included SO_2, NO_X and PM emissions from the stacks as well as fugitive PM emissions from the coal stockyard and ash dumps. The intention was to provide an understanding of the power stations total contribution to ambient concentrations.

The stack emission data were provided by Eskom for the five scenarios based firstly on actual emissions, followed by emissions representing anticipated station performance in different years. Fugitive emissions were estimated based on a worst-case scenario, with little dust control implemented on the ash dumps. Specifically, 60-80% of the entire area of the ash dumps was assumed to be exposed and available for entrainment of particulates. It was assumed that the sides of the ash dumps are in fact partially vegetated, and the tops are partially wet.

To provide an absolute worst-case, it was assumed that the total PM emission from the stacks into the respective PM_{10} and $PM_{2.5}$ fractions. Therefore, the total PM emission was firstly assumed to be PM_{10}, then was assumed to be $PM_{2.5}$. For consistency in the modelling, the total PM emission from the fugitive sources was also assumed to be PM_{10}, then $PM_{2.5}$. The modelled outputs were then compared against the respective National Ambient Air Quality Standards (NAAQS).

The modelled PM_{10} and $PM_{2.5}$ concentrations were high close to the respective power stations and exceeded the NAAQS. Further away from the power stations, the predicted concentrations were relatively low and complied with the NAAQS. From the results it was however impossible to distinguish between the contribution of the fugitive sources and the stack emissions to ambient concentrations, although the results indicated that the high concentrations were due to the fugitive sources rather than the stack emissions themselves.

As Eskom's request to the Minister concerns stack emissions, it was decided to prepare an addendum to the cumulative assessment for the Highveld and Vaal Triangle power stations and to assess the contribution of stack PM emissions only to the ambient PM_{10} and $PM_{2.5}$ concentrations. The same dispersion model, stack parameterisation and model setup are used. In this Addendum to the AIR (uMoya-NILU, 2024), the focus is specifically on stack emissions for PM and the modelled results for PM_{10} and $PM_{2.5}$.

2. STACK EMISSIONS

In this Addendum to the AIR (uMoya-NILU, 2024), the cumulative effect of stack emissions from 13 coal-fired power stations comprising the Highveld and Vaal power station fleet are assessed, i.e. Arnot, Camden, Duvha, Grootvlei, Hendrina, Kendal, Komati, Kriel, Kusile, Majuba, Matla and Tutuka in the Highveld Priority area and Lethabo in the Vaal Triangle Airshed Priority Area.

2.1 Operational Scenarios

The five operational scenarios anticipated by Eskom for the Highveld and Vaal power station fleet in the coming years are:

Scenario 1 (Current): The baseline scenario using actual monthly stack emissions for 2021-2023.

Scenario A (2025): Eskom's planned 2025 stack emissions, representing anticipated station performance between 2025 – 2030. This includes the shutdown of Komati; the completion of some of the PM abatement projects. The approach to selecting emissions was that the highest year of emissions was selected in a 5-year period, so in some cases if the PM projects were not yet complete, the benefit of these would not be modelled.

Scenario B (2031): Eskom's planned 2031 stack emissions, representing anticipated station performance between 2031 – 2035. This includes completion of shutdowns at Arnot, Kriel, Hendrina, Camden, and Grootvlei, including their fugitive sources, with Matla and Duvha also entering shutdown phase; the completion of all PM abatement projects; FGD at Kusile and completion of the DSI at Majuba (SO_2 emissions); reduced SO_2 emissions achieved though load curtailment and efficiency improvement projects; and NO_X abatement (LNB) at Majuba, Lethabo, and Tutuka.

Scenario C (2036): Eskom's planned 2036 stack emissions, representing anticipated station performance from 2036 onwards. This includes the complete shutdown of Matla and Duvha; shutdowns of Tutuka, Lethabo, and Kendal, including their fugitive sources, with Majuba entering shutdown phase in FY2047; SO_2 abatement installed at Kusile (FGD), Majuba (DSI), Kendal (FGD); as well as reduced SO_2 emissions achieved though load curtailment and efficiency improvement projects.

Scenario D (MES): Full compliance with the MES, where relevant (i.e. not for the stations shutdown), and in addition to the abatement included in above scenarios, FGD installations at Tutuka and Lethabo.

The estimated emission rates for SO_2, NO_X and PM_{10} and equivalent emission concentrations that are used in the dispersion modelling for the power stations are shown in Table 2-1 and Table 2-2, respectively. A reminder that the total PM emission is assumed to be PM_{10}. The maximum anticipated emissions during each period are used for simulation in the model. The boiler units are assumed to operate continuously, i.e. 24 hours a day.

Since each future scenario is a snapshot of the period of operation (e.g. Scenario A = 2025 to 2030), the maximum anticipated emissions during that period, in a single year was selected for simulation in the model.

Table 2-1: Stack emission rates (tonnes/annum) for the suite of coal-fired power stations and 5 emission scenarios

Power station	Stack	SCENARIO 1 (Current)			SCENARIO A (2025)			SCENARIO B (2031)			SCENARIO C (2036)			SCENARIO D (MES)		
		NO_X	SO_2	In	NO_X	SO_2	PM_{10}	NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}
Arnot	Stack 1	21 487	24 465	890	21 619	29 833	1 031	0	0	0	0	0	0	0	0	0
	Stack 2	21 487	24 465	890	21 619	29 833	1 031	0	0	0	0	0	0	0	0	0
Camden	Stack 1	8 914	11 941	460	10 730	14 438	473	0	0	0	0	0	0	0	0	0
	Stack 2	8 914	11 941	460	10 730	14 438	473	0	0	0	0	0	0	0	0	0
	Stack 3	8 914	11 941	460	10 730	14 438	473	0	0	0	0	0	0	0	0	0
	Stack 4	8 914	11 941	460	10 730	14 438	473	0	0	0	0	0	0	0	0	0
Duvha	Stack 1	23 685	44 424	1 819	17 200	36 647	1 137	15 709	33 472	692	0	0	0	0	0	0
	Stack 2	23 685	44 424	1 819	25 800	54 971	2 652	23 564	50 208	1 384	0	0	0	0	0	0
Grootvlei	Stack 1	4 894	8 339	143	11 944	23 618	270	0	0	0	0	0	0	0	0	0
	Stack 2	4 894	8 339	143	0	0	0	0	0	0	0	0	0	0	0	0
Hendrina	Stack 1	7 695	15 589	266	10 585	23 572	356	0	0	0	0	0	0	0	0	0
	Stack 2	7 695	15 589	266	10 585	23 572	356	0	0	0	0	0	0	0	0	0
Kendal	Stack 1	22 623	58 298	13 321	26 033	88 749	1 799	22 770	77 970	1 639	27 213	26 557	1 959	27 213	26 557	1 959
	Stack 2	22 623	58 298	13 321	26 033	88 749	1 799	22 770	77 970	1 639	27 213	26 557	1 959	27 213	26 557	1 959
Komati	Stack 1	1 042	1 076	57	0	0	0	0	0	0	0	0	0	0	0	0
	Stack 2	1 042	1 076	57	0	0	0	0	0	0	0	0	0	0	0	0
Kriel	Stack 1	39 460	46 038	7 802	36 937	42 577	5 639	0	0	0	0	0	0	0	0	0
	Stack 2	39 460	46 038	7 802	36 937	42 577	5 639	0	0	0	0	0	0	0	0	0
Kusile	Stack 1	24 940	21 281	737	30 178	46 428	371	23 777	25 752	293	26 703	28 922	329	26 703	28 922	329
	Stack 2	24 940	21 281	737	30 178	46 428	371	23 777	25 752	293	26 703	28 922	329	26 703	28 922	329
Lethabo	Stack 1	51 234	100 147	5 740	46 808	99 197	3 720	28 583	56 370	1 393	22 246	59 258	1 542	22 246	17 777	1 542
	Stack 2	51 234	100 147	5 740	46 808	99 197	3 720	28 583	56 370	1 393	22 246	59 258	1 542	22 246	17 777	1 542
Majuba	Stack 1	58 301	67 177	952	33 034	105 666	837	25 262	80 804	640	33 250	75 779	842	33 250	22 734	842
	Stack 2	58 301	67 177	952	33 034	105 666	837	25 262	80 804	640	33 250	75 779	842	33 250	22 734	842
Matla	Stack 1	49 710	41 603	10 608	49 301	72 014	4 769	38 853	56 752	1 879	0	0	0	0	0	0
	Stack 2	49 710	41 603	10 608	37 490	54 761	3 627	29 545	43 156	1 429	0	0	0	0	0	0
Tutuka	Stack 1	24 217	45 512	7 692	28 989	59 187	7 006	4 945	15 654	597	17 621	55 242	1 982	17 621	16 573	1 982
	Stack 2	24 217	45 512	7 692	28 989	59 187	7 006	4 945	15 654	597	17 621	55 242	1 982	17 621	16 573	1 982

Table 2-2: Stack emission concentration in mg/Nm^3 at 10% O_2 for the suite of coal-fired power stations and 5 emission scenarios

Power station	Stack	SCENARIO 1 (Current)			SCENARIO A (2025)			SCENARIO B (2031)			SCENARIO C (2036)			SCENARIO D (MES)		
		NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}	NO_x	SO_2	PM_{10}
Arnot	Stack 1	334	381	14	587	810	28	0	0	0	0	0	0	0	0	0
	Stack 2	334	381	14	587	810	28	0	0	0	0	0	0	0	0	0
Camden	Stack 1	461	617	24	680	915	30	0	0	0	0	0	0	0	0	0
	Stack 2	461	617	24	680	915	30	0	0	0	0	0	0	0	0	0
	Stack 3	461	617	24	680	915	30	0	0	0	0	0	0	0	0	0
	Stack 4	461	617	24	680	915	30	0	0	0	0	0	0	0	0	0
Duvha	Stack 1	297	557	23	681	1 451	45	681	1 451	30	0	0	0	0	0	0
	Stack 2	297	557	23	681	1 451	70	681	1 451	40	0	0	0	0	0	0
Grootvlei	Stack 1	145	247	4	885	1 750	20	0	0	0	0	0	0	0	0	0
	Stack 2	145	247	4	0	0	0	0	0	0	0	0	0	0	0	0
Hendrina	Stack 1	150	305	5	595	1 325	20	0	0	0	0	0	0	0	0	0
	Stack 2	150	305	5	595	1 325	20	0	0	0	0	0	0	0	0	0
Kendal	Stack 1	269	694	159	550	1 875	38	528	1 808	38	528	515	38	528	515	38
	Stack 2	269	694	159	550	1 875	38	528	1 808	38	528	515	38	528	515	38
Komati	Stack 1	33	35	2	0	0	0	0	0	0	0	0	0	0	0	0
	Stack 2	33	34	2	0	0	0	0	0	0	0	0	0	0	0	0
Kriel	Stack 1	535	624	106	655	755	100	0	0	0	0	0	0	0	0	0
	Stack 2	535	624	106	655	755	100	0	0	0	0	0	0	0	0	0
Kusile	Stack 1	247	210	7.28	325	500	4	325	352	4	325	352	4	325	352	4
	Stack 2	247	210	7.28	325	500	4	325	352	4	325	352	4	325	352	4
Lethabo	Stack 1	696	1 360	78	755	1 600	60	718	1 416	35	505	1 345	35	505	404	35
	Stack 2	696	1 360	78	755	1 600	60	718	1 416	35	505	1 345	35	505	404	35
Majuba	Stack 1	573	660	9	750	2 399	19	750	2 399	19	750	1 709	19	750	513	19
	Stack 2	573	660	9	750	2 399	19	750	2 399	19	750	1 709	19	750	513	19
Matla	Stack 1	551	461	117	827	1 208	80	827	1 208	40	0	0	0	0	0	0
	Stack 2	551	461	118	827	1 208	80	827	1 208	40	0	0	0	0	0	0
Tutuka	Stack 1	244	458	77	600	1 225	145	290	918	35	400	1 254	45	400	376	45
	Stack 2	244	458	77	600	1 225	145	290	918	35	400	1 254	45	400	376	45

2.2 Methodology for determining $PM_{2.5}$ emissions

In terms of the determination of fine particulate matter emissions ($PM_{2.5}$), it is noted that Eskom utilises the dry bottom boiler emission factors from the United States Environmental Protection Agency (US EPA AP42) (US EPA, 1995) to determine the fine particulate matter (PM) emissions ($PM_{2.5}$). The ratio of the $PM_{2.5}$ to PM_{10} is used to calculate $PM_{2.5}$ from the total PM measured from the Continuous Emission Monitoring System (CEMS) equipment at the respective stacks. The utilisation of CEMS equipment is a more accurate representation of site-specific PM and therefore constitutes a Tier 3 method of reporting.

The US EPA defines dry bottom boilers as those burning coal with high fusion temperatures resulting in dry ash. In wet bottom boilers, coal with low fusion temperatures is used, resulting in molten ash or slag. Eskom coal fired power stations are therefore considered to have dry bottom boilers. Eskom has either Electrostatic Precipitators (ESPs) or Fabric Filter Plants (FFPs) installed as air pollution control devices in all its coal fired units. The following ratios determined from dry bottom emission factors in the US EPA AP42 are used:

- ESP controlled - 0.024 lb/ton for $PM_{2.5}$ and 0.054 lb/ton for PM_{10} [ratio = 0.44]
- FFP controlled - 0.01 lb/ton for $PM_{2.5}$ and 0.02 lb/ton for PM_{10} [ratio = 0.5]

The above ratios for PM_{10}:$PM_{2.5}$ have been applied accordingly at the various power stations as follows:

- Arnot, Camden, Grootvlei, Hendrina, Kusile and Majuba have FFPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.50
- Kendal, Kriel, Lethabo, Matla, Tutuka and Komati have ESPs installed on both stacks, hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.44
- Duvha has an FFP on Unit 1 and Unit 2 (Stack 1) hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.50; and ESP on Unit 4, Unit 5 and Unit 6 (Stack 2) hence the PM_{10}:$PM_{2.5}$ ratio is 1:0.44

3. DISPERSION MODELLING RESULTS

The CALPUFF modelling suite provides for the chemical conversion of SO_2 and NO_X to secondary particulates, i.e. sulphates and nitrates in the modelling results. For PM_{10} and $PM_{2.5}$, the predicted concentrations presented are therefore attributed to stack emissions and the contribution from secondary particulate formation.

The DEA (2014) recommends the 99th percentile concentrations for short-term assessment with the NAAQS since the highest predicted ground-level concentrations can be considered outliers due to complex variability of meteorological processes. In addition, the limit value in the NAAQS is the 99th percentile. The impact assessment therefore compares the predicted 99th percentile concentrations with the respective NAAQS limit values and the permitted frequency of exceedance for the five scenarios.

3.1 Maximum predicted ambient concentrations

The maximum predicted annual PM_{10} and $PM_{2.5}$ concentrations and the 99th percentile of the 24-hour predicted concentrations are discussed here and are listed in Table 3-1 for the 5 scenarios.

Changes in the predicted annual average and 24-hour PM_{10} and $PM_{2.5}$ concentrations from one scenario to the next are strongly influenced by changes in PM_{10} and $PM_{2.5}$ emissions, the contribution from secondary particulate formation and stack exit velocity.

In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS. In other words, here are no predicted exceedances of the 24-hour limit value of the respective NAAQS for PM_{10} and for $PM_{2.5}$.

The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted PM_{10} and $PM_{2.5}$ ambient concentrations.

The maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations decrease significantly from Scenario A (2025) when 13 power stations are in operation to Scenario B (2031) due to the shutdown of 5 power stations (Arnot, Camden, Hendrina, Kriel, Grootvlei); and as a result of PM abatement projects at Duvha, Lethabo, Kendal, Matla and Tutuka being completed.

The slight decrease in PM_{10} and $PM_{2.5}$ ambient concentrations from Scenario B (2031) to Scenario C (2036) is mainly due to the shutdown of the Duvha and Matla generating units (which would have occurred by 2035).

Although PM_{10} and $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), it is noted that the maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations show a fairly large decrease between the two scenarios. This decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios.

Table 3-1: Maximum predicted ambient annual PM_{10}, and $PM_{2.5}$ concentrations in µg/m³ and the predicted 99th percentile concentrations for 24-hour averaging periods, with the South African NAAQS

Scenario and Pollutant	Averaging time	
Predicted maximum PM_{10}	**Annual**	**24-hour**
Scenario 1 (Current)	4.1	34.7
Scenario A (2025)	4.7	36.5
Scenario B (2031)	2.2	16.9
Scenario C (2035)	1.8	14.0
Scenario D (MES)	1.2	8.8
NAAQS	**40**	**75**
Predicted maximum $PM_{2.5}$	**Annual**	**24-hour**
Scenario 1 (Current)	3.4	27.1
Scenario A (2025)	4.2	31.3
Scenario B (2031)	2.1	16.0
Scenario C (2035)	1.7	13.2
Scenario D (MES)	1.0	7.0
NAAQS (up to 31 Dec 2029)	**20**	**40**
NAAQS (from 01 Jan 2030)	**15**	**25**

3.2 Predicted concentrations at the AQMSs

The predicted annual PM_{10} and $PM_{2.5}$ concentrations are compared with the measured annual averages in 2021, 2022 and 2023 at several Air Quality Monitoring Stations (AQMSs) in the Highveld modelling domain for Scenario 1 (Current) in Table 3-2 and Table 3-3, respectively.

For PM_{10} and $PM_{2.5}$, the predicted ambient concentrations result from the respective power station stack emissions. At all the AQMSs, the modelled concentrations are considerably lower than the monitored concentrations. This is to be expected since the AQMSs are exposed to all sources of PM_{10} and $PM_{2.5}$. The difference between the predicted concentrations and the measured concentrations provides an indication of the contribution of the power station stack emissions at the respective AQMSs.

Table 3-2: Measured annual average PM_{10} concentration at the Highveld AQMSs compared with predicted concentrations in µg/m³ for Scenario 1 (Current)

Receptor	2021	2022	2023	Modelled
Grootdraai Dam AQMS	-	-	-	**2.6**
eMalahleni AQMS	36.7	40.1	47.5	**2.1**
Kendal AQMS	80.2	74.1	76.8	**2.4**
Kriel Village AQMS	42.7	51.2	50.8	**3.5**
Three Rivers AQMS	65.6	-	56.1	**1.5**
Majuba AQMS	-	54.3	-	**2.9**
Chicken Farm AQMS	21.9	15.8	34.4	**1.9**

Rand Water AQMS	-	-	-	**1.5**
Masakhane AQMS	-	63.8	55.8	**2.5**
Sivukile AQMS	38.7	47.7	42.4	**3.1**
Sharpeville AQMS	-	53.4	64.0	**1.3**

Table 3-3: Measured annual average $PM_{2.5}$ concentration at the Highveld AQMSs compared with predicted concentrations in µg/m^3 for Scenario 1 (Current)

Receptor	2021	2022	2023	Modelled
Grootdraai Dam AQMS	-	-	-	**2.2**
eMalahleni AQMS	19.8	21.2	23.1	**1.8**
Kendal AQMS	6.1	9.1	-	**1.9**
Kriel Village AQMS	23.2	23.2	16.6	**2.6**
Three Rivers AQMS	28.1	-	34.9	**1.3**
Majuba AQMS	14.3	26.8	22.5	**2.5**
Chicken Farm AQMS	-	-	10.1	**1.6**
Rand Water AQMS	18.0	18.5	19.1	**1.3**
Masakhane AQMS	24.9	7.5	-	**2.0**
Sivukile AQMS	-	-	-	**2.6**
Sharpeville AQMS	-	22.1	33.0	**1.1**

3.3 Predicted concentrations at sensitive receptors

In the Highveld and Vaal Triangle study area, 405 sensitive receptors were identified. These are listed in Annexure 1. Predicted ambient concentrations for PM_{10} and $PM_{2.5}$ for the five scenarios are presented in Annexure 2.

At all identified sensitive receptors, the predicted PM_{10} and $PM_{2.5}$ concentrations are low and well below the limit value of the respective NAAQS for all five scenarios. The highest predicted concentrations occur for Scenario A (2025) and the lowest predicted concentrations occur for Scenario D (MES).

Noteworthy is the systematic decrease in predicted PM_{10} and $PM_{2.5}$ concentrations from 2025 to 2036 at all sensitive receptors due to station shutdowns (Arnot, Camden, Hendrina, Kriel, Grootvlei), with most generating units also shutdown at Duvha and Matla by 2035, and PM abatement projects being completed.

3.4 Isopleth maps

Isopleth maps of predicted ambient PM_{10} and $PM_{2.5}$ concentrations are presented in the following sections. The predicted concentrations are shown as isopleths, lines of equal concentration, in µg/m^3 for the respective NAAQS averaging periods. The isopleths are depicted as coloured lines on the various maps, corresponding to a particular predicted ambient concentration. Sensitive receptors are represented by green squares and AQMSs are represented by white dots.

The South African NAAQS permits 4 exceedances of the 24-hour or daily limit value per annum, implying 12 permitted exceedances in a three-year modelling period. In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS, with no predicted exceedances. The predicted 24-hour PM_{10} and $PM_{2.5}$ concentrations therefore comply with the NAAQS for all five scenarios. As discussed above, changes in the predicted concentrations are strongly influenced by changes in emissions, the contribution from secondary particulate formation and stack exit velocity.

3.4.1 Particulates (PM_{10})

In Scenario 1 (Current), the highest predicted annual concentrations occur close to the Kriel, Matla and Camden Power Stations. The highest predicted 24-hour concentrations occur close to the Kendal, Kriel and Matla Power Stations.

The increase in emissions and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted concentrations. In Scenario A (2025), the highest predicted annual concentrations occur close to the Kriel, Matla, Camden, Tutuka and Majuba Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel, Matla and Tutuka Power Stations.

Noticeable is the dramatic effect of station shutdowns of Arnot, Camden, Hendrina, Grootvlei and Kriel by 2031 on the isopleths for Scenario B (2031), where the biggest reductions are seen. In Scenario B (2031), the highest predicted annual concentrations occur close to the Kriel, Matla, Camden, Tutuka, Majuba and Hendrina Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel, Matla and Kendal Power Stations.

The effect of station shutdowns of Duvha and Matla by 2035 are also noticeable on the isopleths for Scenario C (2036). In Scenario C (2036), the highest predicted annual concentrations occur close to the Majuba Power Station. The highest predicted 24-hour concentrations occur close to the Tutuka and Majuba Power Stations.

Although PM_{10} emissions remain the same for Scenario C (2036) and Scenario D (MES), the predicted PM_{10} concentrations show a fairly large decrease on the isopleths for Scenario D (MES) (as discussed previously, this decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios). In Scenario D (MES), the highest predicted annual concentrations occur close to the Camden, Tutuka and Majuba Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel, Matla, Kendal, Tutuka and Majuba Power Stations.

Isopleth maps of the predicted annual average and 99^{th} percentile of the 24-hour PM_{10} concentrations are presented in Figure 3-1 to Figure 3-10.

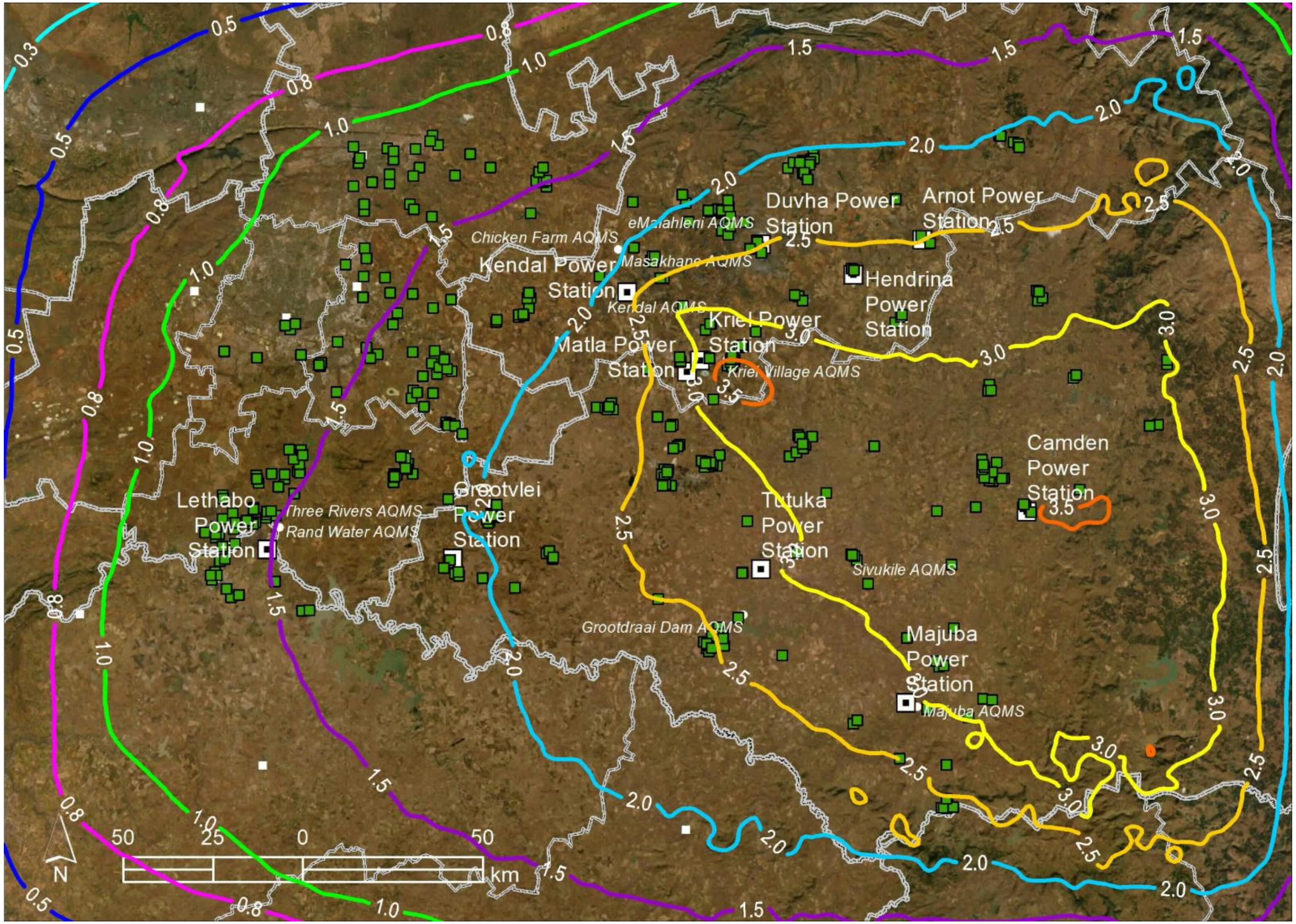

Figure 3-1: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario 1 (Current) (NAAQS Limit is 40 µg/m³)

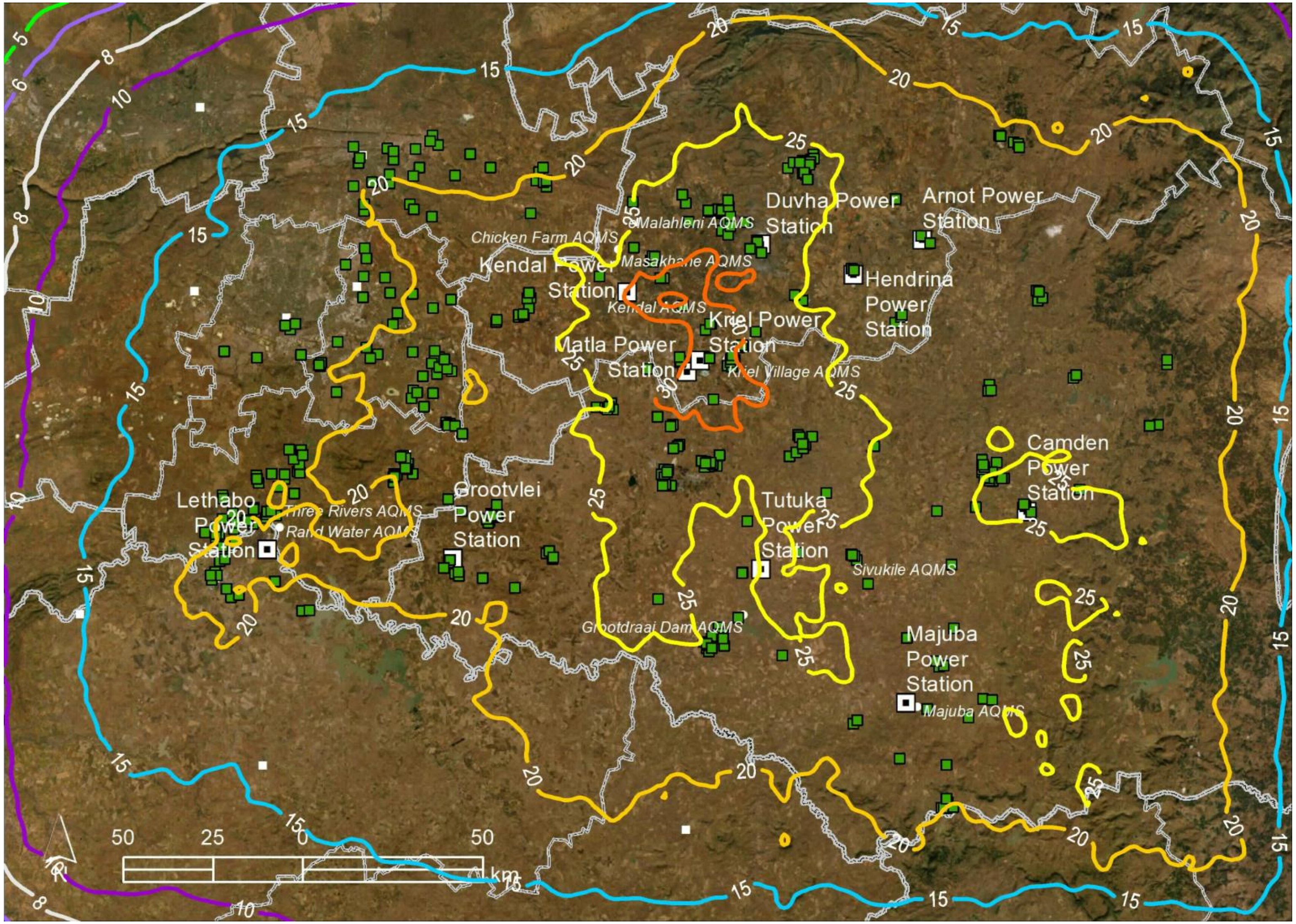

Figure 3-2: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario 1 (Current) (NAAQS Limit is 75 µg/m³)

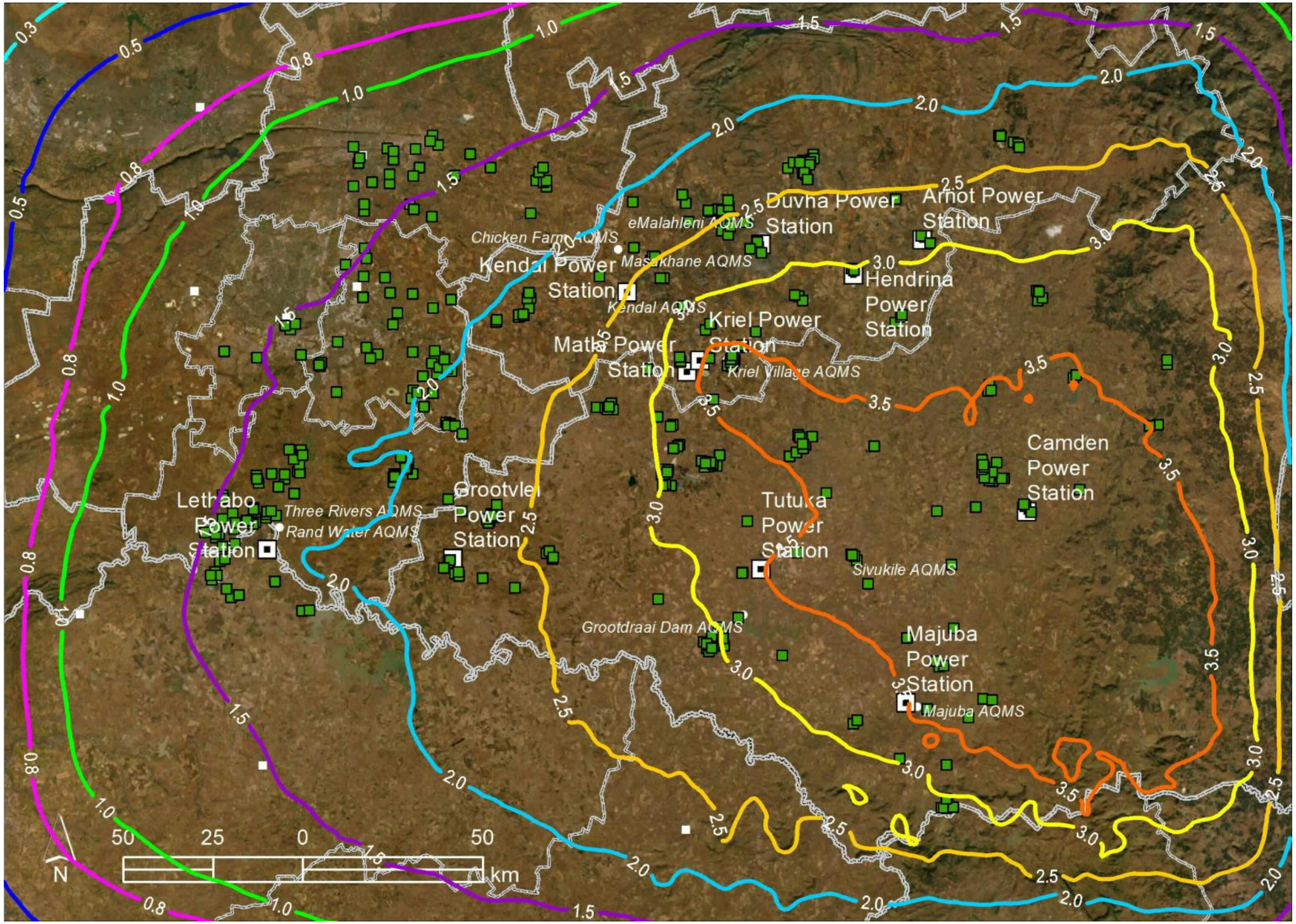

Figure 3-3: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 40 µg/m³)

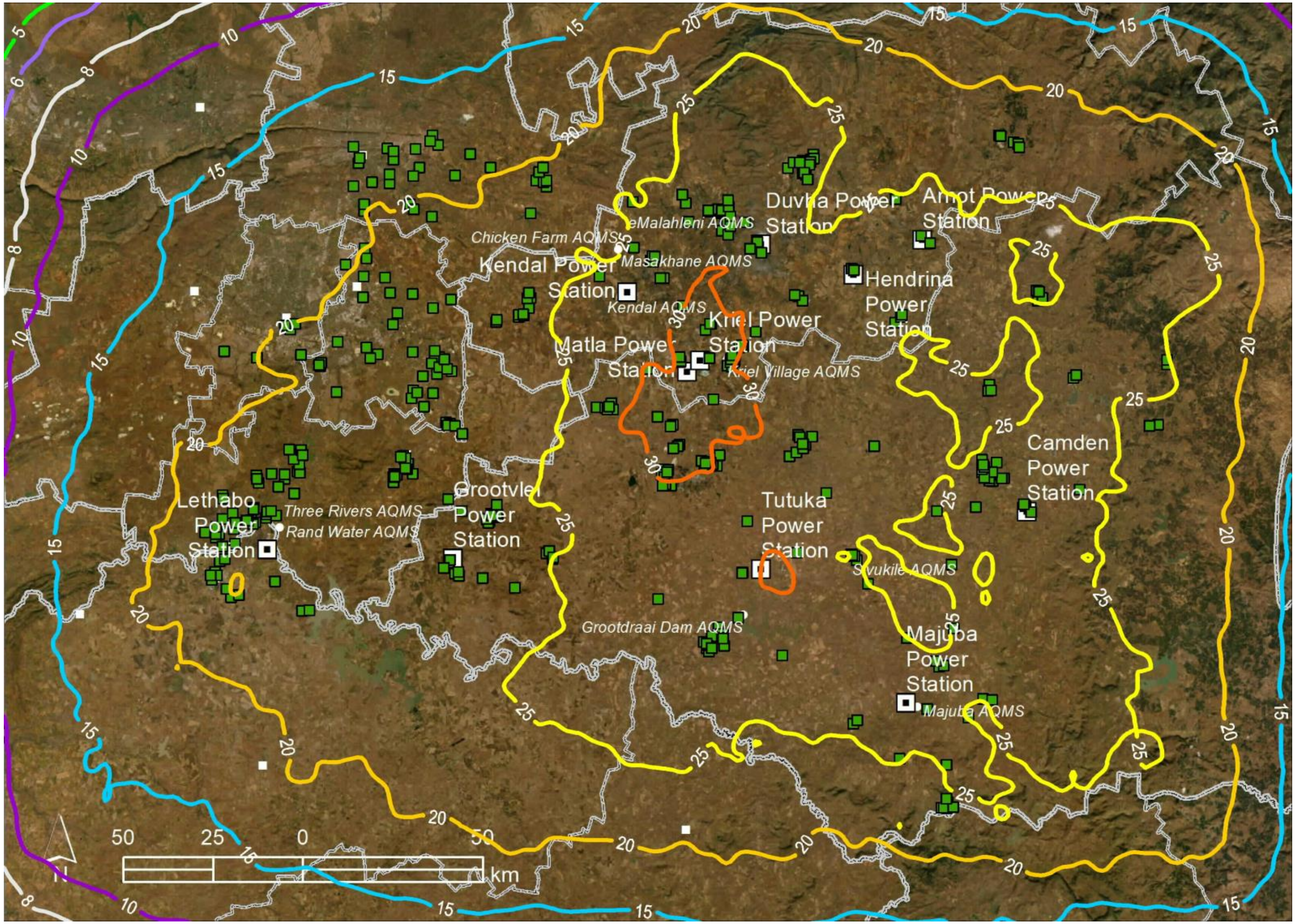

Figure 3-4: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 75 µg/m³)

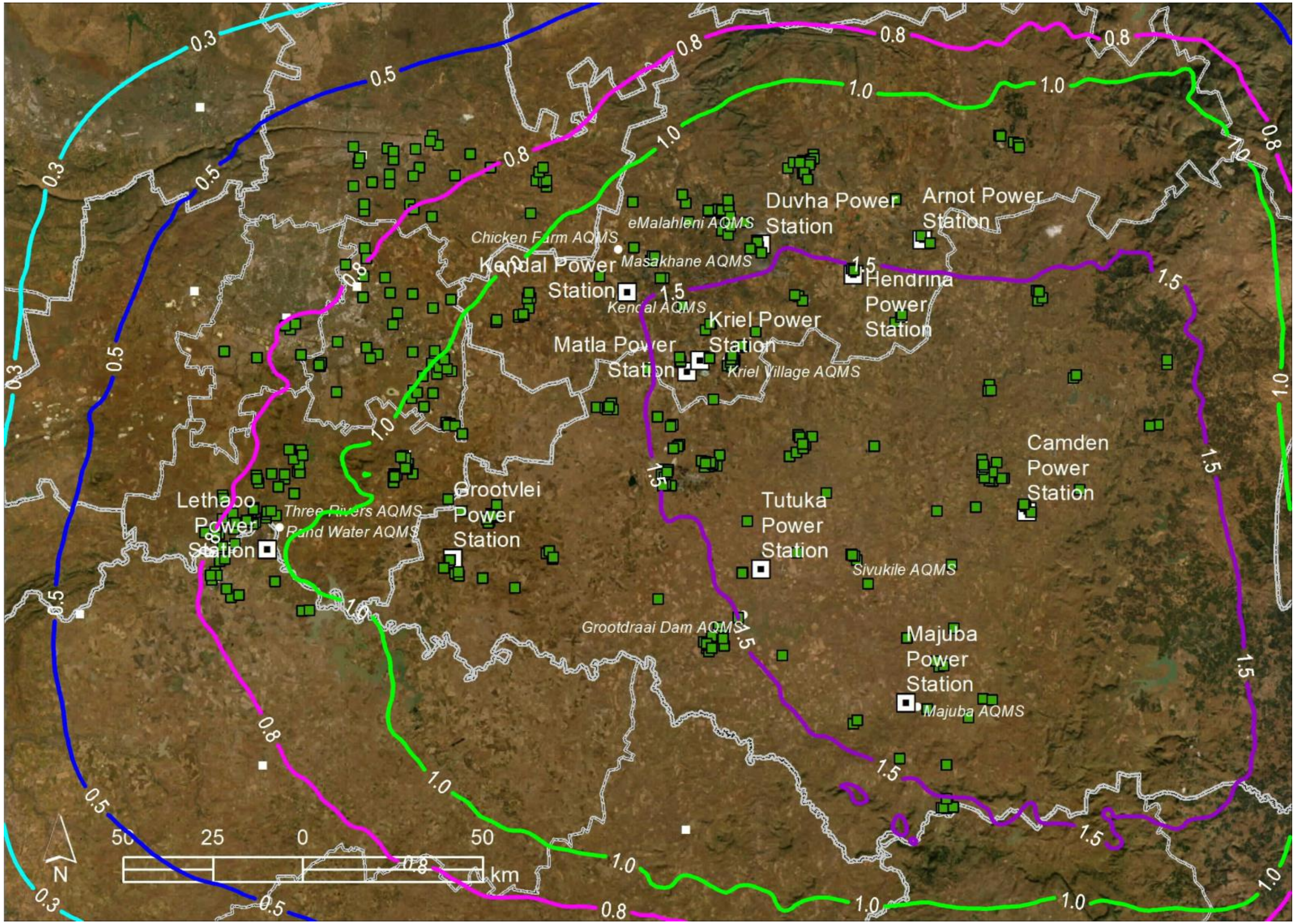

Figure 3-5: Predicted annual average PM_{10} concentrations in $\mu g/m^3$ for Scenario B (2031) (NAAQS Limit is 40 $\mu g/m^3$)

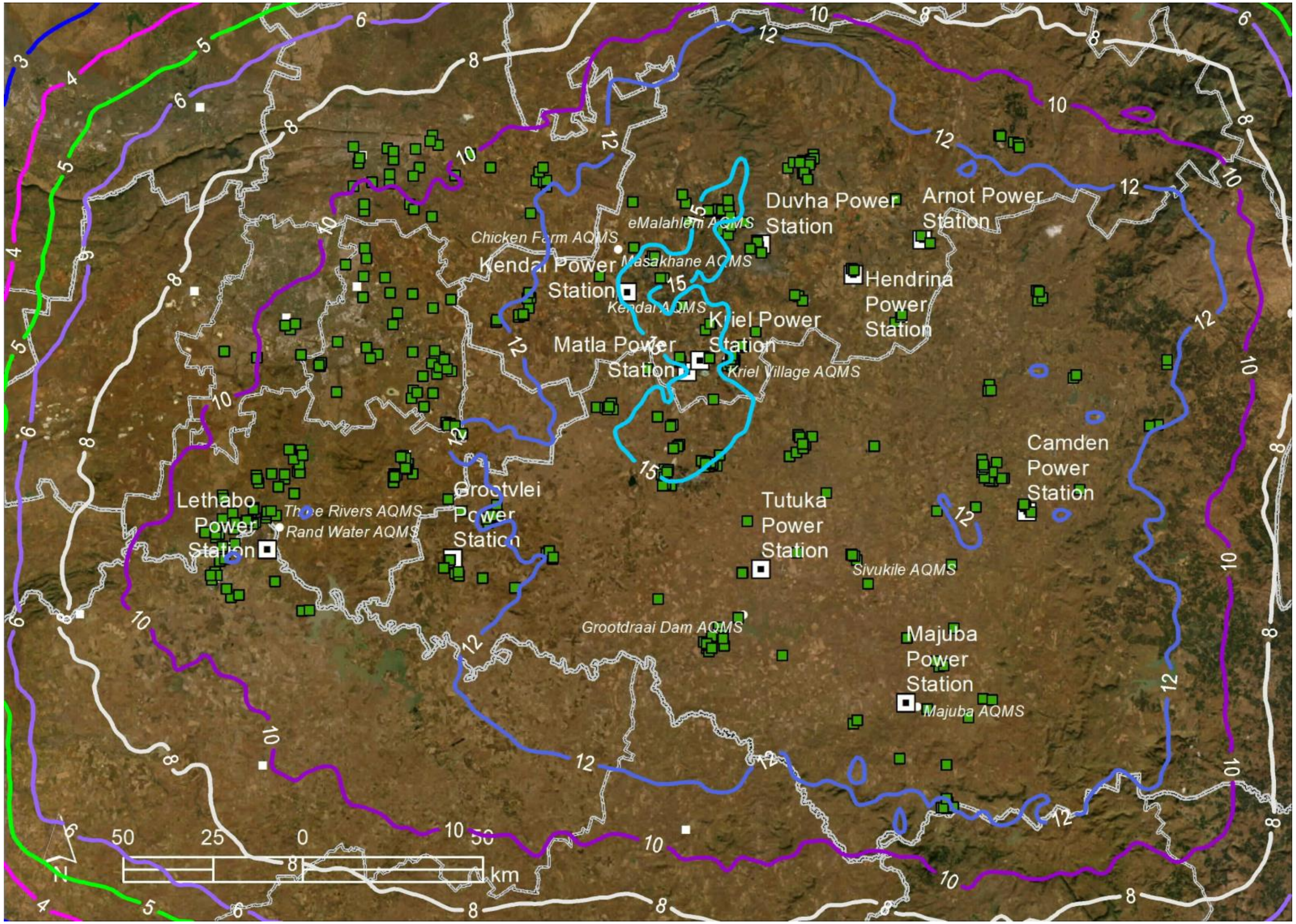

Figure 3-6: Predicted 99th percentile of the 24-hour PM$_{10}$ concentrations in µg/m^3 for Scenario B (2031) (NAAQS Limit is 75 µg/m^3)

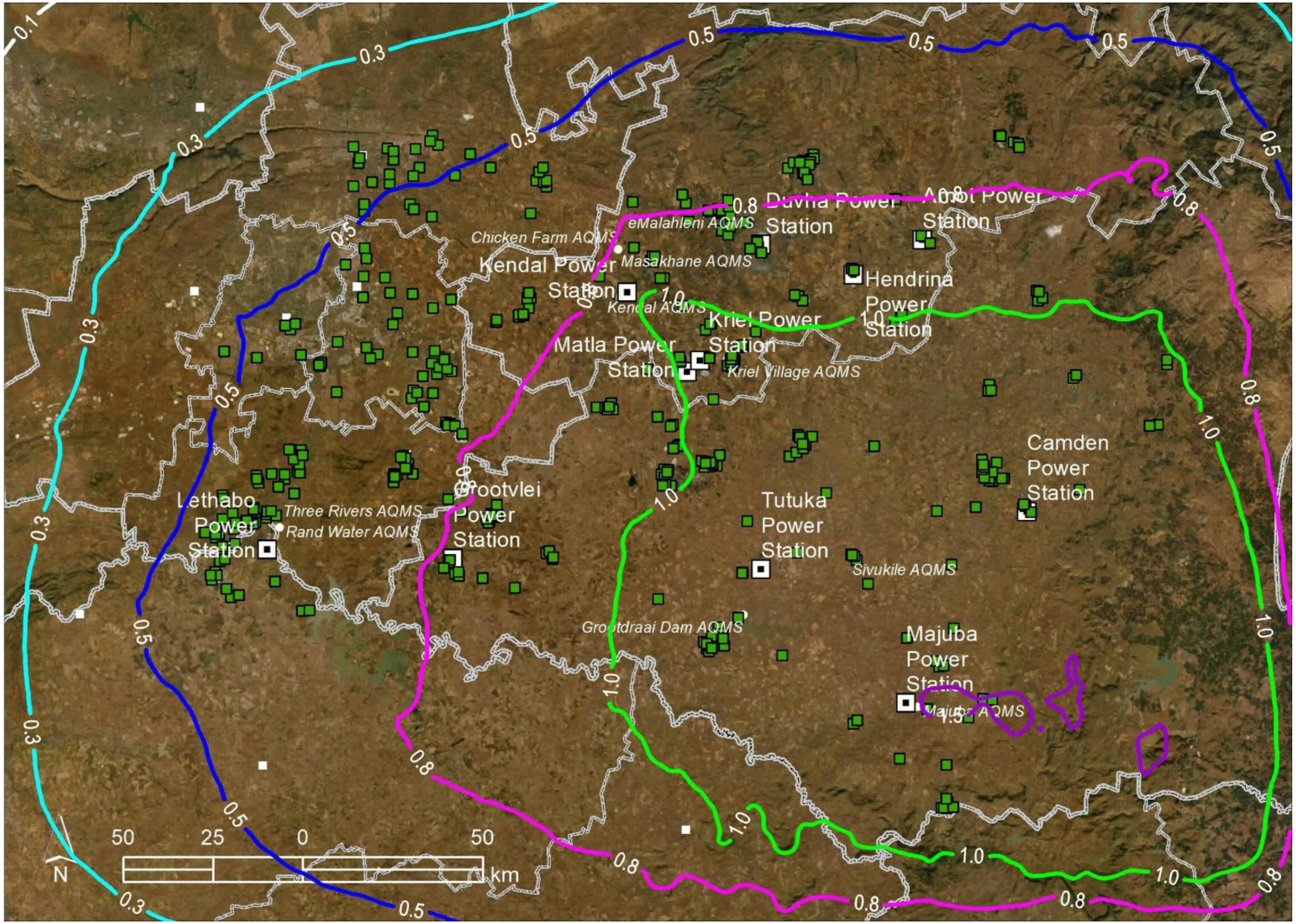

Figure 3-7: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 40 µg/m³)

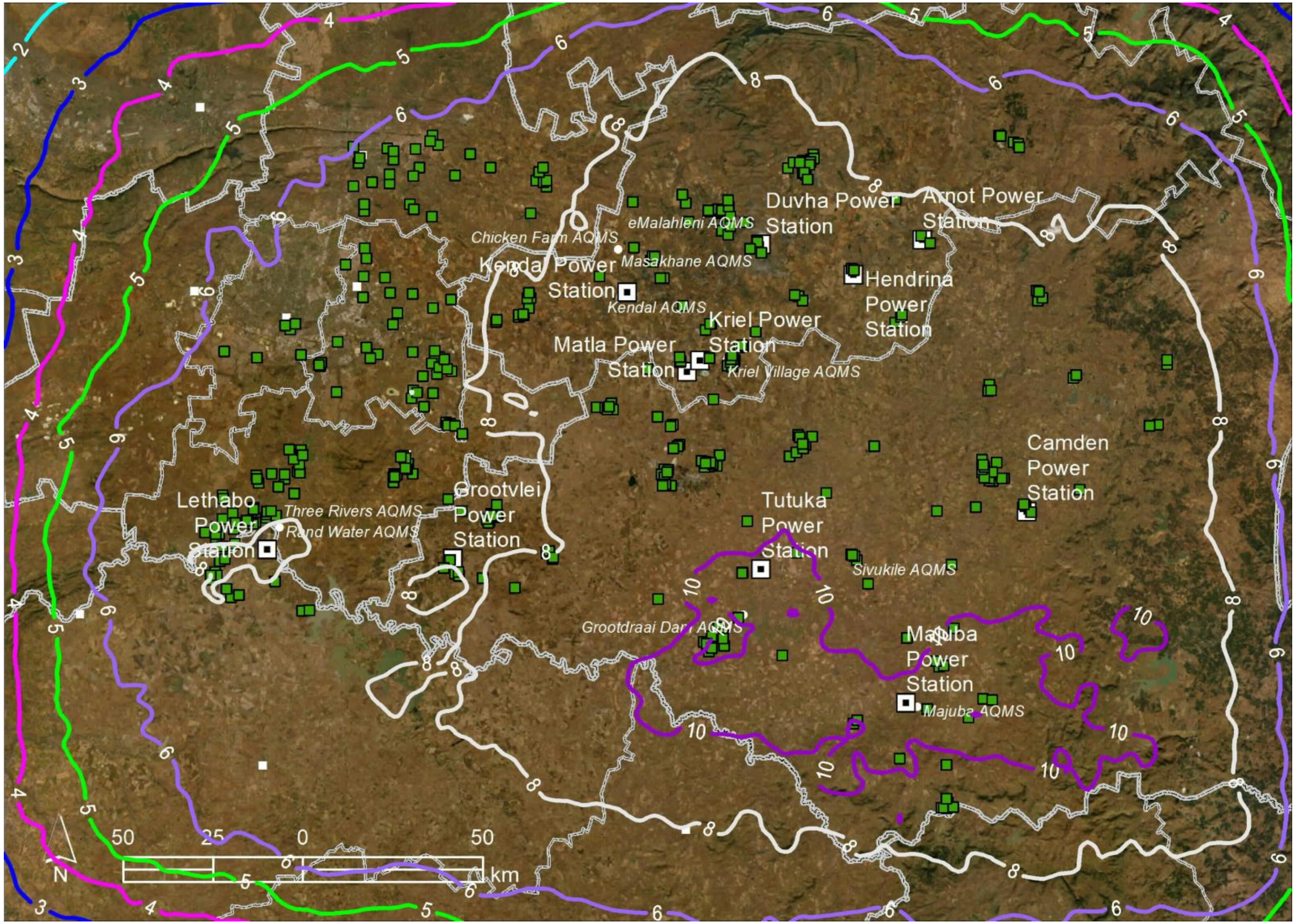

Figure 3-8: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 75 µg/m³)

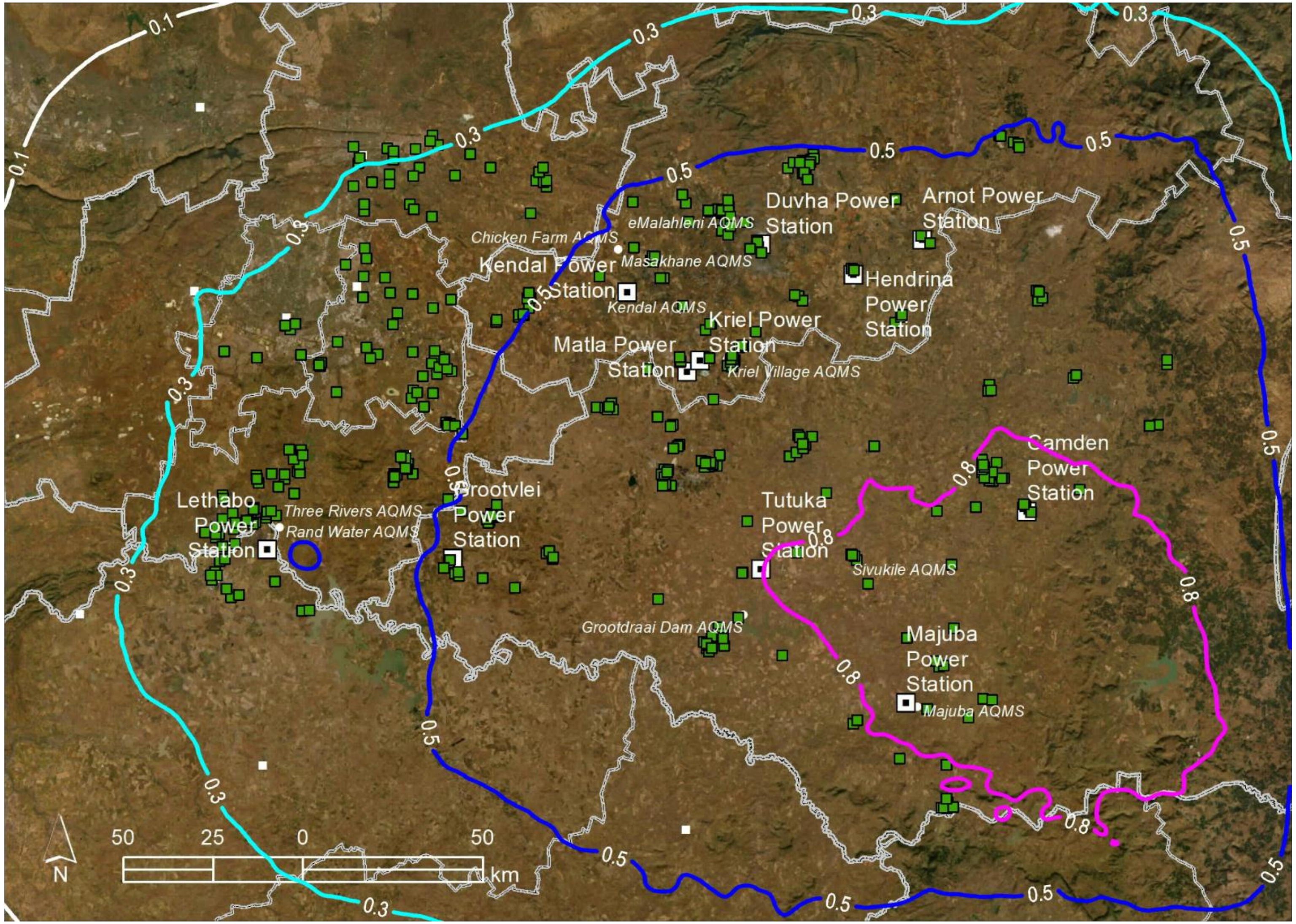

Figure 3-9: Predicted annual average PM_{10} concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 40 µg/m³)

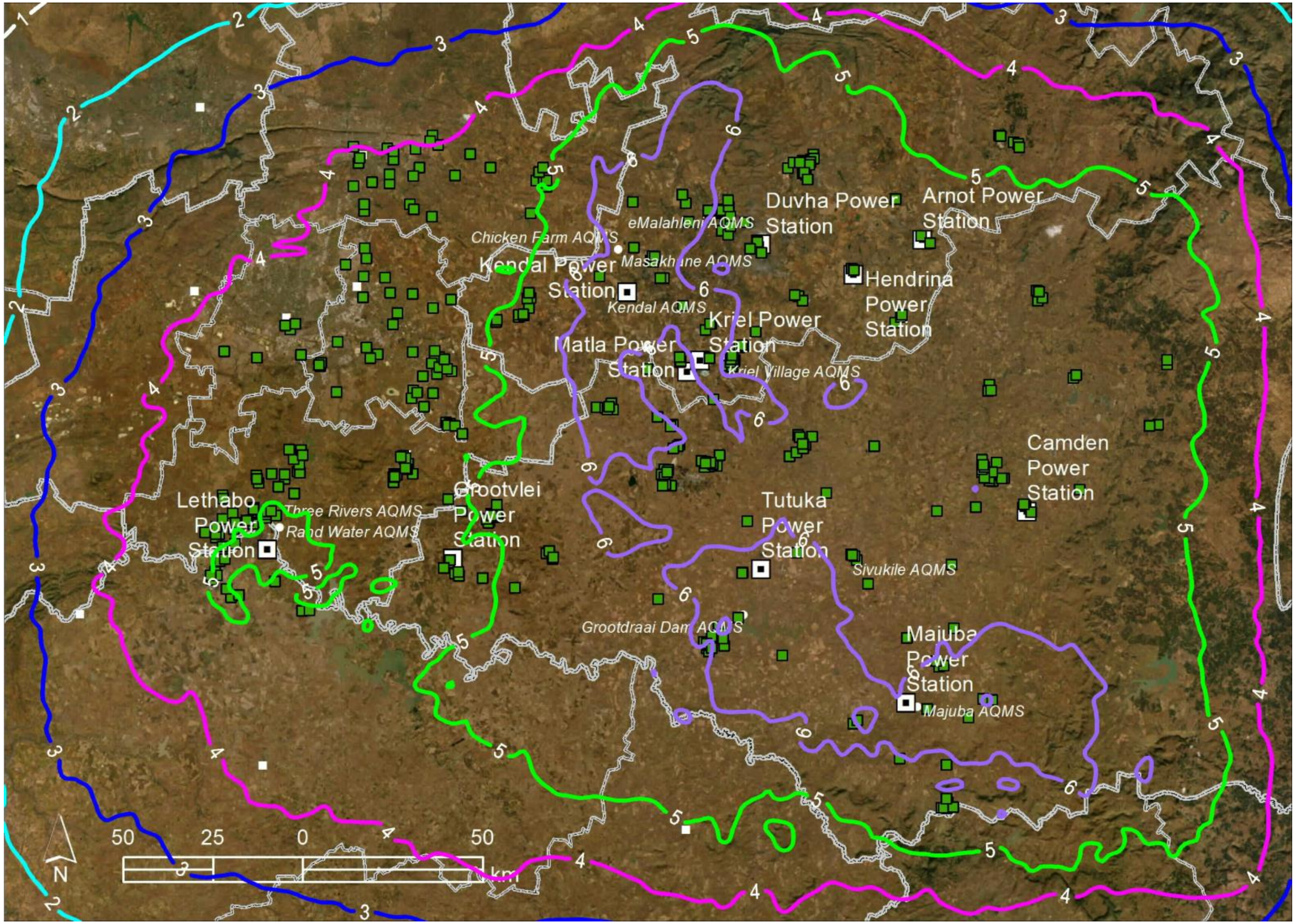

Figure 3-10: Predicted 99th percentile of the 24-hour PM_{10} concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 75 µg/m³)

3.4.2 Particulates ($PM_{2.5}$)

In Scenario 1 (Current), the highest predicted annual concentrations occur close to the Majuba and Camden Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel and Matla Power Stations.

The increase in emissions and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted concentrations. In Scenario A (2025), the highest predicted annual concentrations occur close to the Camden and Majuba Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel, Matla, Kendal, Duvha, Hendrina, Tutuka, Majuba and Camden Power Stations.

Noticeable is the dramatic effect of station shutdowns of Arnot, Camden, Hendrina, Grootvlei and Kriel by 2031 on the isopleths for Scenario B (2031), where the biggest reductions are seen. In Scenario B (2031), the highest predicted annual concentrations occur close to the Camden and Majuba Power Stations. The highest predicted 24-hour concentrations occur close to the Kriel, Matla and Kendal Power Stations.

The effect of station shutdowns of Duvha and Matla by 2035 are also noticeable on the isopleths for Scenario C (2036). In Scenario C (2036), the highest predicted annual concentrations occur close to the Majuba, Tutuka and Camden Power Stations. The highest predicted 24-hour concentrations occur close to the Tutuka and Majuba Power Stations.

Although $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), the predicted $PM_{2.5}$ concentrations show a fairly large decrease on the isopleths for Scenario D (MES) (as discussed previously, this decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios). In Scenario D (MES), the highest predicted annual concentrations occur close to the Majuba Power Station. The highest predicted 24-hour concentrations occur close to the Kendal, Tutuka and Majuba Power Stations.

Isopleth maps of the predicted annual average and 99th percentile of the 24-hour $PM_{2.5}$ concentrations are presented in Figure 3-11 to Figure 3-20.

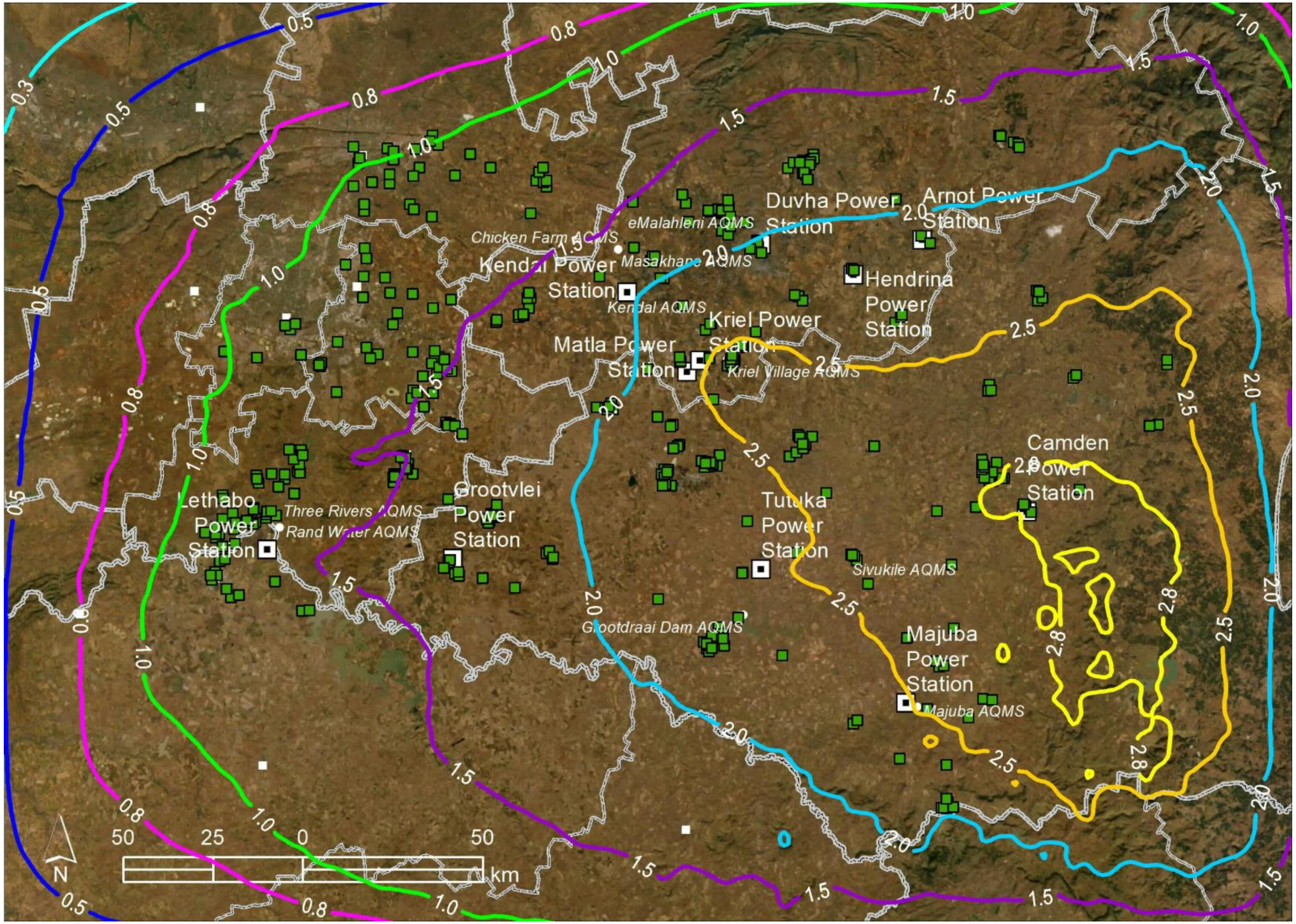

Figure 3-11: Predicted annual average $PM_{2.5}$ concentrations in µg/m^3 for Scenario 1 (Current) (NAAQS Limit is 20 µg/m^3)

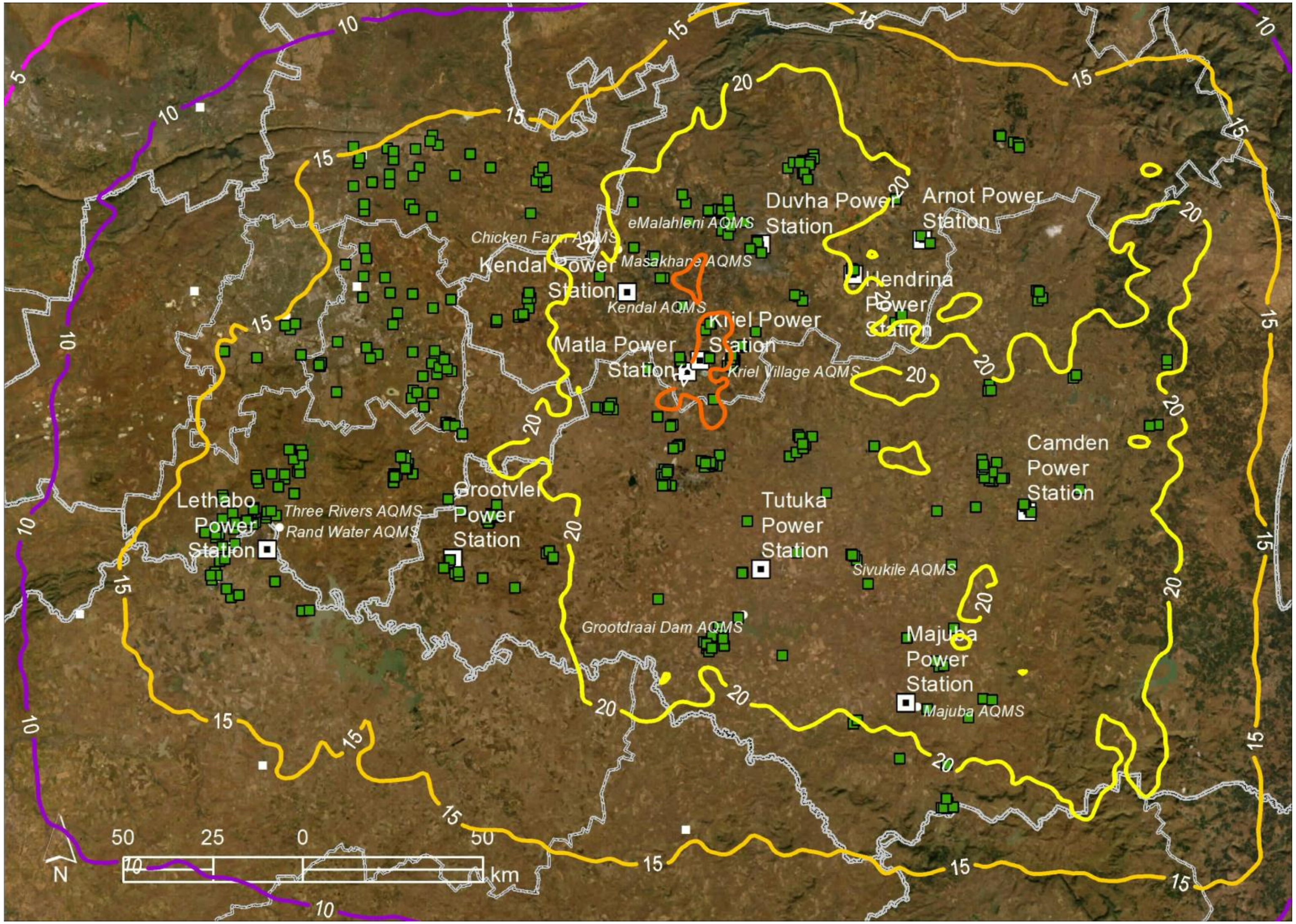

Figure 3-12: Predicted 99th percentile of the 24-hour PM$_{2.5}$ concentrations in µg/m^3 for Scenario 1 (Current) (NAAQS Limit is 40 µg/m^3)

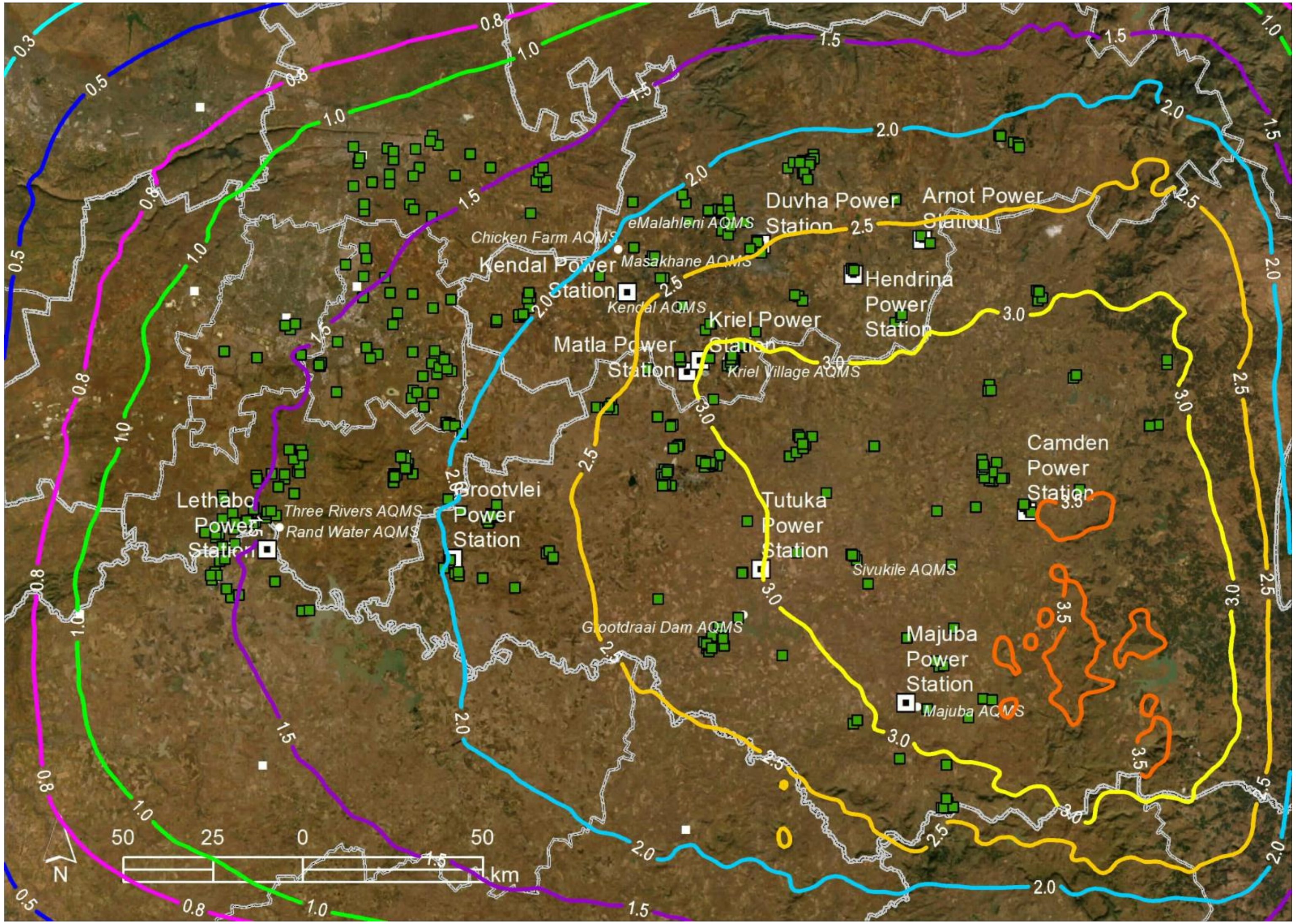

Figure 3-13: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 20 µg/m³)

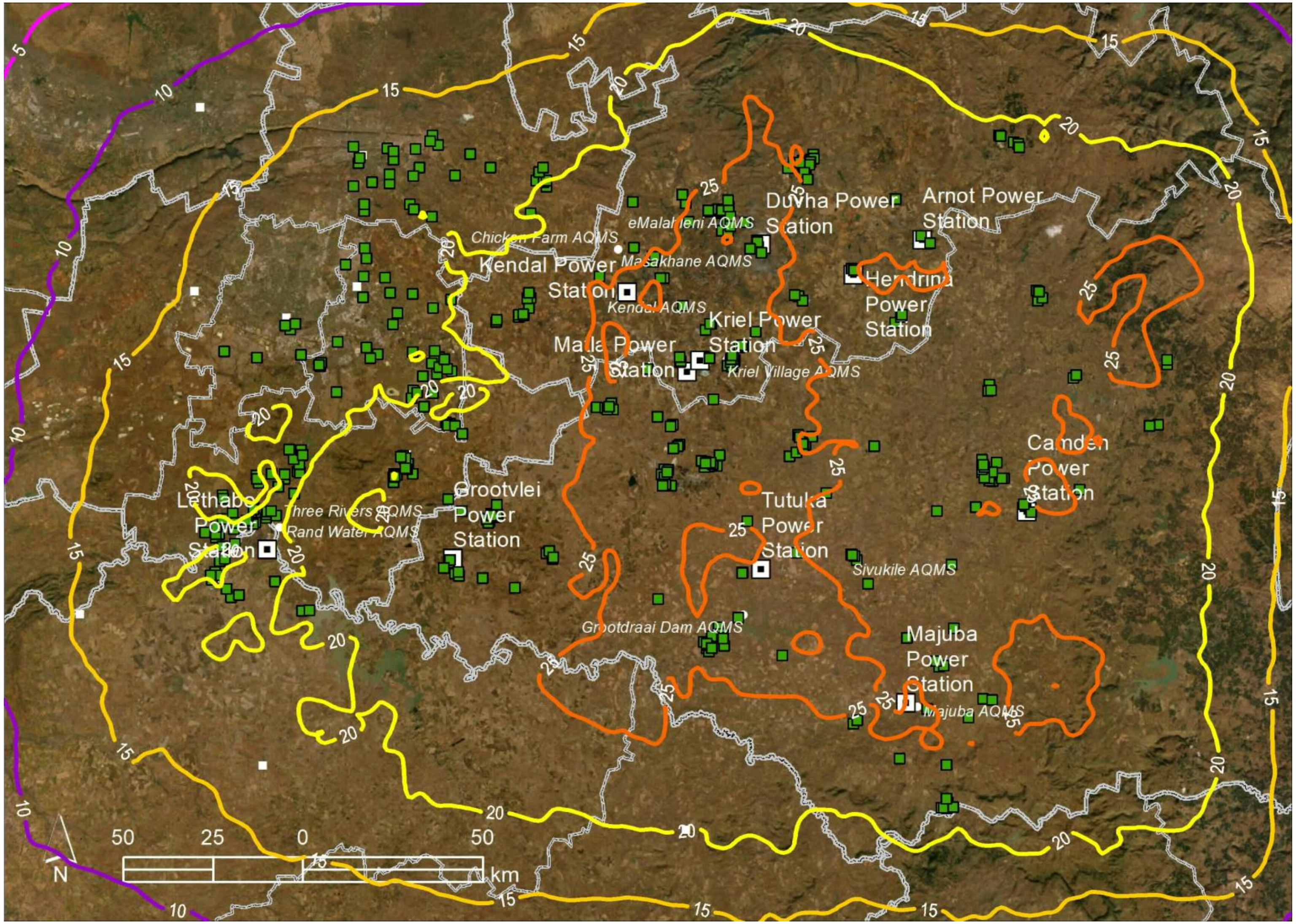

Figure 3-14: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario A (2025) (NAAQS Limit is 40 µg/m³)

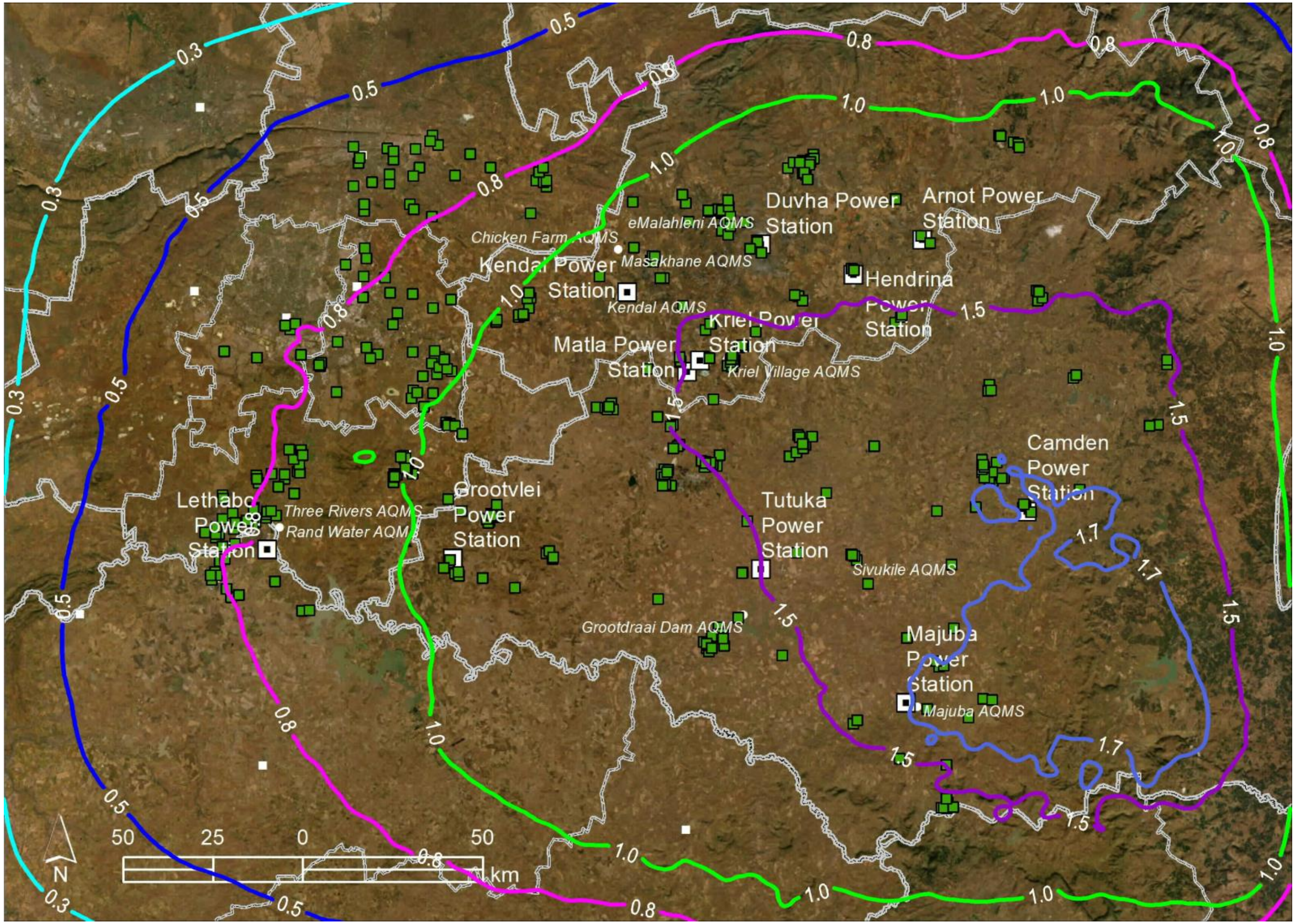

Figure 3-15: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario B (2031) (NAAQS Limit is 15 µg/m³)

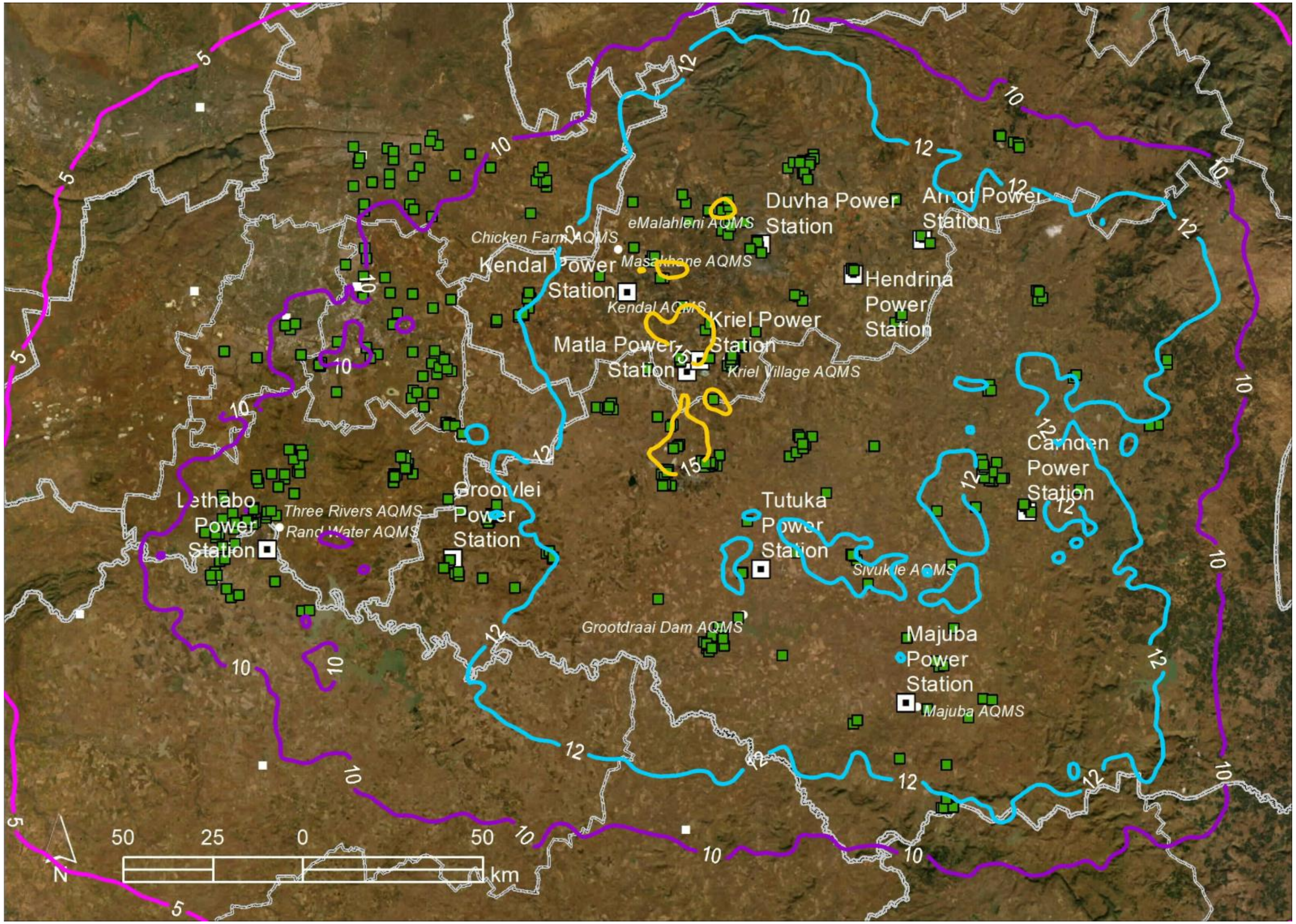

Figure 3-16: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario B (2031) (NAAQS Limit is 25 µg/m³)

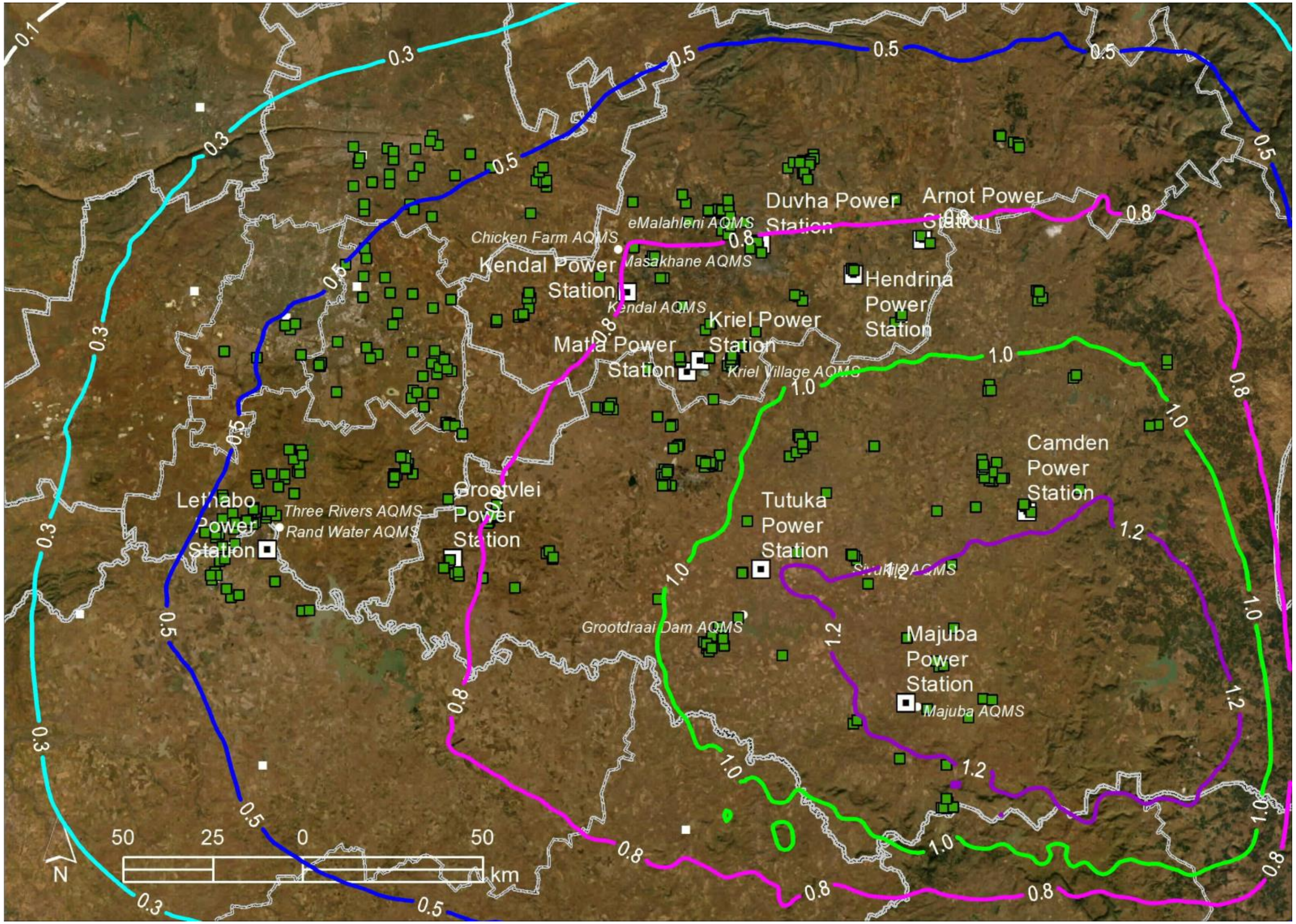

Figure 3-17: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 15 µg/m³)

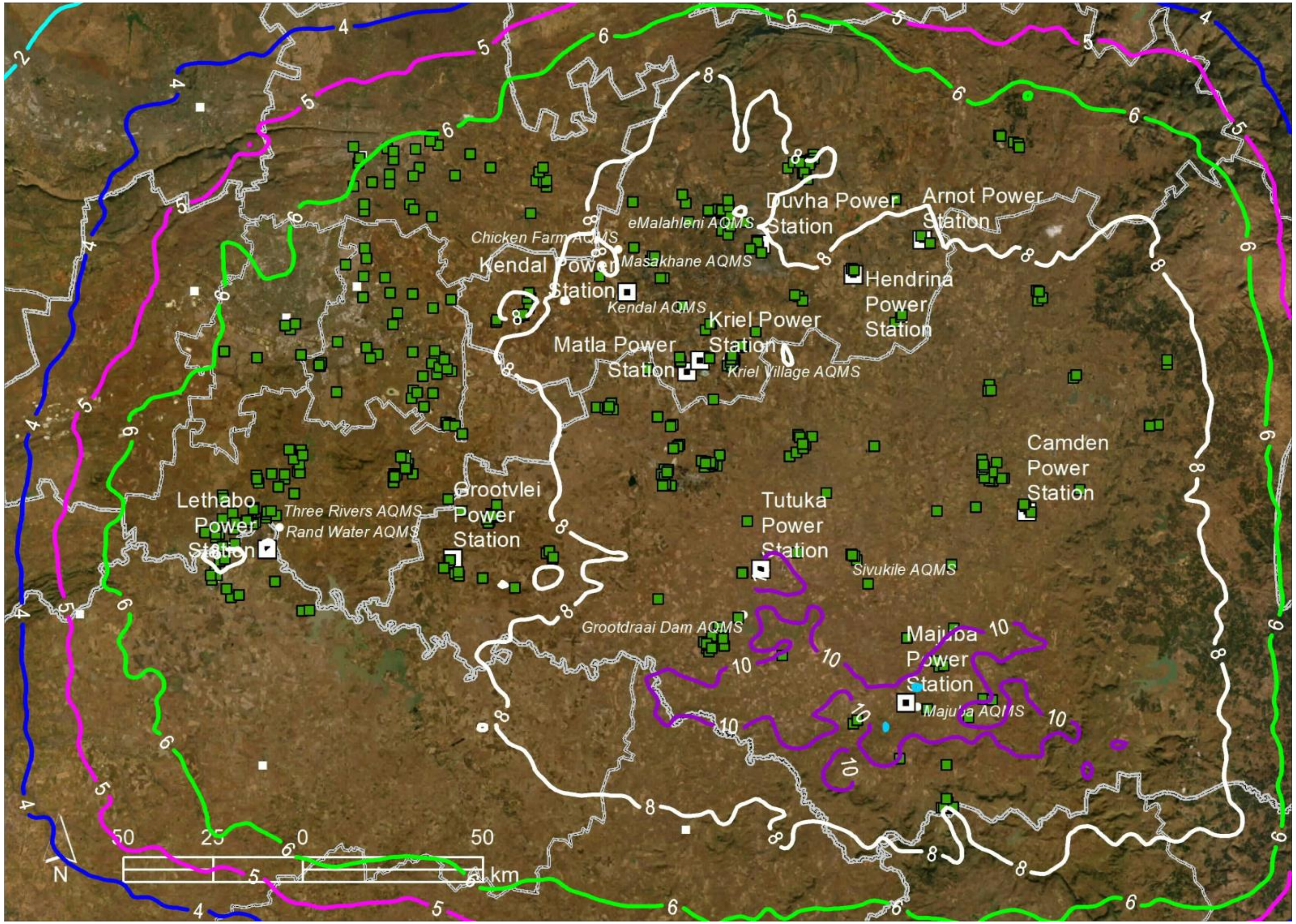

Figure 3-18: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario C (2036) (NAAQS Limit is 25 µg/m³)

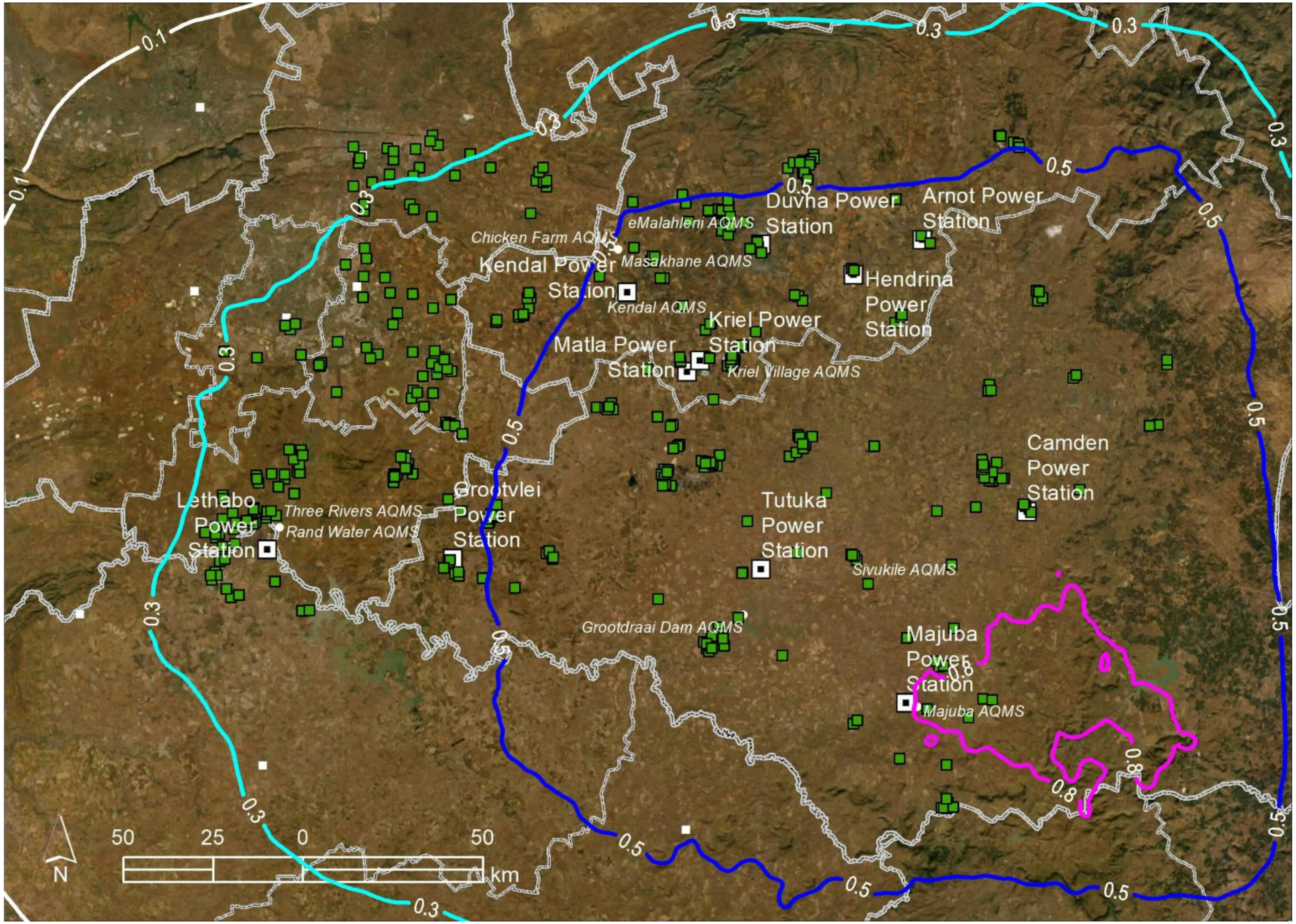

Figure 3-19: Predicted annual average $PM_{2.5}$ concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 15 µg/m³)

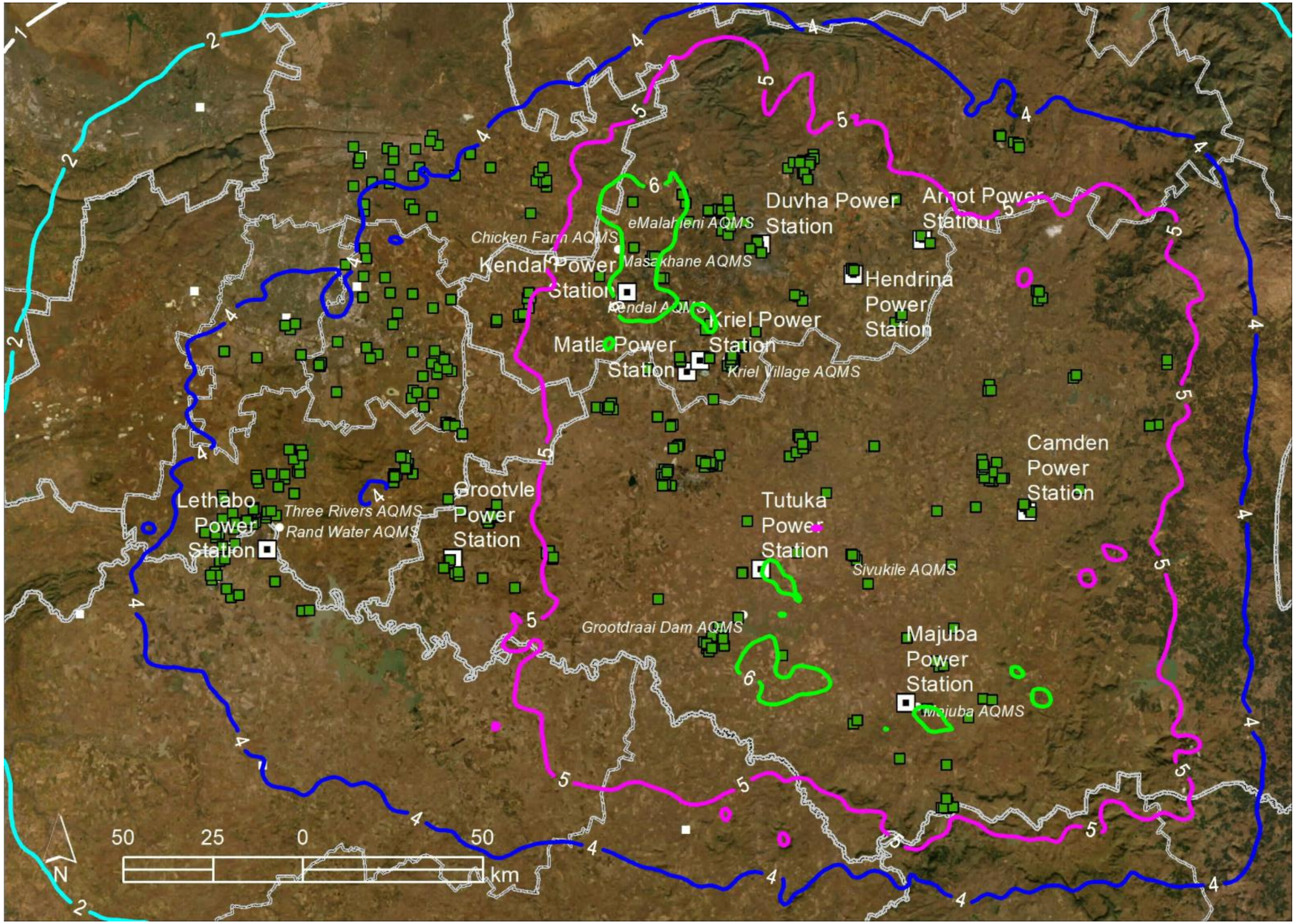

Figure 3-20: Predicted 99th percentile of the 24-hour $PM_{2.5}$ concentrations in µg/m³ for Scenario D (MES) (NAAQS Limit is 25 µg/m³)

4. SUMMARY AND CONCLUSION

In this Addendum to the AIR (uMoya-NILU, 2024), the focus is specifically on stack emissions for PM and the modelled results for PM_{10} and $PM_{2.5}$. In this Addendum, the cumulative effect of stack emissions from 13 coal-fired power stations comprising the Highveld and Vaal power station fleet are assessed, i.e. Arnot, Camden, Duvha, Grootvlei, Hendrina, Kendal, Komati, Kriel, Kusile, Majuba, Matla and Tutuka in the Highveld Priority area and Lethabo in the Vaal Triangle Airshed Priority Area.

Dispersion modelling is used to demonstrate the effect of Eskom's emission reduction strategy by assessing 5 sequential emission scenarios. These are from Scenario 1 using actual emissions from 2021 to 2023, Scenario A using proposed 2025 emissions, Scenario B using proposed 2031 emissions and Scenario C using proposed 2036 emissions. Scenario D uses emissions that comply with the MES to demonstrate the relative effect of compliance.

Noteworthy findings from the modelling results may be summarised as follows:

i) Changes in the predicted annual average and 24-hour PM_{10} and $PM_{2.5}$ concentrations from one scenario to the next are strongly influenced by changes in PM_{10} and $PM_{2.5}$ emissions, the contribution from secondary particulate formation and stack exit velocity.

ii) In all scenarios, the maximum predicted annual average PM_{10} and $PM_{2.5}$ concentrations are well below the limit values of the respective NAAQS. In all scenarios, the maximum predicted 99th percentile of the 24-hour PM_{10} and $PM_{2.5}$ concentrations are in general, relatively low compared to the limit value of the NAAQS. In other words, there are no predicted exceedances of the NAAQS for PM_{10} and $PM_{2.5}$.

iii) The increase in SO_2, NO_X, PM_{10} and $PM_{2.5}$ emissions and a reduction in stack exit velocity from Scenario 1 (Current) to Scenario A (2025) is seen by an increase in the predicted PM_{10} and $PM_{2.5}$ ambient concentrations.

iv) The maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations decrease significantly from Scenario A (2025) when 13 power stations are in operation to Scenario B (2031) due to the shutdown of 5 power stations (Arnot, Camden, Hendrina, Kriel, Grootvlei); and as a result of PM abatement projects being completed.

v) The slight decrease in PM_{10} and $PM_{2.5}$ ambient concentrations from Scenario B (2031) to Scenario C (2036) is mainly due to the shutdown of the Duvha and Matla generating units (which would have occurred by 2035).

vi) Although PM_{10} and $PM_{2.5}$ emissions remain the same for Scenario C (2036) and Scenario D (MES), it is noted that the maximum predicted PM_{10} and $PM_{2.5}$ ambient concentrations show a fairly large decrease between the two scenarios. This decrease is mainly attributed to the reduced formation of secondary particulates brought about by a substantial decrease in SO_2 emissions between these scenarios.

vii) At all AQMSs, the modelled PM_{10} and $PM_{2.5}$ concentrations are considerably lower than the monitored concentrations. This is to be expected since the AQMSs are exposed to all sources of PM_{10} and $PM_{2.5}$. The difference between the predicted concentrations and the measured concentrations provides an indication of the contribution of the power station stack emissions at the respective AQMSs.

viii) At all identified sensitive receptors, the predicted PM_{10} and $PM_{2.5}$ concentrations are low and well below the limit value of the respective NAAQS for all five scenarios. Noteworthy is the systematic decrease in predicted PM_{10} and $PM_{2.5}$ concentrations from 2025 to 2036 at all sensitive receptors due to station shutdowns (Arnot, Camden, Hendrina, Kriel, Grootvlei), with most generating units also shutdown at Duvha and Matla by 2035, and PM abatement projects at Tutuka, Duvha and Matla being completed.

5. REFERENCES

DEA (2014): Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa, Government Notice R.533, Government Gazette, no. 37804, 11 July 2014.

uMoya-NILU (2024): Atmospheric Impact Report in Support of the Application for Exemption from the Minimum Emission Standards for Eskom's Coal-Fired Power Stations on the Highveld and in the Vaal Triangle (A Cumulative Assessment), Report No.: uMN220-24, November 2024.

USEPA (1995): Compilation of air pollutant emission factors. Volume 1: Stationary point and area sources. AP-42 fifth edition January 1995. US EPA

6. FORMAL DECLARATIONS

A declaration of the accuracy of the information contained in this Atmospheric Impact Report is included here. A declaration of the independence of the practitioners in the uMoya-NILU consultancy team that compiled this AIR is also included.

DECLARATION OF ACCURACY OF INFORMATION – APPLICANT

Name of Enterprise: uMoya-NILU Consulting (Pty) Ltd

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act

I, Mark Zunckel [duly authorised], declare that the information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality office is a criminal office in terms of section 51(1)(g) of this Act.

Signed at Durban on this 9th day of December 2024.

____
SIGNATURE

Managing Director – uMoya-NILU Consulting
CAPACITY OF SIGNATORY

DECLARATION OF INDEPENDENCE – PRACTITIONER

Name of Practitioner: Mark Zunckel

Name of Registered Body: South African Council for Natural Scientific Professionals

Professional Registration Number: 400449/04

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act

I, Mark Zunckel declare that I am independent of the applicant. I have the necessary expertise to conduct the assessment required for the report and will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The information provided in the atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality office is a criminal office in terms of section 51(1)(g) of this Act.

Signed at Durban on this 9th day of December 2024.

SIGNATURE

Managing Director – uMoya-NILU Consulting
CAPACITY OF SIGNATORY

ANNEXURE 1: HIGHVELD SENSITIVE RECEPTORS

Area	Sensitive Receptors	Latitude	Longitude
Amersfoort	Elsie Ballot Memorial Hospital	-27.011944	29.858333°
	Laerskool Amersfoort	-27.008678°	29.869944°
	Embuzane Primary School	-27.118291°	29.826786°
	Sangqotho Primary School	-26.941649°	29.765980°
Ezamokuhle	Amersfoort Combined School	-26.997325°	29.850319°
Mooifontein	Injubuko Primary School	-26.914817°	29.897307°
Daggaskraal	Daggakraal Primary School	-27.089170°	29.983250°
	Sizenzele Primary School	-27.137908°	29.943203°
	Seme Secondary School	-27.091589°	30.008177°
	Louwra Primary School	-27.257713°	29.884864°
Perdekop	Perdekop Agricultural School	-27.159970°	29.620400°
	Vukuzenzele Combined School	-27.150944°	29.632386°
	Bambelelani Primary School	-27.175659°	29.749177°
	Gunwana Primary School	-27.244071°	29.752985°
Volksrust	Amajuba Memorial Hospital	-27.351190°	29.890921°
	Volksrust High School	-27.365400°	29.87400°
	Volksrust Municipal Clinic	-27.366264°	29.889272°
	C V O Skool Amajuba	-27.365329°	29.879851°
	Qhubulwazi Combined School	-27.363173°	29.907290°
	Volksrust Primary School	-27.341897°	29.886710°
Ermelo	New Ermelo	-26.534977°	30.026896°
	Ermelo Christian School	-26.543889	29.996389
	Savf Home For Aged	-26.527681°	29.988536°
	Ermelo Hospital	-26.523077°	29.974891°
	Mediclinic Ermelo	-26.542500	29.986389
	Hoerskool Ermelo	-26.526100	29.977900
	Ermelo Indian Combined School	-26.521100	29.965400
	Lungelo Combined School (Outside Town)	-26.622000	29.841700
	New Ermelo Primary School	-26.535600	30.020700
	Kwashashe (Outside Town)	-26.495602°	30.006254°
	Hts Ligbron	-26.536691°	29.986828°
	Laerskool Ermelo	-26.520178°	29.992883°
	JJ Vd Merwe Pre-Primary School	-26.535660°	29.972140°
Wesselton (Ermelo)	Lindile Secondary School	-26.513500°	29.965500°
	Emthonjeni Clinic	-26.508028°	29.971060°
	Reggie Masuku Secondary School	-26.489756°	29.964026°
	Cebisa Secondary School	-26.503265°	29.968324°
Camden	Camden	-26.603573°	30.089437°
	Camden Combined School	-26.618056	30.104444
	Camden School	-26.599100	30.083900
	Umzimvelo Secondary School (Rural Area)	-26.558600	30.238500

Area	Sensitive Receptors	Latitude	Longitude
	BHEKIMFUNDO PRIMARY SCHOOL (Rural Area)	-26.609907°	29.950545°
	ESHWILENI PRIMARY SCHOOL (Rural Area)	-26.754375°	29.885636°
Davel	Davel Combined School	-26.462700°	29.663000°
Morgenzon	Morgenzon Landbou Akademie	-26.749100°	29.621200°
	Nqobangolwazi Secondary School	-26.738700°	29.615000°
	Siqondekhaya Pre Primary School	-26.734260°	29.604270°
	Sizakhele Primary School	-26.734486°	29.607360°
	Phezukwentaba Primary School (South of Morgenzon)	-26.807276°	29.653596°
	Kwaggalaagte Primary School (North of Morgenzon)	-26.581578°	29.531897°
	Sizakhele Clinic/Hospital	-26.735610°	29.608568°
Grootvlei	Grootvlei	-26.765600°	28.483800°
	Olive Grove Country Lodge	-26.785336°	28.467296°
Grootvlei Town	Grootvlei Town (South of Power Station)	-26.798562°	28.505729°
	Laerskool Grootvlei	-26.799705°	28.499296°
	Tokoloho Primary School	-26.805037°	28.509491°
	Tshepeha Combined School	-26.794589°	28.507561°
	Warembo Lodge	-26.809803°	28.575820°
Balfour	Balfour	-26.647368°	28.597344°
	Siyathemba	-26.651574°	28.611242°
	Bonukukhanya Primary (Siyathemba)	-26.656389°	28.610556°
	Qalabocha Primary School (Siyathemba)	-26.648510°	28.610239°
	Vusumuzi Primary School	-26.649302°	28.614483°
	Gekombineerde Skool Balfour	-26.666111°	28.593056°
	Im Manchu Secondary School	-26.662885°	28.585658°
	Isifisosethu Secondary School (Siyathemba)	-26.654091°	28.616910°
	Setsheng Secondary School (Siyathemba)	-26.646036°	28.613849°
	Dr Nieuwoudt And Dr Kok	-26.670556	28.589722
	Balfour Clinic	-26.660521°	28.584954°
	Siyathemba Clinic	-26.651428°	28.598763°
	Mondoro Lodge	-26.641806°	28.515683°
	Wegelegen Manor	-26.625555°	28.612550°
	The Stone Cellar	-26.611667	28.478056
Greylingstad	Greylingstad	-26.744551°	28.753659°
	Nthorwane	-26.759041°	28.771550°
	Laerskool Greylingstad	-26.740120°	28.761680°
	Nthoroane Secondary School	-26.755300	28.772500
	Badgarleur Bush Lodge	-26.832190°	28.666044°
Matla	Matla Village	-26.259808°	29.119138°
	Sifundise Primary School	-26.257623°	29.120118°
	Kwanala Primary School	-26.249384°	29.199724°
	Matla Coal Health Centre	-26.247649°	29.116928°
	Gweda Primary School	-26.352145°	29.212688°

Area	Sensitive Receptors	Latitude	Longitude
	Zithobe Primary School	-26.278423°	29.027500°
Kriel power station area	Kwanala Primary School	-26.249300°	29.200000°
Reedstream Park	Reedstream Park	-26.178723°	29.188144°
	Rietspruit Clinic	-26.162067°	29.202676°
	Lehlaka Combined School	-26.162533°	29.199891°
Blesboklaagte	Mbali Coal/Blesboklaagte Housing	-26.118280°	29.123520°
Kinross	Kinross	-26.417917°	29.100765°
	Kinross Settlement	-26.397865°	29.058050°
	Kinross Municipal Clinic	-26.421365°	29.094224°
Kriel	Kriel	-26.267078°	29.250870°
	Eagles Nest Guest House	-26.269553°	29.262920°
	Merlin Park Primary School	-26.251667°	29.270000°
	Kriel Medical Centre	-26.256300°	29.269300°
	Laerskool Krielpark	-26.258300°	29.258500°
	Laerskool Onverwacht	-26.250423°	29.265348°
	SILWER FLEUR AFTREE OORD (Old Age Home)	-26.251217°	29.260131°
Thubelihle	Thubelihle	-26.220737°	29.282778°
	Sibongamandla Secondary School	-26.215556	29.290000
	Ga-Nala Clinic	-26.241511°	29.263001°
	Impilo Primary School	-26.180232°	29.327259°
	Bonginhlanhla Primary School	-26.217923°	29.294090°
	Sibongamandla Secondary School	-26.215364°	29.290280°
Leandra	Leandra	-26.365552°	28.928450°
	Eendracht	-26.376131°	28.887873°
	Sidingulwazi Primary School	-26.377834°	28.910979°
	Ss Mshayisa Primary School	-26.381610°	28.933930°
	Chief Ampie Mayisa Secondary School	-26.381780°	28.918580°
	Lebogang Clinic	-26.375431°	28.921864°
Standerton	Kleuterskool Haas Das	-26.944550°	29.248400°
	Standerton Primary School	-26.941451°	29.250405°
	Laerskool Jeugkrag	-26.924090°	29.237685°
	Laerskool Standerton	-26.948786°	29.249351°
	Laerskool Kalie De Haas	-26.970223°	29.254828°
	Hoerskool Standerton	-26.941403°	29.250366°
	Standerton Provincial Government Hospital	-26.940531°	29.245199°
	Mar-Peh Medicare Private Hospital	-26.950190°	29.244825°
	Standerton Retirement Home	-26.952576°	29.244483°
	Standerton Ouetehuis/Old Age Home	-26.952129°	29.251705°
	Holmdene Secondary School	-26.854996°	29.068283°
	Cathuza Primary School (SE Of Town)	-26.991900°	29.417721°
Sakhile	Sizanani Pre Primary School	-26.965600°	29.219060°
	Hlobisa Primary School	-26.976914°	29.206318°

Area	Sensitive Receptors	Latitude	Longitude
	Shukuma Primary School	-26.985407°	29.213005°
	Retsebile Primary School	-26.961930°	29.197353°
	Thuto-Thebe Secondary School	-26.947030°	29.220020°
	Jandrell Secondary School	-26.969768°	29.207290°
	Thobelani Secondary School	-26.965240°	29.206523°
	Standerton Tb Hospital	-26.977124°	29.219607°
Thuthukani	Thuthukani Pre Primary School	-26.786030°	29.303590°
	Ulwazi Primary School	-26.785680°	29.301080°
	Zikhetheleni Secondary School	-26.787403°	29.301062°
	Joubertsvlei Primary School (North of Tutuka)	-26.657110°	29.312830°
	Amalumgelo Primary School (NE Of Tutuka)	-26.733160°	29.453775°
Grootdraai Dam	Grootdraaidam Primary School	-26.898947°	29.292610°
Secunda	Laerskool Secunda	-26.509385°	29.193941°
	Laerskool Kruinpark	-26.519159°	29.225740°
	Laerskool Oranjegloed Primary	-26.521260°	29.203110°
	Curro Castle Combined School	-26.523097°	29.191675°
	Hoërskool Oosterland	-26.515283°	29.214972°
	Mediclinic Secunda (Hospital)	-26.507573°	29.182451°
	Mediclinic Highveld (Hospital_Trichardt, Secunda)	-26.492055°	29.232606°
	Daviescourt/Davieshof Old Age Home	-26.511249°	29.198892°
	Highveld Park High School	-26.510499°	29.208618°
	Hoerskool Secunda	-26.512707°	29.194632°
EMBALENHLE	Basizeni Special School	-26.530052°	29.079094°
	Maphala-Gulube Primary School	-26.570566°	29.099115°
	Shapeve Primary School	-26.531614°	29.090534°
	Thomas Nhlabathi Secondary School	-26.543169°	29.071362°
	Embalenhle Hospital / Clinic	-26.550013°	29.080121°
	Vukuzithathe Primary School	-26.567722°	29.083243°
	K I Twala Secondary	-26.570501°	29.075089°
	Allan Makunga Primary School	-26.537324°	29.087230°
Evander	Evander Hospital Arv Clinic	-26.467000°	29.120000°
	Laerskool Hoeveld	-26.470539°	29.115757°
	Hoerskool Evander	-26.477655°	29.103231°
Delmas	Bernice Samuel Hospital	-26.152500°	28.667100°
	Hoerskool Delmas	-26.147355°	28.667599°
	Laerskool Delmas	-26.147749°	28.681442°
	Kangela Primary School (North of Delpark)	-26.130000°	28.695000°
	Savf Ons Eie Ouetehuis / Old Age Home	-26.146154°	28.680927°
Eloff	Laerskool Eloff	-26.165971°	28.605106°
	Rietkol Primary School	-26.159963°	28.606432°
Botleng	Bazani Primary School	-26.104500°	28.699400°
	Phaphamani Secondary School	-26.105839°	28.690500°
	Vezimfundo Primary School	-26.091625°	28.694387°

Area	Sensitive Receptors	Latitude	Longitude
Arbor	Arbor Primary School	-26.048219°	28.889804°
Ogies	Ogies Combined School	-26.049221°	29.068832°
	Umthombo Wolwazi Farm School	-26.156451°	28.930509°
	Kendal	-26.079592°	28.975296°
	Ogies Tb Clinic	-26.049669°	29.059596°
	Ogies Police Station	-26.049669°	29.059596°
Phola	Hlangu Phala Primary School	-26.006460°	29.032484°
	Sukumani Primary School	-26.005724°	29.036428°
	Thuthukani Primary School	-26.008877°	29.038899°
	Mehlwana Secondary School	-25.995286°	29.037621°
	Makause Combined School	-25.996758°	29.043456°
Wilge	Sibongindawo Primary School	-25.974651°	28.984930°
Balmoral	Laerskool Balmoral	-25.859262°	28.980030°
Emalahleni	Clewer Primary School	-25.906838°	29.136114°
	Witbank High School	-25.884914°	29.226438°
	Eden Park Retirement Village	-25.902283°	29.237194°
	Savf House Immergroen Old Age Home	-25.879707°	29.217916°
	MTHIMKULU Housing for the Aged	-25.881082°	29.189281°
	Emalahleni Private Hospital	-25.874996°	29.216316°
	Life Cosmos Hospital	-25.883956°	29.232671°
	Duvha Primary School	-25.928700°	29.228835°
	Laerskool Taalfees	-25.882069°	29.226736°
	Witbank Provincial Hospital	-25.876855°	29.226772°
	Nancy Shiba Primary School (Vosman)	-25.860442°	29.127636°
	Wh De Klerk Skool	-25.867762°	29.246453°
	Laerskool Panorama	-25.852265°	29.244652°
	Laerskool Duvhapark	-25.938354°	29.245539°
	Laerskool Klipfontein	-25.904014°	29.241984°
	Cambridge Academy	-25.893439°	29.251575°
	Besilindile Primary School	-25.839035°	29.116774°
	Reynopark High School	-25.916428°	29.252116°
	Bakenveld Golf Estate	-25.905932°	29.292706°
	Mms Primary School	-25.905558°	29.385417°
	Bongiduvha Primary School	-25.983853°	29.335681°
	Springvalley Primary School	-25.921086°	29.260948°
	Joy Crèche	-25.972528°	29.308427°
	Curro Bankenveld Preschool and Primary School	-25.905248°	29.277348°
	Little Eden Academy	-25.917056°	29.253835°
	Little Steps Pre School	-25.944674°	29.251428°
	Allendale Secondary School	-25.982387°	29.338986°
	Khayalethu Primary School	-25.877710°	29.189130°
	Illanga Secondary School	-25.955537°	29.327107°
	Joy Creche (Duvha)	-25.972408°	29.308161°
Middelburg	Linderus Old Age Home	-25.784009°	29.459212°

Area	Sensitive Receptors	Latitude	Longitude
	Vergeet My Nie Old Age Home	-25.780787°	29.449413°
	Middleburg Frail Care Unit and Home for Elderly	-25.746481°	29.471782°
	Life Midmed Hospital	-25.763147°	29.457650°
	Middelburg Hospital	-25.775692°	29.450413°
	Makhathini Primary School	-25.749305°	29.448461°
	Laerskool Dennesig	-25.733488°	29.478283°
	Hoerskool Kanonkop	-25.742627°	29.479874°
	Laerskool Kanonkop	-25.751354°	29.470764°
	Steelcrest High School	-25.759514°	29.468012°
	Middelburg Primary	-25.778514°	29.453271°
	Middleburg Ext 6 Clinic	-25.768193°	29.407838°
	Sofunda Secondary School	-25.754358°	29.423801°
	Mhluzi Primary School	-25.753279°	29.440498°
	Highlands Primary School	-25.795886°	29.463428°
Komati	Blinkpan Primary School	-26.089884°	29.444406°
	Laerskool Koornfontein	-26.099868°	29.456226°
	Blinkpan	-26.086337°	29.433989°
Pullens Hope	Laerskool Kragveld	-26.016735°	29.590369°
	Pullens Hope	-26.020916°	29.597472°
Rietkuil / Arnot	Arnot Colliery Primary School	-25.932110°	29.780624°
	Laerskool Rietkuil	-25.949477°	29.807062°
	Beestepan Agricultural School	-25.841453°	29.709393°
Hendrina	Gekombineerde Skool Hendrina	-26.151386°	29.713726°
Kwazamokhule	Hendrina Primary School	-26.136847°	29.729098°
	Kwazamokuhle Secondary School	-26.131117°	29.732418°
Lothair	Ubuhle Bolwai Secondary School	-26.391734°	30.452159°
	Lothair Primary School	-26.394524°	30.428535°
Warburton	Warburton Combined School	-26.239852°	30.472477°
	Warburton Town	-26.227585°	30.472905°
Chrissiesmeer	Kwachibikhulu Clinic	-26.280125°	30.213918°
	Kwachibikhulu Primary School	-26.272378°	30.221621°
Carolina	Carolina Hospital	-26.074581°	30.111313°
	Zinikeleni Secondary School (Silobela)	-26.087874°	30.109848°
	Volkskool Carolina	-26.062907°	30.106394°
	Sobuza Primary School	-26.080382°	30.122447°
	Ons Eie Ouetehuis (Old Age Home)	-26.065018°	30.112066°
Breyten	Laerskool Breyten	-26.301603°	29.979961°
	Siyazi Primary School (Kwazanele)	-26.316644°	29.977882°
	Masizakhe Secondary School (Kwazanele)	-26.315348°	29.984385°
Belfast	Belfast Rusoord (Old Age Home)	-25.691737°	30.031956°
	Belfast Hospital	-25.696074°	30.043783°
	Platorand School	-25.704015°	30.047859°
	Belfast Primary School (Siyathuthuka)	-25.675303°	29.991119°
	Siyathuthuka Clinic	-25.676301°	29.995601°

Area	Sensitive Receptors	Latitude	Longitude
Bethal	Life Bethal Hospital	-26.464532°	29.467456°
	Hoerskool Hoogenhout	-26.461930°	29.472023°
	Jim Van Tonderskool	-26.436887°	29.450970°
	Bethal Independent Primary School	-26.442824°	29.454517°
	Laerskool Marietjie Van Niekerk	-26.440565°	29.489773°
	Laerskool Hm Swart	-26.459925°	29.465474°
	Sakhisizwe Primary School (Emzinoni)	-26.492311°	29.427359°
	Alpheus D Nkosi Secondary School (Emzinoni)	-26.480923°	29.446290°
	Silwerjare Old Age Home	-26.470954°	29.465659°
	Residentia Palm Oord	-26.460488°	29.462766°
Bronkhorstspruit	Bronkhorspruit Hospital	-25.803183°	28.716819°
	Cultura High School	-25.824833°	28.739116°
	Bronkhorspruit Primary School	-25.809124°	28.710617°
	Bronkhorspruit Dam	-25.891281°	28.697112°
	Hoerskool Erasmus	-25.813056°	28.732392°
	Althea Independent School	-25.809393°	28.739630°
	Kgoro Primary School (Zithobeni)	-25.787526°	28.718686°
	Zithobeni Secondary School (Zithobeni)	-25.776080°	28.729297°
Sasolburg	Vaal Power Ah	-26.823034°	27.995199°
	Sasolburg Provincial Hospital	-26.801004°	27.827226°
	Moredou Old Age Home	-26.820627°	27.818609°
	Ons Gryse Jeug Old Age Home	-26.808971°	27.829287°
	Noord Primere Skool	-26.809079°	27.833205°
	Sasolburg High School	-26.809493°	27.815540°
Zamdela	Sakhubusa Secondary School	-26.864383°	27.872379°
	Bekezela Primary School	-26.858275°	27.895183°
	Isaac Mhlambi Primary	-26.843253°	27.860477°
Deneysville	Refenkgotso Primary School	-26.896796°	28.071849°
	Deneysville Primary School	-26.894767°	28.091936°
Vaalpark	Netcare Vaalpark Hospital	-26.772921°	27.840020°
	Vaalpark Articon Secondary School	-26.766998°	27.854563°
Vanderbijlpark	Mediclinic Emfuleni	-26.705051°	27.837480°
	Curro Vanderbijlpark	-26.721637°	27.881353°
	Jeugland Old Age Home	-26.714240°	27.829000°
	Herfsoord Huis Old Age Home	-26.705218°	27.828579°
	Vaal Christian Combined School	-26.760827°	27.945336°
	Pele-Ya-Pele Secondary School	-26.758447°	27.948168°
	Huis Prinscilla	-26.686758°	27.830074°
	Laerskool Emfulenipark	-26.736622°	27.848162°
	Nw University_Vaal Campus	-26.729104°	27.882396°
	Emfuleni Primary School	-26.701230°	27.798581°
Vereeniging	Mediclinic Vereeniging	-26.669380°	27.927271°
	Kopanong Provincial Hospital (Duncanville)	-26.638409°	27.933352°

Area	Sensitive Receptors	Latitude	Longitude
	Pride Junior High School	-26.673626°	27.930727°
	Milton Primary School	-26.664438°	27.967937°
	Avondrus Eventide Old Age Home	-26.642726°	27.934453°
	Riviera On Vaal Resort	-26.675535°	27.939516°
	Selborne Primary School	-26.670181°	27.918206°
	Sedibeng TVET College	-26.679262°	27.931965°
	General Smuts High School	-26.672889°	27.917628°
	Eureuka School & Selbourne Primary	-26.670308°	27.914584°
Three Rivers	Midvaal Private Hospital (Three Rivers)	-26.663943°	27.969386°
	Three Rivers Retirement Village	-26.654433°	27.970966°
	Drie Riviere Aftreeoord Old Age Home	-26.648419°	27.972201°
	Fundamental Faculty and Factory	-26.662652°	27.979278°
	Mannabos Retirement Centre	-26.659008°	28.007140°
	Riverside High School	-26.657354°	27.997307°
	Hoërskool Drie Riviere	-26.658617°	27.974794°
	Laerskool Drie Riviere	-26.656514°	27.967703°
	Panfontein Intermediate School	-26.718701°	28.017031°
	Risiville Primary School	-26.645815°	27.982017°
Sebokeng	Sebokeng Hospital	-26.607161°	27.847550°
	Clinix-Naledzi Private Hospital	-26.616004°	27.848311°
Sharpville	Mohloli Secondary School	-26.691794°	27.878703°
	Tshirela Primary School (Boipatong)	-26.667125°	27.846609°
	Tsoaranang Primary School (Thepiso)	-26.672748°	27.875504°
	Thepiso Primary School	-26.652388°	27.875650°
	Emmanuel Primary School	-26.676238°	27.883255°
Rust Ter Vaal	Rust Ter Vaal Combined School	-26.575722°	27.947132°
Dadaville	Roshnee Primary School	-26.557834°	27.940930°
	Roshnee High School	-26.566323°	27.942320°
Meyerton	Hoerskool Dr Malan	-26.564977°	28.019234°
	Laerskool Voorwaarts	-26.601766°	28.046543°
	Meyerton Secondary School	-26.585957°	28.003034°
	Ratasetjhaba Primary School	-26.553412°	27.983147°
	Meyerton Primary School	-26.553487°	28.020296°
Henley On Klip	Oprah Leadership Academy	-26.547041°	28.055309°
	Henley River Retirement Village	-26.548818°	28.062594°
	Henley High & Preparatory School	-26.528413°	28.060892°
	Randvaal Clinic	-26.515421°	28.044906°
Daleside / Valley Settlements	Laerskool Japie Greyling	-26.492618°	28.065508°
	Thomas Nhlapo Primary	-26.506179°	28.069969°
	Randvaal Old Age Home	-26.491357°	28.032070°
Heidelberg	Laerskool Ag Visser	-26.527385°	28.364387°
	Lethaba Siyangobe	-26.535127°	28.363146°

Area	Sensitive Receptors	Latitude	Longitude
	Shalimar Ridge Primary School	-26.512296°	28.352566°
	Jw Luckoff High School	-26.550141°	28.377976°
	Heidelberg Hospital	-26.505180°	28.350463°
	Thulatsatsi Operation (Rensburg)	-26.524848°	28.363676°
	Silwer Akker Tehuis	-26.510276°	28.356255°
	Riversands Retirement Village	-26.507195°	28.343400°
Ratanda	Qhaqholla Primary School	-26.550719°	28.325743°
	Ratanda Primary School	-26.571045°	28.323848°
	Boneha Primary School	-26.551890°	28.328050°
	Sithokomele Primary School	-26.552180°	28.332480°
	Ratanda Bertha Gxowa Primary School	-26.539078°	28.360724°
	Khanya Lesedi Secondary School	-26.558920°	28.323980°
	Ratanda Secondary School	-26.556930°	28.327600°
	New Ratanda Secondary School	-26.536066°	28.356365°
	Kgoro Ya Thuto Secondary School	-26.536087°	28.356288°
Katlehong	Ekurhuleni School For the Deaf	-26.345596°	28.163239°
Tsakane	Pholosong Hospital	-26.340323°	28.376981°
	Tsakane Home For Aged	-26.359892°	28.371919°
	Mmuso Primary School	-26.380790°	28.406465°
	Michael Zulu Primary School	-26.345305°	28.387950°
	Nkabinde Primary School (Thembilisha)	-26.303995°	28.403039°
Nigel	Nigel Clinic	-26.419586°	28.467950°
	Tehuis Vir Bejaardes	-26.422307°	28.479643°
	Hoerskool John Vorster	-26.427357°	28.472668°
	Laerskool Hannes Visagie	-26.427603°	28.494581°
	Nigel Secondary School	-26.447243°	28.514293°
	Laerskool Dunnottar	-26.346668°	28.431510°
Springs	Springs Retirement Village	-26.255461°	28.447029°
	Life Springs Parkland Hospital	-26.266018°	28.435500°
	Netcare N17 Hospital (Springs)	-26.271306°	28.427831°
	Springs Boys High School	-26.298323°	28.442511°
	Laerskool Selectionpark	-26.280731°	28.447617°
	Kwasa College Pre&Primary School	-26.290089°	28.483292°
	Edelweis Medical Centre	-26.285282°	28.469920°
	Laerskool Christiaan Beyers	-26.260785°	28.462528°
	Hoerskool Hugenote	-26.240027°	28.434373°
Brakpan	Brakpan Primary School	-26.243109°	28.373344°
Boksburg	Parkrand Primary School	-26.249653°	28.276180°
	Thabo Memorial Hospital	-26.232875°	28.244243°
	Sunward Park Hospital	-26.260136°	28.256683°
Alberton	Alberton High School	-26.281920°	28.117084°
	Netcare Clinton Hospital	-26.273268°	28.120227°
	Alberton Tuiste Vir Bejaardes	-26.278995°	28.113435°
Germiston	Bertha Gxowa Hospital	-26.220611°	28.165186°

Area	Sensitive Receptors	Latitude	Longitude
Benoni	Linmed Hospital	-26.145829°	28.330060°
	Hoerskool Brandwag (Airfield)	-26.174468°	28.317457°
	Thepiso Noto Intermediate School	-26.110681°	28.478384°
	Laerskool Bredell	-26.095549°	28.309374°
	Sibonelo Primary School (Daveyton)	-26.133366°	28.428877°
	Petit High School (Kempton Park Nu)	-26.097238°	28.371925°
Kempton Park	Arwyp Medical Centre	-26.106876°	28.233229°
	Hoerskool Birchleigh	-26.055418°	28.234975°
	Curro Serengeti Acadamy	-26.056936°	28.294549°
JHB South	South Rand Hospital	-26.252897°	28.062148°
Soweto	Chris Hani Baragwanath Hospital	-26.261492°	27.940355°
	Thulani Primary School	-26.245828°	27.848300°
Johannesburg	University Of Witwatersrand	-26.189947°	28.031656°
	Milpark Hospital	-26.180234°	28.017865°
	Charlotte Maxixe Academic Hospital	-26.175864°	28.045603°
	Thembisa West Secondary School (Thembisa)	-26.026012°	28.184597°
	Lenmed Zamokuhle Private Hospital (Thembisa)	-25.983681°	28.237972°
	Ikusasa Comprehensive School	-26.009079°	28.242320°
Centurion	Gem Village Old Age Home	-25.890517°	28.235196°
	Rustoord Old Age Home	-25.828157°	28.203777°
	Cornwell Hill College (Irene)	-25.873186°	28.234287°
Pretoria East	Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	-25.799673°	28.486162°
	Valtaki AH (Rayton)	-25.777795°	28.584606°
	Laerskool Rayton (Rayton)	-25.744732°	28.527243°
	Tierkop AH	-25.902813°	28.422585°
	Redford House The Hills Private School (Mooikloof Glen)	-25.872295°	28.361134°
	Rietvlei View Country Estate	-25.884742°	28.372901°
	Hazeldean Curro School (Tyger Valley)	-25.780919°	28.387427°
	Tyger Valley College	-25.801750°	28.369799°
	Pretoria East Hospital (Moreletapark)	-25.820584°	28.304652°
	Groenkloof Old Age Home	-25.770356°	28.217846°
Pretoria	Steve Biko Academic Hospital	-25.729693°	28.203318°
	Willow Ridge High School (Wilgers)	-25.760751°	28.315444°
	Hoerskool Waterkloof	-25.818863°	28.255795°
	Hoerskool Garsfontein	-25.797751°	28.304342°
	Afrikaanse Hoer Seunskool	-25.758166°	28.220742°
	Huis Silversig Savf Old Age Home (Silverton)	-25.732724°	28.297254°
	Laersekool Meyerspark (Meyerspark)	-25.740127°	28.313935°
Mamelodi	Curro Academy Mamelodi	-25.698567°	28.422449°
	Impendulo Primary School	-25.723669°	28.437518°
	Nellmapius Ext 6 Primary School	-25.733098°	28.375745°
	Mamelodi Home For Aged	-25.714091°	28.415290°

ANNEXURE 2: PREDICTED CONCENTRATIONS AT SENSITIVE RECEPTORS

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario 1 (Current), together with the limit value of the NAAQS

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Elsie Ballot Memorial Hospital	23.7	3.1	20.6	2.6
Laerskool Amersfoort	23.7	3.1	20.6	2.6
Embuzane Primary School	24.7	3.0	21.8	2.5
Sangqotho Primary School	24.2	3.1	20.8	2.6
Amersfoort Combined School	23.6	3.1	20.5	2.6
Injubuko Primary School	23.2	3.1	20.1	2.6
Daggakraal Primary School	24.1	3.1	20.9	2.6
Sizenzele Primary School	23.6	3.0	20.5	2.6
Seme Secondary School	24.7	3.2	21.4	2.7
Louwra Primary School	22.8	2.6	20.1	2.3
Perdekop Agricultural School	22.5	2.6	19.5	2.3
Vukuzenzele Combined School	22.9	2.6	20.0	2.3
Gunwana Primary School	21.6	2.5	18.9	2.2
Amajuba Memorial Hospital	20.3	2.4	17.5	2.1
Volksrust High School	20.6	2.4	17.8	2.1
Volksrust Municipal Clinic	20.3	2.3	17.5	2.0
C V O Skool Amajuba	20.5	2.3	17.7	2.1
Qhubulwazi Combined School	20.0	2.4	17.3	2.1
Volksrust Primary School	20.6	2.4	17.8	2.1
New Ermelo	25.3	3.3	21.5	2.8
Ermelo Christian School	25.4	3.4	21.7	2.8
SAVF Home For Aged	25.2	3.3	21.5	2.8
Ermelo Hospital	25.0	3.3	21.2	2.7
Mediclinic Ermelo	25.3	3.3	21.6	2.8
Hoerskool Ermelo	25.1	3.3	21.3	2.8
Ermelo Indian Combined School	25.0	3.3	21.2	2.7
Lungelo Combined School (Outside Town)	24.1	3.2	20.7	2.6
New Ermelo Primary School	25.4	3.3	21.6	2.8
Kwashashe (Outside Town)	24.9	3.4	21.3	2.8
Hts Ligbron	25.3	3.3	21.5	2.8
Laerskool Ermelo	25.1	3.3	21.4	2.8
JJ Vd Merwe Pre-Primary School	25.1	3.3	21.3	2.8
Lindile Secondary School	24.6	3.3	21.0	2.7
Emthonjeni Clinic	24.5	3.3	21.0	2.7
Reggie Masuku Secondary School	24.6	3.3	21.2	2.7
Cebisa Secondary School	24.5	3.3	21.0	2.7
Camden	25.9	3.3	22.3	2.8
Camden Combined School	26.3	3.4	22.1	2.8
Camden School	26.2	3.3	22.6	2.8
Umzimvelo Secondary School (Rural Area)	24.4	3.4	21.1	2.9
Bhekimfundo Primary School (Rural Area)	24.6	3.3	20.9	2.8
Eshwileni Primary School (Rural Area)	24.3	3.2	21.0	2.7
Davel Combined School	24.7	3.3	20.5	2.7
Morgenzon Landbou Akademie	23.6	3.1	20.4	2.6
Nqobangolwazi Secondary School	23.7	3.1	20.4	2.6
Siqondekhaya Pre Primary School	24.1	3.1	20.6	2.6
Sizakhele Primary School	24.0	3.1	20.6	2.6

Scenario 1 (Current)	**PM$_{10}$ Total**		**PM$_{2.5}$ Total**	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**40**	**20**
Phezukwentaba Primary School (South of Morgenzon)	24.2	3.1	20.9	2.6
Kwaggalaagte Primary School (North of Morgenzon)	26.7	3.1	22.4	2.5
Sizakhele Clinic/Hospital	24.0	3.1	20.6	2.6
Grootvlei	20.4	1.9	17.3	1.6
Olive Grove Country Lodge	20.4	1.9	17.3	1.6
Grootvlei Town (South of Power Station)	21.4	1.9	18.1	1.6
Laerskool Grootvlei	21.3	1.9	18.0	1.6
Tokoloho Primary School	21.2	1.9	18.0	1.6
Tshepeha Combined School	21.5	1.9	18.2	1.6
Warembo Lodge	21.4	2.0	18.2	1.7
Balfour	22.4	2.0	18.8	1.8
Siyathemba	22.2	2.1	18.7	1.8
Bonukukhanya Primary (Siyathemba)	21.9	2.1	18.5	1.8
Qalabocha Primary School (Siyathemba)	22.2	2.1	18.7	1.8
Vusumuzi Primary School	22.2	2.1	18.7	1.8
Gekombineerde Skool Balfour	21.8	2.0	18.3	1.7
Im Manchu Secondary School	21.9	2.0	18.4	1.7
Isifisosethu Secondary School (Siyathemba)	22.0	2.1	18.5	1.8
Setsheng Secondary School (Siyathemba)	22.3	2.1	18.8	1.8
Dr Nieuwoudt And Dr Kok	21.7	2.0	18.3	1.7
Balfour Clinic	22.1	2.0	18.5	1.7
Siyathemba Clinic	22.2	2.0	18.6	1.8
Mondoro Lodge	22.0	2.0	18.4	1.7
Wegelegen Manor	23.0	2.1	19.3	1.8
The Stone Cellar	20.7	1.9	17.8	1.6
Greylingstad	23.5	2.2	19.6	1.9
Nthorwane	23.7	2.2	19.8	1.9
Laerskool Greylingstad	23.8	2.2	19.9	1.9
Nthoroane Secondary School	23.8	2.2	19.8	1.9
Badgarleur Bush Lodge	20.4	2.1	17.4	1.8
Matla Village	29.4	2.8	23.8	2.2
Sifundise Primary School	29.3	2.8	23.7	2.2
Matla Coal Health Centre	29.0	2.8	23.6	2.2
Gweda Primary School	32.3	3.3	25.4	2.5
Zithobe Primary School	28.5	2.5	23.9	2.0
Kwanala Primary School	32.7	3.3	26.3	2.5
Reedstream Park	32.4	3.2	25.7	2.4
Rietspruit Clinic	32.0	3.2	25.4	2.4
Lehlaka Combined School	32.3	3.2	25.5	2.4
Mbali Coal/Blesboklaagte Housing	30.7	2.9	24.1	2.3
Kinross	29.9	2.7	24.9	2.3
Kinross Settlement	28.8	2.6	24.3	2.2
Kinross Municipal Clinic	29.7	2.7	24.7	2.3
Kriel	30.1	3.6	24.5	2.6
Eagles Nest Guest House	30.2	3.6	24.5	2.7
Merlin Park Primary School	30.3	3.5	24.5	2.6
Kriel Medical Centre	29.7	3.5	24.2	2.6
Laerskool Krielpark	29.3	3.5	24.1	2.6
Laerskool Onverwacht	30.5	3.5	24.7	2.6

Scenario 1 (Current)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Silwer Fleur Aftree Oord (Old Age Home)	30.2	3.5	24.7	2.6
Thubelihle	29.8	3.4	24.5	2.6
Sibongamandla Secondary School	29.6	3.4	24.2	2.6
Ga-Nala Clinic	31.2	3.4	25.5	2.6
Impilo Primary School	29.2	3.1	23.8	2.4
Bonginhlanhla Primary School	29.8	3.4	24.4	2.6
Sibongamandla Secondary School	29.6	3.4	24.2	2.6
Leandra	25.0	2.4	20.9	2.0
Eendracht	24.7	2.3	20.6	2.0
Sidingulwazi Primary School	25.6	2.4	21.2	2.0
Ss Mshayisa Primary School	25.3	2.4	21.0	2.0
Chief Ampie Mayisa Secondary School	25.6	2.4	21.1	2.0
Lebogang Clinic	25.3	2.4	20.9	2.0
Kleuterskool Haas Das	24.1	2.5	20.7	2.2
Standerton Primary School	24.1	2.5	20.7	2.2
Laerskool Jeugkrag	24.0	2.5	20.6	2.2
Laerskool Standerton	24.2	2.5	20.8	2.2
Laerskool Kalie De Haas	24.9	2.5	21.4	2.2
Hoerskool Standerton	24.1	2.5	20.7	2.2
Standerton Provincial Government Hospital	24.0	2.5	20.7	2.2
Mar-Peh Medicare Private Hospital	24.3	2.5	20.9	2.2
Standerton Retirement Home	24.3	2.5	20.9	2.2
Standerton Ouetehuis/Old Age Home	24.4	2.5	20.9	2.2
Holmdene Secondary School	26.6	2.5	22.6	2.1
Cathuza Primary School (SE of Town)	23.9	2.6	20.7	2.3
Sizanani Pre Primary School	24.7	2.5	21.3	2.1
Hlobisa Primary School	24.8	2.5	21.4	2.1
Shukuma Primary School	24.7	2.5	21.4	2.1
Retsebile Primary School	25.0	2.5	21.5	2.1
Thuto-Thebe Secondary School	24.3	2.5	21.0	2.1
Jandrell Secondary School	24.8	2.5	21.4	2.1
Thobelani Secondary School	24.7	2.5	21.3	2.1
Standerton Tb Hospital	24.5	2.5	21.3	2.1
Thuthukani Pre Primary School	24.1	2.6	20.8	2.2
Ulwazi Primary School	24.1	2.6	20.8	2.2
Zikhetheleni Secondary School	24.3	2.6	20.9	2.2
Joubertsvlei Primary School (North of Tutuka)	24.6	2.8	21.3	2.3
Amalumgelo Primary School (NE of Tutuka)	24.9	3.0	21.3	2.5
Grootdraaidam Primary School	24.5	2.6	21.2	2.2
Laerskool Secunda	27.0	2.7	22.8	2.3
Laerskool Kruinpark	26.8	2.8	22.8	2.3
Laerskool Oranjegloed Primary	27.1	2.7	22.8	2.3
Curro Castle Combined School	26.4	2.7	22.5	2.3
Hoërskool Oosterland	27.3	2.8	23.0	2.3
Mediclinic Secunda (Hospital)	26.7	2.7	22.7	2.3
Mediclinic Highveld (Hospital_Trichardt, Secunda)	26.8	2.8	22.7	2.4
Daviescourt/Davieshof Old Age Home	27.2	2.7	22.9	2.3
Highveld Park High School	27.5	2.7	23.1	2.3
Hoerskool Secunda	26.9	2.7	22.8	2.3

Scenario 1 (Current)	PM10 Total		PM2.5 Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Basizeni Special School	26.6	2.6	22.2	2.2
Maphala-Gulube Primary School	26.4	2.6	22.3	2.2
Shapeve Primary School	26.7	2.6	22.3	2.2
Thomas Nhlabathi Secondary School	26.9	2.6	22.4	2.2
Embalenhle Hospital / Clinic	27.0	2.6	22.5	2.2
Vukuzithathe Primary School	26.7	2.6	22.5	2.2
K I Twala Secondary	26.9	2.6	22.6	2.2
Allan Makunga Primary School	26.8	2.6	22.4	2.2
Evander Hospital Arv Clinic	29.3	2.7	24.5	2.3
Laerskool Hoeveld	29.2	2.7	24.2	2.3
Hoerskool Evander	28.0	2.7	23.6	2.2
Bernice Samuel Hospital	22.3	1.9	18.4	1.6
Hoerskool Delmas	22.0	1.8	18.3	1.6
Laerskool Delmas	22.3	1.9	18.4	1.6
Kangela Primary School (North of Delpark)	22.4	1.8	18.6	1.6
Savf Ons Eie Ouetehuis / Old Age Home	22.3	1.9	18.4	1.6
Laerskool Eloff	22.2	1.8	18.4	1.6
Rietkol Primary School	21.9	1.8	18.3	1.6
Bazani Primary School	22.2	1.8	18.7	1.5
Phaphamani Secondary School	22.2	1.8	18.7	1.5
Vezimfundo Primary School	22.0	1.8	18.6	1.5
Arbor Primary School	25.8	2.0	21.1	1.6
Ogies Combined School	30.6	2.5	24.0	2.0
Ogies Tb Clinic	30.6	2.5	23.8	2.0
Ogies Police Station	30.6	2.5	23.8	2.0
Hlangu Phala Primary School	28.1	2.2	22.1	1.8
Sukumani Primary School	28.0	2.2	22.1	1.8
Thuthukani Primary School	27.5	2.2	21.9	1.8
Mehlwana Secondary School	28.0	2.2	22.1	1.8
Makause Combined School	27.3	2.2	21.8	1.8
Sibongindawo Primary School	26.0	2.0	21.0	1.7
Laerskool Balmoral	24.6	1.8	20.7	1.5
Clewer Primary School	26.3	2.1	22.3	1.7
Witbank High School	26.6	2.1	22.5	1.8
Eden Park Retirement Village	26.1	2.2	22.1	1.8
Savf House Immergroen Old Age Home	26.6	2.1	22.7	1.8
Mthimkulu Housing for the Aged	27.2	2.1	23.2	1.8
Emalahleni Private Hospital	26.6	2.1	22.8	1.8
Life Cosmos Hospital	26.3	2.2	22.3	1.8
Duvha Primary School	27.0	2.2	22.6	1.9
Laerskool Taalfees	26.5	2.1	22.5	1.8
Witbank Provincial Hospital	26.4	2.1	22.5	1.8
Nancy Shiba Primary School (Vosman)	26.2	2.0	22.2	1.7
Wh De Klerk Skool	25.9	2.1	22.1	1.8
Laerskool Panorama	26.3	2.1	22.4	1.8
Laerskool Duvhapark	27.5	2.3	22.9	1.9
Laerskool Klipfontein	26.3	2.2	22.2	1.9
Cambridge Academy	26.2	2.2	22.3	1.9
Besilindile Primary School	26.8	1.9	22.5	1.6

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Reynopark High School	27.1	2.3	22.7	1.9
Bakenveld Golf Estate	28.2	2.3	23.7	1.9
Allendale Secondary School	28.4	2.5	23.9	2.1
Khayalethu Primary School	27.2	2.1	23.2	1.8
Illanga Secondary School	28.8	2.5	23.9	2.0
Joy Creche (Duvha)	28.7	2.5	23.9	2.0
Linderus Old Age Home	25.1	2.1	21.0	1.8
Vergeet My Nie Old Age Home	25.0	2.1	21.0	1.8
Middleburg Frail Care Unit and Home For Elderly	25.6	2.1	21.6	1.8
Life Midmed Hospital	25.2	2.1	21.2	1.8
Middelburg Hospital	25.0	2.1	21.0	1.8
Makhathini Primary School	25.4	2.1	21.5	1.8
Laerskool Dennesig	25.7	2.0	21.7	1.7
Hoerskool Kanonkop	25.6	2.1	21.6	1.7
Laerskool Kanonkop	25.4	2.1	21.4	1.8
Steelcrest High School	25.3	2.1	21.3	1.8
Middelburg Primary	25.0	2.1	21.0	1.8
Middleburg Ext 6 Clinic	25.7	2.1	21.9	1.8
Sofunda Secondary School	25.6	2.1	21.8	1.8
Mhluzi Primary School	25.5	2.1	21.6	1.8
Highlands Primary School	25.1	2.2	21.1	1.8
Blinkpan Primary School	25.1	2.8	21.2	2.3
Laerskool Koornfontein	24.7	2.8	20.9	2.3
Blinkpan	25.4	2.8	21.3	2.3
Laerskool Kragveld	23.7	2.7	20.0	2.2
Pullens Hope	23.4	2.7	19.8	2.2
Arnot Colliery Primary School	22.5	2.5	19.3	2.1
Laerskool Rietkuil	22.2	2.5	19.1	2.1
Beestepan Agricultural School	23.3	2.3	19.8	1.9
Gekombineerde Skool Hendrina	23.4	2.9	19.8	2.4
Hendrina Primary School	23.4	2.9	19.8	2.4
Kwazamokuhle Secondary School	23.2	2.9	19.8	2.4
Ubuhle Bolwai Secondary School	23.5	3.1	20.5	2.7
Lothair Primary School	23.4	3.1	20.4	2.7
Warburton Combined School	23.5	3.0	20.5	2.6
Warburton Town	23.4	3.0	20.5	2.6
Kwachibikhulu Clinic	22.8	3.1	20.2	2.6
Kwachibikhulu Primary School	22.8	3.1	20.2	2.6
Carolina Hospital	22.1	2.8	19.1	2.4
Zinikeleni Secondary School (Silobela)	21.9	2.9	19.0	2.4
Volkskool Carolina	22.2	2.8	19.2	2.4
Sobuza Primary School	22.0	2.9	19.1	2.4
Ons Eie Ouetehuis (Old Age Home)	22.2	2.8	19.1	2.4
Laerskool Breyten	23.2	3.1	20.4	2.6
Siyazi Primary School (Kwazanele)	23.2	3.1	20.3	2.6
Masizakhe Secondary School (Kwazanele)	23.2	3.1	20.3	2.6
Belfast Rusoord (Old Age Home)	21.0	2.1	18.1	1.8
Belfast Hospital	21.1	2.1	18.2	1.8
Platorand School	21.0	2.1	18.1	1.8

Scenario 1 (Current)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Belfast Primary School (Siyathuthuka)	20.5	2.0	17.7	1.8
Siyathuthuka Clinic	20.5	2.0	17.7	1.8
Life Bethal Hospital	27.7	3.3	22.5	2.6
Hoerskool Hoogenhout	27.0	3.3	22.1	2.6
Jim Van Tonderskool	26.6	3.3	21.8	2.6
Bethal Independent Primary School	27.0	3.3	22.1	2.6
Laerskool Marietjie Van Niekerk	27.0	3.3	21.8	2.7
Laerskool Hm Swart	27.1	3.3	22.2	2.6
Sakhisizwe Primary School (Emzinoni)	27.4	3.2	22.3	2.6
Alpheus D Nkosi Secondary School (Emzinoni)	27.2	3.2	22.1	2.6
Silwerjare Old Age Home	27.3	3.3	22.3	2.6
Residentia Palm Oord	27.3	3.3	22.3	2.6
Bronkhorspruit Hospital	20.3	1.5	17.1	1.3
Cultura High School	20.6	1.5	17.3	1.3
Bronkhorspruit Primary School	20.4	1.5	17.2	1.3
Bronkhorspruit Dam	22.1	1.6	18.3	1.4
Hoerskool Erasmus	20.5	1.5	17.2	1.3
Althea Independent School	20.2	1.5	17.0	1.3
Kgoro Primary School (Zithobeni)	19.8	1.5	16.7	1.3
Zithobeni Secondary School (Zithobeni)	19.6	1.4	16.6	1.2
Vaal Power AH	20.0	1.5	17.0	1.3
Sasolburg Provincial Hospital	21.1	1.3	18.1	1.2
Moredou Old Age Home	21.5	1.3	18.4	1.2
Ons Gryse Jeug Old Age Home	21.5	1.3	18.3	1.2
Noord Primere Skool	21.6	1.3	18.4	1.2
Sasolburg High School	21.3	1.3	18.2	1.1
Sakhubusa Secondary School	20.2	1.4	17.2	1.2
Bekezela Primary School	19.9	1.4	16.8	1.2
Isaac Mhlambi Primary	20.1	1.4	17.2	1.2
Refenkgotso Primary School	19.9	1.6	17.1	1.4
Deneysville Primary School	19.3	1.7	16.6	1.4
Netcare Vaalpark Hospital	20.8	1.3	17.9	1.2
Vaalpark Articon Secondary School	21.0	1.4	18.0	1.2
Mediclinic Emfuleni	20.1	1.3	17.6	1.1
Jeugland Old Age Home	20.0	1.3	17.5	1.1
Herfsoord Huis Old Age Home	20.2	1.3	17.6	1.1
Huis Prinscilla	20.2	1.3	17.8	1.1
Laerskool Emfulenipark	20.1	1.3	17.4	1.2
Nw University_Vaal Campus	19.9	1.3	17.4	1.2
Emfuleni Primary School	19.3	1.3	16.9	1.1
Mediclinic Vereeniging	20.2	1.4	17.7	1.2
Kopanong Provincial Hospital (Duncanville)	19.5	1.4	17.0	1.2
Avondrus Eventide Old Age Home	19.7	1.4	17.1	1.2
Riviera On Vaal Resort	20.3	1.4	17.8	1.2
Sedibeng Tvet College	20.6	1.4	18.0	1.2
General Smuts High School	20.4	1.3	17.9	1.2
Eureuka School & Selbourne Primary	20.3	1.3	17.8	1.2
Midvaal Private Hospital (Three Rivers)	19.8	1.4	17.3	1.2
Three Rivers Retirement Village	19.8	1.4	17.2	1.2

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Drie Riviere Aftreeoord Old Age Home	19.9	1.4	17.3	1.2
Riverside High School	19.9	1.5	17.2	1.3
Risiville Primary School	19.5	1.4	17.0	1.2
Sebokeng Hospital	19.2	1.3	16.8	1.1
Clinix-Naledzi Private Hospital	19.4	1.3	17.0	1.1
Mohloli Secondary School	20.4	1.3	17.9	1.1
Tshirela Primary School (Boipatong)	19.9	1.3	17.5	1.1
Tsoaranang Primary School (Thepiso)	20.2	1.3	17.8	1.1
Thepiso Primary School	19.9	1.3	17.4	1.1
Emmanuel Primary School	20.1	1.3	17.6	1.1
Rust Ter Vaal Combined School	19.4	1.4	16.8	1.2
Roshnee Primary School	19.5	1.3	16.9	1.2
Roshnee High School	19.5	1.3	16.9	1.2
Hoerskool Dr Malan	20.5	1.4	17.9	1.2
Laerskool Voorwaarts	19.9	1.5	17.2	1.3
Meyerton Secondary School	20.3	1.4	17.6	1.2
Ratasetjhaba Primary School	19.4	1.4	16.8	1.2
Meyerton Primary School	20.2	1.4	17.6	1.2
Oprah Leadership Academy	19.9	1.4	17.1	1.3
Henley River Retirement Village	19.9	1.5	17.2	1.3
Henley High & Preparatory School	19.7	1.4	16.9	1.2
Randvaal Clinic	19.8	1.4	17.1	1.2
Laerskool Japie Greyling	19.6	1.4	16.9	1.2
Thomas Nhlapo Primary	19.9	1.4	17.2	1.2
Randvaal Old Age Home	19.4	1.4	16.7	1.2
Laerskool Ag Visser	20.5	1.7	17.7	1.5
Lethaba Siyangobe	20.6	1.7	17.8	1.5
Shalimar Ridge Primary School	20.5	1.7	17.6	1.5
Jw Luckoff High School	20.4	1.8	17.8	1.5
Heidelberg Hospital	20.4	1.7	17.5	1.5
Thulatsatsi Operation (Rensburg)	20.5	1.7	17.7	1.5
Silwer Akker Tehuis	20.6	1.7	17.7	1.5
Riversands Retirement Village	20.2	1.7	17.3	1.5
Qhaqholla Primary School	20.2	1.7	17.3	1.5
Ratanda Primary School	19.8	1.7	17.1	1.5
Boneha Primary School	20.3	1.7	17.5	1.5
Sithokomele Primary School	20.5	1.7	17.6	1.5
Ratanda Bertha Gxowa Primary School	20.6	1.8	17.8	1.5
Khanya Lesedi Secondary School	20.0	1.7	17.2	1.5
Ratanda Secondary School	20.2	1.7	17.4	1.5
New Ratanda Secondary School	20.6	1.7	17.8	1.5
Kgoro Ya Thuto Secondary School	20.6	1.7	17.8	1.5
Ekurhuleni School for the Deaf	19.2	1.5	16.4	1.3
Pholosong Hospital	21.5	1.7	18.3	1.5
Tsakane Home For Aged	21.0	1.7	18.0	1.5
Mmuso Primary School	21.1	1.8	18.1	1.5
Michael Zulu Primary School	21.5	1.7	18.4	1.5
Nkabinde Primary School (Thembilisha)	22.0	1.7	18.4	1.5
Nigel Clinic	20.5	1.8	17.6	1.6

Scenario 1 (Current)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Tehuis Vir Bejaardes	20.7	1.8	17.8	1.6
Hoerskool John Vorster	20.5	1.8	17.7	1.6
Laerskool Hannes Visagie	21.1	1.8	18.3	1.6
Nigel Secondary School	21.2	1.9	18.3	1.6
Laerskool Dunnottar	21.1	1.8	18.1	1.5
Springs Retirement Village	21.8	1.7	18.0	1.5
Life Springs Parkland Hospital	21.9	1.7	18.1	1.5
Netcare N17 Hospital (Springs)	21.9	1.7	18.1	1.5
Springs Boys High School	21.4	1.7	18.1	1.5
Laerskool Selectionpark	21.5	1.7	17.9	1.5
Kwasa College Pre&Primary School	21.0	1.7	17.9	1.5
Edelweis Medical Centre	21.6	1.7	18.1	1.5
Laerskool Christiaan Beyers	22.0	1.7	18.1	1.5
Hoerskool Hugenote	21.1	1.7	17.6	1.5
Brakpan Primary School	21.7	1.6	17.8	1.4
Parkrand Primary School	20.9	1.5	17.2	1.3
Thabo Memorial Hospital	20.0	1.5	16.8	1.3
Sunward Park Hospital	21.0	1.5	17.3	1.3
Alberton High School	19.6	1.4	16.3	1.2
Netcare Clinton Hospital	19.4	1.4	16.2	1.2
Alberton Tuiste Vir Bejaardes	19.6	1.4	16.3	1.2
Bertha Gxowa Hospital	19.5	1.4	16.1	1.2
Linmed Hospital	19.4	1.5	16.5	1.3
Hoerskool Brandwag (Airfield)	19.9	1.5	16.8	1.3
Thepiso Noto Intermediate School	21.8	1.6	18.5	1.4
Laerskool Bredell	19.2	1.5	16.6	1.3
Sibonelo Primary School (Daveyton)	21.0	1.6	17.9	1.4
Petit High School (Kempton Park Nu)	20.6	1.5	17.6	1.3
Arwyp Medical Centre	19.1	1.4	16.2	1.2
Hoerskool Birchleigh	19.1	1.4	16.1	1.2
Curro Serengeti Acadamy	19.3	1.4	16.5	1.2
South Rand Hospital	19.3	1.4	16.1	1.2
Chris Hani Baragwanath Hospital	18.7	1.2	15.8	1.1
Thulani Primary School	17.4	1.1	14.9	1.0
University of Witwatersrand	18.7	1.4	15.7	1.2
Milpark Hospital	18.2	1.3	15.3	1.1
Charlotte Maxixe Academic Hospital	18.5	1.4	15.5	1.2
Thembisa West Secondary School (Thembisa)	18.0	1.3	15.4	1.1
Lenmed Zamokuhle Private Hospital (Thembisa)	18.3	1.3	15.6	1.1
Ikusasa Comprehensive School	18.2	1.3	15.4	1.1
Gem Village Old Age Home	19.6	1.2	16.5	1.1
Rustoord Old Age Home	20.0	1.2	16.7	1.0
Cornwell Hill College (Irene)	19.6	1.2	16.5	1.1
Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	19.4	1.3	16.2	1.1
Valtaki AH (Rayton)	19.7	1.4	16.7	1.2
Laerskool Rayton (Rayton)	19.1	1.3	16.3	1.1
Tierkop AH	21.3	1.4	17.2	1.2
Redford House The Hills Private School (Mooikloof Glen)	21.8	1.4	17.6	1.2
Rietvlei View Country Estate	21.8	1.4	17.7	1.2

Scenario 1 (Current)	**PM_{10} Total**		**$PM_{2.5}$ Total**	
	24-hr	**Ann**	**24-hr**	**Ann**
Receptor	**75**	**40**	**40**	**20**
Hazeldean Curro School (Tyger Valley)	19.0	1.2	15.9	1.1
Tyger Valley College	19.5	1.3	16.2	1.1
Pretoria East Hospital (Moreletapark)	20.2	1.3	16.8	1.1
Groenkloof Old Age Home	18.6	1.1	15.7	1.0
Steve Biko Academic Hospital	17.4	1.1	14.8	0.9
Willow Ridge High School (Wilgers)	18.4	1.2	15.5	1.0
Hoerskool Waterkloof	20.0	1.2	16.6	1.1
Hoerskool Garsfontein	19.7	1.2	16.5	1.0
Afrikaanse Hoer Seunskool	18.2	1.1	15.4	1.0
Huis Silversig SAVF Old Age Home (Silverton)	17.9	1.1	15.2	1.0
Laersekool Meyerspark (Meyerspark)	18.2	1.1	15.4	1.0
Curro Academy Mamelodi	18.1	1.1	15.5	1.0
Impendulo Primary School	18.8	1.2	15.9	1.0
Nellmapius Ext 6 Primary School	18.4	1.2	15.6	1.0
Mamelodi Home For Aged	18.2	1.1	15.5	1.0

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario A (2025), together with the limit value of the NAAQS

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	40	20
Elsie Ballot Memorial Hospital	25.5	3.6	23.9	3.3
Laerskool Amersfoort	25.2	3.6	23.6	3.3
Embuzane Primary School	28.5	3.7	26.7	3.3
Sangqotho Primary School	25.1	3.7	23.4	3.3
Amersfoort Combined School	25.3	3.7	23.6	3.3
Injubuko Primary School	25.0	3.7	23.6	3.3
Daggakraal Primary School	24.8	3.7	23.4	3.4
Sizenzele Primary School	25.0	3.6	23.4	3.3
Seme Secondary School	25.5	3.8	24.0	3.4
Louwra Primary School	26.3	3.1	24.8	2.9
Perdekop Agricultural School	25.4	3.2	23.8	2.9
Vukuzenzele Combined School	25.7	3.2	24.0	2.9
Gunwana Primary School	25.5	3.0	24.0	2.8
Amajuba Memorial Hospital	22.8	2.9	21.3	2.6
Volksrust High School	22.6	2.8	21.1	2.6
Volksrust Municipal Clinic	22.2	2.8	20.8	2.6
C V O Skool Amajuba	22.2	2.8	20.8	2.6
Qhubulwazi Combined School	22.8	2.8	21.2	2.6
Volksrust Primary School	23.1	2.9	21.5	2.7
New Ermelo	25.7	3.7	24.1	3.4
Ermelo Christian School	25.9	3.8	24.4	3.4
SAVF Home For Aged	25.3	3.7	23.8	3.4
Ermelo Hospital	25.3	3.7	23.8	3.3
Mediclinic Ermelo	25.8	3.7	24.2	3.4
Hoerskool Ermelo	25.4	3.7	23.8	3.3
Ermelo Indian Combined School	25.5	3.7	23.9	3.3
Lungelo Combined School (Outside Town)	25.0	3.6	23.3	3.3
New Ermelo Primary School	25.7	3.7	24.2	3.4
Kwashashe (Outside Town)	25.4	3.7	23.9	3.4
Hts Ligbron	25.6	3.7	24.0	3.4
Laerskool Ermelo	25.2	3.7	23.7	3.4
JJ Vd Merwe Pre-Primary School	25.7	3.7	24.1	3.4
Lindile Secondary School	25.3	3.7	23.8	3.3
Emthonjeni Clinic	25.1	3.7	23.6	3.3
Reggie Masuku Secondary School	25.1	3.7	23.6	3.3
Cebisa Secondary School	25.1	3.7	23.5	3.3
Camden	26.1	3.8	24.5	3.4
Camden Combined School	27.4	3.8	25.2	3.4
Camden School	26.3	3.8	24.7	3.4
Umzimvelo Secondary School (Rural Area)	25.5	3.8	24.0	3.4
Bhekimfundo Primary School (Rural Area)	26.6	3.8	25.0	3.4
Eshwileni Primary School (Rural Area)	25.7	3.7	24.1	3.3
Davel Combined School	26.4	3.6	24.7	3.3
Morgenzon Landbou Akademie	25.4	3.7	23.7	3.2
Nqobangolwazi Secondary School	25.4	3.6	23.6	3.2
Siqondekhaya Pre Primary School	25.6	3.6	23.8	3.2
Sizakhele Primary School	25.5	3.6	23.7	3.2

Scenario A (2025)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Phezukwentaba Primary School (South of Morgenzon)	24.9	3.7	23.3	3.2
Kwaggalaagte Primary School (North of Morgenzon)	27.0	3.5	25.1	3.2
Sizakhele Clinic/Hospital	25.5	3.6	23.7	3.2
Grootvlei	23.8	2.2	22.5	2.0
Olive Grove Country Lodge	23.8	2.2	22.3	2.0
Grootvlei Town (South of Power Station)	22.8	2.2	21.5	2.0
Laerskool Grootvlei	23.0	2.2	21.7	2.0
Tokoloho Primary School	22.5	2.2	21.3	2.0
Tshepeha Combined School	22.8	2.2	21.5	2.0
Warembo Lodge	22.1	2.3	20.8	2.1
Balfour	23.1	2.3	21.8	2.2
Siyathemba	23.4	2.4	22.0	2.2
Bonukukhanya Primary (Siyathemba)	23.5	2.4	22.1	2.2
Qalabocha Primary School (Siyathemba)	23.3	2.4	21.9	2.2
Vusumuzi Primary School	23.5	2.4	22.1	2.2
Gekombineerde Skool Balfour	23.4	2.3	22.1	2.1
Im Manchu Secondary School	23.2	2.3	21.9	2.1
Isifisosethu Secondary School (Siyathemba)	23.6	2.4	22.2	2.2
Setsheng Secondary School (Siyathemba)	23.4	2.4	21.9	2.2
Dr Nieuwoudt And Dr Kok	23.5	2.3	22.2	2.1
Balfour Clinic	23.1	2.3	21.9	2.1
Siyathemba Clinic	23.1	2.3	21.8	2.2
Mondoro Lodge	22.6	2.2	21.2	2.1
Wegelegen Manor	23.3	2.4	21.8	2.2
The Stone Cellar	22.5	2.1	21.1	2.0
Greylingstad	24.5	2.6	23.0	2.4
Nthorwane	25.0	2.6	23.5	2.4
Laerskool Greylingstad	24.7	2.6	23.2	2.4
Nthoroane Secondary School	25.0	2.6	23.5	2.4
Badgarleur Bush Lodge	23.2	2.4	21.8	2.2
Matla Village	30.7	3.1	27.4	2.8
Sifundise Primary School	30.7	3.1	27.5	2.8
Matla Coal Health Centre	31.3	3.1	27.9	2.8
Gweda Primary School	33.5	3.6	30.4	3.1
Zithobe Primary School	30.3	2.9	27.4	2.6
Kwanala Primary School	34.3	3.6	29.4	3.1
Reedstream Park	32.4	3.3	28.5	2.9
Rietspruit Clinic	32.7	3.3	29.2	2.9
Lehlaka Combined School	32.5	3.3	29.0	2.9
Mbali Coal/Blesboklaagte Housing	29.4	3.0	27.2	2.7
Kinross	32.6	3.2	29.6	2.9
Kinross Settlement	31.4	3.0	28.7	2.7
Kinross Municipal Clinic	32.2	3.1	29.3	2.8
Kriel	30.4	3.8	27.4	3.2
Eagles Nest Guest House	30.3	3.8	27.5	3.2
Merlin Park Primary School	30.5	3.7	27.4	3.1
Kriel Medical Centre	30.3	3.7	27.3	3.1
Laerskool Krielpark	30.6	3.7	27.4	3.1
Laerskool Onverwacht	30.6	3.7	27.5	3.1

Scenario A (2025)	PM10 Total		PM2.5 Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	40	20
Silwer Fleur Aftree Oord (Old Age Home)	30.6	3.7	27.4	3.1
Thubelihle	30.2	3.5	27.0	3.1
Sibongamandla Secondary School	30.4	3.5	27.3	3.0
Ga-Nala Clinic	31.0	3.6	27.8	3.1
Impilo Primary School	28.7	3.3	26.2	2.9
Bonginhlanhla Primary School	30.1	3.5	27.2	3.0
Sibongamandla Secondary School	30.4	3.5	27.3	3.0
Leandra	27.8	2.7	25.6	2.5
Eendracht	27.8	2.7	25.7	2.5
Sidingulwazi Primary School	27.9	2.7	25.8	2.5
Ss Mshayisa Primary School	28.3	2.8	26.2	2.5
Chief Ampie Mayisa Secondary School	28.0	2.7	25.9	2.5
Lebogang Clinic	27.9	2.7	25.8	2.5
Kleuterskool Haas Das	27.3	3.0	25.4	2.7
Standerton Primary School	27.4	3.0	25.4	2.7
Laerskool Jeugkrag	27.6	3.0	25.6	2.7
Laerskool Standerton	27.3	3.0	25.4	2.7
Laerskool Kalie De Haas	27.5	3.0	25.5	2.7
Hoerskool Standerton	27.4	3.0	25.4	2.7
Standerton Provincial Government Hospital	27.4	3.0	25.5	2.7
Mar-Peh Medicare Private Hospital	27.3	3.0	25.4	2.7
Standerton Retirement Home	27.3	3.0	25.4	2.7
Standerton Ouetehuis/Old Age Home	27.3	3.0	25.4	2.7
Holmdene Secondary School	28.5	2.9	26.7	2.7
Cathuza Primary School (SE of Town)	27.9	3.2	25.8	2.9
Sizanani Pre Primary School	27.4	3.0	25.6	2.7
Hlobisa Primary School	27.1	2.9	25.3	2.7
Shukuma Primary School	27.1	2.9	25.3	2.7
Retsebile Primary School	27.4	3.0	25.4	2.7
Thuto-Thebe Secondary School	27.5	3.0	25.6	2.7
Jandrell Secondary School	27.3	3.0	25.4	2.7
Thobelani Secondary School	27.3	3.0	25.4	2.7
Standerton Tb Hospital	27.3	3.0	25.5	2.7
Thuthukani Pre Primary School	29.3	3.1	26.1	2.8
Ulwazi Primary School	29.2	3.1	26.1	2.8
Zikhetheleni Secondary School	29.2	3.1	26.1	2.8
Joubertsvlei Primary School (North of Tutuka)	27.4	3.2	25.6	2.9
Amalumgelo Primary School (NE of Tutuka)	28.0	3.6	25.2	3.2
Grootdraaidam Primary School	27.3	3.1	25.2	2.8
Laerskool Secunda	30.4	3.1	28.4	2.8
Laerskool Kruinpark	29.9	3.2	27.9	2.9
Laerskool Oranjegloed Primary	30.0	3.1	27.9	2.8
Curro Castle Combined School	30.1	3.1	28.1	2.8
Hoërskool Oosterland	30.0	3.2	27.9	2.9
Mediclinic Secunda (Hospital)	31.0	3.1	28.8	2.8
Mediclinic Highveld (Hospital_Trichardt, Secunda)	29.5	3.2	27.3	2.9
Daviescourt/Davieshof Old Age Home	30.1	3.1	28.0	2.9
Highveld Park High School	29.9	3.2	27.8	2.9
Hoerskool Secunda	30.1	3.1	28.2	2.8

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Basizeni Special School	30.6	3.0	28.3	2.8
Maphala-Gulube Primary School	29.7	3.0	27.6	2.8
Shapeve Primary School	30.9	3.0	28.5	2.8
Thomas Nhlabathi Secondary School	29.9	3.0	27.7	2.7
Embalenhle Hospital / Clinic	29.9	3.0	27.7	2.7
Vukuzithathe Primary School	29.8	3.0	27.7	2.7
K I Twala Secondary	29.8	3.0	27.6	2.7
Allan Makunga Primary School	30.5	3.0	28.2	2.8
Evander Hospital Arv Clinic	32.0	3.1	29.4	2.8
Laerskool Hoeveld	32.2	3.1	29.6	2.8
Hoerskool Evander	32.4	3.1	29.7	2.8
Bernice Samuel Hospital	22.8	2.1	21.1	2.0
Hoerskool Delmas	22.8	2.1	21.2	1.9
Laerskool Delmas	22.9	2.1	21.2	2.0
Kangela Primary School (North of Delpark)	22.7	2.1	21.1	2.0
Savf Ons Eie Ouetehuis / Old Age Home	22.8	2.1	21.2	2.0
Laerskool Eloff	22.5	2.1	20.8	1.9
Rietkol Primary School	22.6	2.1	20.9	1.9
Bazani Primary School	23.0	2.1	21.4	1.9
Phaphamani Secondary School	22.9	2.1	21.3	1.9
Vezimfundo Primary School	23.0	2.1	21.3	1.9
Arbor Primary School	26.4	2.3	24.7	2.1
Ogies Combined School	27.8	2.7	26.1	2.4
Ogies Tb Clinic	27.5	2.7	25.8	2.4
Ogies Police Station	27.5	2.7	25.8	2.4
Hlangu Phala Primary School	27.4	2.5	25.6	2.3
Sukumani Primary School	27.5	2.5	25.8	2.3
Thuthukani Primary School	27.7	2.5	26.0	2.3
Mehlwana Secondary School	27.1	2.5	25.4	2.2
Makause Combined School	27.5	2.5	25.8	2.3
Sibongindawo Primary School	25.4	2.4	23.6	2.2
Laerskool Balmoral	24.9	2.1	23.3	1.9
Clewer Primary School	27.5	2.4	25.6	2.2
Witbank High School	28.3	2.5	26.3	2.3
Eden Park Retirement Village	27.6	2.5	25.6	2.3
Savf House Immergroen Old Age Home	28.2	2.5	26.3	2.2
Mthimkulu Housing for the Aged	27.3	2.4	25.4	2.2
Emalahleni Private Hospital	28.2	2.4	26.3	2.2
Life Cosmos Hospital	28.2	2.5	26.2	2.3
Duvha Primary School	27.4	2.5	25.4	2.3
Laerskool Taalfees	28.3	2.5	26.3	2.3
Witbank Provincial Hospital	28.2	2.5	26.3	2.3
Nancy Shiba Primary School (Vosman)	26.8	2.3	25.0	2.1
Wh De Klerk Skool	28.0	2.4	26.0	2.2
Laerskool Panorama	27.9	2.4	26.0	2.2
Laerskool Duvhapark	27.2	2.6	25.1	2.4
Laerskool Klipfontein	27.6	2.5	25.5	2.3
Cambridge Academy	27.8	2.5	25.7	2.3
Besilindile Primary School	26.3	2.2	24.5	2.0

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	40	20
Reynopark High School	27.5	2.6	25.5	2.3
Bakenveld Golf Estate	27.1	2.6	25.0	2.3
Allendale Secondary School	27.9	2.8	25.7	2.5
Khayalethu Primary School	27.2	2.4	25.3	2.2
Illanga Secondary School	28.5	2.7	26.1	2.5
Joy Creche (Duvha)	28.7	2.7	26.3	2.5
Linderus Old Age Home	26.6	2.4	24.7	2.2
Vergeet My Nie Old Age Home	26.7	2.4	24.7	2.2
Middleburg Frail Care Unit and Home For Elderly	26.2	2.3	24.3	2.1
Life Midmed Hospital	26.5	2.4	24.6	2.2
Middelburg Hospital	26.7	2.4	24.7	2.2
Makhathini Primary School	26.7	2.3	24.8	2.2
Laerskool Dennesig	26.2	2.3	24.4	2.1
Hoerskool Kanonkop	26.0	2.3	24.2	2.1
Laerskool Kanonkop	26.1	2.3	24.3	2.2
Steelcrest High School	26.3	2.4	24.4	2.2
Middelburg Primary	26.7	2.4	24.7	2.2
Middleburg Ext 6 Clinic	27.4	2.4	25.3	2.2
Sofunda Secondary School	27.3	2.3	25.3	2.2
Mhluzi Primary School	26.9	2.3	25.1	2.2
Highlands Primary School	26.9	2.4	24.9	2.2
Blinkpan Primary School	26.5	3.1	24.8	2.8
Laerskool Koornfontein	26.9	3.1	24.9	2.8
Blinkpan	26.5	3.1	24.8	2.8
Laerskool Kragveld	26.3	3.0	24.6	2.7
Pullens Hope	26.5	3.0	24.8	2.7
Arnot Colliery Primary School	25.7	2.8	23.9	2.6
Laerskool Rietkuil	26.3	2.9	24.5	2.6
Beestepan Agricultural School	25.4	2.6	23.8	2.4
Gekombineerde Skool Hendrina	25.6	3.2	23.9	2.9
Hendrina Primary School	25.5	3.2	23.9	2.9
Kwazamokuhle Secondary School	25.6	3.2	24.0	2.9
Ubuhle Bolwai Secondary School	23.5	3.5	22.2	3.2
Lothair Primary School	23.5	3.5	22.2	3.2
Warburton Combined School	25.6	3.4	24.3	3.1
Warburton Town	25.4	3.4	24.1	3.1
Kwachibikhulu Clinic	25.4	3.5	24.0	3.2
Kwachibikhulu Primary School	25.1	3.5	23.7	3.2
Carolina Hospital	24.7	3.2	23.2	2.9
Zinikeleni Secondary School (Silobela)	25.0	3.2	23.5	3.0
Volkskool Carolina	24.6	3.2	23.0	2.9
Sobuza Primary School	24.7	3.2	23.2	3.0
Ons Eie Ouetehuis (Old Age Home)	24.6	3.2	23.0	2.9
Laerskool Breyten	24.3	3.5	22.9	3.2
Siyazi Primary School (Kwazanele)	24.2	3.5	22.7	3.2
Masizakhe Secondary School (Kwazanele)	24.2	3.5	22.7	3.2
Belfast Rusoord (Old Age Home)	22.2	2.3	20.8	2.2
Belfast Hospital	22.2	2.4	20.9	2.2
Platorand School	22.5	2.4	21.1	2.2

Scenario A (2025)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Belfast Primary School (Siyathuthuka)	22.1	2.3	20.8	2.1
Siyathuthuka Clinic	22.1	2.3	20.8	2.1
Life Bethal Hospital	26.9	3.6	24.8	3.2
Hoerskool Hoogenhout	26.7	3.6	24.6	3.2
Jim Van Tonderskool	27.3	3.6	25.1	3.2
Bethal Independent Primary School	27.2	3.6	25.0	3.2
Laerskool Marietjie Van Niekerk	26.8	3.6	24.7	3.2
Laerskool Hm Swart	26.9	3.6	24.8	3.2
Sakhisizwe Primary School (Emzinoni)	28.3	3.5	26.1	3.2
Alpheus D Nkosi Secondary School (Emzinoni)	27.6	3.6	25.5	3.2
Silwerjare Old Age Home	26.9	3.6	24.8	3.2
Residentia Palm Oord	27.0	3.6	24.8	3.2
Bronkhorspruit Hospital	21.1	1.7	19.7	1.6
Cultura High School	22.0	1.7	20.5	1.6
Bronkhorspruit Primary School	21.1	1.7	19.7	1.6
Bronkhorspruit Dam	21.8	1.8	20.3	1.7
Hoerskool Erasmus	21.5	1.7	20.1	1.6
Althea Independent School	21.4	1.7	20.1	1.6
Kgoro Primary School (Zithobeni)	20.8	1.7	19.5	1.5
Zithobeni Secondary School (Zithobeni)	20.4	1.7	19.0	1.5
Vaal Power AH	20.8	1.7	19.5	1.6
Sasolburg Provincial Hospital	21.9	1.6	20.3	1.5
Moredou Old Age Home	21.9	1.6	20.3	1.4
Ons Gryse Jeug Old Age Home	21.9	1.6	20.3	1.5
Noord Primere Skool	21.9	1.6	20.3	1.5
Sasolburg High School	21.8	1.6	20.3	1.4
Sakhubusa Secondary School	19.7	1.6	18.2	1.5
Bekezela Primary School	20.5	1.6	19.1	1.5
Isaac Mhlambi Primary	19.6	1.6	18.1	1.5
Refenkgotso Primary School	22.4	1.9	21.0	1.7
Deneysville Primary School	22.2	1.9	20.8	1.7
Netcare Vaalpark Hospital	22.9	1.6	21.3	1.5
Vaalpark Articon Secondary School	23.0	1.6	21.3	1.5
Mediclinic Emfuleni	20.8	1.5	19.5	1.4
Jeugland Old Age Home	21.1	1.5	19.7	1.4
Herfsoord Huis Old Age Home	20.9	1.5	19.5	1.4
Huis Prinscilla	21.1	1.5	19.8	1.4
Laerskool Emfulenipark	21.5	1.6	19.9	1.5
Nw University_Vaal Campus	20.7	1.6	19.2	1.5
Emfuleni Primary School	21.2	1.5	19.9	1.4
Mediclinic Vereeniging	21.2	1.6	19.8	1.5
Kopanong Provincial Hospital (Duncanville)	21.4	1.6	20.1	1.5
Avondrus Eventide Old Age Home	21.5	1.6	20.1	1.5
Riviera On Vaal Resort	20.9	1.6	19.5	1.5
Sedibeng Tvet College	20.7	1.6	19.3	1.5
General Smuts High School	21.3	1.6	19.8	1.5
Eureuka School & Selbourne Primary	21.4	1.6	19.9	1.5
Midvaal Private Hospital (Three Rivers)	21.0	1.7	19.5	1.5
Three Rivers Retirement Village	21.1	1.7	19.6	1.5

Scenario A (2025)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	40	20
Drie Riviere Aftreeoord Old Age Home	21.1	1.7	19.7	1.5
Riverside High School	20.7	1.7	19.3	1.6
Risiville Primary School	21.1	1.7	19.6	1.5
Sebokeng Hospital	22.5	1.5	21.0	1.4
Clinix-Naledzi Private Hospital	22.4	1.5	20.9	1.4
Mohloli Secondary School	21.4	1.6	19.9	1.5
Tshirela Primary School (Boipatong)	21.3	1.5	19.9	1.4
Tsoaranang Primary School (Thepiso)	21.5	1.6	20.1	1.4
Thepiso Primary School	21.6	1.6	20.1	1.4
Emmanuel Primary School	21.4	1.6	20.0	1.5
Rust Ter Vaal Combined School	21.1	1.6	19.7	1.5
Roshnee Primary School	21.3	1.6	19.8	1.5
Roshnee High School	21.2	1.6	19.7	1.5
Hoerskool Dr Malan	21.5	1.7	20.1	1.5
Laerskool Voorwaarts	21.2	1.7	19.8	1.6
Meyerton Secondary School	21.4	1.7	20.0	1.5
Ratasetjhaba Primary School	21.6	1.6	20.2	1.5
Meyerton Primary School	21.7	1.7	20.3	1.5
Oprah Leadership Academy	21.4	1.7	20.0	1.6
Henley River Retirement Village	21.2	1.7	19.9	1.6
Henley High & Preparatory School	21.2	1.7	19.8	1.6
Randvaal Clinic	21.2	1.7	19.8	1.5
Laerskool Japie Greyling	21.1	1.7	19.7	1.6
Thomas Nhlapo Primary	21.1	1.7	19.7	1.6
Randvaal Old Age Home	21.3	1.7	19.9	1.5
Laerskool Ag Visser	22.1	2.0	20.7	1.8
Lethaba Siyangobe	22.1	2.0	20.7	1.9
Shalimar Ridge Primary School	22.5	2.0	21.0	1.8
Jw Luckoff High School	22.2	2.0	20.8	1.9
Heidelberg Hospital	22.5	2.0	21.1	1.8
Thulatsatsi Operation (Rensburg)	22.2	2.0	20.8	1.8
Silwer Akker Tehuis	22.5	2.0	21.0	1.8
Riversands Retirement Village	22.5	2.0	21.0	1.8
Qhaqholla Primary School	21.4	2.0	20.0	1.8
Ratanda Primary School	21.5	2.0	20.1	1.8
Boneha Primary School	21.4	2.0	20.0	1.8
Sithokomele Primary School	21.3	2.0	20.0	1.8
Ratanda Bertha Gxowa Primary School	22.0	2.0	20.6	1.9
Khanya Lesedi Secondary School	21.4	2.0	20.0	1.8
Ratanda Secondary School	21.4	2.0	20.0	1.8
New Ratanda Secondary School	21.9	2.0	20.5	1.8
Kgoro Ya Thuto Secondary School	21.9	2.0	20.5	1.8
Ekurhuleni School for the Deaf	20.4	1.7	19.2	1.6
Pholosong Hospital	21.4	2.0	19.9	1.8
Tsakane Home For Aged	21.4	2.0	20.0	1.8
Mmuso Primary School	21.8	2.0	20.3	1.9
Michael Zulu Primary School	21.3	2.0	19.9	1.8
Nkabinde Primary School (Thembilisha)	21.1	2.0	19.7	1.8
Nigel Clinic	21.8	2.1	20.3	1.9

Scenario A (2025)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Tehuis Vir Bejaardes	21.8	2.1	20.3	1.9
Hoerskool John Vorster	22.0	2.1	20.4	1.9
Laerskool Hannes Visagie	21.7	2.1	20.2	2.0
Nigel Secondary School	21.8	2.2	20.2	2.0
Laerskool Dunnottar	21.7	2.0	20.2	1.9
Springs Retirement Village	20.6	1.9	19.2	1.8
Life Springs Parkland Hospital	20.8	1.9	19.3	1.8
Netcare N17 Hospital (Springs)	20.8	1.9	19.4	1.8
Springs Boys High School	20.9	2.0	19.5	1.8
Laerskool Selectionpark	21.0	2.0	19.5	1.8
Kwasa College Pre&Primary School	21.1	2.0	19.7	1.9
Edelweis Medical Centre	21.0	2.0	19.6	1.8
Laerskool Christiaan Beyers	20.8	2.0	19.3	1.8
Hoerskool Hugenote	21.0	1.9	19.6	1.8
Brakpan Primary School	21.3	1.9	19.9	1.7
Parkrand Primary School	20.9	1.8	19.5	1.6
Thabo Memorial Hospital	20.3	1.7	19.0	1.6
Sunward Park Hospital	20.8	1.8	19.5	1.6
Alberton High School	20.4	1.6	19.1	1.5
Netcare Clinton Hospital	20.4	1.6	19.1	1.5
Alberton Tuiste Vir Bejaardes	20.4	1.6	19.1	1.5
Bertha Gxowa Hospital	20.6	1.7	19.2	1.5
Linmed Hospital	20.7	1.8	19.2	1.6
Hoerskool Brandwag (Airfield)	20.7	1.8	19.3	1.6
Thepiso Noto Intermediate School	21.7	1.9	20.1	1.7
Laerskool Bredell	20.7	1.7	19.4	1.6
Sibonelo Primary School (Daveyton)	21.0	1.8	19.5	1.7
Petit High School (Kempton Park Nu)	21.0	1.8	19.6	1.6
Arwyp Medical Centre	21.0	1.6	19.6	1.5
Hoerskool Birchleigh	20.2	1.6	18.9	1.5
Curro Serengeti Acadamy	20.7	1.6	19.5	1.5
South Rand Hospital	20.7	1.6	19.4	1.5
Chris Hani Baragwanath Hospital	19.8	1.5	18.6	1.3
Thulani Primary School	18.2	1.3	17.0	1.2
University of Witwatersrand	20.2	1.6	18.7	1.5
Milpark Hospital	19.7	1.5	18.3	1.4
Charlotte Maxixe Academic Hospital	20.0	1.6	18.6	1.5
Thembisa West Secondary School (Thembisa)	19.7	1.5	18.4	1.4
Lenmed Zamokuhle Private Hospital (Thembisa)	19.9	1.5	18.7	1.4
Ikusasa Comprehensive School	20.4	1.5	19.2	1.4
Gem Village Old Age Home	20.0	1.4	18.7	1.3
Rustoord Old Age Home	18.7	1.3	17.6	1.2
Cornwell Hill College (Irene)	19.8	1.4	18.6	1.3
Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	19.2	1.5	18.0	1.4
Valtaki AH (Rayton)	19.7	1.5	18.5	1.4
Laerskool Rayton (Rayton)	19.1	1.4	18.0	1.3
Tierkop AH	21.3	1.6	20.0	1.5
Redford House The Hills Private School (Mooikloof Glen)	20.3	1.5	19.0	1.4
Rietvlei View Country Estate	20.8	1.5	19.5	1.4

Scenario A (2025)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**40**	**20**
Hazeldean Curro School (Tyger Valley)	18.9	1.4	17.8	1.3
Tyger Valley College	19.0	1.4	17.9	1.3
Pretoria East Hospital (Moreletapark)	19.5	1.4	18.4	1.3
Groenkloof Old Age Home	18.4	1.3	17.3	1.2
Steve Biko Academic Hospital	17.9	1.2	16.9	1.1
Willow Ridge High School (Wilgers)	19.1	1.3	18.0	1.2
Hoerskool Waterkloof	19.8	1.4	18.6	1.3
Hoerskool Garsfontein	19.3	1.4	18.2	1.3
Afrikaanse Hoer Seunskool	18.4	1.3	17.3	1.2
Huis Silversig SAVF Old Age Home (Silverton)	19.0	1.3	17.9	1.2
Laersekool Meyerspark (Meyerspark)	19.1	1.3	18.0	1.2
Curro Academy Mamelodi	18.3	1.3	17.3	1.2
Impendulo Primary School	18.6	1.3	17.5	1.2
Nellmapius Ext 6 Primary School	18.6	1.3	17.4	1.2
Mamelodi Home For Aged	18.5	1.3	17.4	1.2

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario B (2031), together with the limit value of the NAAQS

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Elsie Ballot Memorial Hospital	13.7	1.8	13.3	1.7
Laerskool Amersfoort	13.8	1.8	13.4	1.7
Embuzane Primary School	15.4	1.9	14.8	1.8
Sangqotho Primary School	12.8	1.7	12.4	1.7
Amersfoort Combined School	13.2	1.8	12.9	1.7
Injubuko Primary School	12.6	1.8	12.2	1.7
Daggakraal Primary School	13.1	1.9	12.7	1.8
Sizenzele Primary School	13.0	1.9	12.5	1.8
Seme Secondary School	13.2	1.9	12.8	1.8
Louwra Primary School	12.9	1.6	12.5	1.5
Perdekop Agricultural School	13.7	1.6	13.4	1.5
Vukuzenzele Combined School	13.7	1.6	13.3	1.5
Gunwana Primary School	13.2	1.6	12.9	1.5
Amajuba Memorial Hospital	11.8	1.5	11.4	1.4
Volksrust High School	11.7	1.4	11.4	1.4
Volksrust Municipal Clinic	11.8	1.4	11.4	1.4
C V O Skool Amajuba	11.7	1.4	11.4	1.4
Qhubulwazi Combined School	11.9	1.4	11.5	1.4
Volksrust Primary School	12.0	1.5	11.6	1.4
New Ermelo	12.8	1.8	12.4	1.7
Ermelo Christian School	12.8	1.8	12.4	1.7
SAVF Home For Aged	12.7	1.8	12.3	1.7
Ermelo Hospital	12.6	1.8	12.2	1.7
Mediclinic Ermelo	12.7	1.8	12.4	1.7
Hoerskool Ermelo	12.6	1.8	12.2	1.7
Ermelo Indian Combined School	12.5	1.8	12.1	1.7
Lungelo Combined School (Outside Town)	12.2	1.7	11.8	1.6
New Ermelo Primary School	12.8	1.8	12.4	1.7
Kwashashe (Outside Town)	12.5	1.8	12.2	1.7
Hts Ligbron	12.7	1.8	12.3	1.7
Laerskool Ermelo	12.7	1.8	12.3	1.7
JJ Vd Merwe Pre-Primary School	12.6	1.8	12.2	1.7
Lindile Secondary School	12.5	1.8	12.1	1.7
Emthonjeni Clinic	12.5	1.8	12.2	1.7
Reggie Masuku Secondary School	12.5	1.8	12.1	1.7
Cebisa Secondary School	12.5	1.8	12.2	1.7
Camden	13.1	1.8	12.8	1.7
Camden Combined School	13.2	1.8	12.9	1.7
Camden School	13.0	1.8	12.6	1.7
Umzimvelo Secondary School (Rural Area)	12.5	1.8	12.2	1.7
Bhekimfundo Primary School (Rural Area)	12.5	1.8	12.2	1.7
Eshwileni Primary School (Rural Area)	12.5	1.7	12.2	1.7
Davel Combined School	13.6	1.8	13.1	1.7
Morgenzon Landbou Akademie	12.4	1.7	12.0	1.6
Nqobangolwazi Secondary School	12.3	1.7	12.0	1.6
Siqondekhaya Pre Primary School	12.3	1.7	11.9	1.6
Sizakhele Primary School	12.3	1.7	11.9	1.6

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Phezukwentaba Primary School (South of Morgenzon)	12.4	1.7	12.0	1.6
Kwaggalaagte Primary School (North of Morgenzon)	13.2	1.7	12.7	1.6
Sizakhele Clinic/Hospital	12.3	1.7	11.9	1.6
Grootvlei	11.1	1.1	10.8	1.1
Olive Grove Country Lodge	11.2	1.1	10.9	1.0
Grootvlei Town (South of Power Station)	10.7	1.1	10.3	1.1
Laerskool Grootvlei	10.6	1.1	10.3	1.1
Tokoloho Primary School	10.7	1.1	10.4	1.1
Tshepeha Combined School	10.7	1.1	10.4	1.1
Warembo Lodge	11.1	1.1	10.7	1.1
Balfour	12.3	1.2	11.9	1.1
Siyathemba	12.4	1.2	12.1	1.2
Bonukukhanya Primary (Siyathemba)	12.4	1.2	12.1	1.1
Qalabocha Primary School (Siyathemba)	12.4	1.2	12.1	1.2
Vusumuzi Primary School	12.5	1.2	12.1	1.2
Gekombineerde Skool Balfour	12.3	1.2	11.9	1.1
Im Manchu Secondary School	12.3	1.2	11.9	1.1
Isifisosethu Secondary School (Siyathemba)	12.5	1.2	12.2	1.2
Setsheng Secondary School (Siyathemba)	12.4	1.2	12.1	1.2
Dr Nieuwoudt And Dr Kok	12.2	1.2	11.9	1.1
Balfour Clinic	12.3	1.2	12.0	1.1
Siyathemba Clinic	12.3	1.2	12.0	1.1
Mondoro Lodge	11.2	1.1	10.8	1.1
Wegelegen Manor	12.0	1.2	11.7	1.1
The Stone Cellar	10.6	1.1	10.3	1.0
Greylingstad	12.0	1.3	11.6	1.2
Nthorwane	12.2	1.3	11.8	1.2
Laerskool Greylingstad	12.1	1.3	11.8	1.3
Nthoroane Secondary School	12.2	1.3	11.8	1.2
Badgarleur Bush Lodge	11.9	1.2	11.5	1.2
Matla Village	15.2	1.6	14.2	1.5
Sifundise Primary School	15.7	1.6	14.7	1.5
Matla Coal Health Centre	15.9	1.6	15.1	1.5
Gweda Primary School	16.3	1.8	15.3	1.7
Zithobe Primary School	14.9	1.5	14.2	1.4
Kwanala Primary School	15.0	1.8	14.1	1.6
Reedstream Park	15.9	1.7	15.1	1.6
Rietspruit Clinic	15.8	1.7	15.1	1.5
Lehlaka Combined School	15.9	1.7	15.1	1.5
Mbali Coal/Blesboklaagte Housing	15.9	1.6	15.3	1.4
Kinross	15.6	1.6	14.9	1.5
Kinross Settlement	15.6	1.5	14.8	1.5
Kinross Municipal Clinic	15.6	1.6	14.9	1.5
Kriel	14.6	1.8	13.9	1.6
Eagles Nest Guest House	14.6	1.8	13.9	1.6
Merlin Park Primary School	14.7	1.7	14.1	1.6
Kriel Medical Centre	14.9	1.7	14.3	1.6
Laerskool Krielpark	14.9	1.7	14.3	1.6
Laerskool Onverwacht	14.9	1.7	14.2	1.6

Scenario B (2031)	PM10 Total		PM2.5 Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Silwer Fleur Aftree Oord (Old Age Home)	15.2	1.7	14.5	1.6
Thubelihle	14.5	1.7	13.8	1.6
Sibongamandla Secondary School	14.5	1.7	13.8	1.6
Ga-Nala Clinic	14.7	1.7	14.0	1.6
Impilo Primary School	13.6	1.6	13.1	1.5
Bonginhlanhla Primary School	14.5	1.7	13.9	1.6
Sibongamandla Secondary School	14.5	1.7	13.8	1.6
Leandra	13.5	1.4	13.0	1.3
Eendracht	13.7	1.4	13.2	1.3
Sidingulwazi Primary School	13.7	1.4	13.2	1.3
Ss Mshayisa Primary School	13.6	1.4	13.1	1.3
Chief Ampie Mayisa Secondary School	13.7	1.4	13.2	1.3
Lebogang Clinic	13.5	1.4	13.0	1.3
Kleuterskool Haas Das	12.9	1.5	12.5	1.4
Standerton Primary School	12.8	1.5	12.4	1.4
Laerskool Jeugkrag	12.7	1.5	12.3	1.4
Laerskool Standerton	12.9	1.5	12.5	1.4
Laerskool Kalie De Haas	13.3	1.5	12.9	1.4
Hoerskool Standerton	12.8	1.5	12.4	1.4
Standerton Provincial Government Hospital	12.8	1.5	12.4	1.4
Mar-Peh Medicare Private Hospital	12.9	1.5	12.5	1.4
Standerton Retirement Home	12.9	1.5	12.5	1.4
Standerton Ouetehuis/Old Age Home	13.0	1.5	12.5	1.4
Holmdene Secondary School	13.6	1.4	13.2	1.4
Cathuza Primary School (SE of Town)	14.0	1.5	13.6	1.5
Sizanani Pre Primary School	13.1	1.5	12.7	1.4
Hlobisa Primary School	13.3	1.4	12.9	1.4
Shukuma Primary School	13.3	1.4	12.9	1.4
Retsebile Primary School	13.1	1.4	12.8	1.4
Thuto-Thebe Secondary School	13.0	1.5	12.6	1.4
Jandrell Secondary School	13.2	1.5	12.8	1.4
Thobelani Secondary School	13.2	1.5	12.8	1.4
Standerton Tb Hospital	13.2	1.5	12.8	1.4
Thuthukani Pre Primary School	12.6	1.5	12.0	1.5
Ulwazi Primary School	12.6	1.5	12.0	1.5
Zikhetheleni Secondary School	12.5	1.5	12.0	1.5
Joubertsvlei Primary School (North of Tutuka)	12.3	1.6	11.9	1.5
Amalumgelo Primary School (NE of Tutuka)	12.6	1.7	12.2	1.6
Grootdraaidam Primary School	12.6	1.5	12.1	1.4
Laerskool Secunda	15.6	1.6	15.1	1.5
Laerskool Kruinpark	14.3	1.6	13.8	1.5
Laerskool Oranjegloed Primary	15.0	1.6	14.5	1.5
Curro Castle Combined School	15.2	1.6	14.6	1.5
Hoërskool Oosterland	14.8	1.6	14.3	1.5
Mediclinic Secunda (Hospital)	15.9	1.6	15.4	1.5
Mediclinic Highveld (Hospital_Trichardt, Secunda)	14.7	1.6	14.1	1.5
Daviescourt/Davieshof Old Age Home	15.4	1.6	14.9	1.5
Highveld Park High School	15.1	1.6	14.6	1.5
Hoerskool Secunda	15.5	1.6	14.9	1.5

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Basizeni Special School	15.6	1.5	15.0	1.4
Maphala-Gulube Primary School	14.8	1.5	14.3	1.4
Shapeve Primary School	15.7	1.5	15.2	1.4
Thomas Nhlabathi Secondary School	15.1	1.5	14.5	1.4
Embalenhle Hospital / Clinic	14.9	1.5	14.4	1.4
Vukuzithathe Primary School	14.6	1.5	14.1	1.4
K I Twala Secondary	14.4	1.5	13.9	1.4
Allan Makunga Primary School	15.5	1.5	14.9	1.4
Evander Hospital Arv Clinic	15.9	1.6	15.3	1.5
Laerskool Hoeveld	15.8	1.6	15.2	1.5
Hoerskool Evander	15.8	1.6	15.1	1.5
Bernice Samuel Hospital	12.4	1.1	12.0	1.0
Hoerskool Delmas	12.5	1.1	12.0	1.0
Laerskool Delmas	12.6	1.1	12.1	1.0
Kangela Primary School (North of Delpark)	12.5	1.1	12.0	1.0
Savf Ons Eie Ouetehuis / Old Age Home	12.6	1.1	12.1	1.0
Laerskool Eloff	11.8	1.1	11.4	1.0
Rietkol Primary School	11.9	1.1	11.4	1.0
Bazani Primary School	12.2	1.1	11.7	1.0
Phaphamani Secondary School	12.0	1.1	11.6	1.0
Vezimfundo Primary School	11.8	1.1	11.4	1.0
Arbor Primary School	13.8	1.2	13.1	1.1
Ogies Combined School	16.0	1.4	15.2	1.3
Ogies Tb Clinic	15.7	1.4	15.0	1.3
Ogies Police Station	15.7	1.4	15.0	1.3
Hlangu Phala Primary School	15.5	1.3	14.7	1.2
Sukumani Primary School	15.6	1.3	14.9	1.2
Thuthukani Primary School	15.7	1.3	14.9	1.3
Mehlwana Secondary School	15.7	1.3	14.9	1.2
Makause Combined School	15.7	1.3	15.0	1.2
Sibongindawo Primary School	13.7	1.3	13.0	1.2
Laerskool Balmoral	14.2	1.1	13.7	1.1
Clewer Primary School	14.5	1.3	13.9	1.2
Witbank High School	16.2	1.3	15.6	1.2
Eden Park Retirement Village	14.5	1.3	14.0	1.2
Savf House Immergroen Old Age Home	16.1	1.3	15.5	1.2
Mthimkulu Housing for the Aged	15.3	1.3	14.8	1.2
Emalahleni Private Hospital	15.9	1.3	15.4	1.2
Life Cosmos Hospital	16.1	1.3	15.6	1.2
Duvha Primary School	14.9	1.3	14.3	1.2
Laerskool Taalfees	16.1	1.3	15.6	1.2
Witbank Provincial Hospital	16.0	1.3	15.5	1.2
Nancy Shiba Primary School (Vosman)	14.9	1.2	14.4	1.1
Wh De Klerk Skool	15.8	1.3	15.3	1.2
Laerskool Panorama	15.6	1.3	15.1	1.2
Laerskool Duvhapark	14.7	1.3	14.2	1.3
Laerskool Klipfontein	14.3	1.3	13.7	1.2
Cambridge Academy	15.9	1.3	15.3	1.2
Besilindile Primary School	14.7	1.2	14.1	1.1

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Reynopark High School	14.2	1.3	13.7	1.3
Bakenveld Golf Estate	14.0	1.3	13.4	1.3
Allendale Secondary School	14.1	1.4	13.5	1.3
Khayalethu Primary School	15.3	1.3	14.7	1.2
Illanga Secondary School	14.2	1.4	13.3	1.3
Joy Creche (Duvha)	14.0	1.4	13.5	1.3
Linderus Old Age Home	13.4	1.3	12.8	1.2
Vergeet My Nie Old Age Home	13.6	1.3	13.0	1.2
Middleburg Frail Care Unit and Home For Elderly	13.8	1.2	13.2	1.2
Life Midmed Hospital	13.6	1.2	13.0	1.2
Middelburg Hospital	13.5	1.2	12.9	1.2
Makhathini Primary School	13.8	1.2	13.2	1.2
Laerskool Dennesig	13.8	1.2	13.2	1.2
Hoerskool Kanonkop	13.7	1.2	13.2	1.2
Laerskool Kanonkop	13.7	1.2	13.1	1.2
Steelcrest High School	13.6	1.2	13.0	1.2
Middelburg Primary	13.5	1.3	12.9	1.2
Middleburg Ext 6 Clinic	14.2	1.2	13.7	1.2
Sofunda Secondary School	14.0	1.2	13.4	1.2
Mhluzi Primary School	13.7	1.2	13.1	1.2
Highlands Primary School	13.1	1.3	12.6	1.2
Blinkpan Primary School	13.7	1.6	13.2	1.5
Laerskool Koornfontein	13.5	1.6	13.0	1.5
Blinkpan	13.6	1.6	13.1	1.5
Laerskool Kragveld	13.3	1.5	12.9	1.4
Pullens Hope	13.5	1.5	13.0	1.4
Arnot Colliery Primary School	13.0	1.4	12.5	1.3
Laerskool Rietkuil	13.1	1.4	12.6	1.3
Beestepan Agricultural School	12.9	1.3	12.5	1.2
Gekombineerde Skool Hendrina	12.7	1.6	12.3	1.5
Hendrina Primary School	12.6	1.6	12.2	1.5
Kwazamokuhle Secondary School	12.6	1.6	12.2	1.5
Ubuhle Bolwai Secondary School	12.2	1.6	11.8	1.6
Lothair Primary School	12.1	1.7	11.8	1.6
Warburton Combined School	12.1	1.6	11.8	1.5
Warburton Town	12.1	1.6	11.8	1.5
Kwachibikhulu Clinic	12.3	1.7	11.9	1.6
Kwachibikhulu Primary School	12.4	1.7	12.0	1.6
Carolina Hospital	12.9	1.5	12.5	1.5
Zinikeleni Secondary School (Silobela)	13.0	1.6	12.7	1.5
Volkskool Carolina	12.7	1.5	12.4	1.5
Sobuza Primary School	13.0	1.6	12.7	1.5
Ons Eie Ouetehuis (Old Age Home)	12.8	1.5	12.4	1.5
Laerskool Breyten	12.4	1.7	12.0	1.6
Siyazi Primary School (Kwazanele)	12.4	1.7	12.0	1.6
Masizakhe Secondary School (Kwazanele)	12.4	1.7	12.0	1.6
Belfast Rusoord (Old Age Home)	11.4	1.2	11.0	1.1
Belfast Hospital	11.5	1.2	11.1	1.1
Platorand School	11.4	1.2	11.0	1.1

Scenario B (2031)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Belfast Primary School (Siyathuthuka)	11.4	1.1	11.0	1.1
Siyathuthuka Clinic	11.4	1.1	11.0	1.1
Life Bethal Hospital	13.6	1.7	13.1	1.6
Hoerskool Hoogenhout	13.7	1.8	13.2	1.6
Jim Van Tonderskool	14.3	1.8	13.7	1.7
Bethal Independent Primary School	14.1	1.8	13.6	1.6
Laerskool Marietjie Van Niekerk	14.1	1.8	13.6	1.7
Laerskool Hm Swart	13.7	1.7	13.2	1.6
Sakhisizwe Primary School (Emzinoni)	14.3	1.7	13.8	1.6
Alpheus D Nkosi Secondary School (Emzinoni)	13.8	1.7	13.3	1.6
Silwerjare Old Age Home	13.6	1.7	13.1	1.6
Residentia Palm Oord	13.7	1.7	13.2	1.6
Bronkhorspruit Hospital	11.1	0.9	10.7	0.8
Cultura High School	12.1	0.9	11.7	0.9
Bronkhorspruit Primary School	11.2	0.9	10.8	0.8
Bronkhorspruit Dam	11.7	0.9	11.2	0.9
Hoerskool Erasmus	11.7	0.9	11.2	0.9
Althea Independent School	11.7	0.9	11.3	0.9
Kgoro Primary School (Zithobeni)	11.0	0.9	10.6	0.8
Zithobeni Secondary School (Zithobeni)	11.1	0.9	10.7	0.8
Vaal Power AH	10.8	0.9	10.3	0.9
Sasolburg Provincial Hospital	11.8	0.8	11.3	0.8
Moredou Old Age Home	11.5	0.8	11.0	0.8
Ons Gryse Jeug Old Age Home	11.7	0.8	11.2	0.8
Noord Primere Skool	11.8	0.8	11.3	0.8
Sasolburg High School	11.7	0.8	11.2	0.8
Sakhubusa Secondary School	11.6	0.8	11.1	0.8
Bekezela Primary School	11.1	0.8	10.6	0.8
Isaac Mhlambi Primary	11.4	0.8	10.9	0.8
Refenkgotso Primary School	10.5	1.0	10.1	0.9
Deneysville Primary School	10.5	1.0	10.2	0.9
Netcare Vaalpark Hospital	12.0	0.8	11.5	0.8
Vaalpark Articon Secondary School	11.9	0.8	11.4	0.8
Mediclinic Emfuleni	11.2	0.8	10.8	0.8
Jeugland Old Age Home	11.5	0.8	11.1	0.8
Herfsoord Huis Old Age Home	11.3	0.8	10.9	0.8
Huis Prinscilla	11.0	0.8	10.6	0.8
Laerskool Emfulenipark	11.6	0.8	11.1	0.8
Nw University_Vaal Campus	11.3	0.8	10.8	0.8
Emfuleni Primary School	11.0	0.8	10.6	0.7
Mediclinic Vereeniging	10.4	0.8	10.0	0.8
Kopanong Provincial Hospital (Duncanville)	10.5	0.8	10.1	0.8
Avondrus Eventide Old Age Home	10.4	0.8	10.1	0.8
Riviera On Vaal Resort	10.6	0.8	10.1	0.8
Sedibeng Tvet College	10.6	0.8	10.2	0.8
General Smuts High School	10.6	0.8	10.1	0.8
Eureuka School & Selbourne Primary	10.5	0.8	10.0	0.8
Midvaal Private Hospital (Three Rivers)	11.1	0.9	10.6	0.8
Three Rivers Retirement Village	11.1	0.9	10.6	0.8

Scenario B (2031)	PM10 Total		PM2.5 Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	25	15
Drie Riviere Aftreeoord Old Age Home	11.2	0.9	10.7	0.8
Riverside High School	11.2	0.9	10.7	0.8
Risiville Primary School	11.1	0.9	10.6	0.8
Sebokeng Hospital	11.2	0.8	10.8	0.7
Clinix-Naledzi Private Hospital	11.2	0.8	10.8	0.7
Mohloli Secondary School	11.0	0.8	10.5	0.8
Tshirela Primary School (Boipatong)	11.0	0.8	10.5	0.8
Tsoaranang Primary School (Thepiso)	10.7	0.8	10.2	0.8
Thepiso Primary School	10.6	0.8	10.2	0.8
Emmanuel Primary School	10.8	0.8	10.3	0.8
Rust Ter Vaal Combined School	10.9	0.8	10.5	0.8
Roshnee Primary School	10.9	0.8	10.5	0.8
Roshnee High School	10.9	0.8	10.5	0.8
Hoerskool Dr Malan	10.9	0.9	10.5	0.8
Laerskool Voorwaarts	11.1	0.9	10.7	0.9
Meyerton Secondary School	11.1	0.9	10.7	0.8
Ratasetjhaba Primary School	10.9	0.8	10.5	0.8
Meyerton Primary School	11.1	0.9	10.7	0.8
Oprah Leadership Academy	11.0	0.9	10.6	0.8
Henley River Retirement Village	11.0	0.9	10.6	0.8
Henley High & Preparatory School	10.9	0.9	10.5	0.8
Randvaal Clinic	10.9	0.9	10.5	0.8
Laerskool Japie Greyling	10.7	0.9	10.4	0.8
Thomas Nhlapo Primary	10.7	0.9	10.4	0.8
Randvaal Old Age Home	11.0	0.9	10.6	0.8
Laerskool Ag Visser	10.9	1.0	10.6	1.0
Lethaba Siyangobe	11.0	1.0	10.6	1.0
Shalimar Ridge Primary School	10.8	1.0	10.5	1.0
Jw Luckoff High School	11.0	1.0	10.7	1.0
Heidelberg Hospital	10.8	1.0	10.4	1.0
Thulatsatsi Operation (Rensburg)	10.9	1.0	10.6	1.0
Silwer Akker Tehuis	10.8	1.0	10.5	1.0
Riversands Retirement Village	10.8	1.0	10.4	1.0
Qhaqholla Primary School	10.8	1.0	10.4	1.0
Ratanda Primary School	10.8	1.0	10.5	1.0
Boneha Primary School	10.8	1.0	10.4	1.0
Sithokomele Primary School	10.8	1.0	10.4	1.0
Ratanda Bertha Gxowa Primary School	11.0	1.0	10.6	1.0
Khanya Lesedi Secondary School	10.8	1.0	10.5	1.0
Ratanda Secondary School	10.8	1.0	10.5	1.0
New Ratanda Secondary School	10.9	1.0	10.6	1.0
Kgoro Ya Thuto Secondary School	10.9	1.0	10.6	1.0
Ekurhuleni School for the Deaf	10.5	0.9	10.2	0.8
Pholosong Hospital	10.7	1.0	10.3	1.0
Tsakane Home For Aged	10.6	1.0	10.2	1.0
Mmuso Primary School	11.0	1.0	10.6	1.0
Michael Zulu Primary School	10.8	1.0	10.4	1.0
Nkabinde Primary School (Thembilisha)	10.9	1.0	10.5	1.0
Nigel Clinic	11.7	1.1	11.3	1.0

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Tehuis Vir Bejaardes	11.7	1.1	11.3	1.0
Hoerskool John Vorster	11.7	1.1	11.4	1.0
Laerskool Hannes Visagie	11.8	1.1	11.4	1.0
Nigel Secondary School	12.1	1.1	11.8	1.1
Laerskool Dunnottar	10.8	1.0	10.5	1.0
Springs Retirement Village	10.9	1.0	10.5	1.0
Life Springs Parkland Hospital	11.0	1.0	10.6	1.0
Netcare N17 Hospital (Springs)	11.0	1.0	10.6	1.0
Springs Boys High School	11.0	1.0	10.6	1.0
Laerskool Selectionpark	11.1	1.0	10.7	1.0
Kwasa College Pre&Primary School	10.9	1.0	10.5	1.0
Edelweis Medical Centre	11.0	1.0	10.6	1.0
Laerskool Christiaan Beyers	11.0	1.0	10.6	1.0
Hoerskool Hugenote	10.9	1.0	10.5	0.9
Brakpan Primary School	10.9	1.0	10.6	0.9
Parkrand Primary School	10.4	0.9	10.0	0.9
Thabo Memorial Hospital	10.4	0.9	10.0	0.9
Sunward Park Hospital	10.4	0.9	10.0	0.9
Alberton High School	10.4	0.9	10.0	0.8
Netcare Clinton Hospital	10.3	0.8	9.9	0.8
Alberton Tuiste Vir Bejaardes	10.4	0.8	10.0	0.8
Bertha Gxowa Hospital	10.6	0.9	10.2	0.8
Linmed Hospital	10.5	0.9	10.1	0.9
Hoerskool Brandwag (Airfield)	10.4	0.9	10.0	0.9
Thepiso Noto Intermediate School	10.9	1.0	10.5	0.9
Laerskool Bredell	10.7	0.9	10.3	0.8
Sibonelo Primary School (Daveyton)	10.7	0.9	10.3	0.9
Petit High School (Kempton Park Nu)	10.8	0.9	10.4	0.9
Arwyp Medical Centre	10.3	0.8	9.9	0.8
Hoerskool Birchleigh	10.2	0.8	9.8	0.8
Curro Serengeti Acadamy	10.9	0.8	10.5	0.8
South Rand Hospital	11.0	0.9	10.6	0.8
Chris Hani Baragwanath Hospital	10.0	0.8	9.6	0.7
Thulani Primary School	9.4	0.7	9.1	0.7
University of Witwatersrand	10.9	0.8	10.5	0.8
Milpark Hospital	10.8	0.8	10.4	0.8
Charlotte Maxixe Academic Hospital	10.8	0.8	10.5	0.8
Thembisa West Secondary School (Thembisa)	10.2	0.8	9.8	0.7
Lenmed Zamokuhle Private Hospital (Thembisa)	10.3	0.8	9.9	0.7
Ikusasa Comprehensive School	10.4	0.8	10.0	0.8
Gem Village Old Age Home	10.3	0.7	10.0	0.7
Rustoord Old Age Home	10.0	0.7	9.6	0.7
Cornwell Hill College (Irene)	10.1	0.7	9.8	0.7
Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	10.0	0.8	9.7	0.7
Valtaki AH (Rayton)	10.4	0.8	10.1	0.8
Laerskool Rayton (Rayton)	10.0	0.7	9.6	0.7
Tierkop AH	10.3	0.8	9.9	0.8
Redford House The Hills Private School (Mooikloof Glen)	10.1	0.8	9.7	0.8
Rietvlei View Country Estate	10.1	0.8	9.7	0.8

Scenario B (2031)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Hazeldean Curro School (Tyger Valley)	9.9	0.7	9.5	0.7
Tyger Valley College	9.8	0.7	9.4	0.7
Pretoria East Hospital (Moreletapark)	10.0	0.7	9.7	0.7
Groenkloof Old Age Home	9.6	0.7	9.3	0.6
Steve Biko Academic Hospital	9.5	0.6	9.2	0.6
Willow Ridge High School (Wilgers)	9.5	0.7	9.2	0.7
Hoerskool Waterkloof	10.0	0.7	9.6	0.7
Hoerskool Garsfontein	9.7	0.7	9.4	0.7
Afrikaanse Hoer Seunskool	9.5	0.7	9.2	0.6
Huis Silversig SAVF Old Age Home (Silverton)	9.4	0.7	9.1	0.6
Laersekool Meyerspark (Meyerspark)	9.5	0.7	9.2	0.6
Curro Academy Mamelodi	9.3	0.7	9.0	0.6
Impendulo Primary School	9.6	0.7	9.3	0.7
Nellmapius Ext 6 Primary School	9.5	0.7	9.2	0.6
Mamelodi Home For Aged	9.4	0.7	9.1	0.6

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario C (2036), together with the limit value of the NAAQS

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Elsie Ballot Memorial Hospital	11.4	1.4	11.0	1.3
Laerskool Amersfoort	11.2	1.4	10.8	1.3
Embuzane Primary School	11.6	1.5	11.0	1.4
Sangqotho Primary School	9.2	1.4	8.8	1.3
Amersfoort Combined School	11.3	1.4	10.9	1.3
Injubuko Primary School	10.2	1.4	9.8	1.3
Daggakraal Primary School	10.4	1.5	10.0	1.4
Sizenzele Primary School	10.0	1.5	9.5	1.4
Seme Secondary School	10.3	1.5	9.9	1.4
Louwra Primary School	9.4	1.2	9.0	1.2
Perdekop Agricultural School	10.4	1.3	10.0	1.2
Vukuzenzele Combined School	10.4	1.3	10.0	1.2
Gunwana Primary School	10.5	1.2	10.2	1.2
Amajuba Memorial Hospital	8.5	1.1	8.1	1.1
Volksrust High School	8.5	1.1	8.1	1.1
Volksrust Municipal Clinic	8.4	1.1	8.0	1.1
C V O Skool Amajuba	8.4	1.1	8.0	1.1
Qhubulwazi Combined School	8.5	1.1	8.1	1.1
Volksrust Primary School	8.6	1.2	8.3	1.1
New Ermelo	9.7	1.2	9.4	1.1
Ermelo Christian School	9.5	1.2	9.2	1.2
SAVF Home For Aged	9.5	1.2	9.2	1.1
Ermelo Hospital	9.4	1.2	9.1	1.1
Mediclinic Ermelo	9.5	1.2	9.1	1.1
Hoerskool Ermelo	9.4	1.2	9.1	1.1
Ermelo Indian Combined School	9.3	1.2	9.0	1.1
Lungelo Combined School (Outside Town)	9.5	1.2	9.1	1.1
New Ermelo Primary School	9.7	1.2	9.4	1.1
Kwashashe (Outside Town)	9.7	1.2	9.4	1.1
Hts Ligbron	9.5	1.2	9.2	1.1
Laerskool Ermelo	9.6	1.2	9.2	1.1
JJ Vd Merwe Pre-Primary School	9.4	1.2	9.1	1.1
Lindile Secondary School	9.2	1.2	8.9	1.1
Emthonjeni Clinic	9.3	1.2	9.0	1.1
Reggie Masuku Secondary School	9.0	1.2	8.7	1.1
Cebisa Secondary School	9.2	1.2	8.9	1.1
Camden	9.5	1.2	9.2	1.2
Camden Combined School	9.3	1.2	9.0	1.2
Camden School	9.6	1.2	9.3	1.2
Umzimvelo Secondary School (Rural Area)	9.3	1.2	9.0	1.2
Bhekimfundo Primary School (Rural Area)	9.6	1.2	9.2	1.2
Eshwileni Primary School (Rural Area)	8.8	1.3	8.5	1.2
Davel Combined School	8.6	1.1	8.3	1.1
Morgenzon Landbou Akademie	9.0	1.3	8.6	1.2
Nqobangolwazi Secondary School	9.1	1.3	8.6	1.2
Siqondekhaya Pre Primary School	9.1	1.3	8.6	1.2
Sizakhele Primary School	9.1	1.3	8.6	1.2

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Phezukwentaba Primary School (South of Morgenzon)	8.9	1.3	8.5	1.2
Kwaggalaagte Primary School (North of Morgenzon)	9.6	1.2	9.2	1.1
Sizakhele Clinic/Hospital	9.1	1.3	8.6	1.2
Grootvlei	7.8	0.8	7.5	0.8
Olive Grove Country Lodge	8.0	0.8	7.7	0.8
Grootvlei Town (South of Power Station)	8.1	0.8	7.8	0.8
Laerskool Grootvlei	8.1	0.8	7.8	0.8
Tokoloho Primary School	8.1	0.8	7.8	0.8
Tshepeha Combined School	8.0	0.8	7.7	0.8
Warembo Lodge	7.9	0.9	7.6	0.8
Balfour	7.4	0.8	7.1	0.8
Siyathemba	7.5	0.9	7.2	0.8
Bonukukhanya Primary (Siyathemba)	7.6	0.9	7.3	0.8
Qalabocha Primary School (Siyathemba)	7.5	0.9	7.2	0.8
Vusumuzi Primary School	7.5	0.9	7.2	0.8
Gekombineerde Skool Balfour	7.6	0.9	7.3	0.8
Im Manchu Secondary School	7.5	0.8	7.2	0.8
Isifisosethu Secondary School (Siyathemba)	7.6	0.9	7.3	0.8
Setsheng Secondary School (Siyathemba)	7.5	0.9	7.2	0.8
Dr Nieuwoudt And Dr Kok	7.6	0.9	7.3	0.8
Balfour Clinic	7.5	0.8	7.2	0.8
Siyathemba Clinic	7.4	0.9	7.1	0.8
Mondoro Lodge	7.4	0.8	7.1	0.8
Wegelegen Manor	7.6	0.9	7.3	0.8
The Stone Cellar	7.0	0.8	6.7	0.7
Greylingstad	8.0	0.9	7.6	0.9
Nthorwane	8.1	0.9	7.8	0.9
Laerskool Greylingstad	8.0	0.9	7.7	0.9
Nthoroane Secondary School	8.1	0.9	7.7	0.9
Badgarleur Bush Lodge	8.2	0.9	7.9	0.8
Matla Village	9.6	1.0	9.1	0.9
Sifundise Primary School	9.6	1.0	9.1	0.9
Matla Coal Health Centre	9.6	1.0	9.1	0.9
Gweda Primary School	9.2	1.0	8.8	1.0
Zithobe Primary School	9.4	0.9	9.0	0.9
Kwanala Primary School	9.2	1.0	8.8	1.0
Reedstream Park	9.4	1.0	8.9	0.9
Rietspruit Clinic	9.1	1.0	8.7	0.9
Lehlaka Combined School	9.1	1.0	8.7	0.9
Mbali Coal/Blesboklaagte Housing	9.0	1.0	8.5	0.9
Kinross	9.2	1.0	8.9	0.9
Kinross Settlement	9.3	1.0	8.9	0.9
Kinross Municipal Clinic	9.2	1.0	8.9	0.9
Kriel	9.1	1.0	8.7	1.0
Eagles Nest Guest House	9.0	1.0	8.6	1.0
Merlin Park Primary School	8.9	1.0	8.6	1.0
Kriel Medical Centre	9.0	1.0	8.6	1.0
Laerskool Krielpark	9.0	1.0	8.6	1.0
Laerskool Onverwacht	9.0	1.0	8.6	1.0

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Silwer Fleur Aftree Oord (Old Age Home)	9.0	1.0	8.6	1.0
Thubelihle	8.8	1.0	8.4	1.0
Sibongamandla Secondary School	8.7	1.0	8.4	1.0
Ga-Nala Clinic	8.9	1.0	8.6	1.0
Impilo Primary School	8.6	1.0	8.3	0.9
Bonginhlanhla Primary School	8.7	1.0	8.4	1.0
Sibongamandla Secondary School	8.7	1.0	8.4	1.0
Leandra	9.1	0.9	8.7	0.9
Eendracht	9.0	0.9	8.6	0.9
Sidingulwazi Primary School	8.9	0.9	8.6	0.9
Ss Mshayisa Primary School	8.9	0.9	8.6	0.9
Chief Ampie Mayisa Secondary School	8.9	0.9	8.5	0.9
Lebogang Clinic	9.0	0.9	8.6	0.9
Kleuterskool Haas Das	9.7	1.1	9.3	1.1
Standerton Primary School	9.7	1.1	9.3	1.1
Laerskool Jeugkrag	10.1	1.1	9.6	1.1
Laerskool Standerton	9.7	1.1	9.3	1.1
Laerskool Kalie De Haas	9.8	1.1	9.3	1.1
Hoerskool Standerton	9.7	1.1	9.3	1.1
Standerton Provincial Government Hospital	9.8	1.1	9.3	1.1
Mar-Peh Medicare Private Hospital	9.7	1.1	9.3	1.1
Standerton Retirement Home	9.7	1.1	9.3	1.1
Standerton Ouetehuis/Old Age Home	9.7	1.1	9.3	1.1
Holmdene Secondary School	9.2	1.0	8.8	1.0
Cathuza Primary School (SE of Town)	10.4	1.2	9.9	1.1
Sizanani Pre Primary School	10.0	1.1	9.6	1.1
Hlobisa Primary School	10.0	1.1	9.5	1.1
Shukuma Primary School	9.8	1.1	9.4	1.1
Retsebile Primary School	10.3	1.1	9.9	1.1
Thuto-Thebe Secondary School	10.2	1.1	9.8	1.1
Jandrell Secondary School	10.1	1.1	9.6	1.1
Thobelani Secondary School	10.1	1.1	9.7	1.1
Standerton Tb Hospital	9.8	1.1	9.4	1.1
Thuthukani Pre Primary School	10.6	1.1	9.9	1.0
Ulwazi Primary School	10.7	1.1	9.9	1.0
Zikhetheleni Secondary School	10.7	1.1	9.9	1.0
Joubertsvlei Primary School (North of Tutuka)	9.1	1.1	8.6	1.0
Amalumgelo Primary School (NE of Tutuka)	10.3	1.3	9.5	1.2
Grootdraaidam Primary School	9.8	1.1	9.3	1.1
Laerskool Secunda	9.0	1.0	8.7	1.0
Laerskool Kruinpark	9.0	1.0	8.7	1.0
Laerskool Oranjegloed Primary	9.0	1.0	8.7	1.0
Curro Castle Combined School	9.0	1.0	8.6	1.0
Hoërskool Oosterland	9.0	1.0	8.7	1.0
Mediclinic Secunda (Hospital)	9.0	1.0	8.7	1.0
Mediclinic Highveld (Hospital_Trichardt, Secunda)	8.9	1.0	8.6	1.0
Daviescourt/Davieshof Old Age Home	9.0	1.0	8.7	1.0
Highveld Park High School	9.1	1.0	8.8	1.0
Hoerskool Secunda	9.0	1.0	8.7	1.0

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Basizeni Special School	8.9	1.0	8.6	0.9
Maphala-Gulube Primary School	8.9	1.0	8.5	0.9
Shapeve Primary School	8.9	1.0	8.6	0.9
Thomas Nhlabathi Secondary School	8.9	1.0	8.5	0.9
Embalenhle Hospital / Clinic	8.9	1.0	8.5	0.9
Vukuzithathe Primary School	8.9	1.0	8.6	0.9
K I Twala Secondary	8.9	1.0	8.6	0.9
Allan Makunga Primary School	8.9	1.0	8.6	0.9
Evander Hospital Arv Clinic	9.0	1.0	8.7	0.9
Laerskool Hoeveld	9.0	1.0	8.7	0.9
Hoerskool Evander	9.0	1.0	8.6	0.9
Bernice Samuel Hospital	8.4	0.7	8.0	0.7
Hoerskool Delmas	8.4	0.7	8.1	0.7
Laerskool Delmas	8.4	0.7	8.0	0.7
Kangela Primary School (North of Delpark)	8.6	0.7	8.2	0.7
Savf Ons Eie Ouetehuis / Old Age Home	8.4	0.7	8.0	0.7
Laerskool Eloff	8.3	0.7	7.9	0.7
Rietkol Primary School	8.3	0.7	7.9	0.7
Bazani Primary School	8.4	0.7	8.0	0.7
Phaphamani Secondary School	8.4	0.7	8.1	0.7
Vezimfundo Primary School	8.2	0.7	7.9	0.7
Arbor Primary School	8.6	0.8	8.0	0.8
Ogies Combined School	9.3	1.0	8.5	0.9
Ogies Tb Clinic	9.2	1.0	8.5	0.9
Ogies Police Station	9.2	1.0	8.5	0.9
Hlangu Phala Primary School	9.4	0.9	8.6	0.8
Sukumani Primary School	9.4	0.9	8.6	0.8
Thuthukani Primary School	9.4	0.9	8.6	0.8
Mehlwana Secondary School	9.4	0.9	8.7	0.8
Makause Combined School	9.4	0.9	8.7	0.8
Sibongindawo Primary School	9.2	0.9	8.5	0.8
Laerskool Balmoral	9.7	0.8	9.2	0.7
Clewer Primary School	9.3	0.8	8.8	0.8
Witbank High School	8.6	0.8	8.2	0.8
Eden Park Retirement Village	8.6	0.8	8.2	0.8
Savf House Immergroen Old Age Home	8.7	0.8	8.3	0.8
Mthimkulu Housing for the Aged	9.0	0.8	8.6	0.8
Emalahleni Private Hospital	8.8	0.8	8.4	0.8
Life Cosmos Hospital	8.5	0.8	8.1	0.8
Duvha Primary School	8.7	0.8	8.3	0.8
Laerskool Taalfees	8.6	0.8	8.2	0.8
Witbank Provincial Hospital	8.7	0.8	8.3	0.8
Nancy Shiba Primary School (Vosman)	9.5	0.8	9.1	0.7
Wh De Klerk Skool	8.5	0.8	8.2	0.8
Laerskool Panorama	8.7	0.8	8.3	0.7
Laerskool Duvhapark	8.6	0.8	8.3	0.8
Laerskool Klipfontein	8.6	0.8	8.2	0.8
Cambridge Academy	8.5	0.8	8.1	0.8
Besilindile Primary School	9.1	0.8	8.7	0.7

Scenario C (2036)	PM$_{10}$ Total		PM$_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Reynopark High School	8.6	0.8	8.2	0.8
Bakenveld Golf Estate	8.4	0.8	8.0	0.8
Allendale Secondary School	8.7	0.9	8.3	0.8
Khayalethu Primary School	9.1	0.8	8.7	0.8
Illanga Secondary School	8.6	0.9	8.2	0.8
Joy Creche (Duvha)	8.7	0.9	8.4	0.8
Linderus Old Age Home	8.4	0.8	8.1	0.7
Vergeet My Nie Old Age Home	8.5	0.8	8.1	0.7
Middleburg Frail Care Unit and Home For Elderly	8.3	0.7	8.0	0.7
Life Midmed Hospital	8.3	0.8	8.0	0.7
Middelburg Hospital	8.4	0.8	8.1	0.7
Makhathini Primary School	8.3	0.7	8.0	0.7
Laerskool Dennesig	8.3	0.7	7.9	0.7
Hoerskool Kanonkop	8.3	0.7	8.0	0.7
Laerskool Kanonkop	8.3	0.7	8.0	0.7
Steelcrest High School	8.3	0.8	8.0	0.7
Middelburg Primary	8.4	0.8	8.1	0.7
Middleburg Ext 6 Clinic	8.4	0.8	8.1	0.7
Sofunda Secondary School	8.4	0.8	8.0	0.7
Mhluzi Primary School	8.3	0.7	8.0	0.7
Highlands Primary School	8.4	0.8	8.1	0.7
Blinkpan Primary School	8.6	1.0	8.3	0.9
Laerskool Koornfontein	8.6	1.0	8.2	0.9
Blinkpan	8.7	1.0	8.3	0.9
Laerskool Kragveld	8.7	0.9	8.3	0.9
Pullens Hope	8.7	0.9	8.4	0.9
Arnot Colliery Primary School	8.6	0.9	8.3	0.8
Laerskool Rietkuil	8.4	0.9	8.1	0.8
Beestepan Agricultural School	8.1	0.8	7.8	0.8
Gekombineerde Skool Hendrina	8.6	1.0	8.3	0.9
Hendrina Primary School	8.6	1.0	8.3	0.9
Kwazamokuhle Secondary School	8.5	1.0	8.2	0.9
Ubuhle Bolwai Secondary School	9.1	1.1	8.9	1.1
Lothair Primary School	9.4	1.1	9.1	1.1
Warburton Combined School	9.1	1.0	8.8	1.0
Warburton Town	9.1	1.0	8.8	1.0
Kwachibikhulu Clinic	8.8	1.1	8.5	1.0
Kwachibikhulu Primary School	8.9	1.1	8.6	1.0
Carolina Hospital	8.5	1.0	8.2	0.9
Zinikeleni Secondary School (Silobela)	8.5	1.0	8.2	0.9
Volkskool Carolina	8.5	1.0	8.2	0.9
Sobuza Primary School	8.5	1.0	8.2	0.9
Ons Eie Ouetehuis (Old Age Home)	8.4	1.0	8.2	0.9
Laerskool Breyten	9.0	1.1	8.7	1.0
Siyazi Primary School (Kwazanele)	9.0	1.1	8.7	1.1
Masizakhe Secondary School (Kwazanele)	9.0	1.1	8.7	1.1
Belfast Rusoord (Old Age Home)	6.7	0.7	6.5	0.7
Belfast Hospital	6.8	0.7	6.6	0.7
Platorand School	6.9	0.8	6.7	0.7

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Belfast Primary School (Siyathuthuka)	6.7	0.7	6.4	0.7
Siyathuthuka Clinic	6.7	0.7	6.4	0.7
Life Bethal Hospital	8.7	1.1	8.3	1.0
Hoerskool Hoogenhout	8.6	1.1	8.2	1.0
Jim Van Tonderskool	8.6	1.1	8.3	1.0
Bethal Independent Primary School	8.6	1.1	8.3	1.0
Laerskool Marietjie Van Niekerk	8.7	1.1	8.4	1.0
Laerskool Hm Swart	8.7	1.1	8.3	1.0
Sakhisizwe Primary School (Emzinoni)	9.2	1.1	8.8	1.0
Alpheus D Nkosi Secondary School (Emzinoni)	9.2	1.1	8.8	1.0
Silwerjare Old Age Home	8.8	1.1	8.4	1.0
Residentia Palm Oord	8.7	1.1	8.3	1.0
Bronkhorspruit Hospital	7.4	0.6	7.1	0.5
Cultura High School	7.5	0.6	7.1	0.6
Bronkhorspruit Primary School	7.4	0.6	7.0	0.5
Bronkhorspruit Dam	7.6	0.6	7.2	0.6
Hoerskool Erasmus	7.5	0.6	7.2	0.6
Althea Independent School	7.6	0.6	7.2	0.6
Kgoro Primary School (Zithobeni)	7.5	0.6	7.2	0.5
Zithobeni Secondary School (Zithobeni)	7.5	0.6	7.2	0.5
Vaal Power AH	7.7	0.7	7.3	0.6
Sasolburg Provincial Hospital	8.4	0.6	7.9	0.6
Moredou Old Age Home	8.1	0.6	7.6	0.6
Ons Gryse Jeug Old Age Home	8.0	0.6	7.6	0.6
Noord Primere Skool	8.1	0.6	7.6	0.6
Sasolburg High School	7.9	0.6	7.4	0.6
Sakhubusa Secondary School	8.0	0.6	7.5	0.6
Bekezela Primary School	7.6	0.6	7.2	0.6
Isaac Mhlambi Primary	7.9	0.6	7.4	0.6
Refenkgotso Primary School	7.3	0.7	6.9	0.7
Deneysville Primary School	7.3	0.7	6.9	0.7
Netcare Vaalpark Hospital	8.5	0.6	8.0	0.6
Vaalpark Articon Secondary School	9.1	0.6	8.6	0.6
Mediclinic Emfuleni	7.5	0.6	7.2	0.5
Jeugland Old Age Home	7.6	0.6	7.2	0.5
Herfsoord Huis Old Age Home	7.5	0.6	7.1	0.5
Huis Prinscilla	7.4	0.6	7.0	0.5
Laerskool Emfulenipark	8.2	0.6	7.7	0.6
Nw University_Vaal Campus	7.9	0.6	7.4	0.6
Emfuleni Primary School	7.6	0.5	7.2	0.5
Mediclinic Vereeniging	7.3	0.6	7.0	0.6
Kopanong Provincial Hospital (Duncanville)	7.2	0.6	6.8	0.6
Avondrus Eventide Old Age Home	7.3	0.6	6.9	0.6
Riviera On Vaal Resort	7.5	0.6	7.0	0.6
Sedibeng Tvet College	7.4	0.6	7.0	0.6
General Smuts High School	7.5	0.6	7.1	0.6
Eureuka School & Selbourne Primary	7.5	0.6	7.1	0.6
Midvaal Private Hospital (Three Rivers)	7.6	0.6	7.1	0.6
Three Rivers Retirement Village	7.8	0.6	7.3	0.6

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Drie Riviere Aftreeoord Old Age Home	7.6	0.6	7.2	0.6
Riverside High School	7.6	0.6	7.1	0.6
Risiville Primary School	7.5	0.6	7.1	0.6
Sebokeng Hospital	7.5	0.5	7.2	0.5
Clinix-Naledzi Private Hospital	7.2	0.5	6.9	0.5
Mohloli Secondary School	7.6	0.6	7.1	0.5
Tshirela Primary School (Boipatong)	7.2	0.6	6.9	0.5
Tsoaranang Primary School (Thepiso)	7.4	0.6	7.0	0.5
Thepiso Primary School	7.1	0.6	6.8	0.5
Emmanuel Primary School	7.5	0.6	7.0	0.5
Rust Ter Vaal Combined School	7.0	0.6	6.7	0.5
Roshnee Primary School	7.0	0.6	6.7	0.5
Roshnee High School	7.0	0.6	6.7	0.5
Hoerskool Dr Malan	6.9	0.6	6.6	0.6
Laerskool Voorwaarts	7.3	0.6	6.9	0.6
Meyerton Secondary School	7.1	0.6	6.7	0.6
Ratasetjhaba Primary School	6.9	0.6	6.6	0.6
Meyerton Primary School	6.9	0.6	6.6	0.6
Oprah Leadership Academy	6.8	0.6	6.5	0.6
Henley River Retirement Village	6.9	0.6	6.6	0.6
Henley High & Preparatory School	7.0	0.6	6.6	0.6
Randvaal Clinic	6.8	0.6	6.5	0.6
Laerskool Japie Greyling	6.9	0.6	6.6	0.6
Thomas Nhlapo Primary	7.0	0.6	6.7	0.6
Randvaal Old Age Home	6.9	0.6	6.6	0.6
Laerskool Ag Visser	6.9	0.7	6.6	0.7
Lethaba Siyangobe	6.9	0.7	6.6	0.7
Shalimar Ridge Primary School	6.9	0.7	6.6	0.7
Jw Luckoff High School	7.0	0.7	6.7	0.7
Heidelberg Hospital	7.0	0.7	6.7	0.7
Thulatsatsi Operation (Rensburg)	6.9	0.7	6.6	0.7
Silwer Akker Tehuis	6.9	0.7	6.6	0.7
Riversands Retirement Village	6.9	0.7	6.6	0.7
Qhaqholla Primary School	6.9	0.7	6.6	0.7
Ratanda Primary School	6.9	0.7	6.6	0.7
Boneha Primary School	6.9	0.7	6.6	0.7
Sithokomele Primary School	6.9	0.7	6.6	0.7
Ratanda Bertha Gxowa Primary School	6.9	0.7	6.6	0.7
Khanya Lesedi Secondary School	6.9	0.7	6.6	0.7
Ratanda Secondary School	6.9	0.7	6.6	0.7
New Ratanda Secondary School	6.9	0.7	6.6	0.7
Kgoro Ya Thuto Secondary School	6.9	0.7	6.6	0.7
Ekurhuleni School for the Deaf	7.1	0.6	6.9	0.6
Pholosong Hospital	8.0	0.7	7.7	0.6
Tsakane Home For Aged	8.0	0.7	7.7	0.7
Mmuso Primary School	7.9	0.7	7.6	0.7
Michael Zulu Primary School	8.0	0.7	7.7	0.7
Nkabinde Primary School (Thembilisha)	7.9	0.7	7.6	0.6
Nigel Clinic	7.6	0.7	7.3	0.7

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Tehuis Vir Bejaardes	7.6	0.7	7.4	0.7
Hoerskool John Vorster	7.6	0.7	7.3	0.7
Laerskool Hannes Visagie	7.7	0.7	7.4	0.7
Nigel Secondary School	7.7	0.8	7.4	0.7
Laerskool Dunnottar	7.8	0.7	7.6	0.7
Springs Retirement Village	7.8	0.7	7.6	0.6
Life Springs Parkland Hospital	7.9	0.7	7.6	0.6
Netcare N17 Hospital (Springs)	8.0	0.7	7.7	0.6
Springs Boys High School	7.9	0.7	7.6	0.7
Laerskool Selectionpark	7.9	0.7	7.6	0.6
Kwasa College Pre&Primary School	7.8	0.7	7.5	0.7
Edelweis Medical Centre	7.8	0.7	7.5	0.7
Laerskool Christiaan Beyers	7.9	0.7	7.6	0.6
Hoerskool Hugenote	7.8	0.7	7.5	0.6
Brakpan Primary School	7.5	0.7	7.2	0.6
Parkrand Primary School	7.4	0.6	7.1	0.6
Thabo Memorial Hospital	7.2	0.6	6.9	0.6
Sunward Park Hospital	7.3	0.6	7.0	0.6
Alberton High School	7.2	0.6	6.9	0.6
Netcare Clinton Hospital	7.2	0.6	6.9	0.6
Alberton Tuiste Vir Bejaardes	7.2	0.6	6.9	0.6
Bertha Gxowa Hospital	7.3	0.6	7.0	0.6
Linmed Hospital	7.5	0.6	7.2	0.6
Hoerskool Brandwag (Airfield)	7.5	0.6	7.2	0.6
Thepiso Noto Intermediate School	7.4	0.6	7.1	0.6
Laerskool Bredell	7.2	0.6	6.9	0.6
Sibonelo Primary School (Daveyton)	7.6	0.6	7.3	0.6
Petit High School (Kempton Park Nu)	7.5	0.6	7.2	0.6
Arwyp Medical Centre	7.5	0.6	7.3	0.6
Hoerskool Birchleigh	7.3	0.6	7.0	0.5
Curro Serengeti Acadamy	7.2	0.6	6.9	0.5
South Rand Hospital	7.3	0.6	7.0	0.6
Chris Hani Baragwanath Hospital	6.5	0.5	6.3	0.5
Thulani Primary School	6.4	0.5	6.2	0.5
University of Witwatersrand	7.0	0.6	6.7	0.5
Milpark Hospital	6.9	0.6	6.6	0.5
Charlotte Maxixe Academic Hospital	7.0	0.6	6.7	0.5
Thembisa West Secondary School (Thembisa)	7.0	0.5	6.8	0.5
Lenmed Zamokuhle Private Hospital (Thembisa)	7.0	0.5	6.8	0.5
Ikusasa Comprehensive School	7.2	0.5	6.9	0.5
Gem Village Old Age Home	6.6	0.5	6.3	0.5
Rustoord Old Age Home	6.3	0.5	6.0	0.4
Cornwell Hill College (Irene)	6.5	0.5	6.2	0.5
Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	6.8	0.5	6.6	0.5
Valtaki AH (Rayton)	6.9	0.5	6.6	0.5
Laerskool Rayton (Rayton)	6.6	0.5	6.3	0.5
Tierkop AH	7.0	0.6	6.7	0.5
Redford House The Hills Private School (Mooikloof Glen)	7.0	0.5	6.7	0.5
Rietvlei View Country Estate	7.0	0.5	6.7	0.5

Scenario C (2036)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Hazeldean Curro School (Tyger Valley)	6.8	0.5	6.5	0.5
Tyger Valley College	6.8	0.5	6.5	0.5
Pretoria East Hospital (Moreletapark)	6.7	0.5	6.4	0.5
Groenkloof Old Age Home	6.2	0.4	5.9	0.4
Steve Biko Academic Hospital	6.0	0.4	5.7	0.4
Willow Ridge High School (Wilgers)	6.6	0.5	6.3	0.4
Hoerskool Waterkloof	6.6	0.5	6.3	0.5
Hoerskool Garsfontein	6.7	0.5	6.4	0.5
Afrikaanse Hoer Seunskool	6.1	0.4	5.9	0.4
Huis Silversig SAVF Old Age Home (Silverton)	6.3	0.4	6.1	0.4
Laersekool Meyerspark (Meyerspark)	6.4	0.4	6.2	0.4
Curro Academy Mamelodi	6.2	0.4	6.0	0.4
Impendulo Primary School	6.4	0.5	6.2	0.4
Nellmapius Ext 6 Primary School	6.5	0.4	6.2	0.4
Mamelodi Home For Aged	6.4	0.4	6.1	0.4

Predicted concentrations in µg/m³ at the sensitive receptors for Scenario D (MES), together with the limit value of the NAAQS

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Elsie Ballot Memorial Hospital	6.1	0.9	5.6	0.8
Laerskool Amersfoort	6.0	0.9	5.6	0.8
Embuzane Primary School	6.7	1.0	6.1	0.8
Sangqotho Primary School	6.0	0.9	5.6	0.8
Amersfoort Combined School	6.0	0.9	5.6	0.8
Injubuko Primary School	5.7	0.9	5.3	0.8
Daggakraal Primary School	6.0	0.9	5.6	0.8
Sizenzele Primary School	6.1	0.9	5.6	0.8
Seme Secondary School	5.9	0.9	5.5	0.8
Louwra Primary School	5.7	0.8	5.4	0.7
Perdekop Agricultural School	6.0	0.8	5.6	0.7
Vukuzenzele Combined School	5.9	0.8	5.6	0.7
Gunwana Primary School	6.0	0.8	5.6	0.7
Amajuba Memorial Hospital	5.6	0.7	5.3	0.7
Volksrust High School	5.6	0.7	5.2	0.6
Volksrust Municipal Clinic	5.5	0.7	5.2	0.6
C V O Skool Amajuba	5.5	0.7	5.2	0.6
Qhubulwazi Combined School	5.5	0.7	5.2	0.6
Volksrust Primary School	5.7	0.7	5.3	0.7
New Ermelo	5.7	0.8	5.4	0.7
Ermelo Christian School	5.8	0.8	5.5	0.8
SAVF Home For Aged	5.8	0.8	5.5	0.7
Ermelo Hospital	5.8	0.8	5.5	0.7
Mediclinic Ermelo	5.8	0.8	5.5	0.8
Hoerskool Ermelo	5.8	0.8	5.5	0.7
Ermelo Indian Combined School	5.9	0.8	5.5	0.7
Lungelo Combined School (Outside Town)	5.7	0.8	5.4	0.7
New Ermelo Primary School	5.8	0.8	5.5	0.7
Kwashashe (Outside Town)	5.8	0.8	5.5	0.8
Hts Ligbron	5.8	0.8	5.5	0.7
Laerskool Ermelo	5.8	0.8	5.4	0.7
JJ Vd Merwe Pre-Primary School	5.9	0.8	5.6	0.7
Lindile Secondary School	5.8	0.8	5.5	0.7
Emthonjeni Clinic	5.8	0.8	5.5	0.7
Reggie Masuku Secondary School	5.7	0.8	5.4	0.7
Cebisa Secondary School	5.8	0.8	5.4	0.7
Camden	5.9	0.8	5.6	0.8
Camden Combined School	5.8	0.8	5.5	0.8
Camden School	5.9	0.8	5.6	0.8
Umzimvelo Secondary School (Rural Area)	5.7	0.8	5.4	0.8
Bhekimfundo Primary School (Rural Area)	5.9	0.8	5.6	0.8
Eshwileni Primary School (Rural Area)	5.5	0.8	5.2	0.7
Davel Combined School	5.6	0.8	5.3	0.7
Morgenzon Landbou Akademie	5.6	0.8	5.1	0.7
Nqobangolwazi Secondary School	5.6	0.8	5.1	0.7
Siqondekhaya Pre Primary School	5.6	0.8	5.2	0.7
Sizakhele Primary School	5.6	0.8	5.1	0.7

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Phezukwentaba Primary School (South of Morgenzon)	5.7	0.8	5.3	0.7
Kwaggalaagte Primary School (North of Morgenzon)	5.6	0.8	5.2	0.7
Sizakhele Clinic/Hospital	5.6	0.8	5.1	0.7
Grootvlei	4.9	0.5	4.6	0.5
Olive Grove Country Lodge	4.9	0.5	4.5	0.5
Grootvlei Town (South of Power Station)	4.7	0.5	4.4	0.5
Laerskool Grootvlei	4.7	0.5	4.4	0.5
Tokoloho Primary School	4.7	0.5	4.4	0.5
Tshepeha Combined School	4.7	0.5	4.4	0.5
Warembo Lodge	4.8	0.5	4.5	0.5
Balfour	5.2	0.6	4.9	0.5
Siyathemba	5.2	0.6	4.9	0.5
Bonukukhanya Primary (Siyathemba)	5.2	0.6	4.9	0.5
Qalabocha Primary School (Siyathemba)	5.3	0.6	5.0	0.5
Vusumuzi Primary School	5.3	0.6	5.0	0.5
Gekombineerde Skool Balfour	5.1	0.6	4.8	0.5
Im Manchu Secondary School	5.0	0.5	4.7	0.5
Isifisosethu Secondary School (Siyathemba)	5.2	0.6	4.9	0.5
Setsheng Secondary School (Siyathemba)	5.3	0.6	5.0	0.5
Dr Nieuwoudt And Dr Kok	5.0	0.6	4.7	0.5
Balfour Clinic	5.1	0.5	4.8	0.5
Siyathemba Clinic	5.2	0.6	4.9	0.5
Mondoro Lodge	4.9	0.5	4.6	0.5
Wegelegen Manor	5.3	0.6	5.0	0.5
The Stone Cellar	4.7	0.5	4.5	0.4
Greylingstad	5.4	0.6	5.1	0.6
Nthorwane	5.4	0.6	5.1	0.6
Laerskool Greylingstad	5.5	0.6	5.2	0.6
Nthoroane Secondary School	5.4	0.6	5.1	0.6
Badgarleur Bush Lodge	5.3	0.6	5.0	0.5
Matla Village	5.9	0.7	5.4	0.6
Sifundise Primary School	5.9	0.7	5.4	0.6
Matla Coal Health Centre	5.9	0.7	5.4	0.6
Gweda Primary School	6.0	0.7	5.6	0.7
Zithobe Primary School	5.9	0.7	5.5	0.6
Kwanala Primary School	6.2	0.8	5.8	0.7
Reedstream Park	6.4	0.8	5.9	0.7
Rietspruit Clinic	6.5	0.8	6.1	0.7
Lehlaka Combined School	6.6	0.8	6.1	0.7
Mbali Coal/Blesboklaagte Housing	6.6	0.8	6.0	0.6
Kinross	6.0	0.7	5.7	0.6
Kinross Settlement	6.0	0.7	5.6	0.6
Kinross Municipal Clinic	6.0	0.7	5.7	0.6
Kriel	5.9	0.7	5.5	0.7
Eagles Nest Guest House	5.9	0.7	5.5	0.7
Merlin Park Primary School	5.9	0.7	5.5	0.7
Kriel Medical Centre	5.8	0.7	5.5	0.7
Laerskool Krielpark	5.8	0.7	5.4	0.7
Laerskool Onverwacht	5.8	0.7	5.5	0.7

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Silwer Fleur Aftree Oord (Old Age Home)	5.8	0.7	5.4	0.7
Thubelihle	5.9	0.7	5.5	0.7
Sibongamandla Secondary School	5.9	0.7	5.5	0.7
Ga-Nala Clinic	5.8	0.7	5.4	0.7
Impilo Primary School	5.7	0.7	5.4	0.7
Bonginhlanhla Primary School	5.9	0.7	5.5	0.7
Sibongamandla Secondary School	5.9	0.7	5.5	0.7
Leandra	6.3	0.6	5.9	0.6
Eendracht	6.2	0.6	5.9	0.6
Sidingulwazi Primary School	6.3	0.6	5.9	0.6
Ss Mshayisa Primary School	6.3	0.6	6.0	0.6
Chief Ampie Mayisa Secondary School	6.3	0.6	5.9	0.6
Lebogang Clinic	6.3	0.6	5.9	0.6
Kleuterskool Haas Das	6.0	0.7	5.5	0.6
Standerton Primary School	6.0	0.7	5.5	0.6
Laerskool Jeugkrag	6.0	0.7	5.5	0.6
Laerskool Standerton	6.0	0.7	5.5	0.6
Laerskool Kalie De Haas	6.2	0.7	5.7	0.6
Hoerskool Standerton	6.0	0.7	5.5	0.6
Standerton Provincial Government Hospital	6.0	0.7	5.5	0.6
Mar-Peh Medicare Private Hospital	6.0	0.7	5.5	0.6
Standerton Retirement Home	6.0	0.7	5.5	0.6
Standerton Ouetehuis/Old Age Home	6.0	0.7	5.6	0.6
Holmdene Secondary School	5.7	0.7	5.3	0.6
Cathuza Primary School (SE of Town)	6.5	0.7	6.0	0.7
Sizanani Pre Primary School	6.0	0.7	5.6	0.6
Hlobisa Primary School	5.9	0.7	5.5	0.6
Shukuma Primary School	6.0	0.7	5.5	0.6
Retsebile Primary School	6.1	0.7	5.6	0.6
Thuto-Thebe Secondary School	6.0	0.7	5.5	0.6
Jandrell Secondary School	6.0	0.7	5.6	0.6
Thobelani Secondary School	6.0	0.7	5.6	0.6
Standerton Tb Hospital	6.0	0.7	5.5	0.6
Thuthukani Pre Primary School	6.4	0.7	5.6	0.6
Ulwazi Primary School	6.4	0.7	5.6	0.6
Zikhetheleni Secondary School	6.4	0.7	5.6	0.6
Joubertsvlei Primary School (North of Tutuka)	5.7	0.7	5.2	0.7
Amalumgelo Primary School (NE of Tutuka)	6.3	0.8	5.5	0.7
Grootdraaidam Primary School	6.1	0.7	5.5	0.6
Laerskool Secunda	6.0	0.7	5.6	0.6
Laerskool Kruinpark	5.8	0.7	5.5	0.6
Laerskool Oranjegloed Primary	5.8	0.7	5.5	0.6
Curro Castle Combined School	5.8	0.7	5.5	0.6
Hoërskool Oosterland	5.8	0.7	5.5	0.6
Mediclinic Secunda (Hospital)	5.9	0.7	5.6	0.6
Mediclinic Highveld (Hospital_Trichardt, Secunda)	5.8	0.7	5.5	0.6
Daviescourt/Davieshof Old Age Home	5.9	0.7	5.6	0.6
Highveld Park High School	5.9	0.7	5.5	0.6
Hoerskool Secunda	5.9	0.7	5.6	0.6

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Basizeni Special School	5.9	0.6	5.5	0.6
Maphala-Gulube Primary School	5.8	0.7	5.5	0.6
Shapeve Primary School	5.9	0.7	5.5	0.6
Thomas Nhlabathi Secondary School	5.9	0.6	5.6	0.6
Embalenhle Hospital / Clinic	5.8	0.6	5.5	0.6
Vukuzithathe Primary School	5.9	0.6	5.5	0.6
K I Twala Secondary	5.9	0.6	5.5	0.6
Allan Makunga Primary School	5.9	0.6	5.5	0.6
Evander Hospital Arv Clinic	6.0	0.7	5.7	0.6
Laerskool Hoeveld	6.0	0.7	5.7	0.6
Hoerskool Evander	6.0	0.7	5.7	0.6
Bernice Samuel Hospital	5.3	0.5	4.9	0.5
Hoerskool Delmas	5.3	0.5	4.9	0.5
Laerskool Delmas	5.3	0.5	5.0	0.5
Kangela Primary School (North of Delpark)	5.4	0.5	5.0	0.5
Savf Ons Eie Ouetehuis / Old Age Home	5.3	0.5	5.0	0.5
Laerskool Eloff	5.1	0.5	4.8	0.4
Rietkol Primary School	5.1	0.5	4.8	0.4
Bazani Primary School	5.4	0.5	5.0	0.4
Phaphamani Secondary School	5.3	0.5	4.9	0.4
Vezimfundo Primary School	5.2	0.5	4.9	0.4
Arbor Primary School	6.4	0.6	5.8	0.5
Ogies Combined School	6.5	0.7	5.8	0.6
Ogies Tb Clinic	6.6	0.7	5.8	0.6
Ogies Police Station	6.6	0.7	5.8	0.6
Hlangu Phala Primary School	6.9	0.7	6.1	0.6
Sukumani Primary School	6.9	0.7	6.1	0.6
Thuthukani Primary School	6.9	0.7	6.1	0.6
Mehlwana Secondary School	6.8	0.7	6.1	0.6
Makause Combined School	6.8	0.7	6.1	0.6
Sibongindawo Primary School	6.9	0.6	6.2	0.6
Laerskool Balmoral	6.9	0.5	6.4	0.5
Clewer Primary School	6.3	0.6	5.8	0.5
Witbank High School	5.9	0.6	5.5	0.5
Eden Park Retirement Village	5.7	0.6	5.4	0.5
Savf House Immergroen Old Age Home	6.0	0.6	5.6	0.5
Mthimkulu Housing for the Aged	6.1	0.6	5.7	0.5
Emalahleni Private Hospital	6.1	0.6	5.7	0.5
Life Cosmos Hospital	5.9	0.6	5.5	0.5
Duvha Primary School	5.8	0.6	5.4	0.5
Laerskool Taalfees	5.9	0.6	5.5	0.5
Witbank Provincial Hospital	5.9	0.6	5.5	0.5
Nancy Shiba Primary School (Vosman)	6.5	0.6	6.0	0.5
Wh De Klerk Skool	5.9	0.6	5.5	0.5
Laerskool Panorama	5.9	0.6	5.5	0.5
Laerskool Duvhapark	5.8	0.6	5.4	0.5
Laerskool Klipfontein	5.8	0.6	5.4	0.5
Cambridge Academy	5.7	0.6	5.3	0.5
Besilindile Primary School	6.6	0.5	6.1	0.5

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Reynopark High School	5.8	0.6	5.4	0.5
Bakenveld Golf Estate	5.5	0.6	5.2	0.5
Allendale Secondary School	5.9	0.6	5.5	0.6
Khayalethu Primary School	6.1	0.6	5.7	0.5
Illanga Secondary School	5.8	0.6	5.4	0.6
Joy Creche (Duvha)	5.9	0.6	5.5	0.6
Linderus Old Age Home	5.5	0.5	5.2	0.5
Vergeet My Nie Old Age Home	5.5	0.5	5.2	0.5
Middleburg Frail Care Unit and Home For Elderly	5.4	0.5	5.1	0.5
Life Midmed Hospital	5.4	0.5	5.1	0.5
Middelburg Hospital	5.5	0.5	5.1	0.5
Makhathini Primary School	5.4	0.5	5.1	0.5
Laerskool Dennesig	5.4	0.5	5.1	0.5
Hoerskool Kanonkop	5.4	0.5	5.1	0.5
Laerskool Kanonkop	5.4	0.5	5.1	0.5
Steelcrest High School	5.4	0.5	5.1	0.5
Middelburg Primary	5.5	0.5	5.2	0.5
Middleburg Ext 6 Clinic	5.4	0.5	5.1	0.5
Sofunda Secondary School	5.4	0.5	5.0	0.5
Mhluzi Primary School	5.4	0.5	5.1	0.5
Highlands Primary School	5.5	0.5	5.2	0.5
Blinkpan Primary School	5.7	0.7	5.3	0.6
Laerskool Koornfontein	5.7	0.7	5.4	0.6
Blinkpan	5.7	0.7	5.3	0.6
Laerskool Kragveld	5.9	0.6	5.6	0.6
Pullens Hope	5.9	0.6	5.6	0.6
Arnot Colliery Primary School	5.4	0.6	5.1	0.6
Laerskool Rietkuil	5.5	0.6	5.2	0.6
Beestepan Agricultural School	5.6	0.6	5.3	0.5
Gekombineerde Skool Hendrina	5.6	0.7	5.3	0.6
Hendrina Primary School	5.6	0.7	5.4	0.6
Kwazamokuhle Secondary School	5.6	0.7	5.3	0.6
Ubuhle Bolwai Secondary School	5.6	0.7	5.4	0.7
Lothair Primary School	5.7	0.8	5.4	0.7
Warburton Combined School	5.5	0.7	5.2	0.7
Warburton Town	5.5	0.7	5.2	0.7
Kwachibikhulu Clinic	5.6	0.8	5.3	0.7
Kwachibikhulu Primary School	5.6	0.8	5.3	0.7
Carolina Hospital	5.4	0.7	5.2	0.6
Zinikeleni Secondary School (Silobela)	5.5	0.7	5.2	0.6
Volkskool Carolina	5.4	0.7	5.1	0.6
Sobuza Primary School	5.5	0.7	5.2	0.6
Ons Eie Ouetehuis (Old Age Home)	5.4	0.7	5.1	0.6
Laerskool Breyten	5.5	0.8	5.2	0.7
Siyazi Primary School (Kwazanele)	5.5	0.8	5.2	0.7
Masizakhe Secondary School (Kwazanele)	5.5	0.8	5.2	0.7
Belfast Rusoord (Old Age Home)	4.7	0.5	4.5	0.5
Belfast Hospital	4.8	0.5	4.5	0.5
Platorand School	4.8	0.5	4.6	0.5

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	75	40	25	15
Belfast Primary School (Siyathuthuka)	4.6	0.5	4.4	0.5
Siyathuthuka Clinic	4.6	0.5	4.4	0.5
Life Bethal Hospital	5.8	0.8	5.4	0.7
Hoerskool Hoogenhout	5.7	0.8	5.4	0.7
Jim Van Tonderskool	5.8	0.8	5.5	0.7
Bethal Independent Primary School	5.8	0.8	5.5	0.7
Laerskool Marietjie Van Niekerk	5.7	0.8	5.3	0.7
Laerskool Hm Swart	5.8	0.8	5.4	0.7
Sakhisizwe Primary School (Emzinoni)	5.8	0.8	5.4	0.7
Alpheus D Nkosi Secondary School (Emzinoni)	5.8	0.8	5.4	0.7
Silwerjare Old Age Home	5.8	0.8	5.5	0.7
Residentia Palm Oord	5.8	0.8	5.5	0.7
Bronkhorspruit Hospital	4.9	0.4	4.5	0.4
Cultura High School	5.1	0.4	4.7	0.4
Bronkhorspruit Primary School	4.9	0.4	4.6	0.4
Bronkhorspruit Dam	4.9	0.4	4.5	0.4
Hoerskool Erasmus	5.0	0.4	4.6	0.4
Althea Independent School	4.9	0.4	4.5	0.4
Kgoro Primary School (Zithobeni)	4.8	0.4	4.5	0.3
Zithobeni Secondary School (Zithobeni)	4.7	0.4	4.4	0.3
Vaal Power AH	4.9	0.4	4.4	0.4
Sasolburg Provincial Hospital	5.1	0.4	4.6	0.3
Moredou Old Age Home	5.1	0.4	4.6	0.3
Ons Gryse Jeug Old Age Home	5.1	0.4	4.6	0.3
Noord Primere Skool	5.1	0.4	4.6	0.3
Sasolburg High School	5.0	0.4	4.6	0.3
Sakhubusa Secondary School	5.1	0.4	4.6	0.3
Bekezela Primary School	4.8	0.4	4.4	0.3
Isaac Mhlambi Primary	5.0	0.4	4.6	0.3
Refenkgotso Primary School	4.7	0.4	4.3	0.4
Deneysville Primary School	4.8	0.5	4.4	0.4
Netcare Vaalpark Hospital	5.2	0.4	4.7	0.3
Vaalpark Articon Secondary School	5.3	0.4	4.8	0.3
Mediclinic Emfuleni	4.7	0.4	4.3	0.3
Jeugland Old Age Home	4.7	0.4	4.3	0.3
Herfsoord Huis Old Age Home	4.6	0.4	4.2	0.3
Huis Prinscilla	4.6	0.4	4.2	0.3
Laerskool Emfulenipark	5.0	0.4	4.5	0.3
Nw University_Vaal Campus	5.1	0.4	4.6	0.3
Emfuleni Primary School	4.5	0.4	4.1	0.3
Mediclinic Vereeniging	4.8	0.4	4.4	0.3
Kopanong Provincial Hospital (Duncanville)	4.7	0.4	4.4	0.3
Avondrus Eventide Old Age Home	4.8	0.4	4.4	0.3
Riviera On Vaal Resort	4.9	0.4	4.5	0.3
Sedibeng Tvet College	4.9	0.4	4.4	0.3
General Smuts High School	4.9	0.4	4.5	0.3
Eureuka School & Selbourne Primary	4.9	0.4	4.5	0.3
Midvaal Private Hospital (Three Rivers)	5.1	0.4	4.6	0.4
Three Rivers Retirement Village	5.1	0.4	4.6	0.4

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Drie Riviere Aftreeoord Old Age Home	5.0	0.4	4.6	0.4
Riverside High School	5.1	0.4	4.7	0.4
Risiville Primary School	5.1	0.4	4.6	0.4
Sebokeng Hospital	4.5	0.4	4.2	0.3
Clinix-Naledzi Private Hospital	4.5	0.4	4.2	0.3
Mohloli Secondary School	5.0	0.4	4.6	0.3
Tshirela Primary School (Boipatong)	4.5	0.4	4.1	0.3
Tsoaranang Primary School (Thepiso)	4.8	0.4	4.4	0.3
Thepiso Primary School	4.5	0.4	4.2	0.3
Emmanuel Primary School	4.8	0.4	4.3	0.3
Rust Ter Vaal Combined School	4.5	0.4	4.1	0.3
Roshnee Primary School	4.5	0.4	4.2	0.3
Roshnee High School	4.5	0.4	4.1	0.3
Hoerskool Dr Malan	4.6	0.4	4.2	0.4
Laerskool Voorwaarts	4.7	0.4	4.3	0.4
Meyerton Secondary School	4.7	0.4	4.3	0.4
Ratasetjhaba Primary School	4.5	0.4	4.1	0.3
Meyerton Primary School	4.5	0.4	4.2	0.4
Oprah Leadership Academy	4.5	0.4	4.2	0.4
Henley River Retirement Village	4.5	0.4	4.2	0.4
Henley High & Preparatory School	4.4	0.4	4.1	0.4
Randvaal Clinic	4.3	0.4	4.0	0.4
Laerskool Japie Greyling	4.3	0.4	4.0	0.4
Thomas Nhlapo Primary	4.4	0.4	4.1	0.4
Randvaal Old Age Home	4.5	0.4	4.2	0.4
Laerskool Ag Visser	4.4	0.5	4.1	0.4
Lethaba Siyangobe	4.4	0.5	4.2	0.4
Shalimar Ridge Primary School	4.5	0.5	4.2	0.4
Jw Luckoff High School	4.5	0.5	4.2	0.4
Heidelberg Hospital	4.5	0.5	4.2	0.4
Thulatsatsi Operation (Rensburg)	4.4	0.5	4.1	0.4
Silwer Akker Tehuis	4.5	0.5	4.2	0.4
Riversands Retirement Village	4.5	0.5	4.2	0.4
Qhaqholla Primary School	4.4	0.5	4.1	0.4
Ratanda Primary School	4.3	0.5	4.1	0.4
Boneha Primary School	4.4	0.5	4.1	0.4
Sithokomele Primary School	4.4	0.5	4.1	0.4
Ratanda Bertha Gxowa Primary School	4.5	0.5	4.2	0.4
Khanya Lesedi Secondary School	4.3	0.5	4.1	0.4
Ratanda Secondary School	4.4	0.5	4.1	0.4
New Ratanda Secondary School	4.5	0.5	4.2	0.4
Kgoro Ya Thuto Secondary School	4.5	0.5	4.2	0.4
Ekurhuleni School for the Deaf	4.4	0.4	4.1	0.4
Pholosong Hospital	4.4	0.5	4.2	0.4
Tsakane Home For Aged	4.5	0.5	4.2	0.4
Mmuso Primary School	4.6	0.5	4.3	0.4
Michael Zulu Primary School	4.5	0.5	4.2	0.4
Nkabinde Primary School (Thembilisha)	4.5	0.5	4.2	0.4
Nigel Clinic	4.7	0.5	4.4	0.4

Scenario D (MES)	PM10 Total		PM2.5 Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Tehuis Vir Bejaardes	4.8	0.5	4.5	0.4
Hoerskool John Vorster	4.7	0.5	4.5	0.4
Laerskool Hannes Visagie	4.8	0.5	4.6	0.4
Nigel Secondary School	4.8	0.5	4.5	0.5
Laerskool Dunnottar	4.6	0.5	4.3	0.4
Springs Retirement Village	4.6	0.5	4.3	0.4
Life Springs Parkland Hospital	4.6	0.5	4.3	0.4
Netcare N17 Hospital (Springs)	4.6	0.5	4.3	0.4
Springs Boys High School	4.6	0.5	4.3	0.4
Laerskool Selectionpark	4.6	0.5	4.3	0.4
Kwasa College Pre&Primary School	4.7	0.5	4.5	0.4
Edelweis Medical Centre	4.6	0.5	4.4	0.4
Laerskool Christiaan Beyers	4.7	0.5	4.4	0.4
Hoerskool Hugenote	4.6	0.4	4.3	0.4
Brakpan Primary School	4.4	0.4	4.1	0.4
Parkrand Primary School	4.5	0.4	4.2	0.4
Thabo Memorial Hospital	4.4	0.4	4.1	0.4
Sunward Park Hospital	4.4	0.4	4.1	0.4
Alberton High School	4.4	0.4	4.1	0.4
Netcare Clinton Hospital	4.4	0.4	4.1	0.4
Alberton Tuiste Vir Bejaardes	4.4	0.4	4.1	0.4
Bertha Gxowa Hospital	4.4	0.4	4.1	0.4
Linmed Hospital	4.4	0.4	4.1	0.4
Hoerskool Brandwag (Airfield)	4.5	0.4	4.2	0.4
Thepiso Noto Intermediate School	4.7	0.4	4.4	0.4
Laerskool Bredell	4.3	0.4	4.1	0.4
Sibonelo Primary School (Daveyton)	4.8	0.4	4.5	0.4
Petit High School (Kempton Park Nu)	4.5	0.4	4.2	0.4
Arwyp Medical Centre	4.4	0.4	4.1	0.4
Hoerskool Birchleigh	4.4	0.4	4.1	0.3
Curro Serengeti Acadamy	4.5	0.4	4.2	0.4
South Rand Hospital	4.8	0.4	4.4	0.4
Chris Hani Baragwanath Hospital	4.6	0.4	4.3	0.3
Thulani Primary School	4.6	0.3	4.3	0.3
University of Witwatersrand	4.7	0.4	4.4	0.4
Milpark Hospital	4.7	0.4	4.4	0.3
Charlotte Maxixe Academic Hospital	4.7	0.4	4.4	0.4
Thembisa West Secondary School (Thembisa)	4.2	0.4	4.0	0.3
Lenmed Zamokuhle Private Hospital (Thembisa)	4.4	0.4	4.1	0.3
Ikusasa Comprehensive School	4.4	0.4	4.1	0.3
Gem Village Old Age Home	4.3	0.3	4.0	0.3
Rustoord Old Age Home	4.1	0.3	3.9	0.3
Cornwell Hill College (Irene)	4.3	0.3	4.0	0.3
Kleinfontein Sorg Sentrum Old Age Home (Donkerhoek)	4.3	0.3	4.0	0.3
Valtaki AH (Rayton)	4.5	0.3	4.2	0.3
Laerskool Rayton (Rayton)	4.3	0.3	4.1	0.3
Tierkop AH	4.5	0.4	4.2	0.3
Redford House The Hills Private School (Mooikloof Glen)	4.5	0.4	4.2	0.3
Rietvlei View Country Estate	4.5	0.4	4.2	0.3

Scenario D (MES)	PM_{10} Total		$PM_{2.5}$ Total	
	24-hr	Ann	24-hr	Ann
Receptor	**75**	**40**	**25**	**15**
Hazeldean Curro School (Tyger Valley)	4.3	0.3	4.0	0.3
Tyger Valley College	4.2	0.3	4.0	0.3
Pretoria East Hospital (Moreletapark)	4.3	0.3	4.0	0.3
Groenkloof Old Age Home	4.1	0.3	3.8	0.3
Steve Biko Academic Hospital	4.0	0.3	3.7	0.3
Willow Ridge High School (Wilgers)	4.1	0.3	3.8	0.3
Hoerskool Waterkloof	4.3	0.3	4.0	0.3
Hoerskool Garsfontein	4.2	0.3	3.9	0.3
Afrikaanse Hoer Seunskool	4.1	0.3	3.8	0.3
Huis Silversig SAVF Old Age Home (Silverton)	4.0	0.3	3.7	0.3
Laersekool Meyerspark (Meyerspark)	4.0	0.3	3.8	0.3
Curro Academy Mamelodi	3.9	0.3	3.6	0.3
Impendulo Primary School	4.0	0.3	3.8	0.3
Nellmapius Ext 6 Primary School	4.1	0.3	3.8	0.3
Mamelodi Home For Aged	3.9	0.3	3.7	0.3

Appendix C

AIRSHED SPECIFIC HEALTH COST BENEFIT ANALYSIS

Health impact focused cost benefit analyses for Medupi and Matimba Power Stations in the Waterberg-Bojanala Priority Area

For input into the Minimum Emission Standards Exemption Report Chapter 8

21 October 2024

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PREAMBLE

This study forms part of the project entitled, "Eskom MES Exemption Applications & Decommissioning AIRs" for WSP Group Africa (Pty) Ltd appointed by Eskom SOC Limited for the preparation of the Minimum Emission Standards (MES) exemption application report.

The study investigates the health benefits and implementation costs of mitigating air pollution emissions from Eskom coal-fired power stations, Matimba and Medupi, in the Waterberg-Bojanala Priority Area. The two stations may be retrofitted with air emission abatement technologies. Matimba is scheduled for closure by 2043 and Medupi is scheduled for closure by 2071.

The methodology used in this study is based on World Health Organisation guidelines.

In addition to the authors, the contributors to this analysis include:

- Dr Mark Zunckel and Atham Raghunandan from uMoya-NILU Consulting (Pty) Ltd who were responsible for CALPUFF modelling.
- Ms Rietha Oosthuizen (independent consultant) and Dr Caradee Wright (SA Medical Research Council) who provided advice for the epidemiological evidence used in the study.
- Mr Bryan McCourt and Mr Ebrahim Patel from Eskom provided important details on scenarios and abatement technology costs.

EXECUTIVE SUMMARY

The combustion of fossil fuels results in the emission of numerous atmospheric pollutants, that include but are not limited to sulphur dioxide (SO_2), particulate matter (PM), and nitrogen dioxide (NO_2). Atmospheric pollutants have numerous negative effects on human health and increase the risk of premature mortality.

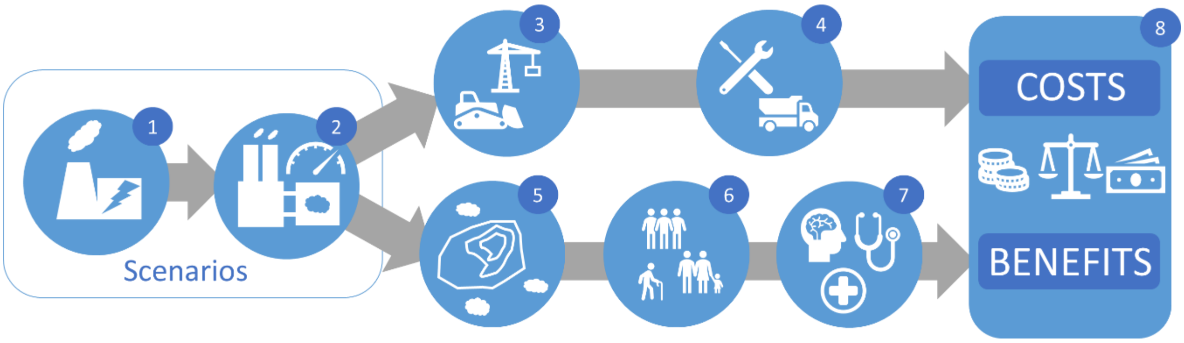
Technologies exist to reduce these emissions and therefore also their negative health effects. Abatement technologies for the power stations include wet and semi-dry Flue Gas Desulphurisation (FGD) for SO_2 reduction and installation of high-frequency power supply (HFPS) to improve Electrostatic Precipitator (ESP) efficiency and reduce PM emissions.

A benefit-cost analysis (BCA) allows for trade-offs between different scenarios to be compared to support decision making.

The aim of this study was to estimate the incremental health benefits associated with abatement technology options, to achieve or move towards compliance with the new Minimum Emission Standards (MES) of the Department of Forestry Fisheries and the Environment (DFFE).

Methodology

An integrated Air Pollution Health Risk Benefit Cost Analysis APHR-BCA model was developed to model the impacts of three different abatement scenarios as developed by Eskom. The APHR-BCA was developed following the General Principles of the World Health Organisation, WHO (WHO, 2016a), for performing air pollution health risk assessments (AP-HRA). The detailed methodology and assumptions are set out in section 2 below. In summary, the methodology proceeded through several steps, as set out in the schematic:



Health benefits resulting from air pollution abatement

The WHO (2016a) recommends that the health risk in a population, associated with air pollution, is to be estimated using exposure-response functions (ERFs). ERFs are based on Relative Risk (RR) estimates derived from primary epidemiological studies. These RR functions estimate the likelihood of health outcomes occurring in a population exposed to a higher level of air pollution relative to that in a population with a lower exposure level. RR is usually expressed as the proportional increase in the assessed health outcome risk incidence associated with a given increase in pollutant concentrations, measured in $\mu g/m^3$. The WHO (2016a) notes that "*the RR estimate cannot be assigned to a specific person; it describes risk in a defined population, not individual risk.*"

Ideally, ERF studies and their RRs should be determined based on primary epidemiological studies focussing on the exposed population. In the absence of such studies, as in the case of South Africa, the WHO (2016a) recommends using ERFs from other countries.

The health outcomes were selected based on the latest WHO systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines. The health outcome that was considered in this study is all-cause mortality. Morbidity was not considered in this study as comprehensive data on morbidity studies is not widely available. Additionally, there are issues relating the transferability of data from one population to another in terms of country and culture as populations have different sensitivities to pollutant exposure (WHO 2000).

Pollution levels, chemical composition and health care systems are typically very different in other settings, and this would affect the accuracy of the ERFs. It is important to understand at what level interval the ERFs would result in significant differences in health outcome incidences. As a result, the WHO (2016a) advises performing an assessment of the uncertainty of the analysis; in this case therefore this requires an assessment related to a lack of knowledge about one or more components of the integrated Health BCA Model. Section 2.5 discusses each source of uncertainty and related limitations. Variation in the health outcome ERFs was dealt with through performing sensitivity analysis in the BCA (refer to section 2.4).

Interpretation of the risk of premature mortality has to be done with care. It is to be noted firstly that these numbers are indicators of health risk at a population level. The relative risk estimate inherent in the ERF is a metric of the likelihood of an adverse health outcome, and it cannot be attributed to an individual person. It can thus be used to quantify risk to a defined population (and not to an individual), (WHO 2016a) and how this risk would vary between various mitigation scenarios.

In this study, the ERFs obtained from the latest WHO systematic reviews, focused exclusively on mortality and thus a monetary measure of mortality was required in order to perform benefit-cost analyses. In air pollution benefit-cost analyses, the concept of value of a statistical life (VSL) is commonly used to monetise mortality related benefits of air pollution reduction. The concept of a VSL is frequently misunderstood. It does not measure the intrinsic value of a human life, and neither does it value the economic productivity of a human. Rather, VSL is estimated by dividing an individual's willingness to pay (WTP) to reduce health risk, by the likelihood of risk reduction. Robinson and Hammitt (2009) defines VSL to represent the rate at which an individual is willing to exchange their own income for a small reduction in their own mortality risk over a particular time period. VSL is not the value that a person, society or the government would place on reducing mortality rates with certainty, but it is rather a representation of the rate at which a person views a change in the money available for spending as equivalent to a small change in their own mortality risk (Robinson et al., 2018).

Primary WTP studies for mortality risk reductions have not been done in South Africa. The VSL for South Africa in the BCA was determined by using the methodology as advised by Viscusi and Masterman (2017) and Robinson et al. (2018) with a base VSL from the U.S, GNI per capita for income measures and adjusted by income elasticity. As advised by Robinson et al. (2018), a sensitivity analysis is conducted to explore various VSL estimates.

Scenario assessment

The three scenarios evaluated in the BCA study, against a baseline included:

- Scenario ERP 2024 A (PM reduction, generating load capped, air quality offsets and SO_2 reduction at Medupi)
- Scenario ERP 2024 B (As per ERP 2024 B)
- Scenario ERP 2024 C (Full compliance with MES for PM, NOx and SO_2 for both Medupi and Matimba)

The detailed emission abatement measures relevant to the scenarios are set out in Table 2-3 in Section 2.3.3. A key difference in the scenarios is the number of stations which are installed with SO_2 reduction technology in the form of wet-Flue Gas Desulphurisation (FGD) or semi-dry FGD. The focus on SO_2 reduction is important given the extent to which it is anticipated to impact on air quality and public health and the very significant cost of SO_2 reduction.

Health benefits associated with each scenario were calculated against the baseline (FY 25) that took into account the anticipated increase in loads in the coming years from 2025 and assumed no additional abatement technologies installed and both stations would continue to emit air pollution at their current rates until shutdown, repowering and repurposing.

- The health benefits of ERP 2024 A deliver immediate impact from 2024. At Medupi Wet FGD is commissioned from 2028 to 2032. Both stations already operate at NOx = 750 mg/Nm^3. Medupi already has Fabric Filter Plant (FFP) for PM reduction. Matimba station is equipped with ESP + HPPS for optimisation of PM reduction. These increase the associated health benefits until 2039. Hereafter the associated health benefits reduce as Matimba shutdown, repowering and repurposing is between 2039 and 2043. Medupi station shutdown, repowering and repurposing is much later from 2065 and the health benefits from the Wet FGD continue until final closure of the station.
- The health benefits of ERP 2024 B include those as discussed for ERP 2024 A above. In addition, efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Medupi and Matimba from 2024 onwards.
- The health benefits of ERP 2024 C include those as discussed for ERP 2024 A and B above. Semi-dry FGD is installed at Matimba by 2035, however the associated health benefits are effectively negated as Matimba starts to shut down in 2039.

With respect to the **abatement costs** associated with each scenario:

- The total Capex and Opex costs of abatement are identical to 2024.
- ERP 2024 A implementation starts in 2025 with Matimba ESP + HFPS technology and in 2028 with Medupi, Wet FGD installation. After 2032 only operational costs continue at Medupi.
- ERP 2024 B is the same as ERP 2024 A discussed above.

- ERP 2024 C is the same as described for ERP 2024 A and B. In addition, implementation starts in 2031 with Matimba semi-dry FGD. The Capex costs decrease after 2032 as Medupi Wet FGD is fully installed and only the Capex of the Matimba semi-dry FGD remains until 2035 whereafter only operational costs remain. After closure of Matimba in 2043 only Medupi continues to operate.

The BCA ratios need to be interpreted with care. They are meant only to provide a perspective on and inform the decision-making process underlying the scenarios. They are not meant to be interpreted as a definitive answer to making abatement decisions. Decisions involving human health have to be informed by non-economic criteria as well. In addition, with uncertainty inherent in the analysis, the cost benefit ratio should thus not be viewed as absolute, but rather as a relative value from which to compare scenarios.

The **BCA results** are provided in Table 0-1. In the upper estimates the lower costs and higher VSL are used and in the lower estimates the higher costs and lower VSL are used as recommended by Robinson et al. 2018.

- The BCA central ratio of ERP 2024 A is significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The reasons for this include the implementation of FGDs at Medupi in conjunction with the small population that benefits. This scenario has a total nominal cost of R58,660 million and is likely to increase electricity tariffs by 0.6% - 0.9% in ERP 2024 A.
- The BCA ratio of ERP 2024 B is also significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The same reasons apply as for ERP 2024 A above. This scenario has a total nominal cost of R58,660 million and is likely to increase electricity tariffs by 0.6% - 0.9% as in ERP 2024 A.
- The BCA ratio of ERP 2024 C is also significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. This scenario has a larger discrepancy in NPV of health benefits and NPV of costs due to implementation of FGDs at both Medupi and Matimba and the small population that benefits. This scenario has a total nominal cost of R101,670 million and is likely to increase electricity tariffs by 0.9% - 1.2% in ERP 2024 C.
- Evaluation of the BCA ratios at a social discount rate of 2% delivers similar results, with all three scenarios ratios remaining less than 1.

Table 0-1: BCA ratios (lower and upper ranges) for each scenario (discounted at Eskom WACC)

	ERP 2024 A		ERP 2024 B		ERP 2024 C	
Million Rands	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
NPV of Costs	-18,970	-13,437	-18,970	-13,437	-27,716	-19,632
NPV of Benefits	3	17	8	39	16	83
NPV of Benefits minus Costs	-18,967	-13,420	-18,962	-13,398	-27,700	-19,549
Benefit:Cost Ratio (*range*)	0.0002	0.0012	0.0004	0.0029	0.0006	0.0042
Benefit:Cost Ratio (*central*)	0.0007		0.0017		0.0024	

ACRONYMS AND ABBREVIATIONS

AP-HRA	Air Pollution Health Risk Assessment
AQA	Air Quality Act
AQMS	Air Quality Monitoring Station
BCA	Benefit-Cost Analysis
CFOI	Census of Fatal Occupational Injuries (USA)
COI	Cost of Illness
DEA	Department of Environmental Affairs (now DFFE)
DFFE	Department of Forestry Fisheries & Environmental Affairs
DSI	Dry Sorbent Injection
ERF	Exposure Response Function
ESP	Electrostatic Precipitators
FFP	Fabric Filter Plants
FGD	Flue Gas Desulphurisation
GNI	Gross National Income
ICD	International Classification of Diseases
kW	Kilowatt
kWh	Kilowatt Hour
MES	Minimum Emissions Standards
NAAQS	National Ambient Air Quality Standard
NAQI	National Air Quality Index
NEMA	National Environmental Management Act
NO_2	Nitrogen Oxide
NPV	Net Present Value
PM	Particulate Matter
RR	Relative Risk
SAMRC	South African Medical Research Council
SO_2	Sulphur Dioxide
USA	United States of America
VSL	Value of a Statistical Life

WBPA	Waterberg-Bojanala Priority Area
WHO	World Health Organisation
WACC	Weighted Average Cost of Capital
WTP	Willingness to Pay

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1 INTRODUCTION

The Earth Summit[1] in Rio de Janeiro in 1991 raised the awareness of the linkages between environmental health and human wellbeing to a global agenda. In the three and half decades since the Summit, significant effort has gone into methods for quantifying these linkages, in all environmental spheres, and informing policy development. During the same period, we have seen an information technology revolution, which has radically improved our ability to collect and analyse large data sets. In the field of air quality health risk assessment specifically, there has been a rapid and continuously improving set of methodologies through which to analyse the linkages between air pollution and health risk.

The World Health Organisation (WHO) has been leading the development of health risk assessment methodology. Formally, air pollution health risk assessments (AP-HRA) are performed to provide quantifiable information for informing public policy decisions. The general principles for AP-HRAs have been published by the WHO (WHO, 2016a). An AP-HRA proceeds through three steps.

Firstly, it assesses the exposure of the target population to specific air pollutants. This requires a quantification of constituents in the atmosphere that are associated with human health risks. The atmosphere we breathe contains various such constituents, both from natural sources (e.g. sea salt and bio-aerosols) and anthropogenic sources (e.g. fuel combustion, suspension of fine particles, and industrial emissions) (refer to FRIDGE (2004) for a comprehensive discussion of pollution sources). When a particular policy option is analysed, specific indicator constituents need to be selected, and the incremental effect of the policy option needs to be estimated in terms of population exposure. In this study, incremental population exposure resulting from Eskom's coal-fired power plant emissions (from two stations in the Waterberg), was estimated through the use of dispersion modelling (uMoya-Nilu, 2024).

Secondly, the AP-HRA estimates the resultant incremental change in health risk. This requires the application of exposure-response functions (ERFs). ERFs quantify the incremental change in health outcomes (compared to the baseline incidence), based on changes in exposure to pollutants. ERFs are derived from epidemiological studies, which are large scale population health studies that compare health outcome incidence between populations exposed to different concentrations of pollution. In this study, ERFs from the latest systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines were used (WHO 2020, 2021). AP-HRA results can be reported in terms of morbidity indicators (e.g. cost of medical treatment and lost economic productivity) or mortality indicators (e.g. premature mortality). These indicators can be converted to monetary impacts by applying cost of illness (COI) methodologies. In this study, premature mortality was evaluated, using a value of a statistical life (VSL) COI methodology.

Thirdly, the AP-HRA process requires the quantification and expression of the uncertainty of the estimated health effects. The WHO states that this step is "*an important and integral component of the results, and … vital to ensure both that the main message is not lost and that the results*

[1] http://www.un.org/geninfo/bp/enviro.html

produced are understandable by policy-makers and others who do not necessarily have a technical background or expertise in AP-HRA." This step requires "*the use of expert judgement (consensus) on the level of confidence of the results*".

This study investigates the health effects of air pollution resulting from two coal-fired power stations in the Waterberg-Bojanala Priority area and applies the AP-HRA methodology described above.

The indicator pollutants used included sulphur dioxide (SO_2), particulate matter (PM), and nitrogen dioxide (NO_2). These pollutants have several negative impacts on public health (WHO, 2016b).

The Department of Forestry, Fisheries and the Environment (DFFE) under the National Environmental Management Act (NEMA: AQA, 2004) sets ambient air quality standards. Where ambient air quality standards are exceeded, specific air quality mitigation actions would be required. Power generation is a Listed Activity in terms of Section 21 of the NEMA: AQA and Minimum Emission Standards (MES) are prescribed for existing and new stations. In 2018 amendments were made to the list of activities and associated minimum emission standards in terms of section 21 (4)(a). Eskom was granted MES postponements for SO_2 at Medupi and Matimba to 2025 (DEA, 2018 a & b). The May 2024 ruling by the Minister of the Department of Forestry, Fisheries and the Environment requires that Eskom submit application in terms of Section 59 of the National Environmental Management: Air Quality Act (NEMA: AQA), for the exemption of the MES for eight power stations that will continue to operate beyond 2030. Matimba and Medupi are included in these eight stations.

Technologies exist for the reduction of emissions and therefore the health effects. These abatement technologies include Flue Gas Desulphurisation (FGD) and Dry Sorbent Injection (DSI) to reduce SO_2, Electrostatic Precipitators (ESP) and high-frequency power supplies (HFPS) to improve Electrostatic Precipitators (ESP) efficiency to reduce PM, Low NO_X Burners (LNB) to reduce NO_2 and Fabric Filter Plants (FFP) to reduce PM.

The current study investigated three air pollution mitigation scenarios for Eskom, through a benefit-cost analysis (BCA). The BCA uses the AP-HRA methodology to estimate the likely changes in health costs resulting from each scenario. The BCA compares these benefits against the capital costs and operational costs of the mitigation options for each scenario (refer to section 2.3).

1.1 Other studies

Other studies have previously been conducted to estimate the health impacts of either fossil fuel power stations, air pollution in general or specific sources in South Africa. They estimated morbidity and mortality, and in some instances attributed costs to these health impacts. Studies of this nature can take either bottom up (deterministic) approaches or top down (stochastic) approaches to modelling pollution exposure with the latter usually preferable in data poor environments or large spatial domains (Dios et al., 2012). These studies also varied in geographic scale, ranging from selected areas to the national scale. Some of the most recent and relevant include:

The World Health Organisation estimated that, in South Africa, in 2009, the relative risk of premature mortality attributed to poor outdoor air quality was approximately 1,100 cases per year (WHO, 2009).

- Scale: National (All Air Pollution)
- Resolution: Course
- Health Outcomes: Mortality
- Modelling Approach: Top-down

The Centre for Research on Energy and Clean Air estimated that full Minimum Emissions Standard (MES) compliance at Eskom power stations remaining in operation until 2030 would reduce the relative risk of premature mortality from air pollution by 2,300 cases per year and economic costs of R42 billion per year (Myllyvirta & Kelly, 2023). The impacts of mercury were also estimated in the study.

- Scale: National (Power Station Air Pollution)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

The Institute for Health Metrics and Evaluation listed air pollution as the 9th largest risk factor driving death and disability combined in 2016 in South Africa (IHME, 2016).

- Scale: National (All Air Pollution)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A study commissioned by Greenpeace in 2014 estimated air pollution emissions from Eskom's coal-fired power stations could increase the relative risk of premature mortality from air pollution by as much as 2,200 cases per year (Myllyvirta, 2014). The study also estimated the impacts of mercury pollution.

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A 2017 study commissioned by Groundwork, estimated the total impact of air pollution resulting from the coal-fired power stations at $2.4 billion of health costs annually in South Africa (Holland, 2017).

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

Van Horen (1996) evaluated the health costs associated with Eskom's power stations as part of understanding the true costs of electricity generation. The valuation of morbidity outcomes was found to be small in terms of costs per kWh generated.

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

The Fund for Research into Industrial Development Growth and Equity, in 2004, assessed the economic impact of air pollution in selected areas in South Africa. The study found that power generation was responsible for 51% of the 8,700 respiratory cases in Mpumalanga (FRIDGE, 2004).

- Scale: Selected Areas (All Air Pollution and Air Pollution from Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A review by Spalding-Fecher and Matibe in 2003 aimed to calculate the external costs of electric power generation in South Africa. They estimated the health costs to be R1.1 billion per year (Spalding-Fecher and Matibe, 2003).

- Scale: National (Air Pollution from Power Stations)
- Resolution: Low
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Top-down.

The methodology used in this investigation is discussed in detail in Section 2 below.

2 METHODOLOGY AND INPUTS

2.1 Overview

An integrated Health BCA Model was developed that combined an AP-HRA with a BCA to assess three air pollution mitigation scenarios for two Eskom coal-fired power stations in the Waterberg region.

Figure 2-1 below provides an overview of the methodology, and Sections 2.2 - 2.5 provide a more detailed discussion of each component.

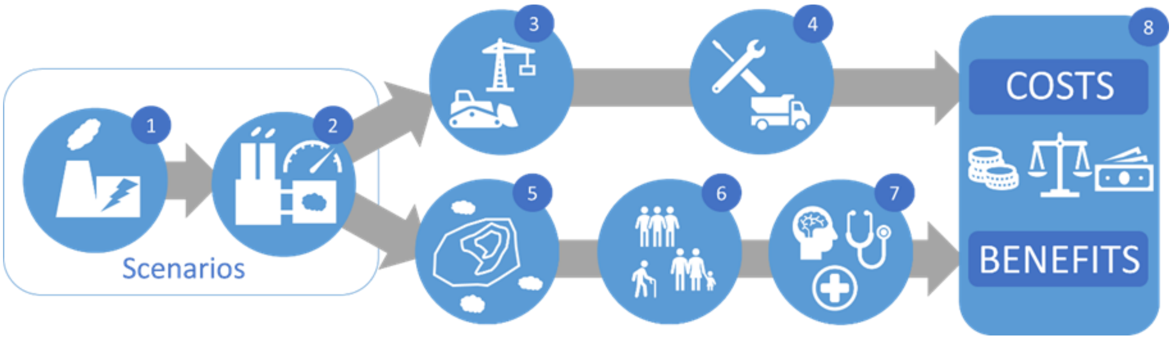


Figure 2-1: Overview of methodology and model architecture

With reference to Figure 2-1, the integrated Health BCA Model includes the following components:

1. Station lifetimes were described for two coal-fired power stations, Medupi and Matimba, and included commissioning and shutdown, repowering and repurposing dates (provided by Eskom).
2. Abatement technologies required for the two power-stations as required in each scenario were defined, by type and likely implementation schedule (refer to section 2.3.3).
3. Capital expenditure required for abatement in each scenario and was obtained from Eskom and attributed per station and per year (refer to section 2.3.4).
4. Operational expenditure required for abatement in each scenario was and was obtained from Eskom and attributed per station and per year (refer to section 2.3.4).
5. Dispersion modelling was done by uMoya-NILU Consulting (Pty) Ltd. This data was then segregated spatially, by municipal ward boundaries to align with population data. Two types of dispersion modelling were performed, one modelling the individual power station predicted ambient concentrations of SO_2, PM, and NO_2 per scenario and the other the cumulative predicted ambient concentrations of SO_2, PM, and NO_2 from both power stations per scenario. Note that for PM, the dispersion modelling predicted primary PM and secondary PM effects, resulting from NO_2 and SO_2 reactions in the atmosphere, as well as fugitive emissions (refer to Section 2.2).
6. Population exposure was estimated at a spatial resolution of municipal wards. At each municipal ward, the number of people exposed to different concentration

ranges were determined per scenario per year, based on Stats SA population estimates and United Nations population growth forecasts (refer to Section 2.2).

7. Health impacts were determined by using the AP-HRA methodology. Epidemiological evidence, in the form of Exposure-response functions (ERFs) and baseline incidence rates were obtained from the World Health Organization (WHO) systematic reviews (2020 & 2021) conducted by various researchers for the WHO as part of the WHO update to the Global Air Quality Guidelines (released in late of September 2021) (refer to Section 2.3). The ERFs were limited to mortality incidence. The Cost of Illness (COI) methodology used was the value of a statistical life (VSL). This method estimates the willingness to pay (WTP) of an individual for reducing their health risk. The VSL should not be interpreted as the intrinsic value of a life. Refer to Section 2.3.2 for a more detailed discussion.
8. The BCA compares the overall scenario health benefits achieved through abatement to the costs of implementation. The outputs of the AP-HRA, i.e. the health cost savings of each scenario, was used as the benefit. The analysis timeline spans 2024 – 2045. (refer to Section 2.4). Finally, an assessment of uncertainty of the results was done (refer to Section 2.5).

2.2 Exposure of the target population to specific air pollutants

2.2.1 Overview

This section comprises the first step of the AP-HRA and assesses the exposure of the target population to specific air pollutants.

This requires an incremental effects quantification of constituents in the atmosphere that are associated with human health risks. These pollutants include SO_2, PM, and NO_2 emitted by the two coal-fired power stations investigated. The emissions from these stations impact the Waterberg-Bojanala Priority area in the Limpopo province of South Africa.

Dispersion modelling combined with population distribution provided an estimate of the exposed population.

2.2.2 Pollutants analysed

The Waterberg-Bojanala Priority Area (WBPA) has three ambient Air Quality Monitoring Stations, Marapong, Medupi and Lephalale stations equipped for continuous monitoring of air quality and meteorological parameters. Marapong AQMS and Medupi AQMS were established by Eskom in 2006 and 2014 respectively and Lephalale is SAWS-DEA owned NAQI (National Air Quality Index) station that was established by DEA (now DFFE) in 2012.

The sections that follow provide a summary of the ambient concentrations of SO_2, NO_2 and PM in the period of 2021 to 2023 at the AQMS at Matimba and Medupi power stations. In the WBPA the main sources of air pollution include agriculture activities, domestic fuel and waste burning, vehicle emissions, mining activities and power generation.

2.2.2.1 Sulphur dioxide (SO_2)

Industrial processes and power generation are the main source of SO_2 in the atmosphere through the combustion or refining of sulphur containing fuels.

During the analysis period from 2021 to 2023, the hourly, daily and annual SO_2 ambient concentrations at Medupi and Lephalale monitoring stations were within the National Ambient Air Quality Standards (NAAQS). There were no exceedances recorded for this time period at Medupi and Lephalale monitoring stations. At Marapong AQMS the hourly, daily and annual SO_2 ambient concentrations were below the NAAQS for 2021 with no exceedances recorded. At this station data recovery for 2022 and 2023 was below 50% and thus not reflected in the analyses.

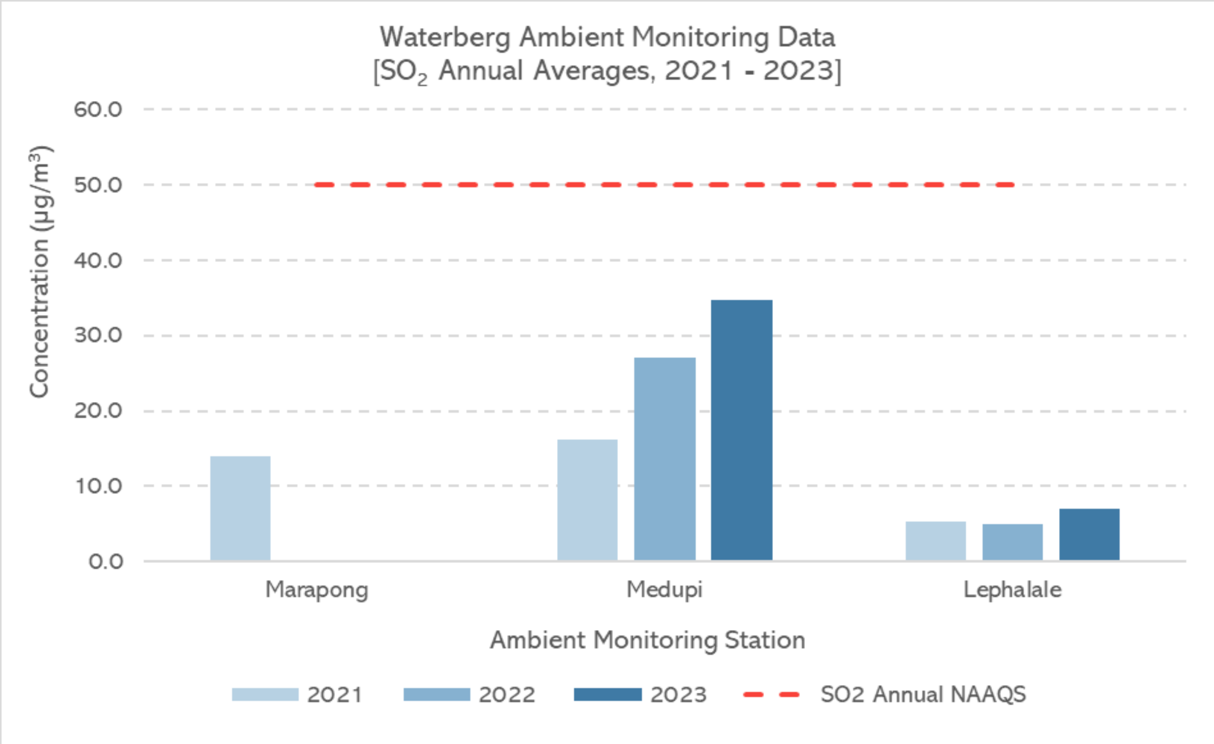


Figure 2-2: Annual average SO_2 concentrations at the Marapong, Medupi and Lephalale AQMS

2.2.2.2 Nitrogen dioxide (NO_2)

Industrial processes and power generation are the main source of NO_2 in the atmosphere through the combustion or refining of fossil fuels, with some contribution from motor vehicle emissions, residential fuel burning and biomass burning.

At Marapong the hourly concentrations for 2021 and 2022 were below NAAQS and no exceedances were recorded and the annual average concentrations were below the average NAAQS for 2021. The hourly concentrations and the annual average concentration for 2021 to 2023 at Medupi and Lephalale monitoring stations were below the average NAAQS with no hourly exceedances recorded.

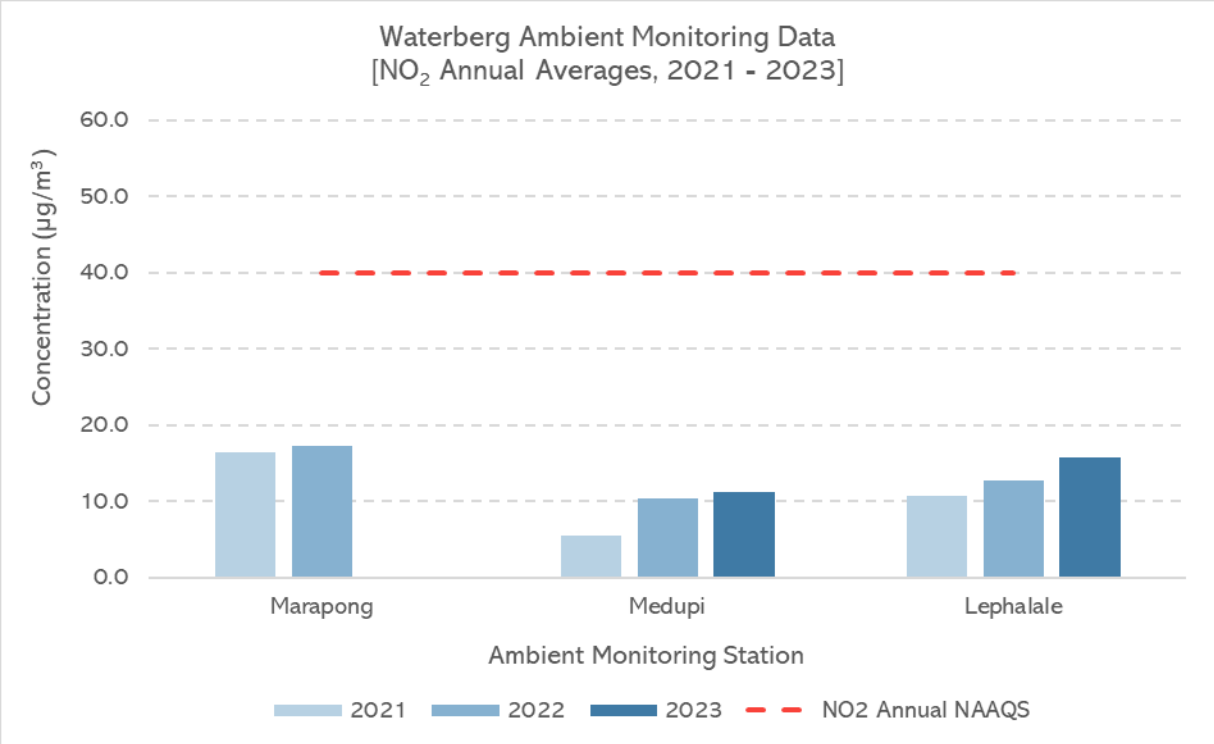


Figure 2-3: Annual average NO_2 concentrations at the Marapong, Medupi and Lephalale AQMS

2.2.2.3 Particulate matter (PM)

There are numerous sources of primary particulate matter, including power generation, industry, mining, biomass burning and agricultural activities, as well as natural sources such as wind entrainment. In addition, secondary PM is produced by NO_2 and SO_2 reactions in the atmosphere.

At the Marapong and Medupi monitoring stations the daily $PM_{2.5}$ and PM_{10} concentrations in 2021 and 2022 were non-compliant with the NAAQS with multiple exceedances reported. The annual average concentrations at Marapong station for PM_{10} in 2021 exceeded the NAAQS average and the annual average concentrations of $PM_{2.5}$ in 2021 and 2022 respectively exceeded NAAQS average and remain non-compliant. At Medupi station annual average concentrations of PM_{10} for 2021 to 2023 exceeded the average NAAQS and the 2021 concentrations for $PM_{2.5}$ also exceeded the average and is thus non-compliant for PM.

The daily and annual average PM_{10} concentrations at the Lephalale station remained below the NAAQS in 2021 and 2023 with one daily exceedance recorded in 2021 and no exceedances recorded in 2023, thus remaining compliant. The daily $PM_{2.5}$ concentrations in 2023 remained below the NAAQS with no exceedances recorded and in 2021 the annual average $PM_{2.5}$ concentrations remained below NAAQS and thus remains compliant. (WSP, 2024)

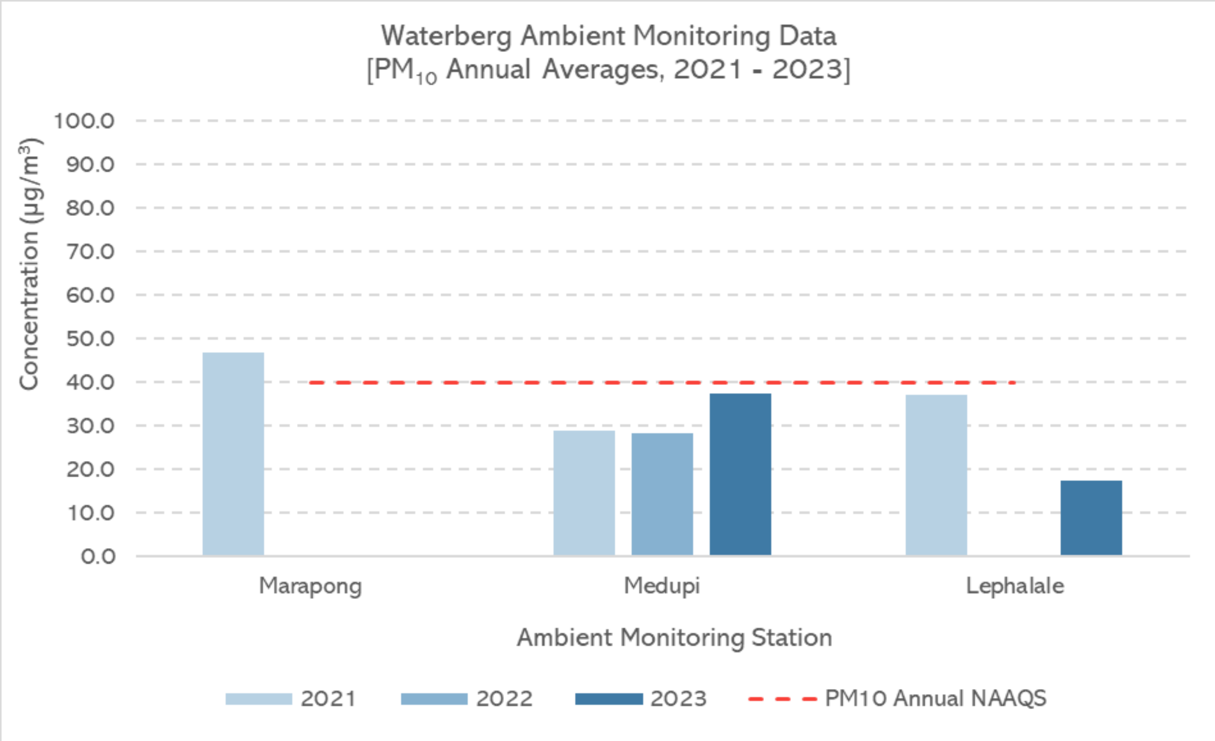


Figure 2-4: Annual average PM_{10} concentrations at the Marapong, Medupi and Lephalale AQMS in µg.m³

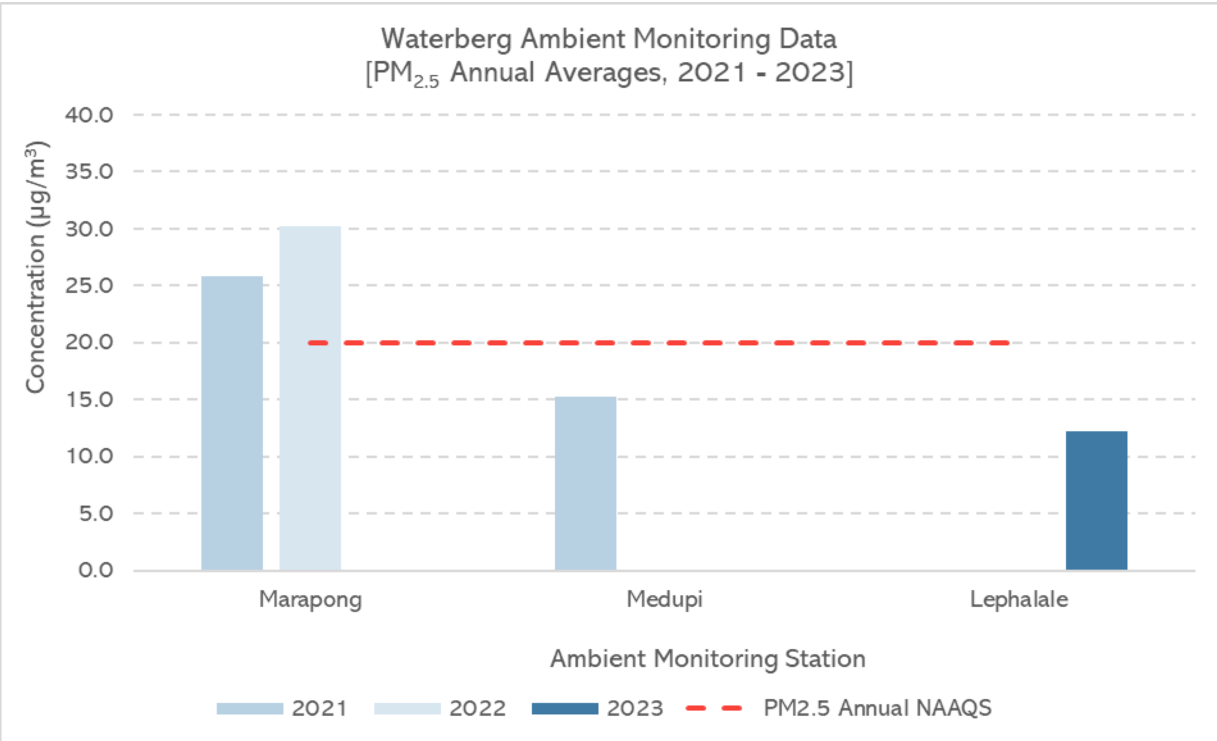


Figure 2-5: Annual average $PM_{2.5}$ concentrations at the Marapong, Medupi and Lephalale AQMS in µg.m³

2.2.3 Description of power stations

The Eskom power stations forming part of this study in the Waterberg-Bojanala Priority Area are Matimba and Medupi. These power stations will have a combined installed capacity of 8,754 MW and are listed in Table 2-1.

Table 2-1: Eskom coal-fired power stations, used in this study, and their installed capacity (Eskom, 2023)

Power Station	Province	Installed capacity (MW)
Matimba	Limpopo	3,990
Medupi	Limpopo	4,760

2.2.4 Dispersion modelling

Dispersion modelling is required to estimate the effects of stack emissions on ambient concentrations of pollutants and describe them spatially.

Dispersion modelling for this study was conducted by uMoya-NILU Consulting (Pty) Ltd and followed the requirements of the Code of Practice for Air Dispersion Modelling, DEA guideline (DEA, 2014).

The work modelled the dispersion of sulphur dioxide (SO_2), primary and secondary particulate matter (PM), fugitive emissions and nitrogen dioxide (NO_2) for the Matimba and the Medupi power stations. Dispersion modelling was performed using the CALPUFF suite of models. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time and space-varying meteorological conditions on pollution transport, transformation and removal. It includes algorithms for sub-grid scale effects, such as terrain effect, as well as longer range effects, such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, and the formation of secondary particulate matter. The Air Pollution Model (TAPM) was used to model surface and upper air meteorological data for the study domain.

Two types of analysis were performed, individual and cumulative models. Individual station dispersion modelling results had a modelling domain covering 4,356 km^2 where the domain extends 66 km (west-east) by 66 km (north-south) and consists of a uniformly spaced receptor grid with 0.5 km spacing, giving 17,424 grid cells (132 x 132 grid cells). The cumulative station dispersion modelling results had a modelling domain that covers an area of 11,664 km^2, where the domain extends 108 km (west-east) by 108 km (north-south) and consists of a uniformly spaced receptor grid with 1 km spacing, giving 11,664 grid cells (108 x 108 grid cells).

There were two baseline scenarios modelled in CALPUFF that are used in the study. The first one (Scenario 1) represents the current performance of stations based on data over the three year period of 2021 to 2023. The second baseline (Scenario A baseline) took into account the anticipated increase in loads (due to several aspects such as economy requirements, possible delays in IPP projects coming online etc.) in the coming years from 2025 to 2030 and is a better representation of what will be happening in the next five years. Scenario A baseline was used for comparison with the different scenarios in the BCA.

Individual power station models: Five emissions scenarios have been modelled for Matimba and Medupi Power Stations individually. These are (1) Scenario 21-23 Actual (Current Scenario 1 Current actual emissions), (2) Scenario FY25 (Baseline Scenario - Emission based on anticipated loads), (3) ERP 2024 A (Scenario B - 2031 planned stack emissions), and (4) ERP 2024 B (Scenario C - 2036 planned stack emissions), (5) Scenario D (Emissions in Full MES compliance 2036) Emissions sources at Matimba included stacks, coal stockpile and ash dump, while those at Medupi included stacks, coal stockpile, excess coal stockyard and ash dump.

Cumulative impact: The same five emissions scenarios listed above have been modelled for Matimba and Medupi Power Stations to assess the combined effect of these power stations on the ambient air quality.

Isopleth maps of predicted ambient SO_2, NO_2, PM_{10} and $PM_{2.5}$ concentrations are presented in Figure 2-6 to Figure 2-9. The predicted concentrations are shown as isopleths, lines of equal concentration, in $\mu g/m^3$ for the respective NAAQS averaging periods. The isopleths are depicted as coloured lines on the maps, corresponding to a particular predicted ambient concentration. Areas within red isopleths indicate an area where exceedances of the respective NAAQS limit value are predicted to occur. Exceedance is only seen for PM_{10} and $PM_{2.5}$ close to the stations. Sensitive receptors are represented by green squares and AQMS are represented by white dots on the maps. (uMoya-NILU, 2024).

National Ambient Air Quality Standards (NAAQS) (DEA, 2009, 2012) apply to the pollutants emitted by stations. The NAAQS consists of a 'limit' value and a permitted frequency of exceedance. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant and the permitted frequency of exceedance represents the acceptable number of exceedances of the limit value expressed as the 99th percentile. Compliance with the ambient standard implies that the frequency of exceedance of the limit value does not exceed the permitted tolerance. The NAAQS limits for the averaging period of 1 year for SO_2 is 50 $\mu g/m^3$, for NO_2 is 40 $\mu g/m^3$, for PM_{10} is 40 $\mu g/m^3$ and for $PM_{2.5}$ is 20 $\mu g/m^3$ (from 2030 is 15 $\mu g/m^3$).

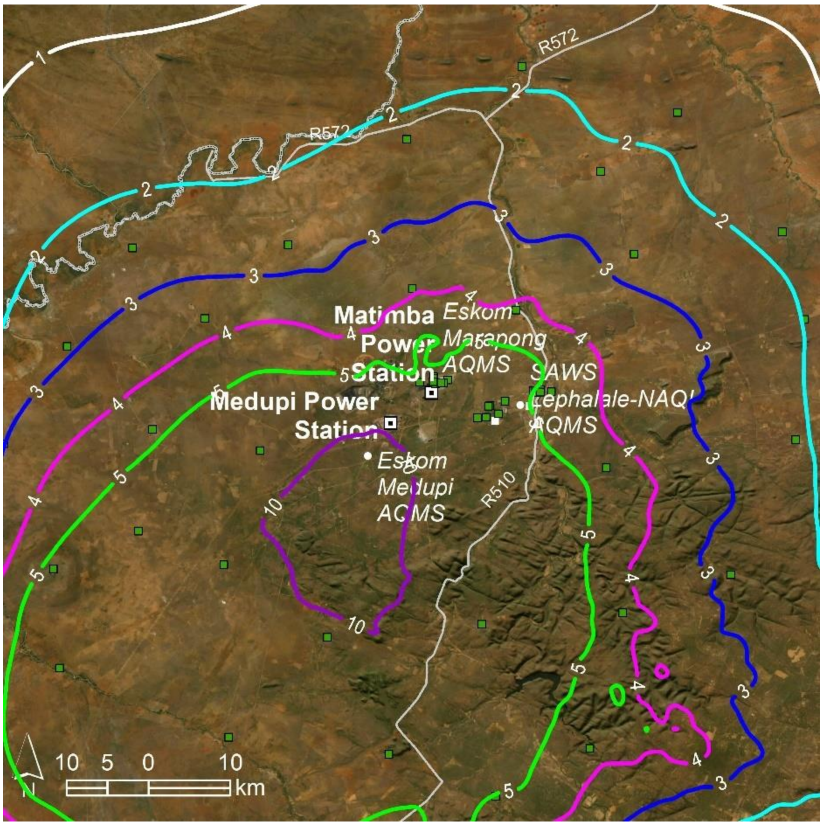


Figure 2-6: Cumulative predicted annual average SO_2 concentrations ($\mu g/m^3$) for Matimba and Medupi Power Stations.

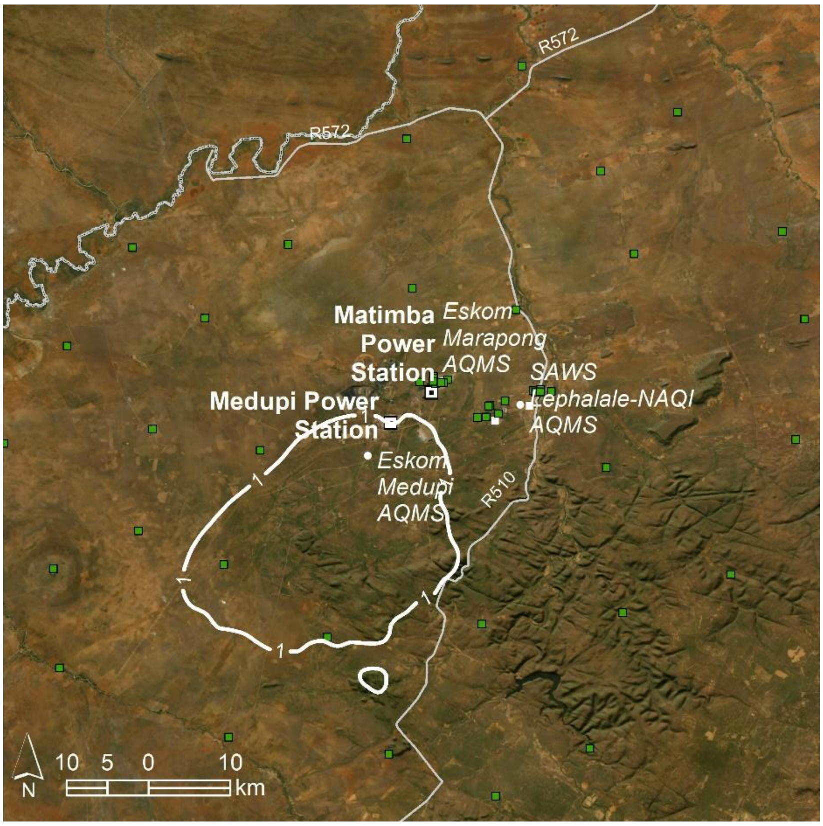


Figure 2-7: Cumulative predicted annual average NO_2 concentrations ($\mu g/m^3$) for Matimba and Medupi Power Stations.

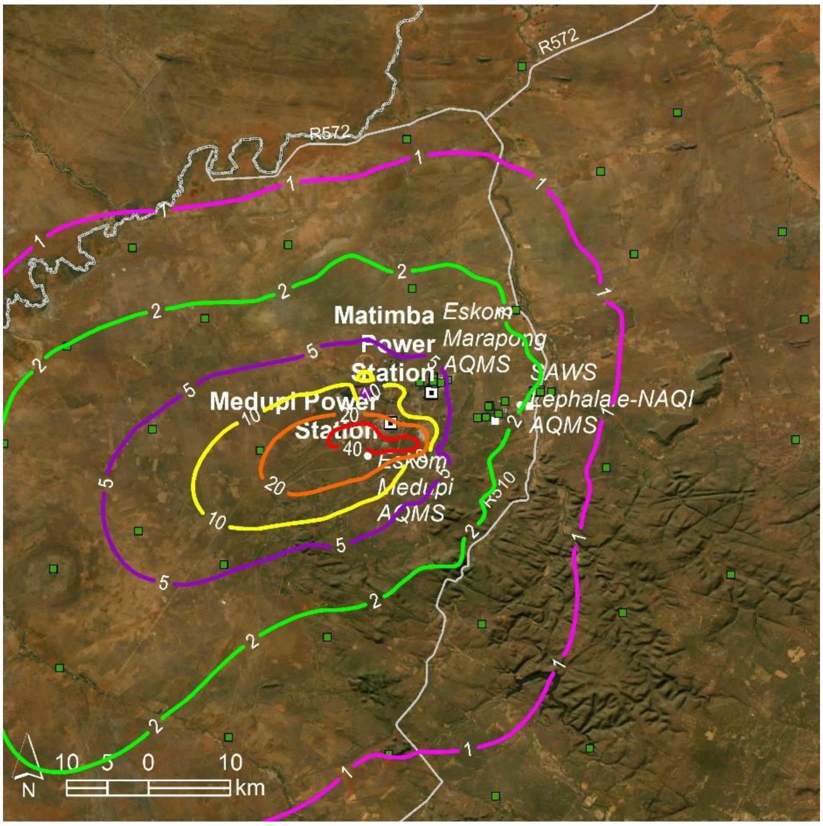


Figure 2-8: Cumulative predicted annual average PM_{10} concentrations (µg/m³) for Matimba and Medupi Power Stations.

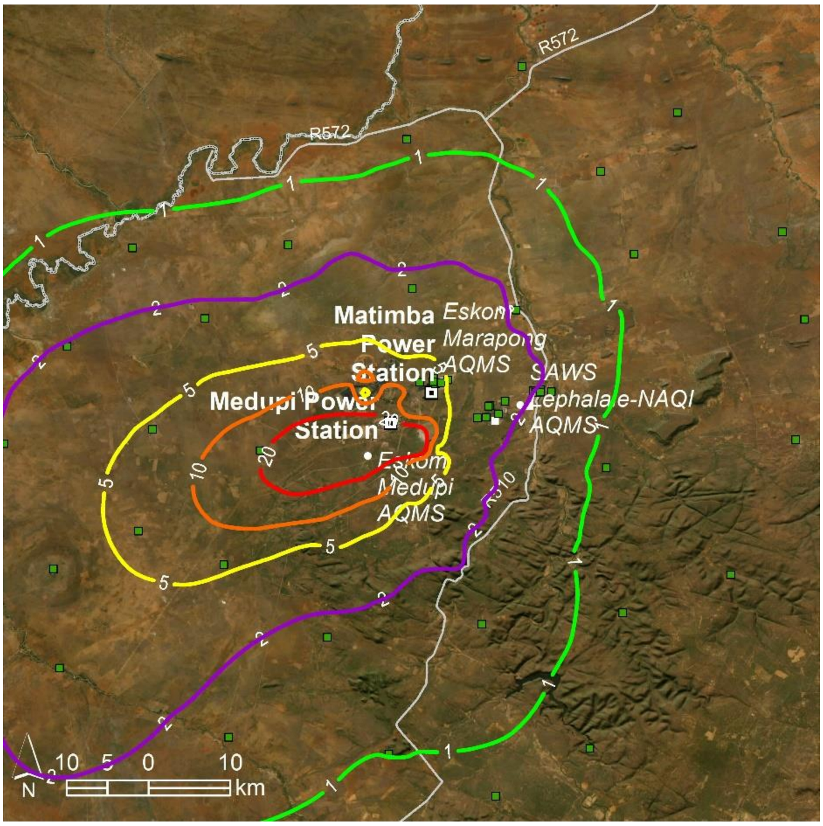


Figure 2-9: Cumulative predicted ambient PM_{10} concentrations (µg/m³) for Matimba and Medupi Power Stations.

2.2.5 Population exposure

Population exposure was estimated at a spatial resolution of municipality and municipal wards. At each municipality or ward, the number of people exposed to different concentration ranges were determined based on Stats SA population estimates (Stats SA, 2012; Stats SA, 2024a,b) and United Nations population prospects growth forecasts (United Nations, 2024).

Population exposure was estimated at a spatial resolution of municipal wards for the data from the dispersion model runs. At each ward, the number of people exposed to different concentration ranges for each pollutant were determined per scenario per year. A small area of the model falls within Botswana and the number of people exposed within this area was also estimated and included in the model runs. Particulate matter (PM) in the model took the primary and secondary particulate matter into account.

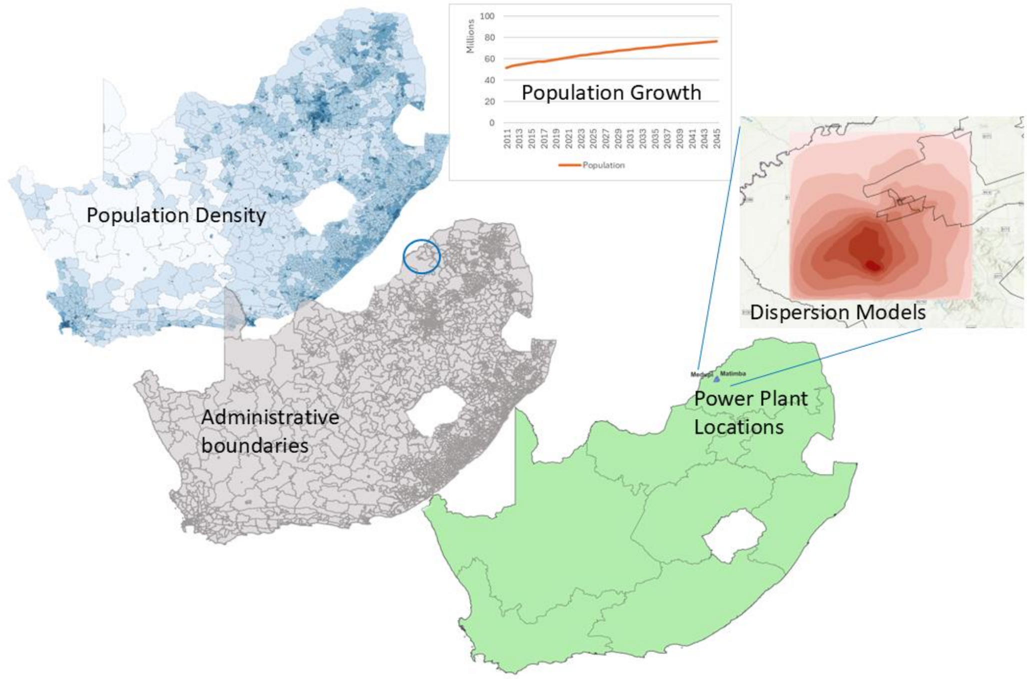


Figure 2-10: Overview of population exposure calculation

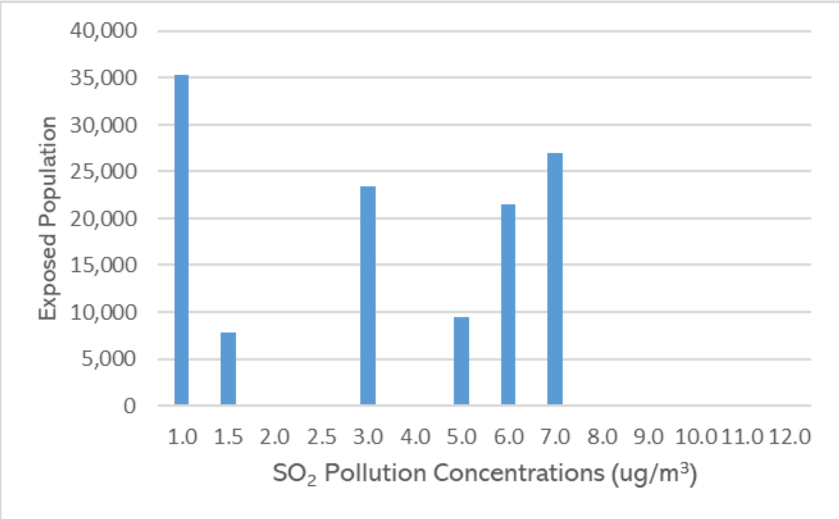
The integrated Health BCA model calculated pollution exposure as follows:

- Dispersion Model outputs were used to spatially apportion pollution concentrations. The co-ordinates (x;y) of receptors from the output files were attributed to specific administrative boundaries.
- Administrative boundaries used were municipalities and municipal wards. The predicted ambient concentrations for each pollutant were averaged for the entire spatial unit.
- Population density (population per ward) was obtained from the Census 2011 (Stats SA, 2012), given that the latest Census 2022 metadata which includes ward level numbers has not been released.
- Total population was obtained from the latest available mid-year population estimates (Stats SA, 2024a,b). Population data for Botswana was obtained from

Census/projection-disaggregated gridded Botswana population datasets (Bondarenko et al. 2020).

- Population growth forecasts were used to determine the growth in population exposure over time (United Nations, 2024). This was used to grow the population numbers in each year following 2024 to the end of the modelled timeframe year of 2045.
- Power station locations were used to determine the wards which were affected by each station, to estimate relative impacts of each power station to the cumulative impact modelled.

If one considers current emissions from Matimba and Medupi over the period 2021 to 2023, approximately 125,000 people in the population were exposed to concentration ranges above 1 µg/m^3 (mean annual average) of SO_2 due to the two power stations. Similarly, 81,000 people were exposed to more than an additional 1 µg/m^3 of PM. During this period there were no ambient concentrations of NO_2 exceeding 1 µg/m^3 from the power stations.



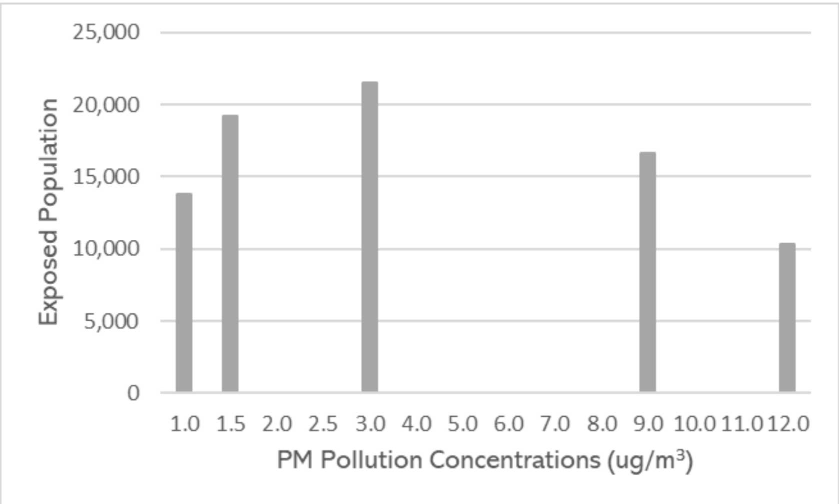


Figure 2-11: Population exposure to SO_2 and PM mean annual average concentration ranges above 1µg/m^3.

2.3 Incremental change in health risk

2.3.1 Health impacts

The WHO (2016a) recommends that the health risk in a population, associated with air pollution, is to be estimated using exposure-response functions (ERFs). ERFs are based on Relative Risk (RR) estimates derived from primary epidemiological studies.

These RR functions estimate the likelihood of health outcomes occurring in a population exposed to a higher level of air pollution relative to that in a population with a lower exposure level (WHO, 2016a). RR is usually expressed as the proportional increase in the assessed health outcome associated with a given increase in pollutant concentrations, measured in $\mu g/m^3$. The WHO (2016) notes that "*the RR estimate cannot be assigned to a specific person; it describes risk in a defined population, not individual risk.*"

Epidemiological studies are mostly based on evidence from population health studies that compare health outcome incidences of populations exposed to higher levels of air pollution to populations exposed to lower levels of air pollution. Most of these studies have been done in Europe and North America.

Ideally, ERF studies and their RRs should be determined based on primary epidemiological studies focussing on the exposed population. In the absence of such studies, as in the case of South Africa, the WHO (2016a) recommends using ERFs from other countries.

It is to be noted that there are inherently significant limitations in transferring ERF studies from other countries. Pollution levels, chemical composition and health care systems are typically very different in other settings, and this would affect the accuracy of the ERFs.

The health outcomes were selected based on the latest WHO systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines. The health outcome considered in this study is all-cause mortality. Morbidity was not considered in this study as comprehensive data on morbidity studies is not widely available. Additionally, there are issues relating the transferability of data from one population to another in terms of country and culture as populations have different sensitivities to pollutant exposure (WHO 2000).

All-cause Mortality: This provides a measure of all the deaths that occur within the population from any natural causes. It includes natural deaths from all causes of death as provided in the WHO (2016b) International statistical classification of diseases and related health problems (ICD-10). In South Africa all-cause mortality makes up 88% of total deaths in South Africa (Stats SA, 2023).

In the AP-HRA, a health outcome must be attributed to an individual indicator pollutant. While health outcomes can be attributed to many different indicator pollutants, using all would result in double counting mixture effects in health impacts as these pollutants are associated with each other (WHO, 2016a, Malmqvist et al., 2018).

Table 2-2: Indicator pollutants, baseline incidence, and relative risks, of each health outcome (Source: WHO systematic reviews by various researchers & baseline incidence – Stats SA 2021)

Indicator Pollutant	Health Outcome	Baseline data	Relative Risk or Hazard Ratio per 10 μg/m³	Reference
$PM_{2.5}$	All-cause Mortality	0.687%	1.08	Chen & Hoek, 2020
PM_{10}	All-cause Mortality	0.687%	1.04	Chen & Hoek, 2020
SO_2	All-cause Mortality	0.687%	1.0059	Orellano et al., 2021
NO_2	All-cause Mortality	0.687%	1.02	Huangfu & Atkinson, 2020

The baseline incidence rates of these health outcomes were determined based on published data from the year 2019 from Stats SA (Stats SA, 2023). The ERFs describing the change in incidence in relation to changes in exposure (RRs) were obtained from the WHO latest systematic reviews for the update of the WHO Global Air Quality guidelines (WHO, 2020, 2021).

2.3.2 Health costs

The detrimental effects of air pollution on human health are borne in the economy by households, insurance companies, employers and public health programs (Romley et al., 2010).

The fundamental goal of health cost or cost of illness (COI) studies is to evaluate the economic burden that illness imposes on society as a whole (Jo, 2014). Rice (1967) and Rice et al. (1985), were instrumental in standardising methodologies for estimating COI, and these methodologies continue to be used internationally, and periodically updated (Rice, 1996; Rice, 2000).

COI studies contextualise adverse diseases effects into monetary terms, with the purpose of informing decision-making. Such decisions could include (a) to simply present the magnitude of disease in monetary terms; (b) to comparatively evaluate intervention programs; (c) to assist in the allocation of research funding on specific diseases; (d) to provide a basis for policy and planning relative to mitigation initiatives; and (e) to provide an economic framework for program evaluation (Rice, 2000).

The COI studies traditionally stratify costs into two categories: direct costs and indirect costs. Direct costs relate to the cost of medical treatment. This would include costs of visiting health care facilities, medicine and hospitalisation. Indirect costs comprise morbidity costs (the cost of lost economic productivity due to absenteeism or temporary or permanent disability) and mortality costs. With respect to mortality costs, valuing human life is contentious, as it can be seen as a judgement on the intrinsic value of life and involves complex ethical considerations. Often, cost-effectiveness analysis is used as an alternative (Muchapondwa, 2009). This side-steps the complexity of life valuation and uses disease or fatality incidence indicators to compare effectiveness of different policy or spending options.

[insert par on direct costs]

The health impact or health risk, associated with air pollution, is estimated using ERFs as described in section 2.3.1 above. In this study, the ERFs obtained from the latest WHO systematic reviews, focussed exclusively on mortality and thus a monetary measure of mortality was required in order to perform benefit-cost analyses. In air pollution benefit-cost analyses, the concept of value per statistical life (VSL) is commonly used to monetise mortality related benefits of air pollution reduction. The concept of a VSL is frequently misunderstood. It does not measure the intrinsic value of a human life, and neither does it value the economic productivity of a human. Rather, VSL is estimated by dividing an individual's willingness to pay (WTP) to reduce health risk, by the likelihood of risk reduction. Robinson and Hammitt (2009) defines VSL to represent the rate at which an individual is willing to exchange their own income for a small reduction in their own mortality risk over a particular time period. VSL is not the value that a person, society or the government would place on reducing the relative risk of mortality with certainty, but it is rather a representation of the rate at which a person views a change in the money available for spending as equivalent to a small change in their own mortality risk (Robinson et al., 2018).

Primary WTP studies for mortality risk reductions have not been done in South Africa. Most countries do not have reliable revealed preference or stated preference estimates of the VSL according to Viscusi and Masterman (2017) and primary research studies require considerable time and expense (Robinson et al., 2018). In these cases a "benefit transfer" method is used to transfer values from other studies. Both the above authors recommend using a United States of America (USA) base VSL (calculated using labour market estimates from their Census of Fatal Occupational Injuries, CFOI, data) and then further adjust it for differences in income between the USA and the country of interest.

The VSL estimate in this study is determined by the following equation ((from Viscusi and Masterman (2017) and Robinson et al. 2018):

$$VSL_{target} = VSL_{base} \times \left(\frac{Income_{target}}{Income_{base}}\right)^{\text{elasticity}}$$

In the above equation the base country is the United States. The VSL is transferred using the income measure of GNI (Gross National Income) per capita from the World Bank which uses the Atlas method which is based on exchange rates and inflation rates.

Data for the US base VSL was obtained from the US Economic Research service and the federal register, the GNI value per capita was sourced from the World Bank. Exchange rates to convert the dollar value of the South African VSL into rands was taken from the annual average exchange rates from the South African Reserve Bank.

A sensitivity analysis was conducted in the BCA based on the recommendations of Robinson et al. 2018. The default values include:

VSL = 160 * GNI per capita of the target country

VSL = 100 * GNI per capita of the target country

VSL extrapolated from USA estimate to target country using an elasticity of 1.5.

Additionally, the sensitivity analysis uses the Masterman and Viscusi (2017) income elasticity of 1.0.

2.3.3 Pollution abatement options

2.3.3.1 Summary

Table 2-3 sets out the detailed abatement options per scenario assessed.

Abatement options include the installation of technologies to reduce emissions. Technologies include Flue Gas Desulphurisation (FGD), Dry Sorbent Injection (DSI), Electrostatic Precipitators (ESP), Low NOx Burners (LNB) and Fabric Filter Plants (FFP). FGD and DSI are used to reduce sulphur dioxide (SO_2) emissions. ESP and FFP are used to reduce particulate matter (PM) emissions, and LNB to reduce nitrogen dioxide (NO_2) emissions. The abatement technologies investigated in the scenarios for this current study in the Waterberg included FGD and Installation of high-frequency power supply (HFPS) to improve ESP efficiency.

The BCA model was setup to compare three different scenarios in terms of abatement technology implementation for the Matimba and Medupi power stations. The dispersion modelling was done for each of these scenarios and the results were used in the BCA model. The model was constructed to allow for a gradual change in pollutant emission concentrations over several years based on the capital and operational expenditure timeframe. This was done to reflect that not all retrofitted units will be operational at the same time. When the abatement technology of all units at a station is operational the model then reflects the compliance emission concentration values related to the specific scenario.

2.3.3.2 Eskom load curtailment strategy

With the proliferation of the alternate energy sources on to the national grid due to the IRP, the existing coal fired power stations are expected to move into a load following mode of operation. This essentially results in lower running load factors for these stations as the renewable energy sources will be given priority over the fossil fuelled stations. This equates to average load factors of 40-45% for stations operating in 2031 and between 40 to 55% for stations operating beyond 2035, i.e. after Matla and Duvha shutdown. The nett effect of this is that less coal will be burnt in the generation of South Africa's electricity which results in direct emissions reduction at no additional cost impact. This is the basis of Eskom's load based alternate emissions limits.

2.3.3.3 Station shutdown

Station lifetimes were described for the two power stations that were modelled. The shutdown, repowering and repurposing dates affect the emissions per year (reduces) in the years that the station units are being shutdown. Only Matimba power station has shutdown, repowering and repurposing dates that fall within the modelling timeframe. The shutdown period for Matimba power station is 2039 to 2043. Medupi will shut down from 2065 to 2071.

Shutdown dates are based on Eskom's present planning and technical requirements, dates are subject to review based on national energy requirements. Eskom will follow all necessary regulator and stakeholder engagement process prior to station shutdown.

2.3.3.4 PM reduction

Abatement technologies considered in the scenarios for PM reduction included Electrostatic Precipitators (ESP) and High Frequency Power Supplies (HFPS) to improve the efficiency of the ESP. An ESP removes particulate matter, from the flue gas using the force of an induced electrostatic charge. ESP upgrades or refurbishments can reduce particulate matter between 95-97%.

2.3.3.5 Flue Gas Desulphurisation (FGD) for SO_2 reduction

FGD is a set of technologies used to reduce SO_2 emissions. FGD systems typically include a fly ash removal and SO_2 removal. SO_2 (an acid gas) removal is facilitated by alkaline sorbents such as limestone to react with the gas. FGDs are typically separated into two types, semi-dry and wet, dependent on their water requirements, and can reduce SO_2 emissions by 90%. Based on coal qualities and station characteristics Eskom considers wet FGD suitable for Medupi and semi-dry FGD suitable for Matimba.

Table 2-3: Detail Summary Table of Scenarios (Source: Eskom)

Scenario	Abatement and additional information
Eskom plan - ERP 2024 A (Scenario B)	Predicted monthly tonnage emitted per stack in 2031 assuming: a. All planned PM emission reduction projects completed. Matimba PM upgrade ensures station continues to operate at PM=50 mg/Nm^3. b. NOx projects completed with Matimba, and Medupi at 750 mg/Nm^3. c. Medupi FGD constructed between 2028 and 2032. Medupi operates at SO_2 = 500 mg/Nm^3 to reduce total SO_2 load. AEL limit is 1,000 mg/Nm^3. d. Efficiency and coal improvement projects reduce total emissions by 5% at Matimba and Medupi. e. Load factor restricted to an average value per station per year (see Appendix A) h. This scenario is similar to the existing Eskom Emission Reduction Plan 2022.
Eskom plan - ERP 2024 B (Scenario C)	Predicted monthly tonnage emitted per stack in 2036 assuming: a. Efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Matimba and Medupi, b. Medupi FGD completed in 2032 Medupi operates at SO_2 = 500 mg/Nm^3 to reduce total SO_2 load. AEL limit is 1,000 mg/Nm^3 c. Load factor restricted to an average value per station per year (see Appendix A)
Full MES compliance – ERP 2024 C (Scenario D)	Predicted monthly tonnage emitted per stack in 2036 assuming: a. Both Matimba and Medupi as per the CDS (Rev 4) shut down schedule. b. All planned PM emission reduction projects completed (by 2028), and stations operate at PM=50 mg/Nm^3. c. Matimba FGD constructed between 2031 and 2036. d. Load factor restricted to an average value per station per year (see Appendix A)

2.3.4 Costs of implementation

Table 2-4: Summary of costs of implementation of abatement for the Waterberg power stations: costs of CAPEX and OPEX and estimated impacts on electricity tariffs

	Scenario	CAPEX and OPEX (Rand million Nominal)	Impact on Electricity Tariff (c/kWh)		Impact on Electricity Tariff (%)	
		-15% +20%	Lower	Upper	Lower	Upper
	ERP 2024 A - Other	1,400	0.036	0.051	0.02	0.03
+	ERP 2024 A – Medupi FGD	57,260	1.07	1.52	0.58	0.82
Sub-total	ERP 2024 A (WRP Sc B)	58,660	1.11	1.57	0.60	0.85
	ERP 2024 B	0	0.00	0.00	0.00	0.00
Sub-total	ERP 2024 B	58,660	1.11	1.57	0.60	0.85
+	ERP 2024 C – Matimba FGD	43,010	0.52	0.73	0.28	0.40
Total	ERP 2024 C	101,670	1.63	2.30	0.88	1.24

The total nominal cost of all Eskom abatement scenarios has been estimated by Eskom at a Class 2 accuracy implying a variance between -15% and +20%:

- ERP 2024 A = R58,660 million
- ERP 2024 B = R58,660 million
- ERP 2024 C = R101,670 million.
- Source: Eskom

We estimated the effect of these additional costs on electricity tariffs. This was based on a cashflow waterfall model set up for each scenario, solving for a tariff that would pay back the cost of abatement technology over the assessment period. This tariff margin may be thought of as an air emissions abatement levy:

- ERP 2024 A = 0.6% - 0.9%
- ERP 2024 B = 0.6% - 0.9%
- ERP 2024 C = 0.9% - 1.2%.
- Note: It is to be noted that these electricity impact tariffs were not sourced by Eskom but were estimated using the method described above.

2.4 Benefit-cost Analysis

A BCA is a widely used approach employed for decision-making support. This approach was formalized in the United States in 1958 with the purpose of justifying public expenditures on alternative investment options competing public funds such as water, roads, and other public utilities' networks construction projects. BCA methodology broadly advises on the treatment of income benefits and costs; externality costs; how to measure them conceptually; how future prices should be treated; the importance of using a discount rate; the proper period of analysis; and cost allocation procedures for projects.

The World Bank[2] defines a Social BCA as an extension of a financial analysis. Ideally, in extending the financial analysis, all relevant economic costs and benefits are quantified and analysed. The BCA pulls together the component analyses of the study to assess the overall impact for a set of scenario options (emission reduction measures).

The objective of the BCA is to comparatively analyse investments or scenarios (in this case interventions in air quality management). The BCA achieves this end by identifying and monetizing the costs and benefits and predicting the timing thereof over the same horizon as the projects' economic lifetime (National Treasury, 2017).

A BCA allows scenarios to be objectively compared according to the benefit:cost relationship to analyse the relative efficiency of various interventions and the magnitude of the benefits to identify the interventions that will have the largest impacts.

In this analysis, the BCA compares the scenario health benefits to capital and operational costs of abatement. This BCA does not capture all potential costs and benefits, both direct and indirect. (Refer to section 2.5.1 below for a discussion of BCA limitations.)

The analysis timeline spans 2024 – 2045. The base year was 2024, due to dispersion modelling timeframe. The BCA was performed in an Excel spreadsheet, which consolidated all data sources, which contains all calculations, to run the large spatial exposure estimates for each scenario for the review period. The benefit-cost analysis apportioned costs (capital and operation expenditure on abatement technologies) and benefits (health benefits) to the years in which they would be realised. Because costs and benefits are accrued in different years according to the intervention schedules, the net present values of costs and benefits, using Eskom's weighted average cost of capital (WACC) rate of 10.8% (Eskom, 2024) as the discount rate allows an objective comparison of scenarios.

The health cost benefits were estimated based on the outputs of the AP-HRA and followed the steps below (Section 3.2 provides the BCA results).

1. Each of the assessed Scenarios implemented an abatement schedule at the two power stations (refer to section 3 for details)
2. The dispersion effects modelled by uMoya-NILU (Pty) Ltd were used to estimate the change in population exposure over the timeline.

[2] http://documents.worldbank.org/curated/en/445971468767366310/pdf/multi-page.pdf

3. The change in population exposure resulting from step 2 above was applied to the ERFs identified in section 2.3.1 to estimate health impact outcomes (sensitivity analysis was performed in the BCA to develop a view on the uncertainty inherent in the ERFs, also refer to section 2.5.1)
4. The VSL (refer to section 2.3.2) was applied to the health impact outcomes for each scenario, to estimate change in health cost benefits.
5. Capital and operational cost estimates were used as the costs in the BCA (refer to section 2.3.4).
6. Sensitivity analysis was performed on the VSL, the health benefit and abatement cost estimates.

2.5 Uncertainty of the estimated health effects

2.5.1 Sources of uncertainty and limitations

The WHO (2016a) advises performing an assessment of the uncertainty of the analysis; in this case therefore this requires an assessment related to a lack of knowledge about one or more components of the integrated Health BCA Model. The sections below discuss each source of uncertainty and related limitations.

Air pollutants exist as a complex mixture: Despite improvements in the science underlying AP-HRAs, it is still not possible to estimate with complete certainty the effects of air pollution on health (WHO Regional Office for Europe, 2014 cited in WHO, 2016a). The observed adverse effects attributed to an individual air pollutant may well be (partly) attributable to other pollutants in the mixture which are correlated with the assessed pollutant (WHO Regional Office for Europe, 2013 cited in WHO 2016a). It is not possible to assess the uncertainty relating to this (WHO, 2016a).

Pollutants modelled: The analysis was limited to SO_2, $PM_{2.5}$ and NO_2 pollutants, , these are the criteria pollutants managed in terms of South African air quality legislation and of most recognised significance in the Priority Area. Other pollutants may also contribute to health risk and these were not modelled in the dispersion modelling. This may under-estimate health risks and thus benefits of health risk mitigation. However, no data or other information exists through which to assess this limitation.

Exposure response functions: ERFs are derived from epidemiological studies, in which the parameters of the epidemiological experiment and assumptions made during the experiment introduce some uncertainty into the results. More significantly, because primary epidemiological evidence on air pollution is not available for South Africa. This is a key limitation. As a result, inference has to be drawn from studies in other parts of the world. It is to be noted that health response per unit change in air pollution in environments with high ambient levels (such as the HPA) may differ from that observed in countries with lower pollution levels. In summary, the WHO (2016a) notes that extrapolated ERF information may not accurately describe the exposure-response relationship in the region to be assessed, leading to uncertainties in the results. In order to deal with these uncertainties, we used variances in ERF outcomes as a measure of BCA ratio variation.

Dispersion model accuracy (uMoya-Nilu, 2024): "Air quality models attempt to predict ambient concentrations based on "known" or measured parameters, such as wind speed, temperature profiles, solar radiation and emissions. There are, however, variations in the parameters that are not measured, the so-called "unknown" parameters as well as unresolved details of atmospheric turbulent flow. Variations in these "unknown" parameters can result in deviations of the predicted concentrations of the same event, even though the "known" parameters are fixed. In the present dispersion modelling conservative assumptions in terms of surface area of ashing facilities giving rise to fugitive emissions were made that have resulted in an over prediction of PM emissions in shorter time periods. Furthermore, for $PM_{2.5}$ and PM_{10} the predicted concentrations are attributed to stack emissions and low-level fugitive sources (ash dump). The inclusion of the fugitive sources was done assuming the entire area is exposed and available for entrainment, while in reality only a small portion of the modelled area would be exposed to entrainment due to the vegetated sides and wet areas of the dump. This approach is extremely conservative. The PM emissions from stacks and fugitive sources are not speciated into PM_{10} and $PM_{2.5}$, rather all PM emitted is assumed to be PM_{10}, and all PM emitted is assumed to be $PM_{2.5}$.

There are also “reducible” uncertainties that result from inaccuracies in the model, errors in input values and errors in the measured concentrations. These might include poor quality or unrepresentative meteorological, geophysical and source emission data, errors in the measured concentrations that are used to compare with model predictions and inadequate model physics and formulation used to predict the concentrations. “Reducible” uncertainties can be controlled or minimised. This is done by using accurate input data, preparing the input files correctly, checking and re-checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics.”

Baseline disease burden: The baseline cases of mortality used were for 2019, based on latest available Stats SA data. The data for this year is therefore accurate. Stats SA data for 2020 was not used as these numbers may be skewed by the effects of COVID. Uncertainty arises however because projections are made of population size growth in future, under the assumption that the relative ratio of mortality in the future remain constant.

Morbidity effects were not assessed: The costs of medical treatment (including visiting health care facilities, and costs of medicine and hospitalisation) and the loss of economic production due to sick-leave absenteeism or temporary or permanent disability, were not assessed. This is because of an absence of official data on health care visits and associated direct costs within both the public and private health care sectors; linked to suitable ERFs. As a result, the BCA underestimates the health benefits of the various scenarios. As before, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation.

Value of a statistical life: VSLs are accurate when estimated based on primary data collected through willingness to pay studies specific to the exposed population. All VSL estimates for South Africa are derived and transferred from studies done in the United States of America. This introduces uncertainty in the BCA results. As before, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation.

Timeline of dispersion modelling predicted concentrations: The data from the dispersion modelling in CALPUFF is from a specific point in time and is then interpolated for the timeline values that are required to run a benefit:cost analysis. Ideally the BCA model should have a CALPUFF run for each year used in the model timeline, however, to do this is not practical. This causes uncertainties in the results.

Cost uncertainty: Eskom uses a cost estimate classification matrix which has different estimate classes associated with different expected accuracy ranges for making project cost estimations (Eskom, 2020). Based on these classes the sensitivity analysis for costs estimates varied by +20% or -15% (Class 2). Eskom is constantly working to refine the accuracy of the emission reduction costing and this may result in internal updates of costing. Anticipated changes in cost are anticipated to fall within the range of variance (-15% and +20%).

The BCA does not capture economic externalities. These include both benefits and costs. The benefits of reduced health risk on households, employers and the health care and insurance industries were not assessed. The costs of implementation of abatement technologies would put additional pressure on Eskom capital (and debt) requirements, and further on electricity price escalations. These would result in additional economic costs, and these were not assessed. Furthermore, the economic benefits and costs of transitioning from coal to alternatives were not assessed. A full electricity system modelling exercise was not completed as part of the Eskom exemption application process given time constraints. Capacity assessments undertaken indicate that attempting to install SO_2 reduction technologies simultaneously on Eskom stations will result in significant electricity supply shortfalls. These capacity shortfalls would need to be addressed by other generation sources, if these are available, which may have additional cost implications. If the capacity is not available then the country would be forced to endure further periods of load shedding with resultant economic, social and environmental impacts.

As above, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation

Level of acceptable risk not quantified: The health benefits assessed are the total health benefits associated with all reductions in modelled ambient air quality as a result of abatement technology. It is to be noted however that the MES implies a level of acceptable health risk, and the quantum of the health costs associated with this level of acceptable risk were not assessed in the BCA.

2.5.2 Dealing with the uncertainties and limitations in the assessment of results

Several important considerations exist when interpreting the results of the integrated Health BCA.

Interpretation of premature mortality has to be done with care. It is to be noted firstly that these numbers are indicators of health risk at a population level. The relative risk estimate inherent in the ERF is a metric of the likelihood of an adverse health outcome, and it cannot be attributed to an individual person. It can thus be used to quantify risk to a defined population (and not to an individual), (WHO 2016) and how this risk would vary between various policy options of scenarios.

The various sources of uncertainty discussed above, affect the accuracy of the absolute values of the assessments. In the absence of primary ERF studies, it is not possible to judge the accuracy of the absolute values of the assessment with a high level of confidence. However, this report uses ranges to reflect uncertainty.

In spite of the various sources of uncertainty discussed above, the analysis still provides valuable insights into the comparison of scenarios tested in the BCA. This is because the uncertainty inherent in the analysis remains constant across all scenarios.

The description of uncertainty sources also serves as a basis for further work to be prioritised in improving future integrated Health BCAs.

3 RESULTS AND DICUSSION

3.1 Scenarios

Three scenarios were evaluated in this study (against a baseline of anticipated emissions 2025 - 2030). A brief description is provided in the sub-sections below and the detailed summary table (see Table 2-3).

3.1.1 ERP 2024 A

This scenario represents the Eskom ERP 2024 A plan. The scenario is similar to the existing Eskom Emission Reduction Plan (ERP) 2022. Abatement projects for emission reduction included in this scenario comprised of PM projects at Matimba and SO_2 projects at Medupi (see Table 2-3 for detailed information).

In this scenario it is additionally assumed:

- Medupi will operate at SO_2 500 mg/Nm^3 instead of the AEL limit of 1000 mg/Nm^3 to reduce total SO_2 emission load into the atmosphere
- Total emissions are reduced by 5% at Matimba and Medupi through efficiency and coal improvement projects.
- See Appendix A for load factors at the stations.

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-1.

2031 emission snapshot

S1 ERP 2024 A	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)		Abatememt Technology Comissioning Period			
Plant	COD start	COD end	S1DS	S1DE	HFPS	FGD	HFPS-S	HFPS-E	FGD-S	FGD-E
Matimba	1987	1991	2038	2042	1		2025	2030		
Medupi	2015	2024	2065	2071		1			2028	2032

Figure 3-1: ERP 2024 A power plant commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown, repowering and repurposing date of the power plant.

3.1.2 ERP 2024 B

This scenario represents the Eskom ERP 2024 B plan. Abatement projects for emission reduction included in this scenario comprised of PM projects at Matimba and SO_2 projects at Medupi (see Table 2-3 for detailed information).

In this scenario it is additionally assumed:

- Efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Matimba and Medupi.

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-2.

2036 emissions snapshot

S2 ERP 2024 B	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)		Abatememt Technology Comissioning Period			
Plant	COD start	COD end	S2DS	S2DE	HFPS	FGD	HFPS-S	HFPS-E	FGD-S	FGD-E
Matimba	1987	1991	2038	2042	1		2025	2030		
Medupi	2015	2024	2065	2071		1			2028	2032

Figure 3-2: ERP 2024 B power plant commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown, repowering and repurposing date of the power plant.

3.1.3 ERP 2024 C

This scenario represents the Eskom ERP 2024 C plan. In 2036 the operating stations will operate according to the Consistent Data Set (CDS) (Rev4) shut down schedule. Matimba will shut down in the period from 2039 to 2043. Abatement projects for emission reduction included in this scenario are comprised of PM projects and SO_2 projects (completed by 2035) (see Table 2-3 for detailed information).

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-3.

Full MES compliance - 2036 emission snaphot

S3 ERP 2024 C	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)		Abatememt Technology Comissioning Period			
Plant	COD start	COD end	S3DS	S3DE	HFPS	FGD	HFPS-S	HFPS-E	FGD-S	FGD-E
Matimba	1987	1991	2038	2042	1	1	2025	2030	2031	2035
Medupi	2015	2024	2065	2071		1			2028	2032

Figure 3-3: ERP 2024 C power station commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown, repowering and repurposing date of the power station.

3.2 Summary

In 2024, approximately 157,000 people are exposed to air pollution from the two power stations modelled, that fall within the modelling domain. The mean additional annual average exposure to air pollution of the population within this domain, resulting from coal-fired power station emissions, was estimated by averaging dispersion modelling results over municipal boundaries. Approximately 145,000 people were exposed to more than an additional 1 µg.m^3 (mean annual average) of SO_2.in the modelled area. Similarly, 81,000 and 48,000 people, were exposed to more than an additional 1 µg.m^3 of PM and NO_2 and respectively.

Health benefits associated with each scenario were calculated against the baseline that took into account the anticipated increase in loads in the coming years from 2025 to 2030 and assumed no abatement technologies installed and both stations would continue to emit air pollution at their current rates until shutdown, repowering and repurposing.

The health benefits over time are summarised in Figure 3-4:

- The health benefits of ERP 2024 A deliver immediate impact from 2024. At Medupi Wet FGD is commissioned from 2028 to 2032. Both stations already operate at NOx = 750 mg/Nm^3. Medupi already has Fabric Filter Plant (FFP) for PM reduction. Matimba station is equipped with ESP + HPPS for optimisation of PM reduction. These increase the associated health benefits until 2039. Hereafter the associated health benefits reduce as Matimba shutdown, repowering and repurposing is between 2039 and 2043. Medupi station shutdown, repowering and repurposing is much later from 2065 and the health benefits from the Wet FGD continue until final closure of the station.
- The health benefits of ERP 2024 B include those as discussed for ERP 2024 A above. In addition, efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Medupi and Matimba from 2024 onwards.
- The health benefits of ERP 2024 C include those as discussed for ERP 2024 A and B above. Semi-dry FGD is installed at Matimba by 2035, however the associated health benefits are effectively negated as Matimba starts to shut down in 2039.

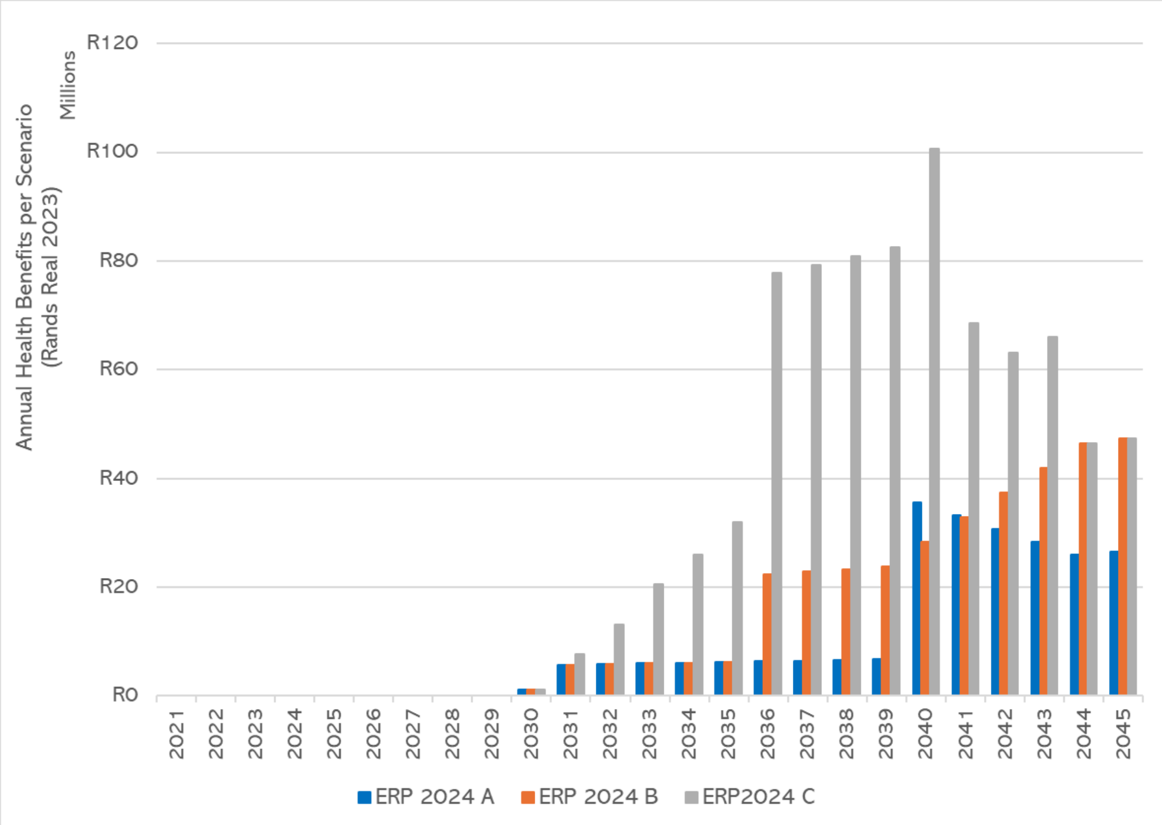


Figure 3-4: Annual health benefits per scenario illustrating the timeline of cumulative health benefits

The **abatement costs** associated with each scenario are set out in Figure 3-5 below:

- The total Capex and Opex costs of abatement are identical to 2024.
- ERP 2024 A implementation starts in 2025 with Matimba ESP + HFPS and in 2028 with Medupi, Wet FGD installation. After 2032 only operational costs continue at Medupi.
- ERP 2024 B is the same as ERP 2024 A discussed above.
- ERP 2024 C is the same as described for ERP 2024 A and B. In addition, implementation starts in 2031 with Matimba semi-dry FGD. The Capex costs decrease after 2032 as Medupi Wet FGD is fully installed and only the Capex of the Matimba semi-dry FGD remains until 2035 whereafter only operational costs remain. After closure of Matimba in 2043 only Medupi continues to operate.

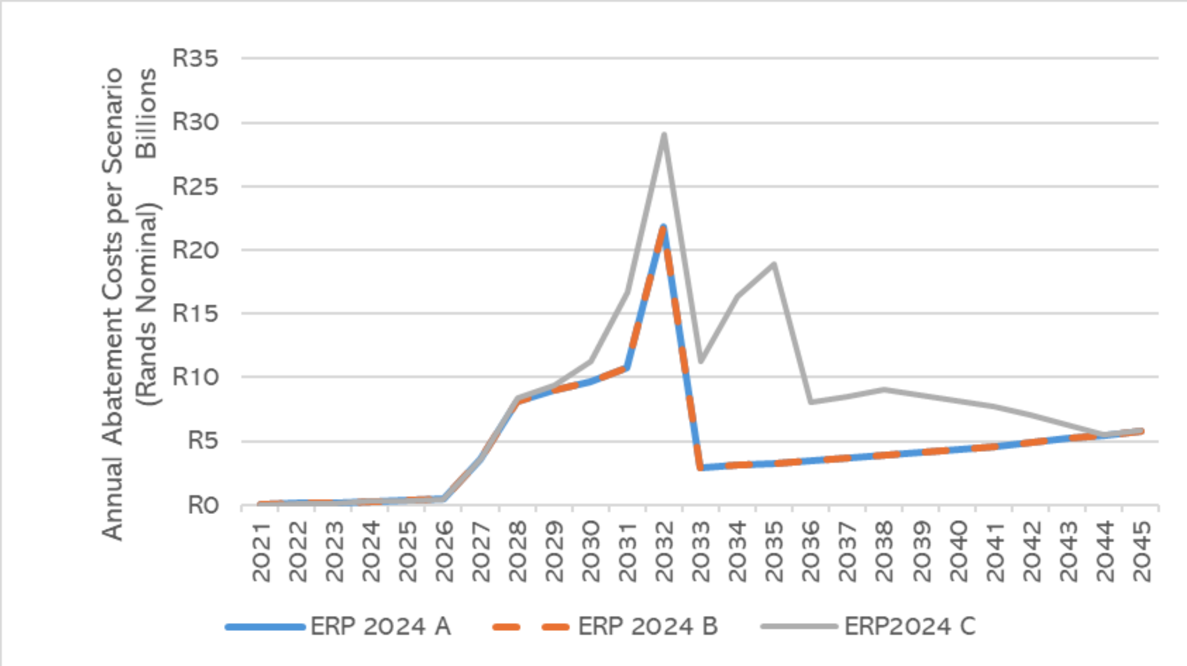


Figure 3-5: Total abatement costs (CAPEX and OPEX) associated with each scenario's abatement retrofits

Scenarios were compared in a benefit-cost analysis. The benefit-cost analysis apportioned costs (capital and operation expenditure on abatement technologies) and benefits (health benefits) to the years in which they would be realised. Because costs and benefits are accrued in different years according to the intervention schedules, the net present values of costs and benefits, used Eskom's weighted average cost of capital (WACC) rate of 10.8% as the discount rate (Eskom, 2024), and additional sensitivity analysis testing using a social discount rate of 2% (Stern, 2006) allowing for an objective comparison of scenarios.

The BCA ratios need to be interpreted with care. They are meant only to provide a perspective on and to inform the decision-making process underlying the scenarios. They are not meant to be interpreted as a definitive answer to making abatement decisions. Decisions involving human health must be informed by non-economic criteria as well. In addition, with uncertainty inherent in the analysis, the cost benefit ratio should thus not be viewed as absolute, but rather as a relative value from which to compare scenarios.

The **BCA results** are provided in Table 3-1. In the upper estimates the lower costs and higher VSL are used and in the lower estimates the higher costs and lower VSL are used as recommended by Robinson et al. 2018.

- The BCA central ratio of ERP 2024 A is significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The reasons for this include the implementation of FGDs at Medupi in conjunction with the small population that benefits. This scenario has a total nominal cost of R58,660 million and is likely to increase electricity tariffs by 0.6% - 0.9% in ERP 2024 A.

- The BCA ratio of ERP 2024 B is also significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The same reasons apply as for ERP 2024 A above. This scenario has a total nominal cost of R58,660 million and is likely to increase electricity tariffs by 0.6% - 0.9% as in ERP 2024 A.
- The BCA ratio of ERP 2024 C is also significantly less than 1, indicating that costs of abatement far exceed the health benefits. This ratio remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. This scenario has a larger discrepancy in NPV of health benefits and NPV of costs due to implementation of FGDs at both Medupi and Matimba and the small population that benefits. This scenario has a total nominal cost of R101,670 million and is likely to increase electricity tariffs by 0.9% - 1.2% in ERP 2024 C.
- Evaluation of the BCA ratios at a social discount rate of 2% delivers similar results, with all three scenarios ratios remaining less than 1.

Table 3-1: BCA ratios (lower and upper ranges) for each scenario (discounted at Eskom WACC)

	ERP 2024 A		**ERP 2024 B**		**ERP 2024 C**	
Million Rands	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
NPV of Costs	-18,970	-13,437	-18,970	-13,437	-27,716	-19,632
NPV of Benefits	3	17	8	39	16	83
NPV of Benefits minus Costs	-18,967	-13,420	-18,962	-13,398	-27,700	-19,549
Benefit:Cost Ratio (*range*)	0.0002	0.0012	0.0004	0.0029	0.0006	0.0042
Benefit:Cost Ratio (*central*)	0.0007		0.0017		0.0024	

In the analyses above the benefits from closure form part of the baseline.

The cumulative health benefits over time of the baseline:

- The power stations planned shutdown schedule (Section 2.3.3 for the years in which this occurs) results in health benefits without associated abatement costs. These benefits are dependent on timing of the shutdown schedule.
- In order to contextualize the three scenarios that were analysed with respect to the baseline Figure 3-7, Figure 3-8 and Figure 3-9 show how each scenario contributes to cumulative health benefits over time. The green area in the figures illustrates the health benefit of Matimba shutdown compared to the baseline, as the station shuts down the population exposed to pollution decreases and the health benefits increase. The blue, orange and grey areas indicating the health benefits of the ERP scenarios described above. The figures illustrate that effectiveness of station shutdown in decreasing health impact and increasing health benefits.

- The health benefits from the respective scenarios contribute an additional 1.5 – 7.6 times the health benefits of the baseline (estimated on a net present value basis).
- The Figures below are shown in Real 2023 Rand terms to better demonstrate in 2023 terms, the relative benefit for scenarios ERP 2024 A, B and C and Matimba closure.

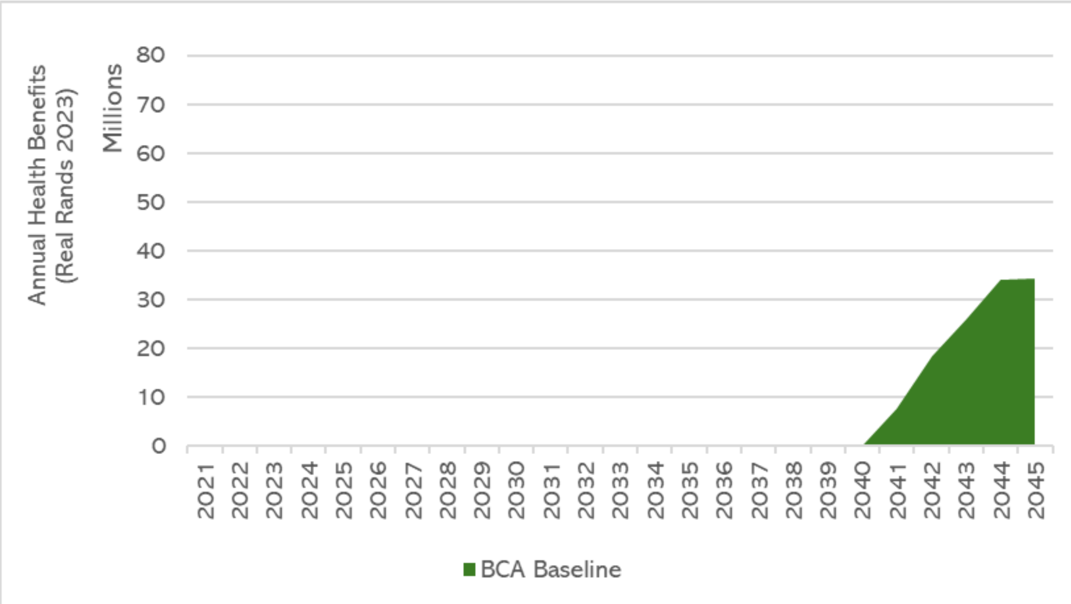


Figure 3-6: Cumulative annual health benefits in the baseline with planned power station shutdown of Matimba

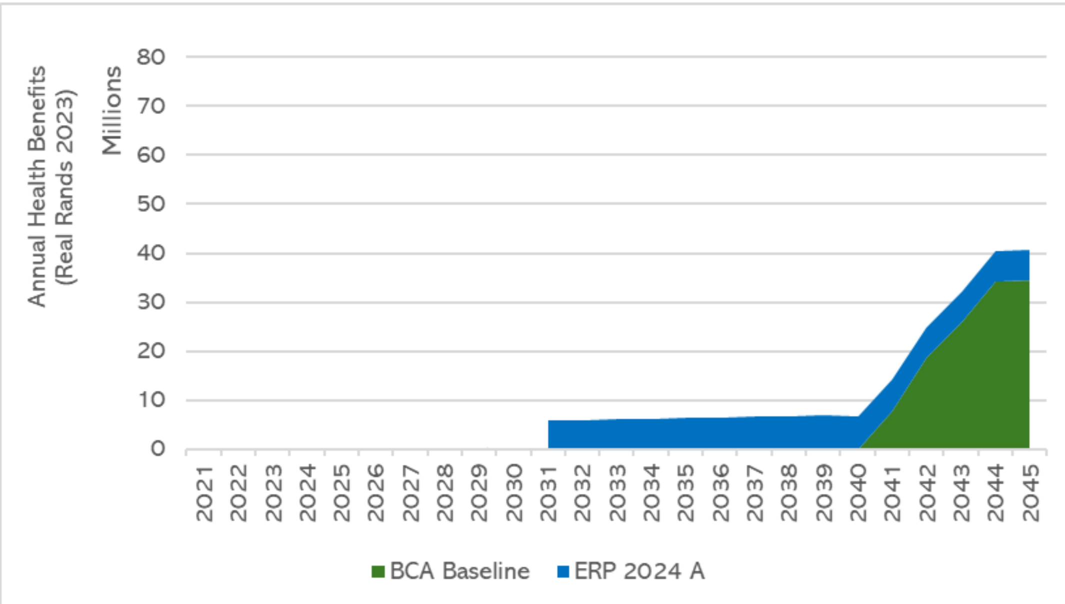


Figure 3-7: Cumulative health benefits of ERP 2024 A over the baseline

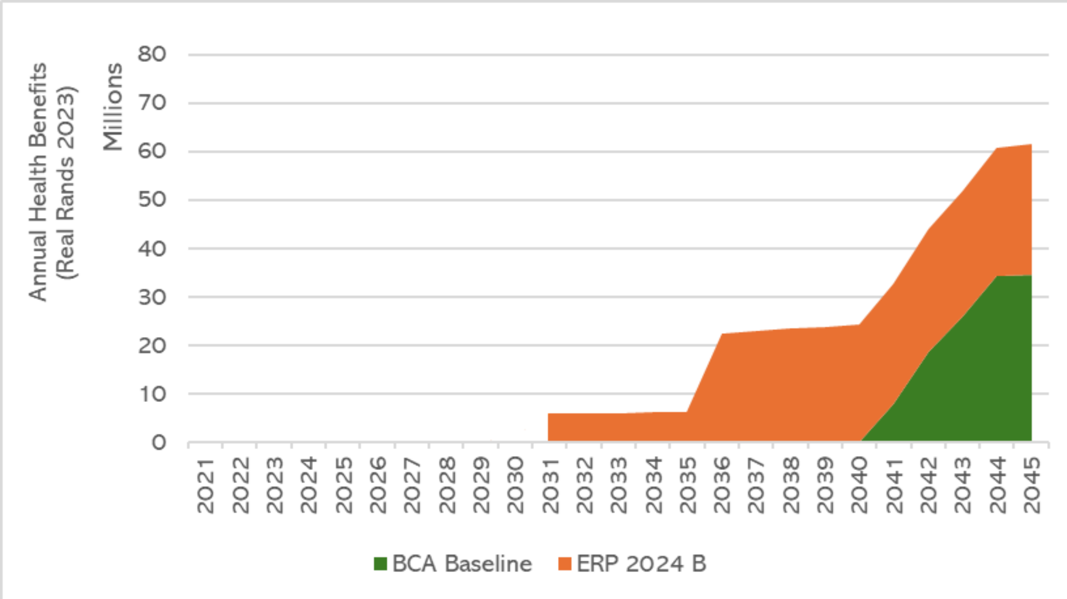


Figure 3-8: Cumulative health benefits of ERP 2024 B over the baseline

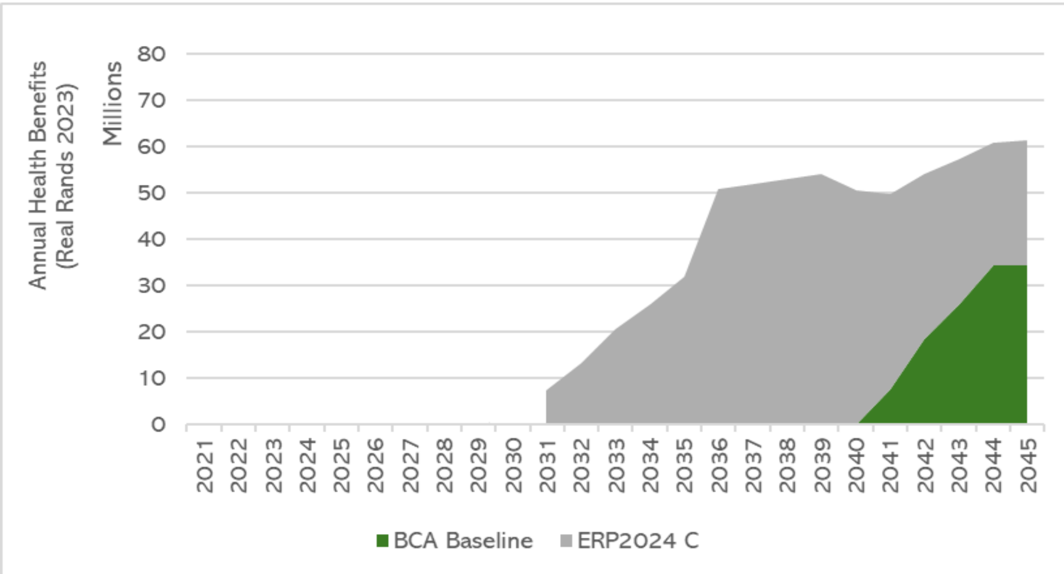


Figure 3-9: Cumulative health benefits of ERP 2024 C over the baseline

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5 APPENDIX A

The estimated calculated load factors for each station in the Waterberg:

Station	Medupi	Matimba
2025	81%	74%
2026	69%	57%
2027	60%	54%
2028	59%	55%
2029	54%	50%
2030	53%	49%
2031	64%	48%
2032	65%	49%
2033	68%	52%
2034	71%	51%
2035	70%	53%
2036	73%	55%
2037	76%	57%
2038	84%	61%
2039	88%	59%
2040	90%	39%
2041	95%	30%
2042	92%	17%
2043	93%	0%
2044	92%	0%
2045	94%	0%
2046	99%	0%
2047	97%	0%
2048	96%	0%
2049	97%	0%
2050	95%	0%

Air Pollution Health Risk Benefit Cost Analysis for exemption power stations in the Highveld Priority Area

For input into the Minimum Emission Standards Exemption Report Chapter 8

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PREAMBLE

This study forms part of the project entitled, "Eskom MES Exemption Applications & Decommissioning AIRs" for WSP Group Africa (Pty) Ltd appointed by Eskom SOC Limited for the preparation of the Minimum Emission Standards (MES) exemption application report.

The study investigates the health benefits and implementation costs of mitigating air pollution emissions from 11 Eskom coal-fired power stations in the Highveld Priority Area. Five of these stations are earmarked for closure by 2030 (Arnot, Camden, Grootvlei, Hendrina and Kriel). The remaining six power stations may be retrofitted with air emission abatement technologies. These are Duvha, Kendal, Lethabo, Majuba, Matla and Tutuka.

The methodology used in this study is based on World Health Organisation guidelines.

In addition to the authors, the contributors to this analysis include:

- Dr Mark Zunckel and Atham Raghunandan uMoya-NILU Consulting (Pty) Ltd who were responsible for CALPUFF modelling
- Ms Rietha Oosthuizen (independent consultant) and Dr Caradee Wright (SA Medical Research Council) who provided advice for the epidemiological evidence used in the study.
- Mr Bryan McCourt and Mr Ebrahim Patel from Eskom provided important details on scenarios and abatement technology costs.

EXECUTIVE SUMMARY

The combustion of fossil fuels by power stations results in the emission of several atmospheric pollutants, that include particulate matter (PM), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2). Atmospheric pollutants have numerous negative effects on human health and may increase the risk of premature mortality.

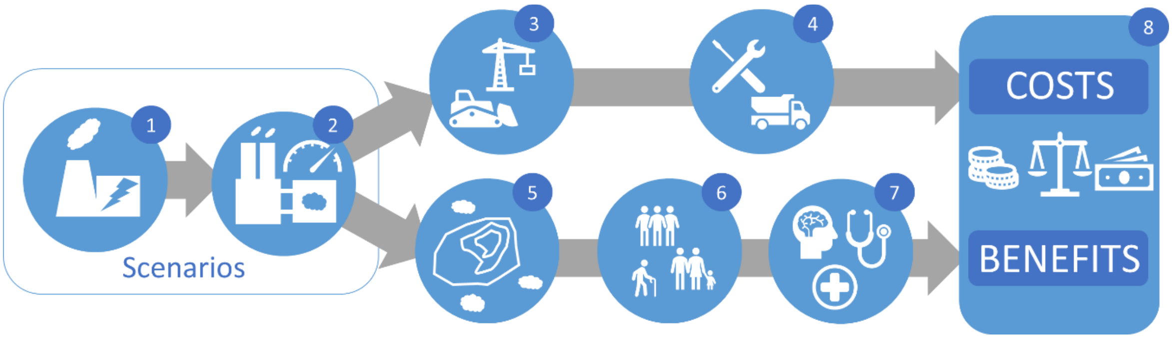
Technologies exist to reduce these emissions and therefore also their negative health effects. Abatement technologies for power stations include Flue Gas Desulphurisation (FGD) and Direct Sorbent Injection (DSI), for SO_2 reduction; installation of high-frequency power supply (HFPS) to improve Electrostatic Precipitator (ESP) efficiency to reduce PM emissions; and Low NO_X Burners (LNB) for NO_2 reduction.

A benefit-cost analysis (BCA) allows for trade-offs between different scenarios to be compared to support decision making.

The aim of this study was to estimate the incremental health benefits associated with abatement technology options as well as plant shutdown, repowering and repurposing, to achieve or move towards compliance with the new Minimum Emission Standards (MES) of the Department of Forestry Fisheries and the Environment (DFFE).

Methodology

An integrated Air Pollution Health Risk Benefit Cost Analysis APHR-BCA model was developed to model the impacts of three different abatement scenarios as developed by Eskom. The APHR-BCA was developed following the General Principles of the World Health Organisation, WHO (WHO, 2016a), for performing air pollution health risk assessments (AP-HRA). The detailed methodology and assumptions are set out in section 2 below. In summary, the methodology proceeded through several steps, as set out in the schematic:



Health benefits resulting from air pollution abatement

The WHO (2016a) recommends that the health risk in a population, associated with air pollution, is to be estimated using exposure-response functions (ERFs). ERFs are based on Relative Risk (RR) estimates derived from primary epidemiological studies. These RR functions estimate the likelihood of health outcomes occurring in a population exposed to a higher level of air pollution relative to that in a population with a lower exposure level. RR is usually expressed as the proportional increase in the assessed health outcome risk incidence associated with a given increase in pollutant concentrations, measured in μg/m^3. The WHO (2016a) notes that "*the RR estimate cannot be assigned to a specific person; it describes risk in a defined population, not individual risk.*"

Ideally, ERF studies and their RRs should be determined based on primary epidemiological studies focussing on the exposed population. In the absence of such studies, as in the case of South Africa, the WHO (2016a) recommends using ERFs from other countries.

The health outcomes were selected based on the latest WHO systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines. The health outcome that was considered in this study is all-cause mortality. Morbidity was not considered in this study as comprehensive data on morbidity studies is not widely available. Additionally, there are issues relating the transferability of data from one population to another in terms of country and culture as populations have different sensitivities to pollutant exposure (WHO 2000).

Pollution levels, chemical composition and health care systems are typically very different in other settings, and this would affect the accuracy of the ERFs. It is important to understand at what level interval the ERFs would result in significant differences in health outcome incidences. As a result, the WHO (2016a) advises performing an assessment of the uncertainty of the analysis; in this case therefore this requires an assessment related to a lack of knowledge about one or more components of the integrated Health BCA Model. Section 2.5 discusses each source of uncertainty and related limitations. Variation resulting from relevant uncertainty factors was assessed through performing sensitivity analysis in the BCA (refer to section 2.4).

Interpretation of the risk of premature mortality must be done with care. It is to be noted firstly that these numbers are indicators of health risk at a population level. The relative risk estimate inherent in the ERF is a metric of the likelihood of an adverse health outcome, and it cannot be attributed to an individual person. It can thus be used to quantify risk to a defined population (and not to an individual), (WHO 2016a) and how this risk would vary between various mitigation scenarios.

In this study, the ERFs obtained from the latest WHO systematic reviews, focussed exclusively on mortality and thus a monetary measure of mortality was required in order to perform benefit-cost analyses. In air pollution benefit-cost analyses, the concept of value of a statistical life (VSL) is commonly used to monetise mortality related benefits of air pollution reduction. The concept of a VSL is frequently misunderstood. It does not measure the intrinsic value of a human life, and neither does it value the economic productivity of a human. Rather, VSL is estimated by dividing an individual's willingness to pay (WTP) to reduce health risk, by the likelihood of risk reduction. Robinson and Hammitt (2009) defines VSL to represent the rate at which an individual is willing to exchange their own income for a small reduction in their own mortality risk over a particular time period. VSL is not the value that a person, society or the government would place on reducing mortality rates with certainty, but it is rather a representation of the rate at which a person views a change in the money available for spending as equivalent to a small change in their own mortality risk (Robinson et al., 2018).

Primary WTP studies for mortality risk reductions have not been done in South Africa. The VSL for South Africa in the BCA was determined by using the methodology as advised by Viscusi and

Masterman (2017) and Robinson et al. (2018) with a base VSL from the U.S, GNI per capita for income measures and adjusted by income elasticity. As advised by Robinson et al. (2018), a sensitivity analysis is conducted to explore various VSL estimates.

Scenario assessment

The three scenarios proposed by Eskom and evaluated in the BCA study were:

- Scenario ERP 2024 A (PM and NOx reduction, generating load capped, air quality offsets and SO_2 reduction at Kusile)
- Scenario ERP 2024 B (As per ERP 2024 A plus SO_2 reduction technology installed at Majuba and Kendal)
- Scenario ERP 2024 C (Full compliance with MES for PM, NOx and SO_2 for Kusile, Majuba, Kendal, Lethabo and Tutuka)

The detailed emission abatement measures relevant to the scenarios are set out in Table 2-6 in Section 2.3.3. A key difference in the scenarios is the number of stations which are installed with SO_2 reduction technology in the form of wet- Flue Gas Desulphurisation (FGD), semi-dry FGD, or Direct Sorbent Injection (DSI). The focus on SO_2 reduction is important given the extent which it is anticipated to impact on air quality and public health and the very significant cost of SO_2 reduction cost.

Health benefits associated with each scenario were calculated against the baseline that took into account the anticipated changes in loads in the coming years from 2025 and assumed no additional abatement technologies installed, and all stations would continue to emit air pollution at their current rates until shutdown, repowering and repurposing. The baseline also includes the health benefits derived from subsequent decrease in load as stations shut down as new alternate energy source capacity becomes available.

- The health benefits of ERP 2024 A deliver immediate impact from 2024. The benefits associated with this scenario start tapering off from 2030 onwards as Duvha and Matla shutdown, repowering and repurposing between 2031 and 2036, and the associated health benefits from the HFPS and LNB technologies reduces accordingly. Tutuka, Lethabo and Kendal shutdown, repowering and repurposing from 2036, 2037 and 2040 respectively. The Electrostatic Precipitators (ESP) plus High Frequency Power Supplies (ESP+HFPS) and Low NOx Burners (LNB) technologies at these stations (refer to Table 2-6) continue to provide health benefits until 2045. Majuba shutdown, repowering and repurposing starts in 2047 and the health benefits from the LNB technology continue until final closure. ERP 2024 A includes wet FGD at Kusile but the costs and benefits of this fall outside of the scope of this scenario assessment.
- The health benefits of ERP 2024 B include those as discussed for ERP 2024 A above. In addition, efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Kendal, Lethabo, Tutuka and Majuba contributing to the increase in health benefits in ERP 2024 B. In addition to the Kusile wet FGD (but the costs and benefits of this fall outside of the scope of this scenario

assessment), at Majuba DSI is commissioned from 2029 – 2033. Kendal is equipped with semi-dry FGD which is implemented from 2036, and this increases health benefits for a short period to 2040 whereafter Kendal shutdown, repowering and repurposing starts.

- The health benefits of ERP 2024 C include those as discussed for ERP 2024 A and B above. All planned PM emission reduction projects are completed (by 2028), and stations operate at PM=50 mg/Nm^3. NOx projects are completed at all stations (completed by 2032), and stations operate at NOx = 750 mg/Nm^3. In addition to the SO_2 reduction at Kendal and Majuba (and Kusile – however these effects are not part of the scenario assessment), semi-dry FGDs are installed at Tutuka and Lethabo by 2035, however, these stations start shutdown, repowering and repurposing from 2036 and 2037 respectively, thus effectively negating the health benefits from the FGD technologies.

With respect to the **abatement costs** associated with each scenario:

- The total Capex and Opex costs of abatement are identical to 2025.
- ERP 2024 B implementation starts in 2026 and 2027 with Majuba and Lethabo's LNB technology. From 2029 DSI installation starts at Majuba and in 2031 FGD starts at Kendal.
- ERP 2024 C builds on ERP 2024 B with implementation of SO_2 reduction technology starting in 2031 for both Lethabo and Tutuka.

The BCA ratios need to be interpreted with care. They are meant only to provide a perspective on and inform the decision-making process underlying the scenarios. They are not meant to be interpreted as a definitive answer to making abatement decisions. Decisions involving human health have to be informed by non-economic criteria as well. In addition, with uncertainty inherent in the analysis, the benefit cost ratio should thus not be viewed as absolute, but rather as a relative value from which to compare scenarios.

Benefits from station closure are included within the baseline so are not visible in the BCA directly. The shutdown of stations does however generally result in less pollution being emitted with increased health benefits compared to the baseline.

The **BCA results** are provided in Table 0-1. In the upper estimates the lower costs and higher VSL are used and in the lower estimates the higher costs and lower VSL are used as recommended by Robinson et al. 2018.

- The BCA central ratio in ERP 2024 A is more than 1 (1.74), showing a very clear benefit and the health benefits exceed the costs of abatement, implying that this is a sound abatement option for Eskom to pursue. This scenario has a total nominal cost of R18,500 million, and is likely to increase electricity tariffs by 0.4% - 0.6%. IN ERP 2024 A
- The central BCA ratio of ERP 2024 B (SO_2 reduction at Majuba and Kendal) is less than 1 although it approaches 1 in the most optimistic (upper) parameters of the sensitivity analysis. The key reason for this is the implementation of the

Kendal semi-dry FGD which is implemented from 2036, but only increases health benefits for a brief period to 2040 whereafter Kendal shutdown, repowering and repurposing starts. In this scenario the total nominal cost increases to R75,970 million (which adds to ERP A the additional cost of SO_2 reduction at Majuba and Kendal) and is likely to increase electricity tariffs by 1.0% - 1.4%.

- The BCA central ratio of ERP 2024 C (SO_2 reduction at Majuba, Kendal, Lethabo and Tutuka) is less than 1 (0.33) and remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The key reason for this is the implementation of FGDs at Tutuka and Lethabo by 2035, followed by immediate shutdown, repowering and repurposing from 2036 and 2037 respectively, thus effectively negating the health benefits from the FGD technologies. In this scenario the total nominal cost increases to R155,320 million (which adds to the ERP 2024 A and B costs the additional costs of SO_2 reduction at Lethabo and Tutuka), and is likely to increase electricity tariffs by 1.6% - 2.2%.
- Evaluation of the BCA ratios at a social discount rate of 2% delivers similar results, with ERP 2024 A above 1 and ERP 2024 B and C both less than 1. This is because of the limited health benefits achieved post 2036.

Table 0-1. **BCA ratios (lower and upper ranges) for each scenario (discounted at Eskom WACC)**

	ERP 2024 A		ERP 2024 B		ERP 2024 C	
Million Rands	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
NPV of Costs	-10,479	-7,423	-33,909	-24,019	-56,964	-40,349
NPV of Benefits	3,575	23,341	3,651	23,831	3,732	24,357
NPV of Benefits minus Costs	-6,904	15,918	-30,258	-188	-53,232	-15,993
Benefit:Cost Ratio (range)	0.34	3.14	0.11	0.99	0.07	0.60
Benefit:Cost Ratio (central)	1.74		0.55		0.33	

In the analyses above the benefits from station closure form part of the baseline.

The power stations planned shutdown schedule (see Table *2-7* in Section 2.3.3 for the years in which this occurs) results in health benefits without associated abatement costs. These benefits are dependent on timing of the shutdown schedule. These benefits have been assumed to form part of the BCA baseline and have therefore not been quantified directly in the BCA.

ACRONYMS AND ABBREVIATIONS

AP-HRA	Air Pollution Health Risk Assessment
AQA	Air Quality Act
AQMS	Air Quality Monitoring Station
BCA	Benefit-Cost Analysis
CFOI	Census of Fatal Occupational Injuries (USA)
COI	Cost of Illness
DEA	Department of Environmental Affairs
DFFE	Department of Forestry Fisheries & Environmental Affairs
ERF	Exposure Response Function
ESP	Electrostatic Precipitators
FFP	Fabric Filter Plants
FGD	Flue Gas Desulphurisation and
GNI	Gross National Income
HPA	Highveld Priority Area
ICD	International Classification of Diseases
kW	Kilowatt
kWh	Kilowatt Hour
LNB	Low NO_X Burners
MES	Minimum Emissions Standards
NAAQS	National Ambient Air Quality Standard
NAQI	National Air Quality Index
NEMA	National Environmental Management Act
NO_2	Nitrogen Oxide
NPV	Net Present Value
PM	Particulate Matter
RR	Relative Risk
SAMRC	South African Medical Research Council
SO_2	Sulphur Dioxide
USA	United States of America

VSL	Value of a Statistical Life
WHO	World Health Organisation
VTAPA	Vaal Triangle Airshed Priority Area
WACC	Weighted Average Cost of Capital
WTP	Willingness to Pay

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1 INTRODUCTION

The Earth Summit[1] in Rio de Janeiro in 1991 raised the awareness of the linkages between environmental health and human wellbeing to a global agenda. In the three and a half decades since the Summit, significant effort has gone into methods for quantifying these linkages, in all environmental spheres, and informing policy development. During the same period, we have seen an information technology revolution, which has radically improved our ability to collect and analyse large data sets. In the field of air quality health risk assessment specifically, there has been a rapid and continuously improving set of methodologies through which to analyse the linkages between air pollution and health risk.

The World Health Organisation (WHO) has been leading the development of health risk assessment methodology. Formally, air pollution health risk assessments (AP-HRA) are performed to provide quantifiable information for informing public policy decisions. The general principles for AP-HRAs have been published by the WHO (WHO, 2016a). An AP-HRA proceeds through three steps.

Firstly, it assesses the exposure of the target population to specific air pollutants. This requires a quantification of constituents in the atmosphere that are associated with human health risks. The atmosphere we breathe contains various such constituents, both from natural sources (e.g. sea salt and bio-aerosols) and anthropogenic sources (e.g. fuel combustion, suspension of fine particles, and industrial emissions) (refer to FRIDGE (2004) for a comprehensive discussion of pollution sources). When a particular policy option is analysed, specific indicator constituents need to be selected, and the incremental effect of the policy option needs to be estimated in terms of population exposure. In this study, incremental population exposure resulting from Eskom's coal-fired power plant emissions (from 11 stations), was estimated through the use of dispersion modelling (uMoya-NILU, 2024).

Secondly, the AP-HRA estimates the resultant incremental change in health risk. This requires the application of exposure-response functions (ERFs). ERFs quantify the incremental change in health outcomes (compared to the baseline incidence), based on changes in exposure to pollutants. ERFs are derived from epidemiological studies, which are large scale population health studies that compare health outcome incidence between populations exposed to different concentrations of pollution. In this study, ERFs from the latest systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines were used (WHO 2020, 2021). AP-HRA results can be reported in terms of morbidity indicators (e.g. cost of medical treatment and lost economic productivity) or mortality indicators (e.g. premature mortality). These indicators can be converted to monetary impacts by applying cost of illness (COI) methodologies. In this study, premature mortality was evaluated, using a value of a statistical life (VSL) COI methodology.

Thirdly, the AP-HRA process requires the quantification and expression of the uncertainty of the estimated health effects. The WHO states that this step is "*an important and integral component of the results, and … vital to ensure both that the main message is not lost and that the results*

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[1] http://www.un.org/geninfo/bp/enviro.html

produced are understandable by policy-makers and others who do not necessarily have a technical background or expertise in AP-HRA." This step requires "*the use of expert judgement (consensus) on the level of confidence of the results*".

This study investigates the health effects of air pollution resulting from coal-fired power stations in the Highveld Priority Area and applies the AP-HRA methodology described (see Section 2).

The indicator pollutants used included sulphur dioxide (SO_2), particulate matter (PM), and nitrogen dioxide (NO_2). These pollutants have several negative impacts on public health (WHO, 2016b).

The Department of Environmental Affairs (now Department of Forestry, Fisheries and the Environment, DFFE) under the National Environmental Management Act (NEMA: AQA, 2004) sets ambient air quality standards. The Highveld, containing most of South Africa's coal-fired power stations, often exceeds the National Ambient Air Quality Standards (NAAQS) (DEA, 2009 and 2012). As a result, the Minister of Environmental Affairs declared the Highveld Priority Area (HPA) in November 2007 in terms of Chapter 18 of the National Environment Management: Air Quality Act, 2004 (Act No. 39 of 2004) (NEMA: AQA). Where ambient air quality standards are exceeded, specific air quality mitigation actions would be required. Power generation is a Listed Activity in terms of Section 21 of the NEMA: AQA and Minimum Emission Standards (MES) are prescribed for existing and new stations. The May 2024 ruling by the Minister of the Department of Forestry, Fisheries and the Environment requires that Eskom submit applications in terms of Section 59 of the National Environmental Management: Air Quality Act (NEMA: AQA), for the exemption of the MES for eight power stations that will continue to operate beyond 2030. These are Duvha, Kendal, Lethabo, Majuba, Matla, Tutuka, Medupi and Matimba.

Technologies exist for the reduction of emissions and therefore the health effects. These abatement technologies include Flue Gas Desulphurisation (FGD) and Dry Sorbent Injection (DSI) to reduce SO_2, Electrostatic Precipitators (ESP) and high-frequency power supplies (HFPS) to improve Electrostatic Precipitator (ESP) efficiency to reduce PM, Low NO_X Burners (LNB) to reduce NO_2 and Fabric Filter Plants (FFP) to reduce PM.

The current study investigated three air pollution mitigation scenarios for Eskom, through a benefit-cost analysis (BCA). The BCA uses the AP-HRA methodology to estimate the likely changes in health costs resulting from each scenario. The BCA compares these benefits against the capital costs and operational costs of the mitigation options for each scenario (refer to section 2.3).

1.1 Other studies

Other studies have previously been conducted to estimate the health impacts of either fossil fuel power plants, air pollution in general or specific sources in South Africa. They estimated morbidity and mortality, and in some instances attributed costs to these health impacts. Studies of this nature can take either bottom up (deterministic) approaches or top down (stochastic) approaches to modelling pollution exposure with the latter usually preferable in data poor environments or large spatial domains (Dios et al., 2012). These studies also varied in geographic scale, ranging from selected areas to the national scale. Some of the most recent and relevant include:

The World Health Organisation estimated that, in South Africa, in 2009, the relative risk of premature mortality attributed to poor outdoor air quality was approximately 1,100 cases per year (WHO, 2009).

- Scale: National (All Air Pollution)
- Resolution: Course
- Health Outcomes: Mortality
- Modelling Approach: Top-down

The Centre for Research on Energy and Clean Air estimated that full Minimum Emissions Standard (MES) compliance at Eskom power stations remaining in operation until 2030 would reduce the relative risk of premature mortality from air pollution by 2,300 cases per year and economic costs of R42 billion per year (Myllyvirta & Kelly, 2023). The impacts of mercury were also estimated in the study.

- Scale: National (Power Station Air Pollution)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

The Institute for Health Metrics and Evaluation listed air pollution as the 9th largest risk factor driving death and disability combined in 2016 in South Africa (IHME, 2016).

- Scale: National (All Air Pollution)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A study commissioned by Greenpeace in 2014 estimated air pollution emissions from Eskom's coal-fired power stations could increase the relative risk of premature mortality from air pollution by as much as 2,200 cases per year (Myllyvirta, 2014). The study also estimated the impacts of mercury pollution.

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A 2017 study commissioned by Groundwork, estimated the total impact of air pollution resulting from the coal-fired power stations at $2.4 billion of health costs annually in South Africa (Holland, 2017).

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

Van Horen (1996) evaluated the health costs associated with Eskom's power stations as part of understanding the true costs of electricity generation. The valuation of morbidity outcomes was found to be small in terms of costs per kWh generated.

- Scale: National (Air Pollution from Coal-fired Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

The Fund for Research into Industrial Development Growth and Equity, in 2004, assessed the economic impact of air pollution in selected areas in South Africa. The study found that power generation was responsible for 51% of the 8,700 respiratory cases in Mpumalanga (FRIDGE, 2004).

- Scale: Selected Areas (All Air Pollution and Air Pollution from Power Stations)
- Resolution: Medium
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Bottom-up

A review by Spalding-Fecher and Matibe in 2003 aimed to calculate the external costs of electric power generation in South Africa. They estimated the health costs to be R1.1 billion per year (Spalding-Fecher and Matibe, 2003).

- Scale: National (Air Pollution from Power Stations)
- Resolution: Low
- Health Outcomes: Morbidity and Mortality
- Modelling Approach: Top-down.

The methodology used in this investigation is discussed in detail in Section 2 below.

2 METHODOLOGY AND INPUTS

2.1 Overview

An integrated Health BCA Model was developed that combined an AP-HRA with a BCA to assess three air pollution mitigation scenarios for 11 Eskom coal-fired power stations in the Highveld region.

Figure 2-1 below provides an overview of the methodology, and Sections 2.2 - 2.5 provide a more detailed discussion of each component.

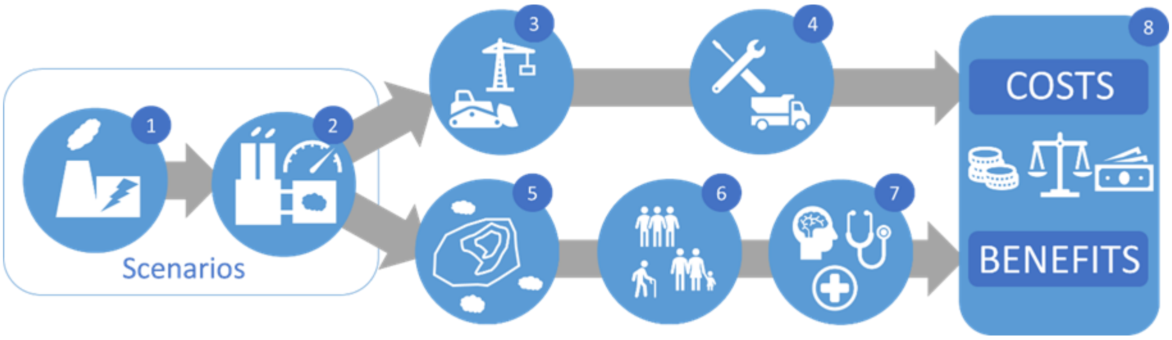

Figure 2-1: Overview of methodology and model architecture

With reference to Figure 2-1, the integrated Health BCA Model includes the following components:

1. Station lifetimes were described for 11 coal-fired power stations and included commissioning and shutdown, repowering and repurposing dates (provided by Eskom).
2. Abatement technologies for the six target power-stations, as required for each scenario, were defined, by type and implementation schedule (refer to section 2.3.3).
3. Capital expenditure required for abatement in each scenario was obtained from Eskom and attributed per plant and per year.
4. Operational expenditure required for abatement in each scenario was obtained from Eskom and attributed per plant and per year.
5. Dispersion modelling was done by uMoya-NILU Consulting (Pty) Ltd. This data was then segregated spatially, by municipal ward boundaries to align with population data. Two types of dispersion modelling were performed, one modelling the individual power station predicted ambient concentrations of PM, SO_2, and NO_2 per scenario and the other the cumulative predicted ambient concentrations of PM, SO_2, and NO_2 from all the power stations per scenario. Note that for PM, the dispersion modelling predicted primary PM and secondary PM effects, resulting from NO_2 and SO_2 reactions in the atmosphere, as well as fugitive emissions (refer to Section 2.2).
6. Population exposure was estimated at a spatial resolution of municipal wards. At each ward, the number of people exposed to different concentration ranges were determined per scenario per year, based on Stats SA population estimates and United Nations population growth forecasts (refer to Section 2.2).

7. Health impacts were determined by using the AP-HRA methodology. Epidemiological evidence, in the form of Exposure-response functions (ERFs) and baseline incidence rates were obtained from the World Health Organization (WHO) systematic reviews (2020 & 2021) conducted by various researchers as part of the WHO update to the Global Air Quality Guidelines (released late September 2021) (refer to Section 2.3). The ERFs were limited to mortality incidence. The Cost of Illness (COI) methodology used was the value of a statistical life (VSL). This method estimates the willingness to pay (WTP) of an individual for reducing their health risk. The VSL should not be interpreted as the intrinsic value of a life. Refer to Section 2.3.2 for a more detailed discussion.
8. The BCA compares the overall scenario health benefits achieved through abatement to the costs of implementation. The outputs of the AP-HRA, i.e. the health cost savings of each scenario, was used as the benefit. The analysis timeline spans 2024 – 2045. (refer to Section 2.4). Finally, an assessment of uncertainty of the results was done (refer to Section 2.5).

2.2 Exposure of the target population to specific air pollutants

2.2.1 Overview

This section comprises the first step of the AP-HRA. It assesses the exposure of the target population to specific air pollutants.

This requires an incremental effects quantification of constituents in the atmosphere that are associated with human health risks. These pollutants include PM, NO_2 and SO_2 emitted by the 11 coal-fired power stations investigated. The emissions from these stations impact the Highveld Priority Area (HPA) and the Vaal Triangle Airshed Priority Area (VTAPA).

Dispersion modelling combined with population distribution provided an estimate of exposed population.

2.2.2 Pollutants analysed

The Highveld Priority Area has several Air Quality Monitoring Stations (AQMS) located in proximity of the power stations equipped for continuous monitoring of air quality and meteorological parameters. These AQMS were established either by Eskom or are SAWS-DEA owned NAQI (National Air Quality Index) stations that were established by DEA (now DFFE).

The sections that follow provide a summary of the ambient concentrations of SO_2, NO_2 and PM in the period of 2021 to 2023 at the AQMS for the exemption power stations of Duvha, Kendal, Lethabo, Matla, Majuba and Tutuka. In the HPA and VTAPA the main sources of air pollution include agriculture activities, mining, domestic fuel and waste burning, vehicle emissions, industrial operations and power generation.

In summary a review of the ambient monitoring confirms that in respect of the NAAQS there is broad PM non-compliance in the area but that SO_2 and NO_x are in general compliance across the area.

2.2.2.1 Sulphur dioxide (SO_2)

Industrial processes and power generation are the main source of SO_2 in the atmosphere through the combustion or refining of sulphur containing fuels. Details at each AQMS are summarised in Table 2-1.

Table 2-1: SO_2 concentrations reported at the HPA AQMS from 2021 to 2023

Power Station	AQMS	Ambient SO_2
Duvha	Masakhane (Eskom)	Hourly, daily average and annual average concentrations below NAAQS with no exceedances
	eMalahleni (SAWS)	The hourly average had one exceedance in 2023. Daily average and annual average concentrations below NAAQS with no exceedances for 2021 and 2023
Kendal	Kendal K2 (Eskom)	Hourly average concentrations in 2023 exceeded the NAAQS three times out of the permitted 88 exceedances per year and remained compliant. Daily and annual average concentrations remained below average NAAQS in all years.

Power Station	AQMS	Ambient SO_2
	Eskom Chicken Farm (Eskom)	Hourly, daily and annual concentrations remained below the respective average NAAQS in all years remaining compliant.
Lethabo	Rand Water (Eskom)	Hourly, daily and annual average concentrations remained below the NAAQS in 2021 and 2023 with no exceedances recorded.
	Three Rivers (SAWS)	Hourly, daily and annual average concentrations remained below the NAAQS in 2021 and 2023 with no exceedances recorded.
	Sharpeville (SAWS)	Hourly concentrations exceeded NAAQS in 2021, 2022 and 2023 however remained within allowable exceedances per year. The daily average only exceeded once in 2022 remaining compliant within the allowable four exceedances per year. In 2021 and 2022 it remained below NAAQS and no exceedances recorded. The annual average concentrations remained below average NAAQS in 2021to 2023 remaining compliant
Matla	Kriel (Eskom)	In all years the hourly and annual average concentrations remained below the average NAAQS with no daily exceedances recorded and remains compliant.
Majuba	Majuba (Eskom)	Hourly, daily and annual concentrations remained below the respective average NAAQS in all the years remaining compliant.
Tutuka	Sivukile (Eskom)	Hourly concentrations remained below the average NAAQS in 2021 (only one exceedance recorded), 2022 and 2023 and remains compliant. The daily and annual concentrations remained below the average NAAQS in 2021 to 2023 and remains compliant.
	Grootdraai Dam (Eskom)	Hourly and daily concentrations remained below the average NAAQS in 2021 to 2023 with no recorded exceedances and the annual concentration also remained below average NAAQS and thus remains compliant.

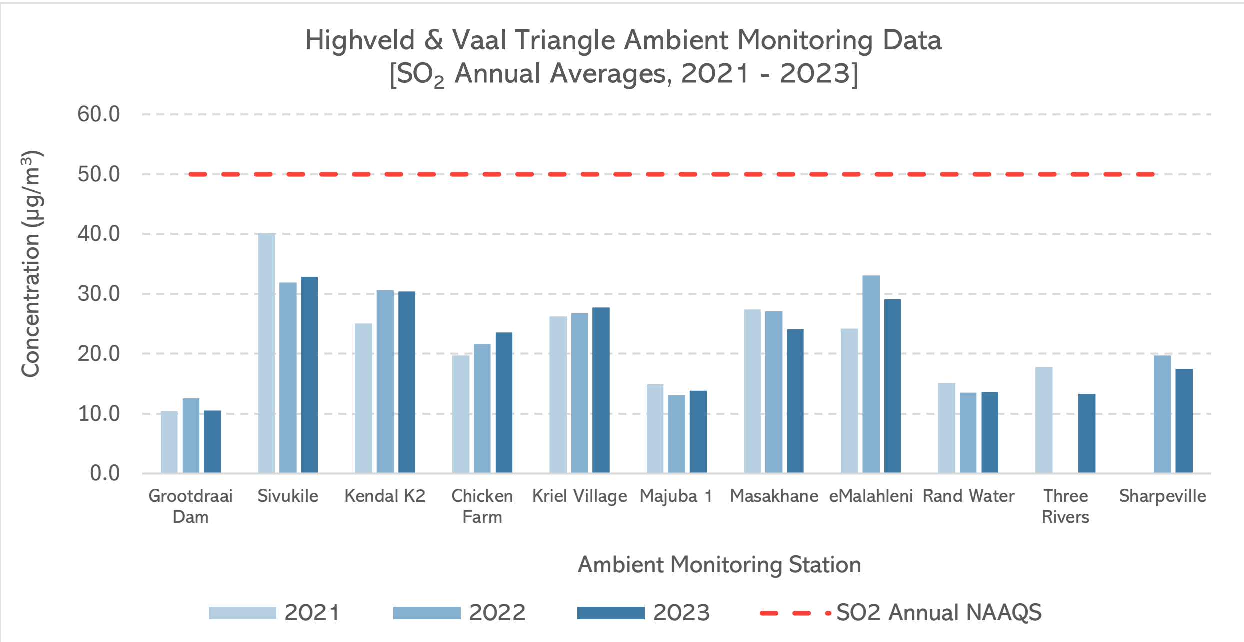

Figure 2-2: Annual average SO_2 concentrations at the Air Quality Monitoring Stations in the HPA in the period 2021 to 2023 in µg/m³

2.2.2.2 *Nitrogen dioxide (NO_2)*

Industrial processes and power generation are the main source of NO_2 in the atmosphere through the combustion or refining of fossil fuels, with some contribution from motor vehicle emissions, residential fuel burning and biomass burning. A summary of the NO_2 pollutant concentrations reported at the HPA AQMS is given in Table 2-2.

Table 2-2: NO_2 concentrations reported at the HPA AQMS from 2021 to 2023

Power Station	AQMS	Ambient NO_2
Duvha	Masakhane (Eskom)	The hourly average concentrations remained below NAAQS between 2021 and 2023. No exceedances recorded. Annual average concentrations for 2021 and 2023 remained below NAAQS.
	eMalahleni (SAWS)	The hourly concentrations remain below NAAQS in 2022 and 2023 with no exceedance recorded. The annual average concentrations for 2022 and 2023 remained below average NAAQS.
Kendal	Kendal K2 (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant.
	Eskom Chicken Farm (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant.
Lethabo	Rand Water (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant with no exceedances.
	Three Rivers (SAWS)	Hourly and annual average concentrations remained below the average NAAQS in 2021 and 2023 remaining compliant with no exceedances.
	Sharpeville (SAWS)	Hourly and daily average concentrations remained below average NAAQS in 2022 and 2023 with no exceedances recorded remaining compliant.
Matla	Kriel (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant with no exceedances.
Majuba	Majuba (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant with no exceedances.
Tutuka	Sivukile (Eskom)	Hourly and annual average concentrations remained below the average NAAQS remaining compliant with no exceedances.
	Grootdraai Dam (Eskom)	Hourly and annual average concentrations in 2021 and 2022 remained below the average NAAQS remaining compliant with no exceedances.

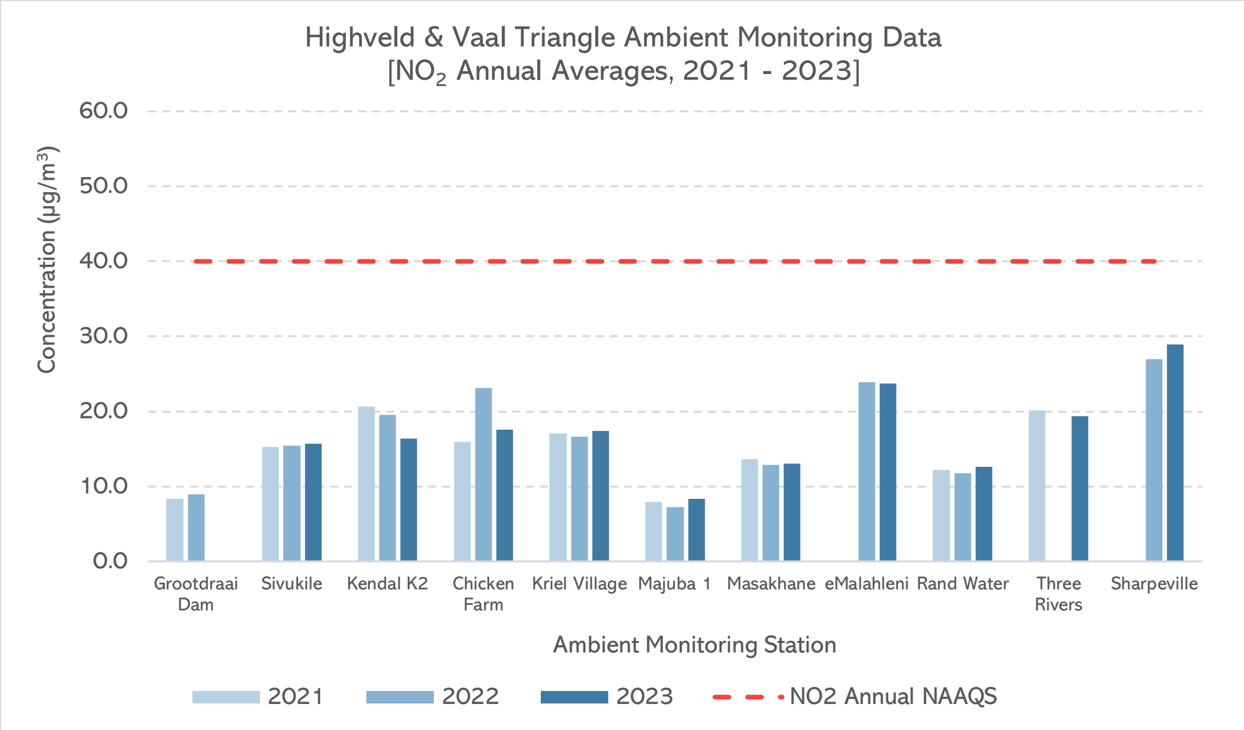

Figure 2-3: Annual average NO_2 concentrations at the HPA monitoring stations in µg/m³

2.2.2.3 Particulate matter (PM)

There are numerous sources of primary particulate matter, including power generation, industry, mining, residential fuel burning, biomass burning and agricultural, as well as natural sources such as wind entrainment. In addition, secondary PM is produced by NO_2 and SO_2 reactions in the atmosphere. The PM pollutant concentrations reported at the AQMS are summarised in Table 2-3.

Table 2-3: PM concentrations reported at the AQMS from 2021 to 2023

Power Station	AQMS	Ambient PM (PM_{10} and $PM_{2.5}$)
Duvha	Masakhane (Eskom)	PM_{10} daily average and annual average exceeded the daily average NAAQS in 2022 and 2023 and is non-compliant with more than the permitted four exceedances per year. The daily and annual $PM_{2.5}$ concentrations exceeded the average NAAQS in 2021 and non-compliant with more than four exceedances, however in 2022 the daily and annual average $PM_{2.5}$ concentrations were below the average NAAQS with no exceedances recorded.
	eMalahleni (SAWS)	The daily average PM_{10} and $PM_{2.5}$ concentrations exceeded the NAAQS in 2021 and 2023 and non-compliant with multiple exceedances reported. The annual average concentrations of both PM_{10} and $PM_{2.5}$ exceeded the annual average NAAQS for 2022 and 2023 but were lower than the NAAQS and compliant in 2021.
Kendal	Kendal K2 (Eskom)	Daily and annual average PM_{10} concentrations exceeded the daily and annual average NAAQS in all years and thus remains non-compliant for PM_{10}.

Power Station	AQMS	Ambient PM (PM_{10} and $PM_{2.5}$)
		In 2021 and 2022 the station remained compliant for $PM_{2.5}$ with only four exceedances for daily average in 2022 and the annual average concentrations in 2021 and 2022 were below the NAAQS.
	Eskom Chicken Farm (Eskom)	Daily PM_{10} concentrations remained below average NAAQS with four exceedances in 2021, none in 2022 remaining compliant but non-compliant in 2023 with eight exceedances. Daily average $PM_{2.5}$ remained below NAAQS in 2023 with one exceedance reported. Annual average PM_{10} and $PM_{2.5}$ were below average NAAQS in 2023 and remain compliant.
Lethabo	Rand Water (Eskom)	Daily $PM_{2.5}$ concentrations exceeded the daily average NAAQS in 2021 and 2022 with more than four exceedances and in 2022 it remained compliant with only four exceedances recorded. Annual average $PM_{2.5}$ remained below average NAAQS in 2021 and 2023 and remains compliant.
	Three Rivers (SAWS)	In 2021 and 2023 the daily and annual average PM_{10} and $PM_{2.5}$ concentrations exceeded the respective daily and annual average NAAQS remaining non-compliant.
	Sharpeville (SAWS)	In 2021 and 2023 the daily and annual average PM_{10} and $PM_{2.5}$ concentrations exceeded the respective daily and annual average NAAQS and remains non-compliant
Matla	Kriel (Eskom)	The daily average PM_{10} and $PM_{2.5}$ concentrations exceeded the NAAQS in 2021 and 2023 and non-compliant with multiple exceedances reported. Annual average concentrations of PM_{10} in 2021 and 2023 and those of $PM_{2.5}$ in 2021 and 2022 exceeded the annual average NAAQS. The 2023 $PM_{2.5}$ concentrations remained below NAAQS and remained compliant in that year.
Majuba	Majuba (Eskom)	Daily and annual average PM_{10} concentrations exceeded the average NAAQS in 2022 and thus non-compliant. Daily average $PM_{2.5}$ concentrations exceeded daily average NAAQS twice in 2021 but remained complaint with under four exceedances. In 2022 and 2023 the daily average $PM_{2.5}$ concentrations exceeded the average NAAQS with multiple exceedances and thus non-compliant. In 2021 the annual average $PM_{2.5}$ was below the annual Average NAAQS and compliant.
Tutuka	Sivukile (Eskom)	Daily concentrations of PM_{10} exceeded the daily average NAAQS with multiple exceedances reported and thus non-compliant. Annual average concentrations in 2021 remained below average NAAQS remaining compliant, however, in 2022 and 2023 the annual average concentrations of PM_{10} exceeded annual average NAAQS
	Grootdraai Dam (Eskom)	Data recovery at the station was below 50% and not reported.

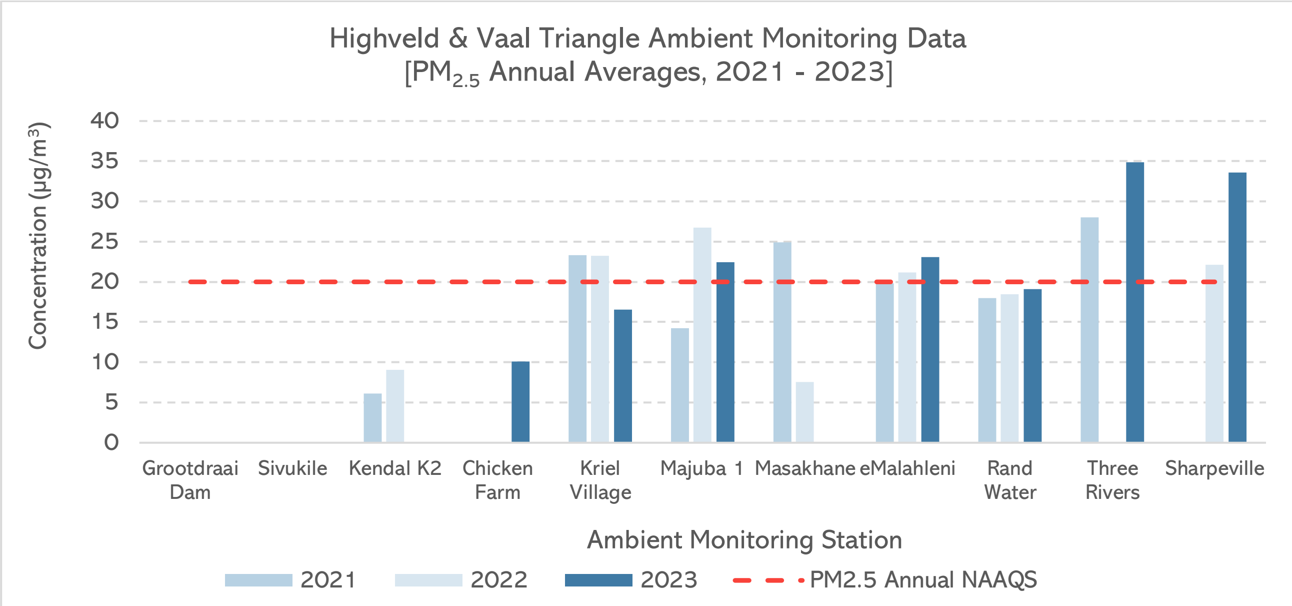

Figure 2-4: Annual average $PM_{2.5}$ concentrations for the HPA in µg/m³

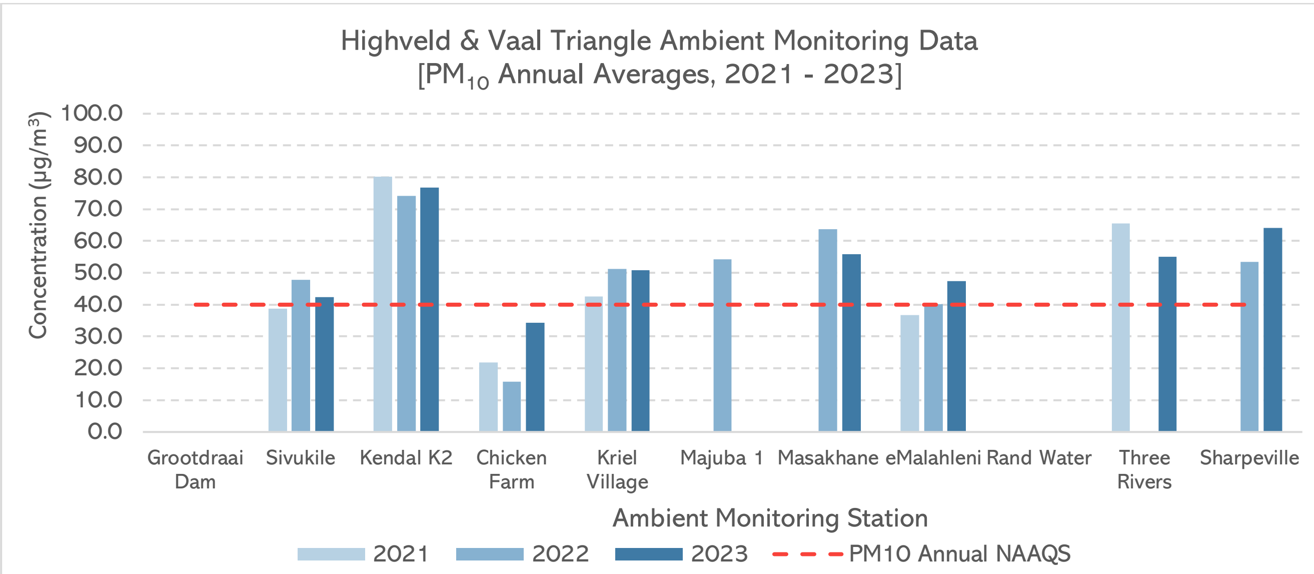

Figure 2-5: Annual average PM_{10} concentrations for the HPA in µg/m³

2.2.3 Description of power stations

The coal-fired power stations forming part of the current HPA and VTAPA study are listed in Table *2-4*. These power stations have a combined installed capacity of 35 848 MW.

Table 2-4: Eskom coal-fired power stations, used in this study, and their installed capacity (Eskom, 2023).

Power Station	Province	Installed capacity (MW)
Arnot	Mpumalanga	2 220
Camden	Mpumalanga	1 561
Duvha	Mpumalanga	3 000
Grootvlei	Mpumalanga	1 180
Hendrina	Mpumalanga	1 723
Kendal	Mpumalanga	4 116
Komati	Mpumalanga	990*
Kriel	Mpumalanga	2 790
Kusile	Mpumalanga	4 796 (on completion of last unit)
Lethabo	Free State	3 708
Majuba	Mpumalanga	4 110
Matla	Mpumalanga	3 600
Tutuka	Mpumalanga	3 654
*All units have been shut down. The last unit was shut down 1 November 2022		

2.2.4 Dispersion modelling

Dispersion modelling is required to estimate the effects of stack emissions on ambient concentrations of pollutants and describe them spatially.

Dispersion modelling for this study was conducted by uMoya-NILU Consulting (Pty) Ltd and followed the requirements of the Code of Practice for Air Dispersion Modelling, DEA guideline (DEA, 2014).

The work modelled the dispersion of sulphur dioxide (SO_2), primary and secondary particulate matter (PM), fugitive emissions and nitrogen dioxide (NO_2) for the Highveld power stations. Dispersion modelling was performed using the CALPUFF suite of models. CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that simulates the effects of time and space-varying meteorological conditions on pollution transport, transformation and removal. It includes algorithms for sub-grid scale effects, such as terrain effect, as well as longer range effects, such as pollutant removal due to wet scavenging and dry deposition, chemical transformation, and the formation of secondary particulate matter. The Air Pollution Model (TAPM) was used to model surface and upper air meteorological data for the study domain.

Two types of analysis were performed, individual and cumulative models. Individual station dispersion modelling domain covers an area of 4,356 km^2, where the domain extends 66 km (west-east) by 66 km (north-south). It consists of a uniformly spaced receptor grid with 0.5 km spacing, giving 17,424 grid cells (132 x 132 grid cells). The cumulative modelling domain covers an area of 97,200 km^2, where the domain extends 360 km (west-east) by 270 km (north-south). It consists of a uniformly spaced receptor grid with 2 km spacing, giving 24,300 grid cells (180 x 135 grid cells).

There were two baseline scenarios modelled in CALPUFF that are used in the study. The first one (Scenario 1) represents the current performance of stations based on actual data over the three year period of 2021 to 2023. The second baseline (Scenario A baseline) took into account the anticipated increase in loads (due to several aspects such as economy requirements, possible delays in IPP projects coming online etc.) in the coming years from 2025 to 2030 and is a better representation of what will be happening in the next five years. Scenario A baseline was used for comparison with the different scenarios in the BCA.

Individual power station models: Five emissions scenarios have been modelled for Highveld Power Stations individually. These are (1) Current Scenario 1 (Current actual emissions), (2) Baseline Scenario (Emission based on anticipated loads), (3) Scenario B (2031 planned stack emissions), and (4) Scenario C (2036 planned stack emissions), (5) Scenario D (Emissions in Full MES compliance 2036).

Cumulative impact: The same five emissions scenarios listed above have been modelled across stations to assess the combined effect of these power stations on the ambient air quality.

Isopleth maps of predicted ambient SO_2, NO_2, PM_{10} and $PM_{2.5}$ concentrations are presented in Figure 2-6 to Figure 2-9. The predicted concentrations are shown as isopleths, lines of equal concentration, in $\mu g/m^3$ for the respective NAAQS averaging periods. The isopleths are depicted as coloured lines on the maps, corresponding to a particular predicted ambient concentration. Areas within red isopleths indicate an area where exceedances of the respective NAAQS limit value are predicted to occur. Sensitive receptors are represented by green squares and AQMS are represented by white dots on the maps. (uMoya-NILU, 2024)

National Ambient Air Quality Standards (NAAQS) (DEA, 2009, 2012) apply to the pollutants emitted by stations. The NAAQS consists of a 'limit' value and a permitted frequency of exceedance. The limit value is the fixed concentration level aimed at reducing the harmful effects of a pollutant and the permitted frequency of exceedance represents the acceptable number of exceedances of the limit value expressed as the 99th percentile. Compliance with the ambient standard implies that the frequency of exceedance of the limit value does not exceed the permitted tolerance. The NAAQS limits for the averaging period of 1 year for SO_2 is 50 $\mu g/m^3$, for NO_2 is 40 $\mu g/m^3$, for PM_{10} is 40 $\mu g/m^3$ and for $PM_{2.5}$ is 20 $\mu g/m^3$ (from 2030 is 15 $\mu g/m^3$).

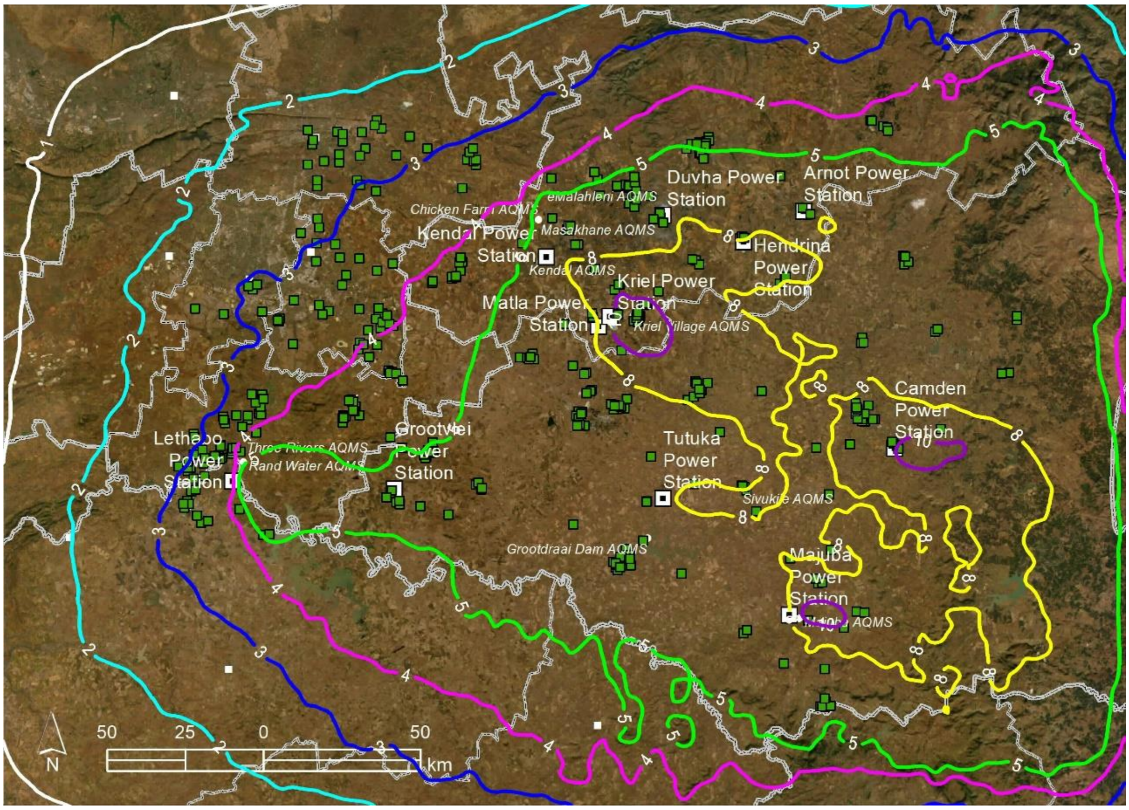

Figure 2-6: Cumulative predicted annual average SO_2 concentrations (µg/m^3) for the Highveld Power Stations

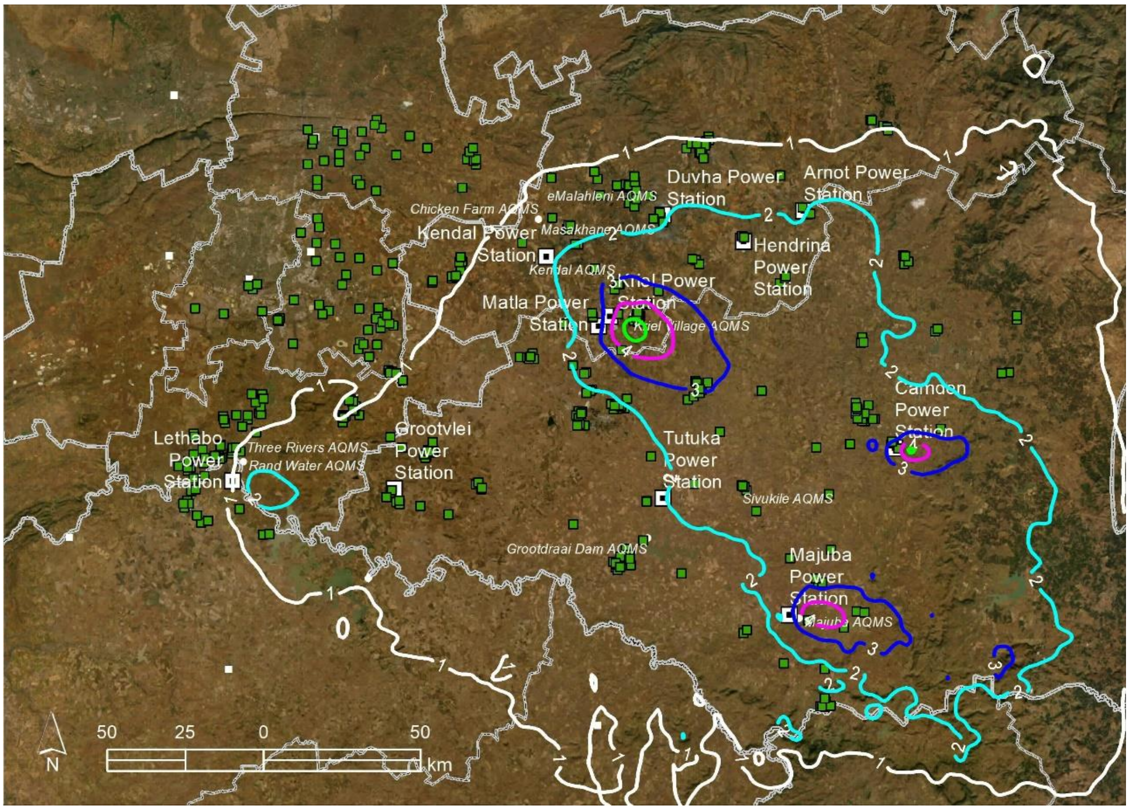

Figure 2-7: Cumulative predicted annual average NO_2 concentrations (µg/m^3) for the Highveld Power Stations

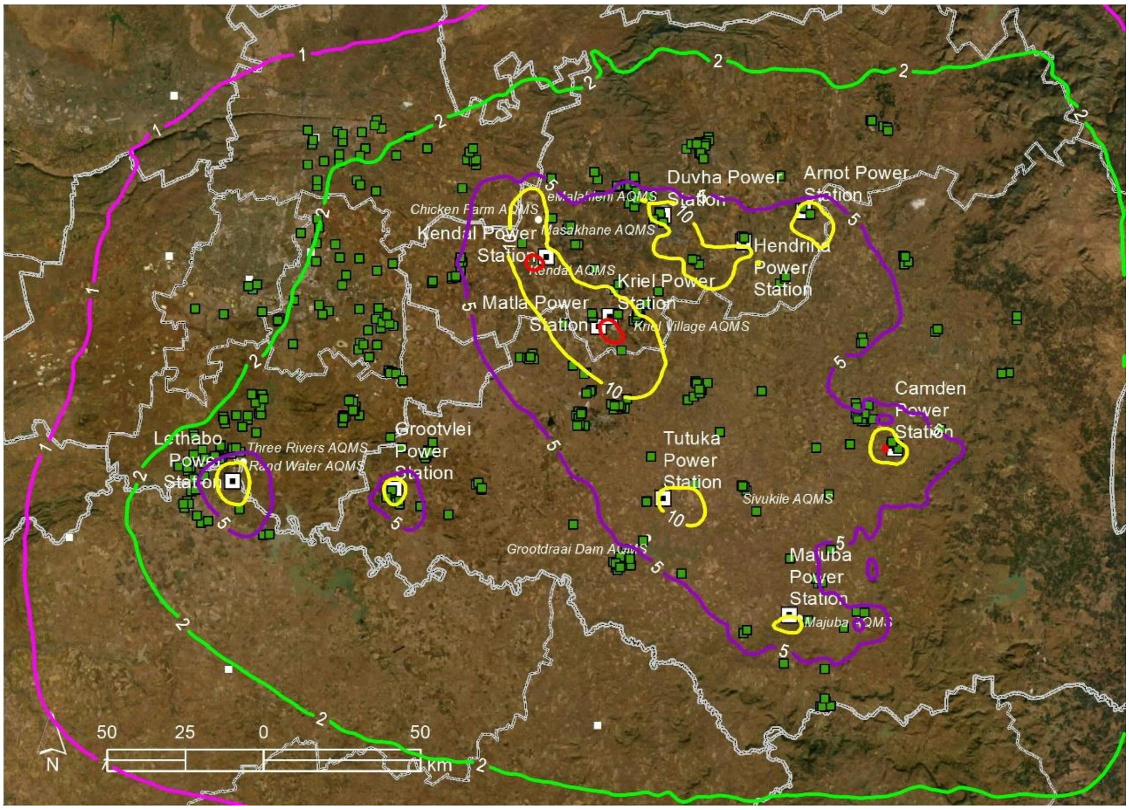

Figure 2-8: Cumulative predicted annual average PM_{10} concentrations (µg/m^3) for the Highveld Power Stations

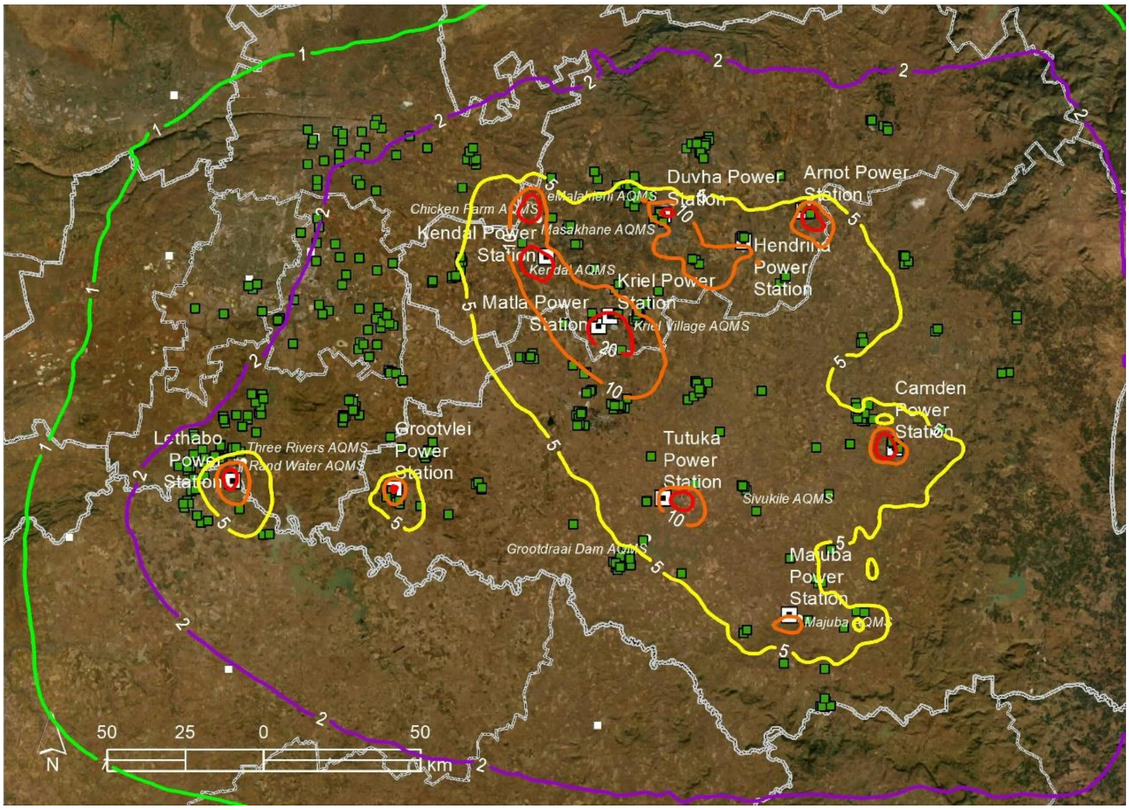

Figure 2-9: Cumulative predicted ambient $PM_{2.5}$ concentrations (µg/m^3) for the Highveld Power Stations

2.2.5 Population exposure

Population exposure was estimated at a spatial resolution of municipality and municipal wards. At each municipality or ward, the number of people exposed to different concentration ranges were determined based on Stats SA population estimates (Stats SA, 2012; Stats SA, 2024a,b) and United Nations population prospects growth forecasts (United Nations, 2024).

Population exposure was estimated at a spatial resolution of municipal wards for the data from the dispersion model runs. At each ward, the number of people exposed to different concentration ranges for each pollutant were determined per scenario per year. Particulate matter (Total PM) in the model took the primary and secondary particulate matter into account.

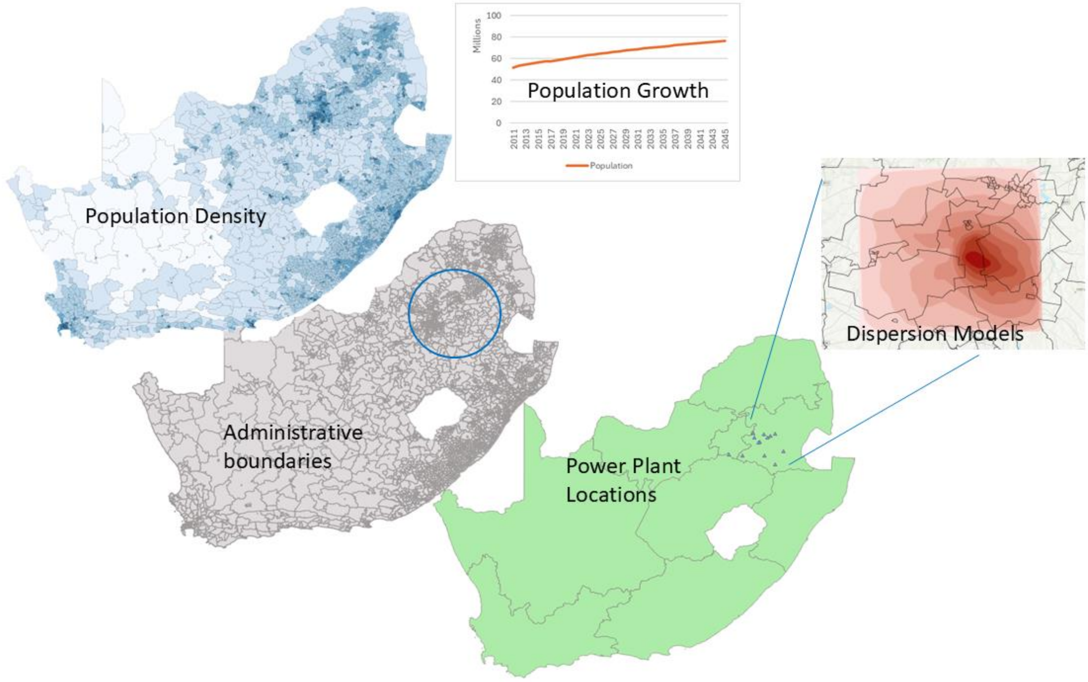

Figure 2-10: Overview of population exposure calculation

The integrated Health BCA model calculated pollution exposure as follows:

- Dispersion Model outputs were used to spatially apportion pollution concentrations. The co-ordinates (x;y) of receptors from the output files were attributed to specific administrative boundaries.
- Administrative boundaries used were municipalities and municipal wards. The predicted ambient concentrations for each pollutant were averaged for the entire spatial unit.
- Population density (population per ward) was obtained from the Census 2011 (Stats SA, 2012), given that the latest Census 2022 metadata which includes ward level numbers has not been released.
- Total population was obtained from the latest available mid-year population estimates (Stats SA, 2024a,b).

- Population growth forecasts were used to determine the growth in population exposure over time (United Nations, 2024). This was used to grow the population numbers in each year following 2024 to the end of the modelled timeframe year of 2045.
- Power station locations were used to determine the wards which were affected by each station, to estimate relative impacts of each power station to the cumulative impact modelled.

Considering the current emission over the period from 2021 to 2023, approximately 15.8 million people were population exposed to more than an additional 1 µg/m^3 (mean annual average) of PM due to the 11 power stations. Similarly, 2.2 and 15.9 million people were exposed to more than an additional 1 µg.m^3 of NO_2 and SO_2, respectively.

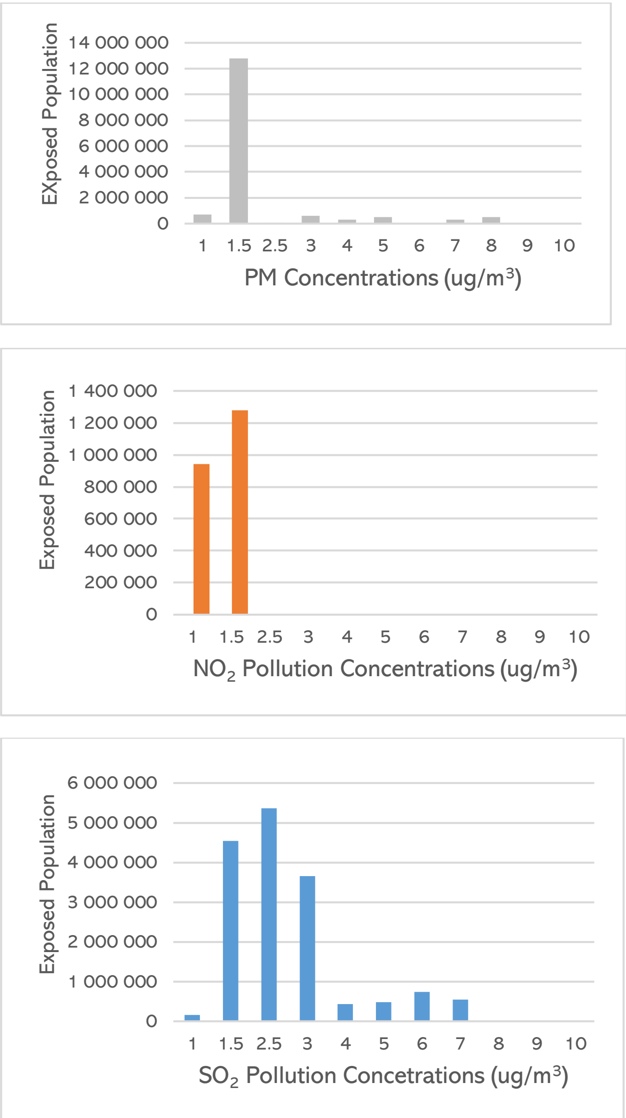

Figure 2-11 Population exposure to PM, SO_2 and NO_2mean annual average concentration ranges.

2.3 Incremental change in health risk

2.3.1 Health impacts

The WHO (2016a) recommends that the health risk in a population, associated with air pollution, is to be estimated using exposure-response functions (ERFs). ERFs are based on Relative Risk (RR) estimates derived from primary epidemiological studies.

These RR functions estimate the likelihood of health outcomes occurring in a population exposed to a higher level of air pollution relative to that in a population with a lower exposure level (WHO, 2016a). RR is usually expressed as the proportional increase in the assessed health outcome associated with a given increase in pollutant concentrations, measured in μg/m^3. The WHO (2016a) notes that "*the RR estimate cannot be assigned to a specific person; it describes risk in a defined population, not individual risk.*"

Epidemiological studies are mostly based on evidence from population health studies that compare health outcome incidences of populations exposed to higher levels of air pollution to populations exposed to lower levels of air pollution. Most of these studies have been done in Europe and North America.

Ideally, ERF studies and their RRs should be determined based on primary epidemiological studies focussing on the exposed population. In the absence of such studies, as in the case of South Africa, the WHO (2016a) recommends using ERFs from other countries.

It is to be noted that there are inherently significant limitations in transferring ERF studies from other countries. Pollution levels, chemical composition and health care systems are typically very different in other settings, and this would affect the accuracy of the ERFs.

The health outcomes were selected based on the latest WHO systematic reviews from 2020 and 2021 that were conducted for the update of the WHO Global Air Quality guidelines. The health outcome considered in this study is all-cause mortality. Morbidity was not considered in this study as comprehensive data on morbidity studies is not widely available. Additionally, there are issues relating the transferability of data from one population to another in terms of country and culture as populations have different sensitivities to pollutant exposure (WHO 2000).

All-cause Mortality: This provides a measure of all the deaths that occur within the population from any natural causes. It includes natural deaths from all causes of death as provided in the WHO (2016b) International statistical classification of diseases and related health problems (ICD-10). In South Africa all-cause mortality makes up 88% of total deaths in South Africa (Stats SA, 2023).

In the AP-HRA, a health outcome must be attributed to an individual indicator pollutant. While health outcomes can be attributed to many different indicator pollutants, using all would result in double counting mixture effects in health impacts as these pollutants are associated with each other (WHO, 2016a, Malmqvist et al., 2018).

Table 2-5: Indicator pollutant, baseline incidence, and relative risks for all-cause mortality (Source: WHO systematic reviews by various researchers & baseline incidence – Stats SA 2023)

Indicator Pollutant	Health Outcome	Baseline data	Relative Risk or Hazard Ratio per 10 μg/m^3	Reference
$PM_{2.5}$	All-cause Mortality	0.687%	1.08	Chen & Hoek, 2020
PM_{10}	All-cause Mortality	0.687%	1.04	Chen & Hoek, 2020
SO_2	All-cause Mortality	0.687%	1.0059	Orellano et al., 2021
NO_2	All-cause Mortality	0.687%	1.02	Huangfu & Atkinson, 2020

The baseline incidence rate of the health outcome was determined based on published data from the year 2019 from Stats SA (Stats SA, 2023). The ERFs describing the change in incidence in relation to changes in exposure (RRs) were obtained from the WHO latest systematic reviews for the update of the WHO Global Air Quality guidelines (WHO, 2020, 2021).

2.3.2 Health costs

The detrimental effects of air pollution on human health are borne in the economy by households, insurance companies, employers and public health programs (Romley et al., 2010).

The fundamental goal of health cost or cost of illness (COI) studies is to evaluate the economic burden that illness imposes on society as a whole (Jo, 2014). Rice (1967) and Rice et al. (1985), were instrumental in standardising methodologies for estimating COI, and these methodologies continue to be used internationally, and periodically updated (Rice, 1996; Rice, 2000).

COI studies contextualise adverse diseases effects into monetary terms, with the purpose of informing decision-making. Such decisions could include (a) to simply present the magnitude of disease in monetary terms; (b) to comparatively evaluate intervention programs; (c) to assist in the allocation of research funding on specific diseases; (d) to provide a basis for policy and planning relative to mitigation initiatives; and (e) to provide an economic framework for program evaluation (Rice, 2000).

The COI studies traditionally stratify costs into two categories: direct costs and indirect costs. Direct costs relate to the cost of medical treatment. This would include costs of visiting health care facilities, medicine and hospitalisation. Indirect costs comprise morbidity costs (the cost of lost economic productivity due to absenteeism or temporary or permanent disability) and mortality costs. With respect to mortality costs, valuing human life is contentious, as it can be seen as a judgement on the intrinsic value of life and involves complex ethical considerations. Sometimes, cost-effectiveness analysis is used as an alternative (Muchapondwa, 2009). This side-steps the complexity of life valuation and uses disease or fatality incidence indicators to compare effectiveness of different policy or spending options.

The health impact or health risk, associated with air pollution, is estimated using ERFs as described in section 2.3.1 above. In this study, the ERFs obtained from the latest WHO systematic reviews, focussed exclusively on mortality and thus a monetary measure of mortality was required in order to estimate the health costs and to perform benefit-cost analyses. In air pollution benefit-cost analyses, the concept of value of a statistical life (VSL) is commonly used to monetise mortality related benefits of air pollution reduction. The concept of a VSL is frequently misunderstood. It does not measure the intrinsic value of a human life, and neither does it value the economic productivity of a human. Rather, VSL is estimated by dividing an individual's willingness to pay (WTP) to reduce health risk, by the likelihood of risk reduction. Robinson and Hammitt (2009) defines VSL to represent the rate at which an individual is willing to exchange their own income for a small reduction in their own mortality risk over a particular time period. VSL is not the value that a person, society or the government would place on averting mortality risk with certainty, but it is rather a representation of the rate at which a person views a change in the money available for spending as equivalent to a small change in their own mortality risk (Robinson et al., 2018).

Primary WTP studies for mortality risk reductions have not been done in South Africa. Most countries do not have reliable revealed preference or stated preference estimates of the VSL (Viscusi and Masterman, 2017) and primary research studies require considerable time and expense (Robinson et al., 2018). In these cases, a "benefit transfer" method is used to transfer values from other studies. Both the above sets of authors recommend using a United States of

America (USA) base VSL (calculated using labour market estimates from the USA's Census of Fatal Occupational Injuries, CFOI, data) and then further adjust it for differences in income between the USA and the country of interest.

The VSL estimate in this study is determined by the following equation (from Viscusi and Masterman (2017) and Robinson et al. 2018):

$$VSL_{target} = VSL_{base} \times \left(\frac{Income_{target}}{Income_{base}}\right)^{\text{elasticity}}$$

In the above equation the base country is the United States. The VSL is transferred using the income measure of GNI (Gross National Income) per capita from the World Bank which uses the Atlas method which is based on exchange rates and inflation rates.

Data for the US base VSL was obtained from the US Economic Research service and the federal register, the GNI value per capita was sourced from the World Bank. Exchange rates to convert the dollar value of the South African VSL into rands was taken from the annual average exchange rates from the South African Reserve Bank.

A sensitivity analysis was conducted in the BCA based on the recommendations of Robinson et al. 2018. The default values include:

VSL = 160 * GNI per capita of the target country

VSL = 100 * GNI per capita of the target country

VSL extrapolated from USA estimate to target country using an elasticity of 1.5.

Additionally, the sensitivity analysis uses the Masterman and Viscusi (2017) income elasticity of 1.0.

2.3.3 Pollution abatement options

2.3.3.1 Summary

Table 2-6 sets out the detailed abatement options per scenario assessed.

Abatement options include limiting generating load, improving plant efficiencies and the installation of technologies to reduce emissions. Technologies include Flue Gas Desulphurisation (FGD), Dry Sorbet Injection (DSI), Electrostatic Precipitators (ESP), Low NOx Burners (LNB) and Fabric Filter Plants (FFP). ESP and FFP are used to reduce particulate matter (PM) emissions, LNB to reduce nitrogen dioxide (NO_2) emissions and FGD and DSI to reduce sulphur dioxide (SO_2) emissions. The model required that each abatement technology applied in each plant in each scenario was described in terms of commissioning periods. The abatement technologies investigated in the scenarios for this current study included FGD, DSI, Low NOx Burners (LNB) and Installation of high-frequency power supply (HFPS) to improve ESP efficiency.

The BCA model was setup to compare three different scenarios in terms of abatement technology implementation for specific Highveld power stations. The dispersion modelling was done for each of these scenarios and the results were used in the BCA model. The model was constructed to allow for a gradual change in pollutant emission concentrations over several years based on operational timeframe. This was done to reflect that not all retrofitted units will be operational at the same time. When the abatement technology of all units at a plant is operational the model then reflects the specific scenario compliance emission concentration values related to the specific scenario.

2.3.3.2 Eskom load curtailment strategy

With the proliferation of the alternate energy sources on to the national grid due to the IRP, the existing coal fired power stations are expected to move into a load following mode of operation. This essentially results in lower running load factors for these stations as the renewable energy sources will be given priority over the fossil fuelled stations. This equates to average load factors of 40-45% for stations operating in 2031 and between 40 to 55% for stations operating beyond 2035, i.e. after Matla and Duvha shutdown. The nett effect of this is that less coal will be burnt in the generation of South Africa’s electricity which results in direct emissions reduction at no additional cost impact. This is the basis of Eskom’s load based alternate emissions limits.

Table 2-6: Detailed summary of Scenarios (Source: Eskom)

Scenario	Abatement and additional information
Eskom plan - ERP 2024 A	Predicted monthly tonnage emitted per stack in 2031 assuming: a. Komati, Grootvlei, Hendrina, Camden, Arnot and Kriel no longer operating. b. All planned PM emission reduction projects completed, and stations operate at PM=50 mg/Nm^3. c. NOx projects completed with Matimba, Kendal, Kusile, Medupi, Lethabo, Tutuka and Majuba at 750 mg/Nm^3. Matla and Duvha continue to operate at 1,100 mg/Nm^3. d. Kusile and Medupi operate at SO_2 = 500 mg/Nm^3 to reduce total SO_2 load. e. All other stations operate at requested alternate SO_2 levels (Kendal, Majuba, Tutuka at 3,000 mg/Nm^3 and Duvha, Matla and Lethabo at 2,600 mg/Nm^3 – annual tonnage average will be 20% below limit value). f. Load factor restricted to an average value per station per year (see Appendix A) g. Efficiency and coal improvement projects reduce total emissions by 5% at Matimba, Kendal, Kusile, Medupi, Lethabo, Tutuka and Majuba (not Matla and Duvha). h. Implementation of expanded air quality offset programme (35,000 + households) i. This scenario is similar to the existing Eskom Emission Reduction Plan 2022.
Eskom plan - ERP 2024 B	Predicted monthly tonnage emitted per stack in 2036 assuming: a. As per Scenario B but at 2036 energy output, and: b. Duvha and Matla no longer operating c. Efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Matimba, Kendal, Kusile, Medupi, Lethabo, Tutuka and Majuba. d. Direct Sorbent Injection (DSI) at Majuba giving a 20% SO_2 reduction (completed by 2031). e. Semi-dry FGD at Kendal giving a 70% SO_2 reduction (completed by 2035).
Full MES compliance – ERP 2024 C	Predicted monthly tonnage emitted per stack in 2036 assuming: a. Komati, Grootvlei, Hendrina, Camden, Arnot and Kriel no longer operating. b. Duvha and Matla no longer operating. c. Operating stations are Majuba, Matimba, Kendal, Kusile, Medupi, Lethabo, Tutuka, as per the CDS (Rev 4) shut down schedule. d. All planned PM emission reduction projects completed (by 2028), and stations operate at PM=50 mg/Nm^3. e. NOx projects completed at all stations (completed by 2032), and stations operate at NOx = 750 mg/Nm^3. f. SO_2 reduction to new plant limit of 1000 mg/Nm^3 completed at all stations (completed by 2035). implementation of existing air quality offset programme (35,000 households).

2.3.3.3 Power station shutdown

Station lifetimes were described for the power stations modelled. The shutdown dates affect the pollution emissions per year in the model (reduction of emissions) in the years when plant units are shutdown. The shutdown dates are shown in Table 2-7.

Table 2-7 Shutdown periods for different scenarios

Power Station	Shutdown Period	
	Start	End
Arnot	2029	2030
Camden	2029	2030
Duvha	2031	2036
Grootvlei	2029	2030
Hendrina	2029	2030
Kendal	2040	2045
Komati	2020	2022
Kriel	2029	2030
Kusile	2069	2073
Lethabo	2037	2042
Majuba	2047	2052
Matla	2031	2036
Tutuka	2036	2041

These station lifetimes were used to describe the base emission rates for each scenario in the integrated model. Shutdown dates are based on Eskom's present planning and technical requirements, dates are subject to review based on national energy requirements. Eskom need to follow all necessary regulator and stakeholder engagement process prior to station shutdown. Shutdown of power stations do result in a reduction of pollutants and an increased health benefit – these are discussed in section 3.2.

2.3.3.4 PM reduction

Abatement technologies considered in the scenarios for PM reduction included Electrostatic Precipitators (ESP) and High Frequency Power Supplies (HFPS) to improve the efficiency of the ESP. An ESP removes particulate matter, from the flue gas using the force of an induced electrostatic charge. ESP upgrades or refurbishments can reduce particulate matter between 95-97%.

2.3.3.5 Low NOx Burners (LNB) for NO_2 reduction

LNBs are an abatement technology to reduce NO_2 emissions. LNBs are designed to control fuel and air mixing to reduce peak flame temperature and thereby reduce NO_2 formation. LNBs can reduce NO_2 emissions by approximately 30%.

2.3.3.6 Flue Gas Desulphurisation (FGD) for SO_2 reduction

FGD is a set of technologies used to reduce SO_2 emissions. FGD systems typically include a fly ash removal and SO_2 removal. SO_2 (an acid gas) removal is facilitated by alkaline sorbents such as limestone to react with the gas. FGDs are typically separated into two types, semi-dry and wet, dependent on their water requirements, and can reduce SO_2 emissions by 90%.

2.3.3.3 Dry Sorbent Injection (DSI) for SO_2 reduction

DSI is also a set of technologies used to reduce SO_2 emissions. DSI systems consist of direct injection of alkaline (sorbent)materials, for example sodium bicarbonate trona or less frequently hydrated lime into the flue gas stream to control SO_2 and other acidic gases (Sahu, 2013; Sahu, 2019). The DSI systems may reduce SO_2 emission by between 45% and 80%. Reduction is dependent on various factors such as sorbent mass injection rate, length of time the sorbent is present in the flue gas stream (dependent on the injection location), sorbent penetration and mixing with flue gases, what type of particulate control device is used, the flue gas temperature profile, and the particle size of the sorbent (Sahu, 2013).

2.3.4 Costs of implementation

Table 2-8. Summary of costs of implementation of abatement for the Highveld power stations: costs of CAPEX and OPEX and estimated impacts on electricity tariffs

	Scenario	CAPEX and OPEX (Rand million Nominal)	Impact on Electricity Tariff (c/kWh)		Impact on Electricity Tariff (%)	
		-15% +20%	Lower	Upper	Lower	Upper
	ERP 2024 A	R18,500	0.78	1.10	0.4%	0.6%
+	ERP 2024 B (Majuba)	R13,100	0.49	0.69	0.3%	0.4%
+	ERP 2024 B (Kendal)	R44,360	0.61	0.86	0.3%	0.5%
Sub-Total	ERP 2024 A + B	R75,970	1.88	2.65	1.0%	1.4%
+	ERP 2024 C (Lethabo)	R39,970	0.54	0.76	0.3%	0.4%
+	ERP 2024 C (Tutuka)	R39,390	0.51	0.73	0.3%	0.4%
Total	ERP 2024 A+B+C	R155,320	2.93	4.14	1.6%	2.2%

The total nominal cost of all Eskom abatement scenarios has been estimated by Eskom at a Class 2 accuracy implying a variance between -15% and +20%.

- ERP 2024 A = R18,500 million
- ERP 2024 B = R75,970 million
- ERP 2024 C = R155,320 million.
- Source: Eskom

We estimated the effect of these additional costs on electricity tariffs. This was based on a cashflow waterfall set up for each scenario, solving for a tariff that would pay back the cost of abatement technology over the assessment period. This tariff margin may be thought of as an air emissions abatement levy:

- ERP 2024 A = 0.4% - 0.6%
- ERP 2024 B = 1.0% - 1.4%
- ERP 2024 C = 1.6% - 2.2%.
- Note: Electricity impact tariffs were not sourced from Eskom but were estimated using the method described above.

2.4 Benefit-Cost Analysis

A BCA is a widely used approach employed for decision-making support. This approach was formalized in the United States in 1958 with the purpose of justifying public expenditures on alternative investment options competing public funds such as water, roads, and other public utilities' networks construction projects. BCA methodology broadly advises on the treatment of income benefits and costs; externality costs; how to measure them conceptually; how future prices should be treated; the importance of using a discount rate; the proper period of analysis; and cost allocation procedures for projects.

The World Bank[2] defines a Social BCA as an extension of a financial analysis. Ideally, in extending the financial analysis, all relevant economic costs and benefits are quantified and analysed. The BCA pulls together the component analyses of the study to assess the overall impact for a set of scenario options (emission reduction measures).

The objective of the BCA is to comparatively analyse investments or scenarios (in this case interventions in air quality management). The BCA achieves this end by identifying and monetizing the costs and benefits and predicting the timing thereof over the same horizon as the projects' economic lifetime (National Treasury, 2017).

A BCA allows scenarios to be objectively compared according to the benefit:cost relationship to analyse the relative efficiency of various interventions and the magnitude of the benefits to identify the interventions that will have the largest impacts.

In this analysis, the BCA compares the scenario health benefits to capital and operational costs pf abatement. This BCA does not capture all potential costs and benefits, both direct and indirect. (Refer to section 2.5.1 below for a discussion of BCA limitations)

The analysis timeline spans 2024 – 2045. The base year was 2024, due to dispersion modelling timeframe. The BCA was performed in an Excel spreadsheet, which consolidated all data sources, which contains all calculations, and was macro-enabled to run the large spatial exposure estimates for each scenario for the review period. The benefit-cost analysis apportioned costs (capital and operation expenditure on abatement technologies) and benefits (health benefits) to the years in which they would be realised. Because costs and benefits are accrued in different years according to the intervention schedules, the net present values of costs and benefits, using Eskom's weighted average cost of capital (WACC) rate of 10.8% (Eskom, 2024) as the discount rate allows an objective comparison of scenarios.

The health cost benefits were estimated based on the outputs of the AP-HRA and followed the steps below:

1. Each of the assessed Scenarios implemented an abatement schedule at specific power stations (refer to section 3 for details)
2. The dispersion effects modelled by uMoya-NILU (Pty) Ltd were used to estimate the change in population exposure over the timeline.

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[2] http://documents.worldbank.org/curated/en/445971468767366310/pdf/multi-page.pdf

3. The change in population exposure resulting from step 2 above was applied to the ERFs identified in section 2.3.1 to estimate health impact outcomes (sensitivity analysis was performed in the BCA to develop a view on the uncertainty inherent in the ERFs, also refer to section 2.5.1).
4. The VSL (refer to section 2.3.2) was applied to the health impact outcomes for each scenario, to estimate change in health cost benefits.
5. Capital and operational cost estimates were used as the costs in the BCA (refer to section 2.3.4).
6. Sensitivity analysis was performed on the VSL, the health benefit and abatement cost estimates.

Section 3.2 provides the BCA results.

2.5 Uncertainty of the estimated health effects

2.5.1 Sources of uncertainty and limitations

The WHO (2016a) advises performing an assessment of the uncertainty of the analysis; in this case therefore this requires an assessment related to a lack of knowledge about one or more components of the integrated Health BCA Model. The sections below discuss each source of uncertainty and related limitations.

Air pollutants exist as a complex mixture: Despite improvements in the science underlying AP-HRAs, it is still not possible to estimate with complete certainty the effects of air pollution on health (WHO Regional Office for Europe, 2014, cited in WHO 2016a). The observed adverse effects attributed to an individual air pollutant may well be (partly) attributable to other pollutants in the mixture which are correlated with the assessed pollutant (WHO Regional Office for Europe, 2013, cited in WHO 2016a). It is not possible to assess the uncertainty relating to this (WHO, 2016a).

Pollutants modelled: The analysis was limited to PM, SO_2, and NO_2 pollutants, these are the criteria pollutants managed in terms of South African air quality legislation and of most recognised significance in the Priority Area. Other pollutants may also contribute to health risk and these were not modelled in the dispersion modelling. This may under-estimate health risks and thus benefits of health risk mitigation. However, no data or other information exists through which to assess this limitation.

Exposure response functions: ERFs are derived from epidemiological studies, in which the parameters of the epidemiological experiment and assumptions made during the experiment introduce some uncertainty into the results. More significantly, because primary epidemiological evidence on air pollution is not available for South Africa. This is a key limitation. As a result, inference has to be drawn from studies in other parts of the world. It is to be noted that health response per unit change in air pollution in environments with high ambient levels (such as the HPA) may differ from that observed in countries with lower pollution levels. In summary, the WHO (2016a) notes that extrapolated ERF information may not accurately describe the exposure-response relationship in the region to be assessed, leading to uncertainties in the results. In order to deal with these uncertainties, we used variances in ERF outcomes as a measure of BCA ratio variation.

Dispersion model accuracy (uMoya-Nilu, 2024): "Air quality models attempt to predict ambient concentrations based on "known" or measured parameters, such as wind speed, temperature profiles, solar radiation and emissions. There are, however, variations in the parameters that are not measured, the so-called "unknown" parameters as well as unresolved details of atmospheric turbulent flow. Variations in these "unknown" parameters can result in deviations of the predicted concentrations of the same event, even though the "known" parameters are fixed. In the present dispersion modelling conservative assumptions in terms of surface area of ashing facilities giving rise to fugitive emissions were made that have resulted in an over prediction of PM emissions in shorter time periods. Furthermore, for $PM_{2.5}$ and PM_{10} the predicted concentrations are attributed to stack emissions and low-level fugitive sources (ash dump). The inclusion of the fugitive sources was done assuming the entire area is exposed and available for entrainment, while in reality only a small portion of the modelled area would be exposed to entrainment due to the vegetated sides and wet areas of the dump. This approach is extremely conservative. The PM emissions from stacks and fugitive sources are not speciated into PM_{10} and $PM_{2.5}$, rather all PM emitted is assumed to be PM_{10}, and all PM emitted is assumed to be $PM_{2.5}$. Further, considering the proximity of the exceedances to Lethabo, as noted in the uMoya-Nilu AIR, the elevated PM can mostly be attributed to the low-level fugitive sources, which have poor buoyancy and disperse poorly, as opposed to the stack emissions which are released at a height of 200 m above ground-level, with considerable buoyancy, and so disperse well.

There are also "reducible" uncertainties that result from inaccuracies in the model, errors in input values and errors in the measured concentrations. These might include poor quality or unrepresentative meteorological, geophysical and source emission data, errors in the measured concentrations that are used to compare with model predictions and inadequate model physics and formulation used to predict the concentrations. "Reducible" uncertainties can be controlled or minimised. This is done by using accurate input data, preparing the input files correctly, checking and re-checking for errors, correcting for odd model behaviour, ensuring that the errors in the measured data are minimised and applying appropriate model physics."

Baseline disease burden: The baseline cases of mortality used were for 2019, based on latest available Stats SA data. The data for this year is therefore accurate. Stats SA data for 2020 was not used as these numbers may be skewed by the effects of COVID. Uncertainty arises however because projections are made of population size growth in future, under the assumption that the relative ratio of mortality in the future remain constant.

Morbidity effects were not assessed: The costs of medical treatment (including visiting health care facilities, and costs of medicine and hospitalisation) and the loss of economic production due to sick-leave absenteeism or temporary or permanent disability, were not assessed. This is because of an absence of official data on health care visits and associated direct costs within both the public and private health care sectors; linked to suitable ERFs. As a result, the BCA underestimates the health benefits of the various scenarios. As before, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation.

Value of a statistical life: VSLs are accurate when estimated based on primary data collected through willingness to pay studies specific to the exposed population. All VSL estimates for South Africa are derived and transferred from studies done in the United States of America. This introduces uncertainty in the BCA results. As before, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation.

Timeline of dispersion modelling predicted concentrations: The data from the dispersion modelling in CALPUFF is from a specific point in time and is then interpolated for the timeline values that are required to run a benefit:cost analysis. Ideally the BCA model should have a CALPUFF run for each year used in the model timeline, however, to do this is not practical. This causes uncertainties in the results.

Cost uncertainty: Eskom uses a cost estimate classification matrix which has different estimate classes associated with different expected accuracy ranges for making project cost estimations (Eskom, 2020). Based on these classes the sensitivity analysis for costs estimates varied by +20% or -15% (Class 2).

Eskom is constantly working to refine the accuracy of the emission reduction costing and this may result in internal updates of costing. Anticipated changes in cost are anticipated to fall within the range of variance (-15% and +20%).

The BCA does not capture economic externalities. These include both benefits and costs. The benefits of reduced health risk on households, employers and the health care and insurance industries were not assessed. The costs of implementation of abatement technologies would put additional pressure on Eskom capital (and debt) requirements, and further on electricity price escalations. These would result in additional economic costs, and these were not assessed. Furthermore, the economic benefits and costs of transitioning from coal to alternatives were not assessed. A full electricity system modelling exercise was not completed as part of the Eskom exemption application process given time constraints. Capacity assessments undertaken indicate that attempting to install SO_2 reduction technologies simultaneously on Eskom stations will result in significant electricity supply shortfalls. These capacity shortfalls would need to be addressed by other generation sources, if these are available, which may have additional cost implications. If the capacity is not available then the country would be forced to endure further periods of load shedding with resultant economic, social and environmental impacts.

As above, within the BCA, this uncertainty remains constant across all scenarios and thus enables inter-scenario evaluation.

Level of acceptable risk not quantified: The health benefits assessed are the total health benefits associated with all reductions in modelled ambient air quality as a result of abatement technology. It is to be noted however that the MES implies a level of acceptable health risk, and the quantum of the health costs associated with this level of acceptable risk were not assessed in the BCA.

2.5.2 Dealing with the uncertainties and limitations in the assessment of results

Several important considerations exist when interpreting the results of the integrated Health BCA.

Interpretation of premature mortality must be done with care. It is to be noted firstly that these numbers are indicators of health risk at a population level. The relative risk estimate inherent in the ERF is a metric of the likelihood of an adverse health outcome, and it cannot be attributed to an individual person. It can thus be used to quantify risk to a defined population (and not to an individual), (WHO 2016) and how this risk would vary between various policy options of scenarios.

The various sources of uncertainty discussed above, affect the accuracy of the absolute values of the assessments. In the absence of primary ERF studies, it is not possible to judge the accuracy of the absolute values of the assessment with a high level of confidence. However, this report uses ranges to reflect uncertainty.

In spite of the various sources of uncertainty discussed above, the analysis still provides valuable insights into the comparison of scenarios tested in the BCA. This is because the uncertainty inherent in the analysis remain constant across all scenarios.

The description of uncertainty sources also serves as a basis for further work to be prioritised in improving future integrated Health BCAs.

3 RESULTS AND DICUSSION

3.1 Scenarios

Three scenarios were evaluated in this study (against a baseline of anticipated emissions 2025 - 2030). A brief description is provided in the sub-sections below and the detailed summary table (see Table *2-6*).

3.1.1 ERP 2024 A

This scenario represents the Eskom ERP 2024 A plan. The scenario is similar to the existing Eskom Emission Reduction Plan (ERP) 2022. In this scenario the Grootvlei, Hendrina, Camden, Arnot and Kriel power stations will no longer be operating post 2030. The power stations that operate in this scenario include Duvha, Kendal, Kusile, Lethabo, Majuba, Matla and Tutuka. Abatement projects for emission reduction included in this scenario comprised of PM projects and NOx projects at specific stations. Kusile is the only station with SO_2 reduction although the associated costs and benefits are not assessed in these scenarios. (see Table *2-6* for detailed information).

In this scenario it is additionally assumed:

- All stations operate at the requested alternate SO_2 levels (see Table *2-6*)
- Load factor restricted to an average per station per year (see Appendix A).
- Total emissions are reduced by 5% at Kendal, Kusile, Lethabo, Tutuka and Majuba through efficiency and coal improvement projects. Matla and Duvha are excluded from this.

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-1.

S1 Scenario ERP 2024 A	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)			Abatememt Technology Comissioning Period					
Plant	COD Start	COD End	S1DS	S1DE	ESP/HFPS	LNB	FGD	ESP/HFPS-S	ESP/HFPS-E	LNB-S	LNB-E	FGD-S	FGD-E
Duvha	1980	1984	2031	2036	1			2022	2023				
Kendal	1988	1992	2040	2045	1			2021	2025				
Lethabo	1985	1990	2037	2042	1	1		2022	2026	2027	2031		
Majuba	1996	2001	2047	2052		1				2026	2030		
Matla	1979	1983	2031	2036	1			2023	2028				
Tutuka	1985	1990	2036	2041	1	1		2023	2028	2023	2028		

Figure 3-1: ERP 2024 A power plant commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown date of the power plant.

3.1.2 ERP 2024 B

This scenario represents the Eskom ERP 2024 B plan. In this scenario the Komati, Grootvlei, Hendrina, Camden, Arnot and Kriel power stations will no longer be operating post 2030. The power stations that operate in this scenario include, Kendal, Kusile, Lethabo, Majuba, and Tutuka.

Duvha and Matla shutdown in the period between 2031 and 2036. Abatement projects for emission reduction included in this scenario comprised of PM projects for PM, NOx projects at specific stations and SO_2 projects at Kusile (as stated for ERP 2024 A costs and associated benefits are not assessed), Majuba and Kendal (see Table *2-6* for detailed information).

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-2.

S2 Scenario ERP 2024 B	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)			Abatememt Technology Comissioning Period					
Plant	COD Start	COD End	S2DS	S2DE	ESP/HFPS	LNB	FGD	ESP/HFPS-S	ESP/HFPS-E	LNB-S	LNB-E	FGD-S	FGD-E
Duvha	1980	1984	2031	2036	1			2022	2023				
Kendal	1988	1992	2040	2045	1		1	2021	2025			2031	2035
Lethabo	1985	1990	2037	2042	1	1		2022	2026	2027	2031		
Majuba	1996	2001	2047	2052		1	1			2026	2030	2029	2033
Matla	1979	1983	2031	2036	1			2022	2023				
Tutuka	1985	1990	2036	2041	1	1		2023	2028	2023	2028		

Figure 3-2: ERP 2024 B power plant commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown date of the power plant.

3.1.3 ERP 2024 C

This scenario represents the Eskom ERP 2024 C plan. In this scenario there are seven stations that will be shut down and these are Arnot, Camden, Duvha, Grootvlei, Hendrina, Kriel and Matla. Duvha and Matla Shutdown in the period between 2031 and 2036. Post 2036 the operating stations will shut down as per Figure 3-3 Abatement projects for emission reduction included in this scenario are comprised of PM projects (completed by 2028), NOx projects (completed by 2032) and SO_2 projects (completed by 2035) at Kusile, Majuba, Kendal, Lethabo and Tutuka (see Table *2-6* for detailed information).

The commissioning and shutdown periods, and abatement technology installation schedules used in the BCA for this scenario are shown in Figure 3-3.

S3 Scenario ERP 2024 C	Plant Commissioning Period		Plant Decomissioning Period		Abatement Technology Installed (1 = yes)			Abatememt Technology Comissioning Period					
Plant	COD Start	COD End	S3DS	S3DE	ESP/HFPS	LNB	FGD	ESP/HFPS-S	ESP/HFPS-E	LNB-S	LNB-E	FGD-S	FGD-E
Duvha	1980	1984	2031	2036	1			2022	2023				
Kendal	1988	1992	2040	2045	1		1	2021	2025			2031	2035
Lethabo	1985	1990	2037	2042	1	1	1	2022	2026	2027	2031	2031	2035
Majuba	1996	2001	2047	2052		1	1			2026	2030	2029	2033
Matla	1979	1983	2031	2036	1			2022	2023				
Tutuka	1985	1990	2036	2041	1	1	1	2023	2028	2023	2028	2031	2035

Figure 3-3: Eskom ERP 2024 C power plant commissioning and shutdown periods, and abatement technology installation schedules. An S-suffix denotes the start of an activity, and the E-suffix denotes the end of the activity. Abatement technologies are assumed to run as units are retrofitted from commissioning date to continue until the shutdown date of the power plant.

3.2 Summary

Approximately 17.4 million people are exposed to air pollution from the 11 power stations remaining in operation in the baseline scenario modelled, and that fall within the modelling domain. The mean additional annual average exposure to air pollution of the population within this domain, resulting from coal-fired power station emissions, was estimated by averaging dispersion modelling results over municipal boundaries. Approximately 15.9 million people were exposed to more than an additional 1 µg.m^3 (mean annual average) of PM (including primary and secondary PM). Similarly, 5.7 and 16.9 million people, respectively, were exposed to more than an additional 1 µg.m^3 of NO_2 and SO_2.

Health benefits associated with each scenario were calculated against the baseline that took into account the anticipated increase in loads in the coming years from 2025 and assumed no abatement technologies installed and all stations would continue to emit air pollution at their current rates until shutdown, repowering and repurposing, The baseline also includes the health benefits derived from subsequent decrease in load as stations shutdown as new alternate energy source capacity becomes available.

The health benefits over time as modelled in the BCA are summarised in Figure 3-4:

- The health benefits of ERP 2024 A deliver immediate impact from 2024 (the BCA base year is 2024 and the effects in 2021 to 2023 are not modelled here). The benefits start tapering off from 2030 onwards as Duvha and Matla shutdown, repowering and repurposing between 2031 and 2036, and the associated health benefits from the HFPS and LNB technologies reduces accordingly. Tutuka, Lethabo and Kendal shutdown, repowering and repurposing is from 2036, 2037 and 2040 respectively. The ESP+HFPS and LNB technologies at these stations (refer to Table *2-6*) continue to provide health benefits until 2045 Majuba shutdown, repowering and repurposing starts in 2047 and the health benefits from the LNB technology continue until final closure.
- The health benefits of ERP 2024 B include those as discussed for ERP 2024 A above. In addition, efficiency and coal improvement projects reduce total sulphur and carbon emissions by 5% for Kendal, Lethabo, Tutuka and Majuba contributing to the increase in health benefits in ERP 2024 B. At Majuba DSI is commissioned from 2029 – 2033. Kendal is equipped with semi-dry FGD which is implemented from 2036, and this increases health benefits for a brief period to 2040 whereafter Kendal shutdown, repowering and repurposing starts.
- The health benefits of ERP 2024 C include those as discussed for ERP 2024 A and B above. All planned PM emission reduction projects completed (by 2028), and stations operate at PM=50 mg/Nm^3. NOx projects completed at all stations (completed by 2032), and stations operate at NOx = 750 mg/Nm^3. In addition to the SO_2 reduction at Kendal and Majuba, semi-dry FGDs are installed at Tutuka and Lethabo by 2035, however, these stations start shutdown, repowering and repurposing from 2036 and 2037 respectively, thus effectively negating the health benefits from the FGD technologies.

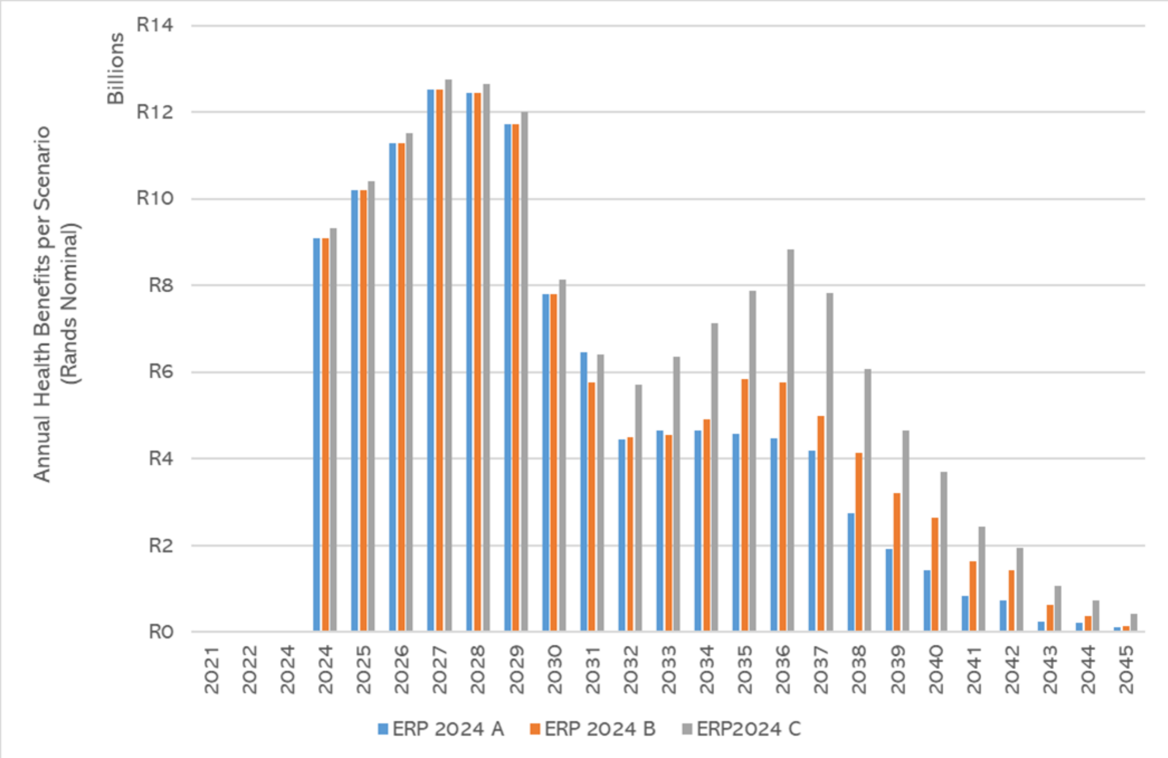

Figure 3-4: Annual health benefits per scenario illustrating the timeline of cumulative health benefits

The **abatement costs** associated with each scenario compared in the BCA are set out in Figure 3-5 below.

- The total Capex and Opex costs of abatement are identical to 2025.
- ERP 2024 B implementation starts in 2026 and 2027 with Majuba and Lethabo's LNB technology. From 2029 DSI installation starts at Majuba and in 2031 FGD starts at Kendal.
- ERP 2024 C builds on ERP 2024 B with implementation of SO_2 reduction technology starting in 2031 for both Lethabo and Tutuka.

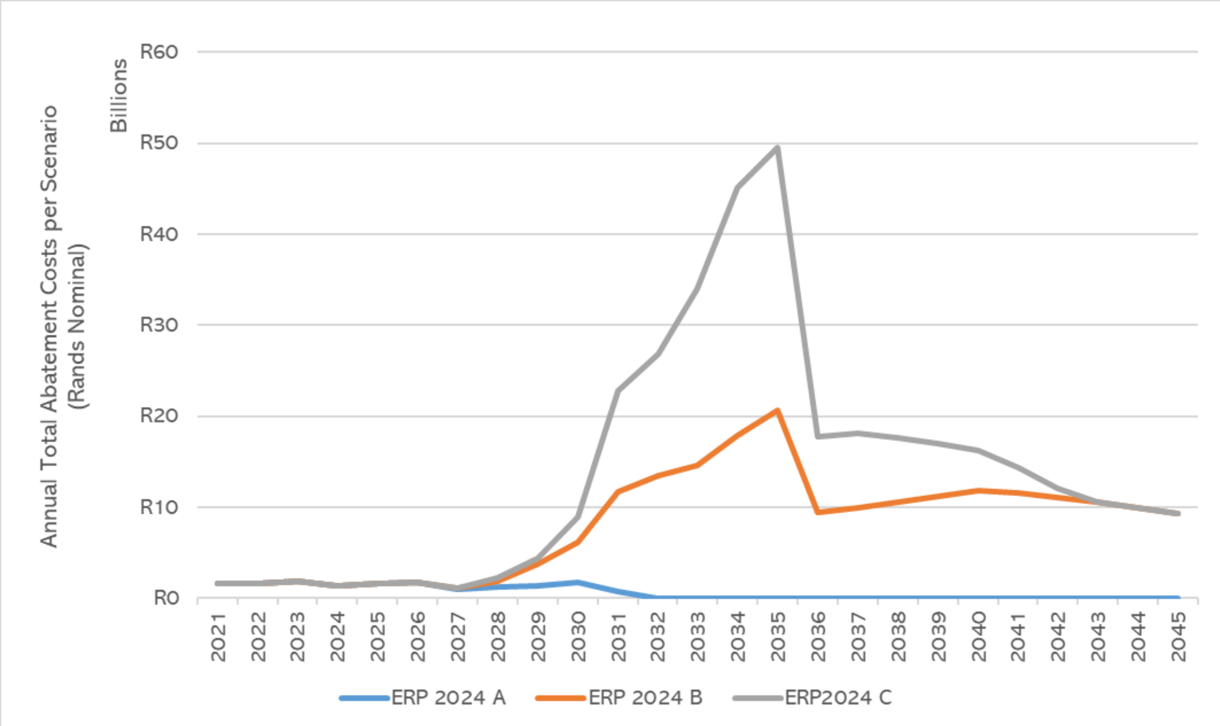

Figure 3-5 Total abatement costs (CAPEX and OPEX) associated with each scenario's abatement retrofits

Scenarios were compared in the benefit-cost analysis. The benefit-cost analysis apportioned costs (capital and operation expenditure on abatement technologies) and benefits (health benefits) to the years in which they would be realised. Because costs and benefits are accrued in different years according to the intervention schedules, the net present values of costs and benefits, used Eskom's weighted average cost of capital (WACC) rate of 10.8% as the discount rate (Eskom, 2024), and additional sensitivity analysis testing using a social discount rate of 2% (Stern, 2006) allowing for an objective comparison of scenarios.

The BCA ratios need to be interpreted with care. They are meant only to provide a perspective on and inform the decision-making process underlying the scenarios. They are not meant to be interpreted as a definitive answer to making abatement decisions. Decisions involving human health has to be informed by non-economic criteria as well. In addition, with uncertainty inherent in the analysis, the cost benefit ratio should thus not be viewed as absolute, but rather as a relative value from which to compare scenarios.

The **BCA results** are provided in Table 3-1. In the upper estimates the lower costs and higher VSL are used and in the lower estimates the higher costs and lower VSL are used as recommended by Robinson et al. 2018.

- The BCA central ratio in ERP 2024 is more than 1 (1.74), showing a very clear benefit and the health benefits exceed the costs of abatement, implying that this is a sound abatement option for Eskom to pursue. This scenario has a total nominal cost of R18,500 million, and is likely to increase electricity tariffs by 0.4% - 0.6%. IN ERP 2024 A

- The central BCA ratio of ERP 2024 B (SO_2 reduction at Majuba and Kendal) is less than 1 although it approaches 1 in the most optimistic (upper) parameters of the sensitivity analysis. The key reason for this is the implementation of the Kendal semi-dry FGD which is implemented from 2036, but only increases health benefits for a brief period to 2040 whereafter Kendal shutdown, repowering and repurposing starts. In this scenario the total nominal cost increases to R75,970 million (which adds to ERP A the additional cost of SO_2 reduction at Majuba and Kendal) and is likely to increase electricity tariffs by 1.0% - 1.4%.
- The BCA central ratio of ERP 2024 C (SO_2 reduction at Majuba, Kendal, Lethabo and Tutuka) is less than 1 (0.33) and remains below 1 even in the most optimistic (upper) parameters of the sensitivity analysis. The key reason for this is the implementation of FGDs at Tutuka and Lethabo by 2035, followed by immediate shutdown, repowering and repurposing from 2036 and 2037 respectively, thus effectively negating the health benefits from the FGD technologies. In this scenario the total nominal cost increases to R155,320 million (which adds to the ERP 2024 A and B costs the additional costs of SO_2 reduction at Lethabo and Tutuka), and is likely to increase electricity tariffs by 1.6% - 2.2%.
- Evaluation of the BCA ratios at a social discount rate of 2% delivers similar results, with ERP 2024 A above 1 and ERP 2024 B and C both less than 1. This is because of the limited health benefits achieved post 2036.

Table 3-1 BCA ratios (lower and upper ranges) for each scenario (discounted at Eskom WACC)

	ERP 2024 A		ERP 2024 B		ERP 2024 C	
Million Rands	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
NPV of Costs	-10,479	-7,423	-33,909	-24,019	-56,964	-40,349
NPV of Benefits	3,575	23,341	3,651	23,831	3,732	24,357
NPV of Benefits min Costs	-6,904	15,918	-30,258	-188	-53,232	-15,993
Benefit:Cost Ratio (range)	0.34	3.14	0.11	0.99	0.07	0.60
Benefit:Cost Ratio (central)	1.74		0.55		0.33	

In the analyses above the **health benefits associated with closure of power stations** form part of the baseline.

Thus, the cumulative health benefits over time are not reflected in the BCA ratios presented above. The power stations planned shutdown schedule (see Table *2-7* in Section 2.3.3 for the years in which this occurs) results in health benefits without associated abatement costs. These benefits are dependent on timing of the shutdown schedule. These benefits have been assumed to form part of the BCA baseline and have therefore not been quantified directly in the BCA.

- The power stations planned shutdown schedule (see Table *2-7* in Section 2.3.3 for the years in which this occurs) results in health benefits without associated abatement costs. These benefits are dependent on timing of the shutdown schedule.

- In order to contextualize the three scenarios that were analysed with respect to the baseline Figure 3-7, Figure 3-9 to Figure 3-9 show how each scenario contributes to cumulative health benefits over time. The green area in the figures illustrates the health benefit of station shutdown compared to the baseline, as the stations shutdown the population exposed to pollution decreases and the health benefits increase. The blue, orange and grey areas indicating the health benefits of the ERP scenarios described above. The figures illustrate that effectiveness of station shutdown in decreasing health impact and increasing health benefits. Extending the life of Majuba or Kendal stations would likely improve station financial viability, however this would reduce the health benefit as shutting down of stations is more effective than retrofits for health benefits.
- In this study no variation in shutdown dates was modelled, and the health benefits of shutdown are considered equivalent in all scenarios and as such are not visible in the benefit graphs in Figure 3-4.
- The health benefits from closure of power stations contribute an additional 2.1 – 2.3 times the health benefits of the respective scenarios (estimated on a net present value basis).
- It is further to be noted that the health benefits assessed are the total health benefits associated with all reductions in modelled ambient air quality as a result of abatement technology. It is to be noted however that the MES implies a level of acceptable health risk, and the quantum of the health costs associated with this level of acceptable risk were not assessed in the BCA. The quantum of this acceptable risk falls within the baseline.
- The Figures below are shown in Real 2023 Rand terms to contextualise the benefits in current value.

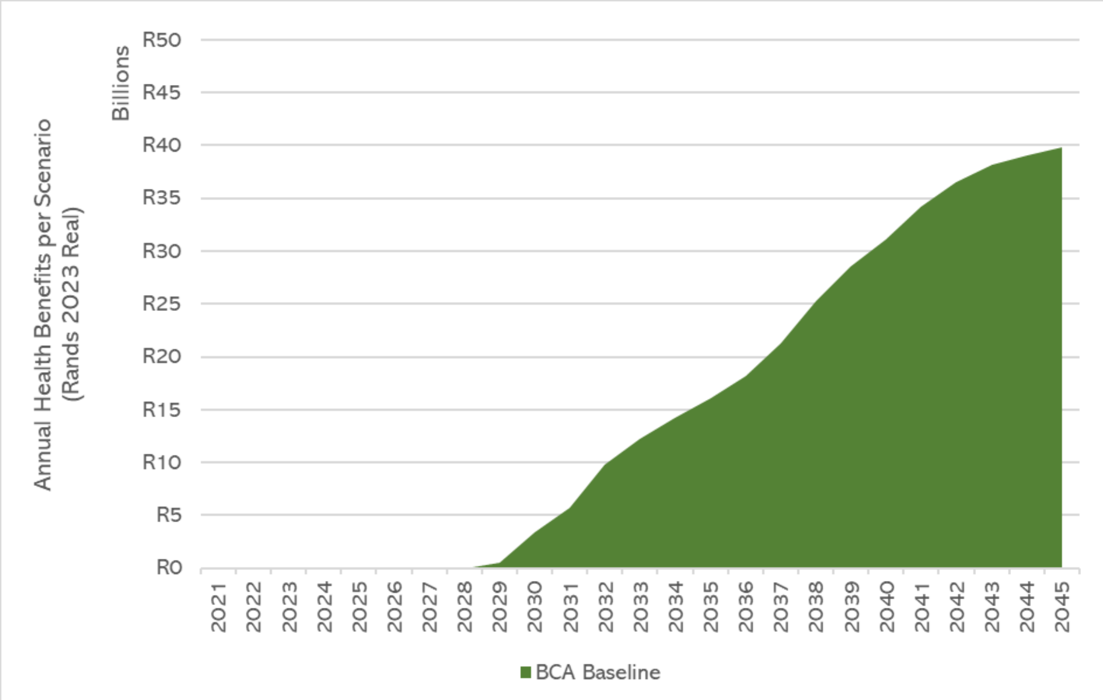

Figure 3-6: Cumulative annual health benefits in the baseline with planned power station shutdowns

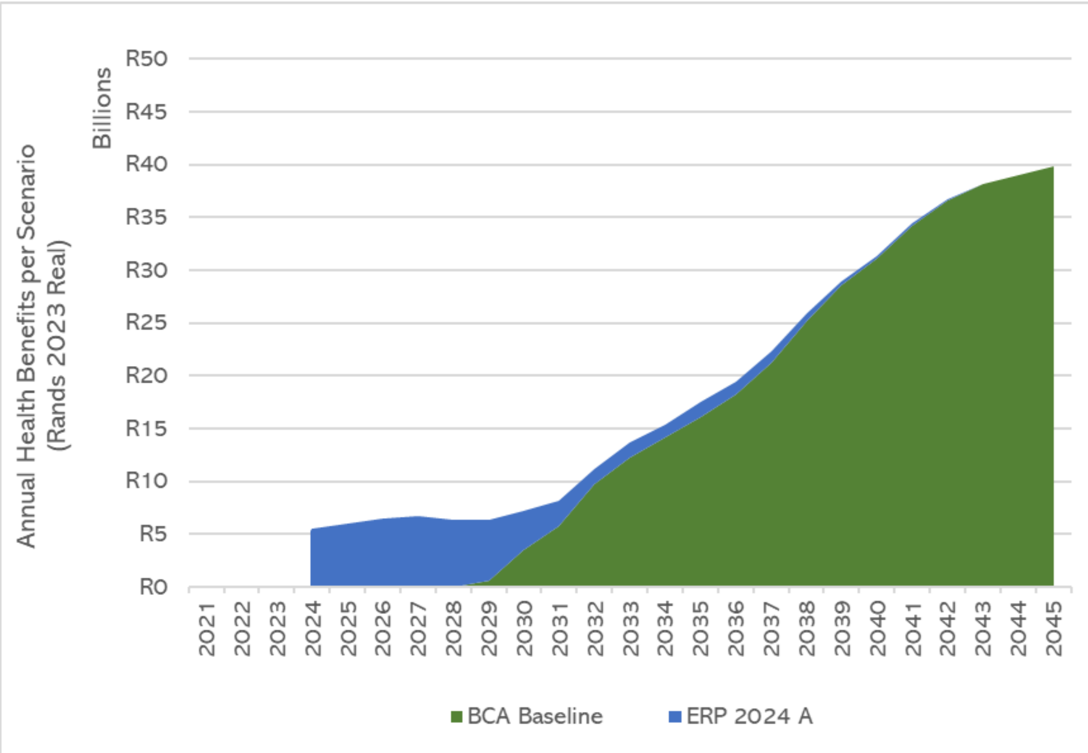

Figure 3-7: Cumulative health benefits of ERP 2024 A over the baseline

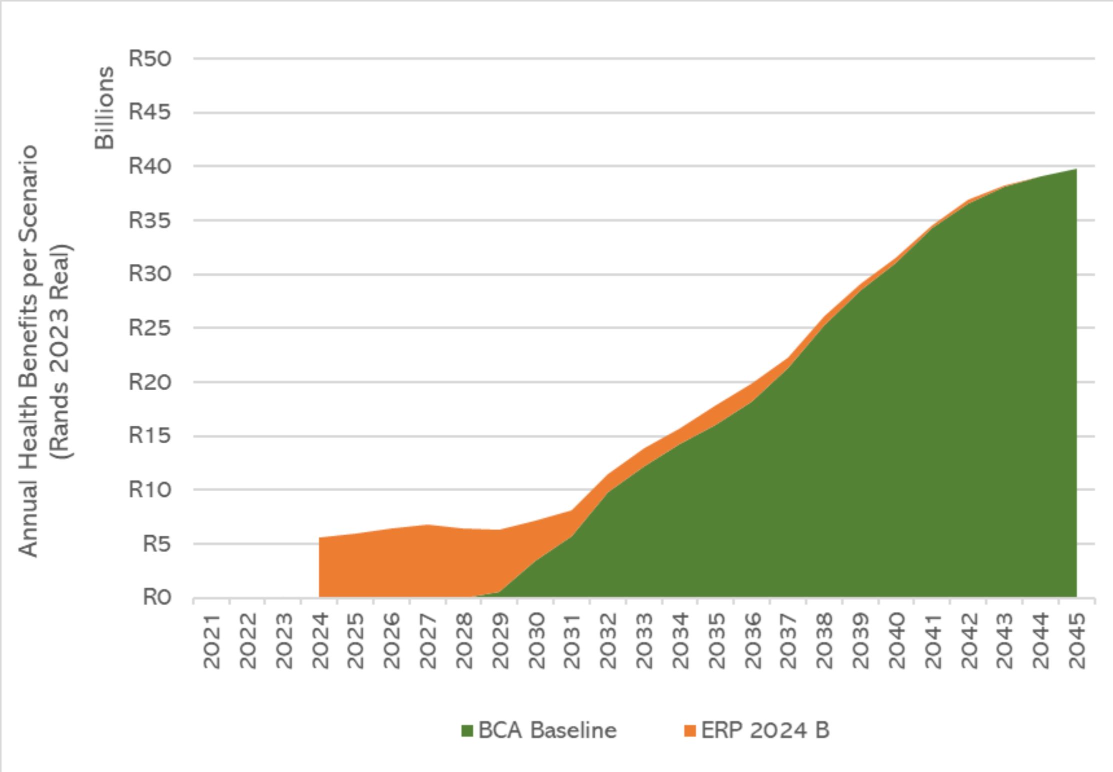

Figure 3-8: Cumulative health benefits of ERP 2024 B over the baseline

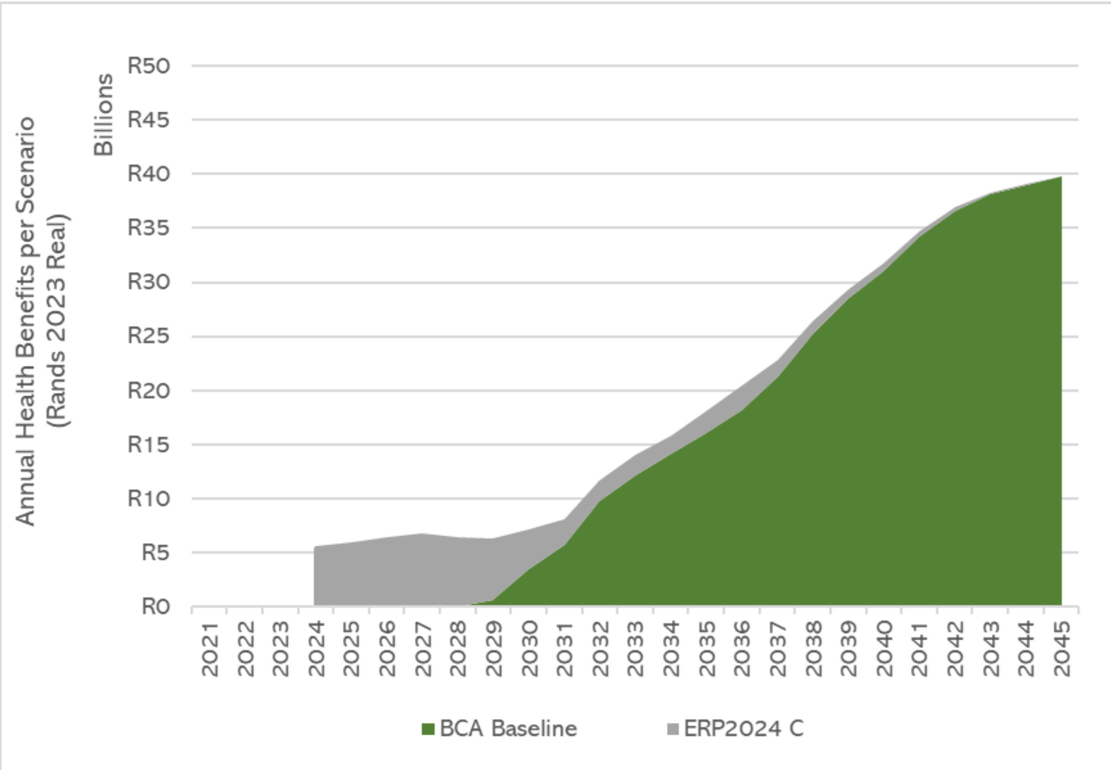

Figure 3-9: Cumulative health benefits of ERP 2024 A and ERP 2024 C over the baseline

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5 APPENDIX A

The estimated calculated load factors for each station in the Highveld:

Station;	Lethabo	Matla	Duvha	Tutuka	Kendal	Majuba
2025	70%	52%	38%	27%	52%	47%
2026	57%	50%	38%	34%	47%	44%
2027	54%	44%	34%	26%	51%	49%
2028	45%	42%	26%	14%	44%	34%
2029	46%	35%	23%	9%	42%	30%
2030	47%	30%	13%	10%	40%	30%
2031	42%	41%	35%	9%	45%	37%
2032	44%	31%	30%	20%	45%	39%
2033	45%	20%	24%	21%	45%	40%
2034	48%	12%	9%	26%	50%	41%
2035	46%	3%	0%	38%	49%	48%
2036	47%	0%	0%	33%	53%	49%
2037	53%	0%	0%	30%	51%	48%
2038	30%	0%	0%	26%	58%	51%
2039	27%	0%	0%	18%	63%	58%
2040	21%	0%	0%	16%	63%	64%
2041	14%	0%	0%	10%	60%	71%
2042	0%	0%	0%	7%	52%	70%
2043	0%	0%	0%	0%	43%	68%
2044	0%	0%	0%	0%	21%	69%
2045	0%	0%	0%	0%	0%	68%
2046	0%	0%	0%	0%	0%	69%
2047	0%	0%	0%	0%	0%	59%
2048	0%	0%	0%	0%	0%	47%
2049	0%	0%	0%	0%	0%	36%
2050	0%	0%	0%	0%	0%	23%

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