REPORT

Kribi-Ebolowa Road Project, Cameroon | Environmental and Social Impact Assessment (ESIA)

Appendix 23 - Air Quality Modelling - Quarry and Site Installations

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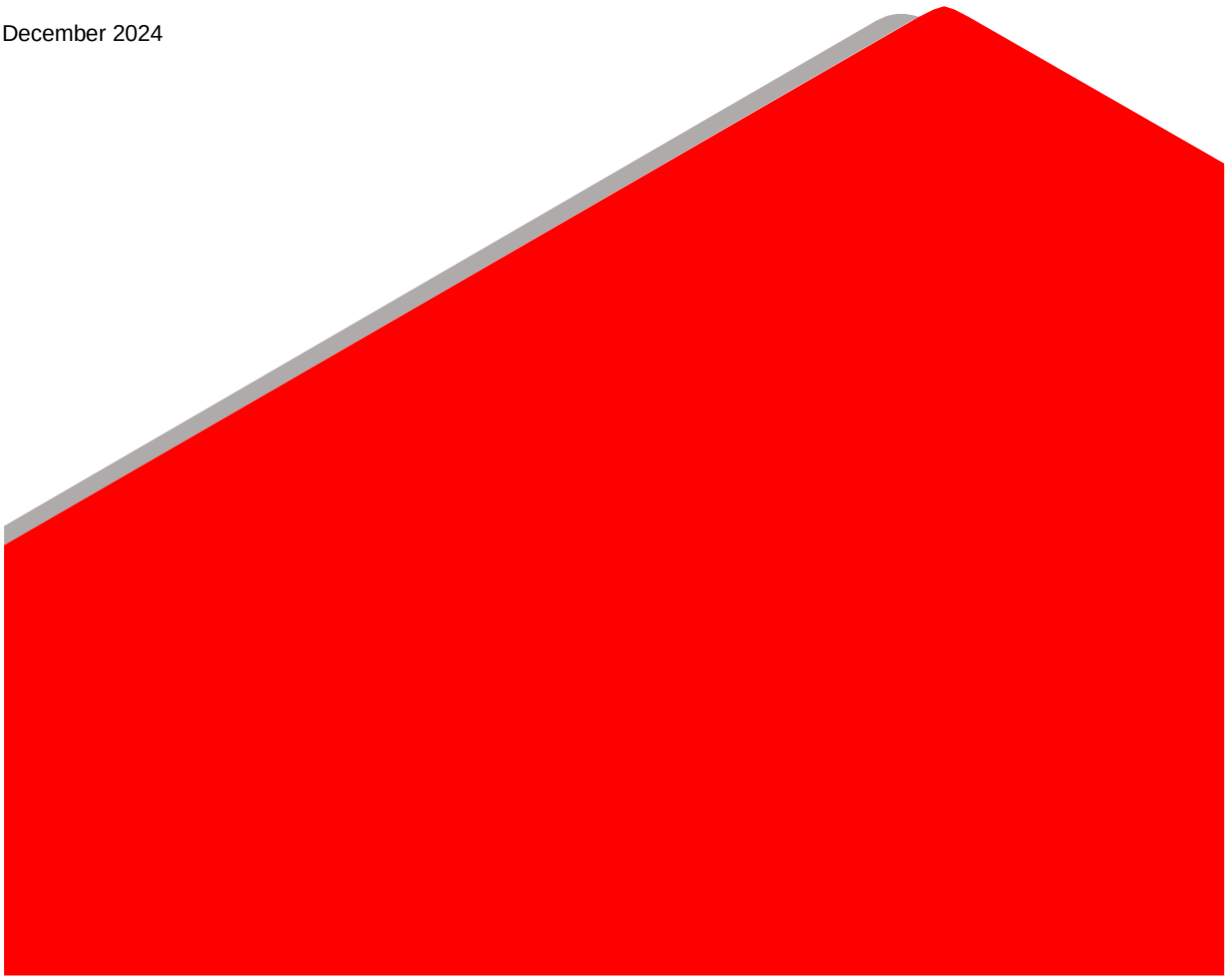
December 2024



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1.0 INTRODUCTION

As part of the Environmental and Social Impact Assessment (ESIA) study prepared for the construction, enlargement, and asphalting of the Ebolowa - Akom II - Kribi road in Cameroon, an air dispersion model has been developed to assess Project impacts on ambient air quality due to operations at the quarry and site installations.

The methodology used for the assessment of the potential effects on the existing ambient air quality includes:

- Defining the Project Standards for ambient air quality, considering the most stringent among national limits and the limits defined in the World Bank General EHS guidelines, if available.
- Collecting and processing meteorological data available for the Quarry and Site Installations Area of Influence (QAoI). An annual series of hourly meteorological dataset produced by the Weather Research and Forecasting (WRF) meteorological model (including temperature, wind velocity and direction, Pasquill atmospheric stability classes) has been acquired to reflect the local anemology and is used to improve accuracy of the model.
- Defining the emission rate of sources based on the nature of quarry and site installations operations (Dust emission estimated according to "AP-42 - Development of emission factors for fugitive dust sources" validated by the U.S Environmental Protection Agency (“USEPA”)).
- Defining the current state of ambient air quality through baseline data measure and used as representative of the current air quality levels.
- Evaluating the potential impacts on ambient air quality due to the operations at the Quarry and site installations through the application of a dispersion model for identified point or areal sources and for road traffic emissions generated by the vehicles involved in quarry operations.

Sulfur dioxide ("SO_2"), nitrogen oxides ("NOx"), particulate matter (“PM_{10} and $PM_{2,5}$”) and carbon monoxide (“CO”) represent air pollutants used as impact factors.

For each pollutant, concentration values at ground level were calculated under medium and/or percentiles conditions, and then compared with the Project Standards for air quality. Concentration maps have also been prepared comparing calculated concentrations with the Project Standards.

2.0 PROJECT STANDARD FOR AMBIENT AIR QUALITY

The assessment of Project effects on existing ambient air quality has considered the most stringent among national limits and the limits defined in the World Bank Group (WBG) General EHS guidelines.

Project standards for air quality are defined in Section 4, “Legal Framework” (please refer to that chapter for more information).

The WBG EHS guidelines do not include limits for CO, therefore reference was made to the limit value reported in WHO global Air Quality Guidelines (AQG 2021) has been used as reference (**Table *1***).

Table 1: WHO global Air Quality Guideline (AQG 2021)

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

3.0 CLIMATIC CONDITIONS

There is no accurate meteorological data available for the Project AoI, nor for areas in the vicinity. Therefore, to define the site-specific meteorological characteristics, meteorological data have been drawn from the mesoscale climatological WRF[1] model, a numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers.

Representative data have been obtained for the entire Project, using four domains that define the meteorological data. The four domains are shown in Figure 1 (see Appendix 9 for more details).

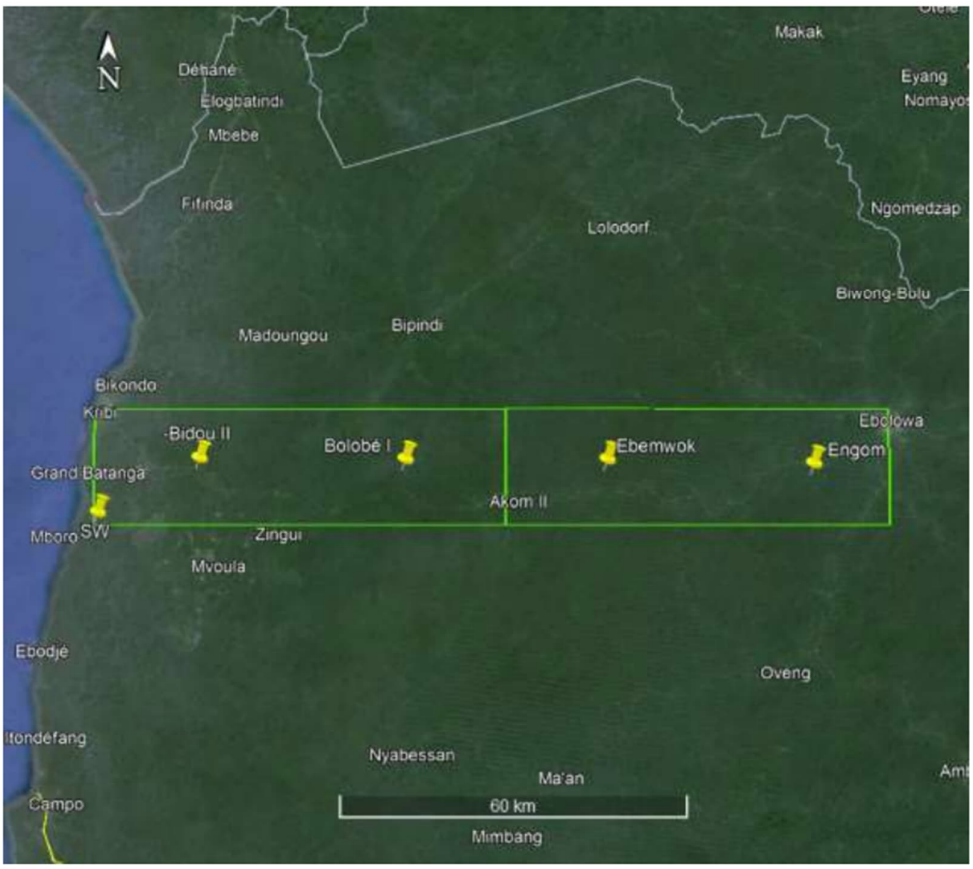


Figure 1: Spatial distribution of sites for meteorological data

The QAoI falls under the Ebemwok domain (2.846743°N – 10.702830°E), so the simulations are conducted considering Ebemwok meteorological data.

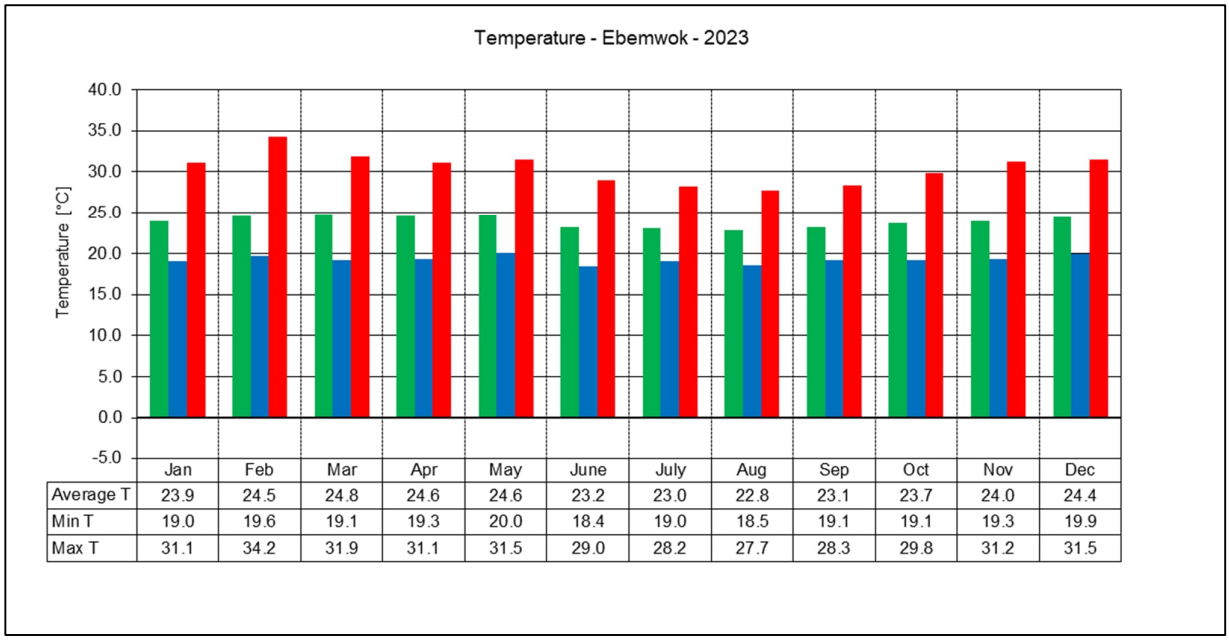
The WRF model is used to perform the spatial "downscale" measurements provided by the world's leading meteorological centres for the site area; the spatial resolution used for the reconstruction is 12 km.

The following sections present the 2023 weather data analysis for Ebemwok point.

[1] Weather Research & Forecasting Model (WRF) | Mesoscale & Microscale Meteorology (ucar.edu)

3.1 Temperature

Figure 2 shows monthly temperatures in 2023.In Ebemwok in 2023 the month with the highest average temperature was March (average monthly temperature of 24.8°C), the coldest month was August (average monthly temperature of 22.8°C). The average annual temperature was 23.9°C.



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Average T	23.9	24.5	24.8	24.6	24.6	23.2	23.0	22.8	23.1	23.7	24.0	24.4
Min T	19.0	19.6	19.1	19.3	20.0	18.4	19.0	18.5	19.1	19.1	19.3	19.9
Max T	31.1	34.2	31.9	31.1	31.5	29.0	28.2	27.7	28.3	29.8	31.2	31.5

Figure 2: Temperature, Ebemwok

3.2 Wind speed and direction

In Ebemwok the wind rose shows a high percentage of W and WNW winds, and a smaller percentage of WSW, SW, SSW and S winds. Winds from other sectors are infrequent (Figure 3).

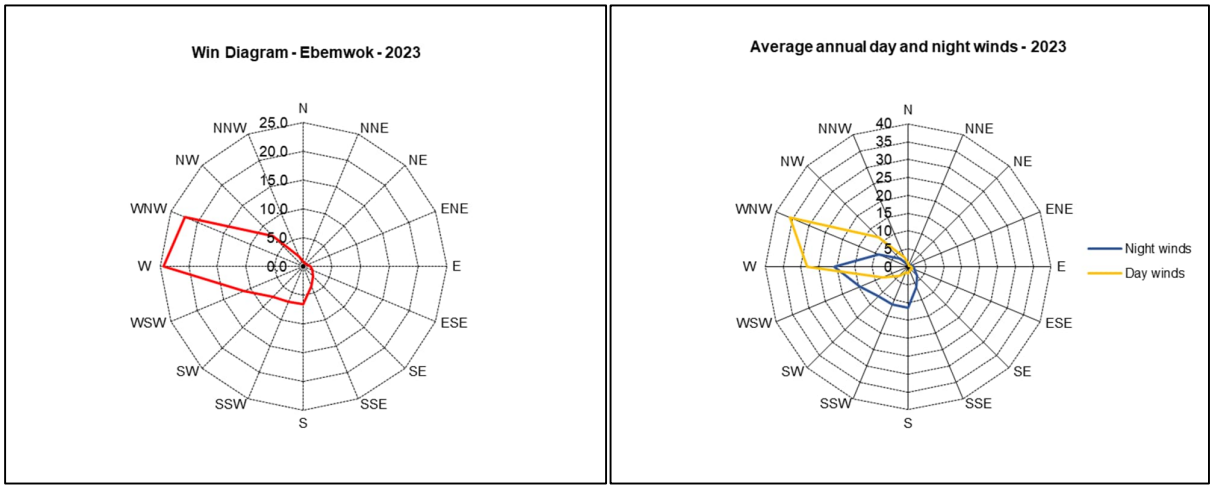


Figure 3: Wind direction, Ebemwok

In Ebemwok the average annual wind speed is 2.1 m/s. Winds below 0.5 m/s are about 1.7%. The wind speed is between 0.5 and 3 m/s in 81.7% of cases, or higher in 16.6% of cases.

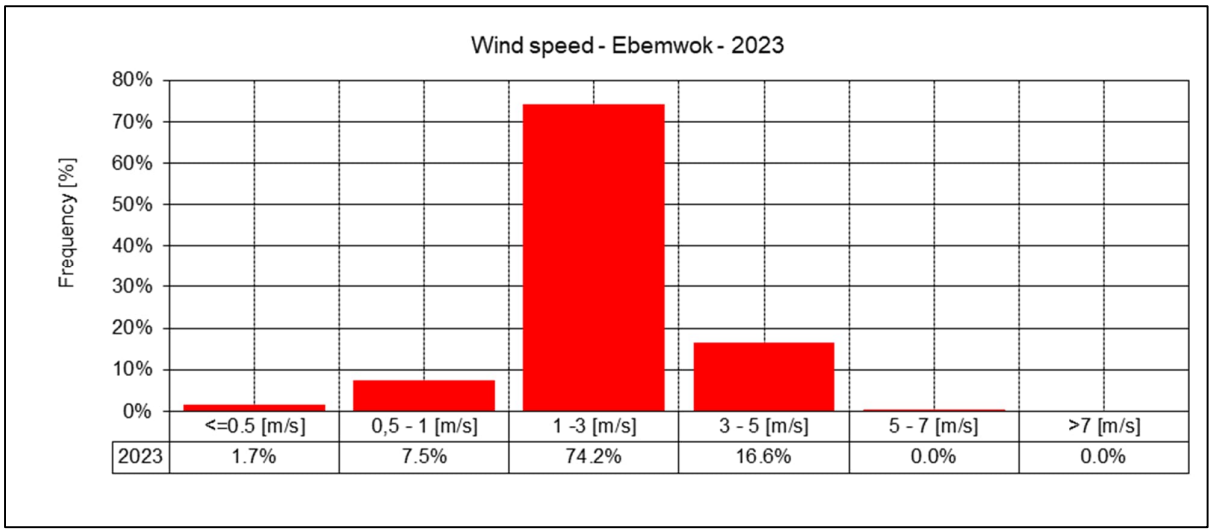


Figure 4: Wind speed, Ebemwok

3.3 Atmospheric stability classes

An important parameter affecting air dispersion is thermodynamic stability of the Earth's lower atmosphere. One of the most common methods for establishing the frequency of the different stability conditions was proposed by Pasquill, that classified the stability conditions in six classes, class A to class F. Such classes are qualitatively specified in terms of the average wind speed (measured at the standard height of 10 m above the ground), the intensity of insolation, or the amount of incident solar radiation and the state of sky coverage for the night period.

The six atmospheric stability classes are as follows:

- Convective categories:
  - A: highly convective conditions with low wind speeds and strong insolation.
  - B: conditions with relatively low solar radiation, or with high wind speeds.
  - C: conditions with high wind speed and low solar radiation.
- Neutral categories:
  - D: adiabatic conditions, which can occur mainly in the cold half-year, with overcast skies or fog, both during the day and at night (clouds at night hinder the cooling of the soil and during the day slow down its warming; in both cases their effect favors the establishment of neutral stratification conditions).
- Steady categories:
  - E: conditions with fairly high wind and partly cloudy skies.
  - F: conditions with low wind speeds and clear skies.

In Ebemwok the frequence of neutral condition in 2023 was 58.4%, 30% for the convective condition and 11.5% for the steady condition (**Figure 5**).

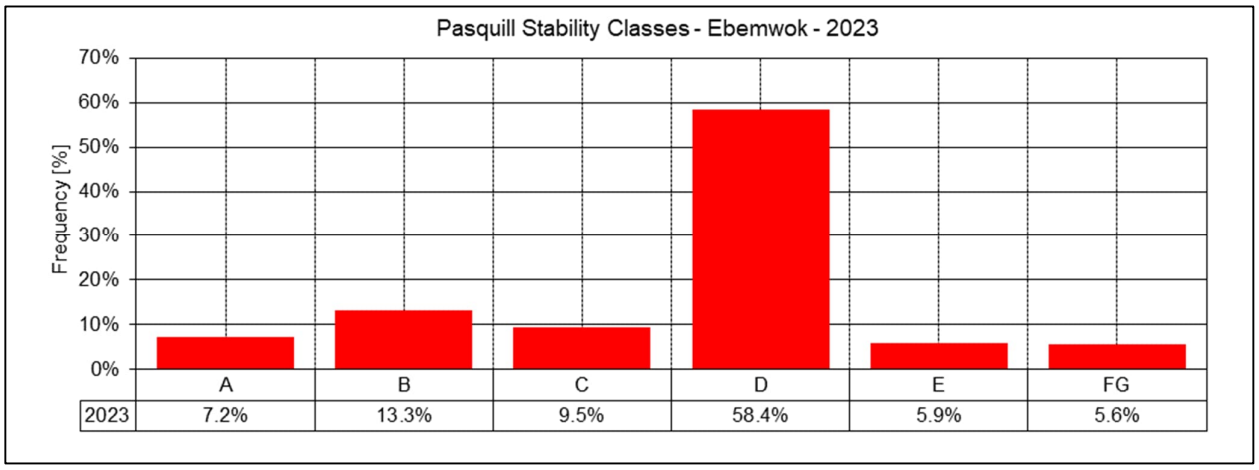


Figure 5: Pasquill atmospheric stability classes, Ebemwok

4.0 AIR QUALITY BASELINE

Cameroon does not have official air quality monitoring stations; therefore, secondary data were not available for establishing the baseline conditions near quarry and site installations. To fill this gap, site surveys were completed in August-September 2024 for monitoring local ambient air quality conditions near the Project AoI. The methodology adopted and the results are presented in Section 6q of this ESIA report.

5.0 AIR DISPERSION MODELING

Air dispersion modelling has been conducted using CALPUFF (MMS-CALPUFF 1.19.0 as G.U.I. (provided by Maind S.r.l.) for point or areal sources dispersion modeling and CALINE 4 (MMS.CALINE 2.4.1 as G.U.I. (provided by Maind S.r.l.) for road traffic sources.

CALPUFF is a puff Gaussian model, not stationary, simulating transport, diffusion and deposition of pollutants emitted, that can work with different spatial scales (short-term and long-term conditions).

Calpuff uses a mathematic model, which is based on the advection-diffusion equation. This solution represents concentration of pollutants (C) in a point (x,y,z) in the domain, produced by a puff (k) in point (x',y',z'), with mass (m_k) (Figure 6).

The Gaussian equation that describes the dispersion of pollutants has the following form:

$$C_K(x,y,z,t) = \frac{m_K}{(2\pi)^{1.5}\sigma_x\sigma_y\sigma_z} exp\left(-\frac{(x-x')^2}{2{\sigma_x}^2}\right) exp\left(-\frac{(y-y')^2}{2{\sigma_y}^2}\right) exp\left(-\frac{(z-z')^2}{2{\sigma_z}^2}\right)$$

The advection of pollutants is simulated by the local velocity of the wind, which is variable in the domain.

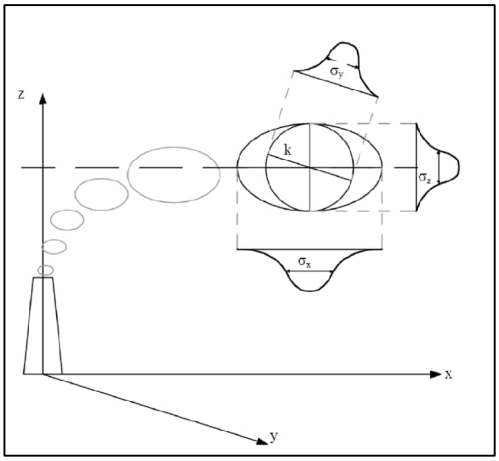


Figure 6: Model puff and dispersion coefficient of puff k

The model considers all puffs which contribute to the total concentration in (x,y,z) at a time (t). The total concentration of pollutants is like in the following form:

$$C_{TOT}(x,y,z,t) = \sum_K C_K(x,y,z,t)$$

CALINE 4 has been used to evaluate air impact assessment due to emissions generated by the vehicles on the access gravel track during the quarry cultivation phase and the operational phase of Site installations.

The estimation of the diffusion is performed using the “Mixing Zone” scheme, in order to consider the horizontal dispersion of pollutant linked to the wake generated by the movement of vehicles. In the transition area due to the passage of vehicles, it is assumed that turbulence and emission are constant. Diffusion within the "mixing zone" depends on the residence time of the pollutant and is shown to be a function of wind speed.

The Gaussian equation that describes the dispersion of pollutants has the following form:

$$dC = \frac{q \cdot dv}{2\pi u \sigma_y \sigma_z} e^{\frac{-y^2}{2\sigma_y^2}} \left(e^{\left(-\frac{(z-H)^2}{2\sigma_z^2} \right)} + e^{\left(-\frac{(z+H)^2}{2\sigma_z^2} \right)} \right)$$

where:

- dC: increase in concentration,
- q: emission on the infinitesimal segment,
- u: wind speed,
- H: source height,
- σ_y, σ_z: horizontal and vertical dispersion coefficients.

A model domain of 6x6km area was used, that includes a Cartesian grid made of 250 m wide square meshes. Calpuff calculates concentrations on each node and discrete receptors.

The access road has instead been subdivided into segments of different lengths, based on the road layout. Each segment is inserted in the Caline model trough the initial and final coordinates.

Caline calculates concentration at the receptors (such as schools, churches and other private and public buildings) and at so-called link receptors, which are points that the model places along the road to calculate concentrations at points where receptors are not present.

Then link receptors have been added along the roads, using fixed distance between receptors equals to 50 m and setting the height to 2 m.

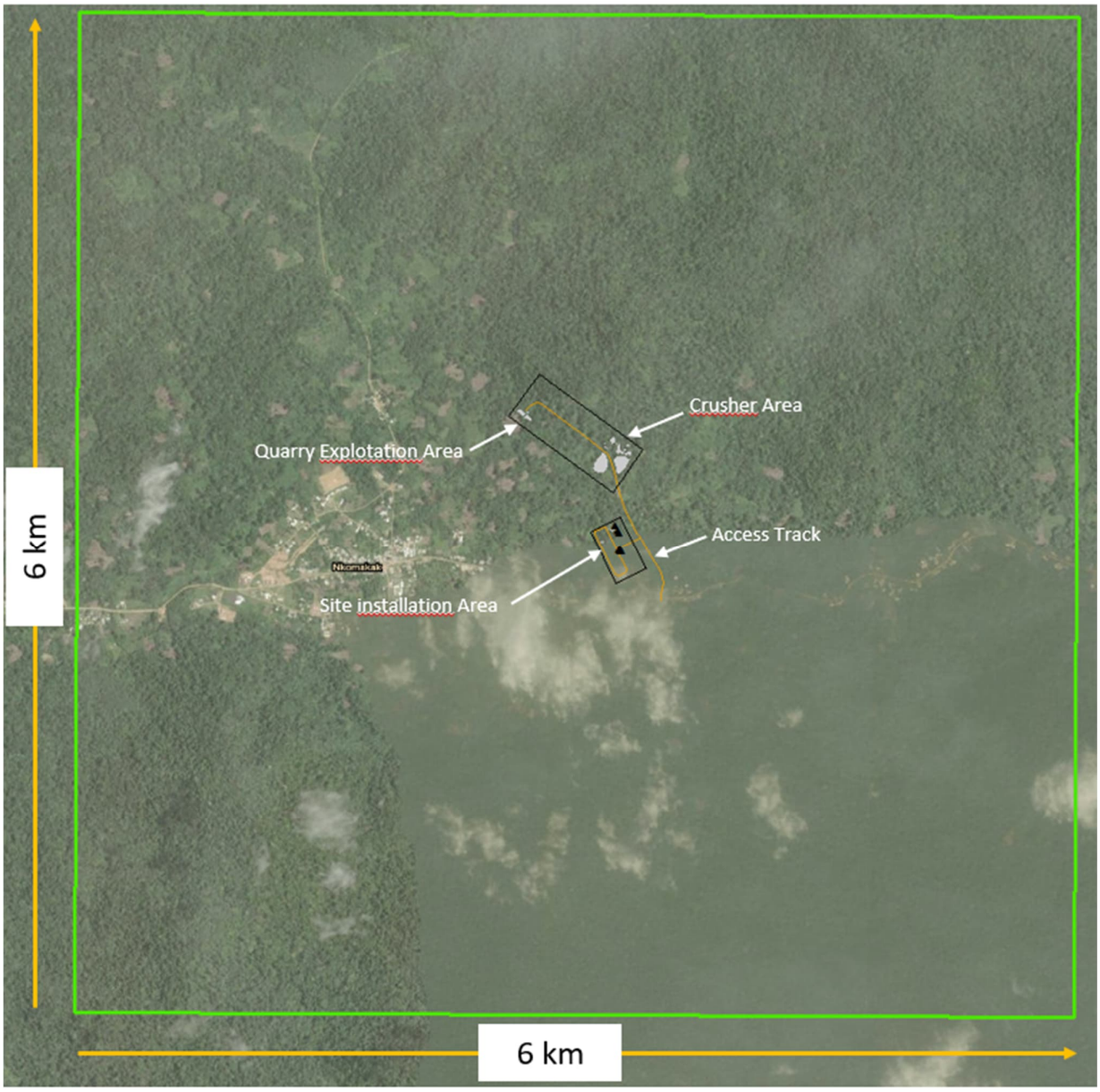


Figure 7: Model domain including the quarry and crusher area (Site 1), site installations (Site 2) and the access road.

5.1 Emission sources

Pollutant emission sources have been defined for the quarry exploitation phase. The following sources have been included in the model:

- Dust (as PM_{10} and $PM_{2.5}$) emissions from Drilling and Blasting.
- Dust (as PM_{10} and $PM_{2.5}$) emissions from truck loading after quarry cultivation.
- Dust (as PM_{10} and $PM_{2.5}$) emissions from movements of vehicles on paved and unpaved road.
- Dust (as PM_{10} and $PM_{2.5}$) emissions from truck unloading in aggregate storage, near crushing plant and near asphalt plant.
- Dust (as PM_{10} and $PM_{2.5}$) emissions from aggregate storage piles and stock piles.
- Dust (as PM_{10} and $PM_{2.5}$) emissions from Crushing Plant (grizzly screen, intermediate screen, final screen, primary crusher, secondary crusher, tertiary crusher, conveyors).
- Dust (as PM_{10} and $PM_{2.5}$) emissions from Batching plant (composed of machines that will be used for cement handling, aggregate handling and mixing).
- NO_2, PM_{10}, $PM_{2.5}$, SO_2 and CO emissions from Asphalt plant (composed of several key, including cold feed bins, conveyor belts, a dryer drum, a dust collector, an elevator, a screening unit, hot bins, a mixer, storage silos, Bag filler stack and boiler) (areal sources and conveyed sources).
- NO_2, PM_{10}, $PM_{2.5}$, SO_2 and CO emission from powerhouse (conveyed sources).

Dust emissions have been quantified using the algorithms recognized and validated by the U.S Environmental Protection Agency (“USEPA”) reported in the document "AP-42 - Development of emission factors for fugitive dust sources". For details with respect to the equations proposed by this methodology, guidelines are available online at the EPA site (AP-42: Compilation of Air Emissions Factors from Stationary Sources | US EPA).

Dust emissions have been quantified according to the daily working hours and the expected duration of the single activity and technical data (i.e. ton of material extracted or handled) reported in the Project description.

In case the emission factor of $PM_{2.5}$ is not available the emission is considered equal to PM_{10}.

All emission factors used for crushing, asphalt and batching plants consider dust reduction due to water suppression (that according to the Project description will be systematically applied), while water suppression to reduce dust emission from the transport of material on unpaved road was not considered.

Figure *8* reports the emission sources considered in the air dispersion model.

Figure 8: Emission sources

5.1.1 Quarry cultivation phase

5.1.1.1 Drilling

4,448 holes will be drilled with a grid of 3.50 x 3.00 m, totalling 66,675 linear m. The drilling will be carried out in 56 stages, with each stage consisting of 80 holes, reaching a maximum depth of 15 m, resulting in the blasting of 12,500 cubic meters per stage, for a total of 700,000 cubic meters of rock (in situ).

The emission factor is drawn from chapter 11.19.2 “Crushed Stone Processing”, AP-42, USEPA.

The emission factor of $PM_{2.5}$ is not available; it is considered equal to PM_{10}.

$$Emission\ (PM_{10}/PM_{2.5})\left(\frac{Kg}{year}\right) = E_f \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 2: Emission parameters for drilling operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Quarry face	4 x 10^{-5}	4 x 10^{-5}	871,111	34.8	34.8

5.1.1.2 Blasting

Dust emissions from blasting were estimated according to the "Emission Estimation Technique Manual for Mining and Processing of Non-Metallic Minerals, National Pollutant Inventory (Environment Australia, 2000), given the declared unreliability of AP-42 for open-pit mines, the emission of dust from blasting is calculated as follows:

$$Emission\ (PM_{10}/PM_{2.5})\left(\frac{Kg}{year}\right) = E_f \times N$$

$$E_f = \frac{K \times 344 \times A^{0,8}}{[D^{1,8} \times M^{1,9}]}$$

- A = blasting area (m^2).
- k = aerodynamic coefficient (PM_{10} = 0.52; $PM_{2.5}$ = 0.03).
- D = deep of blast (m).
- M = moisture (%).
- N = number of blast (blast/year).

Table 3: Emission parameters for blasting operations

Sources	N (blast/year)	A (m^2)	D (m)	M (%)	Ef PM_{10} (kg/blast)	Ef $PM_{2.5}$ (kg/blast)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Quarry face	37.3	833	15	1	29.57	1.71	1103	64

5.1.1.3 Mechanical Crushing

Oversize blasted rock will be reduced using a tracked excavator equipped with a hydraulic hammer before loading to the crushing plant. AP-42 does not provide an emission factor for this operation, therefore a reference was taken from chapter 11.19.2 "Crushed Stone Processing and Pulverized Mineral Processing", AP-42, USEPA (SCC 3-05-020-03 Tertiary Crushing). Assuming 10% of the blasted material:

$$E = E_f \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 4: Emission parameters for mechanical crushing operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Quarry	1.2×10^{-3}	1.2×10^{-3}	87,111	104	104

5.1.1.4 Truck Loading

After each blast rock will be removed by a one to two loaders and two to four dump trucks, depending on daily requirements and urgency. Truck loading operations will take place near the quarry face.

Dust emissions from truck loading were estimated using the “truck loading conveyor” reference, AP-42, USEPA (SCC 3-05-020-32).

The emission factor of $PM_{2.5}$ is not available. The emission is considered equal to PM_{10}.

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 5: Emission parameters for truck loading operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Quarry	5×10^{-5}	5×10^{-5}	871,111	43.6	43.6

5.1.2 Crushing plant

5.1.2.1 Truck unloading

The AP-42 “truck unloading-fragmented stone” (SCC-05-020-31) emission factor was taken as the reference for each operation that involves unloading of material.

Table 6 reports all emission sources from unloading operations. The quantity of material unloaded was estimated assuming be part of the total processed material.

The emission factor of $PM_{2.5}$ is not available. The emission is considered equal to PM_{10}.

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 6: Emission parameters for truck unloading operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Grizzly feeder	8×10^{-6}	8×10^{-6}	871,111	7.0	7.0
Conveyor to stockpile (0-300)	8×10^{-6}	8×10^{-6}	871111	7	7
Conveyor to stockpile (0-80)	8×10^{-6}	8×10^{-6}	871111	7	7
Conveyor to stockpile (0-31.5)	8×10^{-6}	8×10^{-6}	137,200	1.1	1.1
Conveyor to stockpile (12-25)	8×10^{-6}	8×10^{-6}	137,200	1.1	1.1
Conveyor to stockpile (5-12)	8×10^{-6}	8×10^{-6}	137,200	1.1	1.1
Conveyor to stockpile (0-5)	8×10^{-6}	8×10^{-6}	137,200	1.1	1.1
Conveyor to waste stockpile	8×10^{-6}	8×10^{-6}	87111	0.7	0.7
Truck unloading – aggregate storage 1	8×10^{-6}	8×10^{-6}	435,556	3.5	3.5
Truck unloading – aggregate storage 2	8×10^{-6}	8×10^{-6}	435,556	3.5	3.5

5.1.2.2 Crushing

Crushing plant provides three crushing phases:

- Primary crushing reduces rock block to a maximum size of approximately 300 mm.
- Secondary crushing reduces the blocks to a maximum size of 80 mm.
- Tertiary crushing reduces the stone material to the final production size.

AP-42 contains only the tertiary crushing (SCC-05-020-03) emissive factor. The emission factor is precautionary and was used also for primary and secondary crushing.

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

The quantity of material treated in secondary and tertiary crusher was estimated assuming that is part of the total material.

Table 7: Emission parameters for crushing operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Primary Crushing	2.7×10^{-4}	5.0×10^{-5}	871,111	235	44
Secondary Crushing	2.7×10^{-4}	5.0×10^{-5}	696,889	188	35
Tertiary Crushing	2.7×10^{-4}	5.0×10^{-5}	548,800	148	27

5.1.2.3 Screening

There will be four screens in use to separate the material based on different sizes:

- Grizzly screen.
- Intermediate screen.
- Final screen.

The considered emission factor for Grizzly screen and Intermediate screen is screening (SCC 3-05-020-02,03) and for Final screen is fine screening (SSC 3-05-020-21), contained in AP-42.

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

The quantity of material treated in intermediate screen and final screen was estimated assuming that is part of the total material.

The fine screening emission factor of $PM_{2.5}$ is not available. The emission is considered equal to PM_{10}.

Table 8: Emission parameters for screening operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Grizzly screen	3.7×10^{-4}	2.5×10^{-5}	871,111	322	21
Intermediate screen	3.7×10^{-4}	2.5×10^{-5}	696,889	258	17
Final screen	1.1×10^{-3}	1.1×10^{-3}	548,800	603	603

5.1.2.4 Conveyor

The material will be transported to the crushers and stockpiles using conveyors. The AP-42 emission factor used to estimate the emissions of conveyor is “conveyor transfer point” (SSC 3-05-020-06).

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 9: Emission parameters for conveyor operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Conveyor 1	2.3×10^{-5}	6.5×10^{-6}	435,556	10.02	2.83
Conveyor 2	2.3×10^{-5}	6.5×10^{-6}	435,556	10.02	2.83
Conveyor 3	2.3×10^{-5}	6.5×10^{-6}	784,000	18.03	5.10

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Conveyor 4	2.3×10^{-5}	6.5×10^{-6}	696,889	16.03	4.53
Conveyor 5	2.3×10^{-5}	6.5×10^{-6}	43,556	1.00	0.28
Conveyor 6	2.3×10^{-5}	6.5×10^{-6}	43,556	1.00	0.28
Conveyor 7	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 8	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 9	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 10	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 11	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 12	2.3×10^{-5}	6.5×10^{-6}	91,467	2.10	0.59
Conveyor 13	2.3×10^{-5}	6.5×10^{-6}	87,111	2.00	0.57

5.1.2.5 Aggregate storage and stockpiles

In aggregate storage and stockpiles operations the material is accumulated before and after the treatment in the crushing plant. The emissions generated from these activities were estimated according to AP-42 chapter 13.2.4. Below the equation used as reference:

$$E_f = \frac{k \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

- Ef = emission factor (kg/ton).
- k = particle size multiplier (dimensionless) (PM_{10} = 0,35; $PM_{2.5}$ = 0,053).
- U = mean wind speed (m/s).
- M = material moisture content (%).

Table 10: Emission parameters for aggregate storage and stockpiles operations

Sources	U (m/s)	M (%)	Q (ton/year)	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Aggregate storage 1	2.14	5	435,556	1.50×10^{-4}	4.71×10^{-5}	65.2	20.5
Aggregate storage 2	2.14	5	435,556	1.50×10^{-4}	4.71×10^{-5}	65.2	20.5
Stockpile (0-300)	2.14	5	87,111	1.50×10^{-4}	4.71×10^{-5}	13.0	4.1
Stockpile (0-80)	2.14	5	87,111	1.50×10^{-4}	4.71×10^{-5}	13.0	4.1
Stockpile (0-31.5)	2.14	5	137,200	1.50×10^{-4}	4.71×10^{-5}	20.6	6.5
Stockpile (12-25)	2.14	5	137,200	1.50×10^{-4}	4.71×10^{-5}	20.6	6.5

Sources	U (m/s)	M (%)	Q (ton/year)	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Stockpile (5-12)	2.14	5	137,200	1.50×10^{-4}	4.71×10^{-5}	20.6	6.5
Stockpile (0-5)	2.14	5	137,200	1.50×10^{-4}	4.71×10^{-5}	20.6	6.5
Stockpile waste	2.14	5	87,111	1.50×10^{-4}	4.71×10^{-5}	13.0	4.1

5.1.3 Asphalt plant

5.1.3.1 Vibrator

The emissions produced by vibrator were estimated assuming the AP-42 emission factor “screening” (SCC 3-05-020-02,03).

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 11: Emission parameters for vibrator operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Vibrator	3.74×10^{-4}	2.50×10^{-5}	264.600	99.0	6.6

5.1.3.2 Conveyor

The material will be transported to the asphalt plant using conveyors. AP-42 emission factor used to estimate the emissions from the conveyor are “conveyor transfer point” (SSC 3-05-020-06).

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

Table 12: Emission parameters for conveyor operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Conveyor Asphalt Plant 1	2.3×10^{-5}	6.5×10^{-6}	264,600	6.09	1.72
Conveyor Asphalt Plant 2	2.3×10^{-5}	6.5×10^{-6}	264,600	6.09	1.72
Conveyor Filler	2.3×10^{-5}	6.5×10^{-6}	26,460	0.61	0.17

5.1.3.3 Conveyed sources

The asphalt plant includes the emissions from conveyed sources. **Table *13*** includes conveyed sources dynamics and geometrics data.

Table 13: Conveyed sources fluid dynamic and geometric data

Conveyed Sources	Flow rate (Nm^3/h)	Temperature (K)	Velocity (m/s)	Stack Height (m)	Diameter (m)
Bag filler stack	41805	393.15	23.59	19.344	0.95
Boiler stack	3000	523.15	32.53	5.680	0.25
Filler Silo Stack	2600	298.15	69.74	12.380	0.12

Stacks emissions and mass flow are reported in the following tables.

$PM_{2.5}$ emissions are not available; they are considered equal to PM_{10}.

Table 14: Conveyed sources concentrations at stack exit

Conveyed Sources	PM_{10} (mg/Nm^3)	$PM_{2.5}$ (mg/Nm^3)	NO_x (mg/Nm^3)	SO_2 (mg/Nm^3)	CO (mg/Nm^3)
Bag filler stack	20	20	250	1,000	500
Boiler stack	/	/	250	1,000	500
Filler Silo Stack	20	20	/	/	/

Table 15: Conveyed sources mass flows

Conveyed Sources	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	NO_x (g/s)	SO_2 (g/s)	CO (g/s)
Bag filler stack	0.232	0.232	2.903	11.613	5.806
Boiler stack	/	/	0.208	0.833	0.417
Filler Silo Stack	0.014	0.014	/	/	/

5.1.4 Batching plant

5.1.4.1 Cement Handling

The cement used in the batching plant is delivered in 50kg bags. These bags are manually loaded into a bag breaker system that empties the cement into the silos incrementally. This ensures a steady and controlled supply of cement for continuous production.

The emissions produced by Cement Handling were estimated assuming the AP-42 emission factor cement unloading to elevated storage silo (SCC 3-05-011-07). For

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).

- Q = processed material (ton/year).

The emission factor of $PM_{2.5}$ is not available. The emission is considered equal to PM_{10}.

Table 16: Emission parameters for Cement Handling operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Cement Handling	1.7×10^{-4}	1.7×10^{-4}	25317	4.3	4.3

5.1.4.2 Aggregate Handling

The emissions produced by Aggregate Handling operations were estimated assuming the AP-42 emission factor aggregate transfer (SCC 3-05-011-04,21,23).

$$E = Ef \times Q$$

- E = emission (kg/year).
- Ef = emission factor (kg/ton).
- Q = processed material (ton/year).

The emission factor of $PM_{2.5}$ is not available; it is considered equal to PM_{10}.

Table 17: Emission parameters for Aggregate Handling operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Aggregate Handling	1.7×10^{-3}	1.7×10^{-3}	25,317	43	43

5.1.4.3 Mixing

The emissions produced by Mixing operations were estimated assuming the AP-42 emission factor mixer loading (SCC 3-05-011-09).

$$E = Ef \times Q$$

- E = emission (kg/year);
- Ef = emission factor (kg/ton);
- Q = processed material (ton/year).

The emission factor of $PM_{2.5}$ is not available. The emission is considered equals to PM_{10}.

Table 18: Emission parameters for mixing operations

Sources	Ef PM_{10} (kg/ton)	Ef $PM_{2.5}$ (kg/ton)	Q (ton/year)	E PM_{10} (kg/year)	E $PM_{2.5}$ (kg/year)
Mixing	2.8×10^{-3}	2.8×10^{-3}	25,317	70.9	70.9

5.1.5 Powerhouse

The energy for the operations of the quarry and site installations will be supplied by four generators working in parallel.

Powerhouse emissions, dynamics and geometrics data were estimated based on the type of the four generators of 500 kVA. The fuel used for the operation of the generators is assumed to be with a sulfur content of less than 0.2%. The powerhouse emission sources will be stack sources.

Below stack sources fluid dynamic and geometric data are reported.

Table 19: Stack sources fluid dynamic and geometric data

Conveyed Sources	Flow rate (Nm^3/h)	Temperature (K)	Velocity (m/s)	Height (m)	Diameter (m)
Powerhouse 1	1,575	655.15	5.35	5	0.5
Powerhouse 2	1,575	655.15	5.35	5	0.5
Powerhouse 3	1,575	655.15	5.35	5	0.5
Powerhouse 4	1,575	655.15	5.35	5	0.5

Point sources emissions and mass flow are reported below.

The emission of $PM_{2.5}$ is not available. The emission is considered equal to PM_{10}.

Table 20:Stack sources concentrations at stack exit

Conveyed Sources	PM_{10} (mg/Nm^3)	$PM_{2.5}$ (mg/Nm^3)	NO_x (mg/Nm^3)	SO_2 (mg/Nm^3)	CO (mg/Nm^3)
Powerhouse 1	20	20	350	1	85
Powerhouse 2	20	20	350	1	85
Powerhouse 3	20	20	350	1	85
Powerhouse 4	20	20	350	1	85

Table 21: Stack sources mass flows

Conveyed Sources	PM_{10} (mg/Nm^3)	$PM_{2.5}$ (mg/Nm^3)	NO_x (mg/Nm^3)	SO_2 (mg/Nm^3)	CO (mg/Nm^3)
Powerhouse 1	0.009	0.009	0.153	0.0004	0.037
Powerhouse 2	0.009	0.009	0.153	0.0004	0.037
Powerhouse 3	0.009	0.009	0.153	0.0004	0.037
Powerhouse 4	0.009	0.009	0.153	0.0004	0.037

5.1.6 Transport on unpaved roads

The EMEP/EEA air pollutant emission inventory guidebook provides guidance on estimating emissions from both anthropogenic and natural emission sources (2023).

Section 1.A.3.b.i-iv “Exhaust emissions from road transport” of guidebook provides the methodology and emission factors to enable exhaust emissions to be calculated for different vehicle categories, fuels and vehicle technologies, and for the principal pollutants which are affected by vehicle technology.

The vehicle categories considered are dumper and truck for transport of cultivated material to the plants and to the road construction site.

NO_2

NO_2 emission factor has been determined by the EMEP/EEA guidebook (exhaust emission factors for heavy-duty vehicles).

Table *22* shows emission factors for NO_2, considering precautionarily the emissions Diesel Rigid 14-20 t for trucks and Diesel Rigid > 32 t for dumpers, in both cases assuming conventional technology.

Table 22: Emission factors for NO2

heavy-duty vehicles

Type	Technology	CO	NMVOC	NO_x
Units		g/km	g/km	g/km
Notes			Given as $THC-CH_4$	Given as NO_2 equivalent
Diesel Rigid 14 - 20 t	Conventional	2.779	0.999	9.997
	Euro I	1.344	0.356	5.942
	Euro II	1.146	0.223	6.464
	Euro III	1.336	0.196	5.101
	Euro IV	0.644	0.030	3.525
	Conventional	2.779	0.999	9.997
	Euro I	1.344	0.356	5.942
	Euro II	1.146	0.223	6.464
	Euro III	1.336	0.196	5.101
	Euro IV	0.644	0.030	3.525
Diesel Rigid >32 t	Conventional	2.476	0.544	12.256
	Euro I	2.117	0.498	8.746
	Euro II	1.897	0.315	9.380
	Euro III	2.053	0.274	7.560
	Euro IV	0.888	0.047	5.289
	Euro V	1.617	0.048	3.615
	Euro VI A/B/C	0.159	0.032	0.445
	Euro VI D/E	0.159	0.030	0.320

SO_2

SO_2 originates directly from the fuel and lubricant combustion. Therefore, the emissions of SO_2 per fuel-type "m" are estimated using the formula:

$$E_{SO_2,m} = 2 \times k_{S,m} \times FC_m$$

where:

- $E_{SO2,m}$ = emissions of SO_2 per fuel m [g].
- $k_{S,m}$ = weight related sulphur content in fuel of type m [g/g fuel].
- FC_m = fuel consumption of fuel m [g].

Table 3-14 and Table 3-27 of the guidebook provide respectively the typical sulphur content of fuel and the fuel/energy consumption for each different combination of vehicle type, fuel and vehicle technology.

Table 23: Sulphur content and emission factors for SO2

Table 3-14: Tier 1 — Typical sulphur content of the fuel (1 ppm = 10^{-6} g/g fuel)

Fuel	1996 Base fuel (Market average)	Fuel 2000	Fuel 2005	Fuel 2009 and later
Petrol	165 ppm	130 ppm	40 ppm	5 ppm
Diesel	400 ppm	300 ppm	40 ppm	3 ppm

Table 3-27: Tier 2 average fuel/energy consumption values

Vehicle category	Sub-category	Technology	FC (g/km)	EC (MJ/km)*
Heavy-duty trucks	Petrol > 3.5 t	Conventional	177	7.75
	<=7.5 t	Conventional	125	5.34
		Euro I and later	101	4.31
	7.5-16 t	Conventional	182	7.77
		Euro I and later	155	6.62
	16-32 t	Conventional	251	10.72
		Euro I and later	210	8.97
	> 32 t	Conventional	297	12.68
		Euro I and later	251	10.72

Particulate Matter

Particulate matter emissions are generated not only from vehicle exhaust gases but above all from transportation on unpaved or paved road.

Table 24 shows the vehicles considered and the corresponding emission factors from exhaust gases for PM_{10} (considered to be TSP = PM_{10} = $PM_{2.5}$ in the guideline).

Table 24: Emission factors for PM10

heavy-duty vehicles

Type	Technology	PM2.5
Units		g/km
Notes		PM2.5=PM10=TSP
Diesel Rigid 14 - 20 t	Conventional	3.51E-01
	Euro I	2.14E-01
	Euro II	1.20E-01
	Euro III	1.13E-01
	Euro IV	2.64E-02
	Euro V	2.41E-02
	Euro VI A/B/C	2.38E-03
	Euro VI D/E	2.38E-03
Diesel Rigid >32 t	Conventional	4.32E-01
	Euro I	3.34E-01
	Euro II	1.97E-01
	Euro III	1.66E-01
	Euro IV	3.92E-02
	Euro V	3.63E-02
	Euro VI A/B/C	3.59E-03
	Euro VI D/E	3.59E-03

PM_{10} emission factor for transportation on unpaved or paved road has been quantified using the algorithms recognized and validated by the U.S. Environmental Protection Agency ("USEPA") reported in the document "AP-42 - Development of emission factors for fugitive dust sources".

For vehicles traveling on unpaved surfaces emissions are estimated from the following equation:

$$E = k\,(s/12)^a (W/3)^b$$

where:

- E = size-specific emission factor (kg/km).
- k = constant value (PM_{10} = 1,5).
- s = surface material silt content (%) equals to 5% (sand and gravel processing).
- W = mean vehicle weight (tons) equals to 1,5 ton for cars, 10 tons for light vehicles and 21.5 ton for heavy vehicles.
- p = number of days in a year with at least 0.254 mm of precipitation (days), equals to 200 days based on local weather conditions.

The quantity of particulate emissions from resuspension of loose material from the road surface due to vehicles travel on a dry paved road is estimated using the following empirical expression:

$$E = k\ (sL)^{0.91}\ x\ (W)^{1.02}$$

where:

- E = size-specific emission factor (kg/km).
- k = constant value (PM_{10} = 0,62).
- sL = road surface silt loading (g/m^2) equals to 0.6 g/m^2 (ubiquitous baseline).
- W = mean vehicle weight (tons) equals to 1,5 ton for cars.

$PM_{2.5}$ emission factor has been estimated from the PM_{10} one. According to measured concentrations, $PM_{2.5}$ is on average the 77% of PM_{10}. This percentage has been considered in estimating $PM_{2.5}$ emission factor from PM_{10}.

Table 25 summarizes the emission factors used for simulations.

Table 25: Emission factors for different vehicle categories

Vehicle Type	NO_x	SO_2	PM_{10} - paved	PM_{10} - unpaved	$PM_{2,5}$ - paved	$PM_{2,5}$ - unpaved
	g / veic-km	*g / veic-km*	*g / veic-km*	*g / veic-km*	*g / veic-km*	*g / veic-km*
Trucks	9.997	0.201	9.7	215.7	7.5	166.1
Dumper	12.256	0.238	23.8	323.3	18.3	248.9

5.1.7 Work vehicles

The estimation of emissions during activities considers the emission contribution also from the engines of the work vehicles.

For each construction activity, the simultaneous operation of a certain number and type of work vehicles was considered based on what is required by quarry activities.

In the following table, the types of construction vehicles and the PM_{10} emission factors are listed ("SCAB Fleet Average Emission Factors of "2020-2024"):

The emission factor of $PM_{2.5}$ is not available. The emission is considered equals to PM_{10}.

Table 26:Engine work vehicles emission factors

Work vehicles	PM_{10} (g/h)	$PM_{2.5}$ (g/h)
Tracked excavator	6.3	6.3
Wheel loader	4.5	4.5

5.2 Model results

The results of the model are summarized below in graphical and tabular form. Table 27 shows the maximum concentrations resulting from quarry and site installations operations in the QAoI and compares them with limits from the WBG Guidelines (the Project Standards); for CO, WHO global air quality guidelines (AQG levels 2021) have been considered.

Table 27: Predicted impacts – Maximum modelled ground concentrations resulting from the Project in the QAoI

Pollutants	Max Conc. Value in µg/m³	Average exposure time	Value in µg/m³ Project Standards
Particulate matter PM_{10}	45.21	1 year	70 (1st intermediate target) 50 (2nd intermediate target) 30 (3rd intermediate target) 20 (guidelines)
	66.90	24 hours	150 (1st intermediate target) 100 (2nd intermediate target) 75 (3rd intermediate target) 50 (guidelines)
Particulate matter $PM_{2.5}$	34.85	1 year	35 (1st intermediate target) 25 (2nd intermediate target) 15 (3rd intermediate target) 10 (guidelines)
	51.77	24 hours	75 (1st intermediate target) 50 (2nd intermediate target) 37,5 (3rd intermediate target) 25 (guidelines)
SO_2	16.43	1 year	20 (for forests and natural vegetation) 30 (for agricultural crops)
	42.53	24 hours	125 (1st intermediate target) 50 (2nd intermediate target) 20 (guidelines)
	160.90	1 hour	500 (for 10 minutes, guidelines)
NO_2	17.43	1 year	40 (guidelines) 30 (for vegetation) (NOx)
	132.30	1 hour	200 (guidelines)
CO	0.021 (mg/m³)	24 hours	4 mg/m³ (AQG level)

In the QAoI, the maximum daily and annual average concentrations of Particulate Matter (PM_{10} and $PM_{2.5}$) are above the limit values. The maximum modelled daily average SO_2 concentration, is above the limit value, while the hourly and annual average SO_2 concentrations are below. The maximum modelled hourly and annual average NO_2 concentrations are below the limit values. The maximum modelled daily average CO concentration is below. All these maximum values are found in proximity of Site 1 and Site 2.

The modelled contribution of quarry and site installations operations to ambient air conditions significantly decrease and are lower at the sensitive receptors than in proximity to Site1 and Site2. The model provided an output that contains the concentration of each pollutant, for each node of the calculation grid, for each period of the simulation. Concentration values resulting from operations were calculated under medium and/or daily and hourly conditions, which is needed to make compare them with the Project Standards.

The following sections present the results for each parameter considered; they include figures providing a representation of the spatial distribution of the pollutant concentrations resulting from the Project, obtained by interpolating each pollutant's concentrations modelled for each node of the grid.

5.2.1 PM_{10}

The maximum annual average concentration is to the east of the Site boundary . The maximum annual average PM_{10} concentration is 45.21 µg/m^3 (**Figure *9***). The distribution of average daily concentrations shows a maximum concentration of 66.90 µg/m^3 (**Figure *10***).

Daily and annual average PM_{10} concentrations significantly decrease and are below the limit value at each sensitive receptor except for AQ5 where daily and annual average concentrations remain above.

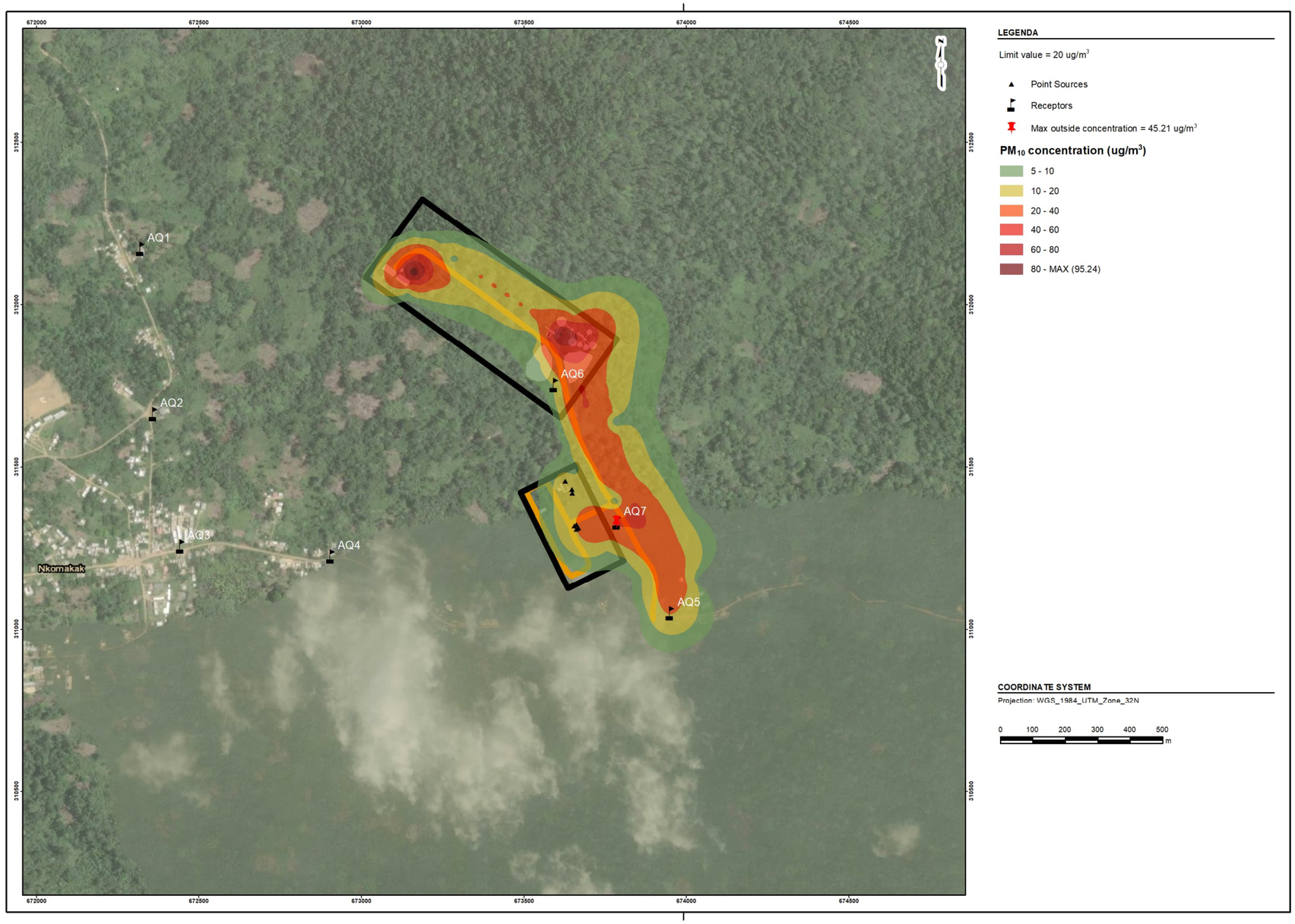


Figure 9: PM10 – Annual average modelled concentrations

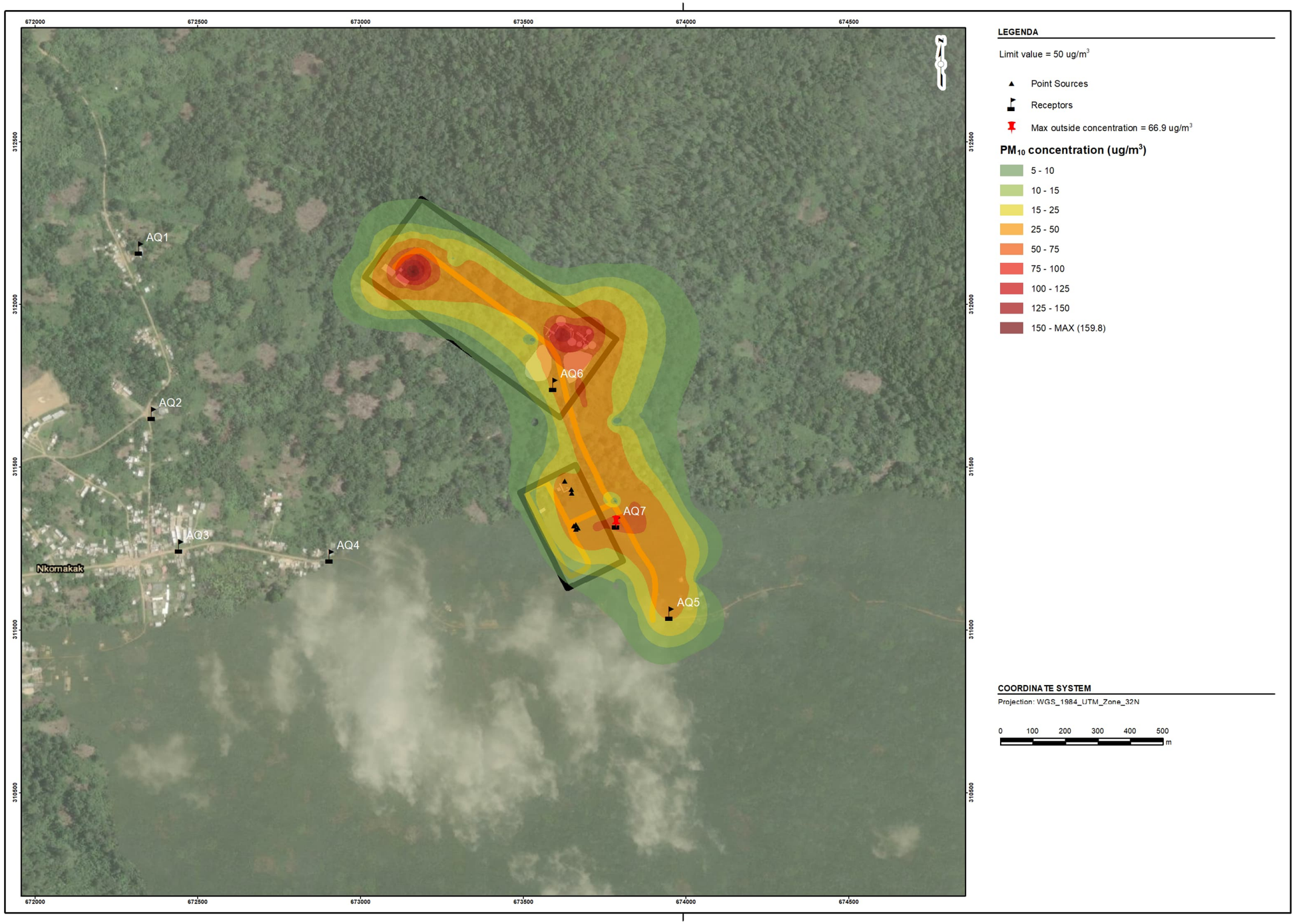


Figure 10: PM10 – Daily average modelled concentrations

5.2.2 $PM_{2.5}$

The maximum annual average concentration is to the east of the Site boundary . The maximum annual average $PM_{2.5}$ concentration is 34.85 µg/m^3 (Figure 11). The distribution of average daily concentrations shows a maximum concentration of 51.77 µg/m^3 (**Figure *12***).

As for PM_{10}, daily and annual average $PM_{2.5}$ concentrations are below the limit value at each sensitive receptor except for AQ5 where daily and annual average concentrations remain above.

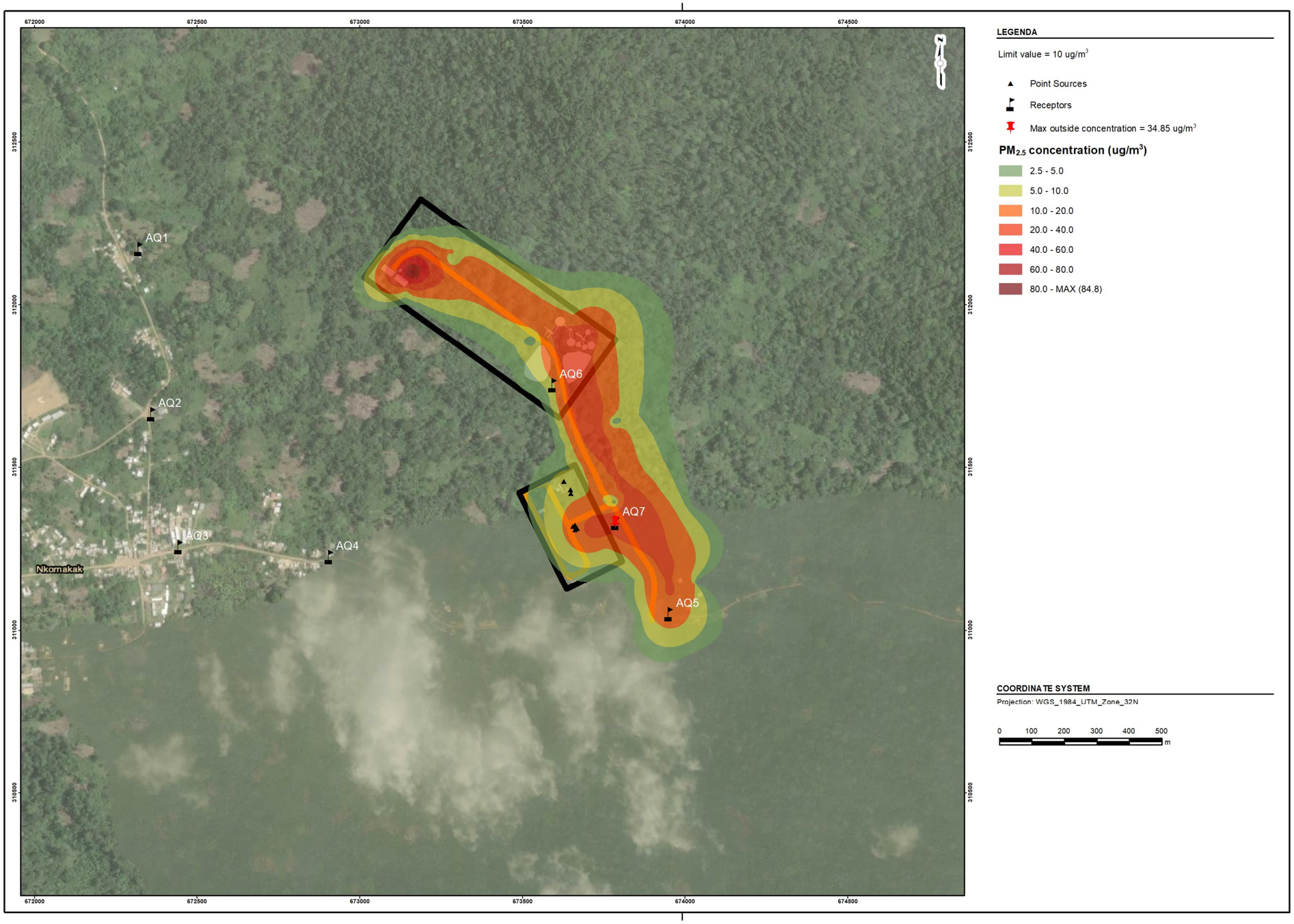


Figure 11: $PM_{2.5}$ – Annual average modelled concentrations

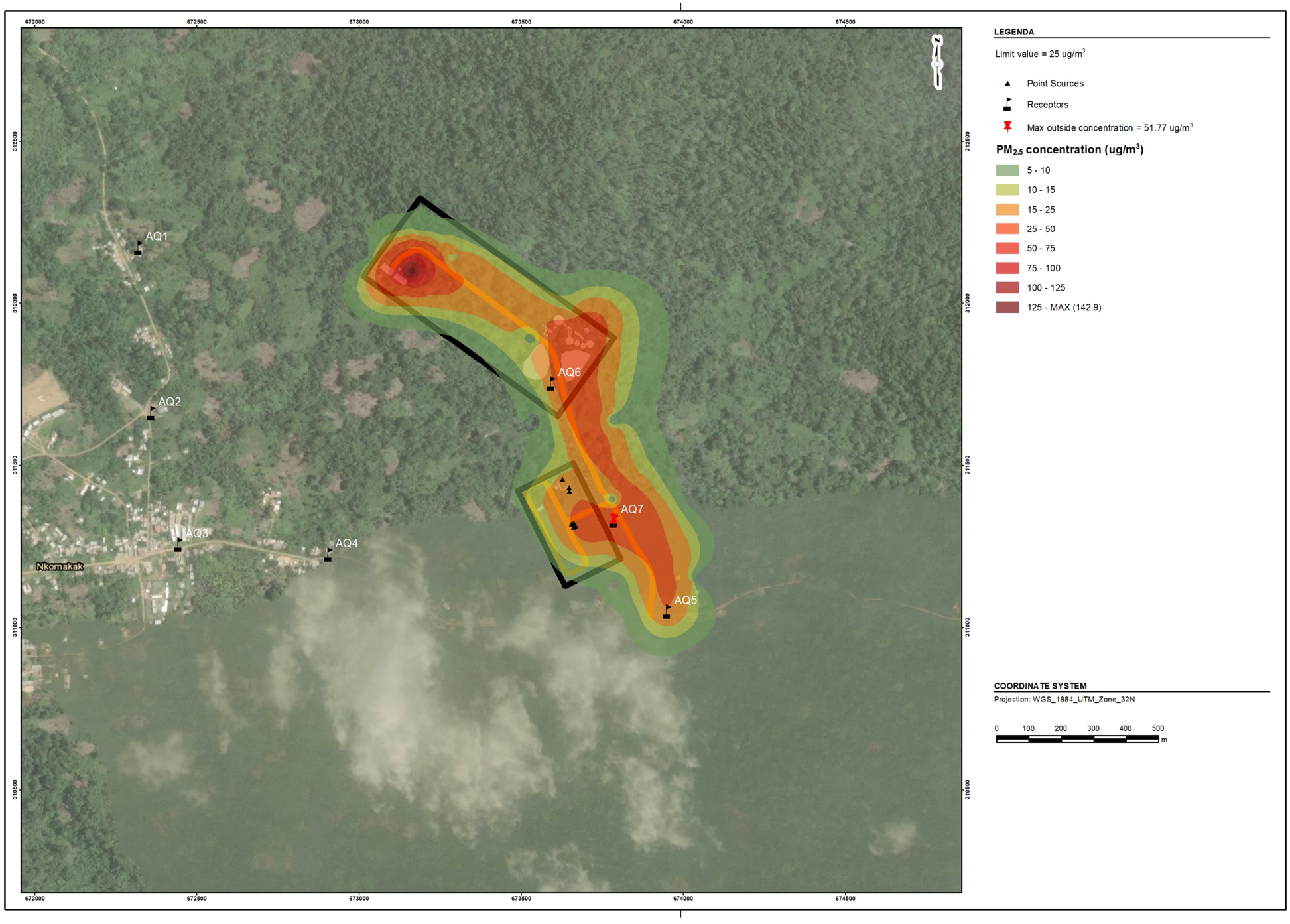


Figure 12: PM2.5 – Daily average modelled concentrations

5.2.3 NO_2

The maximum annual average concentration outside the Sites is near the eastern boundary. The maximum annual average NO_2 concentration is 17.43 µg/m^3 (**Figure *13***). The distribution of average hourly concentrations shows a maximum concentration of 132.30 µg/m^3 (**Figure *14***).

The annual and the hourly average limits are not exceeded at any receptors.

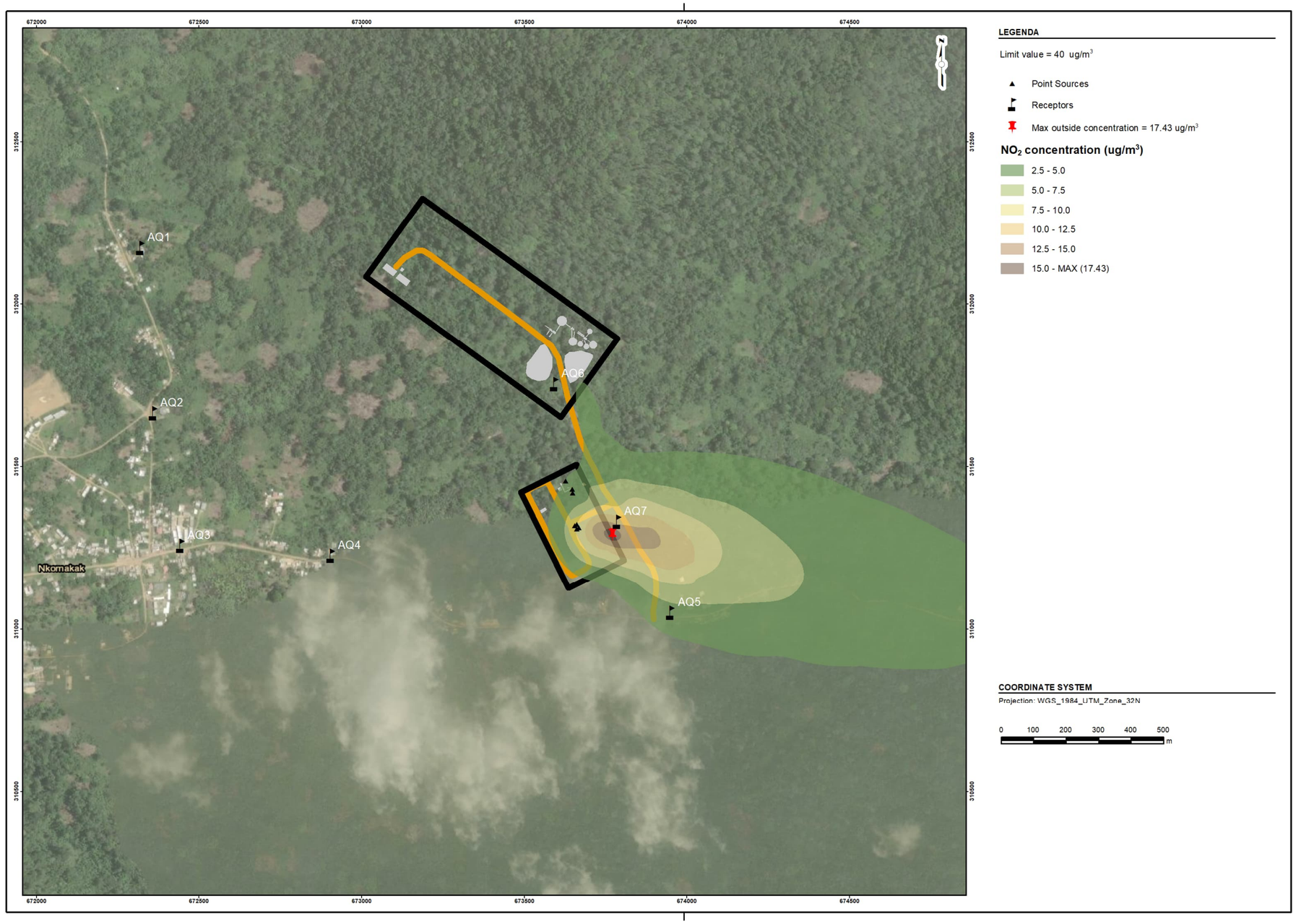


Figure 13: NO2 – Annual average modelled concentrations

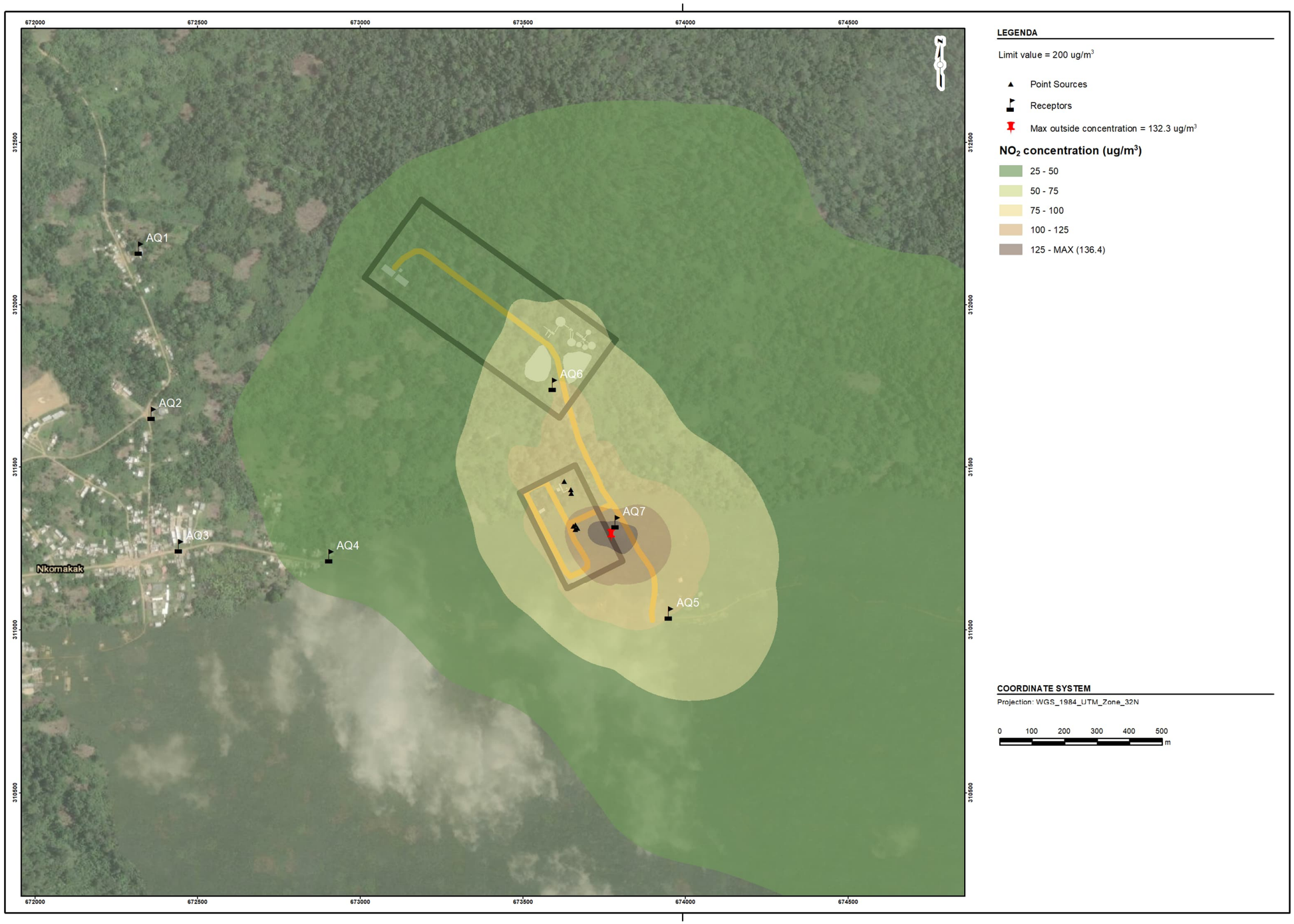


Figure 14: NO2 – Hourly average modelled concentrations

5.2.4 SO_2

The maximum annual average concentration is to the east of the Site boundary. The maximum annual average SO_2 concentration is 16.43 µg/m^3 (**Figure *15***). The distribution of average daily concentrations shows a maximum concentration of 42.53 µg/m^3 (**Figure *16***). The distribution of average hourly concentrations shows a maximum concentration of 160.90 µg/m^3 (**Figure *17***).

The annual and hourly average limit values are not exceeded at any points of the calculation grid. Conversely, daily average SO_2 concentration are above the limit value at sensitive receptor AQ5, while it they remain below at each other sensitive receptors.

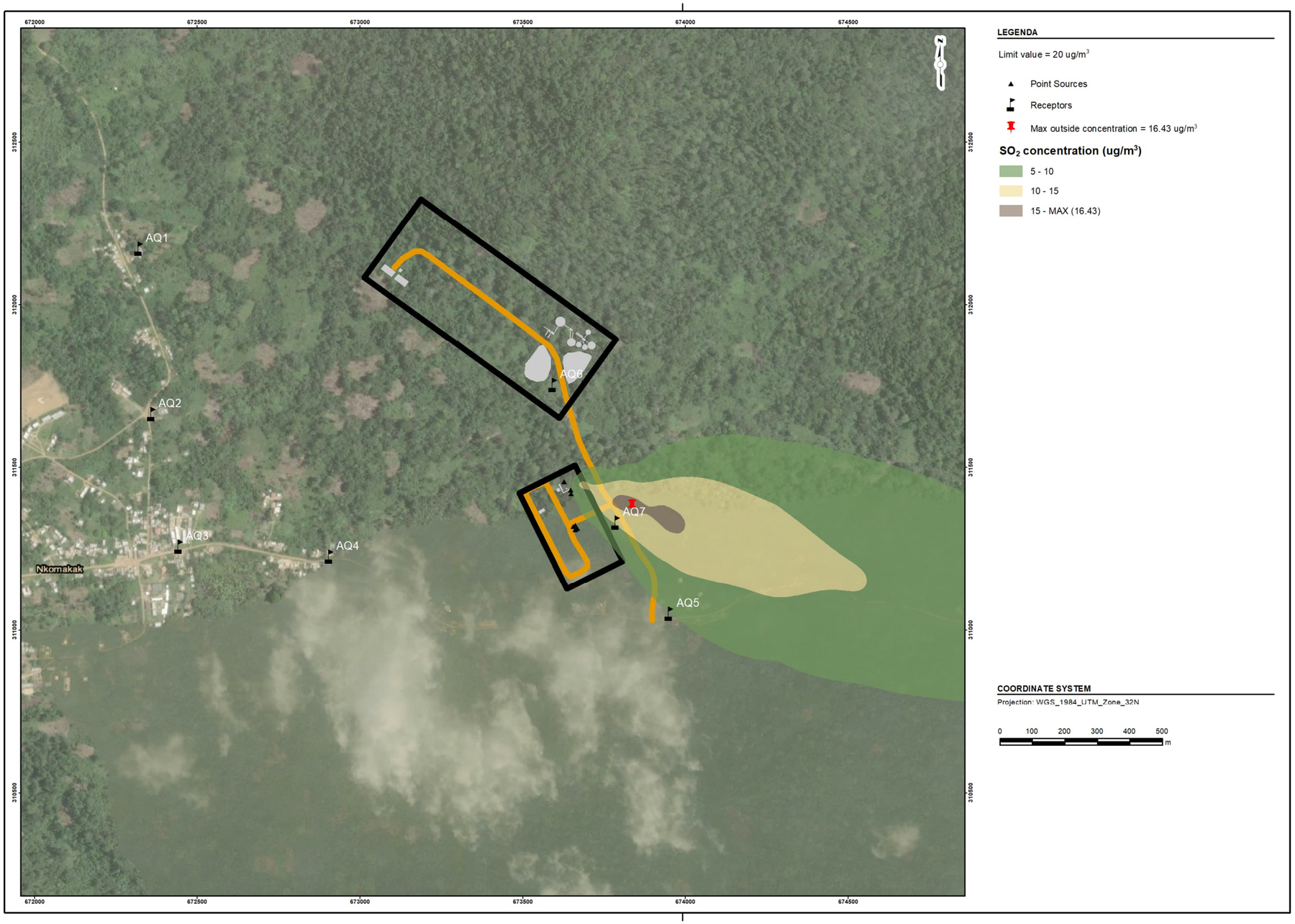


Figure 15: SO2 – Annual average modelled concentrations

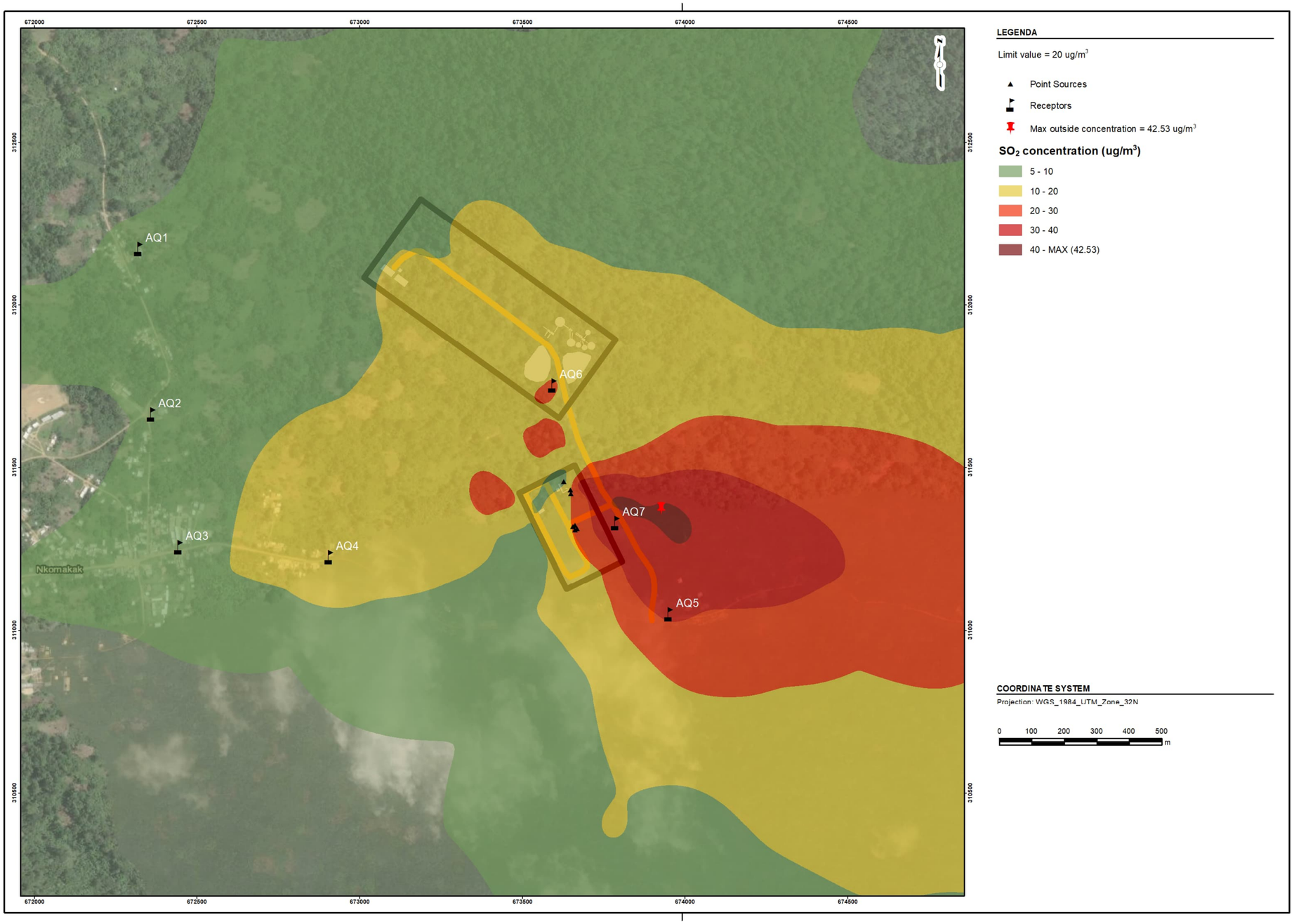


Figure 16: SO_2 – Daily average modelled concentrations

Figure 17: SO2 – Hourly average modelled concentrations

5.2.5 CO

The distribution of average daily CO concentrations shows a maximum concentration of 0.021 mg/m^3 (**Figure *18***). The maximum daily average concentration is to the east of the Site.

The daily average value is not exceeded at any receptors.

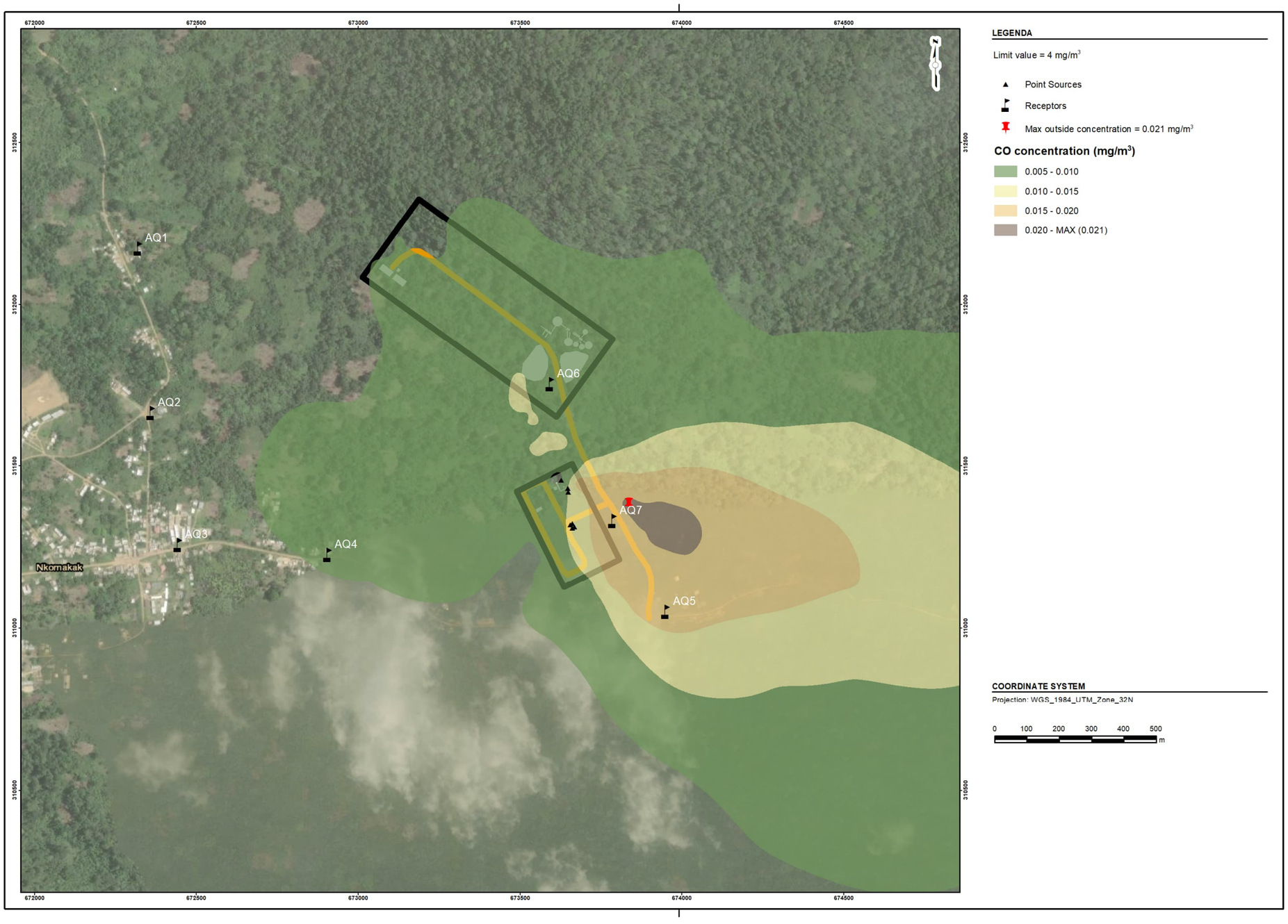


Figure 18: CO – Daily average modelled concentrations

5.3 Modelled ambient air concentrations

The tables below present the cumulative effects of baseline concentrations measured plus modelled concentrations at the identified sensitive receptors listed below:

- AQ1- Minor Community.
- AQ2 - Church Ekowong.
- AQ3 - School nursery.
- AQ4 - Minor Community.
- AQ5 - Integrated Health Centre.

AQ6 and AQ7 points are used only to define the air quality baseline near Site1 and Site 2 and do not represent sensitive receptors.

In the absence of information on annual baseline concentrations for the pollutants considered, the following table uses the maximum hourly measured concentrations for gaseous pollutants and the daily measured concentrations for particulate matter.

Table 28: NO2 - Modelled hourly ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Max Hourly Conc. (ug/m^3) NO_2	Project Hourly Average Conc. (ug/m^3) NO_2	Baseline + Project Conc. (ug/m^3) NO_2
AQ1 – Minor Community	200 (guidelines)	0.019	14.994	15.013
AQ2 – Church Ekowong		0.038	18.816	18.854
AQ3 – School nursery		0.038	18.752	18.790
AQ4 – Minor Community		0.038	31.315	31.353
AQ5 – Integrated Health Centre		0.038	75.718	75.756

Table 29: NO2 – Modelled annual average ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Annual Average Conc. (ug/m^3) NO_2	Project Annual Average Conc. (ug/m^3) NO_2	Baseline + Project Conc. (ug/m^3) NO_2
AQ1 – Minor Community	40 (guidelines) 30 (for vegetation) (NOx)	0.019	0.133	0.152
AQ2 – Church Ekowong		0.038	0.138	0.176
AQ3 – School nursery		0.038	0.133	0.171
AQ4 – Minor Community		0.038	0.242	0.280
AQ5 – Integrated Health Centre		0.038	4.086	4.124

Table 30: SO2 – Modelled hourly ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Max Hourly Conc. (ug/m^3) SO_2	Project Hourly Average Conc. (ug/m^3) SO_2	Baseline + Project Conc. (ug/m^3) SO_2
AQ1 – Minor Community	500 (guidelines)	0.0524	31.3188	31.3712
AQ2 – Church Ekowong		0.0026	34.1294	34.1320
AQ3 – School nursery		0.0524	45.0397	45.0921
AQ4 – Minor Community		0.0786	60.4951	60.5737
AQ5 – Integrated Health Centre		0.0786	140.3278	140.4064

Table 31: SO2 – Modelled daily ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Daily Conc. (ug/m^3) SO_2	Project Daily Average Conc. (ug/m^3) SO_2	Baseline + Project Conc. (ug/m^3) SO_2
AQ1 – Minor Community	20 (guidelines)	0.005	6.175	6.180
AQ2 – Church Ekowong		0.015	6.997	7.012
AQ3 – School nursery		0.023	7.383	7.406
AQ4 – Minor Community		0.022	15.943	15.965
AQ5 – Integrated Health Centre		0.019	31.488	31.507

Table 32: SO2 – Modelled annual average ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Annual Average Conc. (ug/m^3) SO_2	Project Annual Average Conc. (ug/m^3) SO_2	Baseline + Project Conc. (ug/m^3) SO_2
AQ1 – Minor Community	20 (for forests and natural vegetation) 30 (for agricultural crops)	0.0524	0.305	0.3574
AQ2 – Church Ekowong		0.0026	0.300	0.3026
AQ3 – School nursery		0.0524	0.316	0.3684
AQ4 – Minor Community		0.0786	0.509	0.5876
AQ5 – Integrated Health Centre		0.0786	4.901	4.9796

Table 33: PM10 – Modelled daily ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Daily Conc. (ug/m^3) PM_{10}	Project Daily Average Conc. (ug/m^3) PM_{10}	Baseline + Project Conc. (ug/m^3) PM_{10}
AQ1 – Minor Community	50 (guidelines)	3.29	0.38	3.67
AQ2 – Church Ekowong		4.37	0.28	4.65
AQ3 – School nursery		11.00	0.18	11.18
AQ4 – Minor Community		8.00	0.34	8.34
AQ5 – Integrated Health Centre		5.91	29.81	35.72

Table 34: PM10 – Modelled annual average ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Annual Average Conc. (ug/m^3) PM_{10}	Project Annual Average Conc. (ug/m^3) PM_{10}	Baseline + Project Conc. (ug/m^3) PM_{10}
AQ1 – Minor Community	20 (guidelines)	3.29	0.129	3.129
AQ2 – Church Ekowong		4.37	0.114	4.114
AQ3 – School nursery		11.00	0.092	11.092
AQ4 – Minor Community		8.00	0.166	8.166
AQ5 – Integrated Health Centre		5.91	20.807	26.717

Table 35: PM2.5 – Modelled daily ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Daily Conc. (ug/m^3) $PM_{2.5}$	Project Daily Average Conc. (ug/m^3) $PM_{2.5}$	Baseline + Project Conc. (ug/m^3) $PM_{2.5}$
AQ1 – Minor Community	25 (guidelines)	2.08	0.23	2.31
AQ2 – Church Ekowong		3.00	0.20	3.20
AQ3 – School nursery		7.45	0.12	7.65
AQ4 – Minor Community		5.41	0.21	5.62
AQ5 – Integrated Health Centre		4.08	23.07	27.15

Table 36: PM2.5 – Modelled annual average ambient concentrations calculated at the receptors

Location	Project Standard	Baseline Annual Average Conc. (ug/m^3) $PM_{2.5}$	Project Annual Average Conc. (ug/m^3) $PM_{2.5}$	Baseline + Project Conc. (ug/m^3) $PM_{2.5}$
AQ1 – Minor Community	10 (guidelines)	2.08	0.091	2.171
AQ2 – Church Ekowong		3.00	0.083	3.083
AQ3 – School nursery		7.45	0.068	7.518
AQ4 – Minor Community		5.41	0.123	5.533
AQ5 – Integrated Health Centre		4.08	16.056	20.136

The cumulative effect of hourly and annual average NO_2 baseline concentrations and of modelled Project contributions are below the limit values at each sensitive receptor; in AQ5 the increase of hourly concentration due to the Project is greater than 25% of the limit value (200 µg/m^3).

For SO_2, cumulative values are below the limits at each sensitive receptor; in AQ5 hourly concentration increase by more than 25% of the limit value (500 µg/m^3). Daily average SO_2 cumulative concentrations are above the limit value at sensitive receptor AQ5.

Cumulative daily and annual average Particulate Matter (PM_{10} and $PM_{2.5}$) values are above the limits at sensitive receptor AQ5.

6.0 CONCLUSIONS

In summary, the current baseline conditions measured at the receptors indicate low concentrations of gaseous pollutants and of PM_{10} and $PM_{2.5}$ that are all below the Project standards.

The model shows that in many instances pollutant ground concentrations resulting from quarry and site installation operations are above the Project standard in proximity of Site 1 and Site 2. However, these exceedances are found at locations where there are no sensitive receptors.

At sensitive receptors, that are farther west and south from Site 1 and Site 2, modelled ambient concentrations decrease significantly and the cumulative effects of measured baseline conditions and modelled ground concentrations resulting from the Project are below the Project Standards at almost all receptors, with AQ5 representing an exception, likely due to its proximity to the site. At AQ5 the cumulative effects of current baseline conditions and modelled Project effects, show that daily average SO_2 concentrations are above the Project Standards, as well as daily and annual average Particulate Matter (PM_{10} and $PM_{2.5}$) concentrations.

Signature Page

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Project Director

Society subjected to direction and coordination from WSP Global Inc. ex. Art. 2497-bis c.c.