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UK11-24483

NEW BUGESERA INTERNATIONAL AIRPORT
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT REPORT– AIR QUALITY

RAMBOLL ENVIRON

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9. AIR QUALITY

9.1 Introduction

This chapter of the ESIA Report considers the potential impacts of the Proposed Project on air quality. The assessment includes a review of existing air quality and it predicts and evaluates the potential impacts of the Proposed Project and the associated likely impacts on air quality, arising from the construction works and operation of the completed Proposed Project. Potential sources of emissions are identified and assessed in the context of existing air quality and emission sources, as well as the nature and location of receptors.

This chapter is accompanied by the following technical appendices:

- Technical Appendix 9.1: Construction Data for Emissions Assessment;
- Technical Appendix 9.2: Meteorological Data;
- Technical Appendix 9.3: Source Emissions Considered During the Construction Phase;
- Technical Appendix 9.4: Airport Operations Data for Emissions Assessment;
- Technical Appendix 9.5: Source Emissions Considered During Operation Phases;
- Technical Appendix 9.6: Concentration Map - Construction Phase;
- Technical Appendix 9.7: Concentration Map - 2020 Operation Phase;
- Technical Appendix 9.8: Concentration Map - 2045 Operation Phase; and
- Technical Appendix 9.9: Greenhouse Gas Emissions Technical Note.

9.2 Policy, Legal and Administrative Framework

Legal, policy and lender requirements that relate specifically to air quality are set out in this section. Broader legal requirements that apply to the entire Proposed Project and the ESIA Report were presented in Chapter 2: Policy, Legal and Administrative Framework.

9.2.1 Rwandan Policy

The main Rwandan Policy related to the air quality aspects is the *Rwanda Environment Policy* dated 2003. An overview of the specific air quality statements of this Policy are detailed in the following subsection.

9.2.1.1 The Rwanda Environment Policy, 2003

A specific section of The *Rwanda Environment Policy*[1] dated 2003 is dedicated to "*Transport and Communications*" (Section 5.3.2) and include *"strategic actions"* related to air quality. These actions are notably to ensure that air transport regulations minimise pollution and to prevent air and soil pollution by emissions of gases and heavy metals from transport equipment.

This strategy is then enacted through the legislative framework described below.

9.2.2 Legal Framework

Several laws and orders relate to air quality in Rwanda. The main statutes are presented below.

9.2.2.1 Organic Law No. 04/2005

As presented in Chapter 2 of this Report, Organic Law No. 04/2005 dated 8 April 2005 is the law determining the requirements for the protection, conservation and promotion of the environment in Rwanda.

[1] Republic of Rwanda Ministry of Lands, Resettlement and Environment, 2003. Rwanda Environmental Policy

This law includes a section (Section 4) dedicated to “atmospheric pressure” comprising three articles (25 to 27) with the general objective of preserving the atmospheric pressure. These articles refer to ministerial orders for the more detailed requirements. The ministerial orders that relate to the Proposed Project activities are presented in the subsections below.

Additionally, Article 81 of the Organic Law states that it is prohibited to damage “*the quality of air and of the surface or underground water*”.

9.2.2.2 *Law No. 18/2016*

Law No. 18/2016 dated 18 May 2016 governs the preservation of air quality and prevention of air pollution in Rwanda.

This law set out the requirements for the preservation of air quality and the prevention of air pollution in Rwanda. It applies to all measures aimed at the preservation of air quality, as well as all elements or activities likely to affect air quality or pollute the atmosphere.

It states that “*every person must comply with the minimum air quality standards established by the National Authority in charge of setting up regulations for quality standards*”.

The air quality standards/thresholds are not listed directly in this law, but in the Ministerial Order No. 003/16.01 discussed below.

9.2.2.3 *Ministerial Order No. 003/16.01*

The purpose of the Ministerial Order No. 003/16.01, dated 15 May 2010, is to prevent activities that pollute the atmosphere. It provides in its Annex, Ambient Air Quality Tolerance Limits, listed in Table 9-1 below, which are based on, and consistent with, the Air Quality Specification of the Eastern African Standard Guideline[2].

Table 9-1: Ambient Air Quality Tolerance Limits, from the Eastern African Standards Guideline, 2010

Pollutant	Period	Industrial Area	Residential, Rural and Other Areas	Controlled Areas***
Sulphur oxides (SO_X)	Annual Average*	80 µg/m³	60 µg/m³	15 µg/m³
	24 hours**	125 µg/m³	80 µg/m³	30 µg/m³
	Annual Average		50µg/m³	
	24 Hours		125µg/m³	
	Instant Peak (10 min)		500 µg/m³	
Oxides of Nitrogen (NO_X)	Annual Average*	80 µg/m³	60 µg/m³	15 µg/m³
	24 hours**	150 µg/m³	80 µg/m³	30 µg/m³
	Annual Average		0.2 ppm	
	Month Average		0.3 ppm	
	24 Hours		0.4 ppm	
	One Hour		0.8 ppm	
	Instant Peak		1.4 ppm	

[2] Eastern African Standard Organisation, 2010. Air Quality Specification Guideline (CD/T/66/2010).

Table 9-1: Ambient Air Quality Tolerance Limits, from the Eastern African Standards Guideline, 2010

Pollutant	Period	Industrial Area	Residential, Rural and Other Areas	Controlled Areas***
Nitrogen Dioxide	Annual Average	150 μg/m^3	0.05 ppm	
	Month Average		0.08 ppm	
	24 Hours	100 μg/m^3	0.1 ppm	
	One Hour		0.2 ppm	
	Instant Peak		0.5 ppm	
Suspended particulate Matter (SPM)	Annual Average*	360 μg/m^3	140 μg/m^3	70 μg/m^3
	24 hours**	500 μg/m^3	200 μg/m^3	100 μg/m^3
	Annual Average****		100 μg/m^3	
PM_{10} or Respirable Particulate Matter (RPM)	Annual Average*	70 μg/m^3	50 μg/m^3	50 μg/m^3
	24 hours**	150 μg/Nm^3	100 μg/Nm^3	75 μg/Nm^3
$PM_{2.5}$	Annual Average	35 μg/m^3		
	24 hours	75 μg/m^3		
Lead (Pb)	Annual Average*	1 μg/m^3	0.75 μg/m^3	0.5 μg/m^3
	24 hours**	1.5 μg/m^3	1 μg/m^3	0.75 μg/m^3
	Monthly Average		2.5 μg/m^3	
Carbon monoxide (CO)/ carbon dioxide (CO_2)	8 hours**	5.0 mg/m^3	2.0 mg/m^3	1.0 mg/m^3
	1 hour	10.0 mg/m^3	4.0 mg/m^3	2.0 mg/m^3
Non-methane hydrocarbons	Instant Peak	700 ppb****		
Ozone	1-Hour	200 μg/m^3	0.12 ppm	
	8 hour (Instant Peak)	120 μg/m^3	1.25 ppm	

Notes:
Values are expressed at Standard Temperature and Pressure (STP)

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

*** Not to be exceeded more than once per year average concentration.

**** ppb: parts per billion

9.2.2.4 Prime Minister's Instruction No. 005/03 of 27/12/2013

In addition to the Ministerial Order No. 003/16.01, the Government of Rwanda adopted the Prime Minister's Instruction No. 005/03 on 27 December 2013 preventing air pollution caused by vehicular emissions and machines using petroleum products in Rwanda.

With this instruction, vehicle emissions testing became mandatory and only low sulphur fuels were allowed from January 2015. Any vehicle that does not meet applicable emissions standards cannot be awarded a technical control certificate; hence not authorised to operate in Rwanda.

Applicable emissions standards are defined by the Rwanda Standards Boards, in line with the East African Community (EAC) Standards, notably regarding:

- Quality of gasoline (RSEAS 158);
- Quality of diesel (RSEAS 177);
- Air quality specification (RSEAS 751); and
- Code of practice for motor vehicle inspections, including emission limits (RS 741).

9.2.3 International Standards

The main international standard covering air quality requirements are the IFC General EHS Guidelines – Environmental Air Emissions and Ambient Air Quality[3]. This standard refers to the World Health Organization (WHO) Ambient Air Quality Guidelines for recommended values[4]. These international guidelines are summarised in Table 9-2. AfDB Safeguarding Principles have also been considered.

Table 9-2: IFC Air Quality Standards (WHO Quality Guidelines)

Pollutant	Period	Guideline Value (µg/m³)
NO_2	Hourly	200
	Year	40
SO_2	Hourly	500 (10 min)
	Daily (24 hours)	20
	Year	N/A
Particulate Matter PM_{10}	Daily (24 hours)	50[1]
	Year	20
Particulate Matter $PM_{2.5}$	Daily (24 hours)	25[1]
	Year	10
Ozone	8-hour daily maximum	100

[1]The PM_{10} / $PM_{2.5}$ guidelines for daily average may be exceeded up to 3 times per year (i.e. 99.2th per-centile)

According to the IFC General EHS Guidelines – Air Emissions and Ambient Air Quality, projects with significant sources of air emissions and a potential for significant impacts to ambient air quality should prevent or minimise impacts by ensuring that:

- *"Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognised sources; and*
- *Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests 25% of the*

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[3] International Finance Organisation (IFC), 2007. Environmental, Health, and Safety General Guidelines, Chapter 1.1 Air Emissions and Ambient Air Quality.

[4] World Health Organization (WHO), 2005. Air Quality Guidelines: Global Update: Particulate Matter, Ozone, Nitrogen Dioxide, and Sulfur Dioxide, 2006

applicable air quality standards to allow additional, future sustainable development in the same air shed".

Furthermore, the greenhouse gas (GHG) emissions must be estimated for "*projects that are expected to or currently produce more than 25,000 tonnes of CO_2-equivalent annually*" according to the IFC PS3 paragraph No. 8.

9.3 Assessment Methodology

9.3.1 Scope

The scope of the air quality assessment for the Proposed Project Area has been defined through a scoping process, which identified potentially sensitive receptors and potentially significant impacts. The outcome of the scoping process was documented in the Scoping Report[5].

The Air Quality section of the Scoping Report included a high-level overview of the existing Proposed Project Area environment to identify potentially sensitive receptors in the context of possible impacts during the construction and operation phases.

During the scoping phase, potential impacts and general mitigation measures were identified based on publicly available data, in the absence of baseline data and air emission modelling.

Based on the scoping phase conclusions, a baseline air quality campaign, air emissions modelling and an impact assessment were undertaken of the earthworks and construction phase, as well as of the anticipated emission sources during the operation phase of the Proposed Project. These included consideration of the following:

<u>Construction Phase:</u>

- Mass earthworks for the construction of NBIA and the Expressway;
- Off-road machinery for the construction of NBIA and the Expressway;
- Transport of workers;
- Temporary asphalt and concrete batching plants;
- Construction plant; and
- Transport of material by truck over the quarry road.

<u>Operation Phase</u>

- Aircraft movements: including landing, climbing, take-off and taxiing;
- Aircraft Auxiliary Power Units (APUs);
- Ground Support Equipment (GSE);
- Traffic airside and landside at the airport; and
- Traffic on the Expressway.

A technical note estimating the GHGs associated with the Proposed Project is presented in Technical Appendix 9.9.

9.3.2 Scenarios Considered

According to airfield development described in the Master Plan dated February 2017[6], three scenarios were considered for the air quality assessment:

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[5] Ramboll Environ, 2017. NBIA Terms of Reference / Scoping Report.

[6] Airport Design Management: Airport Consulting Vienna (ACV) and by Mota-Engil, February 2017: Master Plan Bugesera Greenfield Airport Final Report (Version 4.0)

- Earthworks and construction phase to the end of the first construction phase; this includes vegetation and top soil removal, cut and fill (approximately 9,000,000 m^3 of cut will be excavated and 7,000,000 m^3 will be filled in the Airport Area for levelling the ground, the remaining 2,000,000m^3 will be stored in piles within the Airport Area), construction of the 14.5 km Expressway linking the airport to the national KK-15 Road, three temporary plants (one for asphalt and two for concrete batching), and the Phase 1 construction activities listed in Table 9-3;
- Operations following the completion of Phase 1, planned for 2020, which will include a 29,900 m^2 Passenger Terminal with a capacity of 1.77 million passengers per annum, a 3,000 m^2 Presidential Terminal, a 1,200 m^2 general aviation (GA) building, a runway 3,750 m in length and 45 m wide, a Runway End Safety Area (RESA) 180 m in length and 160 m wide, and a 180-space parking area. This scenario includes an assumed increase in traffic levels, particularly around the airport on the new Expressway; and
- Operations following the completion of Phase 5, planned in 2045, which will extend the passenger terminal up to 39,400 m^2 providing the airport with a capacity of 5.72 million passengers per annum. This scenario also includes a further assumed increase in traffic levels, particularly around the airport on the new Expressway.

A summary of the anticipated traffic as well as the main construction elements per phase is presented in Table 9-3.

Table 9-3: Assessment Scenarios and Aviation Traffic Volumes Considered

Traffic		2020		2030		2035		2040		2045	
Million Annual Passengers (MAP)		1.77		2.52		3.42		4.48		5.72	
Design Peak Hour (DPH)*	Pax**	856	Pax	1,157	Pax	1,490	Pax	1,859	Pax	2,253	Pax
Main Construction Elements Per Phase		**Phase 1:** Runway Taxiway Apron Passenger Terminal President Terminal Airport Facilities Cargo Aircraft Maintenance Landside Roads Commercial Area Parking Area		**Phase 2:** Apron Passenger Terminal Airport Facilities Parking Area		**Phase 3:** Apron Airport Facilities Cargo Office Area Hotel Aircraft Maintenance Parking Area		**Phase 4:** Taxiway Apron Passenger Terminal Airport Facilities Landside Roads Parking Area		**Phase 5:** Taxiway Apron Passenger Terminal Airport Facilities Cargo Parking Area	

* The Design Peak Hour (DPH) load is the rush-hour volume of passengers (Peak-Hour, Peak Month, Average Day) plus the number of visitors/relatives.

** Pax= Passengers

***Mvts= Movements

Source: Master Plan, Bugesera Greenfield Airport-Rwanda, Final Report Version 4.0, February 2017.

The total number of flight operations is based on the Master Plan to be the following (one operation is a landing or a take-off):

- 2020: 25,581 landings and take-offs; and
- 2045: 62,701 landings and take-offs.

Additionally, contribution of vehicle traffic on roads accessing the airport is considered in this assessment.

Details of the two scenarios that were assessed are presented in Table 9-3. The corresponding total road traffic and its distribution are reported in Table 9-4.

Table 9-4: Vehicle Number and Categories

Scenario	Reference year	Vehicle number					
		Total	Private Car	Taxi	Public Shuttle Bus	Tour Operator / Hotel Shuttle Bus	Rental Car
Phase 1	2020	2,399,274	1,071,864	292,970	741,501	234,315	58,624
Phase 5	2045	11,595,948	5,199,088	1,431,914	3,533,335	1,145,108	286,503

Source: Master Plan, Bugesera Greenfield Airport – Rwanda, Volume 5 – Traffic Forecast, Final Report Version 4.0, February 2017

Onsite combustion plants (for energy production) are not planned to be implemented as part of the present project and were therefore excluded from this assessment.

9.3.3 Baseline Characterisation

Existing and future air quality baseline conditions were characterised using the following methods:

- Review of project related documentation, notably the Master Plan;
- Review of published information and maps related to air quality in Rwanda;
- Implementation of two monitoring campaigns, one during the end of the dry season undertaken in September 2017 and one during the rainy season conducted in end-October 2017, including baseline monitoring of 17 sampling points. The results of these monitoring campaigns are integrated in this present version of the Air Quality Chapter.

Sampling locations and measurements performed are presented below in Sections 9.3.2 and 9.3.3 respectively.

9.3.4 Construction Phase Method of Assessment

9.3.4.1 Pollutant Sources and Pollutants

The sources of emissions during the construction phase are as follows:

- Mass earthworks for the construction of NBIA and the Expressway;
- Off-road machinery (NBIA and Expressway);
- Transport of workers;
- Temporary asphalt and batching plants; and
- Transport of material by heavy goods vehicles (HGVs) over the quarry road.

Construction works typically generate dust in the form of particulate matter (PM) with particles with a diameter of 10 µm or less referred to as PM_{10}. However, in order to be conservative, emissions of NO_x, CO, SO_2 and VOC (considered as benzene) were also estimated.

For the specific case of NO_x, the emission calculations do not provide the NO_2 emission levels explicitly. Only NO_2 has an Air Quality Standard, and no standard exists for NO_x. The model used in the assessment (described in the Section 9.3.4.4) has the capability to process photochemical conversion of NO_x and provide resulting NO_2 concentrations.

9.3.4.2 Emissions Calculation Methodology

Emission Factors

To calculate emissions from the Proposed Project construction phase, two internationally recognised references were used:

- The European Monitoring and Evaluation Programme (EMEP) guidebook recently updated in September 2016 referenced as EMEP (2016)[7] within this document; and
- Emissions factors published by the US EPA (AP-42)[8].

The overall methodology was as follows:

Emission = Emission Factor x Activity

Where the activity refers to a number (off-road machinery, buses, etc.) or a surface of activity (e.g. the area of construction operations)

Following the Intergovernmental Panel on Climate Change (IPCC) classification for the determination of GHGs emissions, the US EPA and EMEP have classified their methodological approaches in three different tiers, according to the quantity of information required and the degree of analytical complexity as follows:

- A Tier 1 method is the simplest way to estimate the emissions of a certain pollutant in a certain source category. It consists of a single emission factor that should be multiplied by a corresponding activity variable, which depends on the source category (e.g. the fuel consumption for the estimation of exhaust off-road machinery emissions);
- A Tier 2 method contains additional detail about the activity. In the Tier 1 approach, one or more technologies are identified that each have their own set of emission factors (for each relevant pollutant). Additionally, Tier 2 provides abatement efficiencies where available (abatement due to watering of work construction surfaces); and
- A Tier 3 method is anything beyond the Tier 2 method. It may consist, for instance, of the use of facility level data.

Emission factors and references used for the emission calculations during the NBIA and the Expressway construction phases are summarised in Table 9-5.

For the determination of the emissions generated during earthworks, chapter (2.A.5.b) from Table 9-5 EMEP (2016) covering mass earthwork construction was referred to. This guidebook provides an estimation of suspended particle emissions and assumes that other pollutants are not released at significant levels. This approach, which was applied in this assessment (Tier 1 level), is considered conservative for the emissions of suspended particles and includes all types of emitters operating inside the area of construction.

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[7] EEA (2016) Air pollutant emission inventory guidebook. Available at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

[8] EPA (AP-42): Compilation of Air Emission Factors. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

As indicated previously, this method does not provide an estimation of emissions for other pollutants that may potentially be emitted (NO_x, SO_2, VOCs considered as to benzene or CO) from, for example, fuel combustion of machinery or the temporary plants. Consequently, for the assessment of the Proposed Project, emissions of pollutants generated from off-road machinery (graders, bulldozers, etc.), emissions from the transport of workers by bus/shuttle and from the temporary plants (batching plant, bitumen plant) were considered independently. References for these two types of sources of emissions are provided in Table 9-5.

Moreover, the Tier 1 approach in the EMEP (2016) does not consider the emissions of particles occurring outside the area of construction activities and on unpaved roads due to the resuspension of particles. As a consequence, emissions during transport of material by HGVs from the quarry road to the construction works within the Airport Area were assessed separately following the AP-42 section 13.2.2 of the US EPA to account for this.

Table 9-5: Summary of Emission Factors Used to Assess the Construction Phase Emissions

Air Emission Sources	Description	Reference	Pollutants
Mass Earthwork	Construction and Demolition Emissions for Non-Residential Construction and Road Construction	EMEP (2016), 2.A.5.b	PM_{10}
Temporary Plants	Emissions during Production	EMEP (2016), Tier 1, 2.D.3.c	CO, NO_x, SO_x
Off-Road Machinery	Non-Road Mobile Sources and Machinery (Combustion)	EMEP (2016), 1.A.4	CO, PM_{10}, NO_x, VOC, SO_2
Road Traffic	Emission Factors for Road Traffic Vehicles (Buses)	EMEP (2016), 1.A.3.b	CO, PM_{10}, NO_x, VOC, SO_2
Particle Resuspension	Emissions Due to Vehicles Travelling Over Unpaved Roads	AP42, Section 13.2.2	PM_{10}

The emissions generated during the resuspension of fugitive particle and assessed in this assessment as PM_{10} are largely of mineral composition and mechanical origin, with soil dust typically comprising a significant part. For the activities resulting in fugitive PM_{10} emissions, emissions are strongly dependent on the material and level of soil moisture content. As indicated in the EMEP (2016), uncertainties on emission calculations may result in the overall uncontrolled emissions of suspended particles calculated by the Tier 1 approach being overestimated, which is therefore considered conservative.

With the caveat of potential overestimations, this method was used to estimate the pollutant emissions from the earthworks within the Proposed Project Area:

- For the NBIA: over borrow pits and spoil areas, as shown in Figure 9-1, and over the construction of the runway and the airport facilities; and
- For the new Expressway: along the entire length of the road according to the Mota-Engil Africa design report[9].

[9] Mota-Engil Africa, New Bugesera International Airport – NBIA, Accesses – Expressway – Conceptual Design, July 2017

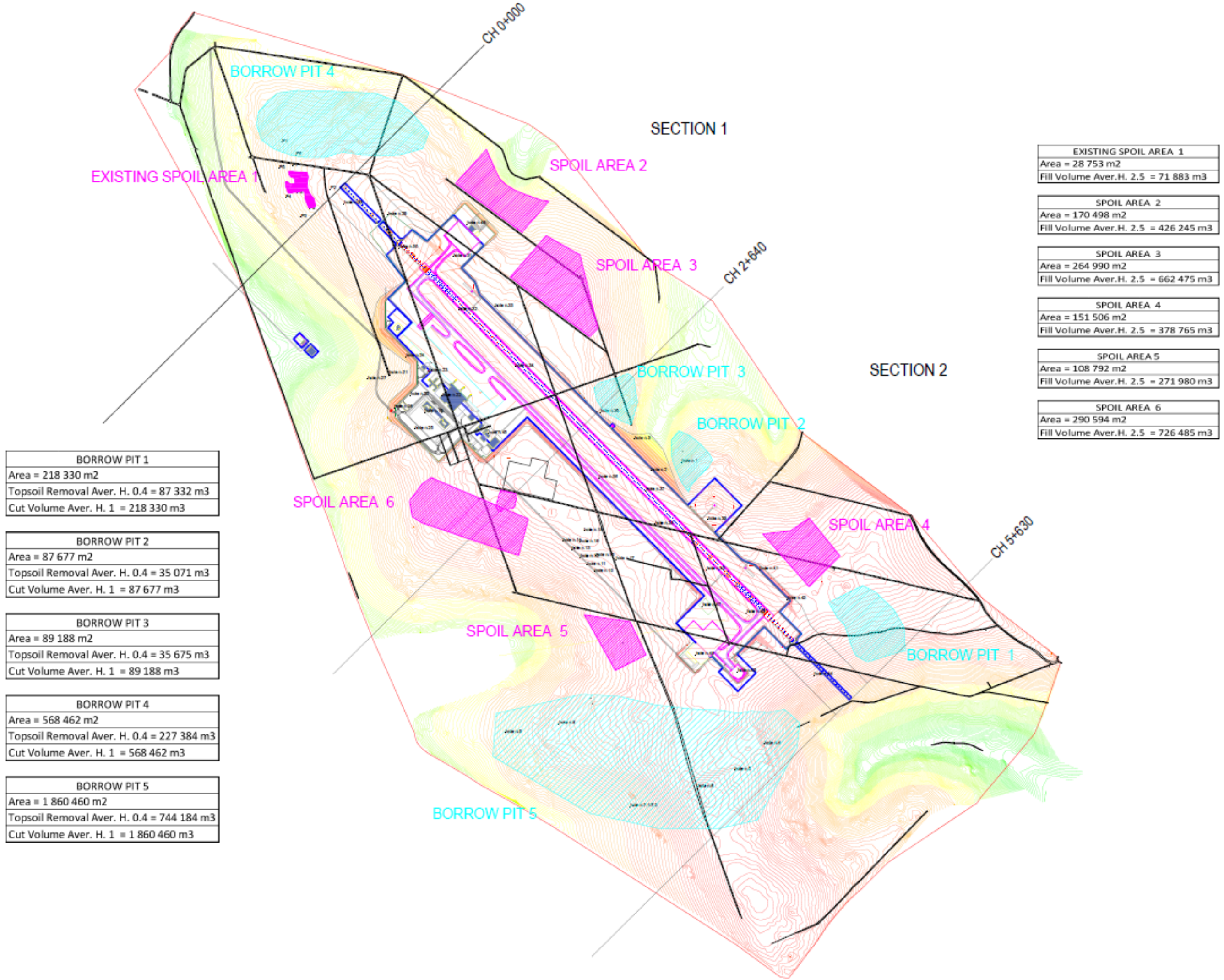

Figure 9-1: Location of Borrow Pits and Spoil Areas

Source: Master Plan, February 2017

Detailed emission calculations are provided in Technical Appendix 9.1. Emissions were derived from the duration of operations, soil sensitivity index and soil silt content. The duration of earthworks has been estimated to be for three months according to the Master Plan and assuming that all earthworks are performed at the same time. Soil sensitivity indices were calculated according to a climatic correction factor that influences the soil moisture content though monthly average temperatures and rainfall.

The list of parameters used for this calculation is provided in Table 9-6.

Table 9-6: Inputs parameters for the determination of Earthwork PM_{10} emissions

Parameter	Value
Duration of Earthworks	3 months (rolling over the meteorological period, 2015-2016)
Soil sensitivity index	67.1
Soil silt content	33% (Sandy load)

Gaseous Emissions from Off-Road Machinery from Fuel Combustion

For off-road vehicles and machinery, emissions will mainly originate from the combustion of fuel to power equipment. The most important emissions include: SO_2, NO_x, CO, VOCs and particulate matter (consolidated in this assessment as PM_{10}) with the relative importance of the emission depending on the type of engine (diesel compression ignition or petrol spark ignition) and the type of equipment. The methodology used for estimating emissions of SO_2 is fuel-based i.e. independent of engine technology or type of equipment.

As discussed in the previous section, PM_{10} emissions from off-road equipment are embedded in the total emissions generated during the mass earthworks activity and therefore not included in this calculation in order to avoid double counting.

Table 9-7 provides a summary of the inputs that are necessary for the calculation of such emissions. These data were provided by Mota-Engil Africa[10], except for fuel consumption per type of equipment that were derived for the most common off-road machinery[11]. The emission factors that were used are summarised in Technical Appendix 9.1.

Table 9-7: Main Characteristics of Equipment During the Construction Phase

Equipment	Number	Operating hours per year	Speed (km/h)	Fuel Consumption (l/hour)
Dozers	20	4,998	<20	41.5 (CAT D8R Dozer)
Graders	13	4,998	25	21.3 (CAT 140M Motor Grader)
Trucks (tipper and dump)	76	4,998	20	10 (CAT 725 off-highway Truck)
Excavators	2	4,998	<20	17 (CAT 329D and Doosan DX520L)
Front Loaders	2	4,998	<20	144 (CAT 980H and Doosan DL420)
Motor-Scrapers	2	4,998	<20	138 (CAT 621G and 627G)

10 Document titled specialist Information Requested (NBIA and Expressway)

11 Fuel consumption are derived from http://alexandrovitch.com/tools/display.php?pid=26 website

Road Transport of Workers

The transport of workers over construction areas (NBIA and the Expressway) can generate emissions of pollutants. Emissions of PM_{10}, SO_2, CO, NO_x and VOC were estimated based on the information provided by BAC and the EMEP (2016) guidebook emission factors[12]. A conservative approach was adopted considering that the worker transport will largely be by diesel-fuelled buses under the EURO III engine norms.

Table 9-8 provides a summary of the data used for the emissions calculations.

Table 9-8: Transport of Workers Data

Number of Buses per Day	Distance Travelled per Day (km/day)	Days Worked per Year
13	28.4 (14.2 km x 2 times per day)	200

Particle Resuspension over the Unpaved Quarry Road

When a vehicle travels on an unpaved road, the force of the wheels on the road surface causes pulverisation of surface materials generating emissions of particles. Particles are lifted and dropped by the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Assumptions made for the calculation of PM_{10} emissions from trucks travelling to and from the quarry along the quarry road are summarised in Technical Appendix 9.1. Table 9-9 presents the main input parameters for the emissions calculations.

Table 9-9: Input Parameters Considered for The Calculation of Resuspended Particles from Trucks Travelling Over the Quarry Road

Parameter	Value
Surface silt (%)	33%
Moisture content	5%
Mean vehicle speed	15 km/h
number of trucks	13
Length of the quarry road	4.6 km

The resulting emissions due to the widening of the quarry road are not estimated in this assessment. It is assumed that the emissions generated are low compared to the resuspension of particles during the transport of materials from the quarry.

Emissions from the Temporary Plants (asphalt and concrete batching)

Combustion in a road stone coating plant is mainly associated with drying of aggregates, which generally occurs in a rotary dryer. Plants produce asphalt and other road coating through either batch or continuous aggregate operations. In either operation, the aggregate is transported first to a gas or oil-fired rotary dryer. Hot dry aggregate is then blended and passed to a mixing chamber where bitumen is added and mixed to produce the hot asphalt mix. This then passes to storage bins prior to discharge to delivery HGVs. For concrete production, combustion occurs in the kiln and, where relevant, the pre-calciner furnace.

The activities associated with these processes generate emissions of PM_{10}, CO, SO_x (assimilated to SO_2) and NO_x. As discussed previously in this section, all PM_{10} emissions will be estimated

[12] EEA (2016) Air pollutant emission inventory guidebook. Available at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2016.

through the method described above. Emissions of the other pollutants considered in this ESIA Report have been calculated and summarised in Technical Appendix 9.1 assuming a Tier 2 approach for the calculation of both asphalt and concrete production. Estimates of the total quantities of materials for the production of asphalt and concrete for surfacing of roads are given in Table 9-10.

Table 9-10: Estimate Quantities for Asphalt Surfacing of Roads

Activity	Unit	Quantities					
		Phase 1	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Total**
Asphalt Base-course	tonnes						
Asphalt Binder-course	tonnes	**420,678**	17,745	370,243	153,003	**21,094**	562,085
Asphalt Surface-course	tonnes						
Concrete	m^3	**123,306**	9,170	20,541	8,941	**6,694**	168,652
Cement	tonnes	**49,322**	3,668	8,216	3,576	**2,678**	67,460
Aggregate	tonnes	**234,281**	17,423	39,028	16,988	**12,719**	120,439

Source: Mota-Engil Estimation of material production

Figures in bold represent the figures used in the Phase 1 (2020) and Phase 5 (2045) air quality assessment scenarios.

9.3.4.3 *Emissions Calculation Results*

Table 9-11 shows the contributions from the different sources during the construction phase to the pollutant emission levels.

Table 9-11: Total Estimated Emissions During the Construction of NBIA and the Expressway

Source of Emissions	**CO**	**NO_x**	**PM_{10}**	**SO_2**	**VOC assimilated to benzene**
Emissions During the Construction Phase (Tonne/Year)					
Road Construction	-	-	208.0	-	-
NBIA Construction	-	-	1,150.0	-	-
Asphalt Plant (temporary)	60.0	10.7	-	5.3	-
Concrete batching plants (temporary)	25.4	18.3	-	1.1	1.0
Transport of Workers	0.1	0.5	0.01	7.4×10^{-3}	1.3×10^{-3}
Off-Road Machinery (Fuel Combustion)	30.8	93.1	-	0.02	9.6

Table 9-11: Total Estimated Emissions During the Construction of NBIA and the Expressway

Particle Resuspension (Quarry Road)	-	-	3.0	-	-
Total	**116.3**	**122.6**	**1,361.0**	**6.4**	**10.6**

9.3.4.4 *Dispersion Modelling*

ADMS-Airport Model Summary

ADMS-Airport is an air quality model developed by Cambridge Environmental Research Consultants[13] (CERC) and designed to calculate pollutant concentrations in the vicinity of an airport. The model represents an extension of the widely-applied ADMS-Urban model, also developed by CERC. ADMS-Urban models the impact of the complex mix of sources typical of an urban area, including road, industrial, commercial and domestic sources, and other diffuse or small sources.

ADMS-Airport was development by the UK Department for Environment, Food and Rural Affairs (DEFRA) in 2005. DEFRA was required to model the impacts of London Heathrow Airport on air quality due to the proposed expansion.

ADMS-Airport is recognised by ICAO[14] and several other organisations and governmental bodies around the world. It has been widely used to model air quality at London Heathrow Airport in the framework of the Project for Sustainable Development of Heathrow (PSDH). It is also currently being used by Gatwick, Schiphol and Beijing airport operators, as well as research bodies, including the French aerospace research centre (ONERA).

The approach used in ADMS is to calculate pollutant concentrations for each hour using as input hourly varying meteorological data, emissions data and background pollutant data. The meteorological input data are derived from standard meteorological measurements from a monitoring station. The model is capable of accounting for the effects of variations in surface elevation and surface roughness on the mean wind and turbulence levels.

ADMS allows for the specific treatment of aircraft sources using “accelerating jets” or volume sources. Full landing and take-off (LTO) cycles, as well as APU and GSE emissions, can be considered in the model. Other aspects of ADMS-Airport of particular relevance to this assessment include treatment of chemistry (NO_x-NO_2 conversion) and “intelligent” gridding. This last feature allows the coverage of a large domain with a standard resolution (250 m) with a focus on emission sources using a much higher resolution gridding (<50 m).

Finally, ADMS-Airport has been widely validated through comparisons with monitored air quality data[15] and other modelling approaches, including semi-empirical methods, the Lagrangian model LASPORT and the FAA model EDMS[16].

Meteorological Data

The Kigali International Airport Meteorological Airport Report (METAR) station was used to derive meteorological parameter statistics (temperature and wind) discussed in this section. The overall characteristics of this station are summarised in Table 9-12. METAR is an

[13] ADMS-Airport description available here: www.cerc.co.uk

[14] The International Civil Aviation Organisation (ICAO), 2011.Airport Air Quality Manual, Document 9889.

[15] CERC, 2007. Air Quality Studies for Heathrow: Base case, Segregated Mode, Mixed Mode and Third Runway Scenarios modelled using ADMS-Airport, prepared for UK Department for Transport.

[16] CERC, 2005. PSDH. Air Dispersion Model Evaluation – Scientific Assessment, Inter-comparison and Validation. Report for the UK Department for Transport.

internationally recognised format for reporting weather information. A METAR weather report is predominantly used by pilots in fulfilment of a part of the pre-flight weather briefing, and by meteorologists, who use aggregated METAR information to assist in weather forecasting and analyses. It is highly standardised through the International Civil Aviation Organisation (ICAO), which allows it to be understood internationally.

Table 9-12: Description of the Kigali International Airport Meteorological Station
Kigali, Rwanda
Kigali International Airport (METAR – TAF)
Latitude: 01-58S, longitude: 030-07E
Altitude: 1491m

Source: Google Earth, 2017

The wind rose for the last two years (period between 2015 and 2016) is shown in Figure 9-2. This figure indicates that the prevailing winds come from the southeast sectors. North-westerly and easterly wind directions are less frequent. The plot also shows that the wind speeds are relatively low (2.46 m/s on average over the two years). A total of 84% of the wind speeds are between 1 m/s and 5 m/s, with a substantial degree of calm conditions (<1 m/s), 11%. Only 1% of winds are > 5m/s. A summary of temperature and rainfall data are presented in Technical Appendix 9.2.

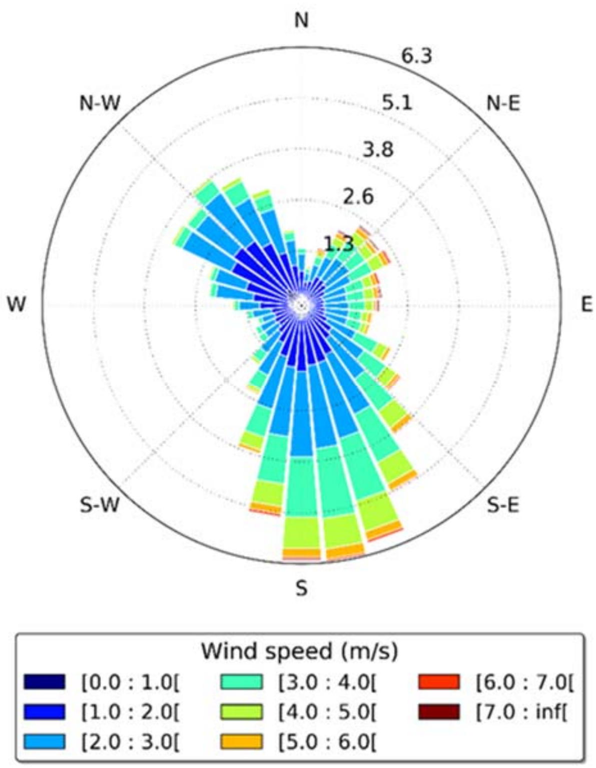

Figure 9-2: Wind rose over Kigali International Airport (from 2015 to 2016)

Model Setup

The model set-up and assumptions used in modelling the dispersion modelling are summarised inn Table 9-13.

Table 9-13: Modelling Parameters	
Meteorology	Kigali International Airport, 2015-2016
Surface Roughness on the Domain (m)	0.5
Minimum Monin-Obukhov Length (m)	20
Pollutant	NO_2, SO_2, PM_{10}, CO and VOC
Chemistry	NO_x-NO_2 correlation (Derwent-Middletown 1996)[17]
Deposition	Gravitational settling for PM_{10}
Emission Sources	Mass earthworks (NBIA, Expressway), road traffic induced by workers over the future Expressway, particles resuspension over the quarry road
Background	Concentrations measured for the baseline study at the sensitive points have been used as background and added to the model results (receptors only)
Grid calculation	30 km x 20 km (80 x 80 grid points in X and Y). Refining gridding close to the emission sources

[17] Derwent, R.G and Midldletown, D.R, 1996: An empirical function for the ratio NO2:NOx. Clean Air, 26, 57-60.

Sources Modelled Description

For the purposes of dispersion modelling, emissions generated during the construction phase were modelled as surface and line sources with the following assumptions:

- 12 surface sources for the construction of the NBIA including the different borrow pits and spoil areas described in the Master Plan dated February 2017;
- One line source along the quarry road for the transport of material from the quarry to the NBIA and the Expressway; and
- One surface source for the construction of the Expressway with a road reserve of 44 m on both sides of the road.

Spatial characteristics of sources for all scenarios are presented in Technical Appendix 9.3. According to the negligible contribution of the emissions related to the transport of workers (see Table 9-13 above), this source was not considered in the model.

9.3.5 Operation Phase Method of Assessment

9.3.5.1 Sources and Pollutants Selection

The operation phase assessment considered the following emission sources:

- Aircraft movements: including landing, climbing, take-off and taxiing;
- Aircraft Auxiliary Power Units (APUs);
- Ground Support Equipment (GSE); and
- Road traffic (to and from the airport) over the Expressway.

As stated previously, two scenarios were considered in accordance with the airfield development described in the Master Plan as follows:

- Operations following the completion of Phase 1, planned for 2020, will provide a 29,900 m^2 Passenger Terminal with a processing capacity of 1.77 million passengers per annum, a 3,000 m^2 Presidential Terminal, a 1,200 m^2 General Aviation (GA) building, a runway which will be 3,750 m long and 45 m wide, a Runway End Safety Area (RESA) of 180 m length and 160 m width, and a 180-space parking area; and
- Operations following the completion of Phase 5, planned for 2045, will extend the Passenger Terminal to 39,400 m^2 providing the airport with a total capacity of 5.72 million passengers per annum.

According to the ICAO Airport Air Quality Manual[18], the following pollutants were considered:

- NO_x;
- Fine PM, fraction size PM_{10} and $PM_{2.5}$ corresponding to particles with diameter less than 10 µm and 2.5 µm respectively;
- SO_2;
- CO; and
- VOCs assimilated to benzene.

For the specific case of NO_x, the emission calculations do not directly or explicitly provide NO_2 emission levels. Only NO_2 has Air Quality Standards; no standards exist for NO_x. The model used (described in the Section 9.3.4.4) is capable of processing photochemical conversion of NO_x and providing resulting NO_2 concentrations.

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[18] International Civil Aviation Organisation, First edition 2011, Airport Air Quality Manual, Doc 9889, ICAO.

9.3.5.2 *Emissions Calculation Methodology*

Emission Factors

To calculate air emissions from the airport operations, air emission factors were used. The general methodology was as follows:

Emission = Emission Factor × Activity

Where the activity is the number of aircraft movements and the duration of annual operations of APUs or GSE.

As part of this assessment, the emission factors and references that were used are summarised in the Table 9-14. All air emission calculations were made using EMIT software developed by the CERC in the United Kingdom[19].

Table 9-14: Summary of Airport Emission Factor Databases

Air Emission Sources	Air Emission Factors Dataset	Description	Reference	Pollutants
Aircraft Movements	ICAO 17	Aircraft engine emissions	UK CAA 2010 FOCA 2007 FOI 2007 AIR5715 2009	CO, NO_x, PM_{10}, SO_2, VOC
APUs	APU 2004	Aircraft auxiliary power units	FAA 2004	CO, NO_x, VOC
GSE	AIRPORT GSE 2007	Airport ground support equipment	UNIQUE 2006	CO, NO_x, PM_{10}, VOC

Notes:

- UK CAA = UK Civil Aviation Authority
- FOCA = Swiss Federal Office of Civil Aviation
- FOI = Swedish Defence Research Agency
- FAA = US Federal Aviation Administration
- UNIQUE = Flughafen Zürich AG
- AIR5715 is a procedure for the calculation of aircraft emissions

Aircraft Movements

Aircraft emit pollutants to the atmosphere through the combustion of kerosene in aircraft engines, and at particularly high levels during take-off when the thrust is at a maximum.

As stated by ICAO, local air quality concerns concentrate on effects created during the landing and take-off (LTO) cycles as these emissions are released below 915 m. The standard assumptions for LTO cycle are presented in Technical Appendix 9.4.

As part of the Project, the Air Transport Movements (ATMs) will be distributed over only one runway for both of the scenarios that were assessed for operations. Moreover, it was also assumed that the number of aircraft departures and arrivals were the same.

Aircraft Types

The emission factors used for the assessment are available per type of aircraft used by airline companies (e.g. Boeing, Airbus, Embraer). For the Proposed Project, the list of aircraft

[19] http://www.cerc.co.uk/environmental-software/EMIT-tool.html

categories used for the assessment is summarised in Table 9-15. Their distribution was based on figures in the Master Plan[20] and the associated ICAO code numbers are also provided. Due to some gaps in the detail of the exact aircraft that will operate at the airport, representative aircraft were considered for each aircraft category.

Table 9-15: Aircraft Fleet Mix and ICAO Classification Code

ICAO code	Description	Scenario – Phase 1	Scenario – Phase 5	Representative Aircraft Considered
A + HELI	All single engine aircraft, some business	5,245	10,345	Cessna 150
B	Commuter aircraft, large Business jets	384	941	Bombardier CRJ-900
C	Medium range transports	16,883	43,891	Boeing 737-800
D	Heavy transports	460	627	Boeing 767-300
E	Heavy transport aircraft	2,609	6,897	Airbus A330-200

Source: Master Plan, Bugesera Greenfield Airport – Rwanda, Volume 5 – Traffic Forecast, Final Report Version 4.0, February 2017

Direction of Operations

NBIA will operate one runway from Phases 1 to 5. Due to the lack of detailed aircraft movement data at this stage, a modal split of northerly and southerly operations was applied as 50% for all cases.

Auxiliary Power Units

An APU is a device that provides energy for functions other than propulsion. The primary purpose of an aircraft APU is to provide power to start the main engines. Aircraft APUs also produce 115 V alternating current (AC) at 400 Hz to run the electrical systems of the aircraft, as well as the air conditioning unit.

For the purposes of this assessment, it was assumed that the APUs were operated in a mode that considered environmental protection with their use limited to five minutes after arrival and five minutes before scheduled time of departure. At the parking stands, it was assumed that the aircraft will be connected to a 400 Hz feed. The total annual hours of use for each type of APU and for each scenario was derived from the ATMs.

The APUs identified for the assessment are the standard ones for each type of aircraft, as proposed by the FAA Air Quality Handbook[21]. The APUs selected for the assessment are listed in Technical Appendix 9.4, with their total annual operating times.

Ground support Equipment (GSE)

Ground Support Equipment (GSE) is the equipment used to service the aircraft between flights and usually located on the ramps. This equipment is used for ground power operations, aircraft mobility and loading operations.

GSE generally includes the following types of equipment:

- Aircraft refuellers, which can be either a self-contained fuel truck or a hydrant truck or a cart;

[20] Master Plan, Bugesera Greenfield Airport – Rwanda, Volume 5 – Traffic Forecast, Final Report Version 4.0, Feb 2017

[21] Federal Aviation Administration Office and Energy, 2015. Aviation Emissions and Air Quality Handbook, Version 3, Update 1.

- Tugs and tractors, including pushback tugs and tractors, which are used to push back aircraft from the gates or used to move other equipment that is not self-propelling;
- Ground power units;
- Buses/coaches;
- Container loader;
- Transporters;
- Air start units, which are vehicles with a built-in gas turbine engine that provide high-pressure air to start the engine. This unit is typically used when an aircraft's APU is not operational;
- Lavatory service vehicles;
- Catering vehicle;
- Belt loaders, which are vehicles with conveyor belts for unloading and loading of baggage and cargo on aircraft; and
- Passengers boarding steps/ramps.

Due to the lack of detailed data that is available at this stage of the Project, GSE numbers for NBIA were estimated using a previous study conducted by Ramboll Environ for Istanbul New Airport[22]. Such GSE numbers correspond to specific ATMs that are representative of large airports, including for instance airports with multiple runways. In order to avoid the overestimation of GSE for the NBIA Project, it was assumed that the number of GSE is proportional to the ATMs. The GSE number was then scaled according to a comparison with the GSE number at Istanbul New Airport. The total number for each scenario is presented in Technical Appendix 9.4.

Finally, the air inventory requires an estimate of the total annual operating hours for each type of GSE. In the absence of specific values for NBIA, the average annual operating hours reported by the California Air Resources Board of 663 hr/year was used[23].

Road Traffic

Road traffic generated by the Proposed Project operational activities are estimated within the Area of Influence of the project. The number of vehicles per category are reported in Table 9-16 and are based on figures from the Master Plan and the estimation of the road traffic over the Expressway (Chapter 8: Traffic and Transportation). According to the transport assessment, it was assumed that 100% of the total road traffic volume will be along the Expressway. Emission factors were derived from the internal model calculation using the EFT v7.0 (2 VC) emission factor dataset[24] for all pollutants (PM_{10}, CO, VOCs and NO_x) except for SO_2. The SO_2 emission factor was determined by setting the maximum sulphur content limit at 50 ppm, according to the Harmonised East African Standard RSEAS 177[25].

Table 9-16: Vehicles Numbers by Category to and from NBIA

Vehicle Type	Scenario – Phase 1	Scenario – Phase 5
Private car	760,032	3,692,416
Taxi	20,774	1,016,952

[22] ENVIRON, May 2015. Istanbul New Airport ESIA. Environmental Baseline and Impact Assessment. Air quality Chapter. IGA, Istanbul, Turkey.

[23] California Environmental Protection Agency, Air Resources Board, July, 2014. Draft Airport Ground Support Equipment Project Criteria, Carl Moyer Program Guidelines.

[24] EFT v7.0 2016 Defra and the Devolved Administrations emission factors release (Version 7.0).

[25] Rwanda Standards Board, 2013. Quality of diesel standard # RSEAS 177.

Table 9-16: Vehicles Numbers by Category to and from NBIA		
Public Shuttle Bus	525,780	2,509,391
Tour Operator/Hotel Shuttle Bus	166,147	813,261
Rental car	41,569	203,476
Total	1,701,265	8,235,495
Source: Master Plan, Bugesera Greenfield Airport – Rwanda, Volume 5 – Traffic Forecast, Final Report Version 4.0, February 2017		

9.3.5.3 *Dispersion Modelling*

ADMS-Airport Model Summary

The model used for this assessment was ADMS-Airport and described in the Section 9.2.4.4 of this chapter.

Meteorological Data

The meteorological data considered as input parameters of the ADMS-Airport model are described in Section 9.2.4.4 of this chapter.

Model Setup

The model setup and options are summarised in Table 9-17.

Table 9-17: Model Setup Accounting for Operation Phase Scenarios	
Meteorology	Kigali International Airport, 2015-2016
Surface Roughness on the Domain (m)	0.5
Minimum Monin-Obukhov Length (m)	20
Pollutant	NO_2, SO_2, PM_{10}, CO and VOC
Chemistry	NO_x-NO_2 correlation (Derwent-Middletown 1996)
Deposition	Gravitational settling for PM_{10}
Emission Sources	Aircraft engines for the different phases (approach, landing, take-off, initial and final climb), taxiing, APU, GSE, roadways (including the Expressway)
Background	Concentrations measured for the baseline study at the sensitive points have been used as background and added to the model results (receptors only)
Grid Calculations	30 km x 20 km (80 x 80 grid points in X and Y) Refining gridding close to the emission sources

Sources Modelled Description

For the two scenarios assessment during the operation phases (2020 and 2045), the aircraft emission sources for take-off and landing were modelled using the following volume sources:

- Two volume sources for landing (approach and landing);
- Two volume sources for climbing (initial climb and climb out); and
- One volume source for take-off.

Each source is represented in the model by a volume defined by a length (e.g. length of the runway for the take-off source), a width (e.g. width of the runway) and a thickness (typically the mixing height of the pollutant).

The dimensions of all the volume sources was defined according to CERC**Error! Bookmark not defined.** study at Heathrow Airport and comprehensive sensitivity tests relating to sources modelling that were performed within this framework. According to this study, emissions above 900 m were considered as insignificant and neglected.

For departure (climb phases), the length of the sources was estimated based on the optimised design that is proposed in the Master Plan considering the relevant aircraft types (A330-200, A350-900, B747-800 and B747-4F). It was assumed that most aircraft would reach 900 m at 11.5 km from the end of the runway. For the approach phase, it was assumed that most aircraft would be at over 900 m at a maximum distance from the runway of approximately 30 km. Similar distances would apply for northerly and southerly operations.

Taxiing is the movement of an aircraft on the ground under its own power in contrast to towing or push-back where the aircraft are moved by a tug. An airplane uses taxiways to taxi from one area of an airport to another; for example, when moving from the terminal to the runway. The routes of the aircraft were estimated based on the Master Plan, and the annual emissions were assumed to be homogeneously distributed over volume sources covering the routes.

The APUs were described as volume sources created around the terminals at the pier stands as well at the remote stands. The number of APUs per source was estimated based on a ratio of the total number of APUs to the surface of the source. Given that the APUs are located at the tail end of the aircraft, the related emissions were considered as diluted in volume sources of 12 m thick (set on the ground), whereas a thickness of 3.5 m was considered for runways and taxiing emissions.

The number of GSE per source was estimated using a ratio of the total number of GSE to the ground surface of the source.

The Expressway was considered as successive segments (line sources) following the Master Plan. The roadway width was also considered and setup as 9 m.

More information about characteristics of volume and line sources for both operation scenarios in 2020 and 2045 is presented in Technical Appendix 9.5.

9.3.6 Significance Criteria

In line with the methodology presented in Chapter 3: Impact Assessment Methodology, specific criteria were defined for the receptor sensitivity and the impact magnitude adapted to the air quality assessment. These criteria are described in Table 9-18 and Table 9-19 below.

Table 9-18: Receptor Sensitivity Criteria

Sensitivity	Description		
	Sensitivity for Human Health		Sensitivity for Protection of Ecosystems/Habitats
High	A zone or agglomeration* designated as exceeding an air quality limit value; or Undesignated areas where concentrations are 85% or more of an air quality limit value.	And it is within an area where members of the public are regularly present; Or any hospital, school, nursing homes or similar facilities considered to be vulnerable to changes in ambient air quality concentrations.	Within an ecosystem/habitat type that is recognised to be of importance at an international level or is a critical habitat as defined by the IFC, and where the habitat has the potential to be affected by baseline concentrations close to or above the air quality critical levels.
Medium	Areas not designated as exceeding the limit values and where baseline concentrations are between 50%-85% of an air quality limit.	And it is within an area where members of the public are regularly present; Or at any hospital, school, nursing homes or similar facilities considered to be vulnerable to changes in ambient air quality concentrations.	Within an ecosystem/habitat type recognised to be of importance at a national scale and where the habitat has the potential to be affected by baseline concentrations close to or above the air quality critical levels.
Low	Areas not designated as exceeding the limit values and where baseline concentrations are between 15%-50% of an air quality limit. Areas not designated as exceeding the limit values and where baseline concentrations are less than 15% of an air quality limit are not considered to be sensitive.	And is within an area where members of the public are regularly present.	Within an ecosystem or habitat type occurring outside of any designation, but which represent a typical example of the feature under consideration within the context of the ecological resource present within the country and is not likely to be affected by air quality levels. Ecosystems or habitat types that are either appreciably degraded/disturbed by human activity, have low diversity of common and widespread species or have high proportions of invasive/non-native species and would not likely to be affected by air quality levels are not considered to be sensitive.

As stated in Section 9.1.3, the IFC General EHS Guidelines – Air Emissions and Ambient Air Quality, projects with significant sources of air emissions and a potential for significant impacts to ambient air quality should prevent or minimise impacts by ensuring that:

- *"Emissions do not result in pollutant concentrations that **reach or exceed relevant ambient quality guidelines and standards** by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognised sources; and*
- *Emissions do not contribute a **significant portion** to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests **25% of the applicable air quality standards** to allow additional, future sustainable development in the same air shed".*

These two criteria were considered in assessing the potential air quality impacts magnitude of the Proposed Project.

Table 9-19: Impact Magnitude

Impact Magnitude	Description
Very Low	No significant change in baseline conditions. The Project contribution does not exceed 5% of the long term* and 25% of the short term* air quality standard levels.
Low	Concentrations at receptors remain within ambient air quality standards.
	The Project contribution does not exceed 25% of the long term and 50% of the short term relevant air quality standard levels.
Medium	Concentrations at receptors remain within ambient air quality standards.
	The incremental impact (Project contribution) exceeds 25% of the long term or 50% of the short term relevant air quality standard levels.
High	Ambient air quality standards (short term or long term) are not attained at receptors.

* Short term corresponds to hourly or daily standards and long term corresponds to annual standards.

Based on a combination of the receptor sensitivity and impact magnitude assessments, the impact significance was then assigned in accordance with the methodology matrix presented in Chapter 3: Impact Assessment Methodology.

9.3.7 Assumptions and Limitations

The samples used as basis for the modelling were taken only at sensitive receptor locations (i.e. in areas were members of the public are regularly present); therefore, representing the most critical scenario from a source point of view. Given the criteria defined for the sensitivity of receptors and the presumed baseline conditions presented in Section 9.3.1, the sensitivity of receptors for which no monitoring values were recorded were considered as medium for all of the receptors.

This assumption was made in order to simplify the assessment prior to the availability of the monitoring results for the baseline conditions and detailed information regarding the receptor locations. However, this criterion has been re-evaluated for the receptors for which data were collected through the monitoring campaigns, using the criteria presented in Table 9-18 now that the monitoring results and receptor location details are available.

$PM_{2.5}$ baseline conditions were calculated based on PM_{10} monitoring values, considering a ratio $PM_{2.5}/PM_{10}$ of 0.6 as advised by the WHO[26]. This is a conservative approach, as this ratio has been derived from measurements mainly in urban areas, where traffic generates generally small particles like PM2.5. A lower ratio could be expected in rural areas like the Proposed Project Area.

For modelling and impact assessment considerations, it was assumed that air emissions associated with earthworks would be generated over a three-month period.

While comparing the modelling results to the applicable standards, the most conservative values were taken into consideration when two values existed for the same parameter.

Only PM_{10} modelling was undertaken for the construction phase, considering that the other emissions (NOx, SO_2, CO and benzene from diesel and petrol-powered equipment, vehicles and machinery, and from the asphalt/concrete batching plants) would be limited compared to the operation phase.

Where the EAC Standards/Rwandan and IFC limit values were different, the most stringent value was selected. When considering the Rwandan air quality standards, only the "Residential, Rural and Other Area" limit values were retained, being the most relevant to the Proposed Project Area of Influence.

$PM_{2.5}$ was taken into consideration only for the operation phase, which would most likely release such fine particles (emissions from fuel engines). They were assimilated to PM_{10} for the purposes of the modelling given that the emissions factors for PM_{10} and $PM_{2.5}$ are similar in the ICAO guidelines, and considering that the fine particles emissions of the Proposed Project will be low (conservative approach for $PM_{2.5}$ emissions).

Total emissions calculated for the Phase 1 and Phase 5 scenarios are summarised in Table 9-20.

Table 9-20: Total Emissions Calculated for Each Scenario

Scenario	Total Emissions (tonnes/year)				
	CO	NO_x	PM_{10} / $PM_{2.5}$	SO_2	VOC considered as benzene
Construction Phase	90.9	104.3	1,361.0	5.3	9.6
Phase 1 2020 Operation	206.5	322.9	8.5	16.2	8.7
Phase 5 2045 Operation	570.7	977.5	24.9	41.6	60.4

Based on the emission calculations, the following assumptions were made for the purposes of the assessment:

- Emissions of PM_{10} only were considered during the construction phase; and
- Emissions of CO, NOx, SO_2 and VOCs (assimilated to benzene) were considered for initial and final operation phase scenarios (2020 and 2045).

The modelling results are likely to be conservative as they did not take into consideration the future likely increased performance of both aircraft and vehicles.

[26] WHO, Ambient Air Pollution Database, 2014.

9.4 Baseline Conditions

9.4.1 Existing Air Quality Data for Rwanda

There is no regular air quality monitoring conducted in Rwanda. A study on air pollution in Kigali City[27] was identified; however, it focused on monitoring of atmospheric pollutants close to roads within a suburban area in Kigali City only. This source of information was consequently not used for the purposes of this assessment.

As discussed previously in Section 9.2, two air quality baseline campaigns were undertaken as part of the ESIA. The first was in early September 2017 (dry season) and the second was conducted at the end of October 2017 (wet season). This ESIA was therefore updated in the form of this revised chapter following the receipt of the dry and wet season analysis results.

While the monitoring data were awaited, the latest available international data (2012) provided by the ECMWF[28] centre for gaseous pollutants (SO_2, CO and NO_x) were referred to in order to provide temporary background values. More specifically, the ECMWF dataset originated from global models with a 0.1°x0.1° horizontal resolution and reanalysed with global international air quality stations under the Copernicus Atmosphere Monitoring Service (CAMs). CAMS use a comprehensive global monitoring and forecasting system that estimates the state of the atmosphere on a daily basis, combining information from models and observations including surface observations of ozone, CO, SO_2 and NO_2 as well as satellite retrievals of CO and tropospheric NO_2. An example of the data provided is given in the Figure 9-3.

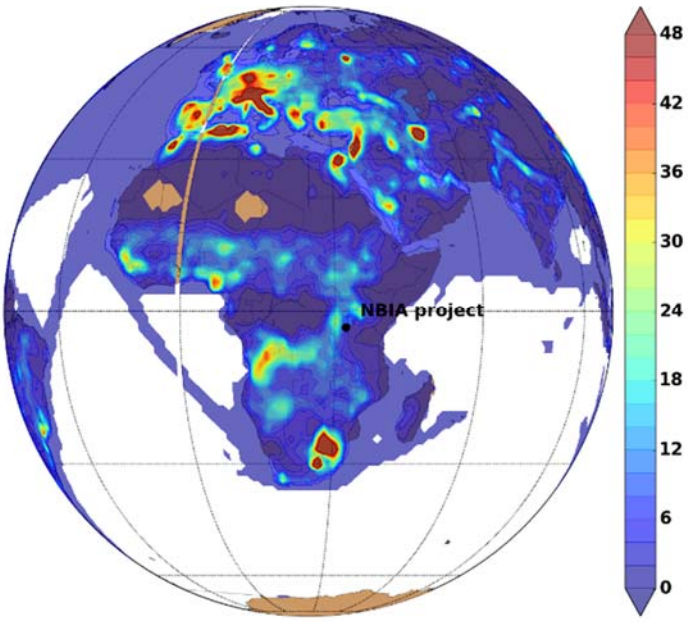

Figure 9-3: Annual Mean Concentrations of NOx in 2012 Provided By ECMWF

The data collected from ECMWF are presented in Table 9-21.

Table 9-21: Concentrations Estimated From ECMWF

Estimated Background Concentrations over NBIA (µg/m³)				
SO_2	NOx	CO	PM_{10}	VOC
0.6	7.8	243.5	N/A	N/A

[27] The National University of Rwanda Consultancy Bureau (NUR-CB), May, 2011. A Study on Air Pollution in Rwanda with Reference to Kigali City and Vehicular Emissions, for REMA.
[28] http://www.ecmwf.int/en/about

For PM_{10}, and while awaiting consolidated results from the baseline assessment, an arbitrary background value of 10 µg/m^3 was used, which corresponds to 50% of the most conservative standard (IFC, 20 µg/m^3 in annual average).

Results from the monitoring campaigns were incorporated into revised calculations to replace previously estimated values.

As explained in the Section 9.3.7, Assumptions and Limitations, $PM_{2.5}$ baseline conditions were calculated based on PM_{10} monitoring values using a conversion factor of 0.6.

9.4.2 Sensitive Receptors

A set of receptors was defined as part of the establishment of the baseline conditions. All communities within the Airport Footprint have been relocated and no inhabitants or livestock are currently located within the Airport Area.

The sensitive receptors include:

- Dwellings/residential areas located close to the boundary of the Proposed Project Area, potentially impacted by dust emissions from earthworks and construction activities (including asphalt/concrete batching), as well as airport operations (aircraft engines and equipment emissions).
- Populations in the main villages/urban areas located within 15 km around the Proposed Project Area, including Rilima, Juru, Mwogo, Nyamata, Kinazi and Kayumba, which could potentially be impacted by airport operations (e.g. aircraft emissions).
- Populations living close to major roads around the Proposed Project Area, potentially impacted by earthworks and truck traffic during the construction phase (e.g. receptors located along the quarry road) and the increase in traffic (atmospheric emissions from vehicles) during the airport operation phase on the Expressway and the connected network.
- Flora and fauna in the vicinity of the Proposed Project Area (this is covered in Chapter 11: Biodiversity).

A total of 16 sensitive receptor locations were identified during the baseline preparation, as presented in Table 9-22 and Figure 9-4 and they have all been assigned a receptor sensitivity of medium.

Table 9-22: List of Sensitive Receptors

Sensitive Receptors	
1- Mwogo	9- Rilima
2- Locale 3	10- Locale 1
3- Locale 4	11- Nyamata
4- Kayumba	12- Expressway 1
5- Kinazi	13- Expressway 2
6- Locale 5	14- Nyamata Road
7- Locale 2	15- Quarry Road 1
8- Juru	16- Quarry Road 2

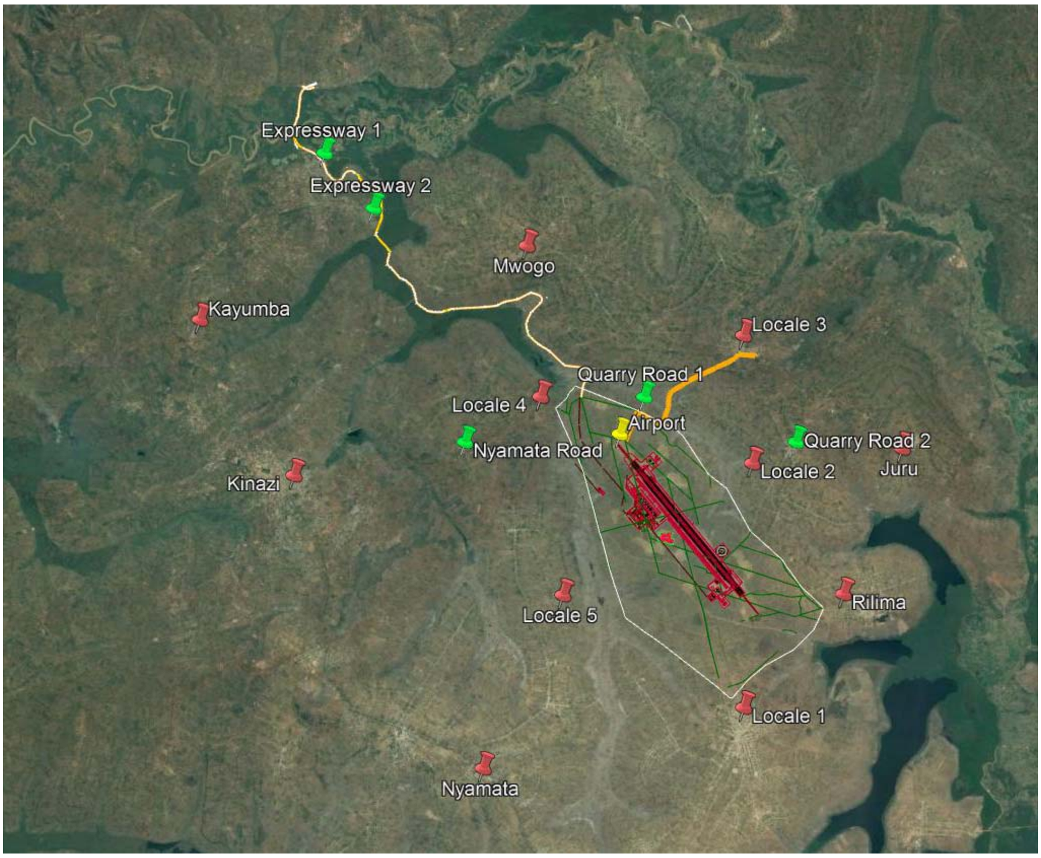

Figure 9-4: Locations of Sensitive Receptors

Source: Google Earth, 2017

9.4.3 Measurements

The baseline assessment is based on sampling performed on the following locations:

- One reference point at the airport (downwind the runway); and
- 16 locations corresponding to the receptors described in the previous section, i.e.:
  - 11 residential locations comprising five sampling points around the Proposed Project boundary and in four villages within close proximity to the NBIA; and
  - Four traffic locations situated in close proximity to existing/projected roads.

The following measurements were performed during the dry and wet seasons:

- NO_2 and SO_2 at all locations by the use of passive samplers. Each passive sampler was cited at each location for a period of seven days; and
- Particulates (PM_{10}) by the use of active mobile samplers at the following three locations: NBIA Airport Footprint, Locale 4, and Expressway 2. Each sampler remained at the location for at least 8 hours.

Benzene was monitored at one of the receptors (Kayumba) during the wet season campaign only. Ozone is considered to be a secondary photochemical pollutant listed by IFC in its General EHS Guidelines – Air Emissions and Ambient Air Quality, and is not generated during the wet season. Therefore, no sampling of VOCs or benzene was undertaken during the wet season. Benzene can be considered as a VOC; however, it is not regulated by Rwanda/EAC Standards.

As mentioned in Section 9.2 above, pollutants have been selected according to the IFC requirements and major emission sources considered in the study. As discussed in Section

9.3.7, where EAC Standards/Rwandan and IFC limit values were different, the most stringent value was selected. When considering the Rwandan air quality standards, only the “Residential, Rural and Other Area” limit values were retained, being the most relevant to the Proposed Project Area of Influence.

The monitoring results as well as the associated sensitivity assessed with these baseline conditions are presented in the tables 9-23 to 9-26 hereafter (all values presented are expressed in µg/m³).

Table 9-23: PM_{10} Monitoring Results and Sensitivity Assessment (in µg/m³)

Location	Dry	Wet	Average	Sensitivity	
				Annual Average	24 hrs (P99.2)
Airport	163.41	29.16	96.285		
Locale 4	109.94	71.5	90.72	High	High
Expressway 2	56.07	36.55	46.31	High	High
"Most conservative" Standards[29]				20	50

These PM_{10} monitoring results indicate that they are being affected by the initial airport construction works, which have now commenced. The baseline levels are therefore considered as likely to be higher than the “real” baseline.

Consequently, the “Expressway 2” baseline average value (which corresponds to the location the least affected by the current construction works) was selected as being the most representative of the baseline conditions.

$PM_{2.5}$ baseline conditions were calculated based on this monitoring value, by using a conversion factor 0.6 (the value of 27.79 µg/m³ was therefore retained for the impact assessment).

The baseline conditions exceed the most stringent standard limits (IFC); however, the levels are within the EAC Standards Guideline (50 µg/m³ daily average and 100 µg/m³ annual average). The sensitivity of receptors for PM_{10} and $PM_{2.5}$ emissions was considered as high for the impact assessment.

Table 9-24: NO_2 Monitoring Results and Sensitivity Assessment (in µg/m³)

				Sensitivity			
Location	**Dry**	**Wet**	**Average**	**Annual**	**Monthly**	**24h**	**1h**
Quarry road 1	15.3	25.3	20.3	Medium	Not sensitive	Not sensitive	Not sensitive
Locale 3	17.4	28.1	22.75	Medium	Low	Not sensitive	Not sensitive
Quarry road 2	17.2		17.2	Low	Not sensitive	Not sensitive	Not sensitive
Locale 2	13.2	25.7	19.45	Low	Not sensitive	Not sensitive	Not sensitive
Kinazi	17.6	35.2	26.4	Medium	Low	Not sensitive	Not sensitive
Expressway 1	21.6	32.3	26.95	Medium	Low	Not sensitive	Not sensitive
Expressway 2	15.9	29.1	22.5	Medium	Not sensitive	Not sensitive	Not sensitive
Kayumba	21.8	36.7	29.25	Medium	Low	Low	Not sensitive
Nyamata road	15.5	29.5	22.5	Medium	Not sensitive	Not sensitive	Not sensitive

[29] Based on WHO Quality Guidelines as these are more stringent than the East African Standards Guideline.

Table 9-24: NO_2 Monitoring Results and Sensitivity Assessment (in µg/m³)

				Sensitivity			
Location	**Dry**	**Wet**	**Average**	**Annual**	**Monthly**	**24h**	**1h**
Locale 4	13.3	26.7	20	Low	Not sensitive	Not sensitive	Not sensitive
Locale 5	15.4	15.4	15.4	Low	Not sensitive	Not sensitive	Not sensitive
Nyamata	16.5	25.9	21.2	Medium	Not sensitive	Not sensitive	Not sensitive
Locale 1	14.4	24.4	19.4	Low	Not sensitive	Not sensitive	Not sensitive
Rilima	11.5	25.1	18.3	Low	Not sensitive	Not sensitive	Not sensitive
Juru	10.5	18.9	14.7	Low	Not sensitive	Not sensitive	Not sensitive
Mwogo		34.5	34.5	High	Low	Low	Low
"Most conservative" Standards[30]				40	150.4	188	200

NO_2 baseline conditions sensitivity were assessed as either 'not sensitive' or 'medium sensitivity' for most of the receptors depending on their location. This means that the first assessment, which had considered a medium sensitivity for all the points, was conservative, except for the Mwogo location, where highly sensitive baseline conditions were calculated.

Table 9-25: SO_2 Monitoring Results and Sensitivity Assessment (in µg/m³)

				Sensitivity		
Location	**Dry**	**Wet**	**Average**	**Annual**	**24h**	**1h**
Quarry road 1	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Locale 3	0.3	0.3	0.3	Low	Not sensitive	Not sensitive
Quarry road 2	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Locale 2	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Kinazi	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Expressway 1	0.6	0.8	0.7	Low	Not sensitive	Not sensitive
Expressway 2	0.3	<LOQ	0.25	Low	Not sensitive	Not sensitive
Kayumba	0.3	<LOQ	0.25	Low	Not sensitive	Not sensitive
Nyamata road	0.3	<LOQ	0.25	Low	Not sensitive	Not sensitive
Locale 4	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Locale 5	1.1	<LOQ	0.65	Low	Not sensitive	Not sensitive
Nyamata	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Locale 1	<LQ	<LOQ	0.2	Low	Not sensitive	Not sensitive
Rilima	0.2	<LOQ	0.2	Low	Not sensitive	Not sensitive
Juru	<LQ	<LOQ	0.2	Low	Not sensitive	Not sensitive
Mwogo		<LOQ	0.2	Low	Not sensitive	Not sensitive
"Most conservative" Standards[31]				60	20	500

30 Based on WHO Quality Guidelines as these are more stringent than the East African Standards Guideline.

31 Based on WHO Quality Guidelines as these are more stringent than the East African Standards Guideline.

It was concluded that all the baseline monitoring results for SO_2 resulted in a sensitivity of between 'not sensitive' and 'low'. The initial impact assessment was again considered conservative (the sensitivity of all receptors had been assessed as medium).

Table 9-26: Benzene Monitoring Results and Sensitivity Assessment (in µg/m³)

	Dry	Wet	Average	Annual
Kayumba	-	7.16	7.16	High
"Most conservative" Standard[32]				5

Baseline conditions for benzene could only be monitored at one location. This high value could not be explained in the present situation (no significant source of benzene emissions is normally present in the area); therefore it could not be retained to assess the sensitivity of receptors related to benzene emissions. The estimated value was consequently retained for the impact assessment.

9.5 Potential Impacts

As described above, each of the sensitive receptors considered within the construction and operation assessments has been assigned a sensitivity of medium.

9.5.1 Construction Phase Impacts

During construction, there are a number of activities that have the potential to result in air emissions of fugitive particles. The following activities, that are typical sources of fugitive particles in construction, were considered in the assessment:

- Vegetation clearing and topsoil removal;
- Earth moving and cut and fill operations;
- Equipment movements;
- Mobile debris crushing equipment;
- Vehicular transport (loading, unloading and hauling of material, track out of dirt on paved roads and subsequent dust resuspension);
- Specific building activities such as concrete, mortar and plaster mixing, drilling, milling, cutting, grinding, sanding welding and sandblasting activities;
- Various finishing activities; and
- Windblown dust from temporary unpaved roads and uncovered construction sites.

9.5.1.1 Design Controls

The low sulphur content of fuels (which became mandatory in Rwanda in January 2015) was taken into consideration while modelling the emissions from vehicles. Standard dust suppression measures and approaches (i.e. controlling vehicle speed limits, etc.) that are to be adopted are also included as design controls and will be managed via the Pollution Prevention Plan.

No other design controls or incorporated mitigation was included as part of the construction phase impact assessment.

9.5.1.2 Impact Assessment Prior to Mitigation

Construction activities associated with the Proposed Project have the potential to impact air quality within the area.

[32] Benzene annual air emission limit of 5 µg/m³ defined in the European Parliament and Council directive 2008/50/CE dated 21 May 2008.

The main potential air quality pollutant during construction is the generation of dust and PM_{10} related to earthworks, the movement of traffic on unsurfaced roads and the loading/unloading of materials. Cut and fill activities will be required to level the topography of the Airport Footprint. Furthermore, the generation of dust can also occur from wind on exposed and unprotected soil stockpiles.

Additionally, air quality will be affected by exhaust emissions from diesel and petrol-powered equipment, vehicles and machinery during the construction phase. This includes the emission of particulate matter, NOx, SO_2, CO and benzene. As stated in Section 9.2, exhaust emissions from the machinery used during the construction phase were not modelled as it was estimated that such emissions will be much lower than those that will be observed during the operation phase (due to road traffic, aircraft engines, GSE, etc.). Given the modelling results of the two operations phases 2020 and 2045, the impact of such emissions during the construction phase is considered as negligible.

Burning of solid waste onsite can generate particulate matter, NOx and associated dioxins; however, there are no plans to burn waste as part of the construction of NBIA. As such, these sources were not taken into consideration for the modelling of air emissions during the construction phase.

Results from PM_{10} modelling and associated impact significance are presented in the Table 9-27. Corresponding concentrations maps of the construction phase are presented in Technical Appendix 9.6.

The receptor sensitivity in combination with the magnitude of impact, in the form of the percentage of the air emission standards expected and the standard meteorological measurements, led to the assignment of the significance of the impacts. The sensitivity for each receptor was reassessed for the compounds for which relevant monitoring values were available (see chapter 9.4.3). For all the other receptors, the sensitivity was considered as medium in accordance with Table 9.18, which sets out the criteria.

Table 9-27: PM_{10} Modelling and Associated Impact Significance – Construction Phase

	PM_{10}											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Mwogo	1.0	Very Low	46.31	47.3	No	Major	41.0	Medium	46.31	87.3	No	Major
Locale 3	1.7	Low	46.31	48.0	No	Major	41.2	Medium	46.31	87.5	No	Major
Locale 4	0.9	Very Low	46.31	47.2	No	Major	42.8	Medium	46.31	89.1	No	Major
Kayumba	0.1	Very Low	46.31	46.4	No	Major	8.7	Very Low	46.31	55.0	No	Major
Kinazi	0.1	Very Low	46.31	46.4	No	Major	11.0	Very Low	46.31	57.3	No	Major
Locale 5	0.6	Very Low	46.31	46.9	No	Major	30.2	Medium	46.31	76.5	No	Major
Locale 2	1.6	Low	46.31	47.9	No	Major	67.4	High	46.31	113.7	No	Major
Juru	0.2	Very Low	46.31	46.5	No	Major	15.2	Low	46.31	61.5	No	Major
Rilima	0.4	Very Low	46.31	46.7	No	Major	27.2	Medium	46.31	73.5	No	Major
Locale 1	0.3	Very Low	46.31	46.6	No	Major	35.0	Medium	46.31	81.3	No	Major
Nyamata	0.1	Very Low	46.31	46.5	No	Major	12.3	Very Low	46.31	58.6	No	Major
Expressway 1	0.8	Very Low	46.31	47.1	No	Major	23.2	Low	46.31	69.5	No	Major
Expressway 2	0.9	Very Low	46.31	47.2	No	Major	28.9	Medium	46.31	75.2	No	Major
Nyamata Road	0.4	Very Low	46.31	46.7	No	Major	22.5	Low	46.31	68.8	No	Major
Quarry Road 1	5.3	Medium	46.31	51.6	No	Major	116.3	High	46.31	162.6	No	Major
Quarry Road 2	0.5	Very Low	46.31	46.9	No	Major	35.7	Medium	46.31	82.0	No	Major
"Most Conservative" Standards	20						50					
Source	IFC						IFC					

Based on the construction phase modelling results presented in Table 9-27, the following observations can be made regarding the Proposed Project's potential contribution to PM_{10} emissions prior to mitigation:

- **Major Adverse** impacts are predicted during the construction phase of the Proposed Project at two locations: Locale 2 and Quarry Road 1, both located downwind and close to the quarry road upgrades and to the largest spoil areas (spoil area 2 and spoil area 3) and borrow pit (borrow pit 4), although these impacts will be short term.
- **Moderate Adverse** impacts will potentially be experienced by eight out of 16 receptor locations in the short term, all of them being the closest to the airport construction works and downwind. However, on a longer term, the impact observed on these receptors is **Negligible**.
- A **Moderate Adverse** impact will also potentially be observed in the longer term at the Quarry Road 1 receptor, which will be exposed both to the road upgrading works and to the soil clearing, excavation and construction works at the airport.

In order to assess the global air quality impacts on receptors, and not only the Proposed Project's contribution to the PM_{10} emissions, modelling results were compared and added to the baseline conditions.

The results, presented in Table 9-27, enable the identification of the potential impacts of the Project on the baseline conditions at the source receptors prior to mitigation. The following should be noted for the construction phase:

- Due to the poor existing baseline conditions, exceedances of the long-term air quality standards for PM_{10} (i.e. in annual average) will be observed. However, it has to be noted that the project contribution to these concentrations will represent less than 2% on average;
- In the short term, the Proposed Project will generate significant levels of PM_{10} emissions compared to baseline conditions especially at the following locations: Mwogo, Locale 2, Locale 3, Locale 4 and Quarry Road 1. Exceedances of the daily WHO PM_{10} standards at all the receptors location are likely to be observed, mainly as a result of the existing baseline conditions. For the locations cited above, this is considered to be a **Major Adverse** impact according to the most stringent WHO Air Quality Standards; and
- When taking into consideration the short term PM_{10} concentrations limit for Rwanda (100 $\mu g/m^3$ exceeded more than 2% of the time), the Proposed Project contribution added to the baseline should not lead to threshold exceedances.

When considering the impacts listed above, it is important to keep in mind that a conservative approach was used in order to consider all potential impacts on ambient dust concentrations during the construction phase.

Effectively, the ADMS-model was configured assuming the following:

- A constant release of pollutant over all the construction period without any interruption for the short-term calculation (daily and hourly);
- Worst-case meteorological conditions were considered over the 2015-2016 period;
- All construction activities in the Airport Area and the Expressway were undertaken simultaneously; and
- Dust emissions were uncontrolled i.e. no mitigation measures were considered.

When taking into consideration the short term PM_{10} concentrations limit for Rwanda (100 $\mu g/m^3$ exceeded more than 2% of the time), the Proposed Project contribution added to the baseline

should not lead to threshold exceedances. Finally, it has to be noted that even if the modelling was undertaken for the entire construction phase, the potential for dust emissions from construction activities would be the greatest during the initial site clearing and removal of top soil.

9.5.2 Operation Phase Impacts

9.5.2.1 Emissions Calculation Results

Tables 9-28 and 9-29 present the total emissions per pollutant and per source group for both the 2020 and 2045 scenarios.

Compared to road traffic, results show that aircraft movements are the main contributor to the inventory for all pollutants (from 56% for PM_{10} and 98% for SO_2).

Among aircraft movements, taxiing is a major contributor to CO and SO_2. This is mainly due to low power settings where combustion aircraft engines operate at lower efficiency compared to cruise power settings. GSE is also a significant contributor to CO. The take-off phase is the main contributor to NO_x emissions due to the very high power needed during this phase. Given the assumptions made for annual operating time of APUs, they are considered to be a minor source of emissions.

In terms of comparison, the NBIA air emission inventory will be lower than other air emissions prepared for large international airports, such as London Heathrow Airport in the UK, Boston Logan International Airport in the US and Istanbul New Airport in Turkey. This is consistent with the ATMs estimated in the Master Plan, which are lower than those found in much larger airports with more than one runway.

Table 9-28: 2020 Scenario Total Emissions (in tonnes per year)

Group	CO	NO_x	PM_{10}	SO_2	VOC considered as benzene
APU	1.91	3.16	-	-	0.15
GSE	13.99	22.29	1.14	-	3.54
Aircraft Approach	5.22	20.45	0.13	1.96	0.31
Aircraft Take-off	2.06	84.53	0.35	2.49	0.30
Aircraft Climb	3.60	78.96	0.41	3.17	0.38
Taxiing	151.90	38.48	2.75	8.50	2.02
Road Traffic	27.78	75.06	3.73	0.05	2.02
TOTAL	**206.46**	**322.93**	**8.51**	**16.17**	**8.72**

Table 9-29: 2045 Scenario Total Emissions (in tonnes per year)

Group	CO	NO_x	PM_{10}	SO_2	VOC considered as benzene
APU	4,92	8.16	-	-	0.39
GSE	33.52	53.63	2.69	-	8.54
Aircraft Approach	11.88	52.48	0.33	5.02	0.74
Take off	4.54	217.01	0.92	6.38	0.75
Aircraft Climb	2.02	202.60	1.07	8.10	0.95

Table 9-29: 2045 Scenario Total Emissions (in tonnes per year)

Taxiing	378.60	99.32	1.94	21.89	39.18
Road Traffic	135.19	365.3	18.13	0.25	9.85
TOTAL	**570.67**	**977.5**	**24.9**	**41.6**	**60.4**

9.5.2.2 *Design Controls*

The low sulphur content of fuels (which became mandatory in Rwanda in January 2015) was taken into consideration while modelling the emissions from vehicles.

No other design controls or incorporated mitigation were included as part of the operation phase impact assessment.

9.5.2.3 *Impact Assessment Prior to Mitigation*

The modelling study was performed for SO_2, NO_2, PM_{10}, CO and benzene for two operation phases (Phase 1 – 2020 and Phase 5 – 2045). Concentration values were calculated at ground level, in the short and long terms, in order to allow a comparison with relevant regulatory limit values.

Average concentration maps for SO_2, NO_2, PM_{10}, CO and benzene are presented in Technical Appendix 9.7 for the 2020 scenario and in Technical Appendix 9.8 for the 2045 scenario. These maps reveal that:

- The maximum concentrations (observed for NO_2 and benzene) are found directly at the source locations, i.e. in the Airport Area at the runway and taxiways, and around the terminals at the piers and remote stands, as well as at the Expressway. These high concentrations decrease significantly with distance from the sources;
- According to the emission inventory, the aircraft movements are the main sources of NO_2 at ground level. The NO_2 concentrations are also significant on the taxiways and around the terminals due to GSE emissions. However, the impact of the climb and approach phases on the ground concentrations appear to be limited, with the pollutant dispersion increasing significantly with the altitude of the aircraft; and
- The highest ground level concentrations of CO, SO_2 and PM_{10} are mainly found on the taxiways and on the stands, as these are mainly emitted by aircraft engines at low thrust and by GSE. Incremental (i.e. due to the Proposed Project) SO_2, CO and PM_{10} concentrations remain low and are only observed within the Airport Area.

The modelling results for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO and benzene for receptor points are presented in Tables 9-30 to 9-37 for Phase 1 (2020) and in Tables 9-38 to 9-45 for Phase 5 (2045). These modelling results take into consideration the Project contribution and the presumed baseline conditions in the absence of baseline monitoring results. Given the traffic forecasts for the two phases, it is estimated that the results obtained for the operation phase for all the other emissions except PM_{10} represent at least twice the expected emissions compared to the construction phase.

As stated in the assumptions and limitations Section, where EAC Standards/Rwandan and IFC limit values were different, the most stringent value was selected.

Furthermore, in the absence of International or Rwandan concentration limit values for benzene, the regulated value applicable in the European Union[33] was selected as stated in Section 9.5.2.3.

[33] Benzene annual air emission limit of 5µg/m^3 defined in the European Parliament and Council directive 2008/50/CE dated 21 May 2008.

Table 9-30: SO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	SO_2											
	Annual Average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Mwogo	0.03	Very Low	0.2	Negligible	0.23	Yes	0.45	Very Low	0.2	Negligible	0.65	Yes
Locale 3	0.08	Very Low	0.3	Negligible	0.38	Yes	0.70	Very Low	0.3	Negligible	1.00	Yes
Locale 4	0.05	Very Low	0.2	Negligible	0.25	Yes	0.65	Very Low	0.2	Negligible	0.85	Yes
Kayumba	0.01	Very Low	0.25	Negligible	0.26	Yes	0.09	Very Low	0.25	Negligible	0.34	Yes
Kinazi	0.01	Very Low	0.2	Negligible	0.21	Yes	0.14	Very Low	0.2	Negligible	0.34	Yes
Locale 5	0.05	Very Low	0.65	Negligible	0.70	Yes	0.44	Very Low	0.65	Negligible	1.09	Yes
Locale 2	0.24	Very Low	0.2	Negligible	0.44	Yes	2.21	Very Low	0.2	Negligible	2.41	Yes
Juru	0.05	Very Low	0.2	Negligible	0.25	Yes	0.48	Very Low	0.2	Negligible	0.68	Yes
Rilima	0.17	Very Low	0.2	Negligible	0.37	Yes	1.12	Very Low	0.2	Negligible	1.32	Yes
Locale 1	0.08	Very Low	0.2	Negligible	0.28	Yes	0.53	Very Low	0.2	Negligible	0.73	Yes
Nyamata	0.02	Very Low	0.2	Negligible	0.22	Yes	0.19	Very Low	0.2	Negligible	0.39	Yes
Expressway 1	0.01	Very Low	0.7	Negligible	0.71	Yes	0.14	Very Low	0.7	Negligible	0.84	Yes
Expressway 2	0.01	Very Low	0.25	Negligible	0.26	Yes	0.18	Very Low	0.25	Negligible	0.43	Yes
Nyamata Road	0.02	Very Low	0.25	Negligible	0.27	Yes	0.41	Very Low	0.25	Negligible	0.66	Yes
Quarry Road 1	0.20	Very Low	0.2	Negligible	0.40	Yes	2.55	Very Low	0.2	Negligible	2.75	Yes
Quarry Road 2	0.09	Very Low	0.2	Negligible	0.29	Yes	1.52	Very Low	0.2	Negligible	1.72	Yes

Table 9-30: SO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	SO_2											
	Annual Average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
"Most Conservative" Standards	60						20					
Source	East Africa Standards/Rwanda Guideline						IFC					

Table 9-31: SO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	SO_2					
	<1 hr (P100)					
	Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative Value	Standard Met
Mwogo	1.97	Very Low	0.60	Negligible	2.57	Yes
Locale 3	2.96	Very Low	0.60	Negligible	3.56	Yes
Locale 4	4.62	Very Low	0.60	Negligible	5.22	Yes
Kayumba	0.80	Very Low	0.60	Negligible	1.40	Yes
Kinazi	1.15	Very Low	0.60	Negligible	1.75	Yes
Locale 5	3.35	Very Low	0.60	Negligible	3.95	Yes
Locale 2	5.55	Very Low	0.60	Negligible	6.15	Yes
Juru	2.07	Very Low	0.60	Negligible	2.67	Yes
Rilima	3.99	Very Low	0.60	Negligible	4.59	Yes
Locale 1	3.01	Very Low	0.60	Negligible	3.61	Yes
Nyamata	1.40	Very Low	0.60	Negligible	2.00	Yes

Table 9-31: SO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	SO_2					
	<1 hr (P100)					
	Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative Value	Standard Met
Expressway 1	0.88	Very Low	0.60	Negligible	1.48	Yes
Expressway 2	1.13	Very Low	0.60	Negligible	1.73	Yes
Nyamata Road	2.63	Very Low	0.60	Negligible	3.23	Yes
Quarry Road 1	8.37	Very Low	0.60	Negligible	8.97	Yes
Quarry Road 2	3.21	Very Low	0.60	Negligible	3.81	Yes
"Most Conservative" Standards	500					
Source	IFC					

Table 9-32: NO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	NO2											
	Annual average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Mwogo	2.59	Low	34.5	Moderate	37.09	Yes	14.68	Very Low	34.5	Minor	49.18	Yes
Locale 3	1.30	Very Low	22.75	Negligible	24.05	Yes	7.61	Very Low	22.75	Negligible	30.36	Yes
Locale 4	1.65	Very Low	20	Negligible	21.65	Yes	6.53	Very Low	20	Negligible	26.53	Yes
Kayumba	0.23	Very Low	29.25	Negligible	29.48	Yes	1.29	Very Low	29.25	Negligible	30.54	Yes
Kinazi	0.27	Very Low	26.4	Negligible	26.67	Yes	1.40	Very Low	26.4	Negligible	27.80	Yes

Table 9-32: NO_2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	NO2											
	Annual average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Locale 5	0.86	Very Low	15.4	Negligible	16.26	Yes	5.12	Very Low	15.4	Negligible	20.52	Yes
Locale 2	3.09	Low	19.45	Negligible	22.54	Yes	21.76	Very Low	19.45	Negligible	41.21	Yes
Juru	0.75	Very Low	14.7	Negligible	15.45	Yes	4.35	Very Low	14.7	Negligible	19.05	Yes
Rilima	2.13	Low	18.3	Negligible	20.43	Yes	11.62	Very Low	18.3	Negligible	29.92	Yes
Locale 1	1.08	Very Low	19.4	Negligible	20.48	Yes	5.97	Very Low	19.4	Negligible	25.37	Yes
Nyamata	0.30	Very Low	21.2	Negligible	21.50	Yes	2.11	Very Low	21.2	Negligible	23.31	Yes
Expressway 1	3.05	Low	26.95	Minor	30.00	Yes	10.28	Very Low	26.95	Negligible	37.23	Yes
Expressway 2	3.11	Low	22.5	Minor	25.61	Yes	11.47	Very Low	22.5	Negligible	33.97	Yes
Nyamata Road	0.72	Very Low	22.5	Negligible	23.22	Yes	4.28	Very Low	22.5	Negligible	26.78	Yes
Quarry Road 1	3.69	Low	20.3	Minor	23.99	Yes	29.69	Very Low	20.3	Negligible	49.99	Yes
Quarry Road 2	1.40	Very Low	17.2	Negligible	18.60	Yes	14.85	Very Low	17.2	Negligible	32.05	Yes
"Most Conservative" Standards	40						188					
Source	IFC						East Africa Standards/Rwanda Guideline)					

Table 9-33: NO2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	NO2											
	Monthly Average						1 hr (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Mwogo	2.59	Very Low	34.5	Minor	37.09	Yes	56.72	Low	34.5	Moderate	91,22	Yes
Locale 3	1.30	Very Low	22.75	Negligible	24.05	Yes	30.23	Very Low	22.75	Negligible	52,98	Yes
Locale 4	1.64	Very Low	20	Negligible	21.64	Yes	46.71	Very Low	20	Negligible	66,71	Yes
Kayumba	0.23	Very Low	29.25	Negligible	29.48	Yes	8.75	Very Low	29.25	Negligible	38,00	Yes
Kinazi	0.26	Very Low	26.4	Negligible	26.66	Yes	11.55	Very Low	26.4	Negligible	37,95	Yes
Locale 5	0.84	Very Low	15.4	Negligible	16.24	Yes	35.88	Very Low	15.4	Negligible	51,28	Yes
Locale 2	3.12	Very Low	19.45	Negligible	22.57	Yes	61.75	Low	19.45	Negligible	81,20	Yes
Juru	0.77	Very Low	14.7	Negligible	15.47	Yes	20.61	Very Low	14.7	Negligible	35,31	Yes
Rilima	2.16	Very Low	18.3	Negligible	20.46	Yes	42.32	Very Low	18.3	Negligible	60,62	Yes
Locale 1	1.07	Very Low	19.4	Negligible	20.47	Yes	29.79	Very Low	19.4	Negligible	49,19	Yes
Nyamata	0.29	Very Low	21.2	Negligible	21.49	Yes	13.29	Very Low	21.2	Negligible	34,49	Yes
Expressway 1	3.01	Very Low	26.95	Negligible	29.96	Yes	53.86	Low	26.95	Minor	80,81	Yes
Expressway 2	3.08	Very Low	22.5	Negligible	25.58	Yes	64.15	Low	22.5	Minor	86,65	Yes
Nyamata Road	0.71	Very Low	22.5	Negligible	23.21	Yes	26.93	Very Low	22.5	Negligible	49,43	Yes
Quarry Road 1	3.70	Very Low	20.3	Negligible	24.00	Yes	83.01	Low	20.3	Minor	103,31	Yes

Table 9-33: NO2 Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	NO2											
	Monthly Average						1 hr (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Quarry Road 2	1.41	Very Low	17.2	Negligible	18.61	Yes	34.25	Very Low	17.2	Negligible	51,45	Yes
"Most Conservative" Standards	150,4						200					
Source	East Africa Standards/Rwanda Guideline						IFC					

Table 9-34: PM_{10} Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	PM_{10}											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Mwogo	0.015	Very Low	46.31	46.32	No	Major	0.039	Very Low	.6.31	46,35	Yes	Minor
Locale 3	0.002	Very Low	46.31	46.31	No	Major	0.004	Very Low	46.31	46.31	Yes	Minor
Locale 4	0.004	Very Low	46.31	46.31	No	Major	0.010	Very Low	46.31	46.32	Yes	Minor
Kayumba	0.001	Very Low	46.31	46.31	No	Major	0.002	Very Low	46.31	46.31	Yes	Minor
Kinazi	0.000	Very Low	46.31	46.31	No	Major	0.002	Very Low	46.31	46.31	Yes	Minor

Table 9-34: PM_{10} Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	PM_{10}											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Locale 5	0.001	Very Low	46.31	46.31	No	Major	0.004	Very Low	46.31	46.31	Yes	Minor
Locale 2	0.003	Very Low	46.31	46.31	No	Major	0.010	Very Low	46.31	46.32	Yes	Minor
Juru	0.001	Very Low	46.31	46.31	No	Major	0.002	Very Low	46.31	46.31	Yes	Minor
Rilima	0.002	Very Low	46.31	46.31	No	Major	0.006	Very Low	46.31	46.32	Yes	Minor
Locale 1	0.001	Very Low	46.31	46.31	No	Major	0.003	Very Low	46.31	46.31	Yes	Minor
Nyamata	0.000	Very Low	46.31	46.31	No	Major	0.001	Very Low	46.31	46.31	Yes	Minor
Expressway 1	0.023	Very Low	46.31	46.33	No	Major	0.060	Very Low	46.31	46.37	Yes	Minor
Expressway 2	0.023	Very Low	46.31	46.33	No	Major	0.071	Very Low	46.31	46.38	Yes	Minor
Nyamata Road	0.001	Very Low	46.31	46.31	No	Major	0.004	Very Low	46.31	46.31	Yes	Minor
Quarry Road 1	0.010	Very Low	46.31	46.32	No	Major	0.025	Very Low	46.31	46.33	Yes	Minor
Quarry Road 2	0.001	Very Low	46.31	46.31	No	Major	0.004	Very Low	46.31	46.31	Yes	Minor
"Most conservative" Standards	20.0						50.0					
Source	IFC						IFC					

Table 9-35: $PM_{2.5}$ Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	PM 2.5											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Mwogo	0.015	Very Low	27.79	27.80	No	Major	0.039	Very Low	27.79	27.83	No	Major
Locale 3	0.002	Very Low	27.79	27.79	No	Major	0.004	Very Low	27.79	27.79	No	Major
Locale 4	0.004	Very Low	27.79	27.79	No	Major	0.010	Very Low	27.79	27.80	No	Major
Kayumba	0.001	Very Low	27.79	27.79	No	Major	0.002	Very Low	27.79	27.79	No	Major
Kinazi	0.000	Very Low	27.79	27.79	No	Major	0.002	Very Low	27.79	27.79	No	Major
Locale 5	0.001	Very Low	27.79	27.79	No	Major	0.004	Very Low	27.79	27.79	No	Major
Locale 2	0.003	Very Low	27.79	27.79	No	Major	0.010	Very Low	27.79	27.80	No	Major
Juru	0.001	Very Low	27.79	27.79	No	Major	0.002	Very Low	27.79	27.79	No	Major
Rilima	0.002	Very Low	27.79	27.79	No	Major	0.006	Very Low	27.79	27.80	No	Major
Locale 1	0.001	Very Low	27.79	27.79	No	Major	0.003	Very Low	27.79	27.79	No	Major
Nyamata	0.000	Very Low	27.79	27.79	No	Major	0.001	Very Low	27.79	27.79	No	Major
Expressway 1	0.023	Very Low	27.79	27.81	No	Major	0.060	Very Low	27.79	27.85	No	Major
Expressway 2	0.023	Very Low	27.79	27.81	No	Major	0.071	Very Low	27.79	27.86	No	Major
Nyamata Road	0.001	Very Low	27.79	27.79	No	Major	0.004	Very Low	27.79	27.79	No	Major
Quarry Road 1	0.010	Very Low	27.79	27.80	No	Major	0.025	Very Low	27.79	27.81	No	Major

Table 9-35: $PM_{2.5}$ Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	PM 2.5											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Quarry Road 2	0.001	Very Low	27.79	27.79	No	Major	0.004	Very Low	27.79	27.79	No	Major
"Most conservative" Standards	10.0						25.0					
Source	IFC						IFC					

Table 9-36: CO Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	CO											
	8 hrs (P98)						1 hr (P100)					
	Project Contribution			Cumulative Concentrations			Project Contribution			Cumulative Concentrations		
Receptors	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met
Mwogo	10.159	1	Negligible	243.50	253.66	Yes	49.101	1	Negligible	243.50	292.60	Yes
Locale 3	13.161	1	Negligible	243.50	256.66	Yes	53.239	1	Negligible	243.50	296.74	Yes
Locale 4	12.641	1	Negligible	243.50	256.14	Yes	83.910	2	Negligible	243.50	327.41	Yes
Kayumba	2.009	<1	Negligible	243.50	245.51	Yes	14.164	<1	Negligible	243.50	257.66	Yes
Kinazi	2.778	<1	Negligible	243.50	246.28	Yes	20.210	1	Negligible	243.50	263.71	Yes
Locale 5	11.697	1	Negligible	243.50	255.20	Yes	63.536	2	Negligible	243.50	307.04	Yes

Table 9-36: CO Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	CO											
	8 hrs (P98)						1 hr (P100)					
	Project Contribution			Cumulative Concentrations			Project Contribution			Cumulative Concentrations		
Receptors	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met
Locale 2	33.288	2	Negligible	243.50	276.79	Yes	105.470	3	Negligible	243.50	348.97	Yes
Juru	9.284	<1	Negligible	243.50	252.78	Yes	35.411	1	Negligible	243.50	278.91	Yes
Rilima	26.614	1	Negligible	243.50	270.11	Yes	66.884	2	Negligible	243.50	310.38	Yes
Locale 1	12.608	1	Negligible	243.50	256.11	Yes	51.430	1	Negligible	243.50	294.93	Yes
Nyamata	4.104	<1	Negligible	243.50	247.60	Yes	23.679	1	Negligible	243.50	267.18	Yes
Expressway 1	7.300	<1	Negligible	243.50	250.80	Yes	22.895	1	Negligible	243.50	266.39	Yes
Expressway 2	8.567	<1	Negligible	243.50	252.07	Yes	37.569	1	Negligible	243.50	281.07	Yes
Nyamata Road	6.263	<1	Negligible	243.50	249.76	Yes	47.508	1	Negligible	243.50	291.01	Yes
Quarry Road 1	35.940	2	Negligible	243.50	279.44	Yes	152.991	4	Negligible	243.50	396.49	Yes
Quarry Road 2	14.875	1	Negligible	243.50	258.37	Yes	60.188	2	Negligible	243.50	303.69	Yes
"Most conservative " Standards	**2,000**						**4,000**					
Source	**East Africa Standards/Rwanda Guideline**						**East Africa Standards/Rwanda Guideline**					

Table 9-37: Benzene Modelling Results and Associated Impacts Significance – Phase 1 (2020)

	Benzene					
	Annual Average					
	Project Contribution		Cumulative Concentrations			
Receptors	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Cumulative Value**	**Standard Met**	**Impact significance**
Mwogo	0.118	Very Low	1.00	1.12	Yes	Negligible
Locale 3	0.165	Very Low	1.00	1.16	Yes	Negligible
Locale 4	0.126	Very Low	1.00	1.13	Yes	Negligible
Kayumba	0.018	Very Low	1.00	1.02	Yes	Negligible
Kinazi	0.023	Very Low	1.00	1.02	Yes	Negligible
Locale 5	0.123	Very Low	1.00	1.12	Yes	Negligible
Locale 2	0.465	Low	1.00	1.47	Yes	Minor
Juru	0.098	Very Low	1.00	1.10	Yes	Negligible
Rilima	0.334	Low	1.00	1.33	Yes	Minor
Locale 1	0.171	Very Low	1.00	1.17	Yes	Negligible
Nyamata	0.039	Very Low	1.00	1.04	Yes	Negligible
Expressway 1	0.099	Very Low	1.00	1.10	Yes	Negligible
Expressway 2	0.105	Very Low	1.00	1.10	Yes	Negligible
Nyamata Road	0.060	Very Low	1.00	1.06	Yes	Negligible
Quarry Road 1	0.471	Low	1.00	1.47	Yes	Minor
Quarry Road 2	0.188	Very Low	1.00	1.19	Yes	Negligible
"Most Conservative" Standards	**5**					
Source	**UE**					

The Phase 1 (2020) modelling results demonstrate that during operations:

- The Proposed Project's contribution to SO_2, NO_2, PM_{10}, CO and benzene concentrations in its vicinity has a **Negligible** to **Minor Adverse** impact on all of the receptors;
- **Major Adverse** impacts are likely to be observed while considering the most stringent Air Quality Standards for PM_{10} and $PM_{2.5}$ emissions given the existing baseline conditions. However, it has to be noted that the project contribution to these impacts will be less than 1% for both PM_{10} and $PM_{2.5}$ emissions;
- One **Moderate Adverse** impact related to NO_2 concentrations could be observed at the Mwogo location due to the existing baseline conditions monitored at this receptor;
- NO_2 and benzene will present **Minor Adverse** impacts for the most exposed receptors only, i.e. Locale 2, Rilima, Expressway 1 and 2, and Quarry Road 1;
- When considering the Proposed Project's contribution and the baseline conditions, it can be observed for Phase 1 (2020) that the Project's contribution to air emissions compared to baseline conditions is expected to be generally very limited; and
- The most stringent Air Quality Standards will be met, except for the PM emissions, given the poor existing baseline conditions monitored. However, Rwandan Air Quality thresholds/AEC Standards will be met in all cases.

Table 9-38: SO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	SO_2											
	Annual Average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Mwogo	0.08	Very Low	0.2	Negligible	0.28	Yes	0.45	Very Low	0.2	Negligible	1.37	Yes
Locale 3	0.20	Very Low	0.3	Negligible	0.50	Yes	0.70	Very Low	0.3	Negligible	2.08	Yes
Locale 4	0.12	Very Low	0.2	Negligible	0.32	Yes	0.65	Very Low	0.2	Negligible	1.87	Yes
Kayumba	0.02	Very Low	0.25	Negligible	0.27	Yes	0.09	Very Low	0.25	Negligible	0.48	Yes
Kinazi	0.02	Very Low	0.2	Negligible	0.22	Yes	0.14	Very Low	0.2	Negligible	0.56	Yes
Locale 5	0.14	Very Low	0.65	Negligible	0.79	Yes	0.44	Very Low	0.65	Negligible	1.95	Yes
Locale 2	0.59	Very Low	0.2	Negligible	0.79	Yes	2.21	Very Low	0.2	Negligible	6.52	Yes
Juru	0.12	Very Low	0.2	Negligible	0.32	Yes	0.48	Very Low	0.2	Negligible	1.34	Yes
Rilima	0.44	Very Low	0.2	Negligible	0.64	Yes	1.12	Very Low	0.2	Negligible	3.03	Yes
Locale 1	0.21	Very Low	0.2	Negligible	0.41	Yes	0.53	Very Low	0.2	Negligible	1.58	Yes
Nyamata	0.05	Very Low	0.2	Negligible	0.25	Yes	0.19	Very Low	0.2	Negligible	0.70	Yes
Expressway 1	0.04	Very Low	0.7	Negligible	0.74	Yes	0.14	Very Low	0.7	Negligible	1.07	Yes
Expressway 2	0.04	Very Low	0.25	Negligible	0.29	Yes	0.18	Very Low	0.25	Negligible	0.72	Yes
Nyamata Road	0.06	Very Low	0.25	Negligible	0.31	Yes	0.41	Very Low	0.25	Negligible	1.33	Yes
Quarry Road 1	0.50	Very Low	0.2	Negligible	0.70	Yes	2.55	Very Low	0.2	Negligible	7.04	Yes
Quarry Road 2	0.23	Very Low	0.2	Negligible	0.43	Yes	1.52	Very Low	0.2	Negligible	4.25	Yes
"Most Conservative" Standards	60						20					
Source	East Africa Standards/Rwanda Guideline						IFC					

Table 9-39: SO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	SO_2					
	<1 hr (P100)					
	Project Contribution		Cumulative Concentrations			
Receptors	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Impact Significance**	**Cumulative Value**	**Standard Met**
Mwogo	5.14	Very Low	0.2	Negligible	5.34	Yes
Locale 3	8.05	Very Low	0.3	Negligible	8.35	Yes
Locale 4	11.92	Very Low	0.2	Negligible	12.12	Yes
Kayumba	2.07	Very Low	0.25	Negligible	2.32	Yes
Kinazi	2.99	Very Low	0.2	Negligible	3.19	Yes
Locale 5	9.45	Very Low	0.65	Negligible	10.10	Yes
Locale 2	16.06	Very Low	0.2	Negligible	16.26	Yes
Juru	5.56	Very Low	0.2	Negligible	5.76	Yes
Rilima	10.17	Very Low	0.2	Negligible	10.37	Yes
Locale 1	7.69	Very Low	0.2	Negligible	7.89	Yes
Nyamata	3.61	Very Low	0.2	Negligible	3.81	Yes
Expressway 1	2.30	Very Low	0.7	Negligible	3.00	Yes
Expressway 2	3.00	Very Low	0.25	Negligible	3.25	Yes
Nyamata Road	6.93	Very Low	0.25	Negligible	7.18	Yes
Quarry Road 1	21.79	Very Low	0.2	Negligible	21.99	Yes
Quarry Road 2	9.15	Very Low	0.2	Negligible	9.35	Yes
"Most Conservative" Standards	**500**					
Source	**IFC**					

Table 9-40: NO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	NO2											
	Annual average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Mwogo	11.78	Medium	34.5	Major	46.28	No	14.68	Very Low	34.5	Negligible	49.18	Yes
Locale 3	4.31	Low	22.75	Minor	27.06	Yes	7.61	Very Low	22.75	Negligible	30.36	Yes
Locale 4	6.78	Low	20	Negligible	26.78	Yes	6.53	Very Low	20	Negligible	26.53	Yes
Kayumba	0.96	Very Low	29.25	Negligible	30.21	Yes	1.29	Very Low	29.25	Negligible	30.54	Yes
Kinazi	1.04	Very Low	26.4	Negligible	27.44	Yes	1.40	Very Low	26.4	Negligible	27.80	Yes
Locale 5	2.78	Low	15.4	Negligible	18.18	Yes	5.12	Very Low	15.4	Negligible	20.52	Yes
Locale 2	8.89	Low	19.45	Negligible	28.34	Yes	21.76	Very Low	19.45	Negligible	41.21	Yes
Juru	2.45	Low	14.7	Negligible	17.15	Yes	4.35	Very Low	14.7	Negligible	19.05	Yes
Rilima	6.03	Low	18.3	Negligible	24.33	Yes	11.62	Very Low	18.3	Negligible	29.92	Yes
Locale 1	3.24	Low	19.4	Negligible	22.64	Yes	5.97	Very Low	19.4	Negligible	25.37	Yes
Nyamata	0.98	Very Low	21.2	Negligible	22.18	Yes	2.11	Very Low	21.2	Negligible	23.31	Yes
Expressway 1	14.54	Medium	26.95	Major	41.49	No	10.28	Very Low	26.95	Negligible	37.23	Yes
Expressway 2	14.79	Medium	22.5	Moderate	37.29	Yes	11.47	Very Low	22.5	Negligible	33.97	Yes
Nyamata Road	2.88	Low	22.5	Minor	25.38	Yes	4.28	Very Low	22.5	Negligible	26.78	Yes
Quarry Road 1	12.47	Medium	20.3	Moderate	32.77	Yes	29.69	Very Low	20.3	Negligible	49.99	Yes

Table 9-40: NO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	NO2											
	Annual average						24 hrs (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Impact Significance**	**Cumulative value**	**Standard Met**	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Impact Significance**	**Cumulative value**	**Standard Met**
Quarry Road 2	4.39	Low	17.2	Negligible	21.59	Yes	14.85	Very Low	17.2	Negligible	32.05	Yes
"Most Conservative" Standards	**40**						**188**					
Source	**IFC**						**East Africa Standards/Rwanda Guideline**					

Table 9-41: NO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	NO_2											
	Monthly Average						1 hr (P100)					
	Project Contribution			Cumulative Concentrations			Project Contribution		Cumulative Concentrations			
Receptors	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Impact Significance**	**Cumulative value**	**Standard Met**	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Impact Significance**	**Cumulative value**	**Standard Met**
Mwogo	11.78	Low	34.5	Negligible	46.28	Yes	119.16	Medium	34.5	Minor	153.66	Yes
Locale 3	4.34	Very Low	22.75	Negligible	27.09	Yes	78.74	Low	22.75	Negligible	101.49	Yes
Locale 4	6.73	Very Low	20	Negligible	26.73	Yes	108.09	Medium	20	Minor	128.09	Yes
Kayumba	0.95	Very Low	29.25	Negligible	30.20	Yes	32.38	Very Low	29.25	Negligible	61.63	Yes
Kinazi	1.02	Very Low	26.4	Negligible	27.42	Yes	29.41	Very Low	26.4	Negligible	55.81	Yes
Locale 5	2.74	Very Low	15.4	Negligible	18.14	Yes	94.59	Low	15.4	Negligible	109.99	Yes
Locale 2	8.98	Low	19.45	Negligible	28.43	Yes	118.36	Medium	19.45	Minor	137.81	Yes

Table 9-41: NO_2 Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	NO_2											
	Monthly Average						1 hr (P100)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met	Modelling Result	Impact Magnitude	Baseline	Impact Significance	Cumulative value	Standard Met
Juru	2.49	Very Low	14.7	Negligible	17.19	Yes	55.15	Low	14.7	Negligible	69.85	Yes
Rilima	6.13	Very Low	18.3	Negligible	24.43	Yes	108.80	Medium	18.3	Minor	127.10	Yes
Locale 1	3.20	Very Low	19.4	Negligible	22.60	Yes	82.19	Low	19.4	Negligible	101.59	Yes
Nyamata	0.96	Very Low	21.2	Negligible	22.16	Yes	34.83	Very Low	21.2	Negligible	56.03	Yes
Expressway 1	14.37	Low	26.95	Negligible	41.32	Yes	117.81	Medium	26.95	Minor	144.76	Yes
Expressway 2	14.65	Low	22.5	Negligible	37.15	Yes	116.24	Medium	22.5	Minor	138.74	Yes
Nyamata Road	2.84	Very Low	22.5	Negligible	25.34	Yes	67.82	Low	22.5	Negligible	90.32	Yes
Quarry Road 1	12.54	Low	20.3	Negligible	32.84	Yes	120.07	Medium	20.3	Minor	140.37	Yes
Quarry Road 2	4.43	Very Low	17.2	Negligible	21.63	Yes	91.98	Low	17.2	Negligible	109.18	Yes
"Most Conservative" Standards	**150.4**						**200**					
Source	**East Africa Standards/Rwanda Guideline**						**IFC**					

Table 9-42: PM_{10} Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	PM_{10}											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Mwogo	0.07	Very Low	46.31	46.38	No	Major	0.19	Very Low	46.31	46.50	Yes	Minor
Locale 3	0.01	Very Low	46.31	46.32	No	Major	0.02	Very Low	46.31	46.33	Yes	Minor
Locale 4	0.02	Very Low	46.31	46.33	No	Major	0.05	Very Low	46.31	46.36	Yes	Minor
Kayumba	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
Kinazi	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
Locale 5	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
Locale 2	0.01	Very Low	46.31	46.32	No	Major	0.03	Very Low	46.31	46.34	Yes	Minor
Juru	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
Rilima	0.00	Very Low	46.31	46.31	No	Major	0.02	Very Low	46.31	46.33	Yes	Minor
Locale 1	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
Nyamata	0.00	Very Low	46.31	46.31	No	Major	0.00	Very Low	46.31	46.31	Yes	Minor
Expressway 1	0.11	Very Low	46.31	46.42	No	Major	0.29	Very Low	46.31	46.60	Yes	Minor
Expressway 2	0.11	Very Low	46.31	46.42	No	Major	0.34	Very Low	46.31	46.65	Yes	Minor
Nyamata Road	0.01	Very Low	46.31	46.32	No	Major	0.02	Very Low	46.31	46.33	Yes	Minor
Quarry Road 1	0.04	Very Low	46.31	46.35	No	Major	0.10	Very Low	46.31	46.41	Yes	Minor

Table 9-42: PM_{10} Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	PM_{10}											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Quarry Road 2	0.00	Very Low	46.31	46.31	No	Major	0.01	Very Low	46.31	46.32	Yes	Minor
"Most conservative" Standards	20.0						50.0					
Source	IFC						IFC					

Table 9-43: $PM_{2.5}$ Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	$PM_{2.5}$											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Mwogo	0.07	Negligible	27.79	27.86	No	Major	0.19	Negligible	27.79	27.98	No	Major
Locale 3	0.01	Negligible	27.79	27.80	No	Major	0.02	Negligible	27.79	27.81	No	Major
Locale 4	0.02	Negligible	27.79	27.81	No	Major	0.05	Negligible	27.79	27.84	No	Major
Kayumba	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major
Kinazi	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major
Locale 5	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major

Table 9-43: $PM_{2.5}$ Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	$PM_{2.5}$											
	Annual Average						24 hrs (P99.2)					
	Project Contribution		Cumulative Concentrations				Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact Significance
Locale 2	0.01	Negligible	27.79	27.80	No	Major	0.03	Negligible	27.79	27.82	No	Major
Juru	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major
Rilima	0.00	Negligible	27.79	27.79	No	Major	0.02	Negligible	27.79	27.81	No	Major
Locale 1	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major
Nyamata	0.00	Negligible	27.79	27.79	No	Major	0.00	Negligible	27.79	27.79	No	Major
Expressway 1	0.11	Negligible	27.79	27.90	No	Major	0.29	Negligible	27.79	28.08	No	Major
Expressway 2	0.11	Negligible	27.79	27.90	No	Major	0.34	Negligible	27.79	28.13	No	Major
Nyamata Road	0.01	Negligible	27.79	27.80	No	Major	0.02	Negligible	27.79	27.81	No	Major
Quarry Road 1	0.04	Negligible	27.79	27.83	No	Major	0.10	Negligible	27.79	27.89	No	Major
Quarry Road 2	0.00	Negligible	27.79	27.79	No	Major	0.01	Negligible	27.79	27.80	No	Major
"Most conservative" Standards	**10.0**						**25.0**					
Source	**IFC**						**IFC**					

Table 9-44: CO Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	CO											
	8 hrs (P98)						1 hr (P100)					
	Project Contribution			Cumulative Concentrations			Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met
Mwogo	35.25	2	Negligible	243.50	278.75	Yes	157.61	4	Negligible	243.50	401.11	Yes
Locale 3	33.93	2	Negligible	243.50	277.43	Yes	140.06	4	Negligible	243.50	383.56	Yes
Locale 4	33.30	2	Negligible	243.50	276.80	Yes	206.03	5	Negligible	243.50	449.53	Yes
Kayumba	5.92	<1	Negligible	243.50	249.42	Yes	35.95	1	Negligible	243.50	279.45	Yes
Kinazi	7.50	<1	Negligible	243.50	251.00	Yes	50.87	1	Negligible	243.50	294.37	Yes
Locale 5	32.21	2	Negligible	243.50	275.71	Yes	172.25	4	Negligible	243.50	415.75	Yes
Locale 2	81.37	4	Negligible	243.50	324.87	Yes	289.10	7	Negligible	243.50	532.60	Yes
Juru	24.23	1	Negligible	243.50	267.73	Yes	93.17	2	Negligible	243.50	336.67	Yes
Rilima	66.76	3	Negligible	243.50	310.26	Yes	169.33	4	Negligible	243.50	412.83	Yes
Locale 1	32.44	2	Negligible	243.50	275.94	Yes	130.60	3	Negligible	243.50	374.10	Yes
Nyamata	10.60	1	Negligible	243.50	254.10	Yes	59.82	1	Negligible	243.50	303.32	Yes
Expressway 1	32.37	2	Negligible	243.50	275.87	Yes	107.62	3	Negligible	243.50	351.12	Yes
Expressway 2	36.46	2	Negligible	243.50	279.96	Yes	147.06	4	Negligible	243.50	390.56	Yes
Nyamata Road	17.08	1	Negligible	243.50	260.58	Yes	120.15	3	Negligible	243.50	363.65	Yes
Quarry Road 1	88.96	4	Negligible	243.50	332.46	Yes	380.19	10	Negligible	243.50	623.69	Yes

Table 9-44: CO Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	CO											
	8 hrs (P98)						1 hr (P100)					
	Project Contribution			Cumulative Concentrations			Project Contribution		Cumulative Concentrations			
Receptors	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met	Modelling Result	% of the Standard	Impact Significance	Baseline	Cumulative Value	Standard Met
Quarry Road 2	37.45	2	Negligible	243.50	280.95	Yes	160.72	4	Negligible	243.50	404.22	Yes
"Most conservative" Standards	2000						4000					
Source	East Africa Standards/Rwanda Guideline						East Africa Standards/Rwanda Guideline					

Table 9-45: Benzene Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	Benzene					
	Annual Average					
	Project Contribution			Cumulative Concentrations		
Receptors	Modelling Result	Impact Magnitude	Baseline	Cumulative Value	Standard Met	Impact significance
Mwogo	0.43	Low	1.00	1.43	Yes	Negligible
Locale 3	0.42	Low	1.00	1.42	Yes	Negligible
Locale 4	0.37	Low	1.00	1.37	Yes	Negligible
Kayumba	0.05	Very Low	1.00	1.05	Yes	Negligible
Kinazi	0.07	Very Low	1.00	1.07	Yes	Negligible
Locale 5	0.32	Low	1.00	1.32	Yes	Negligible
Locale 2	1.13	Low	1.00	2.13	Yes	Negligible

Table 9-45: Benzene Modelling Results and Associated Impacts Significance – Phase 5 (2045)

	Benzene					
	Annual Average					
	Project Contribution		Cumulative Concentrations			
Receptors	**Modelling Result**	**Impact Magnitude**	**Baseline**	**Cumulative Value**	**Standard Met**	**Impact significance**
Juru	0.25	Very Low	1.00	1.25	Yes	Negligible
Rilima	0.81	Low	1.00	1.81	Yes	Negligible
Locale 1	0.43	Low	1.00	1.43	Yes	Negligible
Nyamata	0.10	Very Low	1.00	1.10	Yes	Negligible
Expressway 1	0.43	Low	1.00	1.43	Yes	Negligible
Expressway 2	0.45	Low	1.00	1.45	Yes	Negligible
Nyamata Road	0.17	Very Low	1.00	1.17	Yes	Negligible
Quarry Road 1	1.18	Low	1.00	2.18	Yes	Negligible
Quarry Road 2	0.47	Low	1.00	1.47	Yes	Negligible
"Most Conservative" Standards	**5**					
Source	**UE**					

The Phase 5 modelling results for operations prior to mitigation indicate that:

- Overall, the Proposed Project's contribution to SO_2, NO_2, PM, CO and benzene concentrations in its vicinity will have a **Negligible** to **Moderate Adverse** impact on the receptors;
- Two **Moderate Adverse** impacts will be observed for NO_2, in the long term (annual average) for the following receptors: Expressway 2 and Quarry Road 1; and
- **Negligible** impacts will be observed for PM_{10}, CO and $PM_{2.5}$.

When considering the modelling results with the expected baseline conditions for Phase 5 (2045), it should be noted that:

- The Proposed Project's contribution to air concentrations compared to baseline conditions will be significantly higher during Phase 5 compared to Phase 1, except for PM_{10} emissions. Overall, the most impacted receptors will be those that are located close to the new Expressway (Expressway 1 & 2) and downwind to the airport (Quarry Road 1);
- **Major Adverse** impacts are likely to be observed while considering the most stringent Air Quality Standards for PM_{10} and $PM_{2.5}$ emissions given the existing baseline conditions. However, it should be noted that the Project contribution to these impacts is less than 1% for both PM_{10} and $PM_{2.5}$ emissions;
- Two **Major Adverse** impacts will also be observed for NO_2, mostly in the long term (annual average) mainly due to the poor existing baseline conditions monitored at these locations (Mwogo and Expressway 1); and
- According to the modelling results and the baseline assessment, all the most stringent Air Quality standards will be attained for Phase 5 scenario (2045), except for PM concentrations and two NO_2 concentrations (at Mwogo and Expressway 1 receptors), due to poor existing baseline conditions. The Rwandan Air Quality thresholds/AEC Standards will be met at all locations.

It should to be noted that these modelling results are likely to be conservative as they did not take into consideration the future likely increased performance of both aircraft and vehicles. Furthermore, it is important to note that the receptors were selected in close proximity to the Proposed Project Area in order to be conservative. Based on this conservative approach, **Negligible** to **Major Adverse** impacts would be observed prior to mitigation.

9.6 Mitigation Measures

9.6.1 Construction Phase Mitigation Measures

As presented in Section 9.5.1, the main impacts of the construction phase will be the generation of dust and particulate matter (PM_{10}) related to earthworks, the movement of traffic on unsurfaced roads and the loading/unloading of materials. All of the impacts were assessed **Major Adverse** prior to mitigation, notably due to the poor existing baseline conditions. Receptors located close and downwind the Airport Area prior to mitigation would be exposed to the main **Major Adverse** impacts, namely: Mwogo, Locale 2, Locale 3, Locale 4 and Quarry Road 1.

The following techniques for the reduction and control of fugitive dust emissions will be implemented during the construction phase, especially during the earthworks. They are provided in order of effectiveness, considering the impact at the receptors:

- Vehicle speed limitations, particularly close to sensitive receptors (typically <20 km);
- Restriction on vehicular usage in off-road areas (e.g. tracking vehicles with GPS system);

- Managing dust during Major winds;
- Minimising dust from material handling sources, such as conveyors and bins, by using covers and/or control equipment (water suppression, bag house filters or cyclones);
- Minimising dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and increasing the moisture content;
- Dust suppression techniques, such as applying water or non-toxic chemicals to minimise dust from vehicle movements; and
- Management of emissions from mobile sources, including adequate maintenance of vehicle and equipment.

The Western Regional Air Partnership's (WRAP) Fugitive Dust Handbook[34] outlines measures which can be undertaken to control and reduce fugitive particulate emissions from construction sources (Table 9-46). In the context of the Proposed Project, two types of mitigation measures will be applied:

- Adjusted work practices (wetting unpaved surfaces, planning operations, etc.); and
- Add-on control measures (wind barriers, revegetation, etc.).

Table 9-46: Fugitive Dust Control Measures and Their Efficiency

Control measure	Published Dust Control Efficiency
Adjusted work practices	
Prohibit activities during Major winds	98%
Water unpaved surfaces	10 - 74%
Water exposed area before Major winds	90%
Apply dust suppressant to unpaved areas	84%
Add-on control measures	
Create cross-wind ridges	24 - 93%
Erect artificial wind barriers	4 - 88%
Revegetate; apply cover crop	90%
Plant trees or shrub or mulch to working pens	>10%

Source: Fugitive Dust Handbook, WRAP, September 2006.

Due to the extent of the construction area and the limited duration of the construction phase, adjusted work practices will provide the most efficient methods to reduce air quality impacts.

9.6.2 Operation Phase Mitigation Measures

As discussed in Section 9.5.2 and according to the modelling assessment results, the airport operations for the Phase 1 Scenario (2020) are not predicted to lead to significant air quality impacts. The impact significance is considered to be **Negligible** to **Minor Adverse** for SO_2, benzene and CO. With the PM_{10}, and $PM_{2.5}$ Major Adverse impacts being associated mainly with the poor existing baseline conditions, the Project will not be able to significantly reduce these impacts.

34 Western Regional Air Partnership (WRAP), 2006, Fugitive Dust Handbook, Western Governors' Association.

During the Phase 5 Scenario (2045), prior to mitigation, some receptors would likely be major or moderately impacted, notably by NO_2 emissions. These receptors are located close and downwind the Airport Area (Mwogo, Locale 2, Locale 4, Rilima and Quarry Road 1) and receptors located close to the future Expressway (impact of the road traffic on Expressway 1 and Expressway 2).

The following actions will be implemented in order to avoid or limit the most significant impacts from airport operations for both of the scenarios:

- Optimise aircraft movements on the ground in order to reduce taxiing and therefore reduce NO_x and SO_2 air emissions;
- Implement landing and take-off procedures that minimise air emission impacts by reducing the duration of the landing phase or increasing the climb angle;
- Where possible, ensure that aircraft fleets are the latest models and maintained according to GIIP as dictated by aircraft manufacturers;
- Select GSE with a consideration of low pollutant air emissions and efficient energy consumption where possible, and maintained according to the manufacturers' recommendations;
- Implement Air Traffic Control (ATC) ground delay procedures to minimise ATC delays and flight times in holding patterns; and
- Where possible, use jet fuel with the lowest possible sulphur content (i.e. use of GTP jet fuel), in order to further reduce aircraft SO_2 air emissions.

Major and **Moderate Adverse** impacts are predicted along the Expressway and Quarry Road 1 (2045 scenario only). However, the vehicle fleet in 2045 is expected to be much cleaner, including engines with very low (or zero) NO_x emissions, which would reduce these impacts further.

9.7 Residual Impact Assessment Conclusions

9.7.1 Construction Phase Residual Impacts

Given the expected efficiency of the proposed mitigation measures for the construction phase, a significant reduction of the PM_{10} daily concentrations associated with the Project can be expected.

Therefore, the initial impact magnitude of high to medium adverse (assessed for the receptors Mwogo, Locale 2, Locale 3, Locale 4 and Quarry Road 1) would become at worst **Medium** to **Low Adverse** residual impacts.

Particular attention will be paid to managing air emissions at the Quarry Road 1 receptor (located downwind and close to emission sources) as it corresponds to the Major impact predicted.

9.7.2 Operation Phase Residual Impacts

The mitigation measures that are to be adopted are expected to lead to a significant decrease of the NO_2, SO_2, CO and benzene emissions and therefore a decrease in the average concentrations of these contaminants at the receptors. This is especially expected to be the case during Phase 5 for which the Proposed Project contribution to air quality impacts (hourly NO_2 concentrations) is predicted to be significant for several receptors located downwind; namely, Mwogo, Locale 2, Locale 4 and Quarry Road 1.

As the assessment shows only a slight exceedance of the criterion for the major adverse impacts observed (i.e. exceedance of 50% of the standard for max. hourly NO_2 concentrations), it is expected that the implementation of the proposed mitigation measures would reduce the impact significance from **Major** to **Moderate adverse**. The same decrease should also be observed for the impacts assessed as **Moderate** adverse, which should become **Minor Adverse**.

Emissions generated from vehicles are expected to reduce as technologies develop over the years, therefore by Phase 5 the impact significance of emissions along the Expressway (e.g. receptor Expressway 1 and 2) will reduce from moderate adverse to **Minor Adverse** at worst.

9.8 Summary of Mitigation and Residual Impacts

The most significant impacts of particulate matter will occur during the construction phase; however, these will be reduced by implementing mitigation measures outlined above, i.e. dust control methods. When only considering the Project's contribution, only **Minor Adverse** impacts are expected, except at downwind locations in close proximity to the main construction activities and unpaved roads (receptor Quarry Road 1) where **Moderate Adverse** residual impacts during a limited period (daily episode) may be experienced. However, the poor existing baseline conditions that were monitored revealed that PM concentrations are already exceeding the most stringent IFC (WHO) Standards. It could be expected that the construction of other paved roads in the area towards 2045 would also contribute to a decrease in these PM concentrations. Nonetheless, the Project will not have direct means of improving these environmental conditions.

Other impacts observed are related to the 2045 operation phase, and more specifically the aircraft and APU/GSE combustions emissions (notably NO_2, SO_2 and benzene). Even when adopting a very conservative approach, no significant impacts were identified for both operational scenarios.

Residual impacts are **Negligible** except for NO_2 where **Minor Adverse** are predicted closest to the airport sources of emissions and located downwind. These are at Mwogo, Quarry Road 1, Locale 2, Locale 4 and Rilima.

A summary of the mitigation and residual impacts are shown in Table 9-47.

Table 9-47: Summary of Findings

Impact	Receptor	Phase	Impact Magnitude	Receptor Sensitivity	Pre-mitigation Impact Significance	Design, Enhancement or Mitigation Measures	Management Plan	Residual Significance
Deterioration of ambient air quality (due to fugitive dust emissions and notably PM_{10}) resulting from earthworks and construction equipment	The primary affected receptors are the communities located downwind and close to the emissions sources: Mwogo, Locale 2, Locale 3, Locale 4 and Quarry Road 1.	Construction	**Impact Magnitude:** Major **Nature:** Negative **Type:** Direct **Extent / Scale:** Local **Duration:** Short Term **Reversibility:** Reversible	High	**Major Adverse** *Major Adverse impact to communities downwind*	• Vehicle speed limitations, particularly close to sensitive receptors (typically < 20 km); • Restriction on vehicular usage in off-road areas (e.g. tracking vehicles with GPS system); • Limiting earthwork activities during Major winds; • Minimising dust from material handling sources, such as conveyors and bins, by using covers and/or control equipment (water suppression, bag house filters or cyclones); • Minimising dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and	• Pollution Prevention Plan	**Moderate Adverse** residual impact cannot be completely excluded for closest receptor to unpaved roads and open area sources (e.g. Quarry Road 1)

Table 9-47: Summary of Findings

						increasing the moisture content; • Dust suppression techniques, such as applying water or non-toxic chemicals to minimise dust from vehicle movements; • Management of emissions from mobile sources, including adequate maintenance of vehicle and equipment; and • Visual monitoring for dust emissions.		
Daily deterioration of ambient air quality due to SO_2 emissions	Populations surrounding the Project Area and notably the receptors location Quarry Road 1 and Locale 2	Operation	**Impact Magnitude:** Negligible for the 2020 Scenario Low for the 2045 Scenario **Nature:** Negative **Type:** Direct **Extent / Scale:** Locale (Quarry Road 1 and Local 2) **Duration:**	Low	**Negligible** for the 2020 Scenario **Negligible** for the 2045 Scenario	• Optimise the aircraft ground movements in order to reduce taxiing and therefore reduce NO_x and SO_2 air emissions; • Implement landing and take-off procedures that minimise air emissions impact by respectively reducing the duration of the landing phase or increasing the climb angle; • Ensure that aircraft fleets are the latest	• Pollution Prevention Plan	**Negligible** for both Sce-narios

Table 9-47: Summary of Findings

			Short Term (few days a year) **Reversibility:** Reversible			and maintained according to best practices dictated by aircraft manufacturers; • GSE must be the best possible in terms of pollutant air emissions and electrical GSE should be preferred when possible. The maintenance procedures proposed by suppliers must be respected. • Implement ATC ground delay procedures to minimise ATC delays and flight time in holding patterns. • Technically and financially validate the use of jet fuel with the lowest possible sulphur content (i.e. use of GTP Jet Fuel); and • Air quality monitoring programme at key locations, including sensitive receptor locations.		
Long term deterioration of ambient air quality due to NO_2 emissions	Residential areas surrounding the Project Area	Operation	**Impact Magnitude:** Low to medium for the 2020 Scenario Mainly Medium for the 2045 Scenario **Nature:** Adverse **Type:** Direct **Extent/Scale:** Regional **Duration:** Long term (significant contribution to the annual air quality guideline value) **Reversibility:** Reversible	Low to High depending on the receptors location	**Negligible to Moderate Adverse** (for three receptors) for the 2020 Scenario Mainly **Negligible to Major Adverse (at one receptor, Mwogo)** for the 2045 Scenario		• Pollution Prevention Plan	**Negligible Adverse** for 2020 Scenarios **Minor Adverse** for 2045 Scenarios

Table 9-47: Summary of Findings

Deterioration of ambient air quality due to PM_{10}	Residential areas surrounding the Proposed Project Area	Operation	**Impact Magnitude:** Very Low for both scenarios **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:** Short term (daily) and Long term (annual) impact **Reversibility:** Reversible	High	**Major Adverse** for both scenarios Due to poor existing baseline conditions	• Optimise aircraft movements on the ground in order to reduce taxiing and therefore reduce NOx and SO_2 air emissions; • Implement landing and take-off procedures that minimise air emission impacts by reducing the duration of the landing phase or increasing the climb angle; • Ensure that aircraft fleets are the latest models and maintained according to GIIP as dictated by aircraft manufacturers; • Select GSE with a consideration of low pollutant air emissions and efficient energy consumption where possible, and maintained according to the manufacturers' recommendations; • Implement Air Traffic Control (ATC) ground delay procedures to minimise ATC delays	• Pollution Prevention Plan	Moderate to **Major adverse** for both Scenarios due to poor existing baseline conditions
Deterioration of ambient air quality due to CO emissions	Populations surrounding the Proposed Project Area	Operation	**Impact Magnitude:** Very Low for both scenarios **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:**	Medium	**Negligible Adverse** for both Scenarios			**Negligible** for both Scenarios

Table 9-47: Summary of Findings

			Short term (8 hr period) **Reversibility:** Reversible			and flight times in holding patterns; • Use jet fuel with the lowest possible sulphur content (i.e. use of GTP jet fuel), where possible, in order to further reduce aircraft SO_2 air emissions; and • Greenhouse gas reporting.		
Deterioration of ambient air quality due to benzene emissions	Populations surrounding the Proposed Project Area	Operation	**Impact Magnitude:** Very Low to Low for the 2020 Sce-nario Mainly Low (for 11 receptors) for the 2045 Sce-nario **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:** Long term (an-nual average) **Reversibility:** Reversible	Medium	**Negligible to Minor Adverse** (for three receptors) for the 2020 Scenario Mainly **Minor Adverse** (for 11 receptors) for the 2045 Scenario	• Optimise aircraft movements on the ground in order to reduce taxiing and therefore reduce NOx and SO_2 air emissions; • Implement landing and take-off procedures that minimise air emission impacts by reducing the duration of the landing phase or increasing the climb angle; • Ensure that aircraft fleets are the latest models and maintained according to GIIP as dictated by aircraft manufacturers; • Select GSE with a consideration of low	• Pollution Prevention Plan	**Negligible** For both Scenarios

Table 9-47: Summary of Findings

						pollutant air emissions and efficient energy consumption where possible, and maintained according to the manufacturers' recommendations; • Implement Air Traffic Control (ATC) ground delay procedures to minimise ATC delays and flight times in holding patterns; and • Use jet fuel with the lowest possible sulphur content (i.e. use of GTP jet fuel), where possible, in order to further reduce aircraft SO_2 air emissions.		