Volume D Preface

The Environmental Assessment (EA) for the Ambatovy Project (the project) is intended to meet the information requirements outlined in the Terms of Reference (ToR) in an easily understood and comprehensive package of information. Information is presented in 11 volumes that address specific subject areas. The volumes are as follows, and the structure of each volume is depicted in Figure 1:

- Volume A: Introduction
- Volume B: Environmental Assessment - Mine
- Volume C: Environmental Assessment - Slurry Pipeline
- Volume D: Environmental Assessment - Process Plant
- Volume E: Environmental Assessment - Tailings Facility
- Volume F: EnvironmentalAssessment - Port Expansion
- Volume G: Environmental Assessment - Cumulative Effects
- Volume H: General Appendices
- Volume I: Physical Appendices
- Volume J: Biological Appendices
- Volume K: Social Appendices

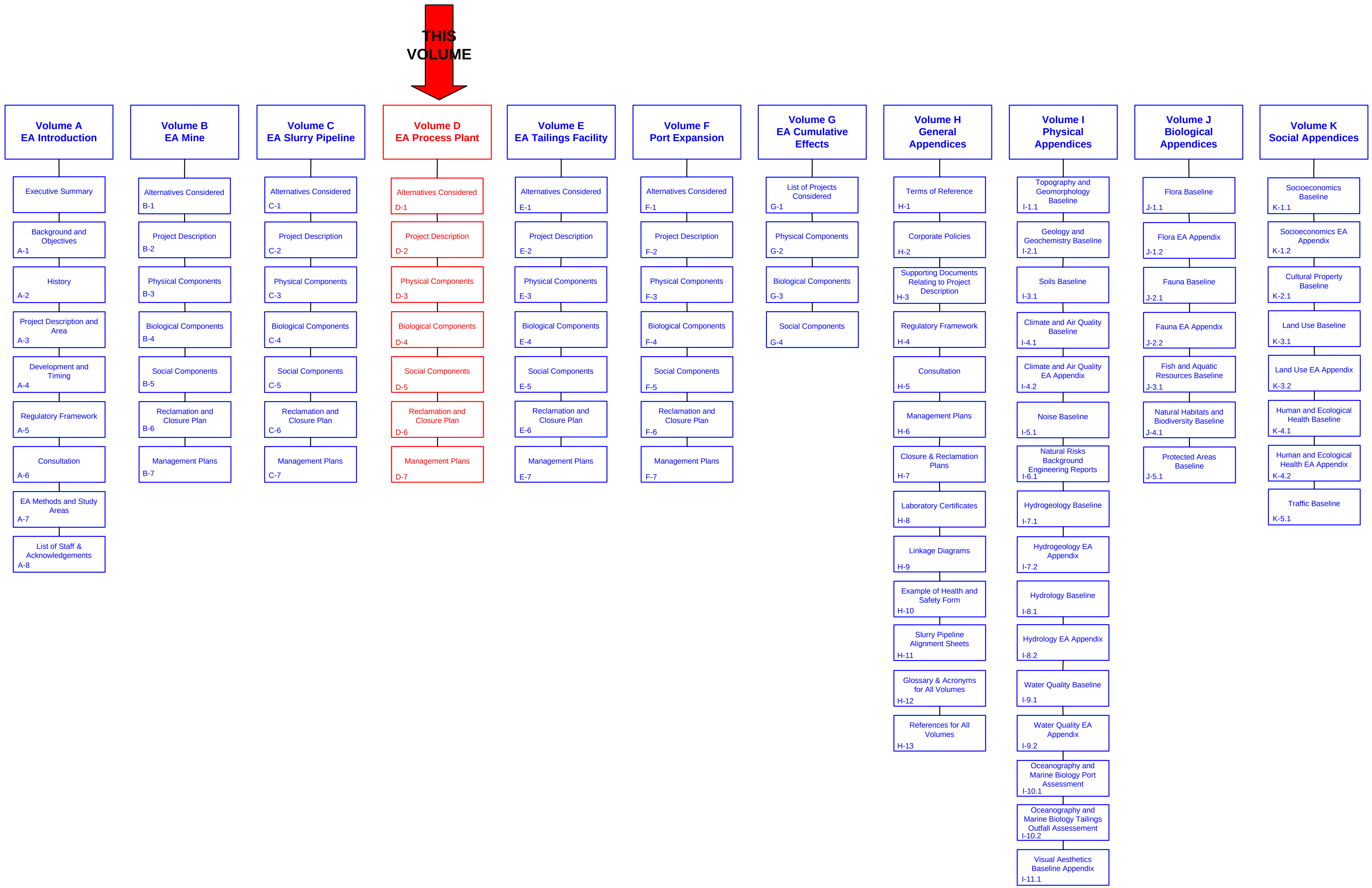
Volume A introduces the EA and contains study area and methodological information pertaining to all disciplines and all project components.

For the convenience of readers who wish to read only specific parts of the EA, each of the assessment volumes B through F include descriptions of the project component being addressed. Therefore, a reader who is interested in one particular component may read the corresponding assessment volume.

Volume G contains a cumulative effects assessment that addresses the combined effects of the project components and cumulative effects of the whole project plus other foreseeable developments in Madagascar.

Where appropriate, the EA refers to separate documents in volumes H through K called Appendices, which contain additional technical and baseline information. These volumes also contain environmental assessment appendices for some disciplines with information of relevance to the environmental assessment for multiple components of the project. The glossary, acronyms and references for all volumes are listed in Volume H Appendices 12 and 13.

Figure 1 Environmental Impact Study Structure for the Ambatovy Project



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1 ALTERNATIVES CONSIDERED

Several alternatives were analyzed by the project proponents for the process plant component of the Ambatovy Project (the project). Each alternative was accessed for its relative engineering, cost, environmental and social advantages or disadvantages to that particular component of the project. The selection of a preferred alternative in some cases eliminated or reduced options for other components to the project. Alternatives for the following process plant components were investigated during the design of the project:

- Process Selection, Nickel Recovery Process.
- Power and Steam Supply.
- Process Plant Location.
- Water Sources.
- Refinery Location.

The alternatives analyzed for each component of the process plant are summarized in Tables 1-1 through 1-5. The ranking of criteria presented are only relative and provide a summary of the analyses of alternatives conducted.

Table 1-1 Analysis of Alternatives – Process Selection, Nickel Recovery Process

Alternative	Engineering	Relative Cost	Environmental	Social
pressure acid leach (PAL) process: sulphuric acid leaching at high temperature and pressure (preferred)	higher metal recoveries	low capital, low operating costs	minimal impact	minimal negative impact
Caron Process: reduction roast ammonia leach	not amenable to this ore body (lower metal recoveries)	moderate capital and operating costs	equivalent impact	equivalent impact
smelting	not applicable for this ore body	not applicable	not applicable	not applicable

Table 1-2 Analysis of Alternatives – Power and Steam Supply

Alternative	Engineering	Relative-Cost	Environmental	Social
coal fired (preferred)	moderate efficiency and availability	moderate capital, lower operating costs	moderate fuel quality, generates greenhouse gases, SO_2/NO_x	minimal impact potential visible stack
oil/diesel fired	moderate/higher efficiency higher availability short construction phase	lower capital, moderate operating costs	higher fuel quality, generates greenhouse gases, SO_2/NO_x	minimal impact potential visible stack
gas fired combustion cycle	high efficiency higher availability no domestic gas supply	lower capital, higher operating costs	higher fuel quality, generates green house gasses, SO_2/NO_x	minimal impact potential visible stack
biomass	lower reliability of supply moderate logistics depending on source	higher/moderate capital, lower operating costs	potential high land use permitting generally easier	viewed often as environmentally friendly
nuclear	typically for larger electrical / steam requirements higher complexity, safeguards	higher capital, lower operating costs	security and environmental concerns with use of uranium permitting more difficult	lower public acceptability
hydroelectric	does not produce steam directly moderate reliability (seasonal/weather) requires transmission line from existing source longer construction phase	higher capital, lower operating costs	permitting generally easier may impact larger land base	potential displacement of people from dammed area viewed often as environmentally friendly
renewable (wind, tidal, wave action, solar)	does not produce steam directly lower reliability(seasonal / weather)	higher/moderate capital, lower operating costs	permitting generally easier renewable energy source	viewed often as environmentally friendly

Table 1-3 Analysis of Alternatives – Process Plant Location

Alternative	Engineering	Relative Cost	Environmental	Social
Toamasina (preferred)	minimal logistics support (transportation requirements between plant and port)	moderate capital, lower operating costs	zoned for industrial use	greater public acceptance due to zoning closer to labour force
mine site	higher logistics (bulk transport)	moderate capital, higher operating costs	greater impact with increased logistical support (traffic between plant and port) advantage of no pipeline requirement	greater interaction with public from transportation requirements between plant and port
Brickaville	moderate site preparation	moderate capital, moderate operating costs	not zoned as industrial site, additional land use issues	less amenable to existing land use

Table 1-4 Analyses of Alternatives – Proven Plant Water Sources

Alternative	Engineering	Relative Cost	Environmental	Social
Ivondro River (main option)	minimal treatment close proximity	lower capital, lower operating costs	minimal impact because of size and flow of Ivondro river	minimal impact
slurry pipeline (also to be used)	restricted base on pipeline minimum solids content	moderate capital and moderate operating costs	potential, greater impact if larger pipe required	minimal impact
tailings pond return water (also to be used)	additional treatment	lower capital, moderate operating costs	reduces discharge to ocean	minimal impact

Table 1-5 Analysis of Alternatives – Refinery Location

Alternative	Engineering	Relative Cost	Environmental	Social
PAL plant including metals refinery	fully integrated, end product produced and shipped	higher capital cost, higher operating costs	moderate impact	potential for greater local economic opportunities
PAL plant only; expansion of off-shore refinery (preferred)	uses infrastructure at refinery location potentially shorter construction phase potentially greater access to skilled labour	lower capital costs, lower operating costs	less impact with reduced project scope	some reduction in local economic opportunities

As a result of the analysis of alternatives, the PAL process was selected as the nickel recovery process and a coal fired power supply system was selected as the main source of steam and power. In addition, Toamasina was selected as the plant location and the utilization of an off shore refinery was chosen.

2 PROJECT DESCRIPTION

2.1 INTRODUCTION

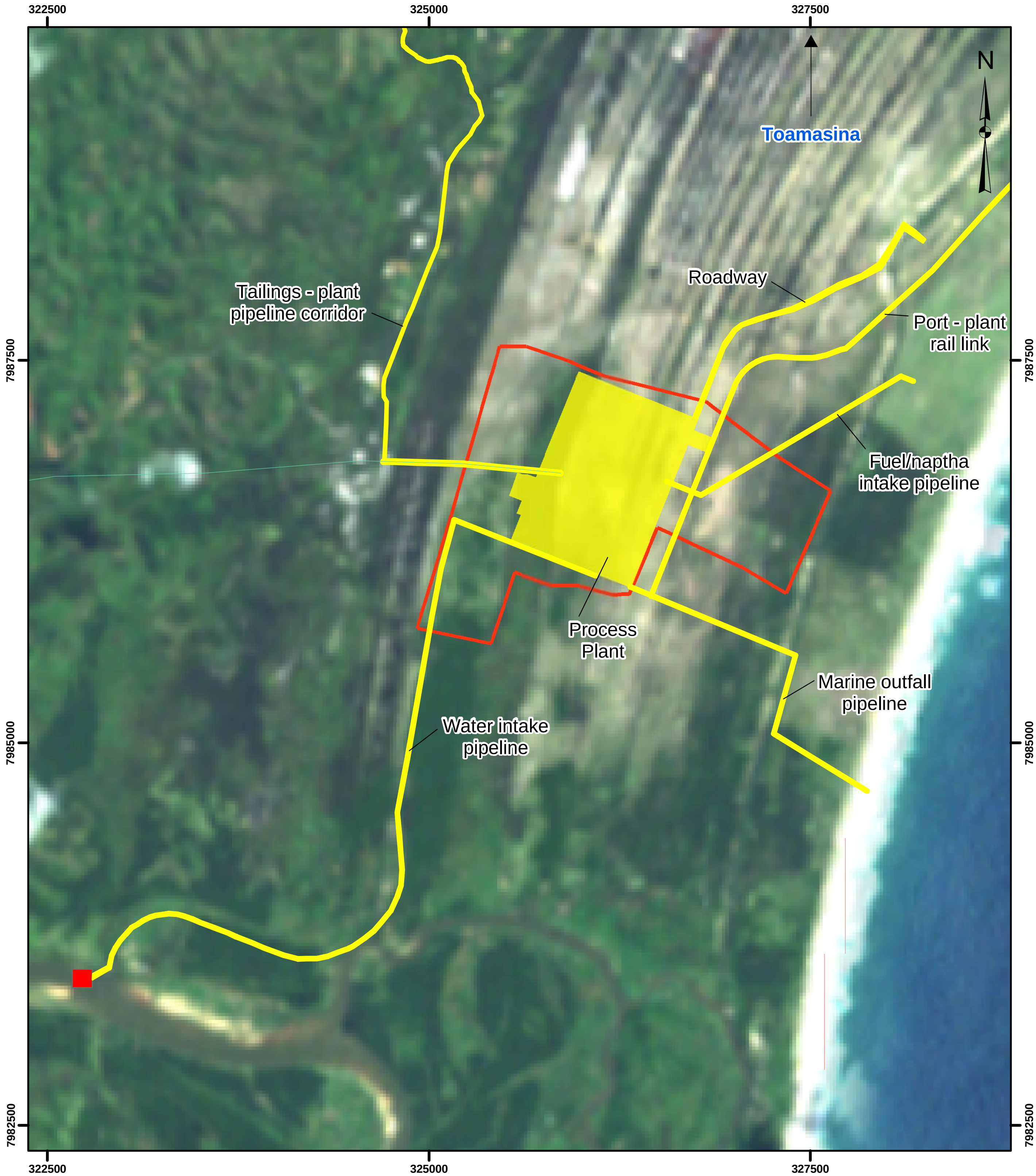
The proposed process plant is situated on an 80 ha site on the southern outskirts of Toamasina (Figure 2.1-1). The plant is about 10 km from the port of Toamasina, on the east coast of Madagascar. The plant site is predominantly a flat (with low undulations) coastal wetlands area at elevations between 6 and 10 masl. Figure 2.1-2 presents the proposed plant layout.

The proposed process plant includes a leach plant and associated utility plants (Figure 2.1-3). The utility plants include: power, steam and water plants, a hydrogen plant, a hydrogen sulphide plant, a sulphuric acid plant, and a limestone and lime plant.

2.2 LEACH PLANT

Laterite ore slurry from the ore preparation plant will be received from the slurry pipeline. The slurry will be partially dewatered or thickened in an ore thickener before being advanced to the pressure acid leach (PAL) circuit. Recovered water from the thickener will be collected in a reclaim pond for use as process water.

The PAL circuit will have five parallel trains, each consisting of a feed tank, slurry heater, autoclave, flash tanks and the associated pumps. In the acid pressure leach circuit, the laterite ore will be heated with steam in a series of direct heaters. The heated slurry will be pumped into the autoclave where it will be reacted with concentrated sulphuric acid. In the autoclaves, nickel, cobalt, copper, zinc, manganese, magnesium and a portion of the aluminum will be leached from the ore as soluble sulphate salts. Most of the iron, chromium and titanium in the ore and the balance of the aluminum will be part of the solid residue as stable oxides and hydroxides. Slurry from the autoclave will be brought to atmospheric pressure and cooled by the evolution of steam in a series of three flash tanks. Steam from the flash tanks will be used in the slurry heaters and other plant areas to optimize heat recovery.



LEGEND

- PLANT SITE PROPERTY BOUNDARY
- WATER SUPPLY STATION
- DISTURBANCE AREA
- SLURRY PIPELINE ENGINEERED ROUTE, 50m CORRIDOR

1 0 1

SCALE 1:35,000 KILOMETRES

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001

Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

PROCESS PLANT LOCATION

Golder Associates

Calgary, Alberta

PROJECT No. 03-1322-003.6100			SCALE AS SHOWN	REV. 0
DESIGN	GJ	17 Oct. 2005	**FIGURE: 2.1-1**	
GIS	TN	18 Oct. 2005		
CHECK	GJ	09 Feb. 2006		
REVIEW	DM	09 Feb. 2006		

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FIGURE 2.1-2

Ambatovy

AMBATOVY OPG APP. ENG COORD	AMBATOVY OPG APP. AREA MAN
SNC·LAVALIN Engineers & Constructors	THIS DRAWING HAS BEEN PREPARED BY SNC-LAVALIN ENGINEERS AND CONSTRUCTORS INC., AND THE USE AND COPYING THEREOF IS SUBJECT TO THE TERMS OF THE AGREEMENT UNDER WHICH IT WAS PREPARED. THIS DRAWING MAY NOT BE COPIED EXCEPT AS EXPRESSLY PROVIDED THEREIN.
PROFESSIONAL ENGINEER NAME	NO.

SLE&C	NAME (PRINT) NOM	INIT.	DATE
DESIGNED PROJETÉ	E. MARKOULAKIS	EM	05/12/16
DRAWN DESSINÉ	J. KAN	JK	05/12/16
CHECKED VÉRIFIÉ	W. PALMER		
APPROVED-LEAD ENG. APPROUVÉ-INGÉNIEUR EN CHEF	W. PALMER		
APPROVED-ENG MAN. APPROUVÉ-DIRECTEUR INGÉNIEUR			
APPROVED-AREA MAN. APPROUVÉ-DIRECTEUR RÉSIDENT			
SCALE ÉCHELLE 1 : 3000			

TITLE

LAYOUT FOR PLANT SITE

PLAN D'AMÉNAGEMENT DE L'USINE DE TRAITEMENT

PROJECT NO.	AREA	DISC.	DOC.	DRAWING NUMBER	REVISION NUMBER
334457	0900	41	DD	PALP	PA

DWG. NO.	REFERENCES	DWG. NO.	REFERENCES	NO.	DATE	REVISIONS	BY	CHK	LEAD DISC.	ENG. MAN.	AREA MAN.	CLIENT ENG. COORD.	CLIENT AREA MAN.	NO.	DATE	REVISIONS	BY	CHK	LEAD DISC.	ENG. MAN.	AREA MAN.	CLIENT ENG. COORD.	CLIENT AREA MAN.	NO.	DATE	REVISIONS	BY	CHK	LEAD DISC.	ENG. MAN.	AREA MAN.	CLIENT ENG. COORD.	CLIENT AREA MAN.

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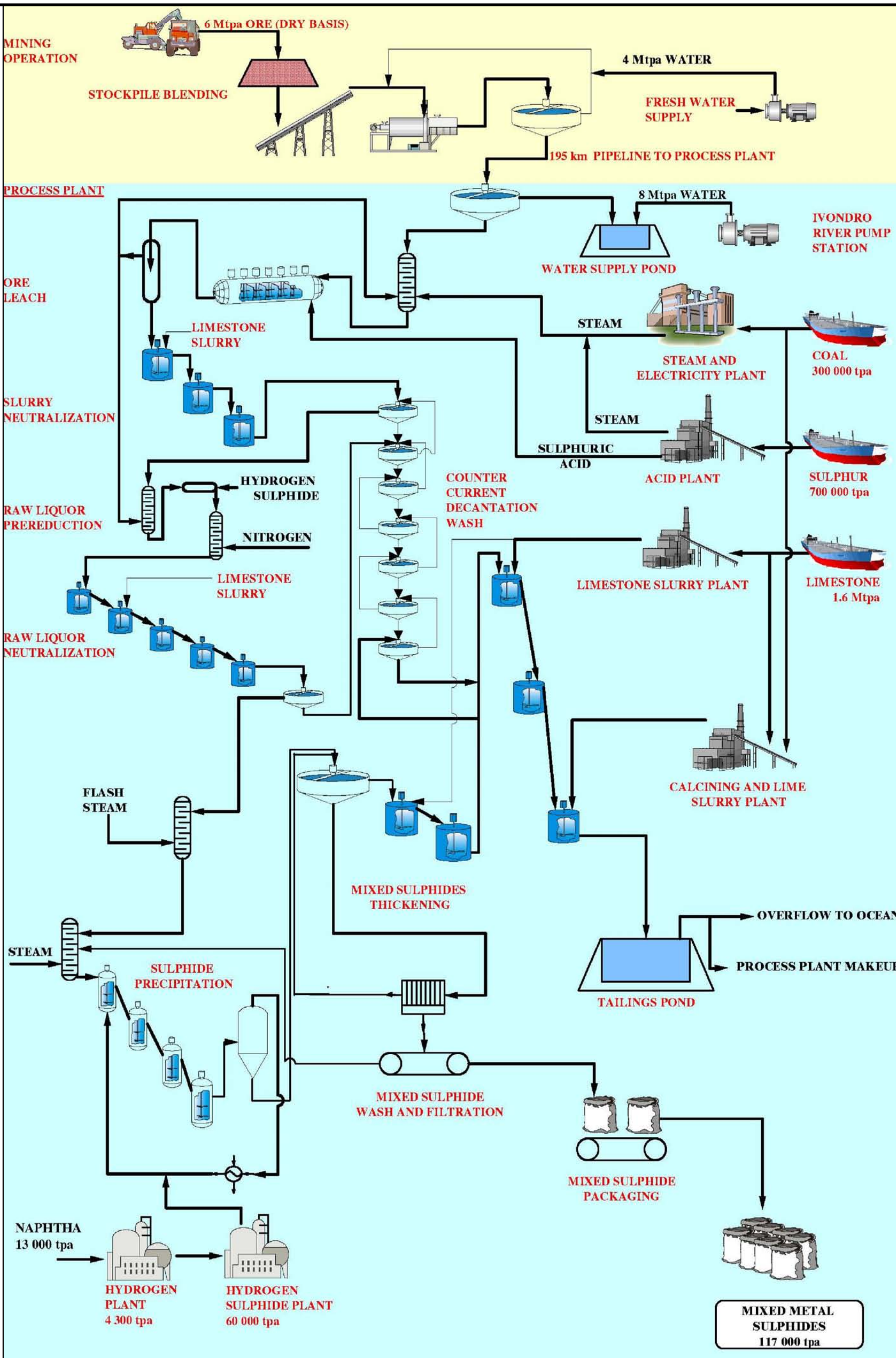


REFERENCE:
ORIGINAL DRAWING OBTAINED FROM CLIENT

PROJECT
AMBATOVY PROJECT

TITLE
PROCESS PLANT FLOW DIAGRAM

Golder Associates
Calgary, Alberta

PROJECT 03-1322-172.6124			FILE No. Process Plant	
DESIGN	GJ	20/10/05	SCALE AS SHOWN	REV. 0
CADD	SWD	28/11/05	FIGURE: 2.1-3	
CHECK	GJ	13/02/06		
REVIEW	DM	13/02/06		

After leaching, the leach discharge slurry will be pumped to the slurry neutralization circuit, where a portion of the free acid in the slurry will be neutralized with limestone in a series of three tanks. Partially neutralized slurry will be pumped to the countercurrent decantation (CCD) wash circuit where the dissolved metals in solution will be separated from the leached solids by washing, in a series of seven thickeners. Washed solids from the final CCD thickener will be pumped to a tailings neutralization circuit. A small portion of washed solids will be diverted to the ferric sulphate circuit for production of a reagent used to oxidize residual H_2S in the barren liquor from the sulphide precipitation area.

Washed solids (tailings) will be mixed in the tailings neutralization tanks for neutralization with limestone and lime. The neutralization step will precipitate and immobilize metals; this material will be disposed to the tailings pond.

Nickel and cobalt bearing solution from the first CCD thickener will be treated with hydrogen sulphide gas to reduce chromium (VI) to chromium (III) before neutralizing the free acid with limestone. The resulting gypsum slurry will be thickened and a portion of the gypsum thickener underflow slurry will be recycled to the neutralization tanks to act as seed to improve the solids settling characteristics. The remainder will be pumped to the CCD for washing and disposal to the tailings pond.

The clear product solution from the thickeners will be treated with hydrogen sulphide in the sulphide precipitation circuit to precipitate nickel and cobalt as a mixed sulphide intermediate product. Copper, zinc and a small portion of iron will co-precipitate with nickel and cobalt in the mixed sulphide product.

The mixed sulphides product will be batch filtered and washed with process water, and delivered to the sulphides bagging and storage. The bagged mixed sulphide product will then be transported to the port for shipment to the nickel refinery.

2.3 UTILITIES

Power

Electricity for the Toamasina process plant site will be provided on-site by three coal-fired 25 MW steam turbine generators. The power plant will not be connected to an external electrical power grid. Diesel generators will provide backup emergency power to operate critical equipment and to restart one boiler when turbines are off line. The power plant will generate and supply power at 20 kV to sub-stations strategically located throughout the process plant.

Power will be supplied to the tailings pond and Ivondro River pump station by locally installed diesel generators.

Steam

High-pressure steam will be produced at the process plant by coal-fired boilers supplemented by steam produced in waste heat boilers in the sulphuric acid plants. There will be three boilers and two acid plant trains and each will be designed to generate superheated steam suitable for the power plant turbines and as process steam. During normal operation one of the coal-fired boilers will be maintained on hot standby as back up, should one of the other boilers be taken off line.

Process steam will be used primarily for direct heating of the ore slurry prior to pressure acid leaching in the ore leach circuit and for direct heating the subsequent nickel and cobalt bearing liquor prior to precipitation as the mixed sulphide product.

Steam condensate will be collected from the turbines and returned to the powerhouse deaerator which will supply boiler feed water to all of the main steam boilers on-site. Because the majority of the steam is injected directly into the process, more than half of the boiler feedwater to the deaerator will be demineralized water.

Water

The principal source of water for the process plant is water recovered from the ore slurry delivered by the pipeline from the mine. This water will be augemented with water from the Ivondro River. A pump house will be constructed on the northern bank of the river to feed the raw water from the Ivondro River to the water treatment plant. In addition, to minimize river water usage tailings pond return water will also be pumped to the process plant for use in gas cleaning scrubbers.

The water treatment plant at the Toamasina site will be designed to treat water reclaimed from ore slurry thickening and raw water from the Ivandro River pump station. An inventory of water recovered from the ore thickener overflow will be stored in a reclaim water pond at the plant site. Process water treatment will consist of clarification followed by filtration. Filter backwash will be returned to the ore thickeners to recover solids. Major users of process water are the demineralized water plant and the cooling tower. The use of tailings pond return water as scrub water, and recovery and recycling of blowndown from various plant operations will minimize process water consumption.

Demineralized water and potable water will be produced at the Toamasina plant by treating process water. The potable water system will chlorinate process water for safe use throughout the facilities. The primary use of demineralized water is to supply the powerhouse deaerator with water for the boilers. Demineralized water will also be used in pressurized systems provided for mechanical seals of agitators in the process plants.

An open re-circulating cooling system will supply cooling water for the entire process plant. Process water will be pumped into the cooling tower basin to maintain the inventory of circulating cooling water. Cooling water chemistry will be controlled by the use of chemical addition and blowdown to control corrosion and biological activity in the system.

Hydrogen Plant

High-purity hydrogen gas will be manufactured by steam reforming desulphurized naphtha, shift conversion and product gas purification using pressure swing adsorption. The minor amount of hydrogen sulphide gas produced during desulphurization of the naphtha feed is routed to flare for incineration. Low-pressure hydrogen is required for hydrogen sulphide production.

Hydrogen Sulphide Plant

High-purity hydrogen sulphide gas will be manufactured at the plant site by reacting hydrogen gas from the hydrogen plant with liquid sulphur supplied from the acid plants. During normal operation there will be no emissions from the hydrogen sulphide plant. On start-up and upsets, excess gas will be burnt to sulphur dioxide gas in a flare stack. Nearly all of the hydrogen sulphide produced will be consumed in sulphide precipitation, with a minor amount consumed in raw liquor reduction.

Sulphuric Acid Plant

Sulphuric acid of 98% purity will be produced at the plant site from elemental sulphur in two sulphur burning double contact, double absorption plants. Waste heat boilers of the sulphuric acid plant trains will be an integral part of the plant facility for generating high-pressure superheated steam. The plant will have eight days of sulphuric acid buffer storage capacity. Most of the sulphuric acid will be consumed in the PAL ore leach with minor usage in the ferric sulphate circuit, the demineralized water plant.

Air

Process and instrument air are supplied to all plant areas by stand-alone air compressors. The compressed air facility includes a backup compressor

Limestone and Lime Plant

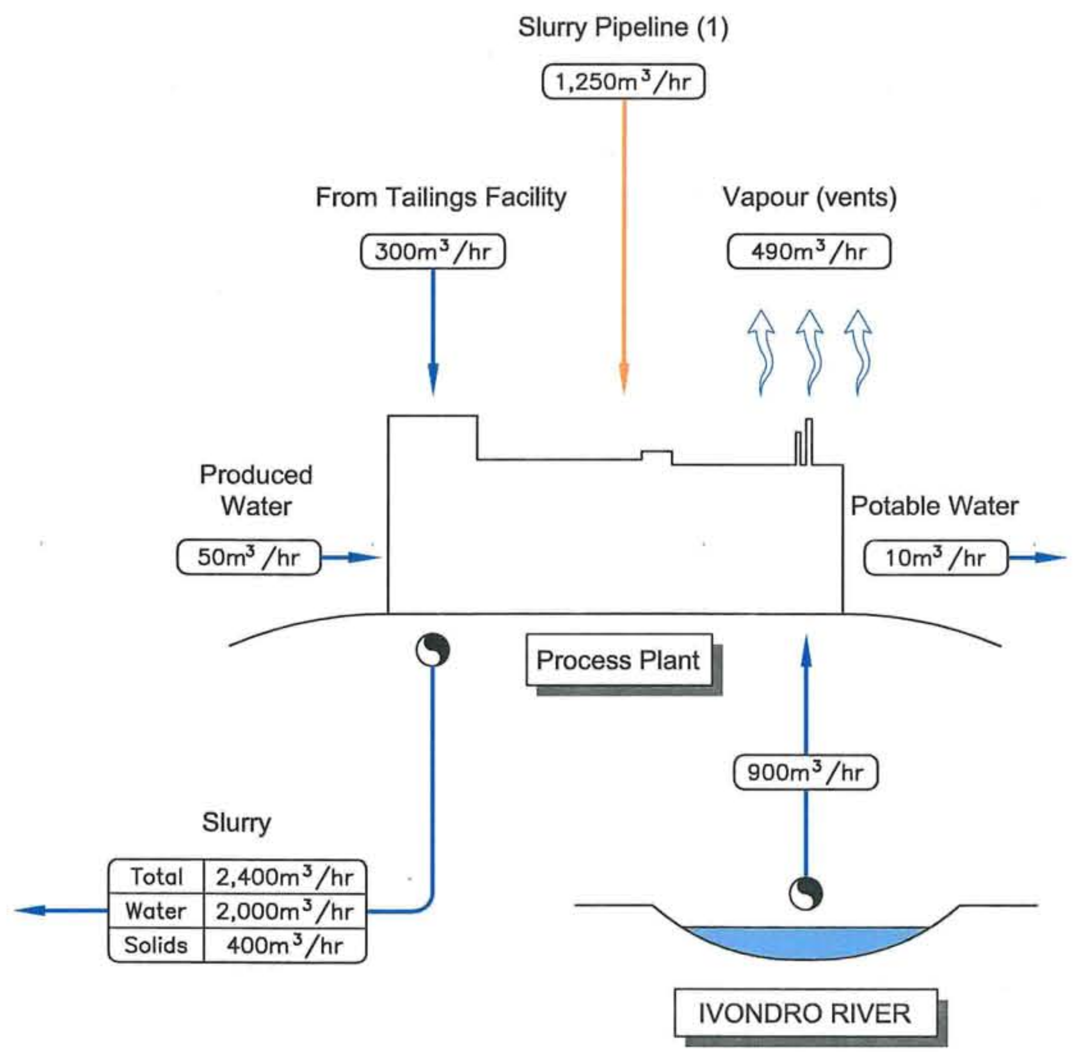
Limestone will be imported via the port of Toamasina, transported to the plant site by train. The crushed limestone stockpiled at the process plant will be reclaimed and split into two streams, one for the production of limestone slurry and the other as feed to the lime plant.

Limestone will be prepared as a solid slurry for use as a neutralizing agent in four locations in the ore leach plant. Limestone for slurry preparation will be crushed and ground in one of two parallel grinding mills with cyclone classifiers. The sized product will be thickened to the required density in a thickener and pumped to the end use locations via a continuously circulating ring pipeline.

Limestone will be calcined in a lime burning plant to produce calcium oxide, which will be slurried in water to produce milk of lime. Milk of lime slurry will be used in the final neutralization step of the tailings slurry.

2.4 WATER MANAGEMENT

The management of water at the plant site is shown in the water balance in Figure 2.1-4. As noted above the largest source of water is from the ore slurry pipeline. Large volumes of water are needed in the process for stream production, cooling and metal extraction processes. The bulk of the demineralized water for boilers will be produced from supplemental water from the Ivondro River. All process water will be treated as part of the neutralization process, and disposed to the tailings facility as a slurry where the solids settle for permanent containment and collected supernatant along with storm water in the tailings facility will be disposed to the ocean. Water vapour emissions (cooling system and steam vents) will account for a large portion of the water loss throughout the process. All site storm water will be segregated such that any potentially contaminated storm water will be used in the process and clean storm water from non process areas will be discharged to the surrounding watershed.



NOTES:

1. *Water fraction only, ore is 45 wt% water, slurry is 40 wt% solids.*

AMBATOVY PROJECT			
AVERAGE WATER BALANCE PROCESS PLANT			
Knight Piésold CONSULTING	P/A NO. NB301-00116/4	REF. N5-0758	REV. 0
	FIGURE 2.1-4		

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2.5 WASTE MANAGEMENT

Non-hazardous waste generated at the process plant will be segregated to allow for suitable re-use and recycle of materials. Clean non-hazardous material that do not have potential for re-use will be disposed in a dedicated containment area within the tailings facility. Hazardous materials will be incinerated in a dedicated waste incinerator on-site with the ash disposed as part of with the tailings following the neutralization process. Similarly, ash from the coal fired burners will be disposed with the tailings to the tailings facility. A dedicated area for waste characterization, segregation and treatment will be located in the utility area of the process plant.

3.1 TOPOGRAPHY AND GEOMORPHOLOGY

3.1.1 Introduction

This section presents the Environmental Assessment for the effects of the process plant on topography and geomorphology, including unique topographic features, as per the Ambatovy Project (the project) Terms of Reference.

3.1.2 Study Area

The process plant Local Study Area (LSA) for topography and geomorphology is the same as the process plant terrestrial study area (a sub-area of the Toamasina region study area) presented in Volume A, Figure 7.2-3. It includes the process plant property and corridors extending to the water intake, marine outfall, Route Nationale (RN) 2, future Logistique Pétrolière Jetty site and future bridge location across the Pangalanes Canal. The study area also includes buffer areas within 500 m of these planned disturbances.

3.1.3 Baseline Summary

The process plant is located about 2 km from the coast. The area is characterized by flat, coastal topography of low to medium relief, dominated by sandy beach ridges extending north-south. Seasonal wetlands are located in the low-lying areas between many of the ridges. The elevation of the plant site varies between 6 and 10 metres above sea level (masl).

Based on a qualitative analysis of the landscape, the process plant LSA is not considered to contain any unique topographic features.

Additional details concerning baseline conditions are provided in Volume I, Section 1.1.

3.1.4 Issue Scoping

The main potential issues relating to topography and geomorphology are:

- initial removal and disturbance of unique or important topographic features important for social or biological reasons; and
- changes in the landscape and underlying geomorphology slope which may represent important issues over the long term to people or the environment.

Depending on the amount of terrain recontouring at the time of reclamation, local changes in topography may have implications for hydrology, hydrogeology, visual effects, growing conditions for flora, habitat for fauna, aquatic habitat and closure planning.

The key question for topography and geomorphology is:

Key Question TG-1 What Effect Will the Process Plant Have on Topography and Geomorphology?

The impact pathways associated with impacts on topography and geomorphology are presented in Volume H, Appendix 9. During construction and operation phases, topographic features of the landscape will be disturbed. Topography will be altered during the construction, operation and closure phases. These impact pathways are valid.

3.1.5 Impact Assessment

3.1.5.1 Assessment Methods

Existing topography was studied using literature and topographic maps. The relative uniqueness of topographic features was assessed by comparing the features to be affected by the project with other features in the LSA. The characteristics of pre-project topography were compared qualitatively with topography following development of the process plant.

3.1.5.2 Assessment Criteria

The assessment criteria used for topography and geomorphology are presented in Table 3.1-1.

Table 3.1-1 Impact Description Criteria for Topography and Geomorphology

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
neutral: no change in topography negative: a change in topography that affects function for human or biological services	negligible: no measurable effect on slopes and landscape-level topographic features low: slight changes in slopes or overall topographic layout moderate: locally prominent changes in slopes or overall topographic layout high: regionally prominent changes in slopes or overall topographic layout	local: effect restricted to the LSA regional: effect extends beyond the LSA	short term: <3 years medium term: 3 to 30 years long term: >30 years	reversible or irreversible	low: occurs once medium: occurs intermittently high: occurs continuously

3.1.5.3 Mitigation

During construction, operations and closure, erosion control measures will be applied as described in Volume D, Section 6 to minimize the formation of gulleys and the removal of surface material due to water and wind erosion.

3.1.5.4 Results

Over the course of construction and operations, and after closure, the project site and associated linear corridors will require minor topographic changes to the existing landscape. Undulating ridges and wetlands will be levelled, and adequate materials will be added to these areas to create pads for the development of plant site facilities and roads. Fill material will be added to complete a terrace for the plant site. This material may be acquired from dune sands in adjacent areas. The flat plant site terrace and associated corridors will be left in a modified state for future industrial use after project closure.

3.1.5.5 Impact Analysis

Residual Impacts

Following mitigation, the residual effects during each project period are summarized in Table 3.1-2.

Table 3.1-2 Potential Effects and Residual Impacts for Topography and Geomorphology

Project Period	Potential Effects	Mitigation	Residual Impacts
construction and operations	changes in the landscape and slopes which may represent important issues over the medium term to stakeholders and biodiversity	erosion control; water management; stable slope engineering	low magnitude/short-term modification undulating topography to level topography

The process plant will have a direct impact on the landscape. Generally, impacts will be long-term, but will be low in magnitude since existing topography at the process plant and along adjacent corridors is nearly level.

An overall residual impact classification for topography and geomorphology for each phase of the project is presented in Table 3.1-3.

Table 3.1-3 Residual Impact Classification for Topography and Geomorphology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Key Question TG-1	**What Effect Will the Process Plant Have on Topography and Geomorphology?**						
construction and operation	negative	low	local	long-term	no	medium	low

Prediction Confidence

The baseline status of topography in the LSA is well understood, and the eventual form of the landscape following project closure has been determined. Overall, the prediction confidence for this assessment is considered high.

Monitoring

No monitoring is proposed specifically for topography and geomorphology. Monitoring of the effectiveness of erosion control measures, slope stability and reclamation success are described in Volume D, Section 6.

3.1.5.6 Conclusions

The process plant will have a low effect on topography, beginning in the construction phase and continuing indefinitely.

3.2 SOILS

3.2.1 Introduction and Study Area

This section presents the Environmental Assessment for the effects of the plant site facility on soils, as per the Ambatovy Project (the project) Terms of Reference.

The plant site study area for soils is the plant site project footprint study area presented in Volume A, Section 7, Figure 7.2-3. It includes all of the plant site facility direct disturbance areas.

3.2.2 Baseline Summary

3.2.2.1 Plant Site Soils

The process plant is located on the east coast of Madagascar just south of Toamasina, in an area of flat coastal topography dominated by ridges of sand. A regional overview is provided in Volume E, Section 3.3.

Incidental soil information has been collected as part of the geotechnical investigations carried out by SNC Lavalin and Geopractica (Geopractica 2004). Soils in the area are developed on stabilized dune sand. In the low lying areas, humic material has accumulated, and soil horizons showed evidence of reduction processes which indicate that the soil is at least periodically saturated with water. The upper landscape positions were well to rapidly drained, with a heavily oxidized B horizon. From the description contained in Geopractica (2004) it is likely that these soils are Spodosols or Entosols. More field studies would be required to confirm these assumptions.

Soils in the process plant area are high in sand and if disturbed would be highly susceptible to wind and water erosion.

The sandy soils in the process plant area are generally unsuitable for reclamation due to their coarse texture. However, certain horizons in the low-lying areas enriched with organic material may be useful as a reclamation material. This material could be salvaged and used to reclaim temporary disturbances associated with the construction of the processing plant.

Additional details concerning baseline conditions are provided in Volume I, Appendix 3.1.

3.2.3 Impact Assesssment

3.2.3.1 Issue Scoping

The list of issues from the Terms of Reference (Volume H, Appendix 1) and the public consultation program (Volume A, Section 6) were reviewed to focus the soil assessment on key issues and group the issues into common themes.

As part of this process, an interaction matrix was used to evaluate all possible plant site activities and facilities with soil resources (Table 3.3-1). The interactions were rated to highlight the key issues and to help focus the assessment.

Only those activities rated moderate or high were analyzed in detail in the assessment.

The main potential issues relating to soils are:

- soil removal and disturbance;
- soil erosion;
- loss of soil nutrients;
- soil compaction;
- soil contamination; and
- reclamation.

Many of these issues are inter-related. For example soil removal and disturbance is related to loss of soil nutrients.

The key question for soils is:

Key Question ST-1 What Effect Will the Plant Site Facility Have on Soils?

A linkage diagram for potential impact pathways is provided in Volume H, Appendix 9. Table 3.3-1 presents the impact of plant site activities with soil resources, focusing on key issues.

Table 3.2-1 Project Interaction Matrix

Project Activities or Facilities	Soil[a]	Issue	Comments
pre-construction phase			
geotechnical drilling	N	increased short-term soil erosion risk on slopes >10%	short-term issue
construction and operation phase			
vegetation clearing	H	wind and water erosion; soil compaction from equipment	water erosion risk will be high until exposed areas revegetated
topsoil removal	M to H	wind and water erosion risk increases, loss of soil quality (nutrient loss, soil compaction)	impact depends on length of time soil exposed
plant site construction	M to H	wind and water erosion; soil compaction from equipment	impact depends on length of time soil exposed
plant site operation	L to M	soil contamination	spills will be cleaned up as required
reclamation and closure phase			
removal of equipment	P	removal of contamination source	positive effect
site remediation	P	remediation of any contamination	positive effect
reclamation	P	reclamation of disturbed areas	positive effect

[a] Interaction Ratings: N – Negligible, L – Low, M – Moderate, H – High and P – Positive.

Impact Pathways

Key Question ST-1 analyzes the effects associated with construction, operation and reclamation of the plant site on the loss or alteration of soil within the Local Study Area (LSA).

Activities resulting in the direct loss or alteration of soil in the plant site area include site clearing and surface disturbance to permit plant construction. Area preparation for facility construction will involve the removal of the soil cover.

Plant site facility construction will result in vegetation removal, thereby exposing the soil and increasing the probability for erosion.

Soil compaction results in a reduction in porosity and an increase in soil bulk density. The potential loss of soil structure from soil compaction can affect vegetation growth, especially root development, aeration and drainage. Plant site construction will involve equipment traffic and activity on soils with possible compaction.

Spills and leaks during operation can result in the alteration of soil chemistry and physical properties, which in turn can affect vegetation, surface water and groundwater quality.

Little topsoil is present in the area and the period to closure is in any case too long to stockpile topsoil. The topsoil will not be replaced following closure, and so loss of nutrients may occur.

Assessment Methods

Soil types directly affected by the plant site were quantified by Geographic Information System (GIS) analysis using the following process:

- the GIS quantified areas of vegetation types to be disturbed within the plant site footprint. The vegetation types were used to rate the water erosion risk of soils of existing soil based on the disturbance types; and
- impact ratings were determined based on the net permanent loss of soils during the construction and operations phase.

3.2.3.2 Assessment Criteria

The criteria used to rate soil residual impacts are outlined in Table 3.3-2.

Table 3.2-2 Assessment Criteria for Soils

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
positive, **negative** or **neutral** for the measurement endpoints	**negligible**: no measurable effect (<1%) **low**: <10% **moderate**: 10 to 20% **high**: >20%	**local**: effect restricted to the LSA **regional**: effect extends beyond the LSA into the region **beyond regional**: effect extends beyond the region	**short-term**: <3 years **medium-term**: 3 to 30 years **long-term**: >30 years	**reversible** or **irreversible**	**low**: occurs once **medium**: occurs intermittently **high**: occurs continuously

3.2.3.3 Mitigation

Soil Erosion

Soil erosion is the displacement of soil by wind or water action. The potential amount of water erosion expected on land may be calculated by the Universal Soil Loss Equation (Wischmeier and Smith 1961; Gee et al. 1976). Details are provided in Volume B, Section 3.3.

The soil erodibility factor (K) is affected by organic matter content and texture. Soils high in silt and very fine sand are more susceptible to water erosion than other soils.

Wind and water erosion risk in the LSA is low when there is a vegetative cover. During disturbance, the risk of wind and water erosion will increase. The risk of wind erosion depends on soil texture, moisture and organic matter content, with sandy soils of the plant site having a higher risk. Water erosion risk increases where slopes exceed 10% and fine-textured sub soils underlay coarse-textured soils. The generally flat surface of the plant site reduces the risk of water erosion. However, to further prevent soil erosion and potential sedimentation from occurring during construction, soil exposure will be minimized and surface runoff controlled, especially during wet weather and in areas close to watercourses.

To prevent water erosion, appropriate site drainage will be constructed to direct surface runoff to suitable containment areas or discharge points.

Loss of Soil Nutrients

Tropical soils are very low in nutrients, with low pH, low phosphorus availability and possible aluminum and manganese toxicity. Nutrient availability is closely tied with soil organic matter content. The soils in this area are very low in nutrients. As noted above, new vegetation growth will be promoted in the areas receiving the stripped soils.

Compaction

Mitigation that will be implemented to prevent or alleviate compaction includes the following:

- minimize the number of passes on an area once reclaimed;
- cultivate compacted soil before revegetation; and
- use deep-rooted vegetation to loosen the compaction.

Soil Contamination

General mitigation to prevent soil contamination will include the following:

- all process areas will be self contained, leak detection/collection systems will be in place and any spills will be collected for reuse or treatment; and
- any spills in non process areas will cleaned up promptly.

3.2.3.4 Results

A total of 322 ha of soils will be disturbed by the plant site over the life of the project (Table 3.3-3). All stripped soil will be placed in areas where vegetation growth will be promoted. The planned land use for the plant site following closure will likely be industrial, so no reclamation to a natural ecosystem is currently planned. Therefore, there will be a permanent loss of 322 ha of soils following plant site construction and operation (Table 3.3-3).

Table 3.2-3 Disturbance of Soil and Vegetation Types in the Process Plant Area

Soil Erosion Risk	Vegetation Types	Area (ha)	Percent of LSA (%)
low	access corridor, forested vegetation, non-forested vegetation (except tavy)	318	99
moderate	tavy matrix	4	1
total		**322**	**100**

3.2.3.5 Impact Analysis

Residual Impacts

The environmental consequence of the plant site on soils is rated as high during construction, high during operation and high following closure (Table 3.3-4).

Plant site construction and operation will result in a permanent disturbance of 322 ha as plant site construction is completed. Also, the erosion risk of soils will increase with the removal of vegetation. Due to the long-term permanent disturbance of soils during operation and closure, the environmental consequence was rated as high. If impacted areas are reclaimed in the future, impacts will be reduced to low.

Table 3.2-4 Residual Impact Classification for Soils

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Key Question ST-1 What Effect Will the Plant Site Have on Soils?							
construction	negative	high	local	short-term	no	low	high
operations	negative	high	local	long-term	no	low	high
closure	negative	high	local	long-term	yes	low	high

3.2.3.6 Prediction Confidence

The soil impact classification relies heavily on the future land use of the plant site. However, it is envisaged that the site will remain industrial. If the plant site was eventually reclaimed to a natural land use, the environmental consequence would be lower.

3.2.3.7 Monitoring

The proponent will implement monitoring programs to ensure soil protection programs are successful and adjusted if necessary. The plant site monitoring plan will consist of:

- ensuring functionality of the on site drainage and containment systems;
- ensuring success of the vegetation growth in the areas where stripped soil has been placed; and
- documenting the monitoring observations.

3.2.4 Conclusions

Following mitigation, the plant site will have a high environmental consequence for soils during the construction phase and a high environmental consequence during operations and closure due to the long-term permanent loss of soils. The potential impact to soils has implications for vegetation, hydrology and water quality. These issues are addressed in other sections of the EA.

3.3 CLIMATE AND AIR QUALITY

3.3.1 Introduction

This section of the Ambatovy Project (the project) Environmental Assessment (EA) presents an air quality impact assessment of the process plant, port expansion and tailings facility as required by the Terms of Reference (ToR) from the Madagascar National Office for the Environment (ONE 2004). The information presented includes details on the following:

- air quality concerns identified by stakeholders and regulators;
- project activities that may affect air quality;
- mitigations incorporated in the project design for these impacts;
- the existing air quality in the study area;
- the dispersion model used for the assessment;
- impact assessment approach and results for key air quality issues;
- monitoring recommendations and identified mitigations to reduce residual air quality impacts associated with the process plant; and
- qualitative assessment of the tailings facility and port expansion associated with the Ambatovy Project.

Potential air quality issues identified in the EA include:

- combustion, process and dust emissions from the construction and operations phases of the process plant;
- combustion and dust emissions from the construction phase of the tailings facility; and
- combustion and dust emissions from the construction and operations phases of the port expansion.

The air quality assessment includes a comprehensive evaluation of the effects on atmospheric concentrations and deposition values that could result from emissions from all significant project sources. Although the air quality assessment is complete as a stand-alone evaluation, it also forms an integral part of the overall evaluation of the project.

The focus of the air assessment is to evaluate changes in the regional air quality and determine compliance with applicable regulations. The effects of air quality on environmental receptors such as human health, wildlife health, aquatic resources and terrestrial resources are addressed in other appropriate sections of Volume D.

3.3.2 Assessment Boundaries

3.3.2.1 Temporal Scope

Temporal considerations for the EA are based on the Ambatovy Project description and they vary among EA components because of the different ways the project components interact with the environment. The air assessment does not represent fixed points in time. Rather, it was completed for the operations phase of the process plant during maximum production. Air emissions from the tailings facility and the port expansion during the operations phase were considered to be negligible compared to the process plant emissions; therefore, they were not included in the assessment.

3.3.2.2 Spatial Scope

The study area selected for the air quality assessment of the process plant, port expansion and tailings facility is 26 x 23 km in size, centred on the process plant site, as illustrated in Volume A, Section 7, Figure 7.2-3. It includes the tailings facility and the city of Toamasina. Within this 598 km^2 study area is where the majority of the air quality effects associated with the process plant, tailings facility and port expansion are expected to occur. The study area has also been used when presenting the air quality predictions graphically.

One of the objectives of the air quality evaluation is to help address questions from regional stakeholders regarding the possible effects of the project on the air quality in their communities. To facilitate this, air quality predictions were made for each of the community receptors indicated in Table 3.3-1.

Table 3.3-1 Community Locations Near Process Plant

Community	Distance [km]	Direction
Ambarimilambana	10.9	SW
Ambatoroa	1.6	NW
Amboakarivo	2.7	S
Ambodikily	15.5	SW
Ambodisaina	6.8	N
Amboditandroho	9.2	SSW
Ampasimbola	2.2	W
Ampasinambo	11.7	WSW
Ampihaonana	11.0	NNW
Ampirasantany	1.5	SE
Analabe	1.8	SW
Antananambo	5.3	WSW
Antanandava	2.6	NNW
Antsiranandakana	2.0	WSW
Mahatsara	5.5	SSW
Manamboasio	1.4	NNE
Toamasina	7.8	NE
Vohitsara	7.9	W

Note: Distance and direction relative to centre of process plant.

3.3.3 Assessment Methodology

The air quality assessment of the process plant made extensive use of an air dispersion model to evaluate potential air quality effects due to emissions from the process plant. The steady-state (2-D) version of the CALPUFF dispersion model was determined to be the best model for assessing the air emissions from the process plant. This modelling system has been reviewed extensively and is recommended for use by regulators in various jurisdictions. One advantage of CALPUFF is that it can account for the chemical transformations of emitted SO_2 and NO_X as well as model wet and dry deposition.

The dispersion modelling completed for the air quality assessment included the following key aspects:

- selection of dispersion modelling receptors;
- conversion of predicted NO_X concentrations to NO_2 concentrations using the Ozone Limited Method (OLM); and
- use of three years of meteorological data from Toamasina.

A detailed description of the air dispersion modelling methodology is presented in Volume I, Appendix 4.2.

3.3.3.1 Assessment Criteria

Madagascar does not have ambient air quality criteria; therefore, World Bank and World Health Organization (WHO) guidelines were used. The World Bank provides recommendations for certain pollutant thresholds (i.e., SO_2, NO_2, PM_{10} and Total Suspended Particulate (TSP) when specific country or project guidelines are not available. The thresholds used for defining a moderately degraded airshed were used as the criteria for this project (World Bank 1998). The World Bank General Environmental Guidelines were also shown for comparison. In the absence of World Bank guidelines, the WHO guidelines were used, including for lead and mercury (WHO 2000). Table 3.3-2 summarizes the air quality criteria used for the process plant.

Table 3.3-2 Ambient Air Quality Criteria

Parameter	World Bank[a]		WHO[c]	Criteria Used for Project
	General	Moderately Degraded Airshed[b]		
Sulphur Dioxide (SO_2)				
24-hour average [µg/m³]	125	150	125	150
annual average [µg/m³]	50	80	50	80
Nitrogen Dioxide (NO_2)				
24-hour average [µg/m³]	150	150	—	150
annual average [µg/m³]	—	100	40	100
Hydrogen Sulphide (H_2S)				
1-hour [µg/m³]	—	—	7[d]	7[d]
24-hour average [µg/m³]	—	—	150	150
Total Suspended Particulate (TSP)				
annual average [µg/m³]	50	80	—	80
PM_{10}				
24-hour average [µg/m³]	—	150	—[e]	150
annual average [µg/m³]	—	50	—[e]	50
Metals				
Lead				
annual [µg/m³]	—	—	0.5	0.5
Mercury				
annual [µg/m³]	—	—	1	1

(a) Source: World Bank 1998.

(b) These values are based on pollutant-specific recommendations from the World Bank when country guidelines are not available.

(c) Source: WHO 2000.

(d) In the absence of a 1-hour H_2S criteria, the WHO 30-minute H_2S recommended odour threshold was used.

(e) WHO recommends a risk-based approach to assessing the effects of PM10 therefore no guidelines are provided.

- = No criteria available.

The impact assessment methodology used for the Ambatovy Project has been described in Volume A, Section 7 and involves the evaluation of residual effects. The residual effects for air were classified using quantification criteria to determine environmental consequence. Each impact is first described in terms of the following criteria: magnitude, geographic extent and duration. Two additional criteria were also used for the air quality assessment: reversibility and frequency. Table 3.3-3 details the Impact Description Criteria for the air quality component of the EA.

Table 3.3-3 Impact Description Criteria for Air Quality

Resource	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
Air Quality	**positive:** a decrease in emissions and/or ambient concentrations **negative:** an increase in emissions and/or ambient concentrations	magnitude varies with the air contaminant being evaluated; specifics provided in Table 3.3-4.	**local**: effect restricted to the LSA **regional:** effect extends beyond the LSA **beyond regional**: effect extends beyond the RSA	**short-term**: <3 years **medium-term**: 3 to 30 years **long-term**: > 30 years	**reversible** or **irreversible**	**low**: occurs once **medium**: occurs intermittently **high**: occurs continuously

Reversibility indicates the potential for recovery of the ecological end point. An effect is defined as not reversible if the resource element cannot be restored to pre-impact condition within the long-term (as defined under duration in Volume A, Section 7). The impact on air quality is always reversible.

Frequency describes how often the effect occurs within a given time period and is classified as low, medium or high in occurrence.

Direction of an impact may be positive or negative with respect to the key question (e.g., a reduction in predicted air concentrations would be considered as positive, whereas an increase in air concentrations would be considered negative).

Magnitude is a measure of the degree of change in a measurement or analysis endpoint, and is classified as negligible, low, moderate or high. The categorization of the impact magnitude was based on a set of criteria, ecological concepts and professional judgment. The air quality resources evaluated and the magnitude criteria used to evaluate the residual effects are outlined in Table 3.3-4.

Table 3.3-4 Magnitude Classifications for Air Quality

Parameter	Magnitude[a]			
	Negligible	Low	Moderate	High
24-hour SO_2 concentration [µg/m³]	no increase	≤ 7.5	≤ 150	> 150
annual SO_2 concentration [µg/m³]	no increase	≤ 4	≤ 80	> 80
24-hour NO_2 concentration [µg/m³]	no increase	≤ 7.5	≤ 150	> 150
annual NO_2 concentration [µg/m³]	no increase	≤ 5	≤ 100	> 100
1-hour H_2S concentration [µg/m³]	no increase	≤ 0.35	≤ 7	> 7
24-hour H_2S concentration [µg/m³]	no increase	≤ 7.5	≤ 150	> 150
annual TSP concentration [µg/m³]	no increase	≤ 4	≤ 80	> 80
24-hour PM_{10} concentration [µg/m³]	no increase	≤ 7.5	≤ 150	> 150
annual PM_{10} concentration [µg/m³]	no increase	≤ 2.5	≤ 50	> 50
annual lead concentration [µg/m³]	no increase	≤ 0.025	≤ 0.5	> 0.5
annual mercury concentration [µg/m³]	no increase	≤ 0.05	≤ 1	> 1

(a) The magnitude is based on the maximum prediction values outside the property boundary.

Generally, the magnitude would be classified as "negligible" if there was no increase predicted to result from the process plant emissions. A "low" magnitude would be assigned when an increase was predicted, however the maximum value remains below 5% of the criteria. A "moderate" magnitude would be assigned when the maximum concentrations are below the criteria but above 5% of the criteria. A "high" magnitude would be assigned when the maximums are greater than the criteria. In some cases, applicable World Bank guidelines were not available. In these cases, WHO criteria were substituted.

Table 3.3-5 shows the screening system for determining environmental consequence. This screening system is based on the fact that the geographic extent of the air quality impacts is local, direction is negative, the duration is medium-term (3 to 30 years) and the impacts are reversible.

Table 3.3-5 Air Quality Screening System of Environmental Consequences

Magnitude	Frequency	Environmental Consequence
negligible	all	negligible
low	low	low
low	moderate	low
low	high	low
moderate	low	low
moderate	moderate	low
moderate	high	low
high	low	moderate
high	moderate	moderate
high	high	moderate

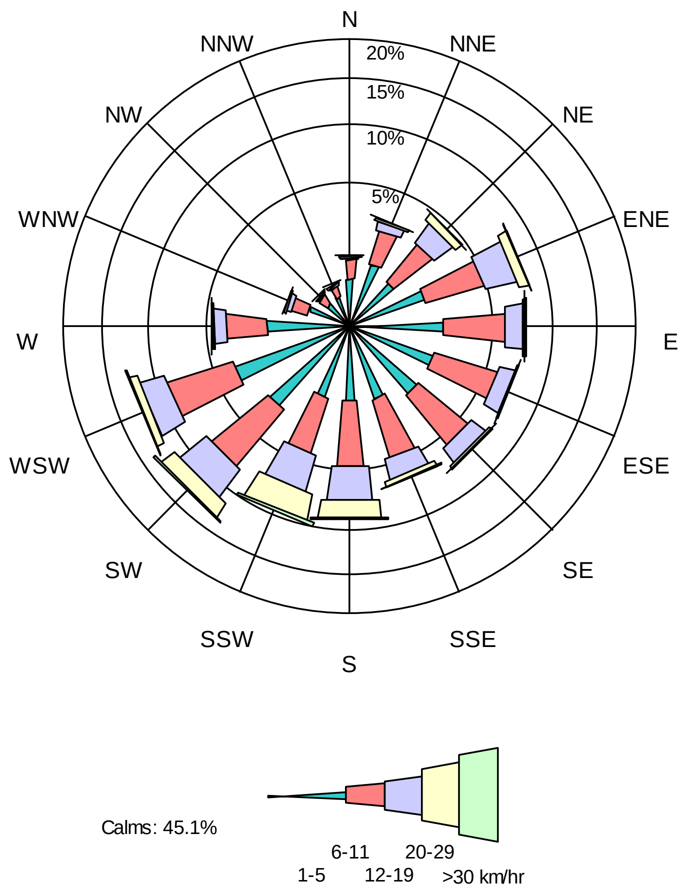
Note: Screening system based on the fact that the geographic extent is local, direction is negative and the impacts are reversible.

3.3.4 Baseline Summary

The process plant will be located southwest of the city of Toamasina on the east coast of Madagascar. Daily maximum temperatures at Toamasina range from 25 to 30°C during the year and daily minimum temperatures range from 17 to 23°C. Toamasina receives one of the highest rainfall amounts per year on the island (3,368 mm) with rain occurring an average of 255 days per year (WMO 2005). A detailed analysis of precipitation at Toamasina is provided in the Hydrology Baseline (Volume I, Appendix 8.1).

Figure 3.3-1 shows a windrose from Toamasina for the period 2001 to 2003. The predominant wind directions are from the south to the west-southwest sector. The average annual wind speed is 6 km/hr with maximum hourly speeds over 60 km/hr. One significant quality of the winds at Toamasina is the high frequency of calm conditions (45.1%). There is a definite diurnal pattern in the winds where calm conditions (less than 3 km/hr) typically occur at night.

Figure 3.3-1 Observed Winds at Toamasina (2001 to 2003)



Since the process plant is close to the city of Toamasina and other industries are nearby, the air quality is expected to be degraded compared to rural areas. There is limited air quality information available for Madagascar; however, a review of air quality in African countries shows that SO_2 and particulate matter concentrations are usually elevated in populated areas where low-grade coal and wood were used as fuel (Engelbrecht et al. 2001, Emberson et al. 2001). The World Health Organization (WHO) states that the average concentration of PM_{10} in urban centres in Madagascar is between 21 and 25 $\mu g/m^3$ (website: WHO 2005).

3.3.5 Impact Assessment

3.3.5.1 Issue Scoping

Through consultation with stakeholders (Volume A, Section 6) and review of previous environmental assessments for resource developments in Madagascar and elsewhere, specific air quality issues were identified. There were concerns raised about carbon emissions, noxious gases and greenhouse gases. The following three main factors could affect air quality in the process plant study area:

- combustion emissions (i.e., coal-fired boilers);
- process emissions; and
- dust emissions (i.e., wind-blown dust from stockpiles).

The key indicators are sulphur dioxide (SO_2), oxides of nitrogen (NO_X), nitrogen dioxide (NO_2), total suspended particulates (TSP), particulate matter with diameter less than 10 µm (PM_{10}), hydrogen sulphide (H_2S), trace metals and greenhouse gases.

Sulphuric acid mist was not considered a key indicator for air quality. Much of the sulphuric acid in the air is formed from SO_2 (sulphur dioxide) released when fuels such as coal, oil and gas are burned. The released SO_2 slowly forms SO_3 (sulphur trioxide), which reacts with water in the air to form sulphuric acid. Sulphuric acid can also be emitted directly from industrial sources like the process plant. Sulphuric acid exists as particles or droplets which dissolve in clouds, fog, rain or snow, resulting in dilute acid solutions that are removed from the atmosphere through wet deposition processes. Since sulphuric acid is removed through wet deposition and since there are no air quality criteria for sulphuric acid, it was not considered a key indicator for the air quality assessment.

A total of two were developed for the air quality as follows:

Key Question AQ-1 How Will The Development of the Process Plant, Port and Tailings Facility Affect Air Quality?

Key Question AQ-2 How Will The Development of the Process Plant Affect the Production And Management of Greenhouse Gases?

The main factors that may affect air quality near the tailings facility are vehicle exhaust emissions during construction. These emissions are expected to be temporary and localized. Negligible effects on air quality are predicted during operation of the tailings facility. Due to the nature of the tailings, there will not be any volatile compounds emitted from the tailings facility. However, there may be localized emissions from vehicles needed for ongoing maintenance of the facility.

The main factors that may affect air quality at the port expansion are vehicle exhaust emissions during the construction of the port expansion as well as emissions from increased marine and land traffic due to the project. Since the construction activities will be localized and temporary, changes to air quality are expected to be negligible during construction. Marine and land traffic are expected to increase during the operations phase of the project, however, vehicle traffic emissions will be negligible in the context of all emissions from the project in the study area.

3.3.5.2 Key Question AQ-1 How Will The Development of the Process Plant, Port and Tailings Facility Affect Air Quality?

Most air effects are expected to occur during the process plant operations phase as shown in the linkage diagrams for air quality (Volume H, Appendix 9). Changes in air quality may have an effect on vegetation, aquatic resources, wildlife health and/or human health. Air quality effects from the tailings facility and port expansion were considered negligible; therefore, they were not included in the assessment.

Emissions Sources

The activities during the operations phase of the process plant will result in the release of emissions of SO_2, NO_X, particulate matter and H_2S to the atmosphere. The emissions during normal maximum production were provided by Dynatec. Sulphur dioxide emissions from the flares and fugitive particulate emissions from the coal and limestone stockpiles were derived by Golder Associates (Golder), based on information from Dynatec. A detailed discussion of emission assumptions is provided in Volume I, Appendix 4.2. The process plant emissions are summarized in Table 3.3-6.

During periods with high wind speeds, it is possible for dust to be eroded from exposed areas of soil and stockpiled materials at the process plant, tailings facility and port site. The emissions due to these events can be calculated; however, it is difficult to model the releases. The CALPUFF dispersion model allows the user to input a threshold wind velocity, below which the emissions of wind-blown dust will not occur. In assessing the particulate releases from the stockpiles, it was determined that wind erosion of the exposed areas would occur when the wind speeds exceeded 5.3 m/s. Such wind speeds were observed to occur at the process plant site 1,251 hours during the year.

Flare emissions during normal operations were assumed to be continuous. Sulphur dioxide emissions were calculated based on the gas composition and volumetric flow rate provided by the proponent. Two other flaring scenarios – maintenance and emergency flaring – were modelled and the results are presented in Volume I, Appendix 4.2.

Table 3.3-6 Process Plant Air Emissions Summary

Source	Emission Rate [t/d]				
	SO_2	NO_X	PM_{10}	TSP	H_2S
leach - liquor neutralization tank (combined)	—	—	—	—	0.239
leach - sulphide area flare	0.042	0.000	—	—	0.000
leach - vent scrubber	—	—	—	—	0.001
utilities - hydrogen plant (combined)	0.058	0.084	—	—	—
utilities - hydrogen sulphide flare stack	0.101	0.000	—	—	0.001
utilities - sulphur melting, neutralization and filtration	0.005	—	—	—	—
utilities - acid plant	6.048	—	—	—	—
utilities - limestone crushing	—	—	0.006	0.006	—
utilities - limestone calcining	1.342	0.720	0.048	0.048	—
utilities - lime slaking	—	—	0.001	0.001	—
utilities – coal-fired boilers	8.194	4.421	0.370	0.370	—
coal stockpile	—	—	0.009	0.017	—
limestone stockpile	—	—	0.009	0.019	—
total[(a)]	**15.789**	**5.225**	**0.443**	**0.460**	**0.242**

"—" indicates no emissions from this source.

(a) Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

Note: Trace metals are scaled off of particulate predictions based on the metal content of coal; therefore, emissions of metals are not presented.

Mitigation

The air quality assessment is based on the preliminary design of the process plant which incorporates some emission controls. The air quality predictions were used to incorporate appropriate emission controls that would reduce air quality impacts. Dynatec has committed to installing equipment that will meet applicable standards and guidelines.

Results

Key Compounds

The expected emissions of SO_2, NO_X, TSP, PM_{10} and trace compounds (including metals) from the process plant were input into the CALPUFF dispersion model to determine ground-level concentrations across the study area and at selected regional communities. The CALPUFF model was run in the steady-state (2-D) mode using three years of meteorological observations from Toamasina. A summary of the maximum ground level modelling predictions is presented in Table 3.3-7. The results and figures are also presented in Volume I, Appendix 4.2.

Table 3.3-7 Maximum Ground Level Air Quality Predictions in the Process Plant Study Area

Parameter	Averaging Period	
	24-Hour	Annual
Sulphur Dioxide (SO_2)		
maximum SO_2 concentration [µg/m³]	69.0	7.9
maximum SO_2 concentration outside property boundary [µg/m³]	68.4	7.8
distance to maximum concentration [km][(a)]	1.0	1.0
direction to maximum concentration[(a)]	WNW	W
Wold Bank SO_2 Criteria [µg/m³]	**150**	**80**
Nitrogen Dioxide (NO_2)		
maximum NO_2 concentration [µg/m³]	20.3	2.3
maximum NO_2 concentration outside property boundary [µg/m³]	20.3	2.3
distance to maximum concentration [km][(a)]	1.3	1.0
direction to maximum concentration[(a)]	WNW	W
World Bank NO_2 Criteria [µg/m³]	**150**	**100**
Total Suspended Particulate (TSP)		
maximum TSP concentration [µg/m³]	—	2.4
maximum TSP concentration outside property boundary [µg/m³]	—	0.8
distance to maximum concentration [km][(a)]	—	0.5
direction to maximum concentration[(a)]	—	NNE
World Bank TSP Criteria [µg/m³]	**—**	**80**
Particulate Matter (PM_{10})		
maximum PM_{10} concentration [µg/m³]	11.1	1.4
maximum PM_{10} concentration outside property boundary [µg/m³]	4.5	0.5
distance to maximum concentration [km][(a)]	0.5	0.5
direction to maximum concentration[(a)]	NNE	NNE
World Bank PM_{10} Criteria [µg/m³]	**150**	**50**

(a) Distance and direction are from the centre of the process plant to the maximum concentration outside the property boundary.

Tables 3.4-8 to 3.4-10 show the maximum predicted 24-hour and annual SO_2, NO_2, TSP and PM_{10} concentrations at the communities due to emissions from the process plant. Background concentrations due to community activities have not been added to the predictions due to a lack of existing ambient air quality information. None of the concentrations exceed the World Bank criteria.

Table 3.3-8 Maximum Predicted SO_2 Concentrations in Communities

Community	Maximum SO_2 Concentration [µg/m³]	
	24-Hour	Annual
Ambarimilambana	14.1	1.2
Ambatoroa	54.6	5.7
Amboakarivo	31.2	1.5
Ambodikily	12.7	1.1
Ambodisaina	26.3	2.8
Amboditandroho	19.3	1.0
Ampasimbola	43.1	4.9
Ampasinambo	11.5	1.3
Ampihaonana	9.9	1.4
Ampirasantany	13.7	1.3
Analabe	39.9	4.0
Antananambo	23.1	2.9
Antanandava	32.6	3.7
Antsiranandakana	48.8	5.7
Mahatsara	30.3	1.5
Manamboasio	37.6	5.1
Toamasina	21.9	3.0
Vohitsara	28.1	1.8
World Bank SO2 Criteria [µg/m³]	**150**	**80**

Note: Predicted community concentrations do not include background values.

Table 3.3-9 Maximum Predicted NO_2 Concentrations in Communities

Community	Maximum NO_2 Concentration [µg/m³]	
	24-Hour	Annual
Ambarimilambana	4.3	0.3
Ambatoroa	16.7	1.8
Amboakarivo	8.3	0.4
Ambodikily	4.1	0.3
Ambodisaina	7.7	0.8
Amboditandroho	5.8	0.3
Ampasimbola	13.6	1.5
Ampasinambo	3.4	0.4
Ampihaonana	3.5	0.5
Ampirasantany	5.4	0.4
Analabe	11.2	1.0
Antananambo	7.4	0.9
Antanandava	10.3	1.1
Antsiranandakana	14.5	1.7
Mahatsara	8.6	0.4
Manamboasio	9.4	1.3
Toamasina	7.7	0.9
Vohitsara	8.5	0.5
World Bank NO_2 Criteria [µg/m³]	**150**	**100**

Note: Predicted community concentrations do not include background values.

Table 3.3-10 Maximum Predicted Particulate Concentrations in Communities

Community	Maximum TSP Concentration [μg/m³]	Maximum PM_{10} Concentration [μg/m³]	
	Annual	24-Hour	Annual
Ambarimilambana	0.0	0.4	0.0
Ambatoroa	0.2	1.5	0.2
Amboakarivo	0.0	0.7	0.0
Ambodikily	0.0	0.3	0.0
Ambodisaina	0.1	0.8	0.1
Amboditandroho	0.0	0.5	0.0
Ampasimbola	0.1	1.1	0.1
Ampasinambo	0.0	0.3	0.0
Ampihaonana	0.0	0.3	0.0
Ampirasantany	0.1	0.5	0.1
Analabe	0.1	1.1	0.1
Antananambo	0.1	0.6	0.1
Antanandava	0.1	0.9	0.1
Antsiranandakana	0.2	1.3	0.2
Mahatsara	0.0	0.7	0.0
Manamboasio	0.2	1.9	0.2
Toamasina	0.1	0.6	0.1
Vohitsara	0.1	0.7	0.1
World Bank Criteria [μg/m³]	**80**	**150**	**50**

Note: Predicted community concentrations do not include background values.

Table 3.3-11 shows the 1-hour and 24-hour H_2S concentrations. All concentrations are below the relevant criteria except for 1-hour H_2S. One-hour H_2S concentrations are above the WHO recommended 30-minute odour threshold of 7 μg/m³ at some communities near the plant site. Unlike the 24-hour H_2S criteria, the 1-hour criteria is based solely on odour perception. Volume D Section 5.4, discusses odour from the process plant.

Annual concentrations of lead and mercury were also predicted at the communities and all values were well below the WHO annual criteria of 0.5 and 1 μg/m³, respectively. The results are shown in Appendix 4.2, Section 4.4.4.

Table 3.3-11 Maximum Predicted H_2S Concentrations in Communities

Community	Maximum 1-Hour Concentration [µg/m³]	Frequency Above 7 µg/m³	Maximum 24-Hour Concentration [µg/m³]
Ambarimilambana	4.3	0.0%	0.6
Ambatoroa	33.7	2.5%	4.9
Amboakarivo	20.6	0.2%	2.2
Ambodikily	5.7	0.0%	0.6
Ambodisaina	16.0	0.1%	1.5
Amboditandroho	7.4	0.0%	1.2
Ampasimbola	24.0	1.4%	5.3
Ampasinambo	4.0	0.0%	0.6
Ampihaonana	7.0	0.0%	0.6
Ampirasantany	35.0	0.1%	1.5
Analabe	29.5	1.1%	3.7
Antananambo	15.8	0.1%	1.2
Antanandava	20.4	0.9%	3.0
Antsiranandakana	27.5	1.4%	3.5
Mahatsara	15.9	0.2%	2.0
Manamboasio	33.5	2.8%	8.8
Toamasina	7.8	0.0%	1.1
Vohitsara	9.4	0.0%	1.5
WHO H_2S Criteria [µg/m³]	**7**	**—**	**150**

Note: Predicted community concentrations do not include background values.

Acidification

The preferred method for evaluating acid deposition is to determine Potential Acid Input (PAI), which takes into account the acidifying effect of the sulphur and nitrogen species. A detailed description of PAI is presented in Volume I, Appendix 4.2. The SO_2 and NO_X emissions from the process plant were input into the CALPUFF dispersion model and PAI values predicted. The maximum annual PAI value predicted outside the plant property boundary was 21.8 keq/ha/yr, which is located on the northern edge of the property boundary. The PAI predictions are shown graphically in Appendix 4.2, Figure 4.2-24. The average PAI value over the study area is 0.4 keq/ha/yr. The effects of PAI on various ecosystems are discussed in appropriate biological sections of Volume D.

Odour

The effect of the process plant emissions on odours in nearby communities were evaluated by predicting ground-level concentrations of odourous compounds with the CALPUFF model in steady-state (2-D) mode. The primary source of odourous emissions from the process plant is the liquor neutralization tank, which emits 0.2 t/d of H_2S. The impact of odours were evaluated through the use of the WHO 30-minute recommended odour threshold value for H_2S of 7 µg/m³ (WHO 2000).

Table 3.3-12 presents the 1-hour and peak odour predictions for the communities considered in the air quality assessment. The values presented are referred to as 1-hour averaged concentrations; however, the CALPUFF model predictions are representative of concentrations averaged over a period from a few minutes to an hour. The actual ground-level concentrations will fluctuate within the averaging period. The ability to detect odours is usually related to the high “peak” concentrations during each hour. To address these fluctuations, a “peak” concentration was determined by applying a multiplication factor to the CALPUFF model estimates. Authors such as Turner (1969), Hanna et al. (1982), and Pasquill and Smith (1983) have proposed various factors suitable to convert 1-hour average predictions to peak concentrations. A factor of 10 is most suitable near to point sources and a factor of 2 is most suitable when receptors are distances of 2 to 5 km away from the emission sources. A factor of 2 was applied to the 1-hour odour predictions to determine peak values.

The results indicate that the process plant emissions may cause an increase in odour levels at some nearby communities with the highest frequency of occurrence that the odour may be detectable about 4% of the time.

Table 3.3-12 One-Hour and Peak Odour Predictions at Communities

Community	1-Hour Odour		Peak Odour	
	Number of Hours > Threshold	Fraction of Time	Hours > Threshold	Fraction of Time
Ambarimilambana	0	0.0%	1	0.0%
Ambatoroa	215	2.5%	371	4.2%
Amboakarivo	16	0.2%	29	0.3%
Ambodikily	0	0.0%	2	0.0%
Ambodisaina	10	0.1%	45	0.5%
Amboditandroho	1	0.0%	15	0.2%
Ampasimbola	124	1.4%	260	3.0%
Ampasinambo	0	0.0%	1	0.0%
Ampihaonana	0	0.0%	3	0.0%
Ampirasantany	11	0.1%	19	0.2%
Analabe	100	1.1%	197	2.2%
Analamboantsihona	360	4.1%	634	7.2%
Antananambo	9	0.1%	40	0.5%
Antanandava	78	0.9%	151	1.7%
Antsiranandakana	122	1.4%	252	2.9%
Mahatsara	16	0.2%	36	0.4%
Manamboasio	246	2.8%	391	4.5%
Toamasina	2	0.0%	32	0.4%
Vohitsara	2	0.0%	14	0.2%

Residual Impacts

Impact Classification

Emissions of SO_2, NO_X, particulates and trace compounds from the process plant will result in changes to the ambient air quality. The magnitude of all of the changes is considered to be low (Table 3.3-13). The predicted concentrations of SO_2, NO_2, TSP, PM_{10} and trace compounds were all within World Bank guidelines within the LSA and at regional communities. These predictions result in low-magnitude ratings for all of the evaluated parameters. Of the 7 parameters evaluated within various averaging periods, all were rated as having a low environmental consequence, except for 1-hour H_2S. The 1-hour H_2S value was rated as moderate because some of the predicted concentrations exceeded the WHO recommended 30-minute odour threshold of 7 µg/m³.

Scientific Uncertainty

The evaluation of changes in air quality depends primarily on the use of air dispersion models to predict the ambient levels expected in the future. As with any form of prediction, there are uncertainties regarding the model's capability to predict concentrations accurately. To minimize some of these uncertainties, an accepted dispersion model (i.e., CALPUFF) was selected for the analysis. This model has been reviewed extensively in the United States to ensure that it provides realistic, but conservative, predictions.

The other uncertainty associated with the air quality predictions is tied to the predicted emissions from the process plant. Possible uncertainty associated with the predicted emissions was limited by using established emission factors and the latest project description. Where uncertainties could not be avoided, conservative emission estimates were used to ensure that possible impacts were not underestimated.

Monitoring and Follow-Up

Monitoring of air emissions at the source will occur during operations. Maximum predicted levels of SO_2, NO_2, particulates, lead and mercury all comply with the World Bank or WHO guidelines.

3.3.5.3 Key Question AQ-2 How Will The Development of the Process Plant Affect the Production And Management of Greenhouse Gases?

The linkage diagram for Key Question AQ-2 is provided in Volume H, Appendix 9.

Table 3.3-13 Residual Impact Classification for Effects to Air Quality

Parameter	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
24-hour SO_2	negative	low	local	medium-term	reversible	medium	low
annual SO_2	negative	low	local	medium-term	reversible	high	low
community 24-hour SO_2	negative	low	local	medium-term	reversible	medium	low
community annual SO_2	negative	low	local	medium-term	reversible	high	low
24-hour NO_2	negative	low	local	medium-term	reversible	medium	low
annual NO_2	negative	low	local	medium-term	reversible	high	low
community 24-hour NO_2	negative	low	local	medium-term	reversible	medium	low
community annual NO_2	negative	low	local	medium-term	reversible	high	low
annual TSP	negative	low	local	medium-term	reversible	high	low
community annual TSP	negative	low	local	medium-term	reversible	high	low
24-hour PM_{10}	negative	low	local	medium-term	reversible	medium	low
annual PM_{10}	negative	low	local	medium-term	reversible	high	low
community 24-hour PM_{10}	negative	low	local	medium-term	reversible	medium	low
community annual PM_{10}	negative	low	local	medium-term	reversible	high	low
community 1-hour H_2S	negative	high	local	medium-term	reversible	low	moderate
community 24-hour H_2S	negative	low	local	medium-term	reversible	medium	low
community annual lead	negative	low	local	medium-term	reversible	high	low
community annual mercury	negative	low	local	medium-term	reversible	high	low

Impact Analysis

Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and total greenhouse gases (expressed as equivalent carbon dioxide [ECO_2], which includes the higher greenhouse potential of CH_4 and N_2O) were estimated for the operations phase of the process plant based on maximum normal production.

Table 3.3-14 presents the estimated greenhouse gas (GHG) emissions during the operations phase of the process plant based on maximum normal production. Greenhouse Gas emissions during operations are estimated to be 1,920 kt ECO_2 per year.

Table 3.3-14 Summary of Greenhouse Gas Emissions From the Process Plant

Source	Annual Greenhouse Gas (GHG) Emissions [kt/yr]			
	CO_2	CH_4	N_2O	ECO_2
leach - vent scrubbers	67.04	—	—	67.04
leach - slurry neutralization tank (combined)	280.45	—	—	280.45
leach - barren liquor neutralization tank (combined)	66.69	—	—	66.69
leach - tailings neutralization tank (combined)	92.40	—	—	92.40
leach - raw liquor heater (combined)	5.76	—	—	5.76
leach - liquor neutralization tank (combined)	210.64	—	—	210.64
leach - sulphide precipitation preheaters	3.17	—	—	3.17
leach - sulphide area flare	0.13	0.00	0.00	0.13
utilities - hydrogen plant (combined)	60.15	0.01	0.00	60.18
utilities - hydrogen plant (h_2 vent)	0.00	0.00	—	0.01
utilities - hydrogen sulphide flare stack	0.19	0.00	0.00	0.20
utilities - limestone calcining	351.69	0.00	0.00	351.69
utilities – coal-fired boilers	781.65	0.01	0.00	781.68
total[(a)]	**1,919.98**	**0.02**	**0.00**	**1,920.05**

"—" indicates no emissions from this source.

[(a)] Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

Table 3.3-15 provides a summary of Madagascar national GHG emissions based on 1994 information. A comparison to the emissions from the process plant (1,920 kt ECO_2/yr), helps to put the project into perspective. The national GHG emissions in 1994 were estimated to be 456,323 kt ECO_2/yr (MEEF 2004). The emissions from the process plant would represent a 0.4% increase in national GHG emissions.

Table 3.3-15 Madagascar National Greenhouse Gas Emissions

Greenhouse Gas Source	CO_2		CH_4	N_2O
	Emissions ***Emission***	**Collected** ***Captage***		
total emissions (kt/yr) *emission totale nationale*	432,429	671,451	426	42
total emissions (kt eco_2/yr) *emission nationale en equivalent co_2*	432,429	671,451	10,444	13,450
i energy sector *i secteur energie*	1,141	0	33	0
ii industrial processes sector *ii secteur procedes industriels*	5	—	0	0
iii agriculture sector *iii secteur agriculture*	0	—	327	42
iv land use change sector *iv secteur changement d'affectation*	431,283	671,451	57	0
v waste management sector *v secteur gestion des dechets*	—	—	10	—
additional information				
a co_2 emissions resulting from biomass *a emission de co_2 issue de biomasses*	10,812			
b sequestration balance *b bilan de sequestration*	-239,022			

Source: Le Ministre de l'Environnement des Eaux et des Forets, 2004.

- = Data not avalable.

3.3.6 Conclusions

The potential for emissions from the process plant, tailings facility and port expansion to affect the quality of air in the region is an issue for regional stakeholders. Despite the mitigation and control techniques incorporated in the design and operations of the process plant, there will be an increase in the atmospheric emissions in the region due to the process plant. The air quality assessment of the process plant included predictions of SO_2, NO_2, TSP, PM_{10}, H_2S, lead and mercury concentrations.

The key findings of the air quality assessment are as follows:

- The maximum predicted concentrations are below applicable World Bank or WHO guidelines.
- All of the predicted concentrations in the regional communities meet the World Bank or WHO guidelines, except for H_2S.

- The predicted 1-hour H_2S concentration at some communities is above the WHO 30-minute recommended odour threshold of 7 µg/m³.

Of the 18 combinations of ambient air quality parameters and averaging periods assessed, 17 were rated as having a low environmental consequence. Only one parameter (1-hour H_2S) was classified as having a moderate environmental consequence, as shown in Table 3.3-16. This environmental consequence was determined based on the WHO 30-minute criteria which is a recommended threshold for odour perception.

Table 3.3-16 Moderate Impact Classifications for the Process Plant

Parameter	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
community 1-hour H_2S	negative	high	local	medium-term	reversible	low	moderate

The main factor that may affect air quality near the tailings facility is vehicle exhaust emissions during construction; however, these emissions are expected to be temporary and localized. Air emissions from the operation of the tailings facility have not been identified; however, there may be occasional emissions from vehicles for ongoing maintenance. The slurry tailings is not a source of air emissions. The impact on air quality due to the tailings facility is expected to be negligible.

The main factors that may affect air quality at the port expansion are vehicle exhaust emissions during the construction of the port expansion as well as emissions from increased marine and land traffic due to the project. Since the construction activities will be localized and temporary, changes to air quality are expected to be insignificant during construction. Marine and land traffic are expected to increase during the operations phase of the project; however, emissions from vehicles are expected to be negligible in comparison to emissions from the project in the process plant study area as a whole. The impact on air quality due to the port expansion is expected to be negligible.

The process plant GHG emissions total 1,920 kt of ECO_2 per year, which represents a 0.4% increase in national GHG emissions.

3.4 NOISE

3.4.1 Introduction

The noise assessment of the Ambatovy Project (the project) provides a complete impact analysis of the proposed project and identifies the potential effects of sound emissions associated with the proposed project activities. In this volume of the Environmental Assessment (EA), project activities associated with the process plant (the plant) are assessed. Information is provided on existing noise levels in the area as well as the changes expected to result from the plant. Due to the proximity and minimal number of associated sources, the tailings facility is also considered under this volume of the EA.

The focus of the noise assessment is on determining changes to the existing ambient noise levels due to project operations and comparing the results with noise guidelines from the World Bank. The assessment is conducted from the point of view of human response. The effects of noise on wildlife are assessed in Volume D, Section 4.2. Noise is also an input to the analysis of social effects in Volume D, Section 5.1.

An introduction to the key concepts associated with noise used in the assessment is provided in Volume B, Section 3.5.

3.4.2 Study Areas

The study area used to assess noise from the process plant and tailings facility encompasses a 7.5 km by 8 km area roughly centred on the plant footprint as illustrated in Volume A, Section 7.2. The following specific receptors within this area were selected as the basis for conducting the impact assessment:

- Ambatoroa;
- Amboakarivo;
- Ampasimbola;
- Ampirasantany;
- Analabe;
- Andranoampandrana;
- Ankazosivy;
- Antsiranandakana;
- Fiadanana;

- Mahatsinjo;
- Manamboasio; and
- Marovato.

These were determined to be the primary residential areas within the study area, based on the results of the socioeconomic surveys (Volume K, Appendix 1.1)

3.4.3 Baseline Summary

3.4.3.1 Introduction

A baseline noise study was completed for the project to establish existing noise levels at the proposed development areas as well as to provide information for the noise impact assessment. Establishing existing noise levels was also necessary in order to use the World Bank noise criteria.

3.4.3.2 Methods

Since Madagascar does not have established guidelines or regulations concerning noise measurements, the study was performed to meet the requirements of the World Bank. The World Bank requires noise be assessed at receptors that lie outside the project boundary based on the following time periods:

- daytime hours (7:00 am to 10:00 pm); and
- nighttime hours (10:00 pm to 7:00 am) (WB, 1998).

One, 24-hour survey was done at each selected monitoring location to represent existing noise levels at community receptors around the plant. Surveys of this type and duration provide information on daily variability in noise levels. The sound level meter used recorded average (L_{eq}) and maximum (L_{max}) sound pressure levels once per minute during the monitoring period.

Weather data was measured at monitoring locations during each 24-hour survey period. Noise measurements are most accurate during weather conditions conducive to low relative humidity, warm temperatures (below 35°C), low winds and no cloud cover. Weather information was recorded throughout the monitoring period and action taken where necessary to ensure conditions remained optimal during noise measurement.

One location near the plant site was selected for conducting the noise survey: Fiadanana. From site visits, this location was considered representative of all community receptors near the process plant.

Detailed information regarding noise monitoring location selection and monitoring methods are provided in Volume I, Appendix 5.1.

3.4.3.3 Summary of Results

A summary of existing noise levels at Fiadanana is provided in Table 3.4-1. These are considered representative of the existing noise levels at all community receptors.

Table 3.4-1 Summary of Existing Noise Levels, Ambatovy Project Process Plant

Location	Period	Quietest Hour L_{eq} [dBA]	Period L_{eq} [dBA]
Fiadanana	day	50	52
	night	44	49

Detailed noise measurements including tables of hourly noise levels and graphs of one-minute raw data are provided in Volume I, Section 5.1.

3.4.4 Impact Assessment

3.4.4.1 Issue Scoping

Through consultation with stakeholders and review of previous environmental assessments for resource developments in Madagascar and elsewhere, several issues were identified with respect to the potential impacts of the project on noise. Specific concerns over possible noise impacts were raised during Toamasina consultations.

Plant site factors that may affect noise levels include:

- Noise generated by process plant equipment including boilers, pumps, fans and miscellaneous motors or valves; and
- Increased traffic on the plant access roads, particularly during the construction phase, but also during operations may lead to localized increases in noise levels.

Noise effects are expected to occur during the construction and operation phases of the project. Changes in noise due to the project may have an effect on human and wildlife health. This results in one key question for noise:

Key Question N-1 What Effect Will Noise From the Ambatovy Process Plant Have on Sensitive Receptors?

An analysis of factors that may affect noise is shown as a linkage diagram in Volume H, Appendix 9.

3.4.4.2 Assessment Methods

The key indicator which will be used to assess potential changes in noise levels is the equivalent sound level or L_{eq}. This indicator is a logarithmic average that represents noise levels measured over a selected period of time and is measured in A-weighted decibels (dBA) to mirror the response of the human ear. This type of average is commonly used in an environmental (outdoor) context as it takes into account natural variations in sound.

The assessment of changes in noise levels was accomplished by:

- determining potential receptors of noise;
- establishing baseline noise levels at those receptors;
- determining the amount of sound generated by project activity;
- predicting the amount of project-related noise that would be experienced at the identified receptors; and
- comparing predicted noise levels with baseline noise levels and applicable noise criteria.

Activities or equipment that have sound emissions were determined based on information contained in the project description and client-supplied equipment lists. Sound emissions for the various sources were based on noise measurements from similar equipment, manufacturer data or standard sound emission formulae.

Noise predictions were conducted using the Computer Aided Noise Abatement Model (CadnaA). The model was used to estimate the noise levels received at neighbouring communities due to sound emitted from the process plant as well as predict noise levels surrounding the process plant. CadnaA is a three-dimensional noise prediction tool that calculates attenuation of noise including effects from the atmosphere, barriers, ground conditions, foliage and terrain. The model methods are consistent with International Standardization Organization (ISO) acoustic standards and World Bank criteria, providing L_{eq} noise levels over selected time periods.

The effects of noise on wildlife are assessed in the fauna section (Volume D, Section 4.2). Noise predictions provided for the fauna assessment are presented here for information purposes only.

The effects of traffic on public roadways has been assessed separately in Volume D, Section 5.5).

3.4.4.3 Residual Impact Criteria

Criteria used for noise are the World Bank noise standards for mining activity:

- an hourly L_{eq} noise level of 55 dBA between 7:00 am and 10:00 pm (daytime);
- an hourly L_{eq} noise level of 45 dBA between 10:00 pm and 7:00 am (nighttime); and
- a maximum increase in background noise levels of 3 dBA (applied where background is higher than 55 or 45 dBA respectively).

Criteria are applied at receptors (homes or communities) outside the project boundary. At the plant site, the boundary is the plant site property boundary.

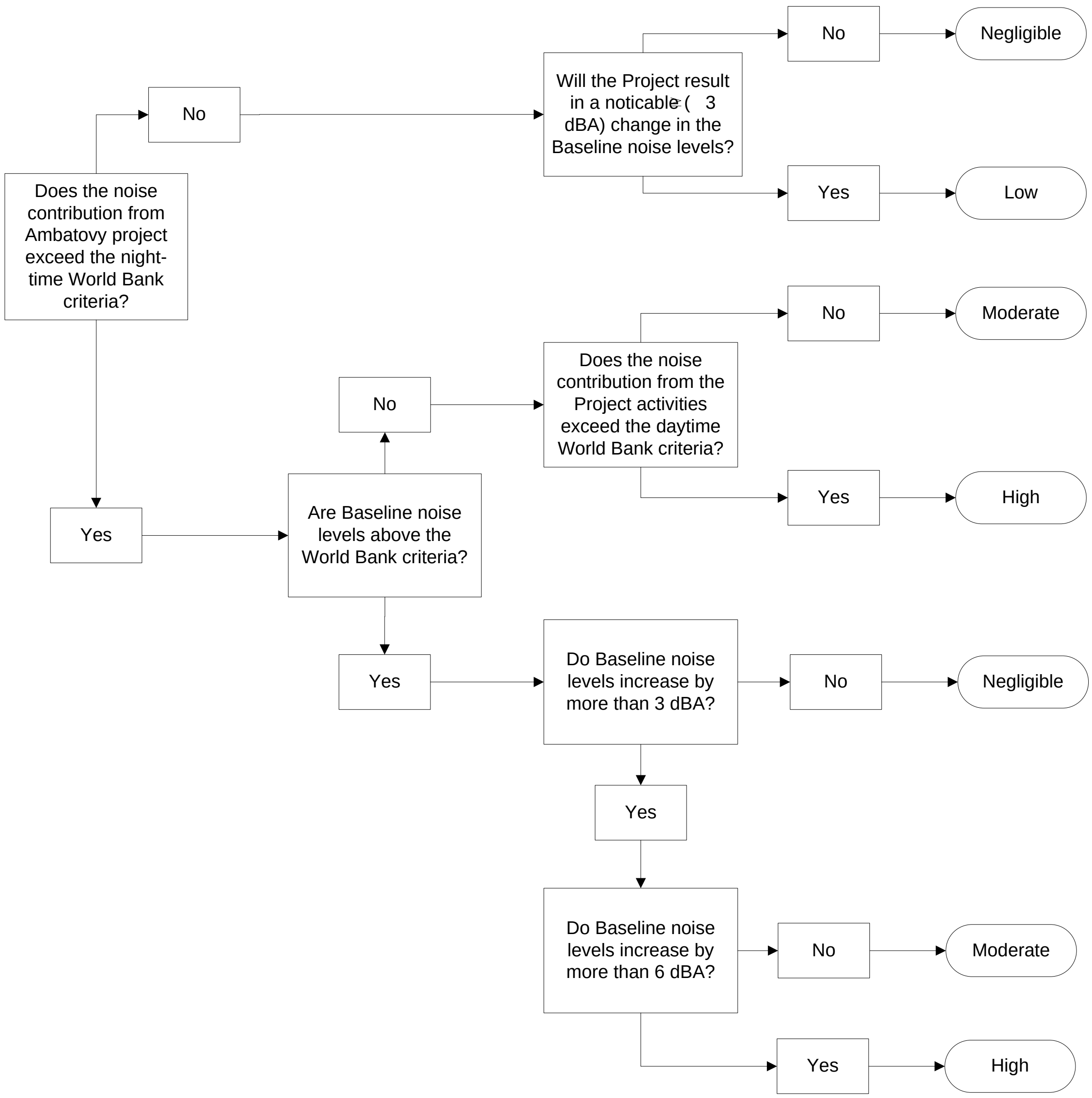
Residual impacts are determined at specific community receptors based on World Bank criteria. The parameters used to determine environmental consequence at the community receptors are direction, magnitude, geographic extent, duration, reversibility and frequency. The only parameter that has a unique definition for noise is magnitude. The impact magnitude ratings are also based on the World Bank (WB) criteria:

- negligible: predicted noise levels are below the WB criteria and will not affect baseline noise levels;
- low: predicted noise levels are below the WB criteria but will increase period (day or night) baseline noise levels, where baseline levels are below WB criteria;
- moderate: predicted noise levels are above the WB nighttime criteria but below the daytime criteria. Where baseline levels are above WB criteria, noise levels increase by more than 3 dBA; and

- high: predicted noise levels exceed both the WB day time and nighttime criteria. Where baseline levels are above WB criteria, noise levels increase by more than 6 dBA.

Figure 3.4-1 illustrates the noise impact magnitude decision process.

Figure 3.4-1 Noise Impact Magnitude Decision Tree



3.4.4.4 Mitigation

Mitigation or noise controls considered in the plant assessment are as follows:

- fans and blowers will have acoustic controls, including silencers and enclosures, to meet a specification of 90 to 95 dBA;
- all pumps, including tailings pumps, will meet an acoustic requirement of 90 to 95 dBA at 1 m (based on the plant area);
- the coal dumper and transfer house will be enclosed; and
- buildings at the coal-fired power plant act as noise / sound barriers.

3.4.4.5 Emissions

Sources of noise considered for the plant site assessment are summarized in Table 3.4-2.

Table 3.4-2 Process Plant Sound Emissions

Source	Type of Source	Sound Power [dBA]
power generation	point	90.4
boiler stack [(a)]	point	100.4
coal transfer house [(b)]	point	115.8
train dumper	point	98.4
process air compressor	point	113.7
material handling conveyor motor [(c)]	point	103.7
coal handling conveyor [(d)]	line	112.8
coal handling conveyor motor [(e)]	line	107.7
area 31 slurry thickening	area	115.6
area 32 acid leach	area	118.6
area 33 slurry neutralization	area	118.6
area 34 raw liquor neutralization	area	117.3
area 35 sulphide precipitation	area	119.6
area 36 sulphide washing and handling	area	115.2
area 72 cooling tower	area	112.0
area 67 acid plant	area	110.0
area 69 limestone plant	area	112.3
area 61 process water supply	area	117.6
area 62 effluent water supply	area	117.6

(a) Sound Power for each occurrence. There are two boiler stacks at the plant site.
(b) Sound Power for each occurrence. There are eight coal transfer houses.
(c) Sound Power for each occurrence. There are four material handling conveyor motors.
(d) Sound Power for each occurrence. There are four coal handling conveyors.
(e) Sound Power for each occurrence. There are two coal handling conveyor motors.

The model presents a snapshot of the expected continuous noise levels generated from the process plant and tailings facility. To ensure a "worst case" or highest expected noise level was assessed, the model is based on the assumption that all equipment will be in use at the design capacity. Other factors that were considered in the model are terrain, meteorological conditions and ground conditions.

Sources of noise at the tailings ponds during operation are expected to consist of a pumphouse and occasional maintenance vehicles. The pumphouse will be similar to the other pumps at the process plant.

3.4.4.6 Results

Predicted noise levels at community receptors due to process plant and tailings facility operations are presented in Table 3.4-3.

Table 3.4-3 Predicted Noise Levels, Process Plant

Location	Sound Levels [dBA]
Ambatoroa	44
Amboakarivo	33
Ampasimbola	37
Ampirasantany	45
Analabe	41
Andranoampandrana	37
Ankazosivy	35
Antsiranandakana	38
Fiadanana	40
Mahatsinjo	39
Manamboasio	45
Marovato	38

Noise levels at the tailings facility due to the pumphouse are expected to have localized effects within a few hundred metres of the pumps. Noise due to maintenance and plant traffic is addressed in Volume D, Section 5.5.

3.4.4.7 Residual Impact Analysis

The basis for the analysis of noise impacts is both a comparison of predicted noise levels to World Bank criteria and a determination of the amount of change in baseline noise levels. Table 3.4-4 compares the predicted noise levels to the

World Bank criteria. Predicted noise levels are also presented as a noise map in Figure 3.4-2. Table 3.4-5 provides an analysis of the amount of change in baseline noise levels.

Table 3.4-4 Comparison of Predicted Noise Levels With World Bank Criteria, Process Plant

Location	Sound Level [dBA]	World Bank Criteria [dBA]		Meets Criteria
		Day	Night	
Ambatoroa	44	55	45	yes
Amboakarivo	33	55	45	yes
Ampasimbola	37	55	45	yes
Ampirasantany	45	55	45	yes
Analabe	41	55	45	yes
Andranoampandrana	37	55	45	yes
Ankazosivy	35	55	45	yes
Antsiranandakana	38	55	45	yes
Fiadanana	40	55	45	yes
Mahatsinjo	39	55	45	yes
Manamboasio	45	55	45	yes
Marovato	38	55	45	yes

LEGEND

- RECEPTOR
- POPULATION CENTRE
- NOISE STUDY LOCATION
- SLURRY PIPELINE ROUTE
- ROAD
- PLANT SITE
- TAILINGS FACILITY
- CORRIDOR DISTURBANCE AND PROPERTY BOUNDARIES

NOISE CONTOUR (dBA)

- 35
- 40
- 45
- 50
- 55
- 60

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001
Datum: WGS 84 Projection: UTM Zone 39S

1 0 1

SCALE 1:50,000 KILOMETRES

PROJECT

AMBATOVY PROJECT

TITLE

PREDICTED NOISE LEVELS FOR THE PLANT FACILITY

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I:/2003/03-1322/03-1322-172/mxd/Noise/Fig3.4-2_PlantSite8.5x11.mxd

Table 3.4-5 Expected Change in Baseline Noise Levels, Process Plant Site

Location	Period	Period L_{eq} [dBA]	Predicted Project Noise Level [dBA]	Combined Noise Level [dBA]	Amount of change [dBA]
Ambatoroa	day	52	44	53	+1
	night	49	44	50	+1
Amboakarivo	day	52	33	52	0
	night	49	33	49	0
Ampasimbola	day	52	37	52	0
	night	49	37	49	0
Ampirasantany	day	52	45	53	+1
	night	49	45	50	+1
Analabe	day	52	41	52	0
	night	49	41	50	+1
Andranoampandrana	day	52	37	52	0
	night	49	37	49	0
Ankazosivy	day	52	35	52	0
	night	49	35	49	0
Antsiranandakana	day	52	38	52	0
	night	49	38	49	0
Fiadanana	day	52	40	52	0
	night	49	40	50	+1
Mahatsinjo	day	52	39	52	0
	night	49	39	49	0
Manamboasio	day	52	45	53	+1
	night	49	45	50	+1
Marovato	day	52	38	52	0
	night	49	38	49	0

The impact magnitudes determined using Figure 3.4-1 are negligible at all community receptors. The World Bank nighttime noise criteria will be met at all communities, although it should be noted that predicted nighttime noise levels at Ampirasantany and Manamboasio are at the World Bank limit of 45 dBA. Baseline noise levels in these communities are expected to already be above the criteria level (at 49 dBA), however, so noise levels are not expected to noticeably increase. The resulting residual impacts have been rated as negligible and are summarized in Table 3.4-6.

The assessment of impact focused on the operations stage of the project as the worst case for noise. All predictions considered that equipment (primarily fans and pumps) would be controlled to between 90 and 95 dBA. There are fewer sources of noise during construction, and the duration of the construction period is shorter than the operations period. Noise due to the construction of the process plant and tailings facility is expected to generate less noise overall than operations. Since operations meet the World Bank criteria, construction noise is also expected to comply.

Table 3.4-6 Residual Impact Classification - Noise

Community	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Ambatoroa Amboakarivo Ampasimbola Ampirasantany Analabe Andranoampandrana Ankazosivy Antsiranandakana Fiadanana Mahatsinjo Manamboasio Marovato	**negative**: an increase in noise levels	**negligible**: no noticeable increase in background noise levels; noise levels meet World Bank criteria	**local**: at specific community receptors according to World Bank criteria	**medium-term**: 3 to 30 years	**reversible** noise is stopped once project activity stops	**high**: occurs continuously	**negligible**

3.4.4.8 Prediction Confidence

The modelling of outdoor noise attenuation is conducted using standard algorithms and assumptions that tend to simplify the acoustic environment. Noise, whether natural or man-made, is normally variable over time. The algorithms and the L_{eq} indicator account for that variability, but do not predict it. The variation of noise sources over time can be addressed in the CadnaA model in many ways, depending on the noise source being assessed and the level of detail required.

The quality and relevance of predictions from the noise model is dependant on the data inputs. For the assessment, noise sources were established with actual field measurement or vendor sound emission data where possible to ensure the accuracy of sources. Modelled noise levels for the existing activity on the site were compared with background noise data to ensure the simulations were representative of the site.

The CadnaA model was designed to predict outdoor noise in accordance with International Standards Organization (ISO) 9613 (1&2): *Attenuation of Sound During Propagation Outdoors* (ISO 9613) as well as several international and

European acoustic standards. The ISO 9613 method will predict noise attenuation to within ± 3 dBA. Supplier literature and third-party publications do not verify this level of accuracy for the CadnaA model. To validate that the CadnaA model meets the ISO standard, an independent study was done. This study verified the model calculates the ISO method correctly and that simulations of outdoor noise levels match field measurements of a known source to within ± 3 dBA.

3.4.4.9 Monitoring Plans

Since noise impacts are predicted to be negligible, a monitoring program for noise is not considered necessary. As part of the on-going community relations program, a process for addressing noise complaints will be developed. Should a noise complaint be received during project operations, an investigation will be conducted to identify the source of the noise and determine possible solutions, if necessary. The investigation may include measurement/monitoring, interviews or modelling.

3.4.5 Conclusions

Key Question N-1 asked: What Effect Will Noise From the Ambatovy Process Plant Have on Sensitive Receptors? The effects of project noise levels were determined by:

- establishing the existing noise levels at specific receptors for noise;
- predicting the amount of sound generated by the major sources of sound from the project; and
- evaluating the resulting noise levels at specific receptors.

Negligible impacts were predicted for the project. All predicted noise levels met the World Bank criteria at the community receptors identified for the assessment. Changes in baseline noise levels are predicted to be 1 dBA or less and are not considered to be noticeable. Since World Bank criteria are met and changes in baseline noise levels are below 3 dBA, the effects of project noise are considered to be of negligible environmental consequence.

3.5 NATURAL RISKS

3.5.1 Introduction

This section presents the Environmental Assessment for the risks of natural hazards to the public and environment due to the Process Plant, as per the Ambatovy Project (the project) Terms of Reference.

3.5.2 Study Area

The Process Plant Local Study Area (LSA) is shown in the tailings and plant site area plan presented in Volume A, Figure 7.2-3. The Process Plant will be located near the city of Toamasina on the east coast of Madagascar. A tailings impoundment area will be located in valleys to the west of the plant site. A water supply will be provided by a pumping station and pipeline from the Ivondro River, approximately 10 km south of the plant site. The port of Toamasina will be used extensively during construction and operations for the plant's import and export requirements.

The plant site is predominantly a flat coastal wetland area with low undulations at elevations between 6 and 10 metres above sea level. The undulations of 1 to 2 m relief are parallel to the coastline and were formed by ancient dunes. The troughs between these dunes typically become swamps during the wet season.

Natural hazards such as earthquakes can originate from a much larger regional area that was studied as appropriate to determine the potential impacts at the plant site.

3.5.3 Baseline Summary

The Environmental Assessment is based on a separate study on natural hazards and risk assessment for the Process Plant (Dynatec 2005, which is provided in Volume I, Appendix 6.1). In this reference study, the baseline for the Process Plant setting is described in terms of location, topography, geomorphology, climate and seismicity. Potential natural hazards, potential consequences of failure due to natural hazards and risks downstream of the tailings facility were assessed.

Baseline data for natural hazards included climate data describing hydrological hazards and earthquake data describing seismicity hazards.

3.5.4 Issue Scoping

Five principal natural hazards are identified in the risk assessment (Dynatec 2005) as seismic, hydrological, wind, geotechnical and tsunami. Issues associated with each of these natural hazards are summarized as follows. All the issues identified from stakeholder consultation were included in these hazard scenarios.

Seismic Hazards

An earthquake could:

- cause a power failure and plant shutdown;
- damage plant structures; and
- rupture containment facilities such as process tanks.

Hydrological Hazards

Heavy rains from a tropical cyclone could trigger:

- flooding from storm rains which cause overloading of the bermed containment areas; and
- flooding due to a storm surge from the sea.

Wind Hazards

High speed winds from a tropical cyclone could:

- cause a power failure and plant shutdown;
- damage plant structures;
- rupture process tanks;
- blow stockpiled materials offsite; and
- damage temporary structures and scatter debris.

Geotechnical Hazard

Unforeseen geotechnical conditions could occur due to a seismic or hydrological event causing plant damage.

Tsunami Hazard

A Tsunami could trigger flooding leading to overloading of the bermed containment areas and damage to the supply roads, railways and water system.

The key question for natural hazards is:

Key Question TG-1 Are the risks of natural hazards to the public and environment increased as a result of the process plant?

3.5.5 Impact Assessment

3.5.5.1 Assessment Methods

A risk assessment was carried out for natural hazards (Dynatec, 2005) using a relative ranking system. For each of the five identified natural hazards described in Section 3.5.4, all potential hazard scenarios were first identified according to failure mode, associated consequences and planned risk mitigation measures. The residual risks for all hazard scenarios were then estimated using a relative risk ranking system. Acceptable risks were determined according to international standards to minimize risk to downstream public and environmental resources.

3.5.5.2 Assessment Criteria

The assessment criteria used for the assessment of natural risks are presented in Table 3.5-1. Five categories of risk are defined by likelihood of occurrence and magnitude of consequences. Overall risk is a product of the relative ranking for likelihood and consequence.

Table 3.5-1 Description of Risk Criteria for the Process Plant

Ranking Categories	Likelihood of Occurrence (Probability)		Magnitude of Consequences		Overall Risk
extremely low	1	negligible chance of occurrence, <1:10,000 yr "doubt it will ever happen"	1	no fatalities possible, minor to no damage beyond owners property	1-5
low	2	not likely to occur, 1:1,000 to 1:10,000 yr "highly unlikely to happen"	2	no fatalities anticipated, minor damages beyond owners property	6-10
moderate	3	moderate frequency of occurrence 1:100 to 1:1,000 yr "it could happen"	3	no fatalities anticipated, moderate property damages	11-15
high	4	frequent occurrences, 1:10 to 1:100 yr "it has happened, or it probably will happen"	4	some fatalities possible, large property damages	16-20
extremely high	5	very frequent occurrences, >1:10 yr "happens all the time"	5	large number of fatalities possible, extreme property damages	21-25

3.5.5.3 Mitigation

A number of risk mitigation measures were identified in the reference report (Dynatec, 2005). The design basis and criteria for the process plant will be based on maximum recorded regional natural hazard events to minimize risk to within recognized acceptable levels for surrounding public and environmental resources.

Risk mitigation measures were identified for all potential natural hazard scenarios. Mitigation is discussed in the referenced report under the five principal natural hazards: seismic, hydrologic, wind, geotechnical and tsunami. These risk mitigation measures include:

- Pipeline is designed for shutdown of several days duration.
- Plant units will be designed to shut down in safe mode.
- H_2S venting from equipment will be burned to SO_2.
- Plant structures will be designed for the maximum regional earthquake.
- Earthquake loads will be considered in piping design. Connections to rigid equipment such as tanks and pumps will be located in bermed areas. Following an earthquake, equipment and piping will be inspected, and any leaks will be isolated.
- Earthquake loads will be considered in tank and vessel designs. Tanks will be contained in bermed areas sized for 110% of largest single vessel in the area.

- An advanced weather reporting and emergency response plan will be implemented to shut down operations in advance of severe cyclonic storms. The emergency response program will be coordinated with the local communities to ensure that the public is not adversely affected by the project. The program will also ensure that the ability of the community to recover from such events is enhanced by the presence of resources available to the project.
- Containment pond for stockpile pads will be designed to hold rainfall normally expected for 1 in 10 year storm event. Stockpiled materials have relatively innocuous effect if transported to the environment via storm drainage.
- Drainage ditches will be designed for a cyclonic event using concrete and riprap sides and bottoms.
- Plant elevation at six meters is above the expected effect from tsunamis originating in East Indian Ocean.
- The pumping station will be designed to withstand high water levels.
- Plant structures will be designed for wind loads from the strongest historical cyclones.
- Wind loads will be considered in tank and vessel designs.
- Construction of facilities not designed for maximum winds will be minimized, good housekeeping will be maintained, and materials will be stowed prior to onset of cyclonic storms. Secure refuge will be provided for personnel in the event of a cyclonic storm.
- Foundations will be designed as appropriate for geotechnical conditions and the maximum regional earthquake.
- Foundations and site drainage ditches will be designed as appropriate for geotechnical conditions and the maximum expected flooding event.

3.5.5.4 Results

The results of the risk assessment are summarized from the reference report (Dynatec, 2005). Risks from a tsunami event have the lowest overall risk rating as consequences are expected at the port but not at the plant due to its location and elevation.

Risks from a seismic event also have an Extremely Low overall risk rating. This is largely due to the fact that Madagascar is in a low seismic area and that application of conservative seismic design parameters will address seismic concerns. Potential failure and subsequent consequences due to geotechnical issues are rated in the Extremely Low category. Detailed geotechnical investigations will be completed to adequately characterize conditions for a suitable design.

Risks from a hydrogeologic event are rated Extremely Low or Low. The two Low risk scenarios involve overflowing bermed containment areas from flooding and damage to roads and railways from a cyclone storm surge. An advanced weather reporting and emergency response plan will be implemented to shut down operations in advance of severe cyclonic storms.

The highest overall risk rating (Moderate) was estimated for an extreme wind event damaging temporary structures (during construction) and blowing airborne debris. Other risks from an extreme wind event were rated Extremely Low or Low. To manage these risks, construction of facilities not designed for maximum winds will be minimized, good housekeeping will be maintained, and materials will be stowed prior to onset of cyclonic storms. Secure refuge will be provided for personnel in the event of a cyclonic storm.

3.5.5.5 Impact Analysis

Residual Impacts

Following mitigation, all but one of the identified residual risks during all project periods are in the Extremely Low or Low categories. One Moderate risk from an extreme wind event will be managed through actions to prevent damage and protect people. The estimated risks are within international standards to minimize risk to downstream public and environmental resources.

Prediction Confidence

The estimation of risk in the reference report (Dynatec, 2005) accounts for the variation in data and prediction confidence. However, risk ratings are also dependent on the success of the mitigations proposed, including those listed in Section 3.5.5.3. Overall, the prediction confidence for this assessment is considered medium.

Monitoring

Monitoring programs will be assessed during detailed design.

3.5.5.6 Conclusions

Following mitigation, increased risks of natural hazards to the public and environment as a result of the process plant are estimated to be within international standards.

3.6 HYDROGEOLOGY

Baseline hydrogeological data is available for the process plant site area (Knight Piésold Report, Process Plant Site Foundation 2005, Site Investigation Report Ref. No. NB301-00116/5-1). The data contained in the report includes:

- borehole coordinates and elevation;
- geology; and
- groundwater levels.

This impact analysis has been conducted for the proponents by Knight Piésold.

3.6.1 Geology

The near surface soils in the area generally comprise alluvial and dune deposited fine to medium grained sands. Soils at depth mainly consist of coastal deposited interbedded fine to medium grained sands and lagoonal silts. In situ testing indicates that the relative density of the soils ranges from loose to very dense. Index testing indicates that the fine to medium grained sands and silts are non-plastic. The bedrock surface generally consists of residual gneiss with weathered corestones in a residual gneiss matrix. The depth to the bedrock surface slopes from 30 to 100 m from the westward to eastward ends of the process plant site.

3.6.2 Hydrogeology

A total of eleven piezometers were installed in selected geotechnical boreholes for long term monitoring. Monitoring results to date show that the ground water levels range between 0.53 and 2.90 meters below ground level or generally between elevation 3.5 and 4.5 meters above sea level (masl). With the soil material displaying a relatively sandy character with little to no fines, the permeability will be relatively high and water migration through the soil will have a high velocity. This renders the underlying aquifer vulnerable to impacts from the processing plant infrastructure and associated operational procedures.

3.6.3 Groundwater Impacts

The impacts are associated with three main time periods: construction phase, operational phase and post-closure phase.

Construction Phase:

During this phase the surface infrastructure will be erected and installed. This will include:

- **Installation of foundations for building stability purposes:** During the installation of the foundations the groundwater flow in the immediate surroundings (<500 m radius) will be disturbed due to dewatering and drainage of excavations. Once the installation of the foundations is completed the groundwater levels and flow will return to relatively normal levels within a short time span (less than 1 year). The short time span is attributed to the high permeability of the lithologies and the high recharge volumes.
- **Construction of buildings and other surface infrastructure:** No high influence on the groundwater conditions is expected during the construction of the surface infrastructure.
- **Construction of ponds:** It is expected that localised dewatering of the aquifer will occur in the event that the floor material has to be re-worked at levels below that of the groundwater table during the construction of water holding ponds. The ponds will be lined and it is expected that the groundwater levels surrounding the ponds will recover relatively close to pre-construction levels after construction is completed.
- **Drainage Ditching:** Drainage ditches will be constructed north and south of the process plant site to provide effective drainage to the Pangalanes Canal to the east. These ditches will lower the groundwater level slightly across the plant site and adjacent area around the site (< 500 m from the perimeter).

Operational Phase:

During the 27 year operational phase, water and tailings material will pass through the processing plant and associated infrastructure. Even though the risk of local contamination always exists during the operational phase of any processing plant, it is not expected that normal operational procedures will pose any high risk to the catchment groundwater quality as long as proper operational and management procedures are applied. The water holding ponds will be lined and will be operated with enough freeboard to allow for flood events. Therefore it is not expected that the ponds will have any influence on the groundwater quality or quantity during the operational phase.

Post-Closure Phase:

At the time of project closure, the process plant will be assessed for potential future usefulness for other industrial projects. It is expected that the plant will be partially decommissioned and waste materials removed. This will remove the possibility of long-term impacts on the groundwater regime.

3.7 SURFACE WATER HYDROLOGY

3.7.1 Introduction

Land disturbance associated with construction and operation of the process plant will involve the removal of vegetation, ground compaction, and other changes to the landscape that may increase runoff rates and sediment yield from the area. However, the process plant is not expected to have a significant impact on the hydrologic conditions within the study area provided that surface runoff is directed to natural receiving water bodies and best management practices are implemented during construction and operations.

The impact assessment is therefore limited to a discussion on mitigations (e.g., use of best management practices) and an evaluation of water withdrawals from the Ivondro River.

3.7.2 Study Areas

The process plant is located southwest of Toamasina, along the main road between Toamasina and Brickaville, and about 3 km from the coast. The hydrology local study area (LSA) includes the plant site and ancillary facilities as shown in Volume A, Figure 7.2-3.

3.7.3 Baseline Summary

A summary of baseline climate and hydrology relevant to the process plant is provided in Volume E, Section 3.8.3 (Tailings Area Hydrology).

3.7.4 Issue Scoping

As discussed in Volumes B and E, Sections 3.8.4, the following hydrology issues have been identified:

- changes in flows, water levels, and sediment loads that could alter channel morphology and sediment concentrations; and
- changes in water availability for various uses (human and animal consumption, irrigation and aquatic habitat).

The key indicators of change due to the Ambatovy Project (the project) are flows, water levels, and sediment concentrations and channel morphology. Changes in these key indicators may also have an effect on water quality, fish health, vegetation (wetlands), and socioeconomic components of the project.

3.7.5 Impact Assessment

Development of the process plant area will involve the construction and operation of plant facilities, camps and housing, a water intake from the Ivondro River, pipelines for water conveyance and transportation corridors including an access corridor and new rail spur. These project components are expected to result in increased runoff rates and sediment yields from the disturbed areas; however, no significant impact on the study area hydrology is expected provided that the appropriate mitigations are used. Mitigation will include directing process area surface runoff to ponds for treatment. Non process areas which may cause high sedimentation will also be directed to ponds prior to release to natural drainage areas. Other non process areas will be a hard pack surface to prevent erosion and sedimentation, and runoff from these areas will be released to surrounding areas. Best management practices will also be implemented as part of mitigation to control sediment generation and sediment transport to receiving water bodies.

Water requirements for the process plant will be supplied by the Ivondro River, as well as by reclaimed water from the ore slurry and tailings. The raw water requirement from the Ivondro River is about 1,000 m^3/h (0.28 m^3/s) on a year-round basis. As shown in Table 3.7-1, these water volumes represent 0.3% of the mean annual flow in the Ivondro River, and 0.8% of the minimum daily flow for dry conditions.

Table 3.7-1 Change in Ivondro River Flow due to Process Plant Withdrawal

Flow	Ivondro River Flow (m^3/s)	Withdrawal for Plant Supply (m^3/s)	Percentage of River Flow Withdrawn for Plant Supply
driest month (Oct)	67.3	0.28	0.4%
mean annual	110	0.28	0.3%
2-yr minimum daily flow	44	0.28	0.6%
5-yr minimum daily flow	36.4	0.28	0.8%
10-yr minimum daily flow	33.1	0.28	0.8%

There will be no plant water requirements following closure, and therefore no need for withdrawals from the Ivondro River.

Construction and operation of the 6.2 km pipeline from the Ivondro River to the plant may result in local increases in runoff and sediment yield due to land disturbance, however these changes are not expected to be measurable in receiving water bodies.

3.7.6 Impact Analysis

Water withdrawal from the Ivondro River for use at the process plant will result in a less than 1% reduction in river flows. This change is not expected to be measureable compared to baseline conditions, and is considered negligible in terms of magnitude. As shown in Table 3.7-2, the environmental consequence of the water withdrawal is also considered negligible. The prediction confidence is high based on the long-term flow records for the Ivondro River that were used to characterize the baseline flow conditions.

Table 3.7-2 Residual Impact Classification for Hydrology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Changes in Streamflows and Water Levels (Ivondro River)							
construction/ operations	negative	negligible	local	medium-term	yes	high (average conditions)	negligible
post-closure	negative	negligible	local	long-term	no	high (average conditions)	negligible

The project water consumption from the Ivondro River will be monitored routinely. Releases from storm ponds within the process plant will be monitored for flow and quality. Erosion control measures and other best management practices will be monitored during construction and operation to ensure proper function and to identify locations where additional erosion control is required.

3.7.7 Conclusions

The process plant is expected to have a negligible impact on local hydrology provided that erosion control measures and suitable storm water management are applied.

3.8 WATER QUALITY

3.8.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the process plant on water quality as per the Ambatovy Project (the project) Terms of Reference, which is provided in Volume H, Appendix 1.

Construction of the process plant will involve varying degrees of land disturbance, such as removal of vegetation, excavation and ground compaction. The plant will also include the construction of roads, buildings and parking lots. These disturbances will result in increased runoff from the area. The increased runoff and disturbed areas could also increase erosion and transport of sediment to downstream watercourses and water bodies. Also, construction of a water intake in the Ivondro River during operations could potentially mobilize sediments from the river bottom or contribute sediments from disturbed areas near the intake site. Potential changes in suspended sediment concentrations due to project activities related to the process plant are addressed in the Hydrology Section (Volume D, Section 3.7).

Decrease in streamflow due to water withdrawals may affect water quality by reducing the assimilative capacity of the Ivondro River. Furthermore, the process plant will produce air emissions that may increase depositional loads of acidifying substances into water bodies. These depositional loads may affect water quality in water bodies near the process plant.

Water quality information has been compiled to characterize baseline conditions in the process plant area (Volume I, Appendix 9.1). The available baseline information is used in the following sections to evaluate potential effects of the process plant on water quality.

3.8.2 Study Area

The process plant is located southwest of Toamasina, along the main road between Toamasina and Brickaville, and about 3 km from the coast. The local study area (LSA) for water quality is the same as the LSA for hydrology, and includes the plant site and ancillary facilities as shown in Volume A, Section 7.

3.8.3 Baseline Summary

3.8.3.1 Water Quality

Based on water quality sampling conducted in 2004, water quality in the watercourses and water bodies within the process plant area ranged from acidic to almost neutral. Measured pH levels typically ranged from 6 to 7. Dissolved oxygen measurements were generally at or below saturation. Water temperatures in both the wet and dry seasons ranged from 25.6 to 32.2^{o}C.

Hardness values for surface waters at most monitoring stations was characterized as very soft (i.e., less than 30 mg/L $CaCO_3$), but ranged from very soft to moderately soft (i.e., 61 to 120 mg/L $CaCO_3$). Several water bodies around the process plant area appeared to be potentially sensitive to acidification based on observed alkalinity values. Nutrient levels were generally low for nitrogen substances, including nitrate, nitrite, Total Kjeldahl nitrogen (TKN) and ammonia, and generally below detection limits for total phosphate.

Observed concentrations for many metals were below detection limits. Aluminum, boron, iron and manganese were generally above detection limits in the wet season. Dry season results for aluminum, arsenic, barium, iron, manganese, silicon, strontium, titanium, vanadium and zinc were typically above detection limits at monitoring stations in the process plant area.

Clear seasonal and spatial patterns in water quality were not observed in the process plant area, with the exception of the following substances and locations. Results for total hardness, magnesium, potassium, aluminum, boron and tin appear to be greater in the wet season compared to the dry season. Observed higher concentrations of many of the major ions and related substances (i.e., total alkalinity, hardness and dissolved solids) in the Pangalanes Canal are likely related to the canal’s connection to the ocean.

Based on the Madagascar classification system (Table 3.8-1), most watercourses and water bodies in the process plant area were Class B or Class C, which indicates most of the water is likely not suitable for swimming. The Class B and Class C categorization were primarily due to observed values for pH, dissolved oxygen, water temperature and chemical oxygen demand. In the wet season, two stations were classified as excessively contaminated (Class HC) due to low dissolved oxygen and high total suspended solids concentrations. In the dry season, two stations were classified as Class HC due mainly to low dissolved oxygen concentrations. Observed concentrations of arsenic, lead and manganese were above World Health Organization (WHO) guideline values for drinking water.

Table 3.8-1 Madagascar Classification System for Surface Water Quality

Factors	Class A	Class B	Class C	Unclassifiable (Class HC)
classification definition	good quality: multiple uses possible	moderate quality: non-contact recreation allowed; swimming may not be allowed	poor quality: swimming not allowed	excessive contamination: no use possible except for boating
Biological Factors				
dissolved oxygen (mg/L)	DO ≥ 5	3 < DO < 5	2 < DO ≤ 3	DO < 2
5-day biological oxygen demand (BOD_5)	$BOD_5 \leq 5$	$5 < BOD_5 \leq 20$	$20 < BOD_5 \leq 70$	$BOD_5 > 70$
chemical oxygen demand (COD)	COD ≤ 20	20 < COD ≤ 50	50 < COD ≤ 100	COD > 100
presence of pathogenic bacteria	no	no	no	yes
Physical and Chemical Factors				
Colour (TCU)	colour < 20	20 ≤ colour ≤ 30	colour < 30	n/a
water temperature (°C)	temperature < 25	25 ≤ temperature < 30	30 ≤ temperature < 35	temperature > 35
pH	6.0 ≤ pH ≤ 8.5	5.5 < pH < 6.0 or 8.5 < pH 9.5	pH ≤ 5.5 or pH ≥ 9.5	N/A
total suspended Solids (TSS) (mg/L)	TSS < 30	30 ≤ TSS < 60	60 ≤ TSS < 100	TSS > 100
conductivity (µS/cm)	conductivity ≤ 250	250 < conductivity ≤ 500	500 < conductivity ≤ 3000	conductivity > 3000

TCU = True colour unit.
N/A = Not applicable.

Madagascar does not have water quality guidelines for the protection of aquatic life. In the absence of national guidelines, international guidelines from other jurisdictions including Canada (Canadian Council of Ministers of the Environment [CCME] 2003) and the United States (US) (US Environmental Protection Agency [EPA] 2004) were used to screen baseline water quality at the plant area. When CCME and EPA guidelines for aquatic life differed, the most stringent guideline from both jurisdictions was used to screen water quality data from the site. South African Ecosystem Guidelines (Department of Forest and Water Affairs, 1996) were used to compare assessment results because they are the closest regionally approved set of water quality guidelines.

Screening results show that pH, dissolved oxygen, ammonia and nine metals (aluminum, arsenic, chromium, copper, iron, lead, mercury, nickel and zinc) were above either EPA or CCME aquatic life guidelines. However, because EPA and CCME guidelines do not take into account local ecological conditions found in Madagascar, exceedances of guidelines should be treated with caution. Indeed, it is not uncommon for baseline water quality data to fall outside the range specified for guideline values even in jurisdictions for which the guidelines have been derived, due to site-specific species and differences in climatic, geological and hydrogeochemical characteristics.

3.8.3.2 Sediment Quality

Bed sediment in the process plant area ranged from predominantly fines to predominantly coarse material. Differences in the physical characteristics of sediments are manifested as differences in key chemical characteristics of the sediment, including nitrogen, organic carbon and phosphorus. However, due to limited sediment quality sampling undertaken so far, it is not possible to identify clear spatial trends in sediment characteristics within the process plant area.

Madagascar does not have sediment quality guidelines. In the absence of national sediment quality guidelines, results of sediment quality sampling at the site were compared to international guidelines from Canada (CCME 2003) and the US (US National Oceanographic and Atmospheric Association [NOAA] 1999). With the exception of arsenic and nickel, substance concentration in bottom sediments were lower than the corresponding international guideline values. Concentrations of arsenic and nickel in bottom sediments were above the CCME and NOAA guideline values, respectively. Because guidelines from other jurisdictions do not take into account local ecological conditions, the guideline exceedances should be treated with caution.

Additional details on baseline conditions are provided in Volume I, Appendix 9.1.

3.8.4 Issue Scoping

Surface water concerns of stakeholders and regulators are focused on water uses because downstream water users and aquatic life may be adversely affected by changes in water and sediment quality associated with construction, operation and closure activities of the project.

The following aspects of the process plant could potentially affect water quality of watercourses and water bodies within the LSA:

- site preparation and clearing (construction only);
- construction of water intake in the Ivondro River (construction only);
- air emissions from process plant (operations only);
- withdrawal of water from the Ivondro (operations only);

- diversion and disruption of natural drainages;
- accidental releases and spills; and
- site closure and reclamation activities (post-closure only).

The linkages between project activities and effects on water and sediment quality are shown in Figure 9-11, Volume H, Appendix 9. Potential water and sediment quality effects can occur during all phases of the project, including construction, operations and post-closure.

The key question for water and sediment quality is:

Key Question SWQ-3 What Effect Will the Process Plant Have on Water and Sediment Quality?

3.8.5 Impact Assessment

The process plant is located about 3 km from the coast and 3 km from the tailings facility area (Volume E). Development of the process plant area will involve the construction and operation of plant facilities, camps and housing, a water intake from the Ivondro River, pipelines for water conveyance and transportation corridors including an access corridor and new rail spur. Storm water from non-process areas will be allowed to be discharged directly back to the natural surroundings. With respect to process areas within the plant, storm water will be collected in a holding pond to allow for settlement and testing prior to release. All treated process water will be managed with the tailings and discharged to the tailings facility. The process plant will produce air emissions from combustion processes within the plant.

The following impact pathways are considered since they have the potential to change water and sediment quality in receiving watercourse and water bodies:

- withdrawal of water from the Ivondro River;
- accidental releases and spills during all phases of the project; and
- air emissions from combustion processes within the process plant.

Construction, operations, and decommissioning of the process plant are expected to result in increased runoff and sediment yields from the disturbed areas; however, no significant impact on water quality within the LSA is expected due to proposed mitigations. Mitigation will include directing surface runoff to a sedimentation pond prior to release to receiving watercourses and water bodies.

Erosion and sediment control systems will be implemented as part of mitigation to control sediment generation and transport to receiving waters.

Water will be pumped from the Ivondro River for water requirements of the process plant. Construction of the water intake could potentially increase the concentrations of sediments and substances associated with sediment. Also, the withdrawal of water has the potential to decrease flows, resulting in a lower dilution (assimilative capacity) of the Ivondro River.

Accidental releases or spills also have the potential to affect water and sediment quality and impair downstream water uses depending on the type of material, magnitude, duration, weather conditions and location of the spill or release.

Nitrogen oxides and sulphur dioxide will be released through air emissions from the process plant. These types of emissions could have the potential to cause acidification (lowering of the pH) in ponds or lakes located around the process plant and tailings study areas.

3.8.5.1 Assessment Methods

The maximum withdrawal of water from the Ivondro River is about 1,000 m^3/h (0.28 m^3/s) on a year-round basis. This water volume represents 0.3% of the mean annual flow in the Ivondro River, and 0.8% of the minimum daily flow for dry conditions. These predicted changes in flow will have negligible effects on the assimilative capacity of the Ivondro River.

Construction of the intake will include erosion control measures to minimize the amount of sediment entering the Ivondro River. The erosion control measures will result in negligible changes in water and sediment quality in the Ivondro River. However, during construction Total Suspended Solids (TSS) will be monitored to confirm that effects on the river are negligible.

Accidental releases or spills also have the potential to affect water and sediment quality and impair downstream water uses depending on the type of material, magnitude, duration, weather conditions and location of the spill or release. Although no accidental releases or spills were assessed in the water quality section, mitigation activities have been identified to reduce and minimize the effects of these events in Section 3.9.5.3. Any potential spills within the process plant area will be contained, collected, and recovered or treated. Emergency response procedures will be established for the safe handling of any accidental releases.

Nitrogen oxides and sulphur dioxide released through air emissions from the process plant have the potential to cause acidification (lowering of the pH) in ponds or lakes located around the process plant and tailings study areas. All emissions are controlled to levels that achieve ambient air quality criteria. Such levels are unlikely to cause any impact on surrounding water bodies. A qualitative review of the potential for acidification of these water bodies due to emissions from the process plant indicated that they are unlikely to be sensitive to acidification. Conditions of the ponds located in the process plant and tailings area were compared to the following general characteristics of acid-sensitive water bodies (Peterson and Sullivan 1998).

- *Concentrations of Dissolved Substances* – Waters sensitive to acidification have low conductivities (typically less than 10 to 25 µS/cm). Conductivity measurements at ponds within the tailings facility and process plant areas were higher than 25 µS/cm and ranged from 30 µS/cm to 152 µS/cm.

- *Topography and Hydrology* – Sensitive waters are typically found at moderate to high elevation, in areas of moderate to high relief, with the potential for rapid changes in water level and minimal contact between drainage water and soil, or geologic material that could dissolve into the waters. In general, the ponds in the tailings facility and process plant areas do not have these characteristics. This area is at low elevation and has low to moderate relief (Volumes D and E, Section 3.1). Documentation from the baseline field program described the monitored ponds as having soft sediments, with organic debris of at least 1 m at some locations, which is not consistent with the scouring effects that occur with rapid level changes.

- *Drainage Area* – Lakes and ponds that are sensitive to acidification generally have small drainage basins. The ponds within the potentially affected area do not appear to be within small headwater streams. In addition, predicted acidifying emissions are lowest for areas that may have smaller drainage areas within the tailings facility area.

Acidification of ponds and streams due to nitrogen emissions is not expected because of the ability of surrounding vegetation to adsorb nitrogen. The predicted area affected by nitrogen emissions is less than 1 km^2 and the maximum predicted emission (7 kg N/ha/yr) is less than the threshold that would cause substantial amounts of nitrogen to leach from surrounding vegetation (10 kg N/ha/yr) (Dise and Wright 1995).

Based on the above qualitative assessment, acidification is not likely to occur in the water bodies near the process plant area.

3.8.5.2 Mitigation

The following mitigations will be implemented in the process plant area:

- implementing runoff and sediment control procedures during site clearing and preparation, and collecting and treating runoff from project facilities and disturbed areas before release into receiving watercourses and water bodies;
- source reductions in air emissions to reduce the potential for acidification;
- waste management practices are established for safe handling and storing all hazardous materials; and
- developing and implementing an effective Emergency and Spill Response Plan as a component of an overall Environmental Management System.

Runoff and sediment control procedures, as described in Section 3.7 (Volume D), will minimize the introduction of sediments and substances adsorbed to sediment into receiving watercourses and water bodies. Also, holding ponds, which promote settling within the pond, are commonly used to reduce sediment concentrations in runoff waters. Mitigation to reduce sediment loading is discussed in more detail in the Hydrology Section (Volume D, Section 3.7).

3.8.5.3 Impact Analysis

Prediction Confidence

The proposed mitigation methods to manage suspended solids, are commonly used and are known to be effective. There is medium to high confidence in the success of the mitigations.

The prediction confidence in changes in the assimilative capacity of the Ivondro River is high, which is based on the high confidence in predictions in changes of flow due to withdrawals and high to medium confidence in the success of mitigations.

The prediction confidence for the potential of acidification of adjacent water bodies due to air emissions from the plant is medium, since baseline information indicates that water bodies near the process plant are not likely sensitive to acidification and emissions will be monitored to ensure they are at or below ambient criteria.

Monitoring

The water quality monitoring program for the process plant area will be designed to monitor suspended solids concentrations in the receiving environment during construction and operations and to identify the potential for acidification in nearby ponds.

During construction, suspended solids will be monitored downstream of instream construction activity at the water intake in the Ivondro River. During operations, water quality will be monitored to ensure discharges meet regulated quality criteria prior to the release to the surrounding area from the holding ponds. Water quality monitoring of water bodies near the process plant will be conducted periodically to ensure that the process plant does not result in a water quality impact.

3.8.5.4 Conclusions

Based on the above assessment of water and sediment quality, the following main conclusions have been identified:

- Negligible changes in water and sediment quality will occur in the Ivondro River due to low proportion of Ivondro River flow diverted to the process plant and erosion control measures implemented at the water intake site.
- Sediment quality in receiving watercourses and water bodies during all phases of the process plant will remain similar to observed baseline levels due to effective erosion control measures and runoff holding ponds.
- Acidification of ponds due to air emissions from the process plant is not likely to occur based on a qualitative assessment, because water bodies that will potentially receive the air emission loads lacked characteristics of acid-sensitive water bodies.

3.9 VISUAL AESTHETICS

3.9.1 Introduction

This section presents the Environmental Assessment for the effects of the process plant on visual aesthetics. As per the Ambatovy Project (the project) Terms of Reference, the viewshed for the process plant is determined and the potential impacts on the nearest habitations or frequented viewpoints are evaluated.

3.9.2 Study Area

The process plant Local Study Area (LSA) for visual aesthetics is an area within 5 km of the process plant property boundaries in all directions, as shown in Volume A, Figure 7.2-3. This study area is designed to include the limits of the area in which the process plant is close enough to be a prominent visible feature within the local terrain.

3.9.3 Baseline Summary

The process plant is located near Antanandava, south of Toamasina, in an area characterized by flat, relatively open coastal topography. The area has sparsely vegetated sand dunes and several ponds or seasonal wetlands, and has been impacted in many areas by prior land clearing. Vegetation varies from grasses to moderately sized shrubs and a woodland to the east. Signs of existing development in the immediate area include huts and powerlines. Within 3 km of the site, there is existing heavy industry, including the Galana refinery.

Key viewpoints for this assessment must be accessible to the public during project activity and must be within the project viewshed. The key viewpoints are summarized in Table 3.9-1. Baseline views from key viewpoints PP1 to PP4 are presented in Volume I, Appendix 11.1, Attachment 1, Photographs 15 through 18.

Additional details concerning baseline conditions are provided in Volume I, Appendix 11.1.

Table 3.9-1 Key Viewpoints: Process Plant Site

Viewpoint Number	Viewpoint Name	GPS Location (UTM Zone 39S)	Possible Viewers	Baseline View Characteristics
PP1	Toamasina (south end) along rail corridor	E 328021 N 7987857	local residents tourists and travelers	heavily human-influenced urban area with residential, industrial and agricultural elements
PP2	Amboakarivo Road (from south of plant)	E 0327374 N 7986213	local residents	village roadway in natural setting, well maintained and scenic
PP3	from west of plant	E 0326108 N 7987111	local residents	sparse vegetation
PP4	from north of plant	E 0326466 N 7987495	local residents	sparse vegetation

Note: GPS = global positioning system; UTM = universal transverse mercator.

3.9.4 Issue Scoping

In public consultations, the main issue of concern expressed by the National Association for the Management of Protected Areas (ANGAP) has been the potential effects of visual impacts on tourism. Areas around the process plant are not considered important tourism areas, but given the proximity of the area to Toamasina, some potential exists for future tourists to view this area. Potential changes that will be seen by local residents, as well as tourists and other visitors include:

- removal of vegetation and changes in landforms, with the development of the plant and all of the associated linear corridors;
- generation of visible dust along the linear access route in dry periods, as well as steam plumes from the plant stacks;
- plant site lighting; and
- the presence of buildings and structures.

The key question for visual aesthetics is:

Key Question VA-1 What Effect Will the Process Plant Have on Visual Aesthetics?

Visual effects will occur during the construction, operation and closure phases of the process plant, similar to the linkages for visual aesthetics at the mine site (Volume H, Appendix 9).

3.9.5 Impact Assessment

During construction and operation phases, vegetation will be cleared, landscape features will be altered, structures will be constructed and periodic visible steam plumes will be visible from the process site. Following closure, the process plant is expected to be used for other industrial purposes, and therefore the visual impacts will remain.

3.9.5.1 Assessment Methods

Topographic information, photographs and on-site observations were used to describe current views. Baseline topographic data and project topography models were used to develop digital elevation maps from which to generate viewsheds.

An overall overhead view of the process plant at its maximum development level was generated to provide a visual impression of the project as a whole for readers; however, this view is not representative of a typical view from ground level to be seen by local residents or tourists, and was not use to evaluate visual impacts.

3.9.5.2 Assessment Criteria

The assessment criteria used for visual aesthetics are presented in Table 3.9-2.

Table 3.9-2 Impact Description Criteria for Visual Aesthetics

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
positive: change in landscape to more natural appearance **negative:** change in landscape to less natural appearance	**negligible:** no measurable effect on visual aesthetics **low:** key viewpoints allow distant or minor views of project effects **moderate:** key viewpoints allow direct but not overwhelming views of project effects **high:** key viewpoints allow for close-in, overwhelming views of project effects (views representing a large proportion of the visible landscape)	**local:** effect restricted to the LSA **regional:** effect extends beyond the LSA	**short term:** <3 years **medium term:** 3 to 30 years **long term:** >30 years	reversible or irreversible	**low:** views occur rarely **medium:** views occur intermittently **high:** views occur continuously

3.9.5.3 Mitigation

Vegetated areas exist in many areas around the perimeter of the process plant property. In these areas, vegetated buffers will be maintained.

A particular emphasis will be placed on vegetation along the Pangalanes Canal, which is used by tourists and other small watercraft users.

Pipelines to and from the process plant will be buried.

Fully shielded light fixtures will be used and directed away from nearby populated areas.

The facilities and grounds of the plant site will be kept in an orderly state.

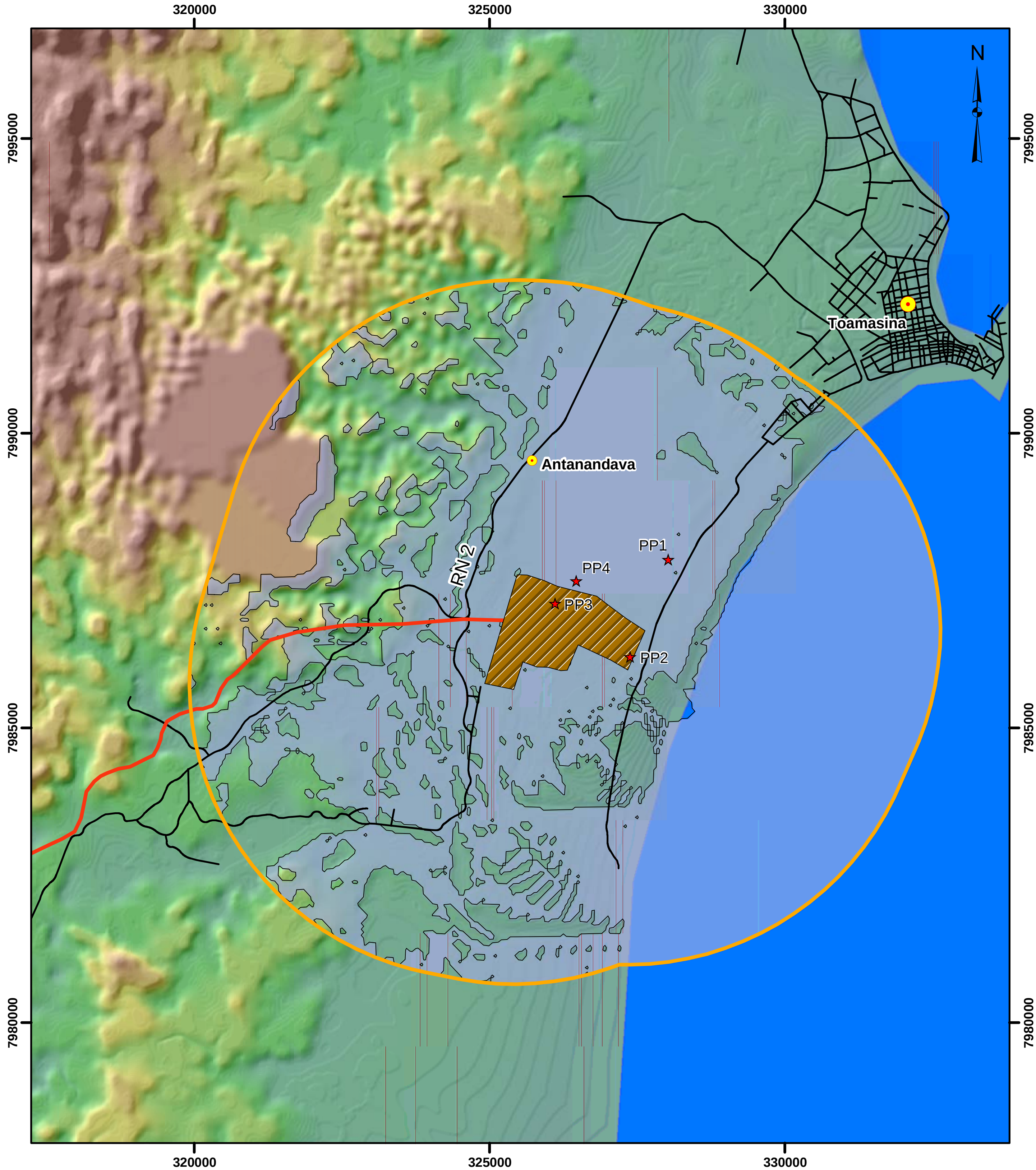
3.9.5.4 Results

A viewshed evaluation for the process plant buildings is presented in Figure 3.9-1. The viewshed evaluation shows that the plant facilities, especially the tops of the taller facilities such as major plant facilities, boilers, tanks and stacks, will be visible throughout much of the LSA. The assumed heights of key facilities for the purpose of this analysis are listed in Table 3.9-3.

Table 3.9-3 Structure Heights (Process Plant)

Structure	Height Above Ground (m)
vent scrubber	30
raw liquor heater	40
sulphide area flare	40
hydrogen plant	50
acid plant	60
coal-fired boiler	80

The visibility of many plant site structures will be relatively high due to their size and the flat terrain surrounding the site. However, the viewshed area shown in Figure 3.9-1 is conservative in that it does not include the effects of vegetation or structural features which obscure views in many locations. Based on the conservative viewshed shown, one or more plant site facilities are visible from 72% of the study area (including virtually all of the Indian Ocean that is within 5 km). Within Toamasina, the viewshed does occur, but views from the city are expected to be negligible in magnitude as a result of the distance to the site and prominence of other, closer, urban and industrial development.



1.5 0 1.5 3

SCALE: 1:90,000 KILOMETRES

LEGEND

- CITY
- POPULATION CENTRE
- VIEWPOINT
- ROAD
- APPROXIMATE SLURRY PIPELINE ROUTE
- PLANT SITE
- VIEWABLE AREA
- VISUAL AESTHETICS STUDY AREA

REFERENCE

Datum: WGS 84 Projection: UTM Zone 39S.

PROJECT

AMBATOVY PROJECT

TITLE

PROCESS PLANT VIEWSHED ANALYSIS

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	GJ	13 Sep. 2005	**FIGURE: 3.9-1**	
GIS	TN	25 Oct. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

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Groups of people likely to be viewing the process plant include local residents, residents of southern Toamasina and passers-by along Route National (RN) 2. For viewers within the viewshed, perceptions of the aesthetic effects of the process plant may be affected by:

- the surrounding landscape, including landforms, vegetation and general level of modification;
- the form, texture, colour, size and level of contrast of the part of the process plant being viewed with the surrounding landscape;
- the distance between the observer and the process plant;
- viewing orientation, frequency and duration; and
- viewer perception as to what is attractive or unattractive, and expectations as to what “should” or should not be seen in this location.

The process plant will cover 2.9 square kilometers (km^2), and will include numerous storage areas, industrial facilities, plants, and processing areas. The main facilities of the plant (1.0 km^2 in size) will be fenced. In general, because of the flat landscape surrounding the process plant, it will present a clear visual impact for almost all surrounding areas. However, existing disturbances in the area, including industrial activity and urban development, will reduce the intensity of the impact for most observers. Views from RN2, and from other areas outside of the LSA, will be at least partially obstructed by vegetation.

An overhead view of a preliminary/conceptual model of the process plant is presented in Figure 3.9-2.

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PROJECT

AMBATOVY PROJECT

TITLE

PROCESS PLANT OVERHEAD VIEW

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172.6500			SCALE AS SHOWN	REV. 0
DESIGN	GJ	26 Aug. 2005	**FIGURE: 3.9-2**	
GIS	TN	26 Aug. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

3.9.5.5 Impact Analysis

Residual Impacts

Following mitigation, the residual effects during each project period are summarized in Table 3.9-4.

Table 3.9-4 Potential Effects and Residual Impacts for Visual Aesthetics

Project Period	Potential Effects	Mitigation	Residual Impacts
construction and operations	clearing of land and changes in landforms	n/a	negligible impact magnitude for key viewpoints
	visible structures	the facilities and grounds will be kept in an orderly state vegetation buffers will be maintained	moderate impact on key viewpoints
	lighting	fully shielded lights directed away from viewers	negligible impact on key viewpoints
	visible steam plumes	n/a	low impact on key viewpoints and surrounding area
closure	changes in landforms will persist beyond closure	n/a	negligible magnitude / long-term modification visible landscape
	visible structures will persist beyond closure	n/a	moderate magnitude / long-term presence of facilities

Note: n/a = Not applicable.

The construction of linear access infrastructure and buildings and storage facilities at the process plant will occur during the construction phase. During the operations phase, storage piles of sulphur, coal and limestorne will be present. The structures will be left in place following closure for other uses.

The geographic extent of impacts of the structures at the site is regional, as flat topography will allow various parts of the project to be visible from outside of the LSA during construction, operations and after closure. In particular, steam plumes may be visible from a long distance.

Landform and facility impacts are not reversible in the time frame of the project, as the landscape will not be returned to its initial state. Viewing frequency is medium, given the proximity to a highly populated urban area, but taking into account that vegetation will obscure views from many viewpoints. Overall, the environmental consequence for visual effects is negligible for topography in all project phases but is moderate due to structures in all project phases.

Lighting will have an impact low in magnitude, due to mitigation and the use of fully shielded lighting fixtures that will not release a great deal of light upward or toward nearby houses or villages. Effects are local in extent, medium-term in duration (during construction and operations only) and are reversible. Viewing frequency is expected to be medium. The overall environmental consequence of lighting for visual aesthetics will be low.

The impact presented by steam plumes will be low in magnitude during the operations phase. Steam plumes will be released from various stacks at the site. The steam plumes are likely to be visible year-round at the site due to high ambient temperature and relative humidity, and will usually be white in colour. Effects are regional in extent, medium-term in duration and are reversible. Viewing frequency is expected to be medium. The overall environmental consequence of steam plumes is moderate.

An overall residual impact classification for visual aesthetics for each key issue and each phase of the project is presented in Table 3.9-5.

Table 3.9-5 Residual Impact Classification for Visual Aesthetics

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Effect of Landforms on Visual Aesthetics							
construction / operations	negative	negligible	local	medium-term	no	low	negligible
closure	negative	negligible	local	long-term	no	low	negligible
Issue: Effect of Structures on Visual Aesthetics							
construction / operations / closure	negative	moderate	regional	medium-term	yes	medium	moderate
Issue: Effect of Lighting on Visual Aesthetics							
construction / operations	negative	low	local	medium-term	yes	low	low
Issue: Effect of Visible Steam Plumes and Dust on Visual Aesthetics							
operations	negative	low	regional	medium-term	yes	low	moderate

Prediction Confidence

The baseline status of topography in the LSA is well understood, and detailed information about the future landscape and future construction at the process plant has been made available through project descriptions. A large variety of people are expected to see the site, and the response of specific individuals to seeing the site is an unknown. Overall, the prediction confidence for this assessment is considered high.

Monitoring

No monitoring is proposed specifically for visual aesthetics.

3.9.6 Conclusions

The process plant will have moderate environmental consequences for visual aesthetics as a result of the process structures, and these effects will occur during all project phases. Moderate environmental consequences are also expected as a result of visible steam plumes from the site in the operations phase.

Low environmental consequences due to lighting are anticipated during construction and operations phases. Negligible effects for visual aesthetics will occur during all project phases due to topographic modification.

4.1 FLORA

4.1.1 Introduction

This section of the Environmental Assessment (EA) provides an evaluation of potential effects of the project on flora within the process plant local study area (LSA). In compliance with the Terms of Reference (Volume H, Appendix 1), site-specific data were collected to address the following elements as they relate to flora within the Ambatovy Project (the project) area:

- inventory the natural plant communities of concern to assess species endemicity (including local endemics);
- map and describe the baseline flora of the study area;
- discuss the mitigation and compensatory mechanisms to be used to reduce/offset losses to flora and natural community types;
- assess residual impacts to flora from construction, operation and closure activities; and
- provide details on flora monitoring and management that include participation of stakeholders.

4.1.2 Study Area

The process plant LSA includes the process plant property, Ivondro River water intake pipeline, fuel supply pipeline from the proposed Logistique Pétrolière Jetty area, the start of the access corridor toward the port to the north, and the marine water outfall pipeline corridor, with a 500 m buffer around all of these areas. The specific boundaries of the process plant LSA are presented in Volume J, Appendix 1.1, Figure 1-16.

4.1.3 Baseline Summary

The following provides a summary of the baseline flora results within the plant site LSA. The summary focuses on those results that are important for assessing impacts from the project. A complete description of the baseline methods, analysis and results are located in Volume J (Appendix 1.1).

4.1.3.1 Vegetation Overview

Vegetation within the region was once part of an extensive coastal band of littoral eastern lowland rainforest of Madagascar. Now, the primary forests are gone in this region and in most areas along the coast have been replaced with highly degraded secondary forest patches, shrublands and grasslands as a result of logging, agricultural clearing and invasion by weeds or exotic species.

Disturbances in the process plant area in addition to the nutrient-poor soils which are sandy and contain low amounts of organic matter, have led to the development of a varied matrix of vegetation consisting of the following main vegetation types:

- coastal shrubland/grassland complex;
- degraded residual coastal woodland;
- beach ridge complex;
- plantation;
- rice paddies; and
- shrubland.

The dominant vegetation type within the plant site LSA is the coastal shrubland/grassland complex (640 ha or 41% of the LSA). This class consists largely of a coarse grass layer interspersed by open shrubland. Deforestation is the prime factor that has lead to the development of this vegetation type.

The second most common vegetation class is the degraded residual coastal woodland (166 ha or 11% of the LSA). This forest community consists of a mixture of native and non-native plants (including *Eucalyptus* and gum). Exotic tree species have altered species composition and forest structure; however, there are still remnant species that once existed here in greater numbers.

The third most common vegetation class is the beach ridge complex which is a geomorphic-induced vegetation unit characterized by a set of former beach ridges that run parallel to the coastline. Vegetation within this unit varies with topographic position, and is characterized by sparse to high cover of coarse grass and herbaceous species on the higher elevations, and dense wetlands vegetation on organic soils within the troughs of the undulating landform. This vegetation type covers a total area of 161 ha representing 10% of the LSA.

4.1.3.2 Vulnerable and Threatened Species

Three endangered or vulnerable International Union for the Conservation of Nature (IUCN) listed species were found within the process plant LSA. These species are at risk to extirpation or extinction because their populations are in decline as a result of deforestation.

4.1.3.3 Plant Species Richness

In total, 185 species were inventoried during the survey. Some of the dominant plant species encountered within the plant site LSA were *Melaleuca quinquenervia, Eucalyptus robusta, Cyperus latifolius, Ficus baroni, Terminalia cattapa* and *Typhonodorum lendleyanum*. Due to the disturbed nature of the study area, many species within the LSA are invasive and common within the region.

4.1.3.4 Species Endemism

No locally endemic species were identified within the process plant LSA. This is largely due to the disturbed nature of the area and that similar habitat exists within the coastal region. Of the 185 species inventoried, 109 were classed as endemic to Madagascar and 73 as regionally endemic. An additional 3 species were classed as exotics.

4.1.4 Issue Scoping

A principal aspect in identifying environmental issues for the project involved public consultations. These meetings provided the opportunity to solicit input from local communities, conservation organizations and government agencies at all levels to identify environmental and social concerns. The following issues related to project impacts on flora were based on the outcome of the public consultation sessions, a review of previous environmental assessments for resource developments in Madagascar and elsewhere, and the Terms of Reference (Volume A, Section 6; Volume H, Appendix 1). The main issues of concern relating to flora within the process plant LSA are:

- loss or alteration of plant communities;
- changes in species diversity;
- air emissions effects to flora; and
- invasion of areas containing native vegetation by exotic or unwanted species.

Throughout the EA, key questions were used to develop cause and effect pathways (Volume A, Section 7). The diagram illustrating the pathways between project activities and effects on flora are shown in Volume H, Appendix 9. The key question for flora is:

Key Question FL-1 What Effect Will the Process Plant Have on the Loss or Alteration of Plant Communities?

Project-related activities anticipated to result in changes to flora include construction and operation of the process plant. Direct losses to plant communities will result from process plant construction and operation activities.

The potential effects of air emissions on plant communities were considered in this assessment. Dispersion modelling for SO_2 and NO_X was carried out for the process plant. Results showed that annual emission levels were below World Health Organization (WHO) guidelines for terrestrial vegetation (WHO 2000). No guidelines exist for the effects of fugitive dust on flora; however, levels modelled were very low and therefore not considered an issue to flora. Therefore, vegetation impacts due to air emissions were not considered further.

The issue of species loss (species extirpation or extinction) was also considered. Results from the reconnaissance aerial and ground surveys showed that the process plant LSA is highly disturbed, and within the coastal region, contains no unique habitat. Vulnerable or endangered species occurring within the process plant LSA are also found in other areas of the region. Thus, these occurrences represent species of concern at the regional level but are not threatened with extirpation or extinction as a result of this project. Additionally, no locally endemic species were found.

The potential effects of the project on the spread or introduction of exotic or unwanted plant species were also considered in this assessment. However, the LSA is highly disturbed and contains exotic and unwanted plant species that are prevalent throughout the region. Eradicating these plants from the LSA during the construction phase is unwarranted.

4.1.5 Key Question FL-1 What Effect Will the Mine Have on the Loss or Alteration of Plant Communities?

During the construction and operations phases, flora will be directly disturbed through the clearing of vegetation.

4.1.5.1 Assessment Methods

Impacts of the project on the loss or alteration of flora is assessed through changes in the total area of vegetation types due to clearing activities for the process plant.

Impact assessments were conducted for the period of construction through operation. It is assumed that maximum impacts will occur during the construction period.

4.1.5.2 Assessment Criteria

Residual impacts were determined based on a classification system that incorporates direction, magnitude, geographic extent, duration, reversibility and frequency of the impact as described in Volume A (Section 7.4). Determination of the overall environmental consequence uses magnitude, geographic extent, and duration, and is described in Volume A (Section 7.4).

The assessment criteria used for plant communities are presented in Table 4.1-1.

Table 4.1-1 Impact Description Criteria for Plant Communities

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
neutral: no change[a] in plant communities **negative:** a change in plant communities	**negligible:** no measurable effect on plant communities **low:** <10% change in plant communities **moderate:** 10-20% change in plant communities **high:** >20% change in plant communities	**local:** effect restricted to the LSA **regional:** effect extends beyond the LSA	**short term:** <3 years **medium term:** 3 to 30 years **long term:** >30 years	reversible or irreversible	**low:** occurs once **medium:** occurs intermittently **high:** occurs continuously

[a]change in structure or composition

4.1.5.3 Mitigation

Mitigations are planned to reduce the magnitude, geographic extent and duration of direct impacts from the project on flora in the process plant LSA. The main areas of mitigation is to maximize avoidance of key plant communities through siting and access design.

4.1.5.4 Results

Direct Losses to Plant Communities Within the Process Plant Local Study Area

Direct losses to disturbed plant communities resulting from construction and operation of the process plant will amount to 322 ha (21% of the plant site LSA) (Table 4.1-2). Of this portion, the coast shrubland/grassland complex will be the most affected with a loss of 220 ha (34% of this class within the LSA). This vegetation type is highly disturbed. The next most affected class is rice paddies with a loss of 44 ha (40% of this type). Other disturbed vegetation types affected include 29 ha of degraded residual coastal woodland (17%), 13 ha of disturbed wetlands (23%), 6 ha of disturbed shrubland (6%), 4 ha of tavy matrix (7%) and 1 ha of disturbed beach ridge complex (<1%).

Table 4.1-2 Change in Vegetation Type Area as a Result of Site Clearing within the Process Plant Local Study Area

Vegetation Type/ Land Use Type	Base Case	Impact Case	Change	Change
	ha	ha	ha	%
Forested Vegetation				
degraded residual coastal woodland	166	137	-29	-17
plantation	151	151	0	0
forested subtotal	*317*	*288*	*-29*	*-9*
Non-Forested Vegetation				
beach ridge complex	161	160	-1	-<1
coastal shrubland/grassland complex	640	422	-220	-34
rice paddies	110	66	-44	-40
shrubland	105	99	-6	-6
tavy matrix	59	55	-4	-7
village	9	8	-1	-11
wetlands	56	43	-13	-23
non-forested subtotal	*1,140*	*851*	*-289*	*-25*
Non-Vegetated Class				
access corridor	11	7	-4	-36
canal	15	15	0	0
quarry	3	3	0	0
river	61	61	0	0
non-vegetated subtotal	*90*	*86*	*-4*	*-4*
total	**1,547**	**1,225**	**-322**	**-21**

Note: Due to rounding, subtotal and totals may not add precisely to expected values.

4.1.5.5 Impact Analysis

Residual Impacts

Residual Impacts to Plant Communities From Clearing Activities

Activities related to construction and operation of the process plant will result in vegetation losses. The types of habitat that occur within the LSA are not unique to the coastal region and the vegetation is highly disturbed or degraded from its original state. Nonetheless, several of the vegetation types do provide some value in terms of biological diversity and wildlife habitat to the local area and region.

Losses to the degraded residual coastal woodland amount to 29 ha or 17% of this vegetation type. Consequently, the magnitude of impact is predicted to be moderate. Reduction in the area of shrubland habitat amounts to 6 ha or 6% of this vegetation type resulting in a low impact magnitude. The magnitude of impacts as a result of direct losses to the coastal shrubland/grassland complex (220 ha representing 34% of this vegetation type) and the wetlands vegetation type (13 ha representing 23% of this vegetation type) are predicted to be high. These high percentage values are of course a function of the small size to the LSA, with only a small buffer around project elements. Recognizing this and that LSA habitats are disturbed, the magnitudes of impacts are lessened and predicted to be moderate based on professional judgement (Table 4.1-3). Residual impacts to rice paddies and plantations are discussed in the Land Use section (Volume D, Section 5.3).

Direct impacts from the project are predicted to be local in geographic extent. Impacts from construction and operations are predicted to be long-term in duration and medium in frequency. The effects from the project will be reversible for all vegetation types except wetlands which will be irreversible.

Taking all criteria into consideration, the environmental consequence of direct impacts from the project on vegetation types with moderate biological value is predicted to be low during construction and operation phases of the process plant. Besides clean-up and decommissioning activities, vegetation reclamation is not planned for the process plant as other industrial uses for the site are expected to occur in the future (see Volume D, Section 6 for additional information).

Mitigation to limit the amount of disturbances in the LSA has in part been achieved through siting design (i.e., locating the process plant in a previously disturbed area). Additionally, appropriate access will be developed to minimize impact on any sensitive vegetation zones.

Table 4.1-3 Residual Impact Classification for Loss of Plant Communities

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Losses To Plant Communities							
degraded residual coastal woodland	negative	moderate	local	long-term	reversible	medium	low
coastal shrubland/grassland complex	negative	moderate	local	long-term	reversible	medium	low
shrubland	negative	low	local	long-term	reversible	medium	low
wetlands	negative	moderate	local	long-term	irreversible	medium	low

Prediction Confidence

The confidence in the impact predictions is related to:

- Adequacy of baseline data for understanding current conditions.
- Understanding of project-related impacts on the ecosystem.

Flora impact predictions are based on the spatial distribution of vegetation types within the process plant LSA. The baseline vegetation map was developed from a combination of air photo interpretation and selected ground-truthing. The vegetation type classification is considered to be relatively accurate and therefore the prediction confidence for direct effects on vegetation (i.e., loss of vegetation types) is considered to be high.

Monitoring

No vegetation monitoring is proposed for the process plant study area.

4.1.5.6 Conclusions

Avoidance of native vegetation through siting design will provide the most effective mitigation to limit native plant community losses. Of the vegetation that will be lost as a result of the process plant, all is highly disturbed consisting primarily of degraded secondary forest patches, shrublands and grasslands as a result of logging, agricultural clearing and invasion by weedy or exotic species. Wetlands also exist in the LSA but are disturbed as well. Because of the relatively poor vegetation condition, the environmental consequence to plant communities is predicted to be low during construction and operation phases. The closure phase will consist of decommissioning activities but will not be reclaimed to allow for future industrial development.

4.2 FAUNA - PROCESS PLANT

4.2.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the process plant and tailings facility on fauna, including potential impacts on rare species, faunal movement and faunal health, as per the Ambatovy Project (the project) Terms of Reference and issues raised during consultation (Volume H, Appendix 1; Volume A, Section 6). The effects of process plant and tailings facility plus the disturbance corridor linkage them were assessed together due to the proximity of the components. Baseline results and project effects are summarized separately for each component, where appropriate.

This EA includes a baseline summary of survey results for key taxa and a summary of key issues. For each identified issue, the following topics were addressed:

- evaluation of potential impact pathways;
- assessment methods;
- assessment criteria;
- mitigation;
- impact analysis;
- residual impact classification;
- prediction confidence; and
- monitoring.

A summary of the main impacts as they relate to key species and habitats is provided.

4.2.2 Study Area

The Toamasina Local Study Area (LSA) is located immediately south of the city of Toamasina. The LSA encompasses the tailings facility and plant site property boundaries, the intake pipeline, marine outfall pipeline and tailings plant pipeline plus a 500 m buffer as well as areas that may potentially be affected by decreases in flows in the downstream watershed from the tailings (Figure 7.2-3, Volume A).

4.2.3 Baseline Summary

4.2.3.1 Introduction

The Toamasina LSA was surveyed for amphibians, reptiles and birds in 2004 and 2005.

Vegetation Classification

Remote sensing data were used to produce spatial land cover maps. Details of the methods used to determine land cover classifications for each study area are provided in Volume J (Appendix 1.1).

Faunal Surveys

Amphibians, Reptiles and Birds

Baseline herpetofauna and bird surveys were conducted in the Toamasina LSA, including the tailings facility site and plant site in April 2004 and again at the plant site in April 2005. The methods followed those described for the mine local study area (LSA) (Volume J, Section 2.1).

4.2.3.2 Results

Vegetation Classification

Vegetation types identified in the Toamasina LSA include the following:

- agroforestry;
- coastal woodland;
- rice paddies;
- shrubland, including coastal;
- tavy; and
- wetlands.

General Fauna Results

Amphibians and Reptiles

Nine amphibian species and 14 reptile species were recorded during the herpetological surveys located in the Toamasina LSA. Of these, one amphibian species, *Hoplobatrachus tigerinus* is not endemic to Madagascar. No species documented during the survey is listed by International Union for the

Conservation of Nature (IUCN). Six species observed during the surveys in the Toamasina LSA are listed by Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) in Appendix II and include one amphibian and five reptile species (Volume J, Appendix 2.2, Table 4).

Species richness was found to be greater in the tailings part of the Toamasina LSA. Both the tailings and plant site areas have a history of disturbance and little primary habitat remains. Seven amphibian and 11 reptile species were recorded within the tailings area. Four amphibian and six reptile species were recorded within the plant site study area. A full species list is provided in Volume J, Appendix 2.1. Of the 23 species observed in the Toamasina LSA, five species were found in both study areas.

Species were summarized by the areas (plant, tailings) and habitats in which they were observed (Volume J, Appendix 2.1). Unique species, i.e., species only observed in one area or habitat, were also identified. As the species accumulation curve calculated for the LSA was still increasing, additional surveys would be required to determine true species richness in the area.

Birds

Fifty-nine bird species were documented within the Toamasina LSA. Thirty-seven of those species are endemic to Madagascar and one, *Acridotheres tristis*, is exotic. Two bird species are listed under IUCN and five species are listed by CITES (Volume J, Appendix 2.2, Table 4).

Fifty-two bird species were documented within the tailings area of the Toamasina LSA, and 34 species within the plant site area. Both IUCN-listed species were reported in both areas; however only one of the five CITES species, *Falco newtoni newtoni*, was observed in the plant area.

4.2.4 Impact Assessment

4.2.4.1 Issue Scoping

The baseline summary described the key faunal species and faunal habitat found within the Toamasina LSA, particularly for species of concern (IUCN 2004; UNEP-WCMC 2005). The purpose of the impact assessment is to assess specific effects on the key species and habitats found within the LSA, identify strategies to reduce potential project-related effects and discuss the potential to return the area to pre-disturbed faunal habitat conditions. Various issues and concerns related to potential project impacts on fauna were raised during consultation, especially with environmental nongovernmental organizations (NGOs) (Volume A, Section 6).

Main issues connected to faunal species include:

- potential impacts to populations of rare and endangered species from construction and operation of the process plant and tailings facility;
- direct and indirect effects on faunal habitats from construction and operations;
- habitat fragmentation and potential impacts on movements of faunal species; and
- potential effects on faunal health due to changes in water and air quality.

These issues can be summarized by the following key questions:

Key Question W-1 What Effect Will the Project Have on Faunal Abundance and Distribution?

Key Question W-2 What Effect Will the Project Have on Movement of Faunal Species?

Key Question W-3 What Effect Will the Project Have on Faunal Health?

Ambatovy Project activities could affect fauna through habitat loss and alteration, direct and indirect mortality and changes in access and use. Direct habitat loss can result from site clearing and changes in hydrology. Indirect habitat loss can result from sensory disturbance and air emissions. Direct and indirect mortality may result from habitat clearing, sensory disturbance from construction or operations, removal of nuisance fauna and interaction of fauna with infrastructure. Changes in access and use may lead to increased hunting and collecting and potential for increased vehicle-fauna collisions. Fragmentation and barriers to movement can affect faunal movement and dispersal. These effects are primarily a result of construction and operation activities. Positive effects to fauna and faunal habitat are expected to result from reclamation.

Impacts to fauna could occur during construction and operations as shown in the linkage diagram (Volume H, Appendix 9).

For each effect associated with the Ambatovy Project, a linkage analysis is provided for each issue, followed by a mitigation section, impact analysis, residual impact classification and monitoring. Where issues were related (e.g., edge effects), they were analyzed and discussed together to avoid repetition.

4.2.4.2 Key Question W-1 What Effect Will the Project Have on Faunal Abundance and Distribution?

Habitat loss can result from activities during the construction and operation phases. Habitat loss can result from the following:

- site clearing;
- change in water flows;
- sensory disturbance;
- air emissions, including dust;
- fragmentation; and
- barriers to movement.

Faunal habitat can be lost through direct or indirect activities. Direct habitat loss results from the physical removal of habitat through site clearing during the construction and operation phase of the Ambatovy Project. Direct habitat loss may also result through habitat fragmentation, where habitat quality is reduced to the point that it is no longer used by fauna. Wetlands drainage or water drawdown is another form of direct habitat loss. Indirect habitat loss is when the habitat is still physically available but fauna choose not to, or may not be able to use it as a result of physical barriers and sensory disturbance.

Direct habitat loss and initial fragmentation are closely associated with the construction phase while barriers to movement, sensory disturbance and habitat loss from air emissions are more closely associated with the operational phase. However, both phases of the Ambatovy Project may result in direct and indirect habitat loss. Habitat fragmentation and barriers to movement are addressed under Key Question W-2.

Direct Habitat Loss

Potential Impact Pathway Evaluation

Site Clearing

Direct habitat loss is the most visible effect and occurs when land is cleared for other uses. Of all possible sources of impact from project construction, permanent habitat loss is one of the most important as it reduces the landscape's capability to support fauna (Fahrig 2003, Laurance et al 1999). Because some facilities (e.g., tailings facility, plant, roads) will be permanent for the life of the Ambatovy Project, habitat loss is a long-term event for these features. Habitat loss may be temporary for other facilities (e.g., buried pipelines).

Change in Water Flows

Wetlands drainage and groundwater or surface water drawdown can directly and indirectly remove or alter habitat for amphibians, waterbirds and other species that occur in wetlands (Coughanowr 1998). In the tailings area, changes in water flows are predicted (Volume D, Section 3.7) and are associated with construction and operations. In the plant area of the LSA, changes in water flows are predicted to be negligible (Volume C, Section 3.6), so this impact pathway requires no further assessment for fauna.

Assessment Methods

Site Clearing

Changes in areal extent of each habitat type were assessed from baseline to impact case based on the mapped vegetation classification for the Toamasina LSA. The project footprint includes the tailings facility, the plant site and associated infrastructure. The location of the roads and construction areas immediately adjacent to the tailings facility are not known, but it is assumed these components will disturb approximately half of the area between the tailings area impact footprint and property boundary. Therefore, 50% of the area of each habitat located in this zone was added to the total disturbance footprint to estimate impacts from site clearing.

Impacts were assessed for total footprint although clearing and reclamation of the tailings area will occur progressively over the life of the project. Thus, the impact analysis is conservative. Reclamation will restore habitat in the tailings area but was not assessed quantitatively.

Change in Hydrology

Changes in water flows from baseline to impact were assessed for the wet and dry season for the three basins in the tailings area. Methods are described in detail in the Hydrology Section (Volume D, Section 3.7). Potential impacts to habitats and associated species are discussed qualitatively.

Assessment Criteria

The Assessment Criteria used for fauna are presented in Table 4.2-1. Where quantitative values are not possible, results from the literature, local specialists and professional judgment were used to determine impacts.

Table 4.2-1 Impact Description Criteria for Fauna

Direction[a]	Magnitude[b]	Geographic Extent[c]	Duration[d]	Reversibility[e]	Frequency[f]
positive, negative or neutral for the measurement endpoints	negligible: no measurable effect on the measurement endpoint low: <10% change in measurement endpoint moderate: 10 to 20% change in measurement endpoint high: >20% change in measurement endpoint	local: effect restricted to the LSA regional: effect extends beyond the LSA into the RSA beyond regional: effect extends beyond the RSA	short-term: <3 years medium-term: 3 to 30 years long-term: >30 years	reversible or irreversible	low: occurs once medium: occurs intermittently high: occurs continuously

(a) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(b) Magnitude: degree of change to analysis endpoint.
(c) Geographic Extent: area affected by the impact.
(d) Duration: length of time over which the environmental effect occurs. Considers a 3-year construction period and a 27-year operations period.
(e) Reversibility: effect on the resource (or resource capability) can or cannot be reversed.
(f) Frequency: how often the environmental effect occurs.

Mitigation

Mitigation measures that will reduce the effects of habitat loss and alteration from site clearing and changes in hydrology in the Toamasina LSA to fauna include:

Design Elements

- Footprint of all sites represents smallest feasible size to meet needs of the project.
- Use of existing disturbance (e.g., road to tailings facility) reduces the area of new clearing.
- Build precautionary design features in tailings dam to reduce the risk of rupture and emergency planning to mitigate effects in event of a failure.

Mitigation Techniques

- Environmental monitors will work ahead of construction. For fauna, an emphasis will be in the few areas where more natural vegetation or treed habitats will be disturbed. Key faunal species will be relocated or collected before site clearing where feasible.
- Tailings area will be progressively cleared during operations.
- Reduce shoreline and in-water disturbance during construction of intake on Ivondro River and water pipeline.
- Maintain watercourse buffers as long as practical to aid in maintaining on-site water quality and provide faunal habitat.

- Establish a closure water management plan and tailings facility monitoring.

Reclamation and Closure

- Tailings area will be progressively reclaimed during operation.
- Develop reclamation and revegetation plan for the tailings facility that includes appropriate vegetation in conjunction with local stakeholders and regional planners

Impact Analysis

The maximum area of new disturbance for the tailings facility, plant site and associated infrastructure will be 1,469 ha (Table 4.2-2). This value includes the known footprint (1,331 ha) and the area predicted to be disturbed by roads and construction laydown areas immediately adjacent to the tailings facility (138 ha). As a conservative estimate of impacts on faunal habitat, it was assumed that construction of all elements would occur at the same time.

Table 4.2-2 Change (%) in Habitat Area as a Result of Site Clearing Within the Toamasina Local Study Area

Habitat Type	Baseline Case (ha)	Impact Case (ha)	Change Due to Known Footprint (ha)[a]	Additional Predicted Change (ha)[b]	Total Change (%)
wetlands	117	85	-26	-3	-24.8
Ivondro River	61	61	0	0	0
coastal woodland	166	137	-29	0	-17.5
shrubland[c]	1,103	873	-230	0	-20.9
agroforest	268	227	-25	-8	-12.3
tavy	2,278	964	-939	-125	-46.7
rice paddies	195	140	-52	-1	-27.2
other[d]	457	424	-30	-1	-6.8
total	**4,645**	**2,911**	**-1,331**	**-138**	**-31.6**
streams and rivers (km)[e]	95	38	-53	-4	-60.0

(a) Footprint includes tailings facility, plant site and associated infrastructure.

(b) The location of roads and construction laydown areas immediately adjacent to the tailings facility is not finalized but the disturbance area is predicted to cover 50% of the area between the tailings facility and tailings property boundary. To assess impacts, 50% of the area of each habitat in this zone was added to the known footprint.

(c) Includes coastal shrubland/grassland complex, shrubland and beach ridge habitat types.

(d) Includes industry and urban infrastructure.

(e) Baseline values include the Ivondro River which will not be disturbed.

Species richness was low for amphibians (9) and reptiles (14) in the Toamasina area but greatest in the tavy, shrubland and wetlands habitats (Volume J,

Appendix 2.2). Habitat loss as a result of site clearing will be greatest in these habitats, with proportional losses of 46.7%, 20.9% and 24.8%, respectively (Table 4.2-2). Although the proportional loss of these habitats is high, all but perhaps the wetlands have been highly degraded and likely do not represent high quality habitat for fauna.

The majority of the 59 bird species recorded during baseline surveys are associated with forested and wetlands habitats. Site clearing will disturb 17.5% (29 ha) of the coastal woodland and 12.3% (25 ha) of the agroforest. Most (96%) of the LSA has been previously disturbed or degraded, yet the natural wetlands support the two IUCN-listed species, *Rallus madagascariensis* and *Tachybaptus pelzenii*, observed during baseline surveys. Both species were observed in both the process plant and tailing facility areas. These species are of most concern as a result of clearing if suitable wetlands habitat is not available in the area and if losses of these wetlands affect population dynamics.

The tailings site will be progressively reclaimed during operations. At closure, a variety of land uses may be proposed for the final tailings facility and will be subject to consultation. End land uses are dependant on the reclamation potential of the tailings materials which will be studied during project operations. The ecological objective for the site will be to re-establish a natural or agro-ecosystem that is physically stable, sustainable and provides good vegetative cover to guard against erosion in the long term.

Change in Hydrology

During construction and operations, the changes in water flow are predicted to be high in the three basins in the tailings area (Table 4.2-3). Impacts are less in the downstream sections, but remain high during operations. At closure, impacts are predicted to be low in all basins except for reach C1, immediately downstream of the reclaimed area in Basin C, which is predicted to have 53% less average flow than at baseline (Volume D, Section 3.7).

Table 4.2-3 Reduction in Water Flows as a Result of Changes in Hydrology within the Toamasina Local Study Area

Basin[(a)]	% Change-Operations[(b)]	% Change-Closure
A	39-65	2-5
B	0-66	0-4
C	37-53	3-53

(a) Basins in the tailings area of the LSA.

(b) Range in average values for all reaches in each basin.

High changes in water flow along riparian areas, can affect floral diversity, thereby affecting faunal diversity.

Expected habitat loss as a result of changes in hydrology, specifically lower flows, will affect species associated with riparian habitats. If water flow to the remaining wetlands in the LSA is reduced, wetlands bird species and amphibians will be the most affected. Of the 59 bird species, 14 are associated with wetlands including the two IUCN-listed bird species. In general, the LSA supports few amphibian species (Volume J, Appendix 2.1), although researchers were surprised to observe a reasonably high diversity of species during the short survey including species typical of primary wet forests, which existed in this area in the past. Changes in water flow may influence the humidity and microclimates that support this diversity.

Residual Impact Classification

Residual impacts and environmental consequences of direct habitat loss on fauna as a result of construction and operation of the Ambatovy Project are presented in Table 4.2-4. Although high environmental consequences were predicted for wetlands, shrubland and stream habitats as a result of site clearing, these impacts are proportional losses of vegetation type and, with perhaps the exception of the wetlands habitat, likely do not represent high-quality faunal habitat. In addition, as these habitats are typical of the region (Volume C and D, Section 4.1) and 96% of the LSA is comprised of degraded vegetation types, residual impacts to fauna, including rare species, are predicted to be low.

Similarly, the proportional loss of coastal woodland habitats results in a moderate impact, but this result is based strictly on areal extent and does not account for habitat quality for fauna. Although this vegetation type no longer functions as a pristine habitat due to previous human impacts, some species do live here. However, no rare forest dwelling species were recorded in the LSA and similar habitat exists in the region, so impacts to populations of species occupying these habitats should be low.

A variable low to high impact is predicted due to changes in hydrology for watershed basins in the tailings facility area during construction and operations (Table 4.2-4). Environmental consequence will be reduced to low in Basin B as the magnitude of the impact is low and the extent local. Following mitigation and reclamation at year 15, the environmental consequence to Basin A is predicted to be moderate because the magnitude of the impacts is low, extends beyond the LSA boundary and the duration will be medium-term. Basin C impacts remain high following closure, because the magnitude of the impact is high, extend beyond the LSA boundary and will be long-term.

Table 4.2-4 Residual Impact Classification for Impacts Related to Direct Habitat Loss

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Site Clearing							
rare species	negative	low	local	long-term	reversible	high	low
other species	negative	low	local	long-term	reversible	high	low
Issue: Change in Water Flows							
Basin A aquatic habitat	negative	low	regional	medium-term	reversible	high	moderate
Basin B aquatic habitat	negative	low	local	long-term	reversible	high	low
Basin C aquatic habitat	negative	high	regional	long-term	reversible	high	high
rare species	negative	low	local	long-term	reversible	high	low
other species	negative	low	local	long-term	reversible	high	low

[a] Includes coastal shrubland/grassland complex, shrubland and beach ridge habitat types.

Changes in habitat are predicted to occur during operations due to changes in water flow, however it is unknown how long these changes will persist or if habitats can be restored after closure. Impacts to wetlands in particular are of concern, as they support two IUCN-listed bird species. However, as discussed above, these habitats are typical of the region (Volume C and D, Section 4.1) so residual impacts to fauna, including rare species, are predicted to be low.

During closure, progressive reclamation at the tailings facility is anticipated to reverse impacts somewhat. However, it is uncertain whether revegetation will provide habitats with similar structure and composition as existing habitats, and provide suitable habitat for some species of endemic species. Regional planning will determine the end land use and if it includes areas of native vegetation, positive effects to fauna may result.

Prediction Confidence

Prediction confidence for impacts to habitats as a result of site clearing is high. The areal extent of the losses as well as national distribution of these habitats is well known. Uncertainties in the impact predictions still exist though, because species habitat associations are derived from limited field survey observations. Prediction confidence for impacts to habitats as a result of changes in water flow is low to medium, as water flows were modelled based on one year of hydrologic data and changes in vegetation due to these impacts have not been established quantitatively.

Monitoring

Monitoring will focus on water quality and flow to ensure protection of the downstream environments. A limited amphibian monitoring program is proposed for the Toamasina area to measure potential changes in key species distribution, abundance and health as a result of changes in water flows and water quality.

Indirect Habitat Loss

Potential Impact Pathways

For justification of the potential causes of indirect habitat loss, see Volume B, Section 4.2.

Sensory Disturbance

Sensory disturbance may result from both construction and operations and may lead to displacement effects and changes in fauna abundance (Forman 1995). For a more detailed discussion of potential effects of sensory disturbance, refer to Volume B, Section 4.2. Construction and operation of the process plant and tailings facility will increase noise and light levels.

Edge Effects

For a detailed discussion of potential impacts of edge effects, refer to Volume B, Section 4.2.

Dust Effects

With an increase in disturbance of soils as a result of construction and operation of the Ambatovy Project, there is an increased likelihood of dust infiltrating surrounding undisturbed habitat, directly and indirectly affecting fauna.

Introduction of Non-Native and Invasive Species

As 96% of the LSA has been previously disturbed or degraded, it is unlikely that activities of the project will further increase the risk of introducing non-native and invasive species. Therefore, this is not considered an impact issue.

Changes in Microclimate

Clearing within the Toamasina LSA will increase the amount of edge habitat between habitats. Faunal changes are likely to occur along the ecotone between them.

Assessment Methods

For a more detailed description of assessment methods for indirect effects, refer to Volume B, Section 4.2.

Sensory Disturbance

Noise

Changes in noise levels were modelled for the process plant based on project activities at baseline and impact during construction and operation to determine potential impacts (Volumes C and D, Section 3.4). Noise levels were not modelled for construction and operation activities in the tailings area.

Noise was considered an impact when it exceeded World Bank guidelines for people (The World Bank Group 1999), 55 dBA daytime and 45 dBA nighttime. Areal extent of each habitat type within two noise bands was calculated to determine impacts. A qualitative assessment of impacts to species using these habitats is discussed. The area of each habitat impacted by noise is additive to direct habitat losses and should be considered with losses due to other indirect effects.

Light

Effects of light on fauna were assessed qualitatively.

Edge Effects

Dust, Invasive Species and Microclimatic Changes

To assess impacts due to edge effects, it was assumed that these effects all occur within a particular distance from all human-caused edges. The project footprint was buffered by 100 m and the areal extent of each habitat type within the buffer zone was calculated to determine impacts. A qualitative assessment of impacts to species using all affected habitats is discussed. The area of each habitat impacted by these edge effects is additive to direct habitat losses and should be considered with losses due to other indirect effects.

Assessment Criteria

The assessment criteria are the same as for direct habitat loss (see Table 4.2-1).

Mitigation

Mitigations that will reduce indirect habitat loss and alteration due to sensory disturbance, dust effects and changes in microclimate in the Toamasina LSA include:

Design Elements

- Mufflers on vehicles to reduce noise.
- Noise level specifications applied to all major noise causing pieces of equipment.
- Lights will be shielded and/or directed away from adjacent habitat.

Mitigation Techniques

- Trapping and removal of non-native rodents around the camp and other buildings.
- Dust control measures, particularly in the dry season.

Reclamation and Closure

- Decommissioning and progressive reclamation of the tailings facility during operations will remove sensory disturbance and reduce edge effects.

Impact Analysis

Sensory Disturbance

Impacts to habitats beyond the footprint due to noise from the process plant are provided in Table 4.2-5. Noise sources are detailed in Volumes C and D, Section 3.4. Coastal woodland, shrubland and wetlands habitats will be impacted the most by noise levels above 45 dBA. The tavy and rice paddies in the tailings area will not be greatly affected by noise from the process plant. During construction, noise would be similar to that described for the pipeline construction: attenuating to 45 dBA (World Bank nighttime standards) at between 200 and 500 m depending on the level of activity. During operations the occasional vehicle will be used during inspection of the pond perimeter and will not be a significant source of noise.

Species most likely to be affected by noise include species in the affected habitats that use vocalization for breeding (e.g., amphibians, birds) and wary species in areas where noise exceeds baseline levels. If noise levels interfere with the ability of individuals to find mates, there could be potential population effects locally over time. Average baseline noise levels at the process plant site, and particularly the tailings facility area, are higher than at the mine site due to existing human activity (Volume I, Appendix 5.1).

Table 4.2-5 Impact (ha) on Habitats as a Result of Project Generated-Noise Within the Local Study Area

Noise Range	Habitat Type	Baseline (ha)	Area Impacted (ha)	Indirect Habitat Loss %
>55 dBA[(a)]	wetlands	117	-1.6	-1.4
	Ivondro River	61	0	0
	coastal woodland	166	0	0
	shrubland[(b)]	1,103	-8.7	-0.8
	agroforest	268	0	0
	tavy	2,278	0	0
	rice paddies	195	-0.2	-0.1
	other[(c)]	457	0	0
45-55 dBA[(d)]	wetlands	117	-27.2	-23.2
	Ivondro River	61	0	0
	coastal woodland	166	-32.3	-19.5
	shrubland	1,103	-201.4	-18.3
	agroforest	268	0	0
	tavy	2,278	-2.1	-0.1
	rice paddies	195	-15.9	-8.2
	other	457	-6.2	-20.1
Total	wetlands	117	-28.8	-24.6
	Ivondro River	61	0	0
	coastal woodland	166	-32.3	-19.5
	shrubland	1,103	-210.1	-19.1
	agroforest	268	0	0
	tavy	2,278	-2.1	-0.1
	rice paddies	195	-16.1	-8.3
	other	457	-6.2	-20.1

(a) Noise levels above daytime World Bank maximum levels (The World Bank Group 1999).
(b) Includes coastal shrubland/grassland complex, shrubland and beach ridge habitat types.
(c) Includes industry and urban infrastructure.
(d) Range between nighttime and daytime World Bank maximum levels.

Species most likely to be affected by light include species that are drawn to light (e.g., moths and insectivorous species such as bats) and those species that are light sensitive (e.g., Elouard et al. 2003). Light mitigation will help reduce impacts.

Edge Effects

Dust and Microclimatic Changes

The largest potential impacts as a result of edge effects due to construction and operation of the process plant and tailings facility will be to tavy (53.8%) (Table 4.2-6). Proportionately, wetlands, coastal woodland and shrubland habitats will be similarly impacted by edge effects, although the area of shrubland (452 ha) affected by dust and microclimatic changes is much larger than the other habitats. These impacts are in addition to the direct losses due to site clearing.

Table 4.2-6 Habitats (ha) Within a 100 m Edge Effects Zone of the Toamasina Local Study Area

Habitat Type	Baseline (ha)	Area Impacted (ha)	Habitat Loss %
wetlands	117	-45	-38.5
Ivondro River	61	-3	-4.9
coastal woodland	166	-65	-39.2
shrubland[(a)]	1,103	-452	-41.0
agroforest	268	-70	-26.1
tavy	2,278	-1,225	-53.8
rice paddies	195	-72	-36.9
other[(b)]	447	-155	-41.2
total	**4,635**	**-2,087**	**-44.9**

(a) Includes coastal shrubland/grassland complex, shrubland and beach ridge habitat types.
(b) Includes industry and urban infrastructure.

Residual Impact Classification

Residual impacts as a result of indirect effects are provided in Table 4.2-7.

Sensory Disturbance

Noise

The environmental consequence of noise from the process plant is negligible to low for most habitats. Little noise will be created in the tailings facility area. In the plant area a high proportion of the habitats immediately adjacent to the plant will be affected by noise above World Bank maximum levels. The noise will last the duration of the project and will be continuous. The habitat areas most affected by this noise are of relatively low quality.

Although average hourly L_{eq} values under baseline conditions in the vicinity of the plant site are below World Bank criteria for people, baseline noise levels (L_{max}) regularly exceeded these criteria (Volume I, Appendix 5.1). Therefore, impacts are predicted to be low for wary fauna species and neutral for other species in affected habitats.

Table 4.2-7 Residual Impact Classification for Fauna due to Indirect Habitat Loss

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Sensory Disturbance – Noise							
species using vocalization for breeding	negative	low	local	medium-term	reversible	high	low
wary species	negative	low	local	medium-term	reversible	high	low
other species	neutral to negative	negligible	local	medium-term	reversible	high	negligible
Issue: Sensory Disturbance – Lights							
species attracted to lights	negative	low	local	long-term	reversible	high	low
species that avoid light	negative	low	local	long-term	reversible	high	low
Issue: Edge Effects							
fauna	negative	low	local	long-term	reversible	low	low

All project-related noise effects at the tailings facility will be removed at closure; however, the process plant will remain an industrial site.

Light

The environmental consequence of light is predicted to be low with effective mitigation.

Edge Effects

Dust and Changes in Microclimate

Edge effects impact a high proportion of each habitat and the duration of changes in dust input and micro-climate is long-term. However, much of the LSA is comprised of previously disturbed habitats so the impacts to fauna due to edge effects will likely be low. The largest impacts from dust could occur in the wetlands habitats if water quality (e.g., light levels, oxygen levels) is affected. The treed habitats may be the most affected by edge creation resulting in microclimatic changes.

Edge effects associated with the process plant will last beyond the life of the project but mitigation will reduce potential impacts due to dust. Depending on the end land use determined by regional planning, reclamation of the tailings facility will reduce edge effects over time.

Prediction Confidence

Prediction confidence for areal extent of impacts to habitats as a result of noise and edge effects is high as these impacts were spatially modelled. Uncertainties still exist though, because species habitat associations are necessarily derived from limited field survey observations.

Monitoring

Monitoring will be as noted in the direct habitat loss section. No specific indirect effects monitoring on fauna is proposed.

Direct Mortality

Potential Impact Pathways

Direct Mortality From Site Clearing

Clearing of vegetation and removal of soil may kill animals that are less mobile or that have small home ranges. Sedentary animals and juvenile animals, including those in nests, are particularly sensitive to mortality through site clearing. Although adult birds can fly away from disturbance, nestlings are vulnerable during site clearing. Slow-moving lizards and amphibians, as well as small mammals, may also be susceptible to this mortality source.

Interaction of Fauna With Infrastructure

Structures associated with the plant site (e.g., poles, associated overhead powerlines and other vertical towers) may lead to bird strikes or electrocution (for more details on possible effects refer to Volume B, Section 4.2). The tailings facility and water holding pond at the plant site could have the potential to trap animals if the edges or bottoms are soft.

Impacts of other infrastructure such as roads have been considered under barriers to movement; changes in hunting/collecting and increased vehicle-fauna collisions.

Vehicle-Fauna Collisions

Virtually all fauna species are subject to road mortality. Road mortality may cause a decline in local populations, but the effects are site-specific, depending on the species and the circumstances (e.g., type of road, volume of traffic). Multiple roads and railways will be constructed for the project.

Hunting/Collecting

As most of the LSA has been previously disturbed and has existing access throughout, it is unlikely that the project will further increase the risk to species. Therefore, mortality due to hunting and collecting is not considered further.

Assessment Methods

Areal extent of site clearing (ha) was determined as per direct habitat loss. A qualitative discussion of the impacts to fauna is discussed.

A qualitative assessment was done for interaction with infrastructure and vehicle-fauna collisions as these effects could not be quantified.

Assessment Criteria

The assessment criteria are the same as for direct habitat loss (see Table 4.2-1).

Mitigation

Design Elements

- Modification of below-road culverts to facilitate faunal crossing.
- Use of markers such as aviation spheres to mark transmission lines.
- Raptor-safe construction standards will be considered during final design of transmission lines

Mitigation Techniques

- Relocation or collection of key fauna in selected areas that would not move ahead of construction, prior to site clearing.
- Signage and post speed limits.
- Develop waste management plan.
- Trap and remove nuisance fauna (rodents) from plant and camp areas.

Reclamation and Closure

- Progressive reclamation of the tailings facility.

Impact Analysis

Site Clearing

A maximum of 1,744 ha of new clearings and disturbances will result from Ambatovy Project activities. Areas most impacted include tavy, shrubland and wetlands habitats with moderate impacts to coastal woodlands and agroforests (see Table 4.2-2). Sedentary and slow-moving species occupying these habitats are most at risk for mortality.

Residual Impact Classification

Residual impacts as a result of indirect effects are provided in Table 4.2-8.

Table 4.2-8 Residual Impact Classification for Fauna due to Direct Mortality

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Direct Mortality from Site Clearing							
rare species	negative	low	local	short-term	reversible	low	negligible
slow-moving or sedentary common species	negative	low	local	short-term	reversible	low	negligible
other species	negative	low	local	short-term	reversible	low	negligible
Issue: Vehicle-Fauna Collisions							
slow-moving common terrestrial species	negative	low	local	long-term	reversible	medium	low
other species	negative	low	local	long-term	reversible	medium	low

Site Clearing

The environmental consequence of direct mortality on all species are predicted to be negligible as the magnitude of the effects are predicted to be low and local to the LSA, the duration will be short-term during the construction phase and the effects will be reversible if remaining populations can compensate for losses. The magnitude of the impacts to rare species were predicted to be low because the existing disturbed habitats were found to support few rare species (Volume J, Appendix 2.2, Figure 4) and the abundance of these species is also predicted to be low. Mitigation, including pre-construction collection and translocation of key species and reclamation of the tailings facility, will minimize impacts.

Vehicle-Fauna Collisions

Vehicle-fauna collisions are expected to occur on all roads for the life of the project. In addition, vehicle traffic will increase along existing roads in the surrounding area due to the Ambatovy Project (Volume D and E, Section 5.5). Impacts are predicted to be greatest for slow-moving terrestrial species as they are most at risk, and rare species or species with low fecundity, as losses of individuals can potentially affect populations. For the latter two species groups, impacts can be regional for populations that extend beyond the LSA. For all affected species, the impact duration will be long-term but the effects are reversible if remaining populations can compensate for losses and the frequency is medium as losses will occur intermittently. Modification of culverts to facilitate faunal movement, worker education, controlling speed limits and signage will help reduce the magnitude of these impacts (i.e., collision rates). In general, the environmental consequence of vehicle-fauna collisions is predicted to be low because the LSA is already largely disturbed, species richness is relatively low and roads will not be in high quality habitats or will be sited on existing routes.

Prediction Confidence

Prediction confidence for direct mortality is medium. While understanding of species densities in the area is limited, surveys have confirmed a general low quality of habitat for fauna in the area.

Monitoring

Monitoring will be conducted to help determine if mitigation is effective or if adjustments must be made. The proponent will carry out a fauna monitoring program that includes:

- Any species removed prior to and during clearing or operations (i.e., nuisance animals) will be recorded.
- To assess the impacts of fauna interaction with project infrastructure, project pond areas will be monitored for sign of fauna use.
- Driving behaviour will be monitored both for safety and fauna protection concerns.

Conclusions

Site clearing at the process plant and tailings facility during construction is the primary cause of direct habitat loss and faunal mortality. As most of the project area occurs in previously disturbed or degraded habitats, including all terrestrial habitats, impacts to fauna are predicted to be low. Wetlands supported the only two rare bird species recorded during baseline surveys and as the habitats in the LSA are typical of the habitats in the region and these species are highly mobile, impacts to these species are predicted to be low. Reclamation of the tailings facility will be a key mitigation of impacts to fauna due to site clearing and indirect effects.

4.2.4.3 Key Question W-2 What Effect Will the Project Have on the Movement of Faunal Species?

Potential Impact Pathway Evaluation

Fragmentation

Habitat fragmentation is another direct effect that occurs as a result of site clearing. Fragmentation occurs when extensive, continuous tracts of habitat are dissected into smaller, more isolated patches (Meffe and Carroll 1994). For most faunal species, small, dispersed habitat patches are considered to be lower quality than larger, continuous tracts. Often the process of fragmentation results in unconnected habitat fragments with a high proportion of open perimeters. Thus, fragmentation increases the amount of edge in the habitat, decreases the amount of habitat interior and increases the distance between habitat patches. For a more detailed discussion see Volume B, Section 4.4.

Indirect effects as a result of edge creation can contribute to fragmentation impacts. Forest edge differs from forest interior in both microclimatic and biotic aspects (for a detailed discussion see Volume B, Section 4.2). Some fragmentation changes can be positive (e.g., butterfly abundance is higher in clearings if suitable habitat exists). However, fragmentation has a negative effect on species that require extensive tracts of habitat (e.g., interior forest and wary species).

Road construction is a major contributor to habitat fragmentation in forested habitats (Reed et al. 1996). Some other disturbances that result in fragmentation include forest clearing for developments, forest clear-cutting and rights-of-way construction (e.g., pipelines, utility corridors).

Barriers to Movement

Faunal movements can be affected through the creation of physical or psychological barriers to movement (e.g., roads, facilities). Barriers can indirectly result in habitat loss by preventing animals from accessing habitat. Large (e.g., Ambatovy Project infrastructure) and narrow disturbances, such as linear corridors (e.g., roads and electrical transmission lines), can affect faunal movement. Barriers to movement may be a result of activities associated with both construction and operation phases. For a detailed discussion see Volume B, Section 4.2.

Assessment Methods

Fragmentation

Fragmentation analyses were conducted as part of the Biodiversity assessment (Volume D, Section 4.4) and methods are summarized here. Four indices were generated to determine changes in landscape composition and structure and changes in landscape connectivity from baseline to impact. Number of patches, patch area and total edge were used to assess changes in landscape composition and structure. Mean nearest neighbour distance was used to assess changes in landscape connectivity.

It was assumed that most species prefer large tracts of uninterrupted habitat or a ‘well-connected’ landscape. This translates to fewer, larger patches and low nearest neighbour distances. Assessments were based on examining the changes in all indices between baseline and impact cases. In general, fragmentation was considered to be negative if changes in the indices resulted in more, smaller patches, increased nearest neighbour distances and more edge creation. A qualitative assessment of the effects of combined changes in fragmentation indices on habitats was conducted and related to potential impacts to fauna.

Barriers to Movement

A qualitative assessment of impacts due to barriers to faunal movement was done. The type of disturbance and the amount of edge created were factors considered in the assessment.

Assessment Criteria

The assessment criteria are the same as for direct habitat loss (see Table 4.2-1).

Mitigation

Design Elements

- Modification of below-road culverts to facilitate faunal movement across certain roads to maintain connectivity between habitat patches.

Mitigation Techniques

- Tailings facility will be progressively cleared during operations.
- During pipeline construction, open trenches will be limited to short sections and duration to limit trapping animals. Animals that fall into trenches will be captured and released.

Reclamation and Closure

- Appropriate vegetation will be utilized for reclamation, the end land use will be developed in consultation with local stakeholders and regional planners.

Impact Analysis

Fragmentation

Mean patch area of wetlands decreased by 30% (3 to 2 ha), with a correspondent increase in the number and spatial dispersion of patches (Volume D, Section 4.4). Smaller patches can result in negative effects similar to those linked to habitat loss. At some point the area of patches may be too small to support a viable local population, or the distance between local populations too great for effective emigration which reduces re-colonization success and metapopulation persistence (Hanski 1996; Pulliam 1996; Fahrig 2003). As the habitats in the LSA are representative of habitats in the region, it is anticipated that fragmentation of local wetlands by the project will only affect local, but not regional fauna populations.

The most fragmented habitat will be the shrubland habitats. Construction will result in a change from larger patches to smaller patches. However, species richness, particularly of rare endemic species, is relatively low in all habitats in the LSA compared to undisturbed habitats because these habitats are previously degraded or disturbed. Therefore, although fragmentation impacts will affect local faunal movement and distribution, the impact to faunal populations is predicted to be low.

Barriers to Movement

All components of the project will create potential barriers to movement for fauna that will be permanent or last the length of the project. Physical barriers include plant infrastructure and the tailings facility. All other components, including roads and pipeline right-of-ways, create barriers through the creation of unnatural edges and sensory disturbance. The pipelines will be buried, so only species that are wary, unwilling or unable to cross open areas will be affected. As all terrestrial habitats in the LSA are already disturbed and support low species richness, the project effects on faunal movement are predicted to be low. Mitigation, including progressive reclamation of the tailings facility and modifications to culverts, will further reduce the magnitude of these impacts.

Residual Impact Classification

Residual impacts as a result of fragmentation and barriers to movement are provided in Table 4.2-9.

Table 4.2-9 Residual Impact Classification for Fauna due to Fragmentation and Barriers to Movement

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Fragmentation							
wetlands[(a)]	negative	Low	local	long-term	irreversible	low	low
shrubland[(b)]	negative	Low	local	long-term	reversible	low	low
wide-ranging species	negative	negligible	local	long-term	reversible	high	negligible
wary species	negative	negligible	local	long-term	reversible	high	negligible
Issue: Barriers to Movement							
wide-ranging species	negative	Low	local to regional	long-term	reversible	high	low to moderate
wary species	negative	Low	local	long-term	reversible	high	low
other species	negative	Low	local	long-term	reversible	high	low

(a) Well represented in tailings facility and plant site areas.

(b) Mainly in the plant site area.

Fragmentation

The environmental consequence to all habitats due to fragmentation is predicted to be low because the magnitude of the change in landscape indices will be low, the effects will be local and the duration is long-term as the impacts will last beyond the life of the project. All effects are reversible where reclamation occurs, except for wetlands as these habitats cannot be reclaimed.

Impacts to fauna are predicted to be greatest for forest interior and wetlands species. However, few large treed patches currently exist in the LSA and similar wetlands habitats occur in the regional area so these impacts should be low. Mitigation, including progressive reclamation of the tailings facility, will further reduce the magnitude of these impacts.

Barriers to Movement

Barriers to movement are predicted to have a low to moderate environmental consequence for wide-ranging species as the impacts can extend beyond the LSA if the ability to disperse and find mates is impaired. For all affected species, the impact duration will be long-term as effects will last until habitats are reclaimed, the effects are reversible if remaining populations can compensate for losses and the frequency is high barriers are occur continuously. As all terrestrial habitats in the LSA are already disturbed and support low species richness, the project effects on faunal movement are predicted to be low. Mitigation, including progressive reclamation of the tailings facility, below road culverts and noise mitigation, will further reduce the magnitude of these impacts.

Prediction Confidence

Prediction confidence for changes in landscape indices as a result of fragmentation is high as these impacts were spatially analyzed. Uncertainties do remain though, because species habitat associations are necessarily derived from limited field surveys.

Monitoring

No specific monitoring, outside earlier noted monitoring for direct habitat loss, is proposed to address fragmentation and barriers to movement.

Conclusions

Impacts to faunal movement due to fragmentation and barriers to movement from construction and operation of the process plant, tailings facility and associated infrastructure will be greatest for forest interior, wary and wide-ranging species However, as all terrestrial habitats in the LSA are already disturbed and support low species richness, the project effects on faunal movement are predicted to be low. Mitigation, including progressive reclamation of the tailings facility, buried pipelines, below-road culverts and noise mitigation, will further reduce the magnitude of these impacts.

4.2.4.4 Key Question W-3 What Effect Will the Project Have on Faunal Health?

Potential Impact Pathways

The potential impacts of the Ambatovy Project on faunal health were qualitatively evaluated by investigating:

- changes in air quality and faunal health; and
- changes in water quality and faunal health.

Air Quality

Uptake of contaminants via inhalation is typically considered to be minor for fauna compared to uptake of contaminants via the food chain. Amphibians can also be exposed to airborne contaminants through the skin and through changes in aquatic environments. Emissions from the process plant are predicted to be within World Health Organization (WHO) ambient air quality guidelines (WHO 2000) so no further assessment is required. To ensure that ambient air quality levels are within the guidelines, the proponent will conduct air quality monitoring throughout the life of the project. A summary of project-specific air monitoring is presented in the Air Quality Section (Volume E, Section 3.4).

Water Quality

Increased concentrations of contaminants can have sub-lethal to toxic effects in fauna, directly and indirectly through ingestion of plants or prey (USEPA 2005).

Assessment Methods

Water Quality

Information from the Water Quality assessments (Volume D, Section 3.8 and Volume E, Section 3.10) was used to help assess the potential impacts to fauna within the Toamasina LSA. Drinking water guidelines for humans (WHO 2004) and aquatic ecosystems (Department of Water Affairs and Forestry 1996) provide general guidelines for fauna. A qualitative assessment for sensitive faunal species is provided. Water quality impacts to aquatic fauna, including fish, are addressed in the Human and Ecological Health (Volume D and E, Section 5.4) and Fish and Aquatic Resources (Volumes D and E, Section 4.3) sections.

Assessment Criteria

The assessment criteria are the same as for direct habitat loss (see Table 4.2-1).

Mitigation

The proponent has incorporated numerous mitigations into the design of the Ambatovy Project facility to reduce impacts from water discharge. These are detailed in the Water Quality sections (Volume D, Section 3.8 and Volume E, Section 3.10). To ensure that project design and mitigations are performing as planned, the proponent will routinely conduct water quality monitoring and to use the results of the monitoring to make adjustments in operations where necessary.

Impact Analysis

Water Quality

Based on the modeling prediction results from the Water Quality assessment of the tailings facility (Volume E, Section 3.10), most of the metals during operations are consistent with baseline levels, with the exception of manganese. At times levels of copper and zinc are marginally above baseline levels but all parameters will be below WHO drinking guidelines. Copper, manganese and zinc entering aquatic systems from the tailings facility during the operations period are predicted to be higher than South African guidelines set for aquatic ecosystems (Department of Water Affairs and Forestry 1996). In the case of copper and zinc, baseline conditions also exceed the guidelines. All of these elements have been shown to impact faunal species (USEPA 2005) but affect different species differently and to varying degrees and in particular are dependent on the concentrations. Copper and zinc and have been shown to cause mortality and growth defects in amphibians (Horne and Dunson 1995, Owen 1981, USEPA 2005) however, the ecological health assessment has confirmed that residual impacts to aquatic resources will be low to negligible. The concentration levels of these heavy metals are predicted to be below WHO drinking water guidelines (WHO 2004), and relatively consistent with existing baseline levels. The magnitude of the impacts is predicted to be low.

All process water from the process plant site will be managed through the tailings facility, since the water is used for tailings treatment. Tailings effluent will be discharged to the ocean and will meet appropriate guidelines. Effects on marine fauna are described in Volume F, Section 3.3. Mitigations during construction (i.e., runoff and sediment control procedures), best practices during operations and the establishment of a sustainable reclamation drainage plan at closure will minimize impacts to water quality.

4.2.4.5 Residual Impact Classification

The results of the residual impact classification for faunal health are presented in Table 4.2-10.

Water Quality

Increases in some heavy metal concentrations above baseline levels are predicted for the tailings area, especially for manganese. The predicted levels are within WHO human drinking water guidelines so the concentrations will likely be too low to cause any adverse effects. These effects will be local in extent and occur continuously over the life of the project. The environmental consequences of changes in water quality are predicted to be low for amphibians and negligible for other species (Table 4.2-10).

Water quality will be monitored routinely to ensure the control systems are functioning as designed. In addition, periodic plant and amphibian health will be monitored to ensure protection is being achieved.

Table 4.2-10 Residual Impact Classification for Fauna Health

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Water quality							
amphibians	negative	low	local to beyond regional	medium-term	reversible	medium	low
other species	negative	negligible	local	medium-term	reversible	medium	negligible

Prediction Confidence

Prediction confidence for potential impacts to faunal health as a result of changes in water quality is medium (see also Volume E, Section 5.4).

Monitoring

Although the impacts and environmental consequences to faunal health are negligible to low, water quality remains an issue of concern to the public. The proponent will conduct water quality monitoring throughout the life of the project with periodic observations of plant and amphibian health.

Conclusions

Air emissions are not predicted to negatively affect faunal health as all constituents are within WHO ambient air quality guidelines for humans and sensitive vegetation. Changes in water quality are predicted to result in negligible to low environmental consequences to faunal health. Although increases in some heavy metal concentrations are predicted for the tailings area, they are within WHO human drinking water guidelines and are not predicted to adversely affect faunal populations. Routine monitoring of water quality will be conducted along with periodic vegetation and amphibian health observations.

4.3 FISH AND AQUATIC RESOURCES

4.3.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the process plant on fish and aquatic resources, in compliance with the Ambatovy Project (the project) Terms of Reference.

The EA presents a review of baseline information and issues, followed by the impact assessment. As a majority of the freshwater habitats and aquatic fauna within the processing plant area are similar to, and interconnected with the tailings facility, the results of investigations and impact evaluations are generally applicable to this study component.

Detailed aquatic resources baseline reports, including baseline methods, analysis and results relevant to this assessment are located in Volume J, Appendix 3.1, Attachment 1.

4.3.2 Study Area

The Toamasina aquatics study area (Volume A, Figure 7.2-3) is located south of the city of Toamasina and includes the tailings facility, the process plant property and associated service corridors and infrastructure for the process plant and tailings, and future bridge location across the Pangalanes Canal. The process plant Local Study Area (LSA) for fish and aquatic resources includes primarily the freshwater and brackish water bodies near the plant site and in areas associated with the plant infrastructure (freshwater pipeline, discharge pipeline and service corridor).

4.3.3 Baseline Summary

Detailed field sampling for fish or other aquatic biota was not specifically conducted within the plant site local water bodies, but was done for the nearby tailings facility (Volume E, Section 4.3) and the slurry pipeline within the vicinity of the plant site (Volume C, Section 4.3). Information on data collection methods and results are contained in these Volumes; summaries of applicable information are presented in subsequent sections of this document.

Aquatic Habitat

The immediate plant site is located about 2 km from the coast and contains only a few seasonal wetlands. Outside the property boundary, permanent watercourses which are associated with the plant infrastructure include the Pangalanes Canal (a series of freshwater and brackish lakes, lagoons and rivers that were joined by the French in colonial times for commercial use, to protect the barges from the Indian Ocean) which is only a few hundred metres from the sea; the Ivondro River south of the plant site, and an unnamed tributary to the Ivondro River.

Fish

A total of 22 fish species, comprising seven endemic, seven native, and eight introduced species were collected from the Toamasina study area and the process plant area in 2004-2005 surveys (Table 4.3-1). One location on the Ivondro River, upstream of the proposed water intake and water pipeline corridor and six sites within the area of the tailings facility and service corridor, were surveyed for this species list. Species diversity was moderately high in the area, largely because of the diversity and varying size of the habitats.

Within the area, specifically in the Ivondro River and Pangalanes Canal, several fish species and invertebrate species are commonly harvested by artisanal fisheries. In the Ivondro, exotic species (i.e., *Tilapia zilli*) were the most commonly harvested fish. Some smaller species (*Bedotia madagascarensis*) along with crustaceans (mostly *atyid* shrimps) were also captured in reed traps and used. Other common exotics used locally in the project area were *Tilapia rendalli*, *Osphronemus goramy*, and *Oreochromis niloticus*. Potential food fish included the *Anguilla* (eel) species and the snakehead; but information was not obtained on their use.

The Pangalanes Canal along the east coast of Madagascar has historically supported an artisanal fishery and Vanden Bossche and Bernacsek (1991) reported 11 primary species being harvested, including *Caranx melampygus, Ptychochromis oligacanthus, Eleotris fusca, Tilapia rendalli, Mugil robustus, Liza macrolepis, Paretroplus polyactis, Oreochromis mossambicus, Ambassis commersoni, Leognatus equila* and *Cyprinus carpio*. Also well established in the canal system is the aggressive predator *Channa maculata* (blotched snakehead) which was introduced into Madagascar in about 1978 and escaped into the canal system from ponds near Vatomandry during floods from cyclones (Courtenay and Williams 2004).

Aquatic Invertebrates

Several freshwater invertebrates are also used locally as food. These include several crustaceans (freshwater shrimp and prawns) and gastropods. Freshwater shrimp were harvested from the Ivondro River using reed and grass traps. *Atyids* (locally known as patsa) are small shrimp (generally less than 35 mm long) and in eastern coastal areas of Madagascar are commonly captured, dried and used as food (Short and Doumenq 2003).

Table 4.3-1 Fish Species Recorded in the Toamasina Study Area (Process Plant and Tailings Facility) in 2004-2005

Family	Species	Origin	Conservation Status[(a)]	IUCN Status[(b)]
Ambassidae	*Ambassis fontoynonti*	E		DD
Anabantidae	*Ctenopoma ansorgii*	I		
Anguillidae	*Anguilla bicolor*	N	S	nl
Anguillidae	*Anguilla marmorata*	N	S	nl
Anguillidae	*Anguilla mossambica*	N	S	nl
Bedotiidae	*Bedotia madagascariensis*	E	T	NT
Clupeidae	*Sauvagella madagascariensis*	E		nl
Cichlidae	*Oreochromis macrochir*	I		
Cichlidae	*Oreochromis niloticus*	I		
Cichlidae	*Tilapia zilii*	I		
Cichlidae	*Tilapia rendalli*	I		
Cichlidae	*Paretroplus poliactis*	E		nl
Eloetridae	*Hypseleotris tohizanae*	E	U	nl
Eloetridae	*Ophiocara macrolepidota*	E	U	nl
Gobiidae	*Glossogobius giuris*	N	S	nl
Gobiidae	*Stenogobius polyzona*	N		nl
Kuhliidae	*Kuhlia sauvagii*	E		nl
Channidae	*Channa maculata*[(c)]	I		
Ophichthidae	*Caecula pterygera*	N		nl
Osphronemidae	*Osphronemus goramy*	I		
Poeceliidae	*Xiphophorus maculatus*	I		
Syngnathidae	*Microphis leiaspsi*	N		nl

(a) Sparks and Stiassny (2003).

(b) International Union for the Conservation of Nature (IUCN) Red List (2004).

(c) Misidentified as *O. striatus*.

Note: E = endemic, I = introduced, N = native; S = secure, T = threatened, U = unknown; IUCN status: nl = not listed, DD= data deficient, NT = near threatened).

Endemic and Native Species

The freshwater fish fauna sampled within the Toamasina study area contained seven endemic fish species (Table 4.3-1). As noted in the tailings facility description (Volume E, Section 4.3), two of these species (*Bedoti madagascariensis* and *Ambassis fontoynonti*) are listed in the International Union for the Conservation of Nature (IUCN) Redlist (2004) and may require specific attention to protection during project activities.

Additonal endemics not present within the streams of the tailings area, but present in the larger Ivondro River and coastal area included *Paretroplus poliactis* and *Kuhlia sauvagii*. Several additional endemic species are likely present in the Pangalanes Canal and lower Ivondro estuary.

Seven native fish species, including three (*Stenogobius polyzona, Caecula pterygera* and *Microphis leiaspsi*) not present in the smaller streams of the tailings facility area were encountered in the process plant study area.

4.3.4 Issue Scoping

4.3.4.1 Issues and Key Questions

The main issues relating to the aquatic biota and environment in the process plant area are:

- loss or disturbance of aquatic habitat (riparian and instream habitat) and impairment of stream water quality (sedimentation) as a result of in-stream activities;
- loss or reduction of fish populations as a result of processing plant and infrastructure construction and operation;
- water quality changes during construction and operation of the processing plant and infrastructure affecting the health, abundance and survival of endemic fish and aquatic fauna in study area water bodies; and
- effects of the project on harvest of local fish / invertebrate (crustaceans /molluscs).

These issues and impacts have been addressed cumulatively by the following key question:

Key Question FA-1 What Effect will the Project Have on Aquatic Habitat, the Abundance of Aquatic Biota, and Local Harvest of Fish or Aquatic Biota?

Impacts to aquatic resources could occur during construction, operations and closure of the processing plant, as illustrated in the linkage diagram (Volume H, Appendix 9).

4.3.4.2 Assessment Methods

Aquatic biota of significance includes both the fish and invertebrates that form part of the aquatic ecosystem in the Toamasina area. By association, the aquatic habitats that these organisms depend on to complete their life history are also a critical part of the aquatic ecosystem.

Measurable parameters used for the assessment of fish and aquatic resources are summarized in Volume E, Section 4.3, Table 4.3-4 for the tailings facility area and the same parameters apply for the process plant and remainder of the Toamasina study area. As the level of available information from the baseline, literature or local specialists did not always allow a quantifiable assessment, qualitative evaluations based on professional judgments were also used.

Conclusions from the surface water, groundwater, water quality investigations and the preliminary design for the plant and service corridors were also used.

4.3.5 Key Question FA-1: What Effect Will the Project Have on Aquatic Habitat, the Abundance of Aquatic Biota, and Local Harvest of Fish or Aquatic Biota?

4.3.5.1 Impact Pathways

Aquatic habitat, the abundance and survival of aquatic biota (fish and invertebrate communities), and local resource use can be affected by activities in the study area during construction, operation and closure. Changes may relate to:

Habitat Modification

Presence, abundance and survival of fish and aquatic biota is directly linked to habitat. Change in water quality can directly affect the life history function of fish downstream of the process plant. Disturbance of fish and invertebrate populations will also occur during watercourse crossings associated with the service corridor. Impacts and mortality to fish may occur as a result of impingement and entrainment by the water intake. Loss and disturbance of the fish and other aquatic communities could occur during the construction, operation and closure of the processing plant.

Surface Water Quality

Changes to surface water quality (i.e., sediments, temperature, and contaminants) could occur as a direct result of runoff from site clearing, riparian vegetation removal and water management of the process plant. Water quality may also be affected by instream activities during construction of ancillary facilities (roads, pipelines and water intake) and by local air quality. These changes may directly or indirectly affect fish and aquatic biota, and the productivity of aquatic habitat.

Fish Health

Change in fish health is habitat related and can result from construction and /or operation of process plant facilities and associated infrastructure. Fish health can be affected by contaminants (from spills, effluent discharges and air emissions), changes in water quality (entrained sediments, introduced contaminants) and quantity (flows), with lethal, sub-lethal or chronic effects on fish.

Change in Resource Use

The use of freshwater aquatic biota by artisanal fisheries (harvest consisting of primarily fish, shrimp, clams and snails) can be affected by activities in the plant area during construction, operation and closure phases. Changes may result from the availability of fish or other biota, fish health or condition, and species changes.

4.3.5.2 Assessment Methods

The location and enumeration of watercourses potentially affected by the plant site, the pipelines and access roads was determined from Landsat images and mapped data. Habitat and aquatic biota species and community data as determined in the baseline for the tailings and slurry pipeline were identified and impacts discussed qualitatively. Predicted changes in water quality (Volume D, Section 3.8) were examined for the process plant area and the watercourses along the access roads and pipelines and related to potential for impacts on aquatic biota.

The conservation status of endemic and native fish species was reviewed from recent published checklists and the IUCN Red List (2004). Fish and ecosystem health was judged by interpretation of predicted water quality and quantity data (Volume D, Sections 3.6, 3.7 and 3.8).

Fish/invertebrate artisanal fisheries use was determined from baseline observations and communications in the study area, projected by professional judgment from the species composition observed, or from published reports.

4.3.5.3 Assessment Criteria

The impact description criteria used to evaluate fish and aquatic resources for all Key Questions are presented in Table 4.3-2.

Table 4.3-2 Impact Description Criteria for Fish and Aquatic Resources

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
positive, **negative** or **neutral** for the measurement endpoints	**negligible**: no measurable effect on the measurement endpoint **low**: <10% change in measurement endpoint **moderate**: 10 to 20% change in measurement endpoint **high**: >20% change in measurement endpoint	**local**: effect restricted to the LSA **regional**: effect extends beyond the LSA into the regional study area (RSA) **beyond regional**: effect extends beyond the RSA	**short-term**: <3 years **medium-term**: 3 to 30 years **long-term**: >30 years	**reversible** or **irreversible**	**low**: occurs once **medium**: occurs intermittently **high**: occurs continuously

4.3.5.4 Mitigation

Mitigations that will moderate the impacts include the following:

Design Features

- Implementation of watercourse crossing guidelines and plans which minimize in-water work and disturbance of aquatic /riparian habitat and control sediment levels within specified levels to protect aquatic habitat and biota.
- Water intake design at the Ivondro River to prevent impingement or entrainment of fish.

Reclamation

- In the area surrounding the permanent core of the plant site, and along disturbed pipeline and road routes, re-establish vegetative cover immediately after construction or closure (part of Environmental Management plans).

4.3.5.5 Results

Habitat Alterations

Process Plant Disturbance Area

Much of this area has been previously disturbed, and other than occasional seasonal wetlands, the plant site will not affect aquatic habitat or fish communities. Runoff waters from the plant site will be managed and not released until meeting appropriate water quality criteria (addressed in Volume D, Section 3.8 Water Quality).

Service Corridors and Infrastructure

Ancillary facilities (i.e., access roads, the marine disposal pipeline, and the process plant freshwater pipeline) can disturb riparian and aquatic habitat and fauna in study area watercourses by instream construction activities and by surface runoff (i.e., sediment from erosion). Most of the watercourses within the service corridors exhibit highly modified habitats, and will exhibit a low sensitivity to minor disturbance.

The freshwater pipeline for the processing plant has a pumphouse and water intake located on the Ivondro River. Pumphouse and intake construction will temporarily disturb riparian and instream aquatic habitat; the pipeline route to the processing plant also crosses one tributary stream.

The marine water disposal pipeline from the processing plant crosses one watercourse, the Pangalenes Canal, and also parallels the canal before reaching the Indian Ocean.

Construction effects from instream activity during crossings of these watercourses will be primarily a short-term disturbance. Watercourse crossing guidelines will be followed to prevent or mitigate harmful effects on aquatic habitat (addressed in Volume E, Section 7, Environmental Management Plans) and impacts are not anticipated from construction activities associated with the service corridors. However, long-term, permanent local disturbance could occur depending on the type and size of road crossing (culvert, bridge) used for roads, and its effect on stream hydrology and channel morphology. Permanent habitat loss will also occur from the footprint of the intake structure on the Ivondro River; this area is anticipated to be small in size.

Water Quality Changes

Water quality changes affecting aquatic habitat and biota in the plant area could occur as a result of runoff, instream work activities, erosion (sedimentation) during surface water runoff, on-site spills of materials and air emission deposition.

Increased turbidity and sedimentation during construction are the primary water quality changes which may affect aquatic ecosystems along the pipelines and access road service corridor. The use of applicable Environmental Management guidelines during construction will minimize potential effects and impacts on water quality from this activity will be low.

Fish Abundance

The fish fauna within the process plant area contains seven endemic fish species. Additional endemics are expected within brackish water not sampled near the coast. Species such as *Paretropulus polyactis* (an important endemic cichlid) are known to inhabit the Pangalanes Canal (de Rham and Nourissat 2004).

The process plant and Toamasina study area contains a low number of endemic fish species relative to the 27 described endemic species reported for this ecoregion of Madagascar (Sparks and Stiassny 2005); however the range of many endemics has contracted and localized due to habitat degradation, and introduced competitors and predators (Ravelomanana 2004). All species encountered in the project area have been previously reported within this eastern lowlands region (CAMP 2001).

Combined populations of endemic species and exotics were encountered at the Ivondro River, above the water intake area. Fish communities using the unnamed tributary to the Ivondro River, crossed by the water pipeline, are expected to be similar in composition to those found in the lower drainages of the tailings facility area, dominated by exotic species and generally tolerant of disturbed conditions. Endemics and exotic species are also reported from the Pangalanes Canal. Disturbance to resident fish populations in these locations may occur as a result of habitat alterations and water quality changes (sedimentation) during construction at watercourse crossings. However these effects will be mitigated, temporary and low impact. Long-term impacts on fish communities will occur if permanent structures such as bridges or culverts are installed at watercourse crossings, but the impact is expected to be low to negligible in magnitude. The low potential for pipeline breaks during operations could impact on water quality and biota; however with proper maintenance and Environmental Management procedures the risk and therefore extent of impact is expected to be low.

Negative impacts will occur on fish and invertebrate populations as a result of operating the Ivondro River water intake. Through stringent design and maintenance standards used for fish protection and screening the impact will be low.

Changes to fish health will occur primarily on a local level as a result of the effect of increased sediment entrainment during construction, accidents and spills into water bodies, effluent discharges into water bodies, and deposition of air emissions into local water bodies. Proper mitigation will limit potential impacts.

Artisanal Fisheries

Changes to fish abundance and health could occur on a local level as a result of the effect of increased sediment entrainment during instream construction activities, pipeline breaks or spills into water bodies, effluent releases, and deposition of air emissions into local water bodies. This could affect the availability of fish or other aquatic biota for the local artisanal fisheries. Mitigations and environmental management plans related to sediment input, air emissions, surface water flow and water will be established to protect fish and aquatic resources and reduce potential impacts. Therefore the potential impacts are considered low after mitigation, with a low environmental consequence.

Species change (i.e., species more tolerant to disturbed habitats) may occur due to habitat degradation caused by project-related activities. Should this happen, the impacts on local fish use and harvest may be neutral as many of the fish presently harvested are exotics (i.e, *Tilapii sp.*).

4.3.5.6 Impact Analysis

Residual Impacts

Residual impacts of aquatic habitat and fish or aquatic biota loss as a result of the construction, operation and closure associated with the Ambatovy Project are summarized in Table 4.3-3.

The status of aquatic habitat in the process plant area is moderately-well understood, but the level of baseline information for habitats, aquatic communities and resource harvest is low. The prediction confidence for impact ratings is considered moderate.

Table 4.3-3 Potential Effects and Residual Impacts

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	effects on downstream flow and water quality during construction effects on aquatic and riparian habitat during pipeline and road construction	local water management "no net loss" guidelines and directives	low magnitude / short-term habitat disturbance during infrastructure construction low magnitude /long-term loss from footprint of some facilities (bridges, culverts, water intake)
operation	potential water quality effects on fish, aquatic biota and habitat mortality of fish as a result of impingement and entrainment potential change in availability of aquatic biota for artisanal fishery	water management erosion and sediment control systems revegetation intake protection and screening system	low magnitude / medium-term modification of watercourses and fish communities neutral effect on existing local harvest as a result of potential habitat disturbances low magnitude/medium-term impact from fish entrainment
closure	change in habitat / fish populations	Entire surface runoff returned to surrounding areas	low magnitude / long-term positive effects on habitat

An overall residual impact classification is presented in Table 4.3-4; the overall environmental consequence scores were based on the screening system described in Volume A, Section 7.

Table 4.3-4 Residual Impact Classification for Effects on Fish and Aquatic Resources

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Effect: Water Pump House and Intake							
construction	negative	low	local	short-term	no	low	negligible
operations	negative	low	local	medium-term	yes	medium	low
Effect: Artisanal Fishery							
construction	negative	low	local	short-term	no	low	negligible
operations	negative	low	local	medium-term	no	medium	low
Effect: Habitat Disturbance and Fish Community (from Watercourse Crossings and Plant Site)							
construction	negative	low	local	short-term	yes	low	negligible
operations	negative	low	local	long-term	yes	low	low
Effect: Site Reclamation and Restoration							
closure	positive	n/a	n/a	n/a	n/a	n/a	n/a

(a) Effect during operations assumed by development of protected areas; effect during closure from both reclamation activities and protected areas.

n/a Criteria not ranked for positive effects.

Monitoring

Designed control systems for sediment control will be monitored to ensure protection of the surrounding water resources.

The Ivondro intake system, designed to prevent fish impingement, will be maintained on a regular basis to ensure effectiveness.

4.3.6 Conclusions

Low or negligible environmental consequences for local aquatic habitat and endemic fish species abundance and survival are expected due to residual impacts from construction and operation of the process plant and infrastructure.

The effects on artisanal harvest of fish are also expected to be of low or negligible consequence.

4.4 NATURAL HABITATS AND BIODIVERSITY

4.4.1 Introduction

This section of the Environmental Assessment (EA) provides an evaluation of potential effects of the proposed Ambatovy Project (the project) on natural habitats and biodiversity in the Toamasina study area (tailings facility, process plant and expanded port). The project sites in the Toamasina area are in close proximity and are connected by various linear developments (Volume C, Section 2). Impact analyses for flora, fauna and aquatic resources can be split between project sites. However, impact analysis at the higher level of biodiversity is best considered for the Toamasina study area as a whole. The assessment is, however, intrinsically linked to the flora, wildlife and fish components. In compliance with the Terms of Reference (Volume H, Appendix 1), site-specific data were collected to address the following elements of natural habitats and biodiversity:

- describe the current level of disturbance and biodiversity of each natural terrestrial and aquatic community type within the study area;
- describe each community type's sensitivity to disturbance and ability to be restored;
- determine the status (distribution and abundance) of each community type;
- describe landscape characteristics of the study area such as habitat connectivity and fragmentation;
- discuss the mitigation and compensatory mechanisms to be used to reduce/offset losses to natural community types;
- discuss if the project has the potential to enhance biodiversity;
- assess residual impacts for both the operations and post-closure phases of the project to natural community types and biodiversity; and
- provide details on natural habitat and biodiversity monitoring and management that include participation of local residents.

This section of the EA presents the following information:

- description of the study area used to collect baseline data and evaluate project-related impacts on natural habitats and biodiversity;
- summary of the baseline data collected and current conditions. The summary focuses on information that is most pertinent to assessing predicted impacts. A complete description of the baseline methods, analysis, and results is located in Volume J (Appendix 4.1);

- assessment of project-related impacts on natural habitats and biodiversity, including issue scoping, assessment methods, mitigations, predicted residual impacts, and an outline of proposed monitoring activities; and
- summary of conclusions regarding predicted residual impacts, and associated mitigations and follow-up monitoring activities.

4.4.2 Study Area

The Toamasina Local Study Area (LSA) is located immediately south of Toamasina. It encompasses the tailings facility and its downstream watershed areas, process plant property boundaries, the intake pipeline, marine outfall pipeline and tailings pipeline, plus a 500 m buffer (Volume A, Section 7, Figure 7.2-3).

4.4.3 Baseline Summary

4.4.3.1 Biodiversity Indicators

Over half of the plant and bird species identified in the Toamasina study area were endemic to Madagascar (Table 4.4-1). With the exception of one amphibian species, all reptiles and amphibians identified were endemic to the island, and none are listed by the World Conservation Union (IUCN). Four plant species and two birds have IUCN status.

Similar to the slurry pipeline LSA, precise sample points were not recorded during vegetation surveys, and subsequently, flora species ecosystem metrics could not be determined by habitat or land use classes (Volume J, Appendix 1.1). Among the current distribution of natural and disturbed habitats within the Toamasina LSA, the number of amphibian and reptile species was greatest in wetlands (marsh), shrubby forest, tavy, and forest of *Melaleuca quinquenervia à Pteridium sp* (Volume J, Appendix 2.1). Species richness for birds was highest in forest habitats (agroforest, coastal woodland, shrub land) (23 species), followed by natural wetlands (12 species), and open areas (10 species).

A total of 17 fish species were recorded in the tailings area (Table 4.4-1). Five species are endemic to Madagascar, four are indigenous but not endemic (native), and eight species are exotic. Similar to the mine and slurry pipeline study areas, habitat loss, and competition and predation from exotics have likely contributed to the contraction and fragmentation of the range of endemic and indigenous fish fauna (Volume J, Appendix 3.1).

Table 4.4-1 Species Richness, Endemism and Conservation Status of Flora, Reptiles and Amphibians, Birds and Fish in the Toamasina Local Study Area

Class	Species Richness	Number of Endemics	IUCN Species	CITES[a] Species
flora	268	185	4	1
amphibians	9	8	0	1
reptiles	14	14	0	5
birds	59	37	2	5
fish	17	5	1	0

[a] CITES = Convention on International Trade in Endangered Species of Wild Flora and Fauna.

4.4.3.2 Landscape Diversity

Currently, the landscape in the Toamasina LSA is 96% disturbed. Natural habitats consisted of wetlands and rivers within the Toamasina LSA, while land use classes include patches of currently disturbed wooded and non-wooded areas. Results of the fragmentation analysis of these land cover types are provided in Table 4.4-2. The following summarizes the results according to biodiversity potential.

- The area of natural wetlands, which have high biodiversity potential (Volume J, Appendix 4.1, Section 6.3.2), represents 2.5% of the LSA. Relative to shrub lands and coastal woodlands (which also have high biodiversity potential), connectivity is low with a mean distance to nearest neighbour (MDNN) of 128 m.
- According to the qualitative assessment of fauna species ecosystem metrics (Volume J, Appendix 4.1, Section 6.3.2), agroforestry and coastal woodland may also have high biodiversity potential in the LSA. These habitats are also poorly represented in the LSA (proportional combined area = 9.4%).
- Shrub land represents the second largest contiguous portion of the landscape in the LSA. Because of the large area, the amount of edge associated with shrub land is also relatively high compared to other land cover types.
- Forested land classes (disturbed agroforest and coastal woodlands) account for 11.4% of the terrestrial habitat in the LSA. Forested patches are fragmented by relatively narrow areas of non-forested and wetlands habitat.
- Tavy comprises the largest land cover type in the Toamasina LSA (49%).
- Currently, rice paddies, industry and urban infrastructure are associated with low biodiversity potential, and constitute 14.1% of the LSA.

Table 4.4-2 Fragmentation Results for Land Classes in the Toamasina Local Study Area

Landscape Metric	Wetlands	River	Tavy	Agroforestry	Shrubland	Coastal Woodland	Rice Paddies	Industry	Urban Infrastructure
total area (ha)	117	61	2,278	268	1,103	166	195	17	440
proportion of total area (%)	2.5	1.3	49.0	5.8	23.8	3.6	4.2	0.4	9.5
mean area of patch (ha)	3	30	142	4	69	28	4	4	16
number of patches	43	2	16	66	16	6	54	4	27
mean distance to nearest neighbour (m)	128	10	59	130	12	54	156	1,517	176
coefficient of variation in distance to nearest neighbour (%)	158	0	231	138	63	137	119	168	200
total edge (km)	77	8	156	52	105	16	50	5	106

4.4.4 Impact Assessment

4.4.4.1 Issue Scoping

The following issues related to project-related impacts on natural habitats and biodiversity were based on public consultation and the Terms of Reference (Volume A, Section 6; Volume H, Appendix 1):

- operations of the plant, emissions effects on the surrounding landscape;
- induced development during operation and closure of the plant;
- changes in rare or sensitive natural habitats;
- changes in species diversity;
- siltation and pollution of coastal habitats from effluent release during operations;
- siltation and pollution of natural riparian habitats and agricultural land from tailings;
- concerns with methods of tailings disposal; and
- reclamation of natural habitats and biodiversity.

Throughout the EA, key questions were used to develop cause and effect pathways, or a linkage diagram (Volume A; Section 7). The linkage diagram illustrating the pathways between project activities and effects on natural habitats and biodiversity are shown in Volume H, Appendix H-9. These project activities also influence plant and animal populations which represent components of biodiversity. Thus, changes to flora and fauna (including fish), and habitat were assessed by asking one key question:

Key Question HB-1 What Impact Will the Ambatovy Project Have on Natural Habitats and Biodiversity?

Only impact pathways, that have the potential to directly affect natural habitats and biodiversity, as measured by ecosystem and landscape metrics (Volume D, Section 4.4.3), are evaluated and assessed. Potential effects from siltation on the receiving environment are addressed in Volume D, Section 4.3 (Fish and Aquatic Resources) and Volume E (Section 4.4) and Volume F (Section 4.1), Marine Ecology. Issues related to induced development during operation and closure of the process plant are evaluated in Volume D, Section 5.3 (Land Use). Concerns and management of tailings disposal are addressed in Volume E, Sections 3.9, 3.10 and 4.4.

Indirect effects on biodiversity components such as flora, fauna, fish and aquatic resources are addressed in Volumes D and E, Sections 4.1, 4.2, and 4.3. A summary of these anticipated effects and the location of the impact analyses in other sections of the EA is provided in Table 4.4-3.

4.4.4.2 Impact Evaluation

Metrics, or indicators, used to rank the biodiversity potential of habitats in the LSA included natural wetlands and treed habitats, and species richness, species endemism, and species conservation status (IUCN and Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES]) for plants, wildlife, and fish (Volume D, Section 4.4.3). Direct impacts of the project on habitat and biodiversity indicators will be assessed through changes in the area, composition, and spatial configuration of habitats on the landscape (i.e., landscape metrics; Volume D, Section 4.4.3).

Table 4.4-3 Location of Impact Analysis Information

Project Activities	Issue	Potential Impacts to Natural Habitats and Biodiversity	Biodiversity EA Section	Flora EA Section	Fauna EA Section	Aquatics EA Section	Health EA Section
Construction and Operation							
site clearing and infrastructure	loss and fragmentation of vegetation and wildlife and aquatic habitat	loss of plant, fauna and fish species	Y	Y	Y	Y	
		loss of endemic and listed plants, fauna and fish	Y	Y	Y	Y	
		change in landscape composition	Y				
		change in landscape configuration	Y				
		direct wildlife mortality			Y	Y	
		barriers to wildlife and fish movement			Y	Y	
		barriers to dispersal		Y	Y	Y	
		sensory disturbance to wildlife and fish			Y	Y	
	change in air quality	change in plant and animal tissue quality		Y	Y	Y	Y
	change in hydrology	change in terrestrial and aquatic habitats		Y	Y	Y	
	change in water quality	change in plant and animal tissue quality		Y	Y	Y	Y
Operation and Closure							
reclamation	replacement of habitat	change in all above potential impacts	Y	Y	Y	Y	

Note: Y = Yes

Potential Impact Pathway Evaluation

Activities that may result in changes to natural habitats and biodiversity include construction and operations of the tailings facility, process plant, port expansion and associated pipelines and roads, and reclamation during closure. Specific details of the project description are described in Volumes D, E and F, Sections 2.0. Briefly, primary facilities in the Toamasina area that will influence natural habitats and biodiversity include:

- Process plant which includes: leach plant and associated utility plants (power, steam and water plants, a hydrogen plant, a hydrogen sulphide plant, a sulphuric acid plant, an air separations plant, and a limestone and lime plant). Total footprint of disturbed area is 2.9 km^2.
- Water intake extending south from the plant to create an additional corridor disturbance 25 m wide by 6.2 km long. The intake station will disturb 0.01 km^2.
- Water outfall pipeline extends alongside the plant coming from the tailings and extending east to the sea from the southeast corner of the plant. Will have a disturbed right-of-way 25 m wide by 2.4 km long.
- Direct access road and bridge over the Pangalanes Canal from the plant site heading north to Toamasina.
- Rail spur close to the road, extending from the plant to the port.
- Upon closure the plant site will be selectively decommissioned dependent upon alternate use of equipment. All wastes will be removed from the site at the completion of the project.
- The tailings facility covers a total area of 9.8 km^2 including tailings basin and immediately surrounding areas disturbed by berms and dam structures. This area will be used in phases and full impact will be reached after 27 years of use.
- The corridor between tailings and plant site follows two existing roads: the ridge road from west to east up to highway Route Nationale (RN) 2, and RN2 to the south to link up with the planned slurry pipeline route. The part of the route along the ridge road will include corridors for the tailings pipe bringing material to the pond, the water pipeline bringing discharge water back to the plant site, a powerline bringing electricity from plant to tailings facility station, and a gravel roadway.
- Reclamation plans are to cover tailings basins with topsoil and organics and re-establish vegetation cover that is physically stable, sustainable and guards against erosion in the long term.
- An expanded port for import of limestone, coal and sulphur with smaller quantities of reagents, and export of nickel and cobalt, from the plant.

Development of the project will result in the loss or alteration of 1,606 ha of habitat in the LSA (including associated buffers). Of particular importance, is the existence of natural wetlands habitats in the study area that support amphibians, reptiles, birds and fish. Human-influenced habitats that contain vegetative structure (treed/shrub habitats), such as agroforests (woodlots, plantations), shrub land and coastal woodland likely also provide functional ecotypes for some insects, reptiles, birds and mammals. Several species are also endemic and/or have special conservation status (Volume D, Section 4.4.3).

The removal and alteration of habitat during construction and operation also results in the fragmentation (or breaking apart) of ecotypes on the landscape. The amount of wetlands and treed/shrub habitats will be influenced by changes in mean patch size and number of patches, making this impact pathway valid (Table 4.4-4). However, connectivity and edge effects do not affect the amount of rare or endemic habitats. Therefore, these potential impact pathways are not valid.

Reclamation during operation and closure is often the first step in re-establishing a natural ecosystem. During closure, successful reclamation could reverse some of the effects of the project on natural habitats and biodiversity.

Table 4.4-4 Summary of Potential Impacts to Natural Habitats and Biodiversity

Natural Habitat and Biodiversity Metrics	Potential Impact Pathways from Project					
	Habitat Area	Mean Patch Size	Number of Patches	Habitat Connectivity	Edge Effects	Reclamation
natural wetlands and treed habitats	Y	Y	Y	N	N	Y
species richness	Y	Y	Y	Y	Y	Y
species endemism	Y	Y	Y	Y	Y	Y
species conservation status	Y	Y	Y	Y	Y	Y

Note: Y = Yes.
N = No.

Assessment Methods

Baseline data for species richness, endemism and conservation status (IUCN and CITES listings) for plants and wildlife were used to estimate the current biodiversity potential of ecotypes within the LSA (Volume D, Section 4.4.3). Information on species richness, endemism and conservation status of fish was also obtained to assess the relative contribution of aquatic macrofauna to biodiversity in the LSA. Fragmentation analysis of the LSA under baseline conditions was completed to quantify the current area, composition and spatial configuration of habitats (Volume D, Section 4.4.3).

Similar to the assessment conducted for the mine site (Volume B, Section 4.4.4.2), direct impacts from the project on habitat and biodiversity indicators were assessed through changes in the area, composition, and spatial configuration of habitats on the landscape. To estimate the change in landscape metrics associated with project, fragmentation analysis was completed on the LSA after applying the project footprint to the landscape (application case). The footprint included the tailings facility, process plant, expanded port, access roads, rail spur and pipeline corridors. Access roads, water intake and tailings pipelines, and the rail spur were buffered by 25 m. The slurry pipeline within the Toamasina LSA was buffered by 40 m.

The potential impact of the project on biodiversity indicators was estimated by calculating the relative difference between application case and baseline landscape metrics using the following equation:

(application case value – baseline value) / baseline value

The resulting value was then multiplied by 100 to give the percent change in a landscape metric associated with the project relative to baseline conditions, and provide both direction and magnitude of the impact. Changes in landscape metrics were then used with assessment criteria (see below) to predict impacts from the project on biodiversity potential among habitats, and within the LSA. Impacts to habitats associated with human land use activities (negligible biodiversity potential) were not assessed here (see Volume D, Section 5.3 [Land Use]).

Impacts were assessed for the period of construction through operation, and the closure phase. It is assumed that maximum impacts will occur during the period of construction through operation, particularly during construction when the direct loss and alteration of habitats will be greatest.

Assessment Criteria

Residual impacts were determined based on a classification system that incorporates direction, magnitude, geographic extent, duration, reversibility and frequency of the impact as described in Volume A (Section 7). Definitions of the residual effect classification terms that are specific to habitats and biodiversity are provided in Table 4.4-5. An explanation for the classification of magnitude is provided in Volume B (Section 4.4.4.2). Determination of the overall environmental consequence uses magnitude, geographic extent and duration, and is described in Volume A (Section 7).

Table 4.4-5 Impact Description Criteria for Natural Habitats and Biodiversity

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
neutral: no change in biodiversity indicators **negative:** a change in biodiversity indicators	*negligible:* no measurable effect on biodiversity indicators *low:* <10% change in biodiversity indicators **moderate:** 10 to 20% change in biodiversity indicators **high:** >20% change in biodiversity indicators	**local:** effect restricted to the LSA **regional:** effect extends beyond the LSA	**short term:** <3 years **medium term:** 3 to 30 years **long term:** >30 years	reversible or irreversible	**low:** occurs once **medium:** occurs intermittently **high:** occurs continuously

Mitigation

Several mitigations are assumed to reduce the magnitude, geographic extent and duration of direct impacts from the project on natural habitats and biodiversity in the Toamasina study area. More details of these mitigations are provided in other relevant sections of Volumes D, E and F, including Sections 4.1, 4.2 and 4.3.

During construction and operation, mitigation includes:

- footprint of all sites represents smallest feasible size to meet needs of the project;
- relocation/collection of any key endemic rare flora and fauna before site clearing;
- minimize shoreline and in-water disturbance during construction of intake on Ivondro River and water pipeline;
- build precautionary design features in tailings dam to reduce the risk of rupture and emergency planning to mitigate effects in event of a failure; and
- stage the clearing of the tailings area; maintain watercourse buffers as long as practical to aid in maintaining on-site water quality.

During closure, mitigations include:

- establish a closure water management plan and tailings facility monitoring.

- reclamation and revegetation plan for the tailings facility that includes appropriate vegetation, developed in conjunction with local stakeholders and regional planners; and
- design and implement a revised tailings facility revegetation program accordingly should there be deficiencies.

It should be emphasized that analyses in this section focus on the local study area. Overall project impacts on biodiversity, including the positive benefits of biodiversity off-sets, are considered in Volume G, Section 3.4.

Results

The empirical and theoretical relationships between habitat loss and negative effects on biodiversity are well documented, however, most studies have been conducted in non-tropical environments. A discussion has been provided in Volume B, Section 4.4.

Analysis indicates that biodiversity potential in the LSA will be most likely impacted by habitat loss and fragmentation of natural wetlands. Although only occupying 2.5% of the LSA, baseline studies determined that wetlands in the tailings and plant site areas and between the two areas, had the highest number of amphibian and reptile species (14 of 15 species are endemic), and the second highest richness of birds (Volume D, Section 4.4.3). Seventeen fish species (five endemics) were also detected in aquatic habitats within the tailings area. Although floral species were not identified to habitat, of the 268 plant species recorded in the LSA, wetlands throughout the LSA would provide highly suitable habitat for many species.

Application of the project resulted in a 27% decrease in the area of natural wetlands habitat (Table 4.4-6), which will likely have a negative impact on amphibian, reptile, bird and fish populations. However, the lack of knowledge regarding current population size and demographic variables for flora, wildlife and fish species (i.e., survival, recruitment and effective dispersal distance) among local wetlands patches on the landscape generates uncertainty in predicting the magnitude of the impact on biodiversity indicators.

Mean patch area of wetlands decreased by 30% (3 to 2 ha), with a correspondent increase in the number and spatial dispersion of patches (i.e., Coefficient of Variation in the distance to nearest neighbour [CVDNN] increased 20% indicating a decrease in connectivity at the landscape scale). Smaller patches can result in negative effects similar to those linked to habitat loss.

Changes in population and community dynamics may result in a loss of plant and animal species. However, the increase in spatial aggregation of wetlands in certain areas of the landscape was associated with an increase in connectivity between patches within a localized area (i.e., MDNN decreased from 128 to 101 m). Total edge habitat for wetlands also decreased by 27% relative to baseline conditions. Both of these changes to the landscape may be considered positive for species inhabiting wetlands (Fahrig 2003).

Impacts from the project on biodiversity potential will also occur through the loss and fragmentation of treed (agroforest and coastal woodland) and shrub habitats, but with less severity than wetlands. Agroforest areas were mainly found in the tailings and surrounding area, while generally degraded coastal woodland occurred at the plant site. Both habitats contained a large number of bird species, and a large number of retiles and amphibians (Volume D, Section 4.4.3). The footprint resulted in a 15% to 21% decrease in treed and shrub habitat (Table 4.4-6), which may negatively influence the current state of plant, reptile, amphibian and bird communities.

Fragmentation analysis of treed and non-treed habitats throughout the LSA indicated that average patch area of treed habitats increased 17%, while the number of patches and distance between patches decreased by about 31%. More specifically, mean patch area of plantations and woodlots increased 50% (4 to 6 ha), and distance to nearest neighbour and total edge decreased by 19% (130 to 105 m) and 35%, respectively. Average patch area for shrub land declined 74% (69 to 18 ha), and 50% (28 to 14 ha) for coastal woodland. Both shrub land and coastal woodland patches became less spatially aggregated on the landscape (i.e., CVDNN decreased by 25% and 51%). By applying the project, mean distance to nearest neighbour increased from 12 m to 15 m for shrub land, and decreased from 54 m to 14 m for coastal woodland. There was a marginal increase in total edge for these two habitats (Table 4.4-6), which should result in negligible changes to current edge effects.

Table 4.4-6 Change (%) in Landscape Metrics for Full Development of Project Infrastructure Relative to Baseline Conditions for Natural Habitats and Land Use Areas in the Local Study Area

Landscape Metric	Wetlands[(a)]	Ivondro River	Tavy[(b)]	Agroforestry[(b)]	Shrub Land[(c)]	Coastal Woodland[(c)]	Rice Paddies[(a)]	Industry[(c)]	Urban Infrastructure [(d)]
total area	-27.4	0.0	-52.2	-15.3	-20.8	-17.5	-28.2	9,441	-6.8
mean area of patch	-29.6	0.0	-81.0	50.0	-73.9	-50.0	5.6	10,050	-43.8
number of patches	7.0	0.0	150	-40.9	200	67.7	-33.3	0.0	77.8
mean distance to nearest neighbour (MDNN)	-21.1	0.0	-67.8	-19.2	20	-74.1	69.2	-98.8	-38.1
coefficient of variation in distance to nearest neighbour (CVDNN)	19.6	0.0	-51.9	3.6	-25.4	-51.1	93.3	-28.6	67.5
total edge	-27.3	0.0	-25.0	-34.6	1.9	6.3	-28.0	50.0	-24.5

Note: Values calculated as (application case – baseline) / baseline x 100%.

(a) Well represented in tailings facility and plant site areas.

(b) Mainly in the tailings facility area.

(c) Mainly in the plant site area.

(d) Mainly in the port area.

The increase in mean patch size and connectivity of plantations and woodlots mainly in the tailings facility area, may be beneficial for some plants and forest birds, but will likely have no influence on reptile and amphibians. For example, Vallan (2003) reported that that open and relatively homogenous structure of *Pinus* and *Eucalytus* plantations generates wide fluctuations in temperature and humidity which is not suitable for most amphibians and reptiles. Alternately, the decrease in average patch size of coastal woodland and shrub land habitats in the plant site area, will likely have a negative effect on plants, birds, and reptile and amphibians. For example, some amphibian species of the family *Mycrohylidae* in Madagascar were detected only in forested fragments of 30 to 40 ha in size (Vallan 2003). However, if water is available in forest fragments, then amphibians may be more tolerant of reductions in patch size than reptiles, birds and small mammals (Vallan 2003).

It is anticipated that the changes in mean distance to nearest neighbour for coastal woodland and shrub land in and near the plant site, will have negligible negative effects on the movement of birds, reptiles and amphibians between patches. However, based on the lack of data concerning species-specific effective dispersal distance, the confidence in this prediction is low.

There was also a decrease in highly disturbed areas with negligible biodiversity potential such as tavy, rice paddies and urban infrastructure (Table 4.4-6). The project resulted in over a 9,000% (ninety times) increase in industrial area within the Toamasina LSA. The project did not influence the area or configuration of the Ivondro River. Thus, project-related landscape changes on biodiversity potential for these habitats and land use areas are expected to be negligible.

Residual Impacts

Despite mitigation, activities related to the plant and tailings facilities will result in negative changes to natural habitats and biodiversity. Although baseline information determined that the Toamasina LSA is currently 96% disturbed, four remnant habitat types were identified to have moderate to high biodiversity potential. These habitat types included natural wetlands throughout the LSA, agroforest mainly in the tailings facility area, coastal woodland and shrub land, both at the plant site.

Analysis of landscape metrics indicated that the fraction of suitable habitat expected to be lost due to the project footprint is 27.4% (32 ha) of natural wetlands, 20.8% (229 ha) of shrub land, 17.5% (29 ha) of coastal woodland, and 15.3% (41 ha) of agroforest. Average patch size of wetlands, shrub land and coastal woodland decreased from 30% to 74%, while mean patch area of agroforest increased 50% (Table 4.4-6). Changes in patch connectivity may benefit species inhabiting wetlands in local areas of the landscape, but will likely have a negligible influence for species residing in treed habitats. Based on the negative changes in habitat area, mean patch size and assessment criteria, but recognizing that the LSA habitats are disturbed, the magnitude of the impact from the project on natural habitats and biodiversity in both the tailings facility and plant site areas, is predicted to be moderate during construction and operation (Table 4.4-7).

Direct impacts from the project are predicted to be local in geographic extent. Impacts from construction and operations are predicted to be long-term in duration and medium in frequency (development of the tailings area will occur in stages). The effects from the project on habitat loss, patch size, connectivity, and biodiversity will extend into the closure period, and will likely be irreversible for natural wetlands, but reversible for the other habitats.

During closure, reclamation at the tailings facility is anticipated to reverse impacts somewhat, but they will likely remain at a moderate magnitude. It is uncertain whether revegetation will provide habitats with similar structure and composition as existing habitats, and provide suitable habitat for some species of endemic plants, amphibians, reptiles and birds. Reclamation will occur periodically (medium frequency), and establishment of suitable habitat is expected to occur within 30 years (medium-term duration). Effects of closure activities should be limited to the LSA, but again, depend on the geographic extent of wetlands metapopulation dynamics. As noted above, the plant would be closed in phases, dependent on alternative uses of equipment. The site will likely remain industrial.

Taking all criteria into consideration, the environmental consequence of direct impacts from the project on natural habitats and biodiversity is predicted to be moderate during construction and operation of both the plant site and tailings facility. At closure the environmental consequence would revert to low at the tailings facility, but remain moderate at the plant site (Table 4.4-7).

Table 4.4-7 Residual Impact Classification for Natural Habitats and Biodiversity

Project Period	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
What Impact Will the Ambatovy Project Have on Natural Habitats and Biodiversity?							
construction / operation	negative	moderate	local	long-term	irreversible	medium	moderate
closure	negative	moderate	local	medium-term	reversible	medium	low / moderate

Prediction Confidence

There are three elements of uncertainty associated with the prediction of impacts (see Volume B, Section 4.4.4 for full discussion of prediction confidence). In this section these elements are identified in the context of how they relate to the Toamasina components of the project given the data and current knowledge of the system. Here, confidence in impact predictions is related to the following:

- adequacy of baseline data for understanding current conditions;
- understanding of project-related impacts on the ecosystem; and
- knowledge of the effectiveness of mitigation.

Even in this largely disturbed area, species accumulation curves indicated that sampling effort during baseline studies was inadequate to provide asymptotic estimates of species richness. As noted in other volumes of the EA, this is not surprising considering the amount of effort required to collect a detailed inventory of tropical species, even from one area (Lawton et al. 1998). Thus, the number of potential impacted species is uncertain. In addition, the basic knowledge about the biology of species (for example, population growth rates, abundance and dispersal mechanisms) is limited in this region. Therefore the effects of habitat loss on individual species locally cannot be predicted with certainty. However, it is understood that impacts are local in extent and occur within a large matrix of similar habitat resulting in a moderate to high confidence in impact prediction levels on a regional basis.

Revegetation of the tailings facility is dependent on the development of appropriate revegetation process through trial testing of various species. Stochastic events (e.g., fire, extreme drought or cyclones) and future human land use practices (e.g., plantations, agriculture) will limit future biodiversity potential of this currently disturbed area.

Monitoring

A monitoring program will be implemented mainly during the construction phase of the project, and will follow the programs stipulated for flora and fauna in Volumes D and E. The overall objective of monitoring is to test the effectiveness of mitigations, and detect unanticipated effects.

Changes to ecosystem processes and function will focus on abiotic variables such as water quality, hydrology and air quality (dust and air emissions). Permanent sample plots will be established in reclamation areas and habitats located at various distances from the project footprint to monitor selected flora and fauna species.

4.4.5 Conclusions

Changes in area, composition and spatial configuration of habitats were used to assess the direct impacts from the project on habitats and biodiversity in the Toamasina LSA as a whole. Following mitigation, analysis indicated that there should be no residual impacts to the Ivondro River, and negligible effects to species inhabiting tavy matrix in the tailings facility area and rice paddies throughout the LSA. The greatest impacts will result from disturbance to remnant, disturbed natural wetlands throughout the LSA, plus shrub land and coastal woodland habitats currently existing in the plant site area. Residual impacts during construction and operation are predicted to be of high magnitude, local in geographic extent, and continue over the long-term. During closure, ongoing reclamation at the tailings facility is anticipated to reverse residual impacts (except for the loss of wetlands) to moderate magnitude. The extent of the effects will be local and medium-term duration. Overall, the environmental consequence of the project on habitats and biodiversity is predicted to be moderate during construction and operation at both plant and tailings areas, and low or moderate during closure at the tailings and plant site areas respectively.

There is a high probability that the project will negatively impact remnant natural habitats and associated biodiversity within the study area. However, the severity of the impact on the ecosystem is uncertain. Tropical ecosystems are inherently complex, and contain a multitude of interactions at the population and community levels for which little empirical data are available. Although baseline data provided good estimates of species richness, endemism and conservation status among natural and moderately disturbed habitats in the study area, there is a lack of basic information for the biology of species. Thus, there is a high degree of uncertainty associated with predicting project-related changes in habitat availability and fragmentation on ecosystem stability and resilience. However, it is predicted that effects will be small on a regional basis, as habitat at the process plant and tailings facility occurs in a matrix of similar habitat that will not be affected by the project.

The monitoring programs used to monitor flora and fauna will be implemented to test the effectiveness of mitigation, and detect unanticipated effects as they relate to biodiversity. If needed, mitigation will be adjusted. Despite the fact that much of the area is disturbed, the project development, as per International Finance Corporation (IFC) revised EA guidelines, will take efforts to minimize impacts to biodiversity in already degraded areas.

4.5 PROTECTED AREAS

4.5.1 Introduction

This section presents the Environmental Assessment for the effects of the process plant and other project developments in the Toamasina area on existing and planned protected areas. As per the Ambatovy Project Terms of Reference, the potential impacts of these developments on the ecological integrity and economic sustainability (e.g., tourism) of protected areas within the regional study area are evaluated.

4.5.2 Study Area

This section addresses the effects of the process plant, tailings facility and port expansion. For protected areas, two study areas are used: a Local Study Area (LSA) that will encompass the area likely to be directly impacted by all of these project elements around Toamasina, and a Regional Study Area (RSA) that includes the area subject to indirect effects of populations who move into the area to work at the plant, tailings facility or port expansion.

The Toamasina LSA for protected areas is the same as the terrestrial study area presented in Volume A, Figure 7.2-3. It includes the process plant, tailings facility and port expansion areas, and linear corridors linking these areas, plus a 500 m buffer around those areas in all directions. The RSA includes all areas within 100 km of the process plant, tailings facility or port expansion.

4.5.3 Baseline Summary

No proposed or existing protected areas are located in the Toamasina area LSA. Within the RSA, the proposed and existing protected areas include:

- Zahamena National Park and Natural Reserve;
- Betampona Natural Reserve;
- Mangerivola Special Reserve; and
- Mantadia – Zahamena Corridor proposed conservation area.

Details concerning these areas are provided in Volume J, Section 6.1.

The province of Toamasina, and a group of tourism operators in the region are working to increase tourism capacity, including ecotourism (PTE/EDENA 2004).

In general, tourism in Madagascar, including protected areas experienced strong growth between 1992 and 2002, and has grown again since 2002, despite a lower level in 2002 for political reasons (PTE/EDENA 2004; Madagascar Contacts Website 2004).

4.5.4 Issue Scoping

Protected areas constitute both a source of tourism income and a way to preserve the natural heritage of Madagascar. Effects on these areas, both existing and proposed, must be considered carefully and minimized wherever possible, either by choosing appropriate location and routing options or by applying effective mitigations.

The key question for protected areas is:

Key Question PR-1 What Effects, Direct and Indirect, Will the Process Plant, Tailings Facility and Port Expansion Have on Protected Areas?

4.5.5 Impact Assessment

The footprints of the process plant, tailings facility and port expansion do not overlap with any existing or planned protected areas.

The development of the process plant, tailings facility and port expansion will lead to an increase in the population of the area. This may result in additional threats on the protected areas, including land use from induced development, and higher tourism levels. These effects may be positive or negative.

4.5.5.1 Assessment methods

The assessment of effects on protected areas is based on socioeconomic impact information, which helps to determine indirect population effects on protected areas in the RSA.

4.5.5.2 Assessment criteria

The assessment criteria presented in Table 4.5-1 were used to evaluate impacts on protected areas.

Table 4.5-1 Impact Description Criteria for Protected Areas

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
positive: enhanced management of protected areas **neutral:** no change in protected areas **negative:** degradation of protected areas	**negligible:** no measurable effect **low:** physical effects on 1% or less of a protected area and/or minor indirect impacts **moderate:** physical effects of 10% or less of a protected area and/or moderate indirect impacts **high:** physical effects of more than 10% of a protected area and/or high indirect impacts	**local:** effect restricted to the LSA **regional:** effect extends beyond the LSA, into the RSA **beyond regional:** effect extends beyond the RSA	**short term:** <3 years **medium term:** 3 to 30 years **long term:** >30 years	reversible or irreversible	**low:** occurs once **medium:** occurs intermittently **high:** occurs continuously

4.5.5.3 Mitigation

The footprints of the process plant, tailings facility and port expansion have been located outside of existing and planned protected areas.

The proponent will provide education and information to both local and overseas workers regarding the importance of protected areas and the natural heritage of Madagascar. The education program will be designed for the benefit of workers, as well as to minimize possible negative indirect effects and to promote positive indirect effects, such as increasing ecotourism through the protected areas in the RSA.

4.5.5.4 Results

Due to direct and indirect economic benefits of the process plant, tailings facility and port expansion, population levels in the Toamasina region are expected to increase.

The Zahamena National Park and Natural Reserve, Betampona Natural Reserve, Mangerivola Special Reserve, Mantadia–Zahamena Corridor proposed conservation area, and other nationally prominent protected areas throughout Madagascar are expected to receive positive benefits from increases in tourism as a result of the population and income increases in Toamasina. In the context of a country where tourism is increasingly important, each of these protected areas has capacity for increased tourism, as described in Volume J, Appendix 6.1.

4.5.5.5 Impact Analysis

Residual Impacts

Residual impacts on protected areas following mitigation are summarized in Table 4.5-2.

Table 4.5-2 Potential Effects and Residual Impacts for Protected Areas

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	Indirect social effects of higher local populations	Education of worker populations	low, positive regional impacts on tourism
operations	Indirect social effects of higher local populations	Education of worker populations	low, positive regional impacts on tourism

The indirect effects of migration of populations to Toamasina and the areas around the process plant are difficult to predict but are conservatively estimated to be low and positive. These effects will be medium term in duration, medium in frequency, and will be reversible.

At closure, with the removal of the economic input from the process plant, tailings facility and port expansion, impacts on protected areas will become negligible.

Table 4.5-3 Residual Impact Classification for Protected Areas

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
issue: indirect impacts of social / population changes (tourism)							
operations	positive[a]	n/a	n/a	n/a	n/a	n/a	n/a

[a] Impact classifications not applicable for positive impacts.

n/a = Not applicable.

Prediction Confidence

The prediction confidence for this assessment is high. The potential for negative impacts on protected areas is very low, and the positive implications of the Ambatovy Project for tourism have been conservatively estimated.

No monitoring of protected areas is required.

4.5.6 Conclusions

Low, positive environmental consequences for protected areas will occur due to the increased potential for tourism from the worker population for the process plant, tailings facility and port expansion at Toamasina. This impact will occur during both construction and operations, and will end at closure.

5.1 SOCIOECONOMICS

5.1.1 Introduction and Study Area

Given the connections between socioeconomic analyses for the plant, tailings facility and port expansion, they are assessed together in this section. The tailings and plant facilities will have effects on the immediate area around their locations, but in addition due to the very large size of the planned construction and operations will also impact on the city of Toamasina, just as the port expansion will. Thus the local area for this assessment includes Toamasina. The effects of the tailings and plant facilities, are mainly in the two communes of Toamasina II and Fanandana, and more particularly the fokontany in these two communes adjacent to the tailings and plant locations. Together, the development of the plant and tailings facilities will require the resettlement of about 167 households (see Resettlement Action Plan).

Toamasina II is a suburban commune, however its fokontany in the area of the tailings and plant facilities have many rural characteristics. Fanandana is a rural commune. The tailings and plant facilities have the potential to transform rural life in multiple ways, most associated with expected and probably unavoidable induced urbanization. The proximity of Toamasina, as well as its urban plan that envisages the extension of the urban boundary southward to within 5 km of the plant site, virtually ensures this urbanization.

Toamasina is a large city, with a more educated population, institutional presence and some depth to business activity. This enables Toamasina to be in a position to take good advantage, particularly over time, of project benefits. Given the location of project facilities relative to Toamasina, there are not expected to be any negative physical effects on natural resources in the urban area.

While it is true that in Madagascar urban populations are generally much better off than rural populations, much of this is contingent on the capacity of government to extend and deliver services and infrastructure to urban populations. Urban centres have tax bases that provide municipal governments with resources, and large populations create demand for goods and services that can be provided with some economies of scale. All these things, arrive after population pressures have been realized; dominant push factors of rural-urban migration include landlessness and poverty and dominant pull factors are job opportunities and higher wages, of which this project has both. With a project of this size, population can grow extremely rapidly and provisioning that population with an urban standard of living will not keep pace. However, policies to control and regulate migration have met with only limited success in many countries. To address the challenges of uncontrolled growth, the proponent will participate in the planning of infrastructure and planning infrastructure investment throughout the life of the project, as well as in efforts to strengthen the capacity for healthy urban development.

The project is committed to ensuring that people are not harmed by its activities, and to contributing to the social and economic development of its area of potential effects, the scale of the project and the potential for consequent economic and social transformation in the local area requires less specific mitigation than it does an adaptive management strategy. Adaptive management incorporates research and action by developing interventions to respond to the results of systematic monitoring. Monitoring of population impacts, strengthening the understanding of migration, helping develop regional institutional capacities to deal with migration challenges, are all objectives of the Ambatovy Project. Impact mitigation and benefit enhancement measures are summarized in Table 5.1-1.

Table 5.1-1 Impact Mitigation and Benefit Enhancement Measures

Plant Site	
Potential Impact	**Mitigation and Benefit Enhancement Measures**
Employment	Local Resource Development Initiative (LRDI), with sections specific to the Toamasina context (labor force, training institutions, employment targets, modalities for identifying prospective employees, recruitment strategy, worker housing, communication plan for hiring, etc.). A main objective of the LRDI will be to use these and other components to reduce in-migration.
Procurement of local goods and services	Procurement Plan (PP) sections specific to plant construction and operations and Toamasina context.
Indirect and induced economic effects (on labor forces and businesses) of direct project employment and procurement	None required additional to LRDI and PP, as above.
Training and capacity building of businesses	None required additional to LRDI and PP, as above. Special focus on small and medium enterprises (SMEs).
Overall economic growth	None required. See Volume G, Section 4.1.
Diversification of regional economy	None required additional to PP, as above.
Increased local government revenue as a result of payment of local taxes and if so any consequent improvements to government services	None required.
Interactions with existing local and regional planning initiatives.	Partnering in planning and capacity building initiatives. Roles and planning model to be identified but will build on stakeholder interactions during EA consultation. Activities will include ongoing consultations to optimise the success of mitigations (developing a strategy to deal with uncontrolled migration, initiatives to address urban planning challenges, education, health issues).
Improved well-being associated with increased employment and incomes	None required.
Resettlement of up to 167 households in tailings and plant areas	Resettlement Action Plan.
Households and livelihood resources affected by linear development land and right-of-way requirements	Detailed alignment of linear developments (pipelines, power lines, roads) will avoid villages, individual households and agriculture land to the extent possible. Where this is not possible, compensation -- or at the limit resettlement -- commensurate with the level of loss of livelihood resources will be paid. Negotiations with land users need to reflect value of livelihood resources lost over time period of loss.

Table 5.1 Impact Mitigation and Benefit Enhancement Measures (continued)

Plant Site	
Potential Impact	**Mitigation and Benefit Enhancement Measures**
Disturbance effects associated with construction and operations activity, increased traffic congestion, noise, dust, changes to air quality, etc.	Full mitigation of environmental effects (so that there are no social effects to mitigate). See EA sections on noise, air quality and traffic in Volumes D, E and F for proposed mitigations.
Ground and surface water quantity and quality effects on livelihoods and health	Full mitigation for water quality and quantity effects (so there are no social effects to mitigate).
Induced urbanization and land speculation in relation to urban growth from Toamasina towards the plant site and consequent population influx	For induced migration to the project, increased demand on basic infrastructure and services such as housing, sanitation, water, schools and health facilities will be monitored and strategies developed through planning and participation with local authorities. Ongoing consultation and grievance mechanisms can capture any particularly negative effects attributable to the project to be dealt with through adaptive management. Job recruitment will occur in Toamasina, following a comprehensive communication plan that will discourage job and opportunity seekers from going directly to the project site. For ongoing urbanization, the proponent will work with appropriate authorities to strengthen understanding of rapid migration and support regional institutional capacities to deal with migration.
Increase in incidence of HIV/AIDS and other transmissible diseases as a result of imported workforces, migration etc.	An HIV/AIDS program will be implemented co-ordinated by the project health office comprising: AIDS education and prevention (information dissemination; education; prevention and treatment of other sexually transmitted diseases; counseling; and provision of condoms); a worker code of conduct that lists expected socially responsible behaviour, plus safe work practices for employees at risk (healthcare workers and first aiders); a malaria control program will include both vector control and personal protection.
Threats to public health and safety as a result of increased incomes, imported workforces, migration, increased traffic, etc.	Workforce management, including cross-cultural training and enforced worker codes of conduct. Participation in community development initiatives, pending consultation with communities, targetting public health and security, may be a priority. Ongoing consultation and grievance mechanism can capture any particularly negative effects attributable to the project for adaptive management.
Pressures on local social and physical infrastructure (schools, health services, housing, etc.) as a result of induced urbanization	Provision of all food and accommodation, medical and recreation services directly to expatriate and out of area workforces. Well-advertised recruitment policy that requires recruitment activities to take place in Toamasina and prohibits hiring at the plant itself. Economic migrants will put pressure on local service delivery, most seriously around the plant site, which can only be mitigated through community development and forward planning efforts to make the provision of social and physical infrastructure a priority. Ongoing consultation and grievance mechanism can capture any particularly negative effects attributable to the project for adaptive management.

Table 5.1 Impact Mitigation and Benefit Enhancement Measures (continued)

Plant Site	
Potential Impact	**Mitigation and Benefit Enhancement Measures**
Social conflict between introduced workers and local residents, new migrants and established communities and between family members, individuals, villages and communes	Workforce management policy for introduced workforces, including cross-cultural training and enforced codes of conduct. Conflict between elements of the local population cannot be directly mitigated. Ongoing consultation and grievance mechanism can capture any particularly negative effects attributable to the project for adaptive management.
Cultural change to the rural communities around the plant site	No direct mitigation practicable. Ongoing consultation and grievance mechanism can capture any particularly negative effects attributable to the project for adaptive management.
Impacts associated with any real or perceived risk of accidents associated with plant and with handling of hazardous materials	Corporate health and safety policy, including health and safety training. Public education on actual risks. Emergency response planning. Medical insurance for employees, including disability insurance. Provision of on site medical facility. International standards to be followed (see Volume H, Appendix 6).
Closure and consequent economic and social effects	Corporate sustainability policy. Integrating acknowledgement of eventual project closure in all social investment plans.

5.1.2 Impact Assessment

5.1.2.1 Economic Opportunities

With the exception of people living along the Route Nationale (RN2), populations adjacent to the plant and tailings sites appear to be somewhat worse off in terms of social and economic development than those at the mine site (Volume K, Appendix 1.1). However they do not report experiencing the same kinds of stresses, or aspirations, which have motivated mine site populations to give employment as large a priority.

Accordingly, the project would intend to offer pre-employment training, basic skills training, jobs and other benefits to local people. To mitigate uncontrolled migration to the project, the recruiting area for job training, employment and procurement opportunities will be Toamasina, which is considered to be “local” to the project. It is likely that with the number of jobs, the potential improvement in quality of life, and the offer of training and pre-employment programs as described elsewhere, the project will employ considerable numbers of people from the Toamasina area. Business opportunities in the immediate vicinity are likely to be less than for Toamasina generally, given there only very few small businesses in what is largely a rural setting, however this has potential to grow with time.

5.1.2.2 Employment

Baseline employment, language, literacy and education data suggest that it will be initially difficult to employ many people from the area immediately adjacent to the project in other than unskilled jobs, although some people have had recent job experience related to the construction of buildings along the route nationale. However, given the size of required construction and operational workforces, the size of the working-age population right adjacent to the work site (about 1,500 people, many of whom are not actually in the labor force, and/or are willing or able to take up full-time wage employment), there is unlikely to be a shortage of opportunity for those near the plant and tailings facility who wish to take on employment. With time, unskilled and inexperienced workers will be developed through education and training programs.

Direct Malagasy labor force requirements will be about 1,100 of the total work force of 2,800 over the 36-month construction phase. Some of these jobs will be short term but unskilled jobs will be more stable. It is expected that many of the more skilled jobs will be sourced in Toamasina. The direct local workforce requirement for the operations phase is estimated at about 1,060 with only about 90 expatriate workers. As local people gain skills and experience through the construction stage, they would be expected to be in a position to access additional, more skilled jobs. The potential impacts of employment are considered to be positive, of high magnitude, long term, and of high consequence.

5.1.2.3 Business

Given the size of the project, the high volumes of materials required for operations and the fact that many of these materials will pass through the port, there will be a large number of business opportunities created by the project. Businesses with capacity to supply, even if located elsewhere in Madagascar, can be expected to expand or relocate to Toamasina in order to be close to what will become a very large customer. In addition, assistance to businesses will expand the capacity to respond to project goods and services needs over time.

It is not expected that there will be many goods and service supply contracts for the areas immediately adjacent to the tailings and plant sites. There are few existing businesses, and those that exist are small and with few exceptions are oriented to serving the consumption needs of local residents. Any encouragement of small fenceline businesses should be considered carefully, so as not to foster in-migration.

The potential impacts of direct business opportunities are considered to be of high magnitude, positive, long term, and of high consequence.

5.1.2.4 Local Economy

It is estimated that US$100 million annually will be spent in the Toamasina area, during the three years of construction. The estimated annual spending during operations would be US$67 million. In addition to the local expenditures, the indirect and induced employment benefits and economic activity will be significant. It is predicted that an additional 6,700 indirect jobs and 1,470 induced jobs will be created during construction. The equivalent numbers for operations would be 3,810 and 710. As well, it is expected that the improvements to infrastructure, some of which will be implemented by others in association with the project, will stimulate the local economy through employment creation.

Preferential consideration will be given to people in the vicinity of the project development, although the majority of local labour force will be from Toamasina, mainly due to the numbers required. Expenditures of wages and purchasing services will be made in the broader economy, including Toamasina.

Project-associated increases in demand for goods and services can be inflationary, introduce more inequalities in the distribution of income and have other effects on the local economy. One challenge will be to ensure that the project does not draw the best of the labour force from other businesses, which will then experience the costs of finding and training new employees. It is in fact not in the interests of the project to do this, as many of the businesses with skilled labour will be suppliers to the project and compromising their ability to operate efficiently would then affect the project. The intention to support training institutions and programs in Toamasina may also assist with increasing the overall availability of an educated labour force.

Because anticipated project expenditures are expected to be comparatively large relative to the size of the local economy, the impact is considered to be of high magnitude, positive, long term, and of high consequence.

5.1.2.5 Education and Training

It is the project’s policy to provide training to employees, both to improve skills needed for better job performance and promotion, and to broaden the skill base of employees so that their enhanced abilities can prepare them for new opportunities in the future. It is also the project’s intention to address the need for a broader-based education and training strategy through support for educational institutions in Toamasina. The formal training program developed for the project will be accessible on a preferential basis for employees local to Toamasina and the tailings and plant sites. As at the mine site, the project will also address the need for a broader-based education and training strategy to provide assistance to those who wish to develop skills that could position them for employment and/or supply of goods and services at levels beyond those they would otherwise be qualified for, both with the project and in the broader economy.

The potential impacts of education and training to the labor force, businesses and to the young are considered to be of high magnitude, positive, long term, and of high consequence.

5.1.2.6 Commune Government Budgets

With little tax base and a national revenue distribution system that disburses on a per capita basis fewer resources to rural than urban communes, rural communes are under-funded in Madagascar. Mining legislation allocates royalties to communes where ore bodies are located, which excludes the communes affected by the tailings and plant facilities.

There may be some potential for increased commune revenues, at least in Toamasina II where the tailings and plant are located, from limited revenues that communes are permitted to raise on their own behalf. The project would be willing to offer support to the local and regional government administrators relative to the planning and use of royalties paid by the project, in affected communes.

Although the sources of increased revenue are undetermined, the determination that communes will require additional sources of revenue and that in some way this requirement will be met, means that the project's effect on commune revenue will be of high magnitude, positive, long term and of high consequence, particularly if any additional funding is managed well.

5.1.2.7 Increased Income

Direct, indirect and induced employment and business creation associated with the project will increase the income levels of individuals local to the project, and their families. Increased income, associated overall with improvements in quality of life despite some potential for associated negative effects, is considered to be a major benefit of the project, both to direct beneficiaries but also to communities as a whole. It is noted that such effects cannot be understood in isolation of expected induced urbanization. The potential impacts of increased income are considered to be of high magnitude, positive, long term, and of high consequence.

5.1.2.8 Migration and Induced Urbanization

The construction and operation of the tailings and plant facilities represent an enormous project relative not only to the adjacent communities, but to the city of Toamasina. The project will represent the largest single employer in the area, with an annual average of 1,680 foreign jobs and 1,130 local jobs during construction, and 90 foreign jobs and 1,060 local jobs during the operations phase.

The project will implement initiatives to limit migration immediately adjacent to the developments. These will include transporting workers to and from the site from designated local locations. Other means of transport may be made available through government service initiatives or private initiatives.

Induced urbanization may begin with the construction stage, migrants being attracted initially to construction camps and perceived potential for employment with the project. Controls will be put in place through the establishment of recruitment offices located only within Toamasina, camp and plant site fencing and transporting workers to and from the site. Through the project development the city of Toamasina may see a rapid growth rate outside its current boundaries. The more rapid urbanization is a process that would have likely occurred even without the project because Toamasina is in the process of expanding residential areas southward, and developments in conjunction with the port have been proposed for nearby land. The project will work with planning authorities to develop a comprehensive strategy for monitoring and dealing with uncontrolled labor migration.

Urbanization will transform what are still predominantly rural ways and conditions of life in the fokontany near the tailings facility, in both positive and negative ways. The processes of change are similar (although more extreme) to those described for the mine site in Volume B, Section 5.1, and for the economic effects directly attributable to the project as described above. The potential for such effects is addressed in the following sections on natural resources, services and infrastructure and well-being.

Urban populations in Madagascar are generally better off in terms of socioeconomic status, and it is in anticipation of this that most people choose to move from rural to more urban areas. Better socioeconomic status in urban environments is due to more economic opportunity and better service delivery than rural environments. Rapid, unplanned urbanization has potential to harm not only those originally resident, but also many migrants whose vision on quality of life improvements may not develop as hoped.

Numbers of migrants (speed of urbanization) are difficult to predict. Without effective planning and preparation, people are likely to concentrate first along the access roads to the plant site, as well as in its immediate neighborhood. Distribution of migrants will depend on land availability and cost, any enforcement of property rights, land allocation decisions on the part of affected fokontany and perhaps most importantly perceptions of advantages to be gained relative to costs of reestablishment of livelihoods in new locations. The project would work with local governments towards containing growth within Toamasina as much as possible to meet the challenges of induced urbanization. As noted previously, the distribution of project benefits relative to needs must take into account expectations regarding royalty and tax payments that are within the purview of the Government of Madagascar to determine. This is likely to include responsibilities on the part of Toamasina I and II to extend services to the new population centers and/or expand existing services that new populations will have recourse to, with the assistance of the project. Notionally, such project assistance would include support to urban and commune planning and implementation capacity. To develop the details of such assistance, the project would expect to engage in discussions with the relevant government authorities over the time until construction begins and continue thereafter.

Social monitoring, ongoing consultations and grievance and dispute resolution mechanisms are also critical to capturing the effects of urbanization which can be addressed with additional mitigation where warranted. These mechanisms are particularly important because whereas the types of effects can be predicted to some extent, the magnitude of these effects and the individuals specifically affected cannot be. In many instances there will be tradeoffs to balance impact and benefit.

The potential effects of migration and induced urbanization are considered of high magnitude, to have both long-term negative and positive components, and to be of high consequence. The balance would shift to the positive side in proportion to the success of efforts to realize most growth through planned urbanization rather than un-controlled in-migration.

5.1.2.9 Access to Natural Resources

Land

The project will require about 14 km^2 of land and rights-of-way for the development of the tailings and plant facilities, and associated infrastructure.

People whose lands are required for the project will be resettled as per the Resettlement Action Plan. This applies to people who live and/or have agricultural lands within the tailings and plant facility areas. Depending on livelihood resources that are affected by project infrastructure land disturbances and requirements for rights-of-way (for roads, pipelines and power lines) people may or may not be resettled. There are alternatives that may be preferable, including replacing that portion of livelihood resources affected by alternative resources, which could include compensation and/or employment. The intent is to ensure that people are not harmed by the project.

Induced urbanization also has the potential to affect land values and consequently land use. Particularly in areas where people have use rights to land, as opposed to legal title, they are concerned about the pressures that can be brought to bear by land speculators, including the potential for land to be sold. Whereas traditional land allocation systems to some extent protect people who access land this way, for people who are on land that is already privately held, and who have various arrangements that permit them to earn livelihoods from that land, the introduction of a speculative land market and consequent more lucrative alternatives for land use is of concern. Land disputes are likely to follow. It is not the project's intention that people originally resident in the tailings and plant site will lose livelihoods as a result of the project, as a result people will be encouraged, through community relations programs, to come forward where they can demonstrate harm.

After mitigation, the potential impact on land resources is largely still negative, of moderate to high magnitude, long term and of moderate to high consequence. However, positive effects could accrue from increasing land prices to land owners who choose to sell.

5.1.2.10 Water

Residents in the three watersheds affected by the tailings depend on both river and spring water for agriculture, drinking water and domestic use. Water quantity and quality effects as a result of the plant have been assessed as of negligible consequence, as have water quality effects as a result of the tailings. Water quantity effects as a result of the tailings are of high consequence (Volume E, Section 3.7 and 3.8). The construction and operations of the tailings facility will reduce water flow to downstream water users by amounts of up to two-thirds. However, baseline studies noted that too much rather than too little water is a main issue now. Also, agricultural analyses showed that even with these reductions, there will be sufficient flow for existing rice fields below the tailings.

As noted in the mine site impact assessment, actual effects on livelihoods due to surface water quantity decreases will vary over time, contingent on timing and amounts of rainfall events as these relate to agricultural activities in river valley bottoms. To the extent that people in the area experience water problems, this is often more a function of too much, rather than too little water. It may be that under certain circumstances the reduction in flow is actually of benefit to local farmers, who frequently see crops inundated. However actual effects, both real and perceived, will need to be monitored and at the limit grieved in order to address them. Options of resettlement, replacement water and improved water management, will be considered if reduction in flows materially affects people's livelihoods.

Finally, construction activity has potential to affect water quality, primarily through erosion. Such effects will be minimized through the use of construction best practice, and are likely to be short term in any case, however may represent a nuisance value to water users.

The impacts on the quality of water, from both agricultural and health points of view, are considered to be negative but of low magnitude, long term and low consequence. Water flow effects downstream from the tailings site are negative, but of low magnitude, of medium term and of low consequence if mitigation is conducted as proposed (Volume E, Section 5.3, Land Use). It may prove that benefits are realized if the reduction in water flow means that floods become less of a problem for farmers.

5.1.2.11 Biological Resources

The development of the tailings and plant facilities will remove vegetation cover. Most of the people affected will be fully resettled, as per the Resettlement Action Plan. Given the poor state of biological resources, people are not overly dependent on these, and have in fact planted woodlots as an alternative. If the tailing facility development requires removing vegetation cover that is proven to be of use to populations not otherwise affected to such an extent that resettlement is warranted, replacement resources will be provided.

Of perhaps more concern is the potential to affect fish resources. From a biological point of view, the reduction in stream flow and water quality effects that are expected to result in exceedances of standards for aquatic life have been assessed as potentially changing the species distribution in rivers. Although tilapia may be an exotic, as a desirable, marketable food fish, there is some potential for negative impact both on nutrition and on household economic well-being. The project is again committed to monitoring for impacts to fisheries and working with local people on improved fishery management.

The effects of the tailings and plant on marine resources, through effects on water quality are considered to be negligible.

The impacts on biological resources are considered to be negative, of low magnitude, long term and of low to moderate consequence.

5.1.2.12 Social and Physical Services and Infrastructure

Demand for social and physical services and infrastructure is both increased (in so far as needs increase) and decreased (in so far as poverty constrains access) by poor socioeconomic status. The very poor socioeconomic status of many people in the immediate area of the tailings and plant facilities, as evidenced by the degree of hunger, low life expectancy and low attendance of children at school, suggests that demand for social services is likely to increase with increased economic opportunity. As well, increased demands for health, policing, education, water, housing and other services and infrastructure will occur as a result of the expected influx of migrants.

It is not expected that migration can be limited to such an extent that additional pressures on not only services, but also goods and land, can be fully mitigated, in the absence of extreme measures. Both in the interests of original residents, and in the interest of any migrants, flexibility in the response to migration are necessary. Responding to migration and induced urbanization will present significant challenges to local government and to the project, requiring forward planning and resources, some of which can be provided by partnering with government agencies and NGOs to support community and economic projects. It is perhaps also worth noting that migrants can, when able to access resources such as those that might be provided by project-related economic opportunity, organize themselves very quickly to meet daily needs.

The project will contribute to the development of local infrastructure, including road improvements and replacement of any existing community infrastructure removed or affected. Of particular interest to people west of the RN2 are improved roads for accessing markets and health services in Toamasina.

With specific reference to Toamasina, it is noted that large cities have formal economies that generate significant tax resources from businesses, including possibly the project and certainly from businesses that supply the project. This is not to say that Toamasina does not experience significant resource constraints, but only to say that a large economic boost will engender additional resources which may be used to meet any increased demand for services.

The project itself will make few demands on services and infrastructure, in so far as imported workers will be housed at camps where all their service requirements will be met. As well, the project will have independent systems for power, water, communications etc. Improvements to transportation infrastructure associated with the project, including roads, the port and the railway, will strengthen the capacity of Toamasina to serve as a full-service transportation node relative to other Madagascar alternatives.

After mitigation the impacts on social services and infrastructure are considered to be of moderate magnitude, both positive and negative and of medium consequence. There is especially potential for longer-term positive impacts on the socioeconomic status of original residents and migrants through careful development of the social programs implemented in cooperation between government agencies, NGOs, and the project.

5.1.2.13 Well-being

Potential impacts on individual and family well-being are complex, far reaching, and unpredictable. Well-being is intimately associated not simply with increased economic opportunity, but also public health and safety, disturbance particularly during the construction phase, socioeconomic and cultural change and availability and access to the necessities of life.

Public Health and Safety

There is a relationship between industrial camps filled primarily with men of single status and/or having increased income and such public health issues as incidents of sexual abuse, teenage pregnancy, single parenthood, and sexually transmitted disease including HIV/AIDS, substance abuse and crime. Using "lessons learned" and current best practice, which is constantly evolving, a comprehensive worker management program will be developed with a view to limiting the potential for contact between migrant workers and local people and encouraging environmentally and socially responsible behavior. Although the project will implement such best practice, employees housed at camp and new migrants will inevitably interact with people of the tailings and plant facilities area. Social monitoring will be critical to determining the actual effects of the project on such public health and security issues in order to respond to any evolving negative community effects of such interactions.

Attention to the potential for increasing the incidence of HIV/AIDS is particularly critical, given that the incidence in the Toamasina area is suspected of being higher than in Madagascar generally. Through enforced codes of behavior and aggressive HIV/AIDS prevention and treatment programs, the movement of workers and migrants into the area as a result of the development of the project will manage the incidence of HIV/AIDS. The proponent has developed an HIV/AIDS protocol and will work to strengthen and support capacity to deliver prevention and treatment campaigns for sexually transmitted infections. World Bank Group and the International Federation of Red Cross and Crescent Societies' best practice guides will be consulted to develop prevention, care, and monitoring programs for the workforce.

Concerns about increased vehicle traffic, and the consequent potential for more road accidents due to the volume of project-related traffic were similar as for the mine site (Volume D, Section 5.5). Project-related emergencies may also occur, and again although risk is considered negligible to low, should a risk be realized the potential for harm could be greater. Health and safety of workers is perhaps more of an issue, since there will be many more workers employed at the tailings and plant site. Public health issues associated with noise, emissions and water quality are, however, not considered to be of consequence (see human health sections).

It is likely that public security will suffer in the rural areas near to the tailings and plant facilities as a result of migration and induced urbanization. The transformation of the local economy will create inequalities in incomes and people may migrate without obvious sources of livelihood.

Worker management, operational procedures, traffic, health and safety, public education, health programming and other relevant best practices will be implemented and enforced by the project. The project will work with all communities, as well as social monitoring, to provide a framework for adaptive management of problems as they evolve.

The potential impacts of the project in regard to public health and safety are negative, and long term. Mitigations to be applied have the potential to reduce the social consequence to low or negligible.

Social and Cultural Values and Integrity

The project represents a significant force of social change, given the size of the tailings and plant facility relative to the local population and the employment it is expected to generate. This will be accentuated by the transformation that is expected to occur in response to migration. However, the interplay of potential negative and positive processes are complex and not amenable to a simple social consequence ranking.

Disturbances

Disturbances will occur in relation to the tailings and plant facility. Project construction and operations will produce impacts on air quality, noise levels, traffic levels and visual aesthetics. In addition, for many people, irrespective of any economic advantage, the movement of large numbers of people into the area will be disturbing to the quality of life.

The project's potential disturbance impacts are negative. Most disturbances will be of low magnitude and short term, as they will occur primarily during the construction phase and only intermittently after that. However any large-scale migration would represent a long-term source of disturbance to those who value rural ways of life, which would be of high consequence.

Social Investment

The proponent alone cannot address in-migration and urbanization issues in the Toamasina area. It would be the project's intention to supplement mitigation and benefit enhancement measures directed at specific project impacts with participation in additional community development efforts. The approach will be to partner with government, NGO and community groups to support interventions to address the effects associated with induced urbanization, both in the interests of the original residents and to ensure that the migratory experience is as positive as it can be. People will choose to migrate largely in the hope of improving the socioeconomic status of their families. Many people choose to migrate under such uncertainty because their current situations are not tenable for themselves and/or their families. With poverty rates hovering at 70% of the population in Madagascar, migration to an area of potential opportunity may in fact be of net benefit, irrespective of any temporary or long-term effects to original populations.

Further developments in project-specific mitigations in the areas of health, training and small business development will evolve from ongoing stakeholder consultation. These contributions will be a benefit of the project to communities immediately adjacent to the tailings and plant facilities and also benefit the broader local population, many of which will be part of the increasing urbanization process in the Toamasina area.

5.1.2.14 Closure

With closure, the direct project contributions to the local economy, and to the welfare of a now urbanized population, will come to an end. As noted earlier, closure can represent severe economic and associated social dislocation.

With closure after 27 years, or possibly much longer if the tailings and plant facilities continue to be used as is possible, the conditions around the tailings and plant facilities are difficult to predict. It is possible for example that the project area would have been absorbed into the city of Toamasina, and have become part of the urban landscape.

The project intends to participate in that transformation as a positive force, contributing to economic and social development through employment, business opportunities and training as well as through expenditures in support of planned urban growth. Iterative closure planning, social monitoring and consultation should permit the integration of sustainable development principles in decision-making, on the part of the project, the city of Toamasina and the communes affected. A healthy, more diverse economy provides some buffer to the effects of closure.

Nevertheless, the reversal of economic and social benefits inherent in the closure of a large project has to be considered as a negative impact of potentially high magnitude, long term and of high consequence. Planning for sustainable communities by establishing procedures to support local businesses and services in the long run will help to reduce the impacts of closure.

5.1.3 Summary

The socioeconomic impacts of the project, as described in this section, are summarized in the socioeconomic impact matrix in Table 5.1-2. The table includes an assessment of potential impacts before and after proposed mitigation, and presents alternative scenarios for certain impacts that could eventually be deemed either positive or negative.

Overall, the project is expected to bring enormous economic benefits to the Toamasina area, through creation of employment, demand for businesses, contributions to educational institutions and improvements in infrastructure. Such an economic stimulus will result in improved socioeconomic status overall. People directly affected by project interruptions to livelihoods will be protected, either resettled or compensated as necessary. The project will partner with the city of Toamasina and commune governments to jointly manage the challenges of urbanisation. Emphasis will be to see that the project is well integrated into the Toamasina area as a sustainable development initiative. It needs to be considered that economic benefits in and of themselves are overall associated with improved socioeconomic status. To the extent that there is potential for negative effect, direct mitigation and an adaptive management strategy put in place to address evolving effects are expected to enhance the realization of overall benefit.

Table 5.1-2 Tailings, Plant and Port Facilities Impact Matrix

TAILINGS FACILITY / PROCESS PLANT								
				Before Mitigation			After Mitigation	
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Direction	Consequence (including magnitude)	Mitigation	Direction	Consequence (including magnitude)
Economic Opportunities								
local employment	potential for an estimated 1,130 local direct jobs during construction and 1,060 local direct jobs during operations	local	construction, operations	positive	low in absence of preferential systems	preferential employment for local Toamasina area; training and skills upgrading programs	positive	high for individuals able to access project related employment opportunities and high at the commune level in relation to population size
procurement of local goods and services	increases in business activity related to project supply contracts	local	construction, operations	positive	negligible in absence of preferential systems	preferential procurement from Toamasina; training programs to support small and medium enterprises (SMEs)	positive	high for individuals owning or working in business that are able to access project opportunities, especially in Toamasina
	potential for 6,700 indirect and 1,470 induced jobs during construction: 3,810 indirect and 710 induced jobs during operations	local	construction, operations	positive	low in absence of preferential systems	none required additional to preferential employment and procurement	positive	high especially in Toamasina
indirect and induced economic growth and economic diversification	Inflation	local	construction, operations	negative	high given size of facilities relative to local economy and taking into consideration population growth	no direct mitigation possible project benefits will contribute to overall community well-being	positive and negative	direction and consequence of effects contingent on one's position in the economy vulnerable groups are most negatively affected
	widening inequality of income	local	construction, operations	negative	moderate	no direct mitigation possible	negative	moderate, given expectations that support for community development initiatives will increase community well-being and can target the needs of the poorest members of society
capacity building of labor force and businesses	education, training and experience for employees and businesses that can be applied to project related jobs and in the larger economy	local	operations	positive	low in absence of preferential systems	none required additional to preferential employment, procurement and training programs	positive	high for individuals and communities
	improved educational achievement in the broader population	local	operations	positive	negligible in absence of education and training strategy	education and training strategy	positive	high for individuals and communities
increased individual income	increased employment opportunities at generally good wages	individual	construction, operations	positive	high for affected individuals	none required additional to preferential employment, procurement and training programs	positive	high for affected individuals

Table 5.1-2 Tailings, Plant and Port Facilities Impact Matrix (continued)

TAILINGS FACILITY / PROCESS PLANT								
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Before Mitigation		Mitigation	After Mitigation	
				Direction	Consequence (including magnitude)		Direction	Consequence (including magnitude)
migration	in-migration	local	construction, operations	largely negative given expected numbers	impact contingent on who might migrate, in what numbers, with what family status and skill sets, some potential for positive effects	no hiring "at gate"; clear communication on hiring needs and skills required however, direct mitigation not likely to be effective	negative and positive	impact contingent on who might migrate, with what family status and skill sets support for community based planning and capacity building will assist with managing migration and will contribute to overall community well-being
induced urbanization	transition from a rural to an urban economy	local	construction, operations	negative and positive	high given the expected changes to economic, social and cultural life	no direct mitigation likely to be effective	negative and positive	high negative to high positive economic growth and urbanization are associated with overall improvements in socioeconomic status although some people will not be able to benefit support for community development planning will contribute to overall community well-being
Natural Resources								
availability of land resources	land use changes (excluding resettlement)	local	construction, operations	negative	moderate	avoidance of villages, households and agricultural land for linear developments compensation where avoidance is not possible	negative	low and some people may benefit as a result of compensation
	land shortages and price increases	local	construction, operations	negative	high given expected levels of migration	no direct mitigation likely to be effective	negative	moderate to high, although it is noted that increasing land prices can benefit those who choose to sell support for community development planning could be used to assist with managing the effects of economic change
	disputes and changes to land tenure systems	local	construction, operations	negative	high given expected pressures on land resources	no direct mitigation likely to be effective	negative	high support for programs could be developed to assist with the enhancement of agricultural productivity and therefore reducing pressure on land resources
	reduced water availability for agriculture as a result of potential environmental effects and project water use	local	operations	negative	moderate given dependence on water resources from the tailings site area	mitigation of potential water quantity effects at source water management program sustainable compensation for any residual effects	negative or positive	low negative, but also some potential for high benefit should reduced flows imply reduced flooding

Table 5.1-2 Tailings, Plant and Port Facilities Impact Matrix (continued)

TAILINGS FACILITY / PROCESS PLANT								
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Before Mitigation		Mitigation	After Mitigation	
				Direction	Consequence (including magnitude)		Direction	Consequence (including magnitude)
effects on water resources	reduced surface water quality for human consumption and agriculture as a result of potential environmental effects	local	operations	negative	low due to mitigation and provision of potable water if needed	mitigation of potential water quality effects at source sustainable compensation for residual effects	negative	negligible support for program could be developed to assist rural communes with potable water
	reduced ground water quality feeding into wells for human consumption	local	operations	negative	low due to limited number of wells in close proximity, mitigation at source and provision of potable water if needed	mitigation of potential water quality effects at source sustainable compensation for residual effects	negative	negligible program could be developed to assist rural communes with potable water
effects on availability of biological resources	reduced access to biological resources used for livelihood purposes	local	construction, operations	negative	low given low dependence on biological resources as a supplement to other livelihood resources	sustainable compensation for residual effects where access and/or use restrictions have economic consequences	negative	low to moderate
effects on availability of marine resources	reduced access to marine resources used for livelihood purposes	local	construction, operations	negative	low given little dependence on marine resources of tailings/plant site population	mitigation of potential environmental effects at source sustainable compensation for residual effects where changes to resource base have economic consequences	negative to positive	negligible
Social and Physical Services and Infrastructure								
social services	population increases and increase in disposable income result in increased demand for the full range of social services	local	construction, operations	negative	high given induced urbanization	project workforces will be provided with health services	negative to positive	moderate negative to moderate positive depending on effectiveness of programs and interventions community partnerships could be developed to enhance social service delivery and contribute to overall community well-being
infrastructure	loss of community infrastructure	local	construction, operations	negative	moderate	replacement of affected infrastructure and building/improvement of other infrastructure	positive	moderate given priority given to infrastructure by population

Table 5.1-2 Tailings, Plant and Port Facilities Impact Matrix (continued)

TAILINGS FACILITY / PROCESS PLANT								
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Before Mitigation		Mitigation	After Mitigation	
				Direction	Consequence (including magnitude)		Direction	Consequence (including magnitude)
Community Well-being								
public safety and security	increase in antisocial public behaviors	local	construction, operations	negative	high given induced urbanization	workforce management through cross cultural training and enforced codes of conduct	negative	low with implementation of mitigations
public health	Increase risk in HIV/AIDS and other transmissible diseases	local	construction, operations	negative	high	project workforces will be provided with health services community and workforce HIV/AIDS prevention programs	negative	mitigations to be applied hence the potential to reduce consequence to low or negligible failure of mitigation would result in high consequence
increased risk to public health and safety due to construction and operations activities	risks associated with traffic, including transport of hazardous materials and accidents	local	construction, operations	negative	consequence of risk is high given the potential harm that any such accident has the potential to cause	full mitigation to limit all effects of increased traffic	negative	consequence of risk is high given the potential harm that any such accident has the potential to cause however mitigation is expected to reduce risk considerably
	water quality effects on public health	local	construction, operations	negative	moderate	full mitigation to limit water quality effects	negative	negligible to low
	noise effects on public health	local	construction, operations	negative	negligible as traffic noise does not represent a threat to public health, although disturbance can occur	full mitigation to limit effects of noise	negative	negligible as traffic noise does not represent a threat to public health, although disturbance can occur
	air quality effects on public health	local	construction, operations	negative	low as with the possible exception of traffic, project emissions are far from population	full mitigation and range of best practice to limit effects on air quality	negative	negligible
social and cultural changes	economic, social and cultural transformation	local	construction, operations	negative	high given induced urbanization	no direct mitigation possible project benefits to contribute to overall community well-being	negative	such change needs to be set beside benefits to socioeconomic status which can only be achieved at some cost to prevailing culture, irrespective of source of benefit: consequence uncertain
changes to social relations	reduced stability of social relations, increased conflict	local	construction, operations	negative	high given removal of a significant part of the population and induced urbanization	no direct mitigation possible project benefits to contribute to overall community well-being	negative	such change is generally considered of high consequence
disturbances	disturbances to quality of life (including economic activity dependent on road use) elements such as visual, traffic, noise changes	local	construction, operations	negative	high given induced urbanization	full mitigation to limit effects on quality of life elements	negative	low to negligible, except potentially high for disturbance linked to uncontrolled in-migration

Table 5.1-2 Tailings, Plant and Port Facilities Impact Matrix (continued)

TAILINGS FACILITY / PROCESS PLANT								
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Before Mitigation		Mitigation	After Mitigation	
				Direction	Consequence (including magnitude)		Direction	Consequence (including magnitude)
disturbances	perceptions of harm as a result of the project	local	construction, operations	negative	moderate	workforce health and safety training, public education on actual risks of harm as a result of the project, emergency response planning	negative	low
improved community well-being	economic and social investment in community and in the agricultural economy	local	operations	positive	not applicable as this is purely a project benefit	project benefits and community development to contribute to overall community well-being	positive	high
	collaborative support to urban planning	local	operations	positive	not applicable as this is purely a project benefit	integration of project mitigation into urban planning process	positive	high
Closure								
closure and consequent economic and social effects	end of economic opportunities	local	closure	negative	high	integrating planning for eventual project closure in social infrastructure initiatives through application of sustainability principles consultative and iterative closure planning will include consideration of employee future	negative	possibly high, but involvement in sustainable community planning will reduce impact

5.2 CULTURAL PROPERTY

5.2.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the proposed plant site on cultural resources, as per the Ambatovy Project (the project) Terms of Reference.

5.2.2 Study Area

The Local Study Area (LSA) used for the cultural property impact assessment comprises the footprint area of the plant site. Some cultural resources have been identified immediately outside of the current footprint area, and are included in this discussion because they may be impacted by activities following construction (increased traffic, etc.).

5.2.3 Baseline Summary

The following provides a summary of the results of cultural resources studies that have been conducted within the plant LSA. A complete description of the baseline methods, analysis and results is located in Volume K, Appendix 2.1.

5.2.3.1 Methodology

Pre-field work consisted of analyzing the results of previous historical studies completed in the general region. Regional toponyms were also studied, as place-names can assist in reconstructing the particular history of an area.

Fieldwork was completed at Toamasina between June and July of 2005. Systematic pedestrian transects were used to visually inspect the study area. Local expertise was also consulted by questioning villagers about the locations of any known archaeological or cultural sites in the area. A global positioning system (GPS) was used to plot the coordinates of such sites found during the survey, which were then mapped.

5.2.3.2 Site Diversity

Table 5.2-1 below illustrates the different kinds of cultural sites that are known to exist in the general region.

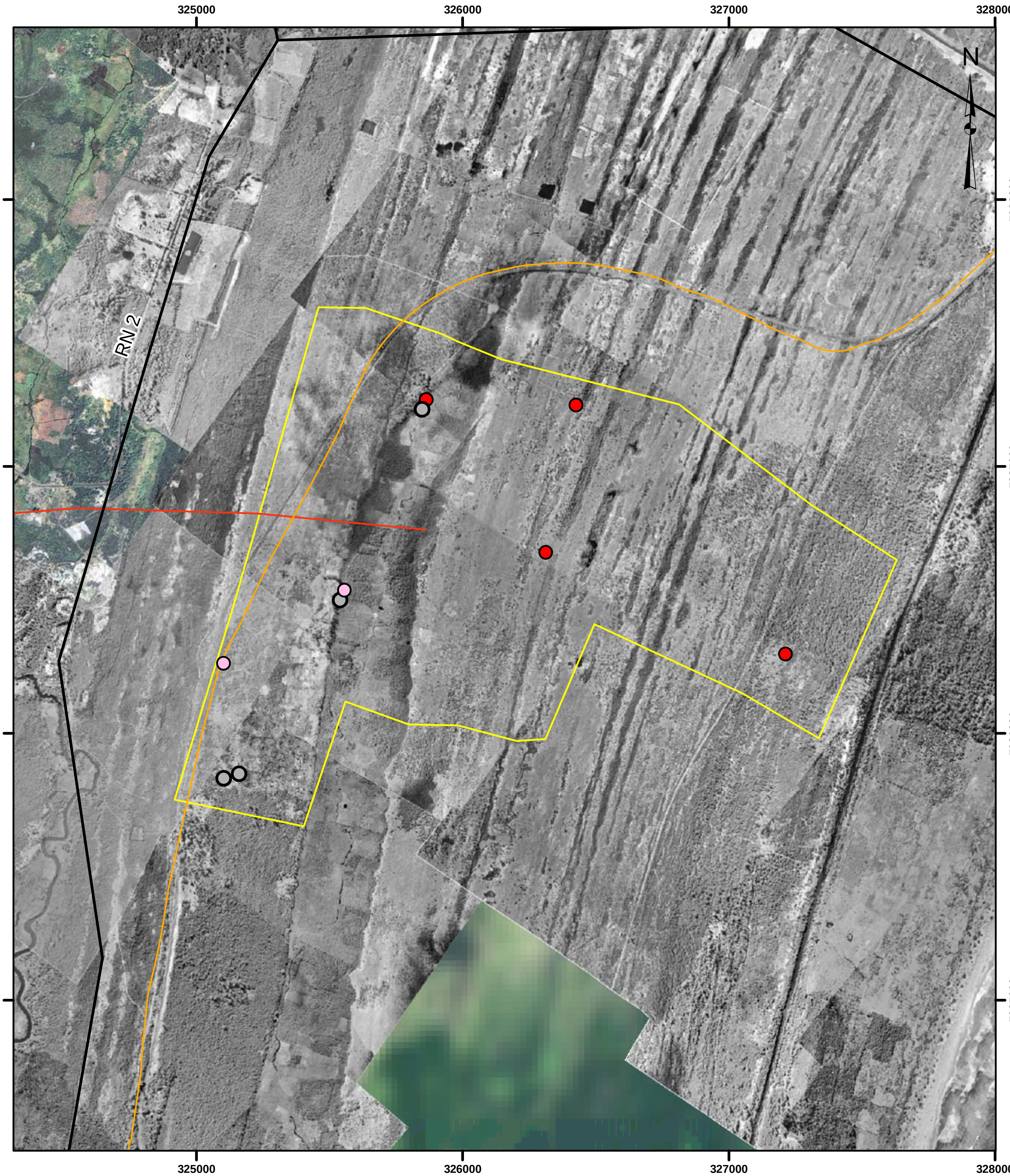
Table 5.2-1 Potential Types of Cultural Sites in the Cultural Resources Study Area

Site Category	Sub-Categories	Cultural Relevance
tombs	Fasana	considered ancestral residences, their displacement requires careful attention to proper ritual
	Tranomanara	
	Feraomby	
cemeteries	--	as above
ceremonial sites	Jiro	family prayer altar
	Fisokona	communal prayer altar
nefarious places	Tany Mahery	bad luck area
sacred waterfalls	Riana	symbolize purity; place for offerings
other cultural / archaeological sites	Vatolahy	large raised stone commemorating an important person or event of the past
	Tsangambato	small raised stones symbolizing a tomb
	Tanana Taloha	ancient abandoned villages

With the exception of the ancient abandoned villages, which are purely archaeological, the rest of these sites listed in Table 5.2.1 may be considered cultural because they continue to play a role in the current culture of the area.

5.2.3.3 Results

During the assessment of the plant area, six tombs, four ceremonial sites, and four archaeological sites were located in and around the future plant location (Figure 5.2-1). All are within the process plant property boundary, and so are considered in the project footprint. The tombs were found in two groupings. The first contains a single tomb belonging to a Mr. Laza (died 1980). The second group contains five tombs belonging to non-locals, and is located near the railway tracks. The two cultural resource sites located within the actual future plant locations are comprised of scant or recent remains of abandoned villages. These were judged unimportant and will not require further studies (Prof. Jean-Aimé Rakotoarisoa pers. comm.; Volume K, Appendix 2.1).



LEGEND

- ARCHAEOLOGICAL SITE
- CEREMONIAL SITE
- TOMB SITE
- SLURRY PIPELINE
- RAILROAD
- ROAD
- PLANT SITE

250 0 250 500
SCALE 1:20,000 METRES

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001
Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

VIEW OF PLANT FACILITY AND LOCATIONS OF ARCHAEOLOGICAL AND CULTURAL SITES

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	LB	13 Sep. 2005	**FIGURE: 5.2-1**	
GIS	LL	25 Oct. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

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5.2.4 Issue Scoping

The main potential issues relating to cultural resources are:

- destruction of cultural sites during plant construction (primary impacts); and
- disturbance of nearby cultural sites during and after plant operation (secondary and tertiary impacts).

Cultural resources are non-renewable resources that may be located at or near ground level, or may be buried. Primary impacts to these comprise disturbances created by the construction of the development project, where the landscape and its contents are disturbed.

Secondary impacts are indirect impacts that occur after construction and reclamation is complete. Erosion of sloping terrain due to alterations in the vegetation, for example, may affect sites. Secondary impacts are of particular concern in situations where cultural resources lie adjacent to development zones.

Tertiary impacts are the results of project-induced changes in demography and land-use patterns. Increased rates of intentional and unintentional impacts can be expected as a result of increased visitation to the region if the project is large enough to affect regional population bases. For this project, tertiary impacts may be possible from non-local workers unfamiliar with local customs.

The key questions for cultural resources are:

Key Question AR-1 **What Effect Will the Project Have on Archaeological Sites?**

Key Question SE-8 **Will the Project Lead to Cultural or Social Conflicts Between Local Residents and Outsiders?**

Key Question SE-10 **What Effect Will Resettlement From the Project Within the Area of Direct Impact Have on Inhabitants?**

5.2.5 Impact Assessment

5.2.5.1 Assessment Methods

Assessment methods consisted of identifying which cultural resources discovered during the fieldwork phase would be directly impacted by construction activities.

Potential secondary effects relating to hydrologic or soil erosion effects off of the project footprint were evaluated based on impacts predicted in the hydrology and soils EA sections (Volume D, Sections 3.6 and 3.2).

Cultural resources may suffer tertiary impacts (through increased visitation and/or traffic in the area by non-local residents following construction of the project). These impacts are difficult to predict, but can be mitigated, and are alluded to only broadly in this report.

5.2.5.2 Assessment Criteria

The assessment criteria used for cultural resources are presented in Table 5.2-2.

Table 5.2-2 Impact Description Criteria for Cultural Resources

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
neutral: no effect on cultural resources **negative:** cultural resources are destroyed	**negligible:** no measurable effect on cultural resources **moderate**: tertiary impact on cultural resources **high:** primary impact on cultural resources	**local:** effect restricted to the plant site footprint **regional:** effect extends beyond the plant site footprint (secondary impacts)	**medium term:** 3 to 30 years **long term:** >30 years to permanent	reversible or irreversible	**low**: occurs once **medium:** occurs intermittently **high:** occurs continuously

5.2.5.3 Impact Analysis

Residual Impacts

Two archaeological sites are located within the area to be developed as the process plant site, and an additional eight cultural resources including archaeological sites, ceremonial sites and tomb sites are within the property boundaries of the process plant (Figure 5.2-1).

The residual impacts during each project period are summarized in Table 5.2-3.

Table 5.2-3 Potential Effects and Residual Impacts for Cultural Resources

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	perturbation of the landscape and associated cultural resources sites	probable relocation of tomb and ceremonial sites	neutral magnitude, but permanent and irreversible effects
operations	increased presence of non-local workers in the region	cultural sensitivity training	potential moderate magnitude, medium-term and reversible effects on cultural resources adjacent to plant site
	off-site (secondary) hydrologic impacts	maintenance of hydrologic regimes	none
closure	none	none	none

5.2.5.4 Mitigation

Immediately outside of the proposed plant site boundary, and within the property boundary, an ancient village, a tomb site, and two ceremonial sites were located. Due to their proximity to the plant site, these sites may be impacted by direct disturbance, traffic or construction. Local residents may wish that the tomb and ceremonial sites be re-located to safer environs. The process involved in re-locating tombs is outlined in Table 5.2-4.

Resettlement that will be required also implies a requirement to relocate tombs or other cultural sites associated with the households that have to be resettled, irrespective of their proximity to the actual construction impact zones.

Any sites which cannot be re-located (other than the two archaeological sites within the main plant site, which are of low significance) will be visited and excavated prior to disturbance to record information from each location.

Tertiary impacts will be mitigated through cultural sensitivity training and by ensuring that non-local workers avoid visiting cultural resource sites adjacent to the direct impact zone of the development.

Table 5.2-4 General Procedure for Displacing Tombs

Steps	Procedures	Comments
1	identification of owners / descendants	this must be formally verified
2	initial discussion of options with owners	this first meeting is only to discuss options, not determine a final solution
3	later re-visit to enquire about owners' ideas and conditions	the choice of when and where the relocation should take place is left to the tomb owners
4	another re-visit to discuss: 1) materials and financial aspects of the owners' stated conditions 2) details of the ceremony	
5	launch the construction of new tombs, and probably new coffins	this requires a small ritual to be performed
6	gathering of required materials: burial linens, alcohol, zebu cattle, etc.	money may also be given to the locals in order for them to partially do this on their own
7	on the appointed day, the ritual will be conducted by an important village person	it would be ideal to conduct this entire process of exhumation and inhumation in one day

5.2.5.5 Conclusions

The plant will have a neutral effect on cultural resources during the construction phase. Although two archaeological sites are located within the proposed process plant boundary, these are judged to be insignificant and no further work with respect to them is necessary. An additional eight cultural sites are within the outer property boundary of the process plant and also may be subject to disturbance during construction. If requested by local groups, the tombs and ceremonial sites located within the property boundaries may have to be displaced. Provided this is accomplished following proper protocol, this can be accomplished without altering these particular sites' inherent cultural meaning, which would also produce a neutral effect.

No secondary effects due to off-site hydrologic or erosion impacts are anticipated.

A potential moderate medium-term effect on cultural resources adjacent to the plant may occur during the operations phase, depending on whether the non-local residents working in this area will come into contact with these.

No effects are envisioned for the plant closure phase.

5.3 LAND USE

5.3.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the process plant on land use. As per the Ambatovy Project (the project) terms of reference, land use has been mapped in the process plant local study area (LSA) and changes in land use areas predicted in comparison to baseline levels. The implications of changes in land use for people are discussed in the context of socioeconomic effects in Volume D, Section 5.1.

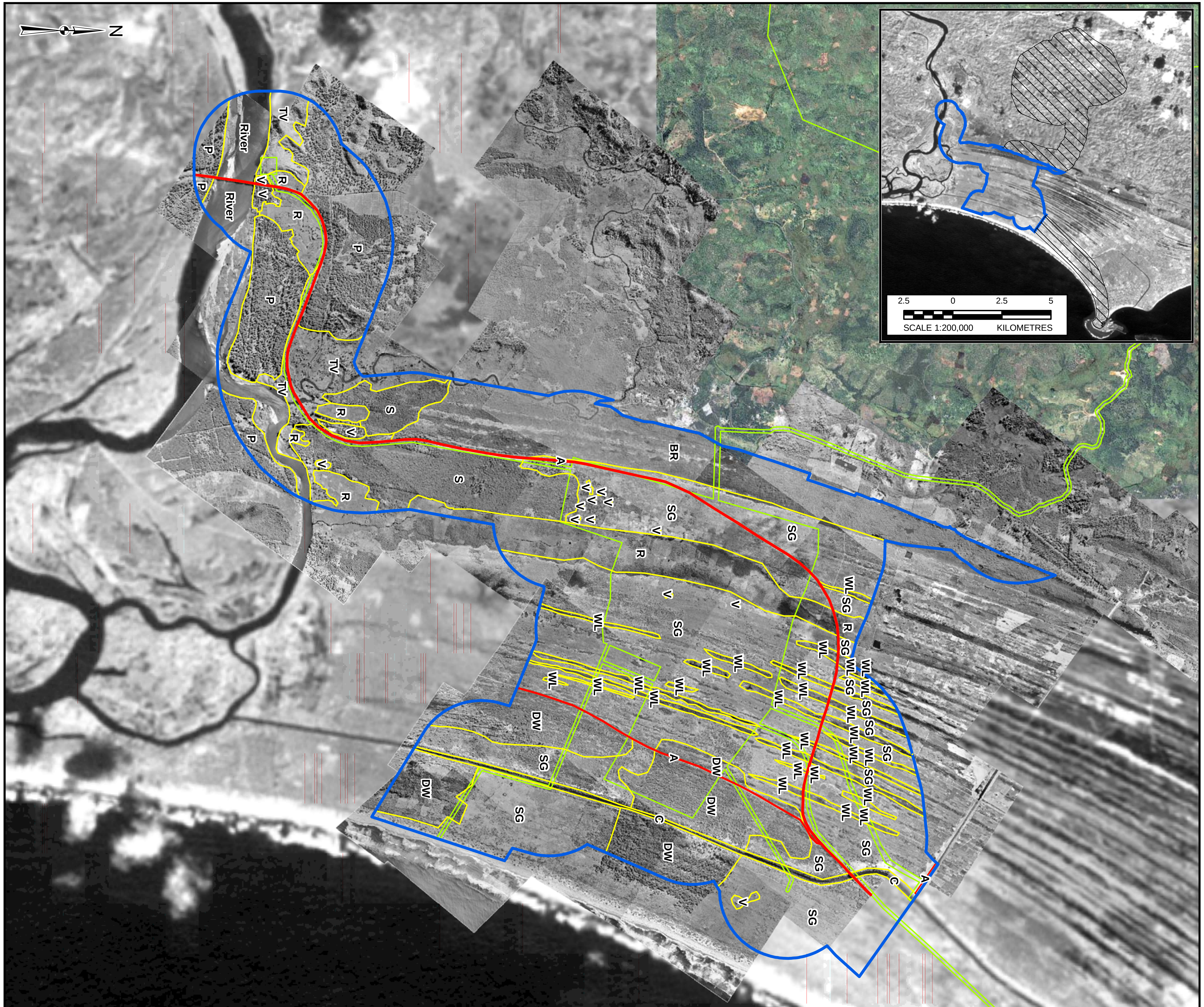
5.3.2 Study Area

The process plant LSA is one-third of the Toamasina terrestrial LSA shown in Volume A, Section 7.2, Figure 7.2-3. This area includes the process plant property, Ivondro River water intake pipeline, supply pipeline from the planned Logistique Petroliere terminal area, the start of the access corridor toward the port to the north, and the marine water outfall pipeline corridor, with a 500 m buffer around all of these areas. The specific boundaries of the process plant LSA are presented in Figure 5.3-1.

5.3.3 Baseline Summary

Ongoing land uses at the site of the process plant include small agricultural plots and household areas (Volume K, Appendix 3.1, Section 3.5.2). The land in this area has a relatively low level of productivity due to the predominance of poor, sandy soils, and it has been zoned by the government for industrial use. However, plants being grown in the LSA in small homestead areas include rice, eucalyptus trees, sugar cane, coconut, litchis, mango trees, avocados, jack fruit, papaya, banana, pineapple, coffee and orange.

The LSA is near the edge of Toamasina, but outside the limit of urban development. The east side of the plant property supports an area of degraded coastal woodland which may be useful for the collection of non-timber forest products.



LEGEND

VEGETATION AND LAND USE CLASSIFICATION

A	ACCESS CORRIDOR
	VEGETATION/LAND USE TYPE
BR	BEACH RIDGE COMPLEX
C	CANAL
SG	COASTAL SHRUBLAND/GRASSLAND COMPLEX
DW	DEGRADED RESIDUAL COASTAL WOODLAND
P	PLANTATION
R	RICE PADDIES
S	SHRUBLAND
TV	TAVY MATRIX
V	VILLAGE
WL	WETLANDS
	PROCESS PLANT SITE SUB-LOCAL STUDY AREA
	CORRIDOR DISTURBANCE

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001
Aerial photograph Mosiac Images; Captured 2004
Datum: WGS 84 Projection: UTM Zone 39S

0.5 0 0.5 1

SCALE 1:30,000 KILOMETRES

PROJECT

AMBATOVY PROJECT

TITLE

LAND USE IMPACT AREAS WITHIN THE PROCESS PLANT SUB-LOCAL STUDY AREA

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172.8000			SCALE AS SHOWN	REV. 0
DESIGN	DN	29 Jun. 2005		
GIS	TN	21 Oct. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

FIGURE: 5.3-1

i:/2003/03-1322/03-1322-172/mxd/Landuse/Fig5.3-1_Landuse_Plant.mxd

5.3.4 Issue Scoping

Key issues raised by the public relating to land use during public consultations include:

- elimination of small-scale agricultural and homestead areas, especially destruction of litchis and coconut trees and other subsistence food sources; and
- compensation for both landowners and land users without title.

Relocation planning is an important issue in relation to land use which is addressed in a separate document from the EA.

5.3.5 Assessment Methods

Land use changes are considered through a spatial analysis of the kinds of land use areas that will be altered by the project. The effects of land use impacts are social in nature and are addressed within the impact rating system in the socioeconomics section (Volume D, Section 5.1).

5.3.6 Impact Assessment

A linkage diagram for land use is presented in Volume H, Appendix 9. Potential impact pathways between the process plant and changes in land use exist for the alteration of soils, terrain and vegetation and increasing pressures on land use due to the settlement of additional people in the area.

Alteration of Soils, Terrain and Vegetation

The impacts of the process plant on areas with a variety of potential land uses are presented in Table 5.3-1. Impact areas are mapped in Figure 5.3-1. Effectively, all lands within the property line of the process plant will become unavailable for land use during and after the project; only a narrow band of terrain along the linear corridors affected by the project will be altered for land use purposes.

Table 5.3-1 Land Use Impact Areas for the Process Plant Local Study Area

Type of Area	Area Within LSA (Baseline) (ha)	Area Impacted (ha)	Proportion of Area in LSA Impacted (%)
degraded residual coastal woodland	166	29	17
azonal/transitional forest and scrub	0	0	0
primary zonal forest and marsh edge	0	0	0
degraded primary zonal forest	0	0	0
agroforest/secondary forest	0	0	0
plantation	151	0	0
woodlot	0	0	0
beach ridge complex	161	1	1
coastal shrubland/grassland complex	640	220	34
rice paddies	110	44	40
shrubland/herbaceous/pasture	105	6	6
tavy matrix	59	4	7
village/urban	9	1	11
wetlands	56	13	23
access corridor (road/rail)	11	4	36
industry (buildings or exploration areas)	0	0	0
canal	15	0	0
quarry	3	0	0
river/water	61	0	0
seasonal pond	0	0	0
total	**1,547**	**322**	**21**

The most valuable land use areas within the process plant LSA at present are plantations, woodlots, rice growing areas, village areas and quarries. Within the LSA, no plantations, woodlots or quarries are affected by the project. Forty percent (110 ha) of potential rice paddy areas are affected. Eleven percent (9 ha) of village or homestead areas are affected.

Eligible land owners and land users will be compensated though relocation to properties of equivalent capability for agriculture; however, the process of re-settlement may have other effects. These subjects are addressed in the socioeconomic section (Volume E, Section 5.1).

Increased Population Pressure

The project will result in the in-migration of a considerable number of people into the LSA and surrounding areas. As a result, there may be increased pressure on lands for residential housing, agricultural land use and the cutting of trees for charcoal or building materials. In turn, this trend has the potential to have both biological and social impacts on the existing environment. These subjects are addressed in the socioeconomic section (Volume B, Section 5.1).

5.3.7 Mitigation

For individuals affected directly by the project, the most important mitigation is the provision of additional, equivalent properties for people to relocate to. Lands for re-settlement are described in the re-settlement plan. In addition, the process plant is being designed to occupy the minimum feasible area of land. Socioeconomic mitigation and compensation measures for those directly or indirectly affected by the project, are described in the socioeconomics section (Volume D, Section 5.1). Pipelines will be buried and pipeline corridor areas will be reclaimed following construction, as described in Volume D, Section 6.

5.3.8 Conclusions

Although much of the process plant area has limited value for agricultural land use, the project will have a large effect on a few land use areas in the immediate area of the project due to direct disturbance of lands used for growing rice and other crops. Small homestead areas will also be affected. The re-settlement of some households to other areas will be required to mitigate the effects of these impacts on livelihoods. The magnitude of these impacts in socioeconomic terms are evaluated in Volume D, Section 5.1.

5.4 HUMAN AND ECOLOGICAL HEALTH

5.4.1 Introduction

This section addresses the health assessment for the Ambatovy Project (the project) mine process plant area and focuses on potential changes in water, air, soil and food quality and possible associated effects on human and ecological health during operations and post-closure of the plant.

A brief summary of baseline assessment for the mine area is provided in Section 5.4.3 (Baseline Summary)**.** Discussion of potential incremental human and aquatic life heath effect to baseline conditions are presented in Section 5.4.4 (Impact Assessment).

5.4.2 Study Areas

The study area focused on water bodies within the drainage basins which may potentially be influenced by the process plant in the future (Figure 7.2-3 in Volume A, Section 7, EA Methods and Study Areas). Areas occupied by communities which may be potentially affected by changes in air quality were also included in the study area. Those communities are listed in Section 3.3, Climate and Air Quality.

5.4.3 Baseline Summary

5.4.3.1 Introduction

A detailed description of the methods used for the screening-level risk assessment of the mine process area and the results are found in Volume K, Appendix 4.1. A short summary is provided below.

5.4.3.2 Methods and Main Results

Human Health

The potential risks to critical receptors (child and composite receptor [a hypothetical receptor which experiences exposure for the first thirty years]) due to ingestion of surface water were evaluated. Arsenic, lead and manganese were considered chemicals of potential concern. That is because their maximum concentrations in water were above the drinking guidelines. However, the frequency in which guidelines were exceeded was low: two cases of arsenic, one for lead and manganese (out of 11 samples collected during the wet season and

10 during the dry season). The only metal with an average concentration exceeding guidelines was lead (dry season).

The risk assessment results suggest non-carcinogenic health risks from arsenic, lead and manganese to be low to negligible at baseline. The carcinogenic health risk from arsenic is more significant. However, much of the exposure data were in fact treated as one-half of a relatively high detection limit that inherently yielded elevated cancer risk. Thus it is likely this apparent health risk may prove negligible through further site monitoring.

Aquatic Health

The aquatic receptors selected for the assessment were aquatic plants, invertebrates and fish living in surface water bodies as well as benthic invertebrates near the process plant and adjacent to the tailings area.

Aluminum, copper, iron, nickel and zinc were considered of potential concern for aquatic receptors' health since their maximum measured concentrations in water and/or sediment exceeded water and/or sediment guidelines for protection of aquatic life.

A screening-level risk analysis suggested iron, copper and ammonia presented potentially elevated risk levels to some aquatic biota, including invertebrates and fish.

5.4.4 Impact Assessment

This section of the health assessment evaluates the potential adverse effects to human and aquatic health due to the process plant in combination with the baseline conditions.

5.4.4.1 Issue Scoping

The central health issues raised during stakeholders' consultation are related to changes in air and water quality and how these changes may affect human health.

Key questions established to address the potential adverse effects on human and ecological health due to the project and related developments are listed below. Linkage diagrams for potential impact pathways are provided in Volume H, Appendix 9.

Key Question HH-1 What Effect Will Chemical Releases From the Process Plant Site Have on Human Health?

Key Question HH-2 What Effect Will Chemical Releases From the Process Plant Site Have on Livelihood Resources?

Key Question EH-1 What Effect Will Chemical Releases From the Process Plant Site Have on Aquatic Life Health?

The following sections provide the methodology and assessment which address each of the above questions.

5.4.4.2 Key Question HH-1 What Effect Will Chemical Releases From the Process Plant Site Have on Human Health?

Impact Pathway Evaluation

The potential impact pathways between the process plant project and human health were evaluated to answer key question HH-1. Potential impact pathways were analyzed between:

- changes in water quality and human health;
- changes in air quality and human health;
- changes in soil quality and human health; and
- changes food quality and human health.

Water Quality

Although arsenic, lead and manganese were considered chemicals of potential concern in drinking water during baseline investigations (See Section 5.4.3 Baseline Summary) no incremental impact on human health is expected because results of water quality assessment (Section 3.9, this volume) suggest impacts of process plant operation are expected to be negligible due to mitigation actions.

Since water quality parameters are predicted to not change substantially during plant operation and post-closure, the impact pathway between changes in water quality and human health using watercourses for drinking water was considered invalid and therefore not retained for further assessment.

Fish Quality

Since chemical levels in surface water are predicted to not change, no substantial increase of chemicals in fish tissue in relation to current conditions is expected. Therefore the impact pathway between changes in fish quality and human health was considered invalid and not assessed further.

Air Quality

This impact pathway was considered to be valid because people living in the nearby communities may be exposed to chemicals released into the air from the process plant.

Soil Quality

Airborne chemicals released during process plant operation can be deposited onto soil and people may contact soil, inhale dust particles generated from potentially impacted soils or accidentally ingest soil. The impact pathway between changes in soil quality and human health was considered valid and retained for further assessment.

Produce Quality

Rice does not predominate in the process plant area as it does in many other areas of Madagascar because of the poor sandy soils. Small homestead areas include rice, eucalyptus trees, sugar cane, coconut, litchis, mango trees, avocados, jack fruit, papaya, banana, pineapple, coffee and orange (Volume K, Appendix 3.1). Changes in soil quality due to deposition of airborne contaminants could lead to an increase of chemicals in vegetables. The impact pathway between changes in produce quality and human health was thus considered valid and retained for further evaluation.

Assessment Methods

The evaluations were conducted according to established risk assessment methods endorsed by Health Canada (HC 2003) and the United States Environmental Protection Agency (USEPA) (1992, 1998) frameworks. The detailed methodological approach as well as receptor parameters and toxicity reference values are presented in the Human and Ecological Health Appendix (Volume K, Appendix 4.2).

Impact Description Criteria

The assessment criteria used for human health are the same as used for the mine area (Volume B, Section 5.4).

Results

Air Inhalation Risk Results

Predicted maximum 1-hour, 24-hour and annual concentrations of chemicals in the air were compared with available acute and chronic exposure limits (1-hour, 24-hour and annual air quality guidelines). Table 5.4.1 only presents the highest air concentrations predicted by air quality modelling to be found in the study area. Concentrations of all substances were less than available exposure limits, which are health-based criteria from the WHO, USEPA and OME (Table 5.4-1). Therefore no health effects are expected to occur in any of the assessed communities due to short or medium-term emissions from the process plant site.

Table 5.4-1 Comparison Between Predicted Air Quality During Process Plant Operation and Air Quality Guidelines

Parameter	Air Quality Guidelines [µg/m³]			Predictions - Maximum values [µg/m³]		
	1-hr max	24-hr max	Annual	1-hr max	24-hr max	Annual
SO_2	500(a,b)	125(a)	50(a)	318(h)	55(h)	6(h)
NO_2	200(a,b)	40(a)	120(a)	104(h)	17(h)	2(h)
H_2S	200(a)	120(a)	-	35(i)	9(j)	not estimated
$PM_{2.5}$	-	65(d)	15(d)	not estimated	1.5(h)	0.2(j)
PM_{10}	-	150(d)	50(d)	not estimated	1.5(h)	0.2(j)
arsenic	0.75(e)	0.3(f)	0.06(g)	0.098(h)	0.015(h)	0.002(h)
lead	1.75(e)	0.7(f,g)	0.14(g)	0.092(h)	0.014(h)	0.001(h)
mercury	5(e)	2(f)	0.4(g)	0.003(h)	0.0004(h)	0.00004(h)

(a) World Health Organization (WHO) (2000).
(b) Averaging time: 10 minutes.
(c) Canadian Council of Ministers of the Environment (CCME) (2002).
(d) USEPA (http://www.epa.gov/air/criteria.html accessed in October 2005).
(e) OME (2001). Calculated from 24 hours guidelines using Averaging Time Conversion Factors (MOE 2004).
(f) OME (2001).
(g) 0.7 - 30 Days +; otherwise 2.
(h) Values predicted for the Ambatoroa community located 1.6 km NE of the plant site.
(i) Values predicted for the Ampirasantany community located 1.5 km SW of the plant site.
(j) Values predicted for the Manamboasio community located 1.4 km NNE of the plant site.

Soil Ingestion Risk Results

Incremental concentrations of metals and polycyclic aromatic hydrocarbons (PAHs) were estimated using air deposition rates from chemicals expected to be emitted during process plant operations. Emissions were estimated based on PAH emission factors for coal-fired boilers (USEPA 1998c). Deposition rates estimated for the Antsiranandakana community were used for calculations since they correspond to the location with the highest deposition rates among all twenty communities evaluated.

Non-carcinogenic risks were calculated for a child and carcinogenic risks for a composite receptor. The total dose was based on doses via accidental soil ingestion, dermal contact and dust inhalation.

Results suggest negligible incremental risks for children and low and likely to be negligible risks for a composite receptor living in the Antsiranandakana community (Volume K, Appendix 4.2, Tables 4.2-16 and 4.2-17). Since soil concentrations in all communities in the study area are expected to be equal or lower than the levels predicted for Antsiranandakana, the incremental risk for receptors in all remaining communities are also considered low to negligible.

Produce Ingestion Risk Results

Incremental levels of metals and polycyclic aromatic hydrocarbons (PAHs) in below-ground vegetables (i.e., roots such as manioc) were estimated using predicted soil concentration in the Antsiranandakana community (the community where the highest levels in soil in the study area are expected) and literature soil-to-root bioconcentration factors. Levels of chemicals in above-ground vegetables (e.g., rice) were calculated using both air deposition rates and soil-to-root uptake of chemicals.

The total dose for each chemical was estimated adding doses by ingestion of above-ground vegetables and roots. Non-carcinogenic and carcinogenic risks were estimated for critical receptors. Results are presented in Volume K, Appendix 4.2, Tables 4.2-18 and 4.2-19. Incremental risk due to vegetable ingestion was considered negligible for a child and low to likely to be negligible for a composite receptor.

5.4.4.3 Key Question HH-2 What Effect Will Chemical Releases From the Process Plant Site Have on Livelihood Resources?

Impact Pathway Evaluation

Water Quality

Livestock are generally not important for livelihoods in this study area. Few households have cattle and livestock do not appear to have large economic value. The area cannot be considered an agriculturally based economy partially because of the poor sandy soils (Volume K, Appendix 1.1 Socioeconomics Baseline Appendix).

The impact pathway between changes in water quality and livelihood resources was not assessed further because chemical levels in surface water are predicted to not change considerably during plant operation (refer to Water Quality Assessment Section, this volume) and because of limited importance of livestock, crops and fishery as livelihood for communities established near the process plant site.

5.4.4.4 Key Question EH-1 What Effect Will Chemical Releases From the Process Plant Site Have on Aquatic Health?

Impact Pathway Evaluation

Water and Sediment Quality

Although ammonia, aluminum, copper, iron, nickel and zinc were considered of potential concern for aquatic receptors' health under baseline conditions, their concentrations in water and sediment in rivers are predicted to not substantially increase during process plant operation and closure. Consequently the incremental risks to the aquatic biota in surface water bodies near the site are expected to be negligible and this impact pathway was not evaluated further.

5.4.4.5 Mitigation

Mitigations that are applicable to human and aquatic health were addressed previously in the Air and Water Quality Assessments in this volume. Results of the risk assessment suggest that additional mitigation is not warranted.

5.4.4.6 Residual Impacts

The residual impact classification on human and aquatic health impacts in the process plant area is provided in Table 5.4-2.

The magnitude of impacts to human health were classified as low and likely to be negative, negligible, local (limited to the communities located about 2 km away from the plant site), medium-term (i.e., lasting until site-closure), reversible and of high frequency (occurring continuously). Their environmental consequence is therefore predicted to be negligible to low.

No residual impacts are predicted to livelihood resources and aquatic life health.

Table 5.4-2 Residual Impact Classification for the Process Plant on Human and Aquatic Health Effects

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Key Question HH-1 What Effect Will Chemical Releases From the Process Plant Have on Human Health?						
negative	low and likely to be negligible	local	medium-term (operation)	reversible	high	negligible to low

5.4.4.7 Monitoring

Monitoring of air and water will be carried out as described in Sections 3.3 and 3.8 of this volume to ensure that the mitigation being applied is working effectively and levels are at or below criteria.

5.4.5 Conclusions

The human and ecological health assessment evaluated the potential for adverse effects to health associated with chemical emissions from the process plant site in combination with baseline conditions. The incremental health risks of human exposure to drinking water, fish and produce ingestion as well as air inhalation, dermal contact with soil and accidental soil ingestion during process plant operation and post-closure were considered low to negligible. Potential impacts on aquatic life and livestock resources were also considered negligible.

5.5 TRAFFIC

5.5.1 Introduction

This section presents the Environmental Assessment for the effects of the process plant and the tailings facility on traffic. As per the Ambatovy Project (the project) terms of reference, the changes in traffic levels are predicted and compared to baseline traffic levels. The effect of increased traffic is assessed qualitatively in relation to potential impacts on nearby residences, livestock and human safety.

5.5.2 Study Area

The key public access routes to be used for traffic coming to and from the process plant and the tailings facility will be the Route Nationale (RN) 2 in the immediate vicinity of Toamasina, the direct access road that will be completed between Toamasina's port and the process plant site, and the ridge road linking RN2 to the tailings facility. Effects on traffic along these routes are assessed.

5.5.3 Baseline Summary

Route Nationale 2 is a two-lane, paved road in good condition. The direct road between the port and the process plant is presently in poor condition; sections in Toamasina are partially paved while sections south of Toamasina are dirt roads or have not yet been constructed. The ridge road to the tailings facility is a dirt road in relatively poor condition, passable only by 4x4 vehicles.

Baseline traffic volumes over 24-hour periods for RN2 in the immediate vicinity of Toamasina and the direct port-process plant access road are provided in Table 5.5-1. Baseline traffic volumes along the ridge road to the future tailings facility location have not been measured, but are very low.

Table 5.5-1 Baseline Traffic Level Summary

Type of Vehicle	24-Hour Traffic Volume Along Existing Portion of Port-Plant Access Road (in Toamasina)		24-hour Traffic Volume Between Moramanga and Toamasina (at Edge of Toamasina)	
	Weekday	Weekend	Weekday	Weekend
private cars	684	548	326	351
transports for people	269	306	204	212
transports for goods	168	149	319	243
two-wheeled vehicles, motorized	5,312	4,883	3,574	3,628
unmotorized vehicles	1,299	1,216	616	694
total	**7,732**	**7,102**	**5,039**	**5,128**

Accident rates under baseline conditions are expected to occur at approximately 3.12 per million vehicle kilometres on RN 2 and other public roads used by the project.

5.5.4 Issue Scoping

Key issues raised by the public relating to traffic during public consultations include:

- Safety: the traffic on RN2, even under baseline conditions is unsafe due to high speeds.
- Noise and vibration: the existing traffic produces noise and vibration which affect houses along roads.
- Accidents: with increased traffic volume during the project, how will an increase in accident rates be prevented? (comment from the technical evaluation committee[CTE]).

It is recognized that the project may have several impacts relating to traffic, including:

- increased traffic flows can cause disturbance from dust, noise and emissions to populations along the roadside, an impact that is stronger to the extent that traffic uses roads that are not paved;
- increased traffic flows and any increases in speed associated with improvements to roads made in relation to the project imply an increase in accidents, to both people and animals;

- traffic accidents involving transport of industrial goods risk contamination of land and water resources from spills;
- any road construction or improvement will cause temporary delays to non-project traffic; and
- increased traffic flows can imply increased congestion, specifically in the town of Toamasina, which already sees a significant amount of congestion as a result of the combination of transport traffic on urban streets that also have many pedestrians, bicycle riders, pousse-pousses (rickshaws), and animals.

There is no Key Question addressed in this section. While changes in traffic are described, the implications and impacts of changes in traffic are assessed in the socioeconomic sections.

5.5.5 Changes in Traffic

5.5.5.1 Assessment Methods

The effects of traffic are assessed quantitatively for traffic volume and traffic accident rates, based on the extrapolation of existing baseline information. The approximate number of vehicles required for project operation is known and is used to calculate proportional effects in comparison to baseline conditions.

The effects of traffic on health, safety, vibration, noise and congestion in towns are assessed qualitatively.

5.5.5.2 Results

The plant site is located to the east of the RN2 as it enters Toamasina. Traffic to the plant site will flow both along RN2 for a distance of about 6 km as far as the plant access road (entering the plant site from the west) and along the port-plant access road to be constructed by the city of Toamasina and the Malagasy State (Volume D, Sections 1 and 2), about 8 km in length, which will approach the process plant from the northeast.

The tailings facility will essentially be located across the RN2 from the process plant, and any traffic impacts specific to the tailings site will be mixed with those of the plant along RN2 adjacent to Toamasina. Traffic travelling to the tailings facility from Toamasina will travel along RN2 for a distance of about 4 km.

Traffic impacts will occur throughout the construction and operations phases of the project. Construction phase effects are often more extreme, as there is movement of equipment and construction materials to sites, construction workforces are generally larger than operational workforces, and construction itself – either to improve roads or to improve associated facilities along roads – can impede traffic flow. The highest congestion levels during the project are expected to occur within Toamasina along the roads linking to these two access routes, as existing traffic is most congested in Toamasina.

Potential impacts include disturbance to local populations, accidents, environmental and consequent social impacts of spills, congestion and migration of populations to the roadside to service additional traffic.

Traffic Volumes

Changes in traffic volumes due to the project are provided based on estimates of the number of personal vehicles, supply trucks and buses (transporting workers) that will be required on a daily basis for the project to operate. The number of vehicles required is summarized for construction and operation phases of the project and for each main road segment in Table 5.5-2. These numbers represent a relatively small fraction of existing baseline traffic provided in Table 5.5-1.

Table 5.5-2 Vehicle Numbers per Day[a]

Project Phase	Vehicle Types	RN2 in Vicinity of Toamasina	Direct Port-Plant Access Road
construction (3 years) (number of round trips per day)	cars	10	10
	trucks	0	51
	buses	16	15
	total	**26**	**76**
operations (27 years) (number of round trips per day)	cars	10	10
	trucks	0	40
	buses	14 / 6[b]	14 / 6[b]
	total	**24 / 16[b]**	**64 / 56[b]**

[a]Traffic numbers are estimates based on project as of May, 2005.
[b]Weekday / weekend numbers.

The largest impacts of the project in relation to traffic volumes will occur during the construction phase, especially along the direct route between the plant and the port. Traffic levels along this route within Toamasina suggest it is already highly congested during peak hours. Numbers of trucks along the route will increase about 30% during weekday construction periods and 34% during weekend construction periods. Numbers of personal vehicles and buses will increase by much smaller percentages along the direct access route. Along RN2 close to

Toamasina, truck traffic will not be affected but bus traffic will increase by about 10% and personal vehicle traffic will increase by about 3%.

During operations, traffic volume changes will again be most pronounced along the direct plant-port access road, as this will be the route for truck traffic to deliver product from the plant to the port. Increases in truck traffic will be about 25% relative to baseline. Along RN2, weekday traffic impacts will be substantially higher than weekend impacts; during weekdays, bus traffic will increase by almost 10% along the RN2 between the city and the process plant. During weekends, the change will be about 4%.

Traffic volumes along the ridge road to the tailings facility are expected to be low in comparison to traffic to the plant site. However, because baseline traffic levels are extremely low, project-related traffic will be a high proportion of the traffic along this route in both the construction and operations phases.

Because of economic effects of the project, additional traffic may result from the development of other businesses and the work of contractors, which is difficult to predict quantitatively and has not been included in Table 5.5-2.

Based on the number of vehicles estimated in Table 5.5-2, the total distances to be travelled by project vehicles along the major access routes is summarized in Table 5.5-3 for a full year.

Table 5.5-3 Vehicle Kilometres per Year

Project Phase	Vehicle Types	RN2 in Vicinity of Toamasina	Direct Port-Plant Access Road
construction (3 years) (km per year)	cars	43,800	58,400
	trucks	0	297,840
	buses	70,080	87,600
	total	**113,880**	**443,840**
operations (27 years) (km per year)	cars	43,800	58,400
	trucks	0	233,600
	buses	51,720	68,340
	total	**95,520**	**360,340**

Based on numbers of kilometres to be travelled, the highest impact of the project will be along the direct route between the plant and port. The largest impacts are expected during the construction phase.

Traffic volume effects will be most apparent in Toamasina, where existing traffic congestion is highest. The project is likely to increase traffic congestion in Toamasina, unless additional by-pass roads are constructed to carry traffic from the port.

In addition to vehicle traffic, the plant site will be serviced by rail. During construction, 14 rail cars per day will travel round-trip between the port and plant along a rail spur separate from the main Madarail rail line out of Toamasina. This will approximately double the rail traffic along the railway RoW between the port and process plant. During operations, four trains per day are expected to make round trips to deliver materials and products to and from the port, with 23 cars per train, on a regular 24-hour per day schedule[1]. This will increase the rail traffic along the rail RoW between the port and process plant to approximately five times baseline levels.

Within the port area, increased traffic volumes, including potential congestion of road and rail traffic, will occur. The impacts and mitigation for traffic within the port will be addressed once a detailed project layout is finalized.

Accident Rates

Existing accident rates (measured as number of reported accidents per one million motor vehicle kilometres driven) have been documented on the RN2 between Brickaville and Toamasina at 3.12 per million vehicle kilometers based on Malagasy government statistics. The road conditions along other parts of RN2 and within Toamasina are assumed to be equivalent to this, and accident rates are assumed to be proportional to the increased traffic. Based on the additional estimated traffic volumes, impacts on accident rates have been estimated and are shown in Table 5.5-4.

[1] Since this analysis was completed, a higher frequency of smaller trains has been selected to meet the demands of rail transport between the port and the plant.

Table 5.5-4 Changes in Accident Numbers due to the Project

	RN2 in Vicinity of Toamasina	Direct Port-Plant Access Road
baseline traffic kilometres per year	1,861,500 trips x 6 km = 11.2 million km	2,737,500 trips x 3 km[a] = 8.2 million km
baseline accident rate	35 per year	26 per year
traffic kilometres per year during construction	base + 0.11 million km	Base + 0.44 million km
traffic kilometres per year during operations	base + 0.09 million km	Base + 0.36 million km
incremental increase (and % increase) in accidents during construction (without mitigation)	<1 accident	1 accident (4%) per year
incremental increase (and % increase) in accidents during operations (without mitigation)	<1 accident	1 accident (4%) per year

(a) Existing portion of road at baseline is 3 km.

Noise and Vibration Disturbance

Noise

The noise assessment of traffic focuses on motorized vehicles only. The primary sources of noise from motorized vehicles are:

- motors; and
- interaction of vehicle tires with the road surface.

The amount of noise generated by individual vehicles used for the project is expected to be similar to vehicles already in use in Madagascar. Therefore changes in noise level would occur based on the number of similar vehicles on the roadways.

The change in the total number of vehicles on the three public roadways being assessed is less than 1% on RN2 near Toamasina, and between 1 and 2% on the existing portion of the plant access road during both construction and operations. The changes in various vehicle types range from 1 to 3% for private cars and 5 to 7% for buses (people transport) to as high as 34% for goods trucks during construction. Changes in truck and bus traffic are considered more important since larger vehicles typically generate more noise than private cars.

The changes in traffic can also be stated from the receiving environment point of view as the number of vehicle “pass-bys” per hour. Vehicles generate noise each time they pass a noise receiver; each “pass-by” is a noise event. Assuming 80%

of traffic occurs during daylight hours (taken as 14 hours per day) and that project related traffic will also be during daylight hours, a change of between one and six vehicles per hour can be expected. On the Port-Plant access road, three to fours trucks per hour can be expected during construction and up to three trucks per hour during normal operations. Table 5.5-5 provides an analysis.

Table 5.5-5 Number of Vehicle Pass-Bys (Noise Events) per Daylight Hour

Vehicle Type	Direct Port-Plant Access Road			RN2 in vicinity of Toamasina		
	Minimum of Weekend/ Weekday	Number due to Project	Total Pass-Bys per Hour	Minimum of Weekend/ Weekday	Change due to Project	Total Pass-Bys per Hour
Construction						
private cars	31	1	32	19	1	19
transports for people (buses)	15	1	16	12	1-2	13-14
transports for goods (trucks)	9	3-4	12-13	14	0	14
two-wheeled vehicles, motorized	279	0	279	204	0	204
total	**334**	**5-6**	**339-340**	**249**	**2-3**	**250-251**
Operation						
private cars	31	1	32	19	1	19
transports for people (buses)	15	1/<1	15-16	12	1/<1	12-13
transports for goods (trucks)	9	3	12	14	0	14
two-wheeled vehicles, motorized	279	0	279	204	0	204
total	**334**	**4-5**	**338-339**	**249**	**0-1**	**249-250**

Changes to noise levels on the project access road depend on the amount of existing traffic. For the existing portion of the road, the amount of project traffic on this road is expected to increase, therefore some increase in noise levels are expected. There is also a portion of the road not yet constructed. Traffic noise levels will increase along the new route since there is no existing traffic. The amount of traffic increase along this road is small, averaging four to five vehicles per hour or one every 12 to 15 minutes.

Vibration

The assessment of ground vibration from traffic focuses on large motorized vehicles (buses and goods transport trucks) only. The primary sources of vibration from motorized vehicles are:

- tires striking irregularities in the road surface (impact load); and
- oscillation of the vehicle suspension or “axle hop” (oscillating load) (Hunaidi 2000).

The amount of vibration generated depends on the speed of the vehicle, the condition of the roadway and the type or condition of the vehicle suspension. Vehicles used for the project are expected to be similar to other vehicles of the same class in Madagascar and will be expected to follow posted speed limits.

Route Nationale 2 is a paved road in relatively good condition, and effects along this route relating to vibrations are expected to be minor. The routes through Toamasina are well used and may have more irregularities (potholes and damage from use) due to the existing traffic levels. Changes to existing levels of ground vibration in Toamasina would occur based on the increase in vehicles due to the project. As shown in Table 5.5-5, the direct road route (through Toamasina) will have a 44% increase in trucks and 7% increase in buses during construction, and slightly lower increases during operations.

The amount of change in ground vibration along the Project access road depends on the amount of existing traffic and the roadway conditions. The amount of project traffic on this road may be as high as six vehicles per hour including up to five heavy vehicles and the road surface is expected to be paved. Mitigation for vibration may be necessary if homes are very close to the roadway (within 200 m), and is dependent on speed and road condition.

5.5.5.3 Mitigation

Mitigations will include construction and operations best practice relative to potential impacts on traffic flows, road improvements to minimize disturbance and risks, and a workforce code of conduct with respect to driving and public education. In Toamasina, Dynatec will work with the municipal government to determine appropriate local procedures (routes and speed limits) for project vehicles moving through the town. Special measures will be taken for very large vehicles that will pass through Toamasina during the construction phase.

Mitigations for noise and vibration include:

- scheduling project traffic for daylight hours, where possible, to minimize sleep disturbance by increased noise events (this has been assumed in the analysis);

- scheduling large vehicle (trucks and buses) trips as convoys to reduce the number of times per day a disturbance may occur, if this option is preferred by noise receivers;
- maintaining vehicles in good condition to ensure they are no louder than other, similar vehicles on the roadways; and
- ensure vehicles travel at reduced speeds to minimize impact and oscillation loads when homes are adjacent (within 200 m) to a roadway.

5.5.6 Conclusions

The presence of the port, tailings facility and plant in the Toamasina area will create substantial traffic volumes, both in the construction and operation project phases. Roads within Toamasina, RN2 and other roads to be constructed will all be affected by this traffic. During construction, numbers of trucks will increase by up to 34% on the direct route between the port and plant. Along RN2, truck Volumes will increase by up to 10% and personal vehicles will increase by up to 3%. Rail traffic between the port and process plant will increase by approximately 100% during construction and 400% during operations. Mitigation including strict speed limits, proper construction and maintenance of site access roads, maintenance of vehicles and driver education will reduce traffic impacts. Following mitigation, residual impacts of Toamasina area traffic may affect residences along roadways, livestock and human safety as a result of traffic congestion, noise, air emissions, dust and vibration. These effects will represent moderate impacts in some areas, especially within Toamasina and along access routes that are presently little used, such as the proposed direct access route between the port and process plant and the ridge road access route from RN2 to the tailings facility. Project related rail traffic will use a new track within an existing rail RoW, so as to avoid creating congestion with existing rail traffic.

6 RECLAMATION AND CLOSURE PLAN

At the time of project completion, the process plant will be assessed for potential future usefulness for other industrial projects. It is expected that the site will be partially decommissioned and sold to another industrial user so that the benefits of the constructed facilities can continue to support the local economy. Buildings and infrastructure at the site with no useful function will be dismantled and removed from the site at the time of project closure. Waste materials will be removed from the site and disposed of properly. Any areas of known or suspected soil contamination, such as fuel storage and transfer areas, will be assessed for contamination. If present, localized areas of contaminated soils or built facilities will be remediated or removed. Buried pipelines will continue to be used or will be abandoned in place, and surface areas along linear routes or parts of the process plant property that are not scheduled for future use will be revegetated with native vegetation species.

7 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLANS

This section provides highlights of selected mitigation and monitoring that will form part of the management plans specific for the Ambatovy Project's (the project) process plant. More detailed information is provided in the mitigation and monitoring sections of each Environmental Assessment (EA) discipline section. A full framework for the Environmental and Social Management Plan is provided in Appendix H, Section 6. Section 7.1 presents activities to be completed for key management plans during operations.

7.1 CONSTRUCTION AND OPERATIONS PHASE ACTIVITIES

7.1.1 Water Management Plan

Suspended solids will be monitored in the Ivondro River downstream and during the construction of the Ivondro River intake.

7.1.2 Air Quality Management Plan

Ambient air quality will be monitored selected locations outside the plant site. In addition, plant process controls will be applied to ensure efficient plant operations and minimize vent emissions.

7.1.3 Human Resource Development Plans

A Local Resource Development Initiative (LRDI) will be developed, which will include training programs for project-specific needs. Residents of Toamasina and other nearby communities will preferentially become part of such programs relating to work at the process plant.

7.1.4 Procurement Plan

A procurement plan will optimize involvement of local businesses. As part of the program, training, business advice and technical assistance will be provided to small and medium sized businesses to enable competitive participation in the project.

7.1.5 Other Socioeconomic Management Activities

An HIV/AIDS program will be established and will be operational before project begins construction.

Ongoing consultation will occur at nearby communities, to address any concerns or issues they may have relative to the plant.

The proponent will participate in assisting local and regional governments and other stakeholders in ways and means of enhancing the net benefit of the project. Any unforeseen social impacts that occur during construction, operations and closure phases will be addressed, including through participatory actions with stakeholders.

7.1.6 Emergency Contingency Plan

The design of drainage and treatment facilities at the plant site will minimize the effect of severe rainfall on the plant, the public and the environment. It is anticipated that for the most extreme storm events, plant operations will be suspended with the exception of management and security personnel.

During severe storms, power outages could occur, making sump systems inoperable. The potential for contamination of storm water due to the overflow of berms isolating process plant areas will me mitigated by general shut-down of the process plant and clean up of bermed areas before the onset of predicted major storms.