Volume C 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: Environmental Assessment - 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

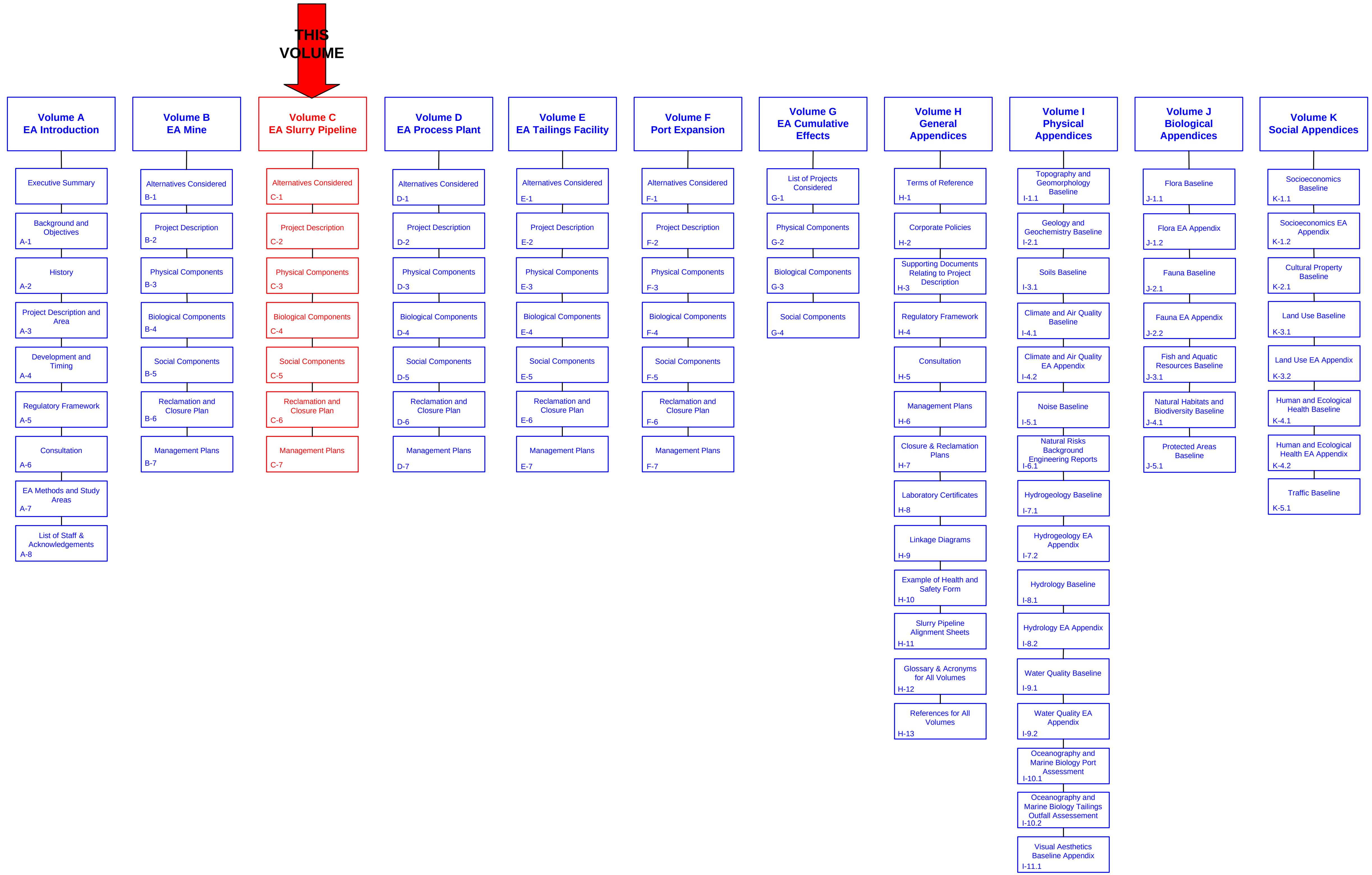


TABLE OF CONTENTS

SECTION **PAGE**

1 ALTERNATIVES CONSIDERED ... 1
1.1 INITIAL PROPOSAL ... 4
1.2 WESTERN ROUTE ALTERNATIVES ... 4
1.3 EASTERN ROUTE ALTERNATIVES ... 7
1.4 CONCLUSIONS ... 8

2 PROJECT DESCRIPTION ... 10
2.1 CONSTRUCTION ... 10
2.1.1 Route Investigations ... 13
2.2 CONTROL SYSTEM ... 14
2.3 SAFETY SYSTEM ... 15
2.4 LEAK DETECTION SYSTEM ... 15
2.5 PIPELINE OVERPRESSURE PROTECTION ... 16
2.6 OTHER PIPELINES ... 17

3 PHYSICAL ... 18
3.1 TOPOGRAPHY AND GEOMORPHOLOGY ... 18
3.1.1 Introduction ... 18
3.1.2 Study Area ... 18
3.1.3 Baseline Summary ... 18
3.1.4 Issue Scoping ... 19
3.1.5 Impact Assessment ... 19
3.1.6 Conclusions ... 22
3.2 SOILS ... 23
3.2.1 Introduction and Study Area ... 23
3.2.2 Baseline Summary ... 23
3.2.3 Impact Assesssment ... 24
3.2.4 Conclusions ... 31
3.3 CLIMATE AND AIR QUALITY ... 32
3.3.1 Introduction ... 32
3.3.2 Assessment Boundaries ... 32
3.3.3 Baseline Summary ... 33
3.3.4 Impact Assessment ... 33
3.3.5 Conclusions ... 34
3.4 NOISE ... 35
3.4.1 Introduction ... 35
3.4.2 Study Areas ... 35
3.4.3 Baseline Summary ... 35
3.4.4 Impact Assessment ... 37
3.4.5 Conclusions ... 41
3.5 NATURAL RISKS ... 42
3.5.1 Introduction ... 42
3.5.2 Study Area ... 42
3.5.3 Baseline Summary ... 42
3.5.4 Issue Scoping ... 42
3.5.5 Impact Assessment ... 43
3.6 SURFACE WATER HYDROLOGY ... 49
3.6.1 Introduction ... 49

3.6.2 Baseline Summary....49
3.6.3 Issue Scoping....52
3.6.4 Impact Assessment....53
3.6.5 Impact Analysis....58
3.6.6 Conclusions....60
3.7 WATER QUALITY....61
3.7.1 Introduction....61
3.7.2 Study Area....61
3.7.3 Baseline Summary....61
3.7.4 Issue Scoping....62
3.7.5 Impact Assessment....63
3.7.6 Impact Analysis....67
3.7.7 Conclusions....68
3.8 VISUAL AESTHETICS....69
3.8.1 Introduction....69
3.8.2 Study Area....69
3.8.3 Baseline Summary....69
3.8.4 Issue Scoping....70
3.8.5 Impact Assessment....71
3.8.6 Conclusions....76

4 BIOLOGICAL....77
4.1 FLORA....77
4.1.1 Introduction....77
4.1.2 Study Area....77
4.1.3 Baseline Summary....77
4.1.4 Issue Scoping....80
4.1.5 Key Question FL-1 What Effect Will the Slurry Pipeline Have on the Loss or Alteration of Plant Communities?....81
4.1.6 Key Question FL-2 What Effect Will the Slurry Pipeline Have on the Introduction of Exotic and Unwanted Plant Species?....87
4.2 FAUNA....91
4.2.1 Introduction....91
4.2.2 Study Area....91
4.2.3 Baseline Summary....92
4.2.4 Impact Assessment....94
4.3 FISH AND AQUATIC RESOURCES....117
4.3.1 Introduction....117
4.3.2 Study Area....117
4.3.3 Baseline Summary....117
4.3.4 Issue Scoping....127
4.3.5 Key Question FA-1: What Effect Will the Project Have on Aquatic Habitat?....129
4.3.6 Key Question FA-2: What Effect Will the Project Have on the Abundance and Survival of Fish?....136
4.3.7 Key Question FA-3 What Effect Will the Project have on Artisanal Fisheries?....141
4.3.8 Conclusions....144
4.4 NATURAL HABITATS AND BIODIVERSITY....145
4.4.1 Introduction....145
4.4.2 Study Area....146
4.4.3 Baseline Summary....146
4.4.4 Impact Assessment....148
4.4.5 Conclusions....158

4.5 PROTECTED AREAS 160
4.5.1 Introduction 160
4.5.2 Study Area 160
4.5.3 Baseline Summary 160
4.5.4 Issue Scoping 161
4.5.5 Impact Assessment 162
4.5.6 Conclusions 167

5 SOCIAL 168
5.1 SOCIOECONOMICS 168
5.1.1 Introduction 168
5.1.2 Impact Assessment 169
5.1.3 Summary 177
5.2 CULTURAL PROPERTY 180
5.2.1 Introduction 180
5.2.2 Study Area 180
5.2.3 Baseline Summary 180
5.2.4 Issue Scoping 183
5.2.5 Impact Assessment 184
5.3 LAND USE 187
5.3.2 Baseline Summary 187
5.3.3 Issue Scoping 188
5.3.4 Assessment Methods 188
5.3.5 Impact Assessment 188
5.3.6 Mitigation 191
5.3.7 Conclusions 191
5.4 HUMAN AND ECOLOGICAL HEALTH 192
5.4.1 Introduction 192
5.4.2 Study Areas 192
5.4.3 Baseline Summary 192
5.4.4 Impact Assessment 192
5.4.5 Conclusions 196
5.5 TRAFFIC 197
5.5.1 Introduction 197
5.5.2 Study Area 197
5.5.3 Baseline Summary 197
5.5.4 Issue Scoping 198
5.5.5 Changes in Traffic 199
5.5.6 Conclusions 204

6 RECLAMATION PLAN 205
6.1 CLEAN-UP AND RECLAMATION 205
6.1.1 Roads and Slurry Pipeline Right-of-Way 207
6.1.2 Borrow Pits 207
6.1.3 Stream Crossings 207
6.1.4 Spills 207
6.1.5 Revegetation 208
6.2 DECOMMISSIONING AND ABANDONMENT 209
6.3 GENERAL CONSTRUCTION MITIGATIONS 209
6.3.1 Timber Salvage 210
6.3.2 Grubbing and Stripping 210
6.3.3 Soil Stability and Erosion Control 210
6.3.4 Watercourse Crossings 211

7 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLANS 212
7.1 PRE-CONSTRUCTION STUDIES 212
7.1.1 Water Management Plan 212
7.1.2 Flora and Fauna Management Plans 212
7.1.3 Fish and Aquatics Management Plan 212
7.2 CONSTRUCTION AND OPERATIONS PHASE ACTIVITIES 213
7.2.1 Emergency Contingency Plan..213
7.2.2 Fish and Aquatics Management Plan 213
7.2.3 Human Resource Development Plans..213
7.2.4 Other Socioeconomic Management Activities 213
7.3 CLOSURE AND RECLAMATION ACTIVITIES...214
7.3.1 Flora and Fauna Management Plans 214

LIST OF TABLES

Table 1-1 Alternative Slurry Pipeline Route Comparison 3
Table 2-1 Other Similar Pipelines 17
Table 3.1-1 Impact Description Criteria for Topography and Geomorphology 20
Table 3.1-2 Potential Effects and Residual Impacts for Topography and Geomorphology 21
Table 3.1-3 Residual Impact Classification for Topography and Geomorphology 22
Table 3.2-1 Summary of Pipeline Soil Characteristics...24
Table 3.2-2 Project Interaction Matrix 24
Table 3.2-3 Assessment Criteria for Soils..26
Table 3.2-4 Disturbance of Soil Types Along the Slurry Pipeline 30
Table 3.2-5 Residual Impact Classification for Soils...30
Table 3.4-1 Summary of Existing Noise Levels, Slurry Pipeline..37
Table 3.4-2 Construction Equipment Sound Emissions 39
Table 3.6-1 Maximum 24-Hour Rainfall Amount..51
Table 3.6-2 Typical Derived Monthly and Annual Runoff for Pipeline Route (Based on 2004-2005 Monitoring Program)...51
Table 3.6-3 Reach Characteristics and Discharges Along the Pipeline Route.........................52
Table 3.6-4 Impact Description Criteria and Numerical Scores for the Ambatovy Project – Surface Water Hydrology 54
Table 3.6-5 Typical Erosion and Sediment Control 57
Table 3.6-6 Residual Impact Classification for Hydrology 59
Table 3.8-1 Key Viewpoints: Slurry Pipeline Route 70
Table 3.8-2 Impact Description Criteria for Visual Aesthetics..71
Table 3.8-3 Potential Effects and Residual Impacts for Visual Aesthetics 74
Table 3.8-4 Residual Impact Classification for Visual Aesthetics..76
Table 4.1-1 Impact Description Criteria for Plant Communities, Structure and Diversity 82
Table 4.1-2 Change in Vegetation Type Area as a Result of Site Clearing Within the Slurry Pipeline Local Study Area 84
Table 4.1-3 Residual Impact Classification for Loss or Alteration of Plant Communities.........85
Table 4.1-4 Impact Description Criteria for Exotic and Unwanted Plant Species.....................88
Table 4.1-5 Residual Impact Classification for Exotic and Unwanted Plant Species 89
Table 4.2-1 Impact Description Criteria for Fauna...97
Table 4.2-2 Change (%) in Habitat Area as a Result of Site Clearing Within the Slurry Pipeline Local Study Area...99
Table 4.2-3 Watercourses Affected by the Slurry Pipeline Route..101
Table 4.2-4 Residual Impact Classification for Impacts Related to Direct Habitat Loss.........101

Table 4.2-5 Habitats (ha) Within a 100 m Edge Effects Zone of the Slurry Pipeline 105
Table 4.2-6 Residual Impact Classification for Fauna due to Indirect Habitat Loss 106
Table 4.2-7 Residual Impact Classification for Fauna due to Direct Mortality........................110
Table 4.2-8 Residual Impact Classification for Fauna due to Fragmentation and Barriers to Movement 115
Table 4.3-1 Habitat Condition and characteristics of Sampling Sites in the Slurry Pipeline Local Study Area..120
Table 4.3-2 Fish Species Recorded at the Slurry Pipeline Local Study Area During 2004-2005 Surveys...122
Table 4.3-3 Aquatic Invertebrate Taxa Recorded at the Slurry Pipeline Local Study Area During the 2004-2005 Survey 123
Table 4.3-4 Ecosystem Components, Parameters and Criteria for Fish and Aquatic Resources...128
Table 4.3-5 Impact Description Criteria for Fish and Aquatic Resources...............................131
Table 4.3-6 Total Estimated Aquatic Habitat Disturbance in the Slurry Pipeline Local Study Area 133
Table 4.3-7 Potential Effects and Residual Impacts for Aquatic Habitat 135
Table 4.3-8 Residual Impact Classification for Effects on Aquatic Habitat.............................136
Table 4.3-9 Distribution, Number of Species and Relative Abundance (Compared to Exotic Species in each Sample) of Endemic Fish Species in the Slurry Pipeline Local Study Area...138
Table 4.3-10 Potential Effects and Residual Impacts for Aquatic Species Abundance and Health in the Slurry Pipeline Area...140
Table 4.3-11 Residual Impact Classification for Effects on Aquatic Species Abundance and Health in the Slurry Pipeline Area...140
Table 4.3-12 Potential Effects and Residual Impacts for Artisanal Fisheries 143
Table 4.3-13 Residual Impact Classification for Effects on Artisanal Fisheries........................143
Table 4.4-1 Species Richness, Endemism and Conservation Status of Flora, Reptiles, Amphibians, Birds, and Fish in the Slurry Pipeline Local Study Area 147
Table 4.4-2 Land Classification for the Slurry Pipeline Local Study Area 148
Table 4.4-3 Location of Biodiversity Impact Analysis Information 150
Table 4.4-4 Summary of Potential Impacts to Natural Habitats and Biodiversity 152
Table 4.4-5 Impact Description Criteria for Natural Habitats and Biodiversity........................154
Table 4.4-6 Change in Area of Each Land Class for Full Development of the Pipeline Relative to Baseline Conditions in the Local Study Area....................................156
Table 4.4-7 Residual Impact Classification for Natural Habitats and Biodiversity 156
Table 4.5-1 Impact Description Criteria for Protected Areas 163
Table 4.5-2 Potential Effects and Residual Impacts for Protected Areas...............................165
Table 4.5-3 Residual Impact Classification for Protected Areas...166
Table 5.1-1 Impact Mitigation and Benefit Enhancement Measures 170
Table 5.1-2 Slurry Pipeline Impact Matrix 178
Table 5.2-1 Potential Types of Cultural Sites in the Cultural Resources Study Area.............181
Table 5.2-2 Impact Description Criteria for Cultural Resources 184
Table 5.2-3 Potential Effects and Residual Impacts for Cultural Resources 185
Table 5.2-4 General Procedure for Relocating Tombs 186
Table 5.3-1 Land Use Impact Areas for the Slurry Pipeline Local Study Area 189
Table 5.5-1 Baseline Traffic Level Summary 198
Table 5.5-2 Pipeline Vehicle Numbers per Day along a Portion of RN2 between Toamasina and Moramanga...200
Table 5.5-3 Vehicle Kilometres per Year Along RN2..200
Table 5.5-4 Changes in Accident Numbers Between Moramanga and Toamasina During Pipeline Construction 201
Table 5.5-5 Number of Vehicle Pass-Bys (Noise Events) per Daylight Hour 202
Table 6.1-1 Potential Issues and Proposed Mitigation for Slurry Pipeline Construction.........205

LIST OF FIGURES

Figure 1-1 Slurry Pipeline Route Alternatives 2
Figure 1-2 Slurry Pipeline Route Alternatives – Mine Site Area 5
Figure 3.6-1 Derived Mean Annual Precipitation Along the Pipeline Route 51
Figure 4.3-1 Distribution of Endemic Fish in the Regional Area 125
Figure 5.2-1 View of Pipeline Right-of-Way and Locations of Archaeological and Cultural Sites 182

LIST OF PHOTOGRAPHS

Photograph 2-1 Typical Pipeline Rights-of-Way During Construction in a Tropical Environment 11
Photograph 2-2 Erosion Control on Pipeline Right-of-Way in a Tropical Environment 11
Photograph 2-3 Typical Backfilling for a Buried Pipeline in a Tropical Environment 12
Photograph 2-4 Typical Reclaimed Pipeline Right-of-Way in a Tropical Environment 12

1 ALTERNATIVES CONSIDERED

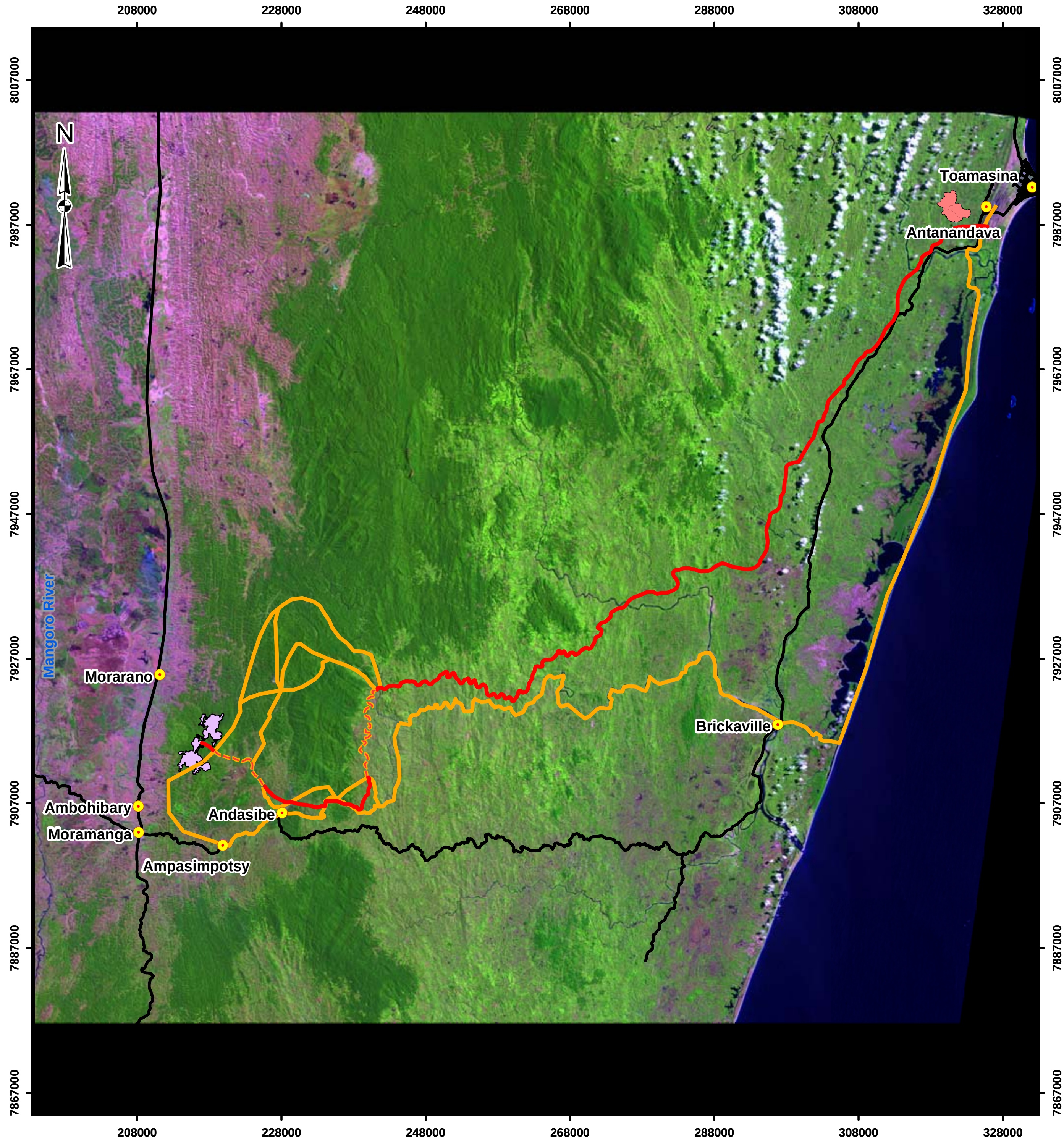
Much attention has been given to considering route alternatives for the slurry pipeline, including focused consultations for routing via the Mantadia-Zahamena forest corridor (Volume A, Section 6). This section describes the chronology of analyses that led to the choice of routing assessed in this Environmental Assessment (EA). Additional route refinement that is ongoing as of November 2005 is also discussed, along with the means by which any change will be assessed in an EA Addendum to be issued separate from this main EA.

Initial investigations of a pipeline route from the mine site to the Port of Toamasina followed an existing railway line from the mine site to Brickaville and then on to the process plant. This was defined as the 'Railway Route'. Subsequent investigations identified a possible alternate or more direct route across country between the mine site and process plant. This was defined as the 'Direct Route'. As a result of a favaourable outcome of this investigation the Base Case was modified to reflect the Direct Route.

The selected Base Case pipeline will run adjacent to the CIBA (forest) railway line from the mine site to near the town of Andasibe where it turns east circumventing the National Park before heading north to the town of Fitanisirana. Here it turns east to the north of Lanonana up to south of Ankarefa, past Androsalabo and generally follows the RN2 National road to the Toamasina plant site terminal station, resulting in a total pipeline length of about 195 km.

A pipeline is required to transport the ore in a slurry from the ore processing facility to the plant site on the coast. It will be 55 cm in diameter and will be buried for most of its length. This section describes the alternative selection process for the "railway route" and a variety of route options for the western portion of a more "direct route".

Table 1-1 summarizes the engineering, social, environmental and cost criteria and conclusions for the pipeline options, while Figure 1-1 outlines the route alternatives.



LEGEND

- POPULATION CENTRE
- ORE BODY (MINE SITE)
- TAILINGS FACILITY
- ROAD
- PROPOSED PIPELINE ROUTE
- ALTERNATE PIPELINE ROUTE
- OVERLAPPING PROPOSED AND ALTERNATIVE ROUTES

20 0 20

SCALE 1:775,000 KILOMETRES

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001

Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

SLURRY PIPELINE ROUTE ALTERNATIVES

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	GJ	29 Jun. 2004	**FIGURE: 1-1**	
GIS	TN	21 Nov. 2005		
CHECK	GJ	11 Jan. 2006		
REVIEW	DM	11 Jan. 2006		

I:/2003/03-1322/03-1322-172/mxd/General/Fig1-1_Alternate_Pipelines.mxd

Table 1-1 Alternative Slurry Pipeline Route Comparison

Route	Route Description	Engineering/Constructability[a]	Social Issues[a]	Environmental Issues[a]	Approximate Cost[a]	Conclusions
A	railway baseline route	difficult due to interference with railway operations and rail bed soils (*)	major disruption in villages along railway line (*)	low impact due to use of existing corridor (****)	due to technical problems, is most expensive option (*)	problematic from engineering, social and cost perspectives; positive from biological perspective (7*)
B-1	direct north route in Mantadia National Park	difficult terrain, but feasible (**)	impact very low (****)	avoids Torotorofotsy but passing through National Park rules this route out (X)	cost is lowest (****)	feasible but ruled out due to National Park issues (X)
B-2	= B-1, first leg Torotorofotsy	difficult terrain, but feasible (**)	impact very low (****)	less forest impact than B-1 but passing through National Park rules this out (X)	cost is lowest (****)	feasible but ruled out due to National Park issues (X)
C-1	north route bypass Mantadia National Park	difficult terrain, but feasible (**)	impact very low (****)	passing adjacent to National Park, within high quality habitat in planned corridor (*)	cost is on low end (***)	feasible but unlikely due to park corridor issues (10*)
C-2	= C-1, first leg Torotorofotsy	difficult terrain, but feasible (**)	impact very low (****)	passing adjacent to National Park, within high quality habitat in planned corridor not an option (*)	cost is on low end (***)	feasible but unlikely due to park corridor issues (10*)
D-1	north route bypass buffer	difficult terrain, but feasible (**)	impact very low (****)	passing close to National Park, within high quality habitat in planned corridor not an option (*)	cost moderately low (***)	feasible but unlikely due to park corridor issues (10*)
D-2	= D-1, first leg Torotorofotsy	difficult terrain, but feasible (**)	impact very low (****)	passing close to National Park, within high quality habitat in planned corridor not an option (*)	cost moderately low (***)	feasible but unlikely due to park corridor issues (10*)
E-1	south route, rail corridor	moderate interference with railway operations and rail bed soils (**)	disruptions at Andasibe, Sandranady, Faunovana, Ambatovola (**)	avoids new impact to most important forest corridor (***)	costs moderately high (**)	high costs, engineering issues and social disruptions make this option somewhat unfavourable (9*)
E-2	= E-1, bypass railway ("private" route)	difficult terrain, but feasible (***)	impact very low (****)	moderate impacts in Torotorofotsy and new corridor south of national park (**)	costs moderately low (***)	moderate environmental effects, low social effects; completely avoids rail corridor (12*)
E-3	hybrid e-1 and e-2. follows rail line for 5-10 km to Fanovana	5-10 km of interference with railway operations and rail bed soils (***)	disruptions at Andasibe, Sandranady (***)	avoids new impact to most important forest corridor (***)	costs moderately high (**)	limits rail route impact to short corridor, reducing environmental impact in critical 5 to 10 km (11*)
F	south route bypass Torotorofotsy (uses RN 2)	good for most of route (****)	many residents along road; impact predicted to be high (*)	avoids both Torotorofotsy and new impact to most important forest corridor (****)	cost is close to most expensive option (*)	high cost but otherwise reasonable, with low environmental and social impacts (10*)

[a] Ranking system: X: option ruled out; *: worst relative option in category, **: below average option, ***: above average, ****: best option available.

1.1 INITIAL PROPOSAL

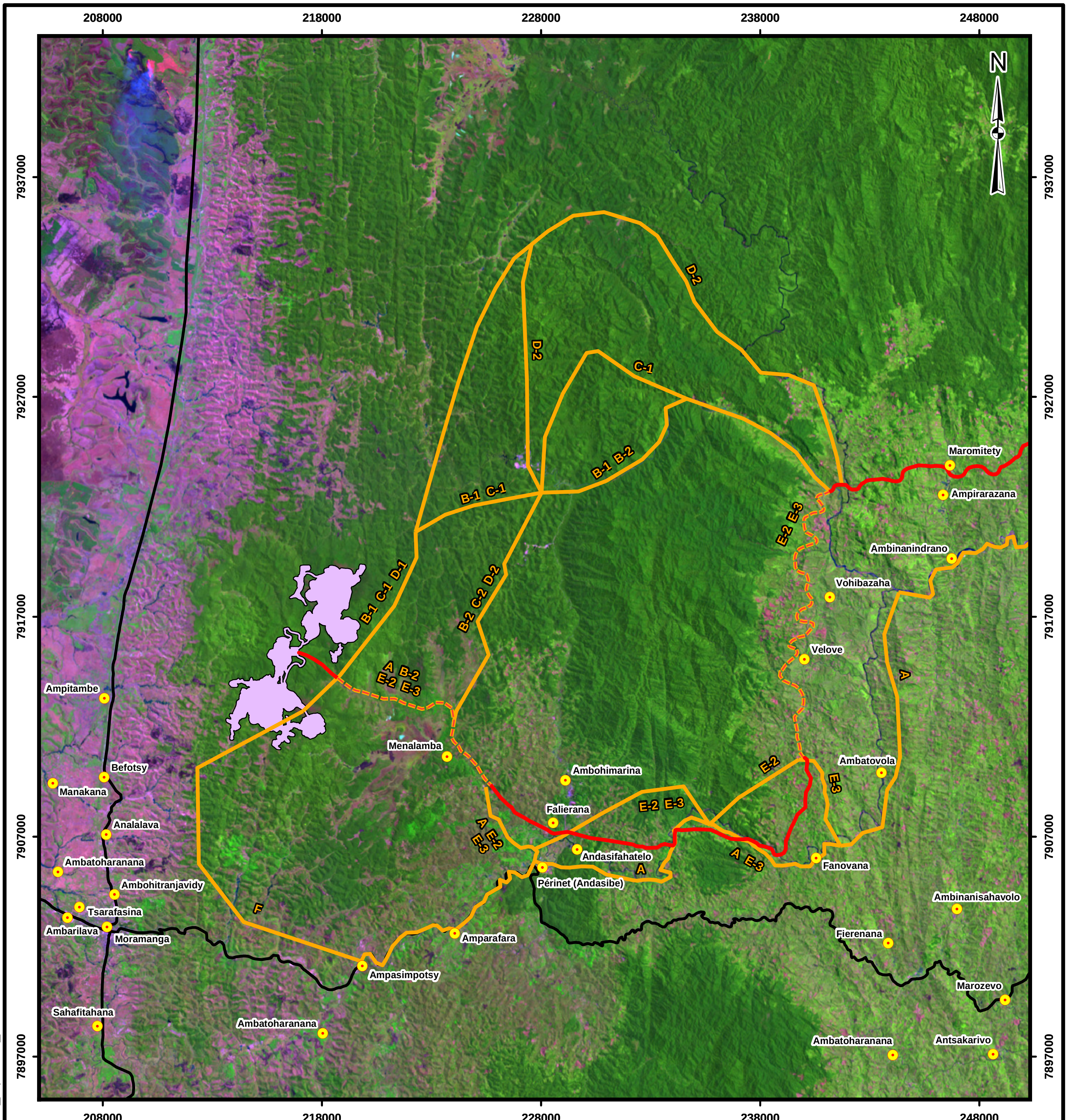
The railway route (Route A) was initially considered by the proponents due to the convenience of using an existing cleared right-of-way. The main benefit of this route was the relatively small amount of new clearing (footprint area) that would be required, and thus a relatively small environmental impact. The route was to extend from the Ambatovy mine site to Andasibe, from Andasibe to the Ambila-Leimatso station on the east coast along the main railway line, and from Ambila-Leimatso station to the process plant at Toamasina following the eastern coastline rail route (Figure 1-1). This route was considered the preferred one in the early stages of the project (early 2004).

A general survey of the route was undertaken by a team consisting of personnel from Murray & Roberts – Engineering Solutions and Geopractica Consulting Geotechnical Engineers that outlined technical details of how the construction would proceed. Social investigations were also conducted along the route. Following these evaluations, problems with constructability (potential damage to the railway bed) and social concerns (use of the route for settlements and travel) were clarified. The surveys to date have now confirmed that, because of these issues, this option is both technically difficult and expensive (Table 1-1).

1.2 WESTERN ROUTE ALTERNATIVES

In March, 2004, two versions of a direct route for the pipeline were proposed. At the west end, one extended initially northeast from the mine and cut through the northern end of Mantadia National Park, and incorporated slightly different options to pass the Torotorofotsy Wetlands (B-1 and B-2), and the other looped southeast along the railway route (E-1) (Figure 1-2). These planned routes came together near Vohibazaha to head in a nearly straight line northeast toward the plant site at Toamasina. Though these routes were less expensive from an engineering perspective (short and without the need for a pumping station), concerns for the "B" routes arose due to the impact on sensitive habitats close to Mantadia National Park and through the Mantadia-Zahamena corridor. In addition, there was still concern that it would be too expensive to use the railway route exclusively as part of route E-1.

An initial reconnaissance was made to evaluate all routes on May 12, 2004. The survey focused on the forest sector in which the most problematic environmental issues arise. Significant environmental problems were identified for all B, C and D routes related to the amount of primary forest that would have to be crossed. It was again concluded that from an environmental perspective, the rail route would clearly be preferable for the western pipeline section.



LEGEND

- POPULATION CENTRE
- ORE BODY (MINE SITE)
- ROAD
- PROPOSED PIPELINE ROUTE
- ALTERNATE PIPELINE ROUTE
- OVERLAPPING PROPOSED AND ALTERNATIVE ROUTES

5 0 5

SCALE 1:250,000 KILOMETRES

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001

Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

SLURRY PIPELINE ROUTE ALTERNATES-MINE SITE AREA

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	GJ	29 Jun. 2004	**FIGURE: 1-2**	
GIS	TN	21 Nov. 2005		
CHECK	GJ	11 Jan. 2006		
REVIEW	DM	20 Jan. 2006		

I:/2003/03-1322/03-1322-172/mxd/General/Fig1-2_Alternate_Pipelines_Minesite.mxd

To further refine route options, a meeting was held on June 3, 2004 with non-governmental organizations (NGOs) conservation organizations and government representatives (Volume A, Section 6). Options were considered for various routes both north and south of Mantadia National Park. During the meeting it was mutually determined that traversing the park, or even passing the pipeline along the park border or within a buffer zone to the north of the park, would not be an acceptable plan. This decision was reached because, aside from the park itself, the Vohitra River and other zones of biological importance lie to the north, forming an important biological corridor. Routes C-1, C-2, D-1 and D-2, consisting of various combinations of traversing areas north of Mantadia National Park or areas within the Torotorofotsy Wetlands (all within the potential Site de Conversation), were therefore ruled out due to these critical biological issues.

Results of baseline studies presented at the June 3 meeting indicated that the routes north of the Mantadia National Park are, as expected, biologically rich, with stands of primary and near-primary forests (although selective logging is occurring in these areas). The topography was confirmed to be quite rough. Previous preliminary conclusions regarding problems with routes B, C and D were confirmed. Topography also appears to be challenging for the “E” options south of Mantadia National Park that involve detouring off of the railway route.

The corridor currently maintaining the link between forests south of Mantadia National Park and the private reserve south of the Sahatandra River appears to be functional. Nevertheless, a proposed pipeline route between Mantadia National Park and the railroad, or a combination of this route with part of the railroad route, was generally thought of as the best alternative, as it reduces social impacts and can be built more easily compared to the full railway route, and also results in a minimum level of environmental impact relative to most other alternatives.

During the June 3 meeting, it was concluded that although it is not without impacts, a route to the south of Mantadia National Park was likely going to be the best option. Three southern routes seemed to be options: along the railway as originally planned (E-1), completely avoiding the railway by routing the pipeline through private lands south of the park (E-2), or, as suggested by a participant at the June 3 meeting, a combination of the private-land route (E-3) with a short 5 to 10 km stretch along the track north of Vohimana private reserve through the most sensitive forest. A final option (F) proposed at the meeting was a route bypassing Torotorofotsy by following a road south from the mine and continuing along RN2 to Andasibe, where it would rejoin the rail route. In each case, once east of the planned protected corridor, the route would then run directly to the coast along a direct routing (Figure 1-1).

Subsequently, in June, an engineering report was prepared delineating a feasible route (approximately along E-2, and shown as the "proposed pipeline route" in Figure 1-2). This route took the extra step of taking topography into account, and should therefore be considered a more realistic version of Route E-2.

On July 7 and 8, 2004, a meeting was held near the mine site, bringing together stakeholders from Toamasina and Antananarivo to re-examine alternatives including the Torotorofotsy bypass route (F) and the forest corridor bypass alternatives. The proponent's technical and budgetary information concerning this route was presented, showing that the use of this option could ultimately jeopardize the financial feasibility of the project, in addition to having significant social impacts along the road. Stakeholders reiterated that crossing the Torotorofotsy Wetlands was considered undesirable, and indicated that if essential, a pipeline along the railway spur through the wetlands would require stringent environmental and social mitigation during the design and construction phases. The development of a management plan within the Ramsar process for the Torotorofotsy system was also discussed.

During the July 7-8 site visit, stakeholders also voiced the concern that crossing the primary forest corridor north of the railway parallel to the Sahatandra River would impact and fragment the forest over a distance of about 5 km. Because of the typical recovery rate of such forest after a disturbance such as pipeline construction, this would likely be a long-term impact. The group present voiced a consensus that the bypass routing following the track along the south side of the river over about 5 km (Route E-3) should be favoured over the routing that follows the forested, northern side of the valley (Route E-2).

1.3 EASTERN ROUTE ALTERNATIVES

The eastern section of the direct route has a variety of options to bypass locally important habitats, areas of social importance and locations unfavourable for stream and river crossings. This section of the pipeline is less subject to critical, problematic issues than the western segment (both social and environmental). Potential eastern routes have been surveyed by helicopter and the route assessed is shown as the proposed route in Figure 1-1. Issues with the east section of the direct route include social effects (routings near villages and through agricultural areas), environmental effects in some areas, and stream crossings.

During the second half of 2005, the proponents moved ahead with more engineering planning for the slurry pipeline, including considering more advanced results from the EA. It became clear that the section as amended, running north from near Fanovana along the eastern edge of Mantadia National

Park, was problematic due to both constructability and environmental concerns. The terrain in the area was particularly rough and the route impinged in a buffer zone next to the park. The system of hills and main rivers did not allow the line to be moved a little east away from the park edge, as requested by the EA team. Construction of new access into this area could have serious impacts to the integrity of the park.

The engineering team are therefore suggesting a revised route from near Fanovana, that would head east and into less rough terrain, before slanting north-east to Toamasina. This route is believed to have major constructability and environmental benefits. However, since it has not been assessed in the EA an EA Addendum will be produced. The addendum will cover the whole pipeline route, including the new eastern section, plus all access roads, camps and lay down areas.

1.4 CONCLUSIONS

Based on the decision process chronology and the assessment table provided, which bring together a considerable amount of effort including field studies, consultation meetings and analysis of options from social, environmental and engineering perspectives, the conclusions to for the pipeline's western section are:

- A route south of Mandadia National Park is preferable.
- Routes E-2 and E-3 were preferred. E-2 is the route south of the National Park that avoids the railway.
- Route E-2 was considered the optimal route for most of its length. E-3 was also desirable, however was not selected due to the difficulty of building along the railway.
- The route chosen as the "proposed pipeline route" (Figures 1-1 and 1-2) is a compromise between E-2 and E-3 that avoids sensitive forest environments north of the Sahatandra River within the Mantadia-Zahamena corridor, and also avoids most of the railway.
- F is a route that is not recommended due to, amongst other things, potential social impacts and economic costs. Therefore, a pipeline along the railspur in the Torotorofotsy has been selected as the most viable route. The pipeline to be built will require additional mitigation consistent with the pending Ramsar site status of the area.

The western "proposed pipeline route" (Figure 1-2) will have slight modifications made to it as a result of this EA, engineering input and further consultation with stakeholders.

The conclusions for the pipeline's eastern section are:

- a direct route is preferable for social impact reasons;
- the route passes through mainly slash and burn and agricultural areas. To avoid social and environmental impacts, it will be diverted around pockets of land that are valuable or sensitive for environmental or social reasons;
- for engineering purposes, where possible the pipeline will avoid highlands and problematic water-crossing locations; and
- a large re-route is recommended in the east as a result of engineering and environmental concerns. The slurry pipeline will therefore be the subject of an EA amendment.

Overall, the preferred routing is a compromise between constructability/ engineering costs versus environmental/social costs. In addition the large re-route in the east, fine tuning of the route will occur to minimize social and environmental impacts as detailed in this Volume.

2 PROJECT DESCRIPTION

The slurry pipeline will connect the outlets of the ore preparation slurry plant at the mine to the process plant at Toamasina.

The pipeline is designed to handle up to 826 dry metric tonnes per hour of nickel laterite ore. The design is based on a solids density of 35-40%. The maximum design flow rate is 1,753 m^3/h and the pipeline will be used approximately 350 days per year, 24 hours per day for 27 years.

The pipeline will be buried and will be about 195 km long. The material of construction is steel, with a 550 mm outside diameter and a wall thickness of 9.5 mm. The pipeline will be equipped with cathodic protection. An increase in wall thickness will be applied at stream or river crossings as an added safety factor.

Photographs 2-1 to 2-4 show typical pipeline construction and reclamation stages in pipeline development from previous tropical projects.

2.1 CONSTRUCTION

The pipeline will be buried over its entire length, except at two rivers (KP 68.6 and 70.3) and several smaller streams in deep and narrow valleys. As assessed, the pipeline would require about 100 watercourse crossings. The majority of crossings will be buried and will involve excavating across the channel, laying the pipe, and back-filling the French. Where possible, water will be diverted to one side of the channel to enable a relatively dry workspace in the opposite side. Sub-surface directional drilling may be applied at some crossings to avoid stream disturbances.

The route has been split into two sections – the west and east for construction logistics and control purposes. The west section is considerably more complex and expensive than the east section.

The west section will run from the mine site to the west bank of the Rianila River at kilometre post (KP) 107. Access is a major concern as there are only five access points to the area in very difficult and mountainous terrain. Right-of-way ground grading, new access roads and improvements, construction camps, pipe storage areas and some pipe hauling will be done during the first seasonal 'dry window'. The pipe laying activities will take place during the second 'dry window'.

Photograph 2-1 Typical Pipeline Rights-of-Way During Construction in a Tropical Environment

Photograph 2-2 Erosion Control on Pipeline Right-of-Way in a Tropical Environment

Photograph 2-3 Typical Backfilling for a Buried Pipeline in a Tropical Environment

Photograph 2-4 Typical Reclaimed Pipeline Right-of-Way in a Tropical Environment

In this section from KP 6 to KP 14.5 the approximately 8.5 km of forest rail track around the north of the Torotorfotsy Wetlands will be removed and the pipeline installed. On completion the rail track will be reinstated. A further section from KP 21 to KP 35 will be constructed on a narrow section base to limit the clearing effect.

The east section runs from KP 107 to the process plant site and is less of a concern with 10 access points. Access road improvements, construction camp and pipe storage areas will be constructed during the first 'dry window'. The balance of the activities will be completed during the second 'dry window'.

The pipe material will be shipped to Toamasina in loads of about 10,000 tonnes. They will be unloaded from the ship and trucked to dedicated stockpile areas located next to the process plant site. The delivery from these central stockpiles to the lay down areas along the pipeline will be by truck or by rail.

2.1.1 Route Investigations

Although many field studies took place as part of this EA, a combined environmental and social survey team will work with the engineering team ahead of construction, to do a final fine-tuning of the alignment to minimize impacts.

The following additional surveys will be undertaken during the final design phase of the project:

- detailed survey of the selected pipeline route and demarcation of the pipeline centreline – this may prove to be logistically difficult due to access limitations and may be supplemented by aerial surveys and global positioning system (GPS) demarcation;
- geotechnical surveys of pipeline route and intended station sites;
- hydrological surveys to identify peak water flow rates in rivers – this ensures that the pipeline is buried below the potential scour depth;
- environmental surveys to allow final route fine-tuning to minimize impacts:
  - ecological surveys;
  - cultural surveys;
  - land owners surveys; and
  - permit negotiations.

Each activity may impose local or general design requirements on the pipeline facilities. These requirements will be implemented during the detailed engineering phase of the project and incorporated into the resulting construction specifications.

2.2 CONTROL SYSTEM

All pertinent monitoring data will be available at the mine site and plant site local control consoles. Control will be effected only from the mine site control room, or locally at the pump station. One operator from the mine site control room will normally control the pipeline – this is typically a shared duty with other functions. This operator has the capability of performing all normal system operations, and most of the emergency procedures, from the control operator console at the control room.

The control room will be manned around the clock when the pipeline is operational. The control system monitors all critical pipeline points, allowing manual set point adjustments. The valve and the terminal stations are not normally manned. Local personnel will be required only to perform routine maintenance repairs, and calibrations.

Ancillary systems including Supervisory Control and Data Acquisition (SCADA), telecommunications, remote power supply, and cathodic protection will be located in the control building. Control of the system will be automatic in the steady-state mode with operator intervention required during process upsets. Monitoring will include flow, pressure, density and temperature measurement at various points along the pipeline. The “expert” software is integrated to the SCADA system to provide advisories to the pipeline operator. Automatic system shutdowns will only occur after time is given to the pipeline operator to correct a potentially dangerous situation.

An intermediate valve station with two pressure monitoring stations and a terminal station at the Toamasina process plant will also be provided and report to the control room.

The pipeline will be monitored by a leak detection system. This system analyses operating data from the SCADA system. During detailed design, the pipeline hydraulics will be optimized using a computer simulation program that models the pipeline operation under varying conditions. This program will be incorporated into the pipeline control system during construction. This arrangement has been used on several new long-distance pipelines and is being retro-fitted to existing systems. The benefits of simulation-based control systems include reduced capital cost by optimizing pipeline wall thickness requirements and the number of choke station valves, reduced risk of pipeline blockage, and more efficient operation.

The simulation system will also incorporate a leak detection facility that detects the presence and position of pipeline leaks.

2.3 SAFETY SYSTEM

The pipeline contains only non-flammable liquid/solid product, and does not pose an explosion risk. High-pressure slurry is a non-compressible liquid, but can be aggressively abrasive if a leak occurs. Operators will be instructed in the safe operation of high-pressure slurry piping.

Additional design techniques and safety factors will be applied for all special design points (e.g., thicker steel pipe wall at river crossings and in the more sensitive environmental areas).

Typically a pipeline system design requires at least one signal augmentation station about every 50 km to support fibre optic regeneration and cathodic protection in addition to providing pipeline pressure information. These facilities will be co-located with the pressure monitoring station as needed.

Self-contained solar units with battery back-up will provide power to the pressure monitoring stations (PMSs). The units will be sized to provide power for station instruments, SCADA components, telecommunications system, cathodic protection system, and area lighting.

The pressure transmitter installed in a remote location (intermediate PMS) will be equipped with an RTU (remote terminal unit and solar or thermal power supply). Communication between the intermediate PMS site and the pump station will be through fibre optic cable that will serve SCADA between both ends of the pipeline. For redundancy, the radio link will be to both ends of the pipeline. Basically, the leak detection system is considered as one of the SCADA modules.

2.4 LEAK DETECTION SYSTEM

As noted above, a leak detection system will be provided for the pipeline. The objective of the system is to detect system leaks and predict their location as well as issue warnings to operators. The target number for the system resolution is 3 to 5% of the flow specified in the system operating envelope as presented in the operating range. Detection is expected within 2 to 10 minutes of occurrence depending on the size and the location of the leak.

Leak detection involves comparing the flow-rates, pressures and densities along the pipeline based on current flow regime in the line and position of the pipeline valves. A leak would be recognized by the departure from established norms for these parameters.

The leak detection system is based on two methods, mass balance (MB) monitoring and section characteristic parameter (SCP) monitoring. The more reliable SCP is defined as $Q^2/(dh/dL)$, with Q representing the local flow rate and (dh/dL) representing the slope of the hydraulic gradient (headloss) in the monitoring section. The MB method alone would create false alarms when the pipeline is in transient conditions.

The on-line monitoring of data provides pipeline operating personnel instant access to information about process flow conditions. This access to information allows safer operation and better maintenance of the pipeline. If there is an indication of a leak, the pipeline will be shut down, and an inspection team will be dispatched.

2.5 PIPELINE OVERPRESSURE PROTECTION

A discharge pressure override will always be engaged during pumping operations to ensure unsafe operating conditions are addressed quickly. The system will be controlled by pump speed (target steady pipeline flow) with a density alarm on high or low density from the storage tank. High and low density limits will be established during commissioning. Adjustments to the concentrate feed rate must be made which provide a steady-state concentrator operation, which minimizes pipeline shutdowns.

The pipeline and equipment will be protected from over-pressurization by several levels of protection by:

- implementing proven operating procedures;
- the use of SCADA system software;
- the use of electrical interlocks (physical or by control loops); and
- mechanical pressure relieving devices.

The pressure-relief devices will be located at the discharge of the mainline pump, upstream of the valve station, and upstream of the terminal valves. The pump station relief devices direct their flow to the pump station agitated storage tanks.

The valve station rupture disc will bypass the station block valves. The terminal station relief devices direct their flow to the receiving thickener.

2.6 OTHER PIPELINES

The two particular characteristics of the proposed Ambatovy ore pipeline that differentiate it from most other ore pipelines are the relatively high tonnage and the fact that reinforcing pump stations in the mainline are not required in spite of the relatively long pipeline length. The pipeline that offers the most useful comparison is the Los Bronces copper ore pipeline operated by Anglo American Chile. The pipeline diameter varies from 600 mm to 500 mm and is similar to that of the proposed Ambatovy pipeline. A significantly higher tonnage of 58,000 t/d is transported for a distance of 58 km with a static head of about 2,700 m without any mainline pumps. Four choke stations are required to dissipate the static head.

The system has been operating since 1992 and currently the 500 mm diameter sections are being upgraded to 600 mm to increase throughput and to replace worn sections of pipeline.

In terms of diameter and length, the 500 mm diameter, 396 km Samarco iron ore pipeline in Brazil offers some points of comparison. The throughput of this pipeline is about 30,000 t/d and it incorporates two high-pressure pump stations, one combined choke and isolation station and one isolation valve station. This pipeline system has operated very successfully since 1977 with minimal production downtime due to unplanned pump or pipeline maintenance.

Table 2-1 summarizes additional pipeline data from other existing projects. For comparison, the Ambatory pipeline will transport nickel laterite ore slurry, will be about 195 km in length, will have a diameter of 550 mm and will have a capacity of 7.2 MTA. It is planned to operate for 27 years.

Table 2-1 Other Similar Pipelines

Pipeline	Mineral	Length (km)	Pipe Dia. (mm)	Capacity (MTA)	Years Operating
SF Phosphate, Utah	phosphate	92	250	2.9	20
Simplot, Idaho	phosphate	133	200	1.9	22
Kennecott, Utah	copper tailings	20	700/500[a]	35.2	16
Chino Mines, New Mexico	copper tailings	14.4	400[a]	14	22
Century Zinc, Australia	lead & zinc concentrates	300	300[a]	2.6	5
Antamina, Peru	copper & zinc concentrates	303	250/225/200[a]	1.8	3

[a] Note: Internally lined steel pipeline.

3.1 TOPOGRAPHY AND GEOMORPHOLOGY

3.1.1 Introduction

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

3.1.2 Study Area

The slurry pipeline Local Study Area (LSA) for topography and geomorphology is the same as the general slurry pipeline study area presented in Volume A, Figure 7.2-2. It includes areas within 500 m of the planned pipeline route.

3.1.3 Baseline Summary

The slurry pipeline runs from land of medium elevation near Moramanga, through the Torotorofotsy Wetlands complex, passes through a series of watersheds with steep valleys characterized by granite outcrops and continues over topography with gradually lower relief until reaching the flat coastal dune structures of the Madagascar east coast.

The geomorphology of the Torotorofotsy Wetlands system is characterized by rolling hills and alluvium-filled valleys. The topography of the central highlands includes steep-sided, irregularly shaped valley formations with slopes reaching a typical maximum of 45 degrees. The topography of the east coast is relatively flat, with a surface layer of sand.

Based on a qualitative analysis of the landscape, the slurry pipeline LSA contains one unique topographic feature: the Torotorofotsy Wetlands, which constitute the largest and most intact marsh in eastern Madagascar (BirdLife International Website: 2003).

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 Slurry Pipeline Have on Topography and Geomorphology?

Impact pathways associated with impacts on topography and geomorphology are shown in the topography and geomorphology figure in Volume H, Appendix 9. During construction and operation phases, topographic and geomorphologic features of the landscape will be disturbed. Slopes and topography will be altered during the construction, operation and closure phases.

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 considered generally in comparison to the modified topography typically required for pipeline construction.

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 C, Section 6 to minimize the formation of gulleys and the removal of surface material due to water and wind erosion.

During construction, operations and the beginning of the closure phase, water management systems will be used to catch flows along the base of disturbed features and mitigate siltation in downstream basins. This will be particularly important to mitigate effects on valleys downstream that are productive for rice production and other land uses.

During the operations and closure phases, reclamation will occur. Revegetation will reduce erosion of surface material and will help to maintain slopes and other topographic features. Slopes will be contoured to maintain long-term stability. Closure landforms will be designed such that there will be continuity of landforms and watershed systems between undisturbed land and reclaimed areas.

3.1.5.4 Results

All along the pipeline route, small-scale topographic modifications will be necessary to accommodate a flat pipeline RoW (right-of-way) with a width of between 25 and 100 m. Areas with steeper side slopes require greater topographic modification to create adequate, flat pipeline RoWs. Slope cutting is expected to create a variety of locally noticeable landscape modifications along the length of the pipeline, given the prevalence of locally steep slopes for most of the route. Virtually all impacts will occur at the time of construction, including both the pipeline itself and the development of access routes to and along the pipeline.

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	removal and disturbance of important topographic features important for social or biological reasons (Torotorofotsy Wetlands) changes in the landscape due to pipeline construction	erosion control; water management; stable slope engineering; progressive reclamation	low magnitude/long-term modification of row and access routes
operations	changes in the landscape and slopes which may represent important issues over the long term to stakeholders and biodiversity	erosion control; water management; stable slope engineering; progressive reclamation	low magnitude/long-term modification of RoW and access routes
closure	n/a	n/a	n/a

n/a Not applicable.

The existing topography of the LSA is hilly with relatively steep slopes, except at the eastern end of the slurry pipeline corridor, which extends into level terrain in coastal areas. The areas affected by topographic change due to the slurry pipeline are mainly the steep-sided valleys.

The portion of the pipeline traversing the Torotorofotsy Wetlands will pass over level terrain along an existing, disturbed corridor. Impacts to topography are therefore not expected to have negative implications for this unique topographic feature, given the successful implementation of mitigation measures to prevent erosion into the wetlands themselves.

The slurry pipeline and its associated access corridors will have a direct, but localized impact on the landscape. Generally, impacts will be long-term, because the terrain will not be changed back to its original form as the time of closure. The magnitude of the changes are considered low during construction and operations, as the pipeline affects only a narrow corridor and the associated linear access routes, and mitigation is expected. The low impact magnitude assumes successful implementation of erosion control measures, as erosion along steep slopes could lead to larger-scale impacts on valleys and watersheds.

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 Slurry Pipeline Have on Topography and Geomorphology?**						
construction	negative	low	local	long-term	no	continuous	low
operations	negative	low	local	long-term	no	continuous	low

Prediction Confidence

The baseline status of topography in the LSA is well understood. However, the eventual form of the landscape following construction is not yet certain. Impact ratings are dependent on the success of the mitigations proposed, including erosion control and slope stability engineering. Overall, the prediction confidence for this assessment is considered medium.

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 C, Section 6.

3.1.6 Conclusions

The slurry pipeline and its associated infrastructure will have a low consequence for topography during the construction and operation phases. The pipeline is not expected to have an impact on unique topographic features. No additional effects or changes for topography are expected during the closure phase; the landscape will remain in an altered state for the long term after closure.

3.2 SOILS

3.2.1 Introduction and Study Area

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

The slurry pipeline study area for soils is the pipeline project footprint study area presented in Volume A, Section 7, Figure 7.2-2.

3.2.2 Baseline Summary

3.2.2.1 Pipeline Soils

Soils of the pipeline region have developed on old, geomorphically stable terrain with almost no vestige of the original rock structure. Intense weathering in the humid tropics from high temperatures, abundant moisture and time has resulted in deep soil development.

The soils in the slurry pipeline region are generically known as laterites, which are defined as highly weathered iron-rich tropical soils (Young 1976). The word laterite has been widely used in the literature to describe soils of the tropical and subtropical regions of the world. These general terms are often used to describe various morphologic, physical and chemical properties.

In general, soils along the pipeline route followed a relatively predictable pattern. On slope crests, Oxisols were found, at midslope positions soils were generally Ultisols and at the toe of slopes and in depressions, the soils were either Histosols or Oxisols, depending on drainage. Characteristics of these soils are summarized in Table 3.2-1.

In the western part of the pipeline, the soils have developed on heavily weathered cretacious rock (Delbos 1961) consisting mostly of gneiss, migmatite, granite and migmatic granites. Deep soils have developed on the easily weathered gneiss, while soils developed on granite tend to be thinner. At some locations, erosional processes have occurred more recently and soils were classified as Entisols.

Table 3.2-1 Summary of Pipeline Soil Characteristics

Slope Position	Soil Type	Soil Characteristics
summit (crest)	ferrilitic soils – typical blocky structure (Oxisols)	soil has a "good" blocky structure, soil is chemically rich due to enrichment by bases and minerals (mica); soil cohesion is weak to medium
mid slope	strongly altered or changed ferrilitic soils (Ultisols)	soil horizon with weak cohesion low and weak structure; soil aggregates are porous; primary minerals are more or less altered (disappeared)
base of slope (depressions)	poorly developed hydromorphic soils (Histosols)	soils are more or less rich in altered minerals; horizons have formed from valley alluvium; soils are sandy or silty with low clay content; soils have concretions

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 slurry pipeline impacts on soil resources (Table 3.2-2). 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.

Table 3.2-2 Project Interaction Matrix

Project Activities or Facilities	Soil[(a)]	Issue	Comments
construction phase			
vegetation clearing	M to H	increase in wind and water erosion risk; soil compaction from equipment	impact depends on length of time soil exposed and timing of construction (e.g., dry season)
topsoil removal	H	increase in wind and water erosion risk; loss of soil nutrients, soil compaction	final impact depends on whether topsoil is salvaged and stored
overburden removal	M to H	wind and water erosion; soil compaction from equipment	impact depends on length of time soil exposed
potential spills	L to M	contamination from spills	impact depends on clean spill response
reclamation and closure phase			
reclamation	P	reclamation of disturbed areas	positive effect

(a) Interaction Ratings: N - Negligible; L - Low; M - Moderate; H - High; and P - Positive.

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 productivity.

The key question for soils is:

Key Question ST-1 What Effect Will the Slurry Pipeline Have on Soils?

A linkage diagram for potential impact pathways is provided in Volume H, Appendix 9. Table 3.2-2 presents the impact of pipeline activities with soil resources, focusing on key issues.

Potential Impact Pathways

Key Question ST-1 analyzes the effects associated with construction, operations and reclamation of the slurry pipeline on the loss or alteration of soil within the LSA.

Activities resulting in the direct loss or alteration of soil in the slurry pipeline include site clearing and surface disturbance to permit slurry pipeline construction. Site preparation for pipeline installation will involve removing the topsoil cover. While the slurry pipeline right-of-way (RoW) will be reclaimed shortly after pipeline construction is complete, tropical soil reclamation methods are still in development.

Soil erosion is a process involving soil movement from one area to another by wind and water. Soil erosion can result in alteration or loss of soil quality, a process that can subsequently affect vegetation growth. The slurry pipeline 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. It is caused by external pressure resulting from construction related equipment and vehicle traffic. The potential loss of soil structure from soil compaction can affect vegetation growth, especially root development, aeration and drainage. The slurry pipeline will involve equipment traffic and activity on soils with potential 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.

Assessment Methods

Soil and terrain units directly affected by the slurry pipeline were quantified by Geographic Information System (GIS) analysis using the following process:

- the areas of soils to be disturbed within the slurry pipeline footprint was GIS quantified;
- the areas of reclaimed soils following pipeline RoW reclamation were calculated; and
- impact ratings were determined based on the net permanent loss of soils and the expected changes in soil quality.

3.2.3.2 Assessment Criteria

The criteria used to rate soil residual impacts are outlined in Table 3.2-3.

Table 3.2-3 Assessment Criteria for Soils

Resource	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
Soils	**positive**, **negative** or **neutral** for the measurement endpoints	**negligible**: no measurable effect (<1%) **low**: <10% loss **moderate**: 10 to 20% loss **high**: >20% loss	**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. The steep slopes along the pipeline RoW suggests that the soils will have a high erosion potential due to the fine-textured surficial soils.

Wind and water erosion risk along the pipeline RoW 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 having a higher risk. Water erosion risk increases where slopes exceed 10% and fine-textured subsoils underlay coarse-textured soils. The topography of the existing route has many areas with slopes greater than 10%, thus potential for water erosion exists

To prevent soil erosion and potential sedimentation from occurring during construction, soil exposure must be minimized and surface runoff controlled, especially during the wetter months and in areas close to watercourses.

The following mitigations will be applied to prevent soil erosion by water:

- where possible, salvage topsoil and store securely along the RoW away from areas of potential erosion;
- construct temporary cross ditches to redirect surface runoff;
- construct temporary berms of logs, construction timbers, sandbags or other material as appropriate and available on steep slopes;
- construct slurry pipeline roads so natural drainage patterns are not impeded and in a manner that runoff to road ditches enters natural drainage systems or contoured containment areas;
- use temporary erosion control measures such as mulches, mats, netting, or straw crimping to control erosion until a protective vegetative cover is established;
- apply tackifiers where necessary to stabilize soils and use hydroseeders for seeding on steep slopes; and

- promptly seed exposed areas with a self-sustaining, erosion-controlling seed mix appropriate to the region. It is suggested that Vetiver grass (Vetiveria zizanioides) be planted in strips parallel to slopes for testing (NRC 1993) (Volume B, Section 6). Trials of Vetiver are proposed for the initial pipeline slopes that are disturbed.

The following mitigations will be applied to prevent the siltation of watercourses:

- Prohibit the operation of construction equipment close to the banks of watercourses where there is a risk of bank sloughing, failure of the vehicle crossing or flooding of the work area.
- Excavate cross ditches to divert runoff away from watercourses.
- Construct berms of overburden, timber, lumber, sandbags, rock, straw bales or hay bales on approach slopes and/or banks to divert runoff off the site and onto well vegetated lands.
- Import sand bags and place strategically to help stabilize and add height to banks to prevent flooding of nearby areas especially where vegetation has been removed.

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 dependant on soil organic matter. These characteristics were discussed in Volume B, Section 3.3.

Mitigations to restore soil nutrients in reclaimed slurry pipeline soils include:

- Incorporation of organic matter in the surface layer of the reclaimed soil profile including direct topsoil salvage and replacement, placement of composted organic material, mulching and “green manuring”.
- As required supplement nutrients to promote faster plant growth with fertilizer amendments.
- Where needed applying liming agents such as calcium and magnesium carbonates to increase soil pH and reduce metal toxicities (Ludwig et al. 2000).

Sustainability of soil nutrients in disturbed soil has been identified as a potential issue in the tropics and will be a major issue in reclaiming the slurry pipeline right-of-way. It will be important to ensure that organic matter is reincorporated during reclamation since the organic matter has an important controlling function on soil fertility. This will be especially important in those key sections of the

RoW within the Mantadia-Zahamena Corridor, which are to be reclaimed to forest during operations (Volume C, Section 6).

Compaction

Soil compaction occurs when force compresses the larger soil pores and reduces the air volume of the soil. Compacted soils have a higher bulk density than non-compacted soils. The potential of a soil to compact is dependant on soil physical properties such as texture, water content and the amount and nature of the force applied. Soil compaction is most severe under moist conditions, high loads, and areas of repeated traffic use. The effects of soil compaction were discussed in Volume B, Section 3.3.

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

- conduct soil salvage and replacement operations in the dry season as much as possible, thereby reducing the potential for compaction;
- minimize the number of passes on an area once it is 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:

- ensure equipment has suitable spill containment systems to minimize the risk of leaks; and
- inspect equipment and area routinely and clean up all spills and leaks promptly.

3.2.3.4 Results

A total of about 896 ha of the soils will be disturbed by the slurry pipeline (Table 3.2-4). The majority of disturbed soils have a high to moderate erosion risk (clearing/tavy 800 ha, 89% of total) before pipeline construction. The remaining 96 ha have a low risk before pipeline construction. With the completion of pipeline construction, the erosion risk is expected to be high for the majority of the pipeline RoW for several months until vegetation is re-established.

Table 3.2-4 Disturbance of Soil Types Along the Slurry Pipeline

Soil Type	Length of Slurry Pipeline (km)	Area (ha)	Percent of LSA (%)
high to moderate erosion risk (clearing/tavy vegetation type)	170	800	89
low erosion risk (remaining vegetation types)	25	96	11
Total	**195**	**896**	**100**

3.2.3.5 Residual Impact Analysis

The environmental consequence of the slurry pipeline on soils is rated as moderate during construction, low during operation and low following closure (Table 3.2-5).

Slurry pipeline construction will result in a short-term disturbance of the pipeline RoW. The erosion risk of all soils will increase substantially with the removal of vegetation, particularly the 96 ha with substantial vegetation cover (Table 3.2-4). Due to the relatively short construction time period, the environmental consequence was rated as moderate.

During pipeline operation, the surface soil erosion risk will decrease substantially once vegetation re-establishes and slopes are stabilized. Many mitigations will be implemented to control erosion (Section 3.2.4.1). The high intensity of precipitation in the region makes erosion events highly likely.

The environmental consequence was rated as low following closure since natural erosion rates are expected once a stable vegetation cover is established (see Volume C, Section 6).

Table 3.2-5 Residual Impact Classification for Soils

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

3.2.3.6 Prediction Confidence

The soil impact classification relies heavily on the planned reclamation program to return a productive soil to the disturbed RoW. There are uncertainties regarding reclamation and erosion control in tropical soils. However, the proposed fast reclamation of the RoW immediately following construction assists with predicting that reclamation will be successful. Planned reclamation research will address these issues.

3.2.3.7 Monitoring

The proponent will implement reclamation monitoring programs to ensure the mitigation processes are successful and adjust if necessary. The slurry pipeline reclamation monitoring plan will consist of:

- ensuring that environmental protection measures are being followed during slurry pipeline construction;
- ensuring slope stability;
- measuring vegetation performance; and
- documentation of the monitoring results.

3.2.4 Conclusions

Following mitigation, the pipeline will have a moderate environmental consequence for soils during the construction phase, a low environmental consequence during the operation phase and a low environmental consequence following closure and reclamation. The main issue is the increase in erosion risk of the fine-texture soils once vegetation is cleared. The potential impact to soils has implications for vegetation, hydrology and particularly water quality, where there is a likelihood of increased sediment runoff. 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 Impact Assessment (EA) presents information on the air quality impact assessment of the slurry pipeline as required by the Terms of Reference (ToR) from the Madagascar Office National pour l'Environnement (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 and mitigations incorporated in the project design for these impacts;
- the existing air quality in the study area; and
- monitoring recommendations and further mitigations to reduce residual air quality impacts associated with the slurry pipeline.

Potential air quality issues identified in the EA due to the slurry pipeline include emissions from construction activities.

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 component does not represent fixed points in time. Rather, the assessment was based on the construction phase of the slurry pipeline.

3.3.2.2 Spatial Scope

The air quality assessment is a qualitative assessment of the area occupied by the slurry pipeline. Emissions from construction activities will be localized and there will not be any emissions during the operations phase that will affect air quality on a regional scale.

3.3.3 Baseline Summary

Rainfall patterns and amounts vary along the pipeline route. About 80% of the rainfall at the mine site occurs from November to March. Rainfall at Toamasina occurs year-round with rainfall amounts reaching more than double the amount received at the mine site. Temperatures also vary along the pipeline route due to elevation differences between the mine site and the east coast. Temperatures at the mine site are typically cooler than at Toamasina.

Since the pipeline will be located mainly in rural areas and there are no major industrial activities along the pipeline route, the air quality is expected to be relatively good. In an air quality monitoring study done in southern Madagascar, the air quality at all monitoring locations was classified as pristine (less than 20% of the reference standard) or clean (20 to 39% of the reference standard) (SENES 2001).

3.3.4 Impact Assessment

3.3.4.1 Issue Scoping

The main factors that may affect air quality are vehicle exhaust and dust emissions during the construction of the pipeline. Air emissions from the operations phase of the pipeline have not been identified; therefore, impacts on air quality during the operation phase are not expected to occur.

The key question for air quality is:

Key Question AQ-1 How Will the Development of the Slurry Pipeline Affect Air Quality?

Since the construction activities will be localized and temporary, changes to air quality are expected to be negligible; therefore no further assessment was conducted.

Mitigation

Although the effects on air quality during construction and operation of the pipeline are expected to be minimal, mitigations will be incorporated. This includes regular maintenance on construction vehicles and equipment, and controlling dust during construction and operation of the slurry pipeline.

Impact Analysis

Effects on air quality will occur primarily during construction, including clearing, grading and pipe-laying. The highest emissions are expected to occur during pipe-laying due to the number of trucks and heavy equipment to be used. Pipe-laying will also occur for the longest period in any area along the pipeline route, as it is the slowest activity.

Emissions of SO_2, NO_X and particulate matter from construction equipment are expected. These emissions may be sustained at any point along the pipeline for a period of several days up to a week, based on an estimated 700 m daily progression along the route.

Emissions from vehicles travelling on access roads will also occur; however, these emissions are expected to be minimal and short-term. A discussion of traffic on access roads is presented in Volume C, Section 5.5.

The impact on air quality during the operation phase of the pipeline is expected to be insignificant since there will only be occasional emissions from maintenance vehicles along the pipeline route.

Monitoring

Since the impact on air quality from construction and operation activities of the pipeline will be negligible over the long-term, air emission monitoring will not be conducted.

3.3.5 Conclusions

The main factors that may affect air quality are vehicle exhaust and dust emissions during the construction of the pipeline. The effect on air quality is expected to be insignificant because the emissions will be localized, and only occur temporarily at any location along the route (i.e., one week or less).

During operation of the pipeline, the only source of air emissions will be from an occasional maintenance vehicle; therefore the impact on air quality during the operation phase is expected to be negligible.

3.4 NOISE

3.4.1 Introduction

The noise assessment provides an impact analysis of the proposed Ambatovy Project (the 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 slurry pipeline are assessed. Information is provided on existing noise levels in the area, potential sources of sound emissions associated with the project and the potential for changes in noise levels that may to result from the pipeline.

The potential noise issue identified in the EA due to the slurry pipeline is due to construction activity.

The focus of the pipeline noise assessment is on determining the potential for changes to the existing ambient noise levels due to project construction 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 C, Section 4.2. Noise is also an input to the analysis of social effects in Volume C, Section 5.1 (Socioeconomics).

An introduction to the key outdoor acoustics concepts used in the assessment is provided in Volume B, Section 3.5.1.

3.4.2 Study Areas

The noise assessment is a qualitative assessment of the area occupied by the slurry pipeline. Sound emitted from construction activities will be localized to the active construction area and there will not be any noise during the operations phase that will affect receptors near the route.

3.4.3 Baseline Summary

3.4.3.1 Introduction

A baseline noise study was conducted for the Ambatovy 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 completed 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.

Specific locations along the slurry pipeline route were not selected for baseline monitoring. Noise levels along the route are expected to be similar to the noise levels measured at Berano and Amboakarivo, sites near each end of the pipeline.

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 Berano and Amboakarivo is provided in Table 3.4-1. These are considered representative of the existing noise levels at all community receptors near the route.

Table 3.4-1 Summary of Existing Noise Levels, Slurry Pipeline

Location	Period	Quietest Hour L_{eq} [dBA]	Period L_{eq} [dBA]
Berano	day	23	41
	night	20	40
Amboakarivo	day	39	42
	night	37	42

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

Slurry pipeline factors that may affect noise levels include:

- construction noise generated by mobile heavy equipment, welders, chainsaws and other miscellaneous motors; and
- maintenance and inspection traffic on public and local access roads may lead to localized increases in noise levels.

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

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

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 qualitative assessment of changes in noise levels for the slurry pipeline was accomplished by:

- establishing baseline noise levels at potential receptors;
- determining the amount of sound generated by construction activity; and
- calculating the distance required from project-related noise that would experience noise levels over the World Bank criteria.

Activities or equipment that have sound emissions were determined based on information contained in the project description (Volume C, Section 2) 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.

Calculations were conducted using formulae 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 have been addressed in the fauna impact assessement section. Noise predictions provided for the wildlife assessment are presented here for information purposes only.

The effects of traffic on public roadways has been assessed separately in Volume C, 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
- where background noise is higher than 55 or 45 dBA respectively, a maximum increase in background levels of 3 dBA.

Criteria are applied at receptors (homes or communities) outside the project boundary. Towns near the slurry pipeline route have been identified and mapped in Volume C, Section 5.1 (Socioeconomics). As the slurry pipeline route within the proposed corridor has not been finalized, exact distances between pipeline construction machinery noise sources and residences have not been defined.

Residual impacts are not being assessed for the slurry pipeline as the majority of noise only occurs during construction and specific community receptors have not been identified. This assessment is intended to provide information on localized effects which may occur during pipeline construction. Once constructed, noise effects will be negligible (occasional traffic for monitoring and maintenance).

3.4.4.4 Mitigation

No specific mitigation was considered for the pipeline construction. However, it is expected that all heavy equipment will be fitted with standard silencers (mufflers) and that construction 'best management practice' for maintaining equipment will be observed.

3.4.4.5 Sound Emissions

Table 3.4-2 lists noise levels for typical construction equipment that is used for pipeline construction.

Table 3.4-2 Construction Equipment Sound Emissions

Source	Sound Output (at distance)
bulldozers (2)[a]	87 dBA (15 m)
dump trucks[b]	82-89 dBA (12 m)
front-end loader[b]	79-93 dBA (15 m)
vibratory compactor[a]	87 dBA (12 m)
generator, small[a]	76 dBA (15 m)
chain saw cutting trees[b]	89-95 dBA (3 m)
backhoe[b]	87-99 dBA (9 m)
backhoe, idling[b]	74 dBA (9 m)
scraper[a]	88 dBA (15 m)

(a) Source: May 1978.
(b) Source: Cowan 1994.

The number and type of noise sources will also depend on the type of construction activity. Activities that have multiple noise sources are clearing, grading and pipe laying operations.

3.4.4.6 Residual Impact Analysis

Based on the proposed construction schedule, clearing will occur one or two seasons in advance of grading and pipe laying operations. Noise from clearing activity will include chain saws and rough terrain vehicles pulling salvageable lumber from the pipeline route. Noise from this type pf equipment is expected to attenuate to the World Bank nighttime criteria of 45 dBA within 500 m of the activity. During the normal operation of the pipeline, no noise will be emitted.

The loudest activity is expected to be pipe laying due to the number of trucks and heavy equipment to be used. Pipe laying will also occur for the longest period in any area along the pipeline route, as it is the activity with the slowest advance. Pipe construction activity will occur sequentially along a 1 to 2 km section (based on standard pipeline practices). Along this area will be various excavators, welders, trucks and people.

This type of construction activity will typically have three or more large diesel engines active. Attenuation calculated based on four, 1,500 HP diesel engine machines. will result in noise levels of 45 dBA within 500 to 700 m of the activity. These noise levels may be sustained at any point along the pipeline for a period of several days up to a week, based on a 700 m daily progression along the route.

Due to the localized effects for noise and expected short duration of construction, impacts are not considered significant.

Traffic on public and access roads during construction is discussed in Section 5.5 of this volume.

3.4.4.7 Prediction Confidence

The calculation 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 noise 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.

3.4.4.8 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

Noise levels from pipeline construction activity are expected to attenuate to World Bank nighttime criteria of 45 dBA within 500 to 700 m from activity. These noise levels could be sustained for as long as one week at any point along the route. Due to the localized effects for noise and expected short duration of construction, impacts are not considered significant.

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 pipeline, as per the Ambatovy Project (the project) Terms of Reference.

3.5.2 Study Area

The slurry pipeline Local Study Area (LSA) is shown in the plan presented in Volume A, Figure 7.2-2. The pipeline is about 195 km long and will transport up to 7.1 million dry metric tones per annum of nickel laterite from the mine to the plant. Natural hazards such as earthquakes can originate from a wide regional area that was studied as appropriate to determine the potential impacts on the pipeline.

3.5.3 Baseline Summary

The Environmental Assessment is based on a separate study on natural risks for the pipeline (Pipeline Systems Incorporated [PSI] 2005, which is provided in Volume I, Appendix 6.1). A 195 km slurry pipeline was designed with 550 mm outside diameter steel pipe and one pump station with two trains of six slurry pumps. In this reference study, the baseline for the pipeline setting is described in terms of route, climate and seismicity. Potential natural hazards, potential consequences of failure due to natural hazards, industry experience and risks were assessed.

3.5.4 Issue Scoping

Three primary natural hazards were identified in the risk assessment (PSI, 2005) that could result in pipeline breakage and release of slurry. These were land slides along the pipeline route, water erosion from rainfall and flooding, plus seismic hazards. All the issues identified from stakeholder consultation were also included in these hazard scenarios (Volume A, Section 6).

Land Slides

Pipeline damage can occur if a land slide or land slip should occur along the pipeline route. In a land slide, material above the pipeline right-of-way would slide down on top of the pipeline right-of-way and potentially damage the pipeline platform and the pipeline route. A land slip would involve movement of the land containing the pipeline platform and pipeline. Either movement, if large enough, could cause a pipe failure.

Water Erosion

During rainfall events, water soaks into the ground increasing the risk of landslips and/or landslides. When the ground is saturated, water runs across the surface to local low spots which usually drain to an area waterway.

The selected pipeline route crosses many streams and rivers as well as dry valleys that could become flooded during rainfall events. There is a risk at each of these crossings that erosion during a rainfall event damages the pipe. The damage could be caused by undermining supports for an aerial crossing, exposing a buried crossing, or widening the waterway exposing pipe outside the waterway. The exposed pipe may fail due to pressure of the flowing water, lack of adequate support (lost support in aerial crossing), or damage from rocks and debris moving in the river.

Seismic Hazards

There are three major events that could damage a pipeline during a seismic event:

- Significant land shift at a specific fault could shear the buried pipeline at the point of crossing the fault.
- Liquefaction of the soil containing the pipeline during an earthquake eliminates the support causing the pipeline to sink into the earth. This could overstress the pipeline to the point of failure.
- Land/rock fall could occur dropping material onto the pipeline right-of-way. This event would be similar to a land slide event discussed above. The impact (and mitigation methods) are the same.

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 Pipeline?

3.5.5 Impact Assessment

3.5.5.1 Assessment Methods

A risk assessment was completed for natural hazards (PSI, 2005) using a qualitative estimate based on worldwide pipeline experience. For each of the three identified natural hazards described in Section 3.5.4, potential hazard scenarios were first identified and planned risk mitigations were then described. The residual risks for all hazard scenarios were then estimated based on experience and the local route and design. 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 included five categories of risk:

- Extremely Low
- Low
- Moderate
- High
- Extremely High

3.5.5.3 Mitigation

Long-term safe and reliable operation of a slurry pipeline begins in the design phase and continues through ongoing pipeline operations. Application of proven design practices and development of project-specific safety systems ensures this reliability can be achieved. Commercially operating slurry pipelines have provided reliable service without environmental impact in high earthquake zones (Chile and Peru), extremely wet environments (Brazil), and in remote regions (China and Australia).

The proposed slurry pipeline does not present unique conditions for which successful pipeline designs have not been achieved. In all aspects, the pipeline is within commercially proven limits.

The selected route and design for the pipeline mitigate the risk of damage during operations and include the following strategies:

- The selected route is generally located away from human activity.
- The pipeline will be installed below ground. Weather events (cyclones, tornados, lightning, etc.) and surface disturbances (landslides, earthquakes, etc.) present less risk of damage to a buried pipeline than one installed on the surface.

- The selected route will avoid geotechnically unstable areas and where this is not possible, special designs will be applied to mitigate any geotechnical risk.
- In sensitive areas such as at river or road crossings, within inhabited zones, etc., a deeper burial depth and/or thicker pipe will be considered to mitigate the risk of damage. This design is particularly effective in river crossings where the pipe can be buried below the "worst case" scour event.

The proposed pipeline will be designed, constructed, operated and maintained in accordance with American Society of Mechanical Engineers (ASME) B31.11 – "Slurry Transportation Pipeline Systems". This code has been applied to other slurry pipelines around the world and provides proven guidelines which ensure pipeline safety. Use of an experienced design team will result in a state-of-the-art pipeline system.

Safety systems will be installed to minimize operational risks including those from natural hazards. To ensure rapid operator response to an unexpected event, the pipeline will be equipped with a state-of-the-art control system including a leak detection system. Early detection of a pipeline leak ensures rapid response and minimizes the risk of environmental impact.

Specific risk mitigation prevention measures planned to address the three principal natural hazards follow.

Land Slides

The major risk of damage to a pipeline is land slip or failure of the pipeline platform. The route optimization/selection will seek mature, stable geotechnical structure to minimize the risk of slip. The following additional designs will be implemented:

- The pipeline will always be installed on the uphill side/shoulder of the pipeline platform ensuring maximum distance from the natural surface.
- Special attention will be paid to natural water drainage for the land above the pipeline platform to ensure no blockage. Culverts and other water diversion structures will be used to provide drainage and prevent saturation of the earth containing the pipeline.
- The pipeline will only be installed in natural, cut soil. It will not be installed in fill material which could fail more easily than mature soils.
- Erosion control measures including reseeding, water diversion, geo-textiles, etc., will be used along the pipeline platform to prevent damage after construction is completed.

Water Erosion

Risk mitigations planned for the detailed engineering phase of the project include:

- a detailed survey of the pipeline route including geotechnical data;
- a hydrological survey of the region; and
- design features for river crossings to “armour” the pipeline against damage include:
  - The calculated minimum burial depth (buried crossings) is maintained through the entire waterway floodplain to allow for shifting of the river path within the plain.
  - Buried crossings will be concrete-coated to prevent mechanical damage to the pipe if the waterway bed is shifting.
  - Extra pipe wall thickness will be added at crossings. The extra thickness will be maintained through the entire waterway floodplain.
  - Erosion control will be constructed for aerial span supports and at banks near the crossing to add localized protection.

Seismic Hazards

During detailed engineering a complete geotechnical survey will be completed to assess seismic activity along the right-of-way and identify fault crossings and potential liquefaction zones.

In general, a buried pipeline is not impacted by an earthquake. The pipe has adequate flexibility to move with the earth except at fault crossings where special designs are incorporated to mitigate the effects.

The pipeline will be routed around all areas of potential liquefaction. If an area can not be avoided, friction piles will likely be installed under the pipeline. This piling provides support if the soil cannot because it is liquefied during an earthquake.

In addition to prevention measures, a primary method to mitigate the impact of any pipeline leak is early detection and implementation of emergency response. The slurry pipeline will be monitored by a Supervisory Control and Data Acquisition (SCADA) leak detection system that will detect any system leaks and predict their location as well as issue warnings to operators.

Another key method for minimizing the risk of damage due to natural hazards is regular inspection of the pipeline right-of-way to identify changes that may impact pipeline integrity. These pipeline route inspections will be integrated into the maintenance programs.

3.5.5.4 Results

The results of the risk assessment are summarized from the reference report (Pipeline Systems Incorporated, 2005). Risks were estimated based on worldwide operating experience and project conditions for each of the three principal natural hazards.

Land Slides

There is almost no commercial experience where a land slide has damaged the pipeline. Application of the planned design and construction techniques will result in a secure pipeline installation. Based on this commercial operating experience and the planned pipeline design, the risk of failure due to landslide is estimated as Low.

Water Erosion

Commercial experience suggests that the planned design methods provide adequate protection at waterway crossings. Robust design to the proposed pipe itself offers significant resistance to mechanical damage even if exposed by a storm event. Based on commercial operating experience and the project site-specific conditions, the risk of pipeline failure due to water erosion is estimated as Low considering a proper right-of-way inspection and maintenance program that includes timely repairs.

Seismic Hazards

There are very few known incidents of any type of pipeline failing during an earthquake and there is no information that a slurry pipeline has ever failed during a seismic event. The planned pipeline designs including commercially proven designs for fault crossings are effective in mitigating this risk of failure. Based on commercial operating experience and the planned pipeline design, the risk of failure due to an earthquake is estimated as Low.

3.5.5.5 Impact Analysis

Residual Impacts

Following mitigation, the residual risks during all project periods are in the Low category and within international standards to minimize risk to downstream public and environmental resources.

Prediction Confidence

The estimation of risk in the reference report (Pipeline Systems Incorporated, 2005) accounts for the variation in data and prediction confidence as described in Section 3.5.5.4. 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 were summarized in Section 3.5.5.3 for the leak detection system and pipeline route inspection and maintenance program.

3.5.5.6 Conclusions

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

3.6 SURFACE WATER HYDROLOGY

3.6.1 Introduction

Construction of the slurry pipeline will involve clearing and excavation along the pipeline right-of-way as well as disturbance to the streambed at most watercourse crossing locations. Water withdrawal and disposal will also be required for hydrostatic testing of the pipeline. Changes in runoff and sediment yield along the right-of-way can be mitigated by erosion control measures and best management practices. Channel disturbance during construction may affect flow velocities and associated water levels, and may also result in increased suspended sediment in downstream reaches.

Stream morphology, discharge measurements, and cross-sectional surveys were conducted to help characterize baseline conditions along the pipeline route (Volume I, Appendix 8.1). The available baseline information is summarized in the following sections for evaluation of potential effects of the Ambatovy Project (the project) on streamflow and sediment yield.

The local study area (LSA) for the slurry pipeline is shown in Volume A, Figure 7.2-2. The study area includes a 1 km buffer either side of the route, along the length of the corridor.

3.6.2 Baseline Summary

3.6.2.1 Introduction

Baseline conditions along the slurry pipeline route were characterized by analyzing available climate and hydrologic (streamflow) data from the mine area and the coastal plant and port areas. A summary of the climate and hydrology baseline study is provided in the following sections. Details can be found in Volume I, Appendix 8.1.

3.6.2.2 Methods

Information on Madagascar's climate was obtained primarily from Chaperon et al. (1993). Climate information was also obtained from the World Meteorological Organization, from rainfall stations at regional railway stations, and from the Madagascar Ministry of Public Works and Transport, Meteorology Branch.

Site-specific streamflow data were collected at 12 pipeline watercourse crossing locations along the route. Discharge measurements were taken during September and October 2004 to characterize late dry-season flows.

3.6.2.3 Results

The slurry pipeline route is about 195 km long and runs between the ore preparation plant at the mine and the process plant at the coast. The first 30 km of the route descends from the highlands to the coastal plain, with mean annual temperatures along this section increasing from about 17 to 22°C. The remaining portion of the route runs from the base of the escarpment, across the coastal plain and finally to the plant. Mean annual temperatures along this portion of the route are above 24°C.

Mean annual precipitation along the pipeline route was estimated from isohytes (lines on a map connecting places receiving equal rainfall) provided in Chaperon et al. (1993). The variation in precipitation is shown in Figure 3.6-1.

For the purpose of this assessment, rainfall intensities along the pipeline corridor were assumed to be similar to those at the mine or tailings facility, depending on location and the amount of rainfall that is characteristic of the area. Maximum rainfall statistics derived for the tailings area are assumed to be applicable to the majority of the pipeline length as it crosses the coastal plain. For the first 30 km of the pipeline route, however, maximum rainfall amounts will vary from those derived for the mine site to those derived for the coast. Maximum 24-hour rainfall amounts have been estimated by interpolating between the mine and tailings amounts based on the mean annual rainfalls at the sites (Table 3.6-1).

Runoff volumes depend on the basin size for each stream as well as the runoff per unit area. Estimates of monthly runoff along the route are provided in Table 3.6-2 for the early dry, late dry, and wet seasons. These monthly and extreme daily values are derived from observed streamflows over the 2004-2005 monitoring season.

A summary of the discharge measurements taken at watercourse crossings along the pipeline route is provided in Table 3.6-3.

Figure 3.6-1 Derived Mean Annual Precipitation Along the Pipeline Route

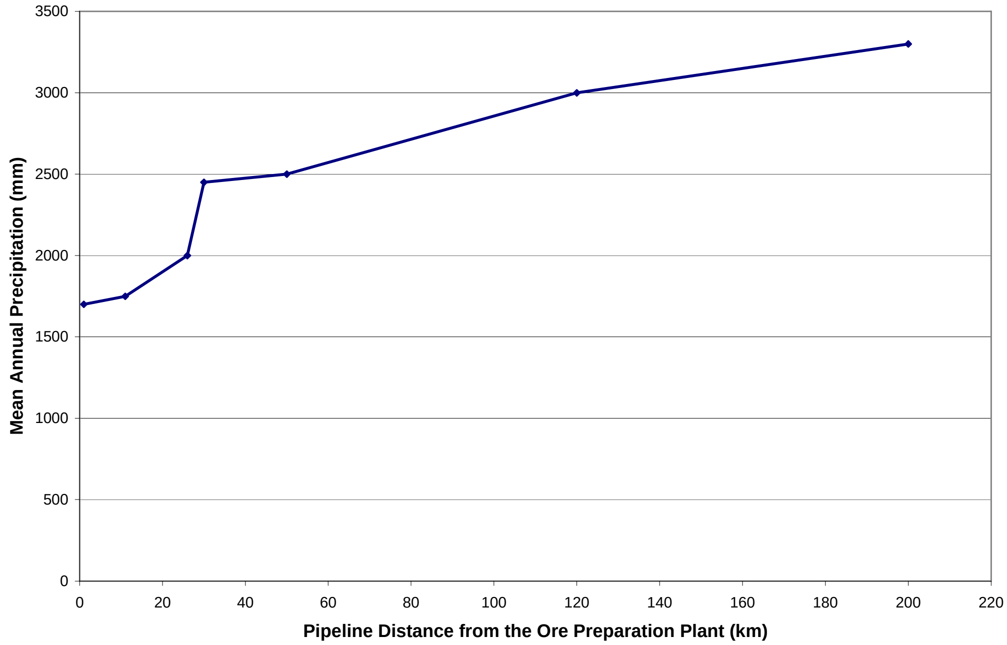


Table 3.6-1 Maximum 24-Hour Rainfall Amount

Area	Maximum 24-Hour Rainfall (mm) for Various Return Periods					
	2-yr	5-yr	10-y	20-yr	50-yr	100-yr
pipeline km 0-30[a]	122-172	181-242	231-295	287-352	374-434	453-502
pipeline km 30-200[b]	172	242	295	352	434	502

(a) Interpolated between rainfall amounts for the mine and tailings areas based on differences in annual precipitation.
(b) Assumed to be equal to conditions at the tailings area.

Table 3.6-2 Typical Derived Monthly and Annual Runoff for Pipeline Route (Based on 2004-2005 Monitoring Program)

Area	Annual Precipitation	Monthly Runoff[a] (mm)			Annual Runoff (mm)
		Early Dry Season (April/May)	Late Dry Season (October/November)	Peak Wet Season (January – March)	
Pipeline km 0-15	1,750	25-35	5-10	100-150	500-600
Pipeline km 15-25	2,000	50	15	140	730
Pipeline km 25-100	2,500	90	30	175	1,100
Pipeline km 100-130	3,000	125	40	200	1,500
Pipeline km 130-187	3,300	150	50	225	1,700

(a) Runoff along the pipeline is estimated by interpolation between the mine area and tailings area.

Table 3.6-3 Reach Characteristics and Discharges Along the Pipeline Route

Pipeline Kilometre Post	Stream Name	Drainage Area (km^2)	Survey Date	Wetted Width[(a)] (m)	Discharge (m^3/s)
XR2+000	Vondronina (upper reaches of the Torotorofotsy River)	4.7	Sep. 30, 2004	3.5	0.58
XR7+510	Unnamed	~1	Oct. 18, 2004	1.2	0.04
XR16+100	Sahatany (Tributary to Sahatandra)	38	Oct. 03, 2004	7.2	1.10
X42+300[(b)]	Volove	28	Oct. 19, 2004	15.0	1.14
X107+200	Rianila (Tributary to Vohitra)	~1,860	Sep. 25, 2004	126	57.4
X136+200	Sahanavo	n/a	Sep. 22,2004	77.0	18.4
X145+700	Morongolo	~1,000	Oct. 16, 2004	51.4	9.81
X157+700	Berohondry	n/a	Oct. 12, 2004	3.2	0.08
X175+200	Sandranentana (Tributary to Fanandrana)	n/a	Oct. 13, 2004	3.0	0.08
X178+900	Ivondro	~2,560	Oct .14, 2004	183	50.0
E3 007+000[(c)(d)]	Vohimana	6.5	Sep. 30, 2004	5.45	0.22
E3 011+950[(d)]	Sahatandra	~7	Oct. 01, 2004	26.5	9.66

(a) Wetted width at discharge measurement location.
(b) Recorded as 041+600 (same river within 1 km).
(c) Recorded as E3 005+150.
(d) Alternate watercourse crossing location.
n/a = Not available.
~ = Indicates approximate drainage area.

3.6.3 Issue Scoping

Hydrology issues related to the project were identified through consultation with stakeholders and by reviewing previous environmental assessments for resource developments in Madagascar and elsewhere. As described in Volume A, the issues were identified, tracked and summarized at a high level for consideration in the impact assessment. The following hydrology issues were 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).

For both issue areas, there was strong concern that the pipeline not affect water quantity or quality in the Torotorofotsy Wetlands. The key indicators of change due to the project are flows, water levels, sediment concentrations and channel morphology. These changes may also have an effect on water quality, fish health, vegetation (wetlands), and socioeconomic components of the project.

The Key Questions for the hydrology surrounding the slurry pipeline are:

Key Question H-1 What Effect Will the Slurry Pipeline Have on Flows and Water Levels in Water Bodies?

Key Question H-2 What Effect Will the Slurry Pipeline Have on Sediment Levels in Water Bodies?

3.6.4 Impact Assessment

3.6.4.1 Impact Pathway Evaluation

As shown by the surface water hydrology linkage diagram in Volume H, Appendix 9, project activities during pipeline construction may result in the following: i) changes in flows and water levels in receiving water bodies; and ii) changes in sediment levels. These changes may occur along the pipeline right-of-way, at watercourse crossing locations as a result of disturbance to the streambed during construction, and due to water withdrawal and disposal associated with pipeline hydrostatic testing.

Changes in flows and water levels, in conjunction with changes in sediment supply, may also affect channel morphology as the channel attempts to reach new equilibrium conditions.

Changes in flows, water levels and sediment levels in receiving water bodies may also affect water quality, fish and aquatic resources, socioeconomics and land use. Water users are described in the socioeconomic and land use baseline reports (Volume K, Appendices 1.1 and 3.1) and effects of hydrologic changes on water users are described in the socioeconomic and land use EA reports (Volume C, Sections 5.1 and 5.3).

3.6.4.2 Assessment Methods

Changes in flows, water levels and sediment levels in receiving streams were evaluated based on a qualitative evaluation of proposed mitigation, stream hydrologic characteristics, and construction techniques.

3.6.4.3 Impact Description Criteria

The assessment criteria used for hydrology are presented in Table 3.6-4.

Table 3.6-4 Impact Description Criteria and Numerical Scores for the Ambatovy Project – Surface Water Hydrology

Resource	Direction[(a)]	Magnitude[(b)]	Geographic Extent[(c)]	Duration[(d)]	Reversibility[(e)]	Frequency[(f)]
Surface Water Hydrology	**positive**, **negative** or **neutral** for the measurement endpoints	**negligible**: <5% change **low**: 5 to 10% change **moderate**: 10 to 30% change **high**: >30% change	**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 (1 to 10 times per year) **high**: occurs frequently (>10 times per year)

(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 three-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.

3.6.4.4 Mitigation

To mitigate the effects on flows, water levels and sediment levels, the Ambatovy Project will implement the following measures:

- selection of construction season, timing and method to minimize sediment generation at stream crossing locations;
- use of erosion control measures, revegetation and best management practices to control sediment runoff along the pipeline right-of-way during and after construction;
- routine inspection of the disturbed areas and watercourse crossing locations; and
- selection of water withdrawal/discharge locations and rates to minimize changes in water levels and sediment concentrations associated with pipeline hydrostatic testing.

3.6.4.5 Results for Key Question H-1: What Effect Will the Slurry Pipeline Have on Flows and Water Levels in Water Bodies?

Pipeline Right-of-Way

Construction and installation of the pipeline will involve land disturbance including removal of vegetation, excavation and backfilling, and compaction. These activities will result in higher runoff rates from the disturbed areas compared to baseline conditions. However, the percentage of disturbed area within a given basin is typically very small relative to the overall drainage area. Changes in flows and water levels in receiving streams are not expected to be measurable provided best management practices are used and natural drainage paths are maintained. Any increases in runoff that occur during construction will decrease once the disturbed areas are reclaimed and as vegetation is re-established through the operations and closure phases.

Pipeline Watercourse Crossings

Construction of the slurry pipeline will involve about 100 watercourse crossings of a variety of sizes, along the route. Initial assessments of the crossings have already been conducted to assist in pipeline routing. Prior to construction, an environmental team will conduct a field assessment of the crossing locations and identify any areas with high sensitivities. Where feasible, the pipeline route will be adjusted through design or reroute to avoid or minimize impacts on the sensitive areas.

Based on the initial crossing assessment, aerial crossings are expected to be required at two rivers (K.P. 68.6 and 70.3) as well as several smaller watercourses in deep and narrow valleys. Subsurface directional drilling may be applied in some instances to avoid stream disturbances, in which case no changes in flows, water levels, or sediment concentrations are expected.

The majority of crossings will be buried and will involve excavating across the channel, laying the pipe, and backfilling the trench. Construction of the crossings will typically be conducted during low flow conditions to minimize water depths and the amount of suspended sediment generated and transported to downstream reaches. Where possible, water will be diverted to one side of the stream to enable a relatively dry work space on the opposite side. Several techniques may be used to isolate areas for construction to occur. On larger watercourses, coffer dams may be used. On smaller watercourses, berms may be established across the channel both upstream and downstream of the construction zone, and water either conveyed by gravity or pumped across the construction site. Effects on water levels are expected to be high during construction;

however, the duration will be short, i.e., on the order of hours for small streams and up to a few days for very large streams.

No effects on flows or water levels are expected in the streams during operation or post-closure provided revegetation and erosion control is established and stream banks are stabilized. Design and construction specifications, e.g., minimum burial depths, size of armour material, and sag-bend setbacks, will also minimize the possibility of channel instability and geomorphic change.

Pipeline Hydrostatic Testing

Hydrostatic testing of the pipeline will require water withdrawal from rivers and/or streams. The pipeline will be tested in sections and may require multiple water withdrawals along the pipeline length. Withdrawal volumes and rates will be specified at later stages in the project. Withdrawal locations will also be selected with the aim of minimizing changes in affected water bodies. Water will typically be disposed of to designated vegetated areas. Any water disposed directly to receiving water bodies will be controlled to minimize flow impacts and ensure there are no quality related issues. .

3.6.4.6 Results for Key Question H-2: What Effect Will the Slurry Pipeline Have on Sediment Levels in Water Bodies?

Pipeline Right-of-Way

The clearing and excavation activities associated with the pipeline right-of-way will expose large volumes of sediment and may result in increased sediment transport from the disturbed areas. To reduce the exposure of sediments, construction activities and active work areas will be phased. Erosion and sediment control measures will also be implemented to limit the amount of sediment transported away from the construction area. Typical examples of erosion and sediment control practices are provided in Table 3.6-5. Throughout pipeline construction and operation, performance of the control measures will be monitored and maintenance and repairs performed as necessary. Any increases in sediment yield that occurs during construction will decrease once the disturbed areas are reclaimed and as vegetation is re-established through the operations and closure phases.

Table 3.6-5 Typical Erosion and Sediment Control

Type	Application	Examples
procedural	site management	minimum exposure of soils; perimeter control; site access management; stockpile management
	scheduling	optimize construction sequence; install BMPs early; restore and reclaim early
water management	various	diversions; proper design of drainage channels; management of shallow groundwater
erosion control	protection of exposed surfaces	mulching; tree and shrub planting; riparian zone preservation
	runoff control	grading; drains; diversion ditches and berms
sediment control	infiltration	buffer strips; hay bales
	settling	silt fences, rock berms, sediment traps and basins

Source: adapted from TAC 2005.

Pipeline Watercourse Crossings

The majority of watercourse crossings will be buried and will involve excavating across the channel, laying the pipe and backfilling the trench. Construction of the crossings will typically be conducted during low flow conditions to minimize water depths and the amount of suspended sediment generated and transported to downstream reaches. As with water levels, the effects on sediment levels are expected to be high during construction and to last only a short time, i.e., on the order of hours for small streams and up to a few days for very large streams. An initial flush of sediment is also expected at the onset of the wet season when high flows transport previously disturbed sediments to downstream locations. At locations where aerial crossings are used, construction activities will not affect the stream channel; therefore, no changes in sediment concentrations are expected.

No effects on sediment levels are expected in the streams during operation or post-closure provided revegetation and erosion control is applied and stream banks are stabilized. Design and construction specifications, e.g., minimum burial depths, size of armour material and sag-bend setbacks, will also minimize the possibility of channel instability and geomorphic change.

Pipeline burial depths beneath streams will be a minimum of 1.2 m below the bottom of the stream bed in rock material and 2 m below the stream bed in earth material. Site-specific scour depth calculations will be conducted for streams where maximum scour depth associated with the 1:100 year flood is expected to be greater than the minimum covers noted above. These estimates rely on-site specific characteristics including descriptions of substrate, channel cross-sectional shape, channel width, and design flows, etc. This information will be gathered and applied during detailed design phase of the pipeline.

Pipeline Hydrostatic Testing

No effects on sediment levels are expected from the withdrawal of water for hydrostatic testing. Effects associated with the disposal of test water will be minimized by release to vegetated areas and the use of sediment control measures at these locations. Any discharges directly to receiving water bodies will be controlled to minimize flow disturbances and ensure water quality discharge criteria are met.

3.6.5 Impact Analysis

3.6.5.1 Residual Impacts

During construction, the slurry pipeline right-of-way is expected to have negligible effects on flow and water levels, and low to moderate effects on sediment levels in receiving water bodies. Effects during operations and post-closure are expected to be negligible to low due to the proposed mitigation, erosion control measures, and revegetation of the right-of-way. The impacts will be short-term and the environmental consequence is therefore considered negligible to low. A summary of the residual impacts is provided in Table 3.6-6.

Construction of the buried pipeline watercourse crossings will result in high-magnitude impacts on flows and water levels in the immediate vicinity of the crossings, but low to negligible impacts downstream of the crossings. At crossings where instream construction is required, the impact on the sediment levels will be high but of very short duration (on the order of hours and days rather than months or years). The extent of the effects will be local, therefore the environmental consequence is considered moderate based on Table 3.6-4. No effects are expected during operation and post-closure provided that erosion control measures are implemented and the stream banks are stabilized.

The location for water withdrawal and discharge for hydrostatic testing will be determined upon detailed design. The volumes involved for testing will be limited and withdrawal and discharge impacts will be minimized based on stream sizes (using larger streams and rivers), receiving locations, quality and quantity of the water discharged. Any changes in flows, water levels and quality are expected to be negligible to low in magnitude. The extent of impacts will be local and of short-term duration. The environmental consequence associated with these types of effects is considered negligible.

Table 3.6-6 Residual Impact Classification for Hydrology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Changes in Streamflows and Water Levels In Receiving Water Bodies							
construction	negative	**right-of-way:** negligible **watercourse crossings:** high **hydrostatic testing:** negligible to low	local	short-term	yes	**right-of-way:** high (average conditions) **watercourse crossings:** low **hydrostatic testing:** low	**right-of-way:** negligible **watercourse crossings:** moderate[(a)] **hydrostatic testing:** negligible
operation/closure	negative	negligible	local	medium to long-term	yes	high (average conditions)	negligible
Issue: Changes in Sediment Levels In Receiving Water Bodies							
construction	negative	**right-of-way:** low to moderate **watercourse crossings:** high **hydrostatic testing:** negligible	local	short-term	yes	high (average conditions) **watercourse crossings:** low **hydrostatic testing:** low	**right-of-way:** low **watercourse crossings:** moderate **hydrostatic testing:** negligible
operation/closure	negative	negligible to low	local	medium to long-term	yes	high (average conditions)	negligible to low

(a) Very short-term (hours to days).

3.6.5.2 Prediction Confidence

The prediction confidence associated with changes in flows, water levels and sediment levels from development of the slurry pipeline is considered moderate to high. Moderate to high changes in these characteristics are primarily associated with construction of watercourse crossings and water withdrawals for hydrostatic testing. In both cases, the duration will be short which results in a maximum impact rating of moderate in terms of environmental consequence. The prediction confidence associated with the pipeline right-of-way and increased sediment levels is considered moderate based on erosion control measures that are available for limiting sediment transport from disturbed areas to receiving water bodies.

3.6.5.3 Monitoring

Routine visual inspections during pipeline construction will be conducted to ensure the effectiveness of erosion and sediment control measures. During instream works all control measures will be maintained and repaired as necessary to restrict sediment transport to off-site locations. Routine inspections of the pipeline right-of-way and watercourse crossing locations will also be conducted during operations to monitor and evaluate the effectiveness of erosion control measures, slope stability, stream bank stability and revegetated and reclaimed areas, as described in Volume B, Section 6. Water withdrawal rates and discharge rates will be controlled to minimize short term flow impacts and minimize any potential erosion effects. Monitoring during water withdrawal and disposal of hydrostatic test water will also ensure that regulatory and permit requirements are met at all times.

3.6.6 Conclusions

Construction of pipeline watercourse crossings may result in a moderate environmental consequence with respect to flows, water levels and sediment levels in affected water bodies. Construction of the pipeline right-of-way is expected to have a low to moderate effect on sediment levels, while hydrostatic testing will have a negligible effect on flows and water levels. The environmental consequence associated with other construction activities, as well as with operational and post-closure conditions, is expected to be negligible to low.

3.7 WATER QUALITY

3.7.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the slurry pipeline on sediment and water quality as per the Ambatovy Project Terms of Reference, which is described in Volume H, Appendix 1.

Construction of the slurry pipeline will involve clearing and excavation along the pipeline right-of-way as well as disturbance to the streambed at watercourse crossing locations. Channel disturbance during construction may affect water and sediment quality in downstream reaches. Water withdrawal and disposal will also be required for hydrostatic testing of the pipeline. The disposal of hydrostatic testing waters may affect water and sediment quality.

Field water quality data were measured along the pipeline route (Volume I, Appendix 9.1) and is summarized briefly in Section 3.7.3 below. The available baseline water quality is summarized in this section to evaluate potential effects of the Ambatovy Project (the project) on water quality.

3.7.2 Study Area

The local study area (LSA) for the slurry pipeline is shown in Volume A, Figure 7.2-2 and is the same as the LSA for hydrology assessment. The study area includes a 1 km buffer on both sides of the route, along the length of the pipeline corridor.

3.7.3 Baseline Summary

Field measurements were taken at watercourse stations along the proposed slurry pipeline route. The watercourses were slightly acidic to slightly alkaline with pH ranging from 6.2 to 7.6. Temperature values ranged from 17.5 to 27°C and dissolved oxygen results were generally at or below saturation.

Based on the Madagascar classification system for water quality, five watercourses were classified as Class A, which indicates that these watercourses are suitable for multiple uses, including swimming. Seven of the watercourses were classified as Class B, which indicates that although the water is suitable for non-contact recreation, it may not be suitable for swimming.

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. When CCME and EPA guidelines for aquatic life differed, the most stringent guideline from both jurisdictions was compared to observed water quality data. All results were within EPA and CCME aquatic life guidelines for pH and dissolved oxygen. South African Aquatic 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.

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

3.7.4 Issue Scoping

Water quality issues related to the project were identified through consultation with stakeholders. As described in Volume A, the issues were identified, tracked and summarized at a high level for consideration in the impact assessment.

The following aspects of the slurry pipeline could potentially affect the quality of surface watercourses along the proposed pipeline route:

- site preparation and clearing along the right-of-way of the pipeline;
- watercourse crossings by heavy equipment;
- trenching of watercourse crossings;
- hydrostatic testing of pipeline;
- accidental releases and spills; and
- pipeline decommissioning.

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-2 What Effect Will the Slurry Pipeline Have on Water and Sediment Quality?

3.7.5 Impact Assessment

The slurry pipeline route is about 195 km long and runs along a route from the mine site at Ambatovy to the processing plant at Toamasina near the coast (Volume A, Figure 7.2-2). The first 30 km of the route descends from the highlands to the coastal plain. The remaining portion of the route runs from the base of the escarpment, across the coastal plain and finally to the plant. The route crosses numerous watercourses (streams, rivers and wetlands) that could be potentially influenced by construction, operation and post-closure activities related to the slurry pipeline.

During the construction phase, site preparation and clearing has the potential to result in increases in suspended sediment concentrations in receiving watercourses and water bodies. Suspended sediments may also be introduced during installation of the pipeline at watercourse and water body crossings. Changes in suspended sediment concentrations are addressed in the Hydrology Section (Volume C, Section 3.7). The bed sediments disturbed during installation of the pipeline may release water quality substances that are typically associated with particulate material.

Water withdrawals for hydrostatic testing of the pipeline will be required during the construction and operations phases. Water withdrawals and disposal of hydrostatic waters have the potential to cause changes in flow and local hydraulic characteristics of the watercourse or water body. The flow and hydraulic characteristics changes could potentially cause mobilization of bed sediments and sedimentary-bound contaminants to the water column.

If a pipeline failure occurs, releases of substances into receiving watercourses and water bodies could potentially change surface water and bottom sediment quality downstream of the pipeline crossing. Spills during construction or leaks during operations also have the potential to affect water quality.

Finally, erosion during the decommissioning phase could potentially introduce sediments and water quality substances associated with sediments into water bodies. Changes in water quality, particularly for metals and nutrients that tend to be adsorbed to sediment particles, may cause changes in sediment quality in receiving watercourses and water bodies.

3.7.5.1 Assessment Methods

In general, effects on water quality associated with construction, operation and decommissioning activities related to the slurry pipeline are expected to be low because of the use of appropriate mitigations. The potential changes in water and sediment quality are addressed in the assessment methods under the following components of construction, operation and decommissioning of the pipeline:

- right-of-way;
- watercourse and water body crossings;
- hydrostatic testing; and
- failure or spill.

The potential for additive changes in water and sediment quality due to the slurry pipeline and other components of the project, including the mine, process plant and tailings facility, is also assessed.

Right-of-Way

Construction of the pipeline right-of-way will involve land disturbance including removal of vegetation, excavation and backfilling, and compaction. These activities will result in higher runoff rates from the disturbed areas which have the potential to increase loads of sediment and water quality substances in the runoff compared to baseline conditions. The percentage of disturbed area within a given basin, however, is typically very small relative to the overall drainage area. Changes in water and sediment quality in receiving streams are expected to be negligible provided that best management practices are used and natural drainage paths are maintained. Any changes in water or sediment quality due to increases in runoff during construction will return to baseline levels once the disturbed areas are reclaimed and as vegetation is re-established through the operations and closure phases.

Watercourse and Water Body Crossings

Construction of the slurry pipeline will involve about 100 watercourse and water body crossings along the route. As discussed in the Hydrology Section (Volume C, Section 3.6), a detailed assessment of each crossing prior to construction will identify highly sensitive areas. Impacts on these sensitive areas will either be avoided or minimized by fine tuning the route of the pipeline, using an aerial crossing or applying additional appropriate mitigations.

Based on the initial crossing assessment, aerial crossings are expected to be required at two rivers as well as several smaller watercourses in deep and narrow valleys (Volume C, Section 3.6). The pipeline crossing on the Ivondro River south of the tailings facility and plant will be directionally drilled. In these cases, construction activities will not affect the stream channel; therefore, no changes in water or sediment quality are expected to occur.

Most crossings will be buried and will involve excavating across the channel, laying the pipe and backfilling the trench. Construction of the crossings will typically be conducted during low flow conditions to minimize the amount of suspended sediment generated and transported to downstream reaches. Best management practices will be used to control erosion and minimize sediment from entering the water via runoff from disturbed areas. Water quality substances associated with particulate matter (i.e., nutrients and metals) may increase temporarily due to their release from disturbed bed material. The duration of these increases is expected to be short (i.e., hours for small crossing and a few days for larger crossings); therefore, the overall predicted effects on water quality during construction are negligible.

No effects on water or sediment quality are expected in the streams during operation or post-closure due to implementation of best management practices, and stabilization and restoration of stream banks. Design and construction specifications, as discussed in the Hydrology Section (Volume C, Section 3.6), will also minimize the possibility of sediments being introduced as a result of channel instability or geomorphic change.

Hydrostatic Testing

Hydrostatic testing of the pipeline will require water withdrawal from rivers and/or streams. The pipeline will be tested in sections and may require multiple water withdrawals along the pipeline length. Withdrawal volumes and rates will be specified at later stages of the project. Withdrawal locations will also be selected with the aim of minimizing potential changes in water and sediment quality in affected watercourses and water bodies. Water will typically be disposed of to designated vegetated areas but may also be disposed directly to watercourses and water bodies. However, before any discharge, the quality of all disposed water will meet required effluent criteria, which will be dependent on the following conditions:

- receiving environment (i.e., vegetated areas, watercourse or water body);
- discharge volume (flow rate and duration) and concentrations; and
- assimilative capacity of receiving environment (i.e., flow and water quality concentrations if receiving environment is a watercourse).

Failure or Spill

Pipeline failure 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 release or spill. The risk of pipeline failure will be minimized by using proper design and construction methods. During operations, a monitoring program will be able to:

- detect substantial pipeline failures immediately;
- detect minor failures (i.e., a leak in the pipeline); and
- identify the potential for pipeline failures.

Although no accidental releases or spills were assessed in the water quality section, mitigations have been identified to reduce and minimize the effects of these events. Furthermore, Environmental Management Systems will be developed and implemented to minimize potential occurrence, characterize water quality changes, and reduce likely effects, if such an event should occur.

3.7.5.2 Mitigation

To mitigate the effects on water and sediment quality, the Ambatovy Project will implement the following measures for the slurry pipeline:

- selection of construction season, timing and method to minimize sediment generation at watercourse and water body crossings;
- further assessment of proposed crossings just prior to construction to determine the need for minor adjustments in the pipeline route to avoid or minimize impacts to sensitive areas;
- use of erosion control measures during construction and decommissioning phases;
- revegetation and other erosion control measures along the pipeline right-of-way following construction;
- disposal of hydrostatic test waters into either watercourses or water bodies with sufficient volumes and/or flow rates to maximize dilution or vegetated areas of sufficient size to minimize impacts;
- routine inspection of the disturbed areas and pipeline crossing at watercourse or water body locations;
- implementation of best management practices for handling and storing all hazardous materials; and

- development and implementation of an effective Emergency and Spill Response Plan as a component of an overall Environmental Management System.

3.7.6 Impact Analysis

3.7.6.1 Prediction Confidence

The prediction confidence associated with changes in water and sediment quality from development of the slurry pipeline is considered to be moderate to high. The potential for changes in water and sediment quality are primarily associated with construction and decommissioning of pipeline crossings at watercourse or water body locations and water withdrawals for hydrostatic testing. The duration of these activities will be short; therefore, the effect of change in average water quality conditions will remain negligible.

The proposed mitigation, such as erosion control measures and decommissioning methods are based on standard practices, and are known to be effective when implemented properly. The implementation of these measures is relatively simple. Therefore, there is medium to high confidence in the success of the mitigation measures. The prediction confidence associated with changes in water and sediment quality due to runoff is considered moderate based on best management practices and erosion control measures that are available for limiting sediment transport from disturbed areas to receiving water bodies.

3.7.6.2 Monitoring

Routine inspections during pipeline construction will be conducted to verify the effectiveness of erosion and sediment control measures. Suspended sediment concentrations will be monitored during instream works. Routine inspections of the pipeline right-of-way and pipeline crossings at watercourse or water body locations will also be conducted during operations to monitor and evaluate the effectiveness of erosion control measures, slope stability, stream bank stability and revegetated and reclaimed areas, as described in Volume B, Section 6. Careful observations and operations during water withdrawal and disposal for hydrostatic testing will also ensure that impacts are minimized.

3.7.7 Conclusions

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

- Changes in water and sediment quality due to the construction, operations and closure of the pipeline will be negligible due to mitigations.
- Through design, construction practices and routine inspections, potential effects of the pipeline on water and sediment quality will be minimized.
- Any potential leaks within the pipeline will be rapidly detected through leakage detection systems and routine inspections. This will minimize any changes in water and sediment quality. The remote possibility of a catastrophic failure will be addressed within an Emergency and Spill Response Plan.

3.8 VISUAL AESTHETICS

3.8.1 Introduction

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

3.8.2 Study Area

The slurry pipeline Local Study Area (LSA) for visual aesthetics is the same as the general study area presented in Volume A, Figure 7.2-2. It includes a 1 km buffer around the preliminary pipeline route centreline. This LSA passes through the Torotorofotsy Ramsar Site and the planned Mantadia-Zahamena conservation area, and immediately adjacent to Mantadia National Park.

3.8.3 Baseline Summary

The pipeline route traverses a variety of landscapes, including the central highlands and coastal plains. It crosses through the Torotorofotsy Wetlands complex, adjacent to Mantadia Park in some locations, and parallels a portion of the Madarail system for a short distance. The pipeline will have many potential viewpoints along its route, and passes through scenic landscapes characterized by steep topographic features, small and large waterways, and vegetation ranging from primary forest to barren dune areas.

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 3.8-1. Baseline views from key viewpoints SP1 to SP4 are presented in Volume I, Appendix 11.1, Attachment 1, Photographs 10 through 13.

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

Table 3.8-1 Key Viewpoints: Slurry Pipeline Route

Viewpoint Number	Viewpoint Name	GPS Location (UTM Zone 39S)	Possible Viewers	Baseline View Characteristics
SP1	Torotorofotsy Wetlands	E 222731 N 7910838	local residents ecotourists	relatively natural and undisturbed; heavy vegetation cover
SP2	village of Sahavolo	E 274500 N 7930600	local residents	at village of Sahavolo along pipeline, characterized by agricultural land use areas
SP3	Vohitra River crossing	E 337367 N 7955595	local residents	relatively natural with heavy vegetation cover; small town adjacent
SP4	Ivondro River crossing	E 0316115 N 7980851	local residents	wide, scenic river with moderate bank vegetation cover, prominent signs of human use including nearby road corridor/bridge

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

3.8.4 Issue Scoping

In public consultations, the main question regarding aesthetics has been: how will changes in visual aesthetics affect tourism? This question has been raised both by local residents and by the National Association for the Management of Protected Areas (ANGAP). Potential changes that will be seen by local residents, as well as tourists and other visitors include:

- removal of vegetation for the RoW and maintenance road: this will extend from construction through operations, except for some sections in the Torotorofotsy Ramsar site and Mantadia-Zahamena Conservation Area, which will be re-forested immediately following construction;
- the presence of temporary camp facilities during construction;
- generation of visible clouds of dust in dry periods, as well as some locally visible fossil fuel emissions during construction; and
- night time lighting during construction.

The key question for visual aesthetics is:

Key Question VA-1 What Effect Will the Slurry Pipeline Have On Visual Aesthetics?

Visual effects will occur during the construction, operation and closure phases of the project, as shown in the linkage diagram for visual aesthetics (Volume H, Appendix 9).

3.8.5 Impact Assessment

During the construction phase, vegetation will be cleared and a linear corridor of between 25 and 100 m will be developed to include the pipeline and a parallel access road. Access roads will be constructed to facilitate the transport of construction materials to the site and allow for access of construction personnel. Laydown areas and camp areas will be constructed temporarily, and progressively reclaimed as soon as feasible. During the operations phase, the major access routes could be maintained, in accordance with the wishes of local communities and the needs of the project. A linear scar from the preparation of a flat right-of-way (RoW) of adequate width through hilly terrain will remain as a relatively prominent visual feature during construction and operations. This feature will be fully reclaimed with native species or other species appropriate to local land uses at closure unless authorized access is desired by locals within particular areas. Some sections of the pipeline, including forested areas of the Torotorofotsy Ramsar Site and Mantadia-Zahamena Conservation Area, will be reclaimed immediately following construction.

3.8.5.1 Assessment Methods

Topographic information, photographs and on-site observations were used to describe current views. A general understanding of the pipeline route and cross-sectional requirements for the pipeline RoW were used to assess potential visual effects qualitatively. Experience in the evaluation of the visual effects of other pipelines and linear corridors was applied to assess a range of potential impacts in the context of Madagascar.

3.8.5.2 Assessment Criteria

The assessment criteria used for visual aesthetics are presented in Table 3.8-2.

Table 3.8-2 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

3.8.5.3 Mitigation

As much of the pipeline as possible will be buried. Although a road will be built along much of the route, in some areas the pipeline will be engineered with extra-thick walls to allow for the regrowth of endemic vegetation across the RoW immediately after construction. These areas will include sections of the pipeline in forested areas through the Torotorofotsy Ramsar site and through the Mantadia-Zahamena Conservation Area.

The number of new linear corridors developed will be minimized by using existing road access to the route and/or planning with other land users to ensure new roads meet their needs and no additional future access roads will be needed.

Dust control measures, such as the use of water tankers, will be used along access roads in hot, dry weather.

During very wet weather, construction activity will be minimized. Any damage from severe road rutting and erosion will be repaired/reclaimed after the wet season.

Construction will be minimized on side slopes, which necessitate a wider footprint and increase erosion risk.

Cleared areas such as camps and staging areas will be promptly revegetated following construction.

3.8.5.4 Results

The proposed project would result in two types of potential impacts on visual resources:

- short-term impacts resulting from construction activities and related materials and equipment staging; and
- long-term impacts from pipeline route opening of the landscape.

Groups of people likely to be viewing the slurry pipeline RoW include local residents, passers-by along access routes traversed by the pipeline, and tourists, particularly those visiting the Torotorofotsy Wetlands. The visual effect of the slurry pipeline on people will vary widely based on personal perception, and may affect the enjoyment of the natural aesthetic qualities of the area. For viewers within the viewshed, perceptions of the aesthetic effects of the mine may be affected by:

- the surrounding landscape, including landforms, vegetation and general level of modification;
- the slope, vegetation cover and texture of the RoW surface in contrast to that of the surrounding landscape;
- the distance between the observer and the impact;
- 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.

Effects are summarized below for each project phase.

Construction

The existing visual quality of the project area is influenced by historical and current land uses, including tavy agriculture. However, the remoteness of much of the route has meant that urban and industrial development occurs along very little of the route, and even linear access corridors are very limited. Therefore, the presence of the pipeline route will be a contrast to the surrounding aesthetic conditions.

Landform and vegetation changes will introduce contrasts in form, line, colour and texture along the RoW. The rough nature of topography along most of the slurry pipeline route will allow unobstructed views of equipment and construction activities only within local topographic basins. Dust generated from these activities, as well as the presence of equipment, staging areas, camps and construction vehicles, will be observed from within the same valley as the pipeline is passing through, as well as the basins that are traversed by access roads to the route, and surrounding high topographic points. However, the entire length of the LSA has a relatively low population density. Roadways (including Route National (RN) 2 and access roads and trails close to Torotorofotsy, Analamazaotra and Mantadia) will be the most sensitive to the temporary visual impacts.

The greatest visual impacts are expected to occur from construction scars along steep hillsides that require especially wide construction rights-of-way of up to 100 m. The potential for erosion in high-rainfall seasons poses a risk of additional aesthetic impacts extending downhill from the route.

Operation

Progressive reclamation of construction staging areas, camps, and the surface of the pipeline route will substantially reduce visual impacts during the operations phase. The success of erosion control measures will be critical to keep the visual impacts of the pipeline low throughout the operation phase.

Re-forestation of the RoW immediately after construction in the Torotorofotsy Ramsar Site and Mantadia-Zahamena protected area will reduce visual effects in these key areas during the operation phase.

Closure

The slurry pipeline will be left in place (buried) at the time of closure. Exposed sections will be removed and disposed of, unless a regional planning process determines that there is an advantage to leaving them in place. The road along the slurry pipeline and associated access routes and bridges that have been constructed will usually be left in place but could be replaced or decommissioned, depending on the decision of local stakeholders and government planners at the time of closure (most local peoples favour the maintenance of such access routes at present).

3.8.5.5 Impact Analysis

Residual Impacts

Following mitigation, the residual effects during each project period are summarized in Table 3.8-3.

Table 3.8-3 Potential Effects and Residual Impacts for Visual Aesthetics

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	clearing of land and changes in landforms (pipeline route and access roads)	minimize construction along steep slopes; progressive reclamation and regular maintenance; thick walled pipeline so route can be reforested in critical locations	low-magnitude modification of visible landscape from key viewpoints
	changes in visible facilities and construction machinery	remove and reclaim after construction	negligible impact on key viewpoints
	changes in visible emissions and dust	dust control measures	negligible-magnitude effects which may be visible from longer distances
operations	clearing of land and changes in landforms	progressive reclamation	low-magnitude modification of visible landscape from key viewpoints
closure	clearing of land and changes in landforms along the row	full reclamation	negligible / long-term modification visible landscape
	changes in visible pipeline	decommissioning and removal of visible sections of pipeline	none

Clearing of land and changes to localized topography will occur along the pipeline RoW and associated access routes during construction. Progressive reclamation will occur as construction proceeds. The magnitude of landform visual impacts is considered moderate during construction and low during operations. The geographic extent of impacts is local, as rough topography obscures the views of most areas outside the LSA.

The most prominent impacts (during construction) are short-term, while the lower-magnitude impacts of the operations phase are medium-term in duration. Landform impacts are not reversible, as the landscape will not be returned to its initial state. Viewing frequency is medium, as the pipeline is relatively long and viewers will intermittently be at specific viewpoints from which the project will be visible. Key views from the Torotorofotsy Ramsar Site and Mantadia-Zahamena Protected Area will be improved through reclamation immediately after construction, so that new forest is established by early in the operations phase. Overall, the environmental consequence for visual effects is low for the construction and operation phases, and will be negligible after closure.

The construction of facilities along the pipeline route will present an impact low in magnitude, since such facilities will appear out of place in a rural setting but will be relatively small in size. Effects are local in extent, short-term in duration (during construction only) and are reversible. Viewing frequency is expected to be low due to the low number of viewpoints from which the facilities will be visible. The overall environmental consequence of pipeline construction camps and facilities for visual aesthetics will be negligible.

Release of dust and visible emissions will occur during construction along roadways to the pipeline and along the pipeline RoW. The visual effects from these releases will have an impact negligible in magnitude. Mitigation such as dust control measures will be implemented. Effects are regional in extent because dust and other emissions may be visible from outside the LSA. Effects are short-term in duration (almost all traffic will occur during construction) and are reversible. Viewing frequency is expected to be medium. The overall environmental consequence of emissions and dust for visual aesthetics will be negligible.

An overall residual impact classification for visual aesthetics for each key issue and each phase of the project is presented in Table 3.8-4.

Prediction Confidence

The baseline status of topography in the LSA is well understood, and general information about the construction measures along the pipeline RoW has been provided. Impact ratings are dependent on the success of the mitigations proposed, including erosion control under challenging conditions. Overall, the prediction confidence for this assessment is considered medium to high.

Table 3.8-4 Residual Impact Classification for Visual Aesthetics

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Effect of Pipeline Landforms on Visual Aesthetics							
construction	negative	moderate	local	short-term	no	medium	low
operation	negative	low	local	medium-term	no	medium	low
closure	negative	negligible	local	long-term	no	medium	negligible
Issue: Effect of Pipeline Facilities on Visual Aesthetics							
construction	negative	low	local	short-term	yes	low	negligible
Issue: Effect of Visible Emissions and Dust on Visual Aesthetics							
construction	negative	negligible	regional	short-term	yes	medium	negligible

Monitoring

No monitoring is proposed specifically for visual aesthetics. Monitoring of the effectiveness of erosion control measures and reclamation success, which have important implications for visual effects, are described in Volume C, Section 6.

3.8.6 Conclusions

The slurry pipeline will have low environmental consequences for visual aesthetics as a result of the construction scar to be left along the RoW and along any new access routes to the RoW. This effect will be greatest during the construction phase, when reclamation has not yet been initiated. The most serious impacts on views likely to be seen by ecotourists, in areas like the Torotorofotsy Ramsar Site and Mantadia-Zahamena Corridor, will be progressively reforested after pipeline installation. The mitigation of both operations-phase and construction-phase effects will depend on the success of reclamation and erosion control applied all along the route.

Other effects of negligible consequence during construction will be the presence of facilities along the pipeline route and the release of dust and emissions which may be regularly visible from outside of the LSA. The greatest effects are likely to be during the construction phase, on ecotourists in the Torotorofotsy area, who will have specific notions about desirable views in the area and will not expect to see a pipeline, or construction activity in the Ramsar site.

4.1 FLORA

4.1.1 Introduction

This section of the Environmental Assessment (EA) provides an evaluation of potential effects of the proposed Ambatovy Project (the project) on flora in the slurry pipeline 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 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 including forest rehabilitation activities;
- assess residual impacts to flora through pipeline construction, operation and closure activities; and
- provide details on flora monitoring and management that include participation of stakeholders.

4.1.2 Study Area

The slurry pipeline Local Study Area (LSA) includes the approximately 195 km slurry pipeline footprint, plus a 1 km buffer on either side of the proposed pipeline route, from the ore body complex at the mine site to the plant site near Toamasina (Volume A, Figure 7.2-2).

The vegetation along the pipeline route is variable but can generally be classed into three primary zones. The western zone occurs within a primary and degraded humid evergreen forest corridor and also passes alongside the Torotorofotsy Wetlands. The central zone is dominated by tavy matrix and passes around primary and degraded forest fragments within the Mantadia-Zahamena Conservation Corridor. The eastern zone contains secondary vegetation and agricultural areas.

4.1.3 Baseline Summary

The following provides a summary of the baseline flora results in the slurry pipeline 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

The dominant vegetation type along the slurry pipeline is tavy (30,778 ha or 85% of the LSA). This class is largely represented by cleared forest and scattered shrubby vegetation or trees, often dominated by *Ravenala madagascariens*. This species is endemic to Madagascar but is widespread and used most frequently for the walls and roofs of buildings (Rouquette 2002).

The second most common vegetation class is degraded primary forest (1,537 ha or 4% of the LSA). It represents either heavily logged forest or very small forest patches that have been invaded with exotic species or have been altered in terms of species composition and abundance due to edge effects and associated changes in lighting levels.

Primary forest is the third most dominant vegetation type along the slurry pipeline corridor (1,403 ha or 4% of the LSA). It primarily occurs within the overlap area with the mine site LSA and within the Mantadia-Zahamena corridor. This is zonal forest that may have been sparsely logged but is still structurally and floristically intact, and contains an assemblage of species that is generally characteristic of a pristine forest.

There is a relatively small amount of azonal forest, azonal type transitional forest, and transitional forest at the western end of the slurry pipeline LSA where it ties in with the mine site facilities.

4.1.3.2 Torotorofotsy Wetlands Vegetation

The Torotorofotsy Wetlands are located southeast of the proposed mine and have been declared as a Ramsar site by the Madagascar government and by international and national conservation organizations (Ramsar 2005).

The Torotorofotsy Wetlands primarily consists of herbaceous marsh vegetation on organic soils (Wetlands International 2005). On the Torotorofotsy Wetlands fringe and along creeks and rivers within the wetlands is a small amount of marsh edge vegetation on nutrient-poor, inorganic soil. This marsh edge forest contains dominant to sporadic cover of *Pandanus*. Scattered pasture land, eucalyptus plantations and groves, and a small but significant portion of rice paddies also exist in and around the edges of the wetlands.

4.1.3.3 Vegetation of the Mantadia-Zahamena Area

The Mantadia-Zahamena Conservation Corridor is covered with a heterogeneous mix or matrix of vegetation. This matrix contains both non-forested and forested formations. The non-forested component is the result of past disturbances and natural succession. The non-woody secondary vegetation is not of particular ecological interest in terms of unique habitat or species. The forested fragments consist of primary or near-primary forest, degraded forest, secondary forest (savoka), *Eucalyptus* forest and residual forest.

4.1.3.4 Vulnerable, Threatened and CITES Species

Five endangered, vulnerable or near threatened species, based on International Union for the Conservation of Nature (IUCN), were found within the Mantadia-Zahamena Conservation Corridor. The majority of these species are widespread but are still at risk to extirpation or extinction because their populations are in decline due to their value as a source of fuel (firewood) and building materials. One species has a more restricted geographic range and is at risk to extirpation or extinction from agricultural or human settlement activities.

Three species are listed Appendix 2 of CITES which accounts for internationally traded species of concern. The level of trading for these species ranges between nil and low and therefore currently they do not appear to be threatened.

4.1.3.5 Plant Species Richness

In total, 66 species were identified along the slurry pipeline corridor adjacent to the Torotorofotsy Wetlands. A total of 333 plant species were identified in surveys carried out within the Mantadia-Zahamena Conservation Corridor between kilometre points R22+000 and R29+000.

4.1.3.6 Species Endemism

No locally endemic species were identified within the area of Torotorofotsy Wetlands and the slurry pipeline corridor route. This is largely due to the disturbed nature of the area.

Within the Mantadia-Zahamena Conservation Corridor, 257 of 333 species were classed as endemic to Madagascar and 63 as regionally endemic. No species were listed as local endemics. An additional 13 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-related impacts on flora were based on the outcome from 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 along the pipeline route are:

- loss or alteration of native primary forest with main concern focused in the Mantadia-Zahamena corridor; 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 questions for flora are:

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

Key Question FL-2 What Effect Will the Slurry Pipeline Have on the Introduction of Exotic and Unwanted Plant Species?

Project-related activities anticipated to result in changes to flora include construction and operation of the slurry pipeline, and site reclamation at closure. Direct losses to plant communities will result from pipeline development activities. Natural plant communities may also be indirectly affected by the project from the encroachment of exotic and unwanted species.

These effects are primarily the result of construction, and secondarily, operation activities. Positive effects to flora are expected as a result of closure activities and implementation of the mitigation strategy. All project-related effects to flora may have implication for visual aesthetics, protected areas, land use, fauna and biodiversity.

The issue of species loss (species extirpation or extinction) was considered at the initial and mid-stages of the slurry pipeline assessment. Because of the importance of maintaining species diversity and avoiding species loss, this issue was addressed through elements of project design (routing), rather than through post-construction mitigation. Much of the work involved to reduce or eliminate potential environmental impacts along the pipeline route are outlined in Volume B, Section 1, which describes the various project alternatives considered. This consideration included focused consultation sessions with non-governmental organizations (NGOs) and government in 2004 (Volume A, Section 6). The key element in addressing the issue of species loss was in selecting a suitable route that not only met environmental criteria, but also accommodated socioeconomic, engineering and financial criteria. After more than 10 routes through the corridor were considered and analyzed, the final route was chosen to minimize native habitat loss. This habitat avoidance approach to mitigation eliminated the need to analyze impacts at the plant species-level. All vulnerable or endangered species found within the slurry pipeline LSA are also found in other areas of the region; therefore, these species are not threatened with extirpation or extinction. During the construction phase there will be additional opportunities to refine the route even further and reduce the amount of native habitat loss to an absolute minimum. The impact analysis below, therefore, focuses in community (habitat) level impacts.

For each potential effect associated with project-related activities of the slurry pipeline, a linkage analysis is provided, followed by assessment methods and criteria, mitigation, impact analysis, residual impact classification and monitoring. A linkage diagram for flora issues is shown in Volume H, Appendix 9.

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

During the construction phase, 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 installation of the slurry pipeline.

Impact assessments were conducted for the period of construction through operation and the closure phase. 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, Structure and Diversity

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

Several mitigations are planned to reduce the magnitude, geographic extent, and duration of direct impacts from the project on flora in the slurry pipeline LSA. The main areas of mitigation include:

- Maximize avoidance of native forest vegetation through pipeline alignment design.
- Establishment of research-based reclamation trials.
- Reclamation using native species and effective soil treatments in designated areas.
- Reclamation strategies that support natural habitat restoration, where this fits into local land use priorities (i.e., Mantadia-Zahamena corridor).
- Rapid establishment of prescribed vegetation cover following pipeline installation.
- Careful consideration applied upon development of access routes, and implementation of an access management plan in biologically sensitive areas.

- Adherence to a conservation and reclamation plan.

4.1.5.4 Results

Direct Losses to Plant Communities Within the Slurry Pipeline Local Study Area

Direct losses to native plant communities resulting from construction of the slurry pipeline will amount to 938 ha (3% of the slurry pipeline LSA) (Table 4.1-2). Of this portion, the non-forest slash and burn/tavy matrix vegetation type will be the most affected with a loss of 800 ha (3% of this class within the LSA). This vegetation type is inherently a highly disturbed land class. The next most affected class is the degraded/heavily logged zonal forest vegetation type with a loss of 49 ha (3% of this type). Other vegetation types affected include 39 ha of woodlot/plantation (6%), 23 ha of zonal forest (2%) and 5 ha of transitional forest (3%). Several other classes affected represent a very small portion of the overall impact disturbance to vegetation within the slurry pipeline LSA. No direct impacts will occur to the azonal, azonal type transitional and marsh edge forest vegetation types.

4.1.5.5 Impact Analysis

Residual Impacts

Residual Impacts to the Transitional Vegetation Type from Clearing Activities

Despite mitigation, activities related to construction of the slurry pipeline will result in vegetation losses, primarily to areas that are already highly disturbed. However, at the western end of the pipeline within the vicinity of the mine site, rare habitat types exist including the transitional forest vegetation type. Within this zone, there will be a loss of 5 ha of transitional vegetation (3% of this vegetation type). The magnitude of the losses is deemed low, local in extent, of long-term duration and resulting in a low environmental consequence (Table 4.1-3).

Although the loss to transitional vegetation is rated as being low, it is unique to the region and therefore deserves special attention. Mitigation and monitoring to deal with these direct effects are outlined in detail within the mine EA Volume B, Section 4.1.

Table 4.1-2 Change in Vegetation Type Area as a Result of Site Clearing Within the Slurry Pipeline Local Study Area

Vegetation Type	Base Case	Impact Case	Change	Change
	ha	ha	ha	%
Forested Vegetation				
azonal forest	81	81	0	0
azonal type transitional forest	36	36	0	0
transitional forest	151	146	-5	-3
zonal (primary) forest	1,403	1,380	-23	-2
degraded/heavily logged zonal forest	1,537	1,488	-49	-3
woodlot/plantation	693	654	-39	-6
marsh edge forest	26	26	0	0
forested subtotal	*3,927*	*3,811*	*-116*	-3
Non-Forested Vegetation				
non-forest slash and burn/tavy matrix	30,778	29,978	-800	-3
beach ridge complex	70	68	-2	-2
coastal shrubland/grassland complex	227	225	*-2*	-1
herbaceous vegetation cover and pasture	308	306	-2	-1
marsh herbaceous vegetation	406	401	-5	-1
rice paddies	278	269	-9	-3
non-forested subtotal	*32,067*	*31,247*	*-820*	-3
Non-Vegetated Class				
industry (buildings or exploration areas)	13	13	0	0
quarry	12	12	0	0
access corridor (road/rail)	8	8	0	-1
village	120	118	-2	-2
river/water	128	128	0	0
non-vegetated subtotal	*281*	*279*	*-2*	-1
total	**36,275**	**35,337**	**-938**	**-3**

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

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

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
losses or alterations to (natural) plant communities							
azonal forest	neutral	n/a	n/a	n/a	n/a	n/a	n/a
azonal type transitional forest	neutral	n/a	n/a	n/a	n/a	n/a	n/a
transitional forest	negative	low	local	long-term	irreversible	medium	low
zonal forest	negative	moderate	local	medium-term	reversible	high	low
marsh edge forest	neutral	n/a	n/a	n/a	n/a	n/a	n/a
marsh herbaceous vegetation	negative	low	local	medium-term	reversible	high	low

n/a Not applicable (neutral impacts not classified).

Residual Impacts to Zonal Vegetation

A total of 23 ha of zonal forest will be impacted from slurry pipeline construction activities (2% of this vegetation type) resulting in a low magnitude. The extent of effects will be restricted to the local area but will extend beyond the life of the project (long-term duration). Effects are generally considered irreversible; however, with the use of native species during reclamation, the area will exhibit similarities to pre-disturbance conditions when it reaches maturity. Based on this, the environmental consequence for clearing zonal vegetation within the slurry pipeline LSA is predicted to be low.

Reclamation

To address the concern of native forest habitat loss, the proponent has made a commitment to reclaim sections of the pipeline rights-of-way to a zonal forest status (or as close to this state as technically and ecologically possible) using native species. These sections occur immediately east of the mine footprint (R0+000 to R2+000) and within the Mantadia-Zahamena Conservation Corridor (R16+000 to R26+000; Volume C, Section 4.1) amounting to 60 ha in total.

Two general methods of reclamation will be used along the slurry pipeline route. For a majority of the length where areas have been previously disturbed, the primary reclamation objective is to control erosion. Within sections where transitional and zonal forest exist (i.e, between R0+000 and R2+000 and between R16+000 and R26+000) habitat rehabilitation will incorporate the use of native species with the long-term objective of re-establishing native primary forest.

Little is known about re-establishing native tropical forest vegetation in Madagascar and therefore revegetation trials will be established to increase this knowledge base and develop pragmatic reclamation solutions. The lessons learned from these trials will be made available to other reclamation efforts planned by other organizations in the Mantadia-Zahamena corridor. Additional details of the slurry pipeline reclamation program are provided in Volume B, Section 6.

Prediction Confidence

The confidence in the impact predictions are related to:

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

Flora impact predictions are based on the spatial distribution of vegetation types within the pipeline site LSA. The baseline vegetation map was developed from a combination of air photograph 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.

It is assumed that forest rehabilitation efforts within the Mantadia-Zahamena Conservation Corridor will be successful in regenerating disturbance areas to a semi-natural habitat status. Adaptive management of reclamation will occur to improve reclamation methods with experience.

Monitoring

A vegetation monitoring program will be implemented to ensure that vegetation rehabilitation efforts are successful and that the vegetation cover is maintained and erosion control measures are working effectively.

4.1.5.6 Conclusions

Avoidance of native forest vegetation through pipeline alignment design provides the most effective mitigation to limit native plant community losses. Of the total footprint, over 96% of the pipeline right-of-way occurs in areas that have already been severely disturbed or impacted by human settlement. A total of 116 ha of forest land (12 % of total LSA) will be affected from the construction and operation of the pipeline. Of this portion, native forest vegetation considered of good quality amounts to 28 ha (5 ha of transitional forest and 23 ha of zonal forest) while disturbed or managed forests amount to 88 ha (49 ha of degraded or heavily logged forest and 39 ha of woodlot plantation).

To help mitigate the effects to native forest vegetation, 60 ha of the pipeline corridor within regionally important habitat zones will be reclaimed to a forest state using native species. This initiative will complement other reclamation projects initiated by other organizations in the region.

Along sections of the pipeline where the reclamation goal is to achieve a grass type vegetation cover, monitoring will continue until erosion risks are minimized. In the sections designated for reforestation, monitoring will continue for a longer period to ensure the trajectory of forest succession is proceeding along the desire pathway.

4.1.6 Key Question FL-2 What Effect Will the Slurry Pipeline Have on the Introduction of Exotic and Unwanted Plant Species?

Roads (including access corridors associated with pipelines) contribute to increases in the spread of exotic species (Trombulak and Frissell 2000). Edge effects from forest clearings increases light which in turn increases the density of adaptive or early successional species that prefer high light levels such as within disturbance areas (Mehrhoff 1989). Exotic or unwanted (weeds) species typically increase along disturbed forest edges as a result of preferred habitat conditions, stressing or removing native species, and providing a contact zone for dispersal (Trombulak and Frissell 2000).

4.1.6.1 Assessment Methods

Assessing the potential effects of the pipeline on exotic and unwanted species (i.e., weeds) was done in a qualitative manner.

4.1.6.2 Assessment Criteria

The assessment criteria used for exotic and unwanted species are presented in Table 4.1-4.

Table 4.1-4 Impact Description Criteria for Exotic and Unwanted Plant Species

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
neutral: no change in exotic and unwanted species **negative:** a change in exotic and unwanted species	**negligible:** no measurable effect on exotic and unwanted species **low:** low amounts of exotic and unwanted species **moderate:** moderate amounts of exotic and unwanted species **high:** high amounts of exotic and unwanted species	**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

4.1.6.3 Mitigation

The primary mitigation to reduce or eliminate the invasion of exotic or unwanted plant species due to project-related effects is through the implementation of an invasive species control program. This invasive species control program will be made operational only along targeted sections of the pipeline route, where the conservation of adjacent native habitats is desired by Malagasy society.

4.1.6.4 Results

There is a high potential for the spread of weeds or unwanted species along the slurry pipeline corridor. Currently the risk has already been observed within the Mantadia-Zahamena Conservation Corridor with the presence of Eucalyptus trees and other exotics (13 species identified during the field surveys), which can pose a threat to the area's ecological integrity. Increasing the amount of edge along the perimeter of primary forest stands will also support and increase the probability of invasion by heliophytic (sun-adapted) vines like lianas. These vines may permanently alter forest stand succession by spreading into primary forest stands as vegetation is cleared during the construction phase under increased sun conditions and where there are few competitors. The numbers of vehicles and machinery will increase sharply as pipeline construction is initiated. Vehicles provide a vector to transport weeds from areas on- and off-site into new areas as they are become cleared.

4.1.6.5 Impact Analysis

Residual Impacts to Exotic and Unwanted Species

During the construction and operation phases it is expected that exotics and unwanted plant species will invade reclaimed areas and forest edges. Aggressive control measures will be used to eradicate the species as soon as they are discovered. Initially, unwanted species may be difficult to recognize as troublesome since they may be native species. In certain cases, a species may become prominent in an area, which may be part of a normal successional pathway. In other cases, a species may simply choke out others, reducing diversity and limiting succession.

Control measures planned cannot eliminate unwanted species totally, and therefore, a low negative environmental consequence is predicted (Table 4.1-5).

Table 4.1-5 Residual Impact Classification for Exotic and Unwanted Plant Species

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
exotic or unwanted plant species	negative	low	local	medium-term	reversible	medium	low

During construction, operation and closure phases, control measures will be used to rid exotic and unwanted (weeds) species along the pipeline route and along the edges of primary forests that the pipeline passes through.

Prediction Confidence

The general behavior of invasive unwanted species is well understood. Additional information on specific weeds that may be found on-site will need to be gathered as part of the mitigation plan. This information will include species' preferred habitat, invasive strategies, means of propagation and eradication methods.

Monitoring

A vegetation monitoring program will be implemented to ensure that a suitable level of control is being achieved for low levels of exotic and unwanted species. This program includes monitoring the effectiveness of exotic and unwanted species control measures within the high-priority forest rehabilitation zones (i.e., the forested 2 km of the pipeline and within the Mantadia-Zahamena Conservation Corridor).

4.1.6.6 Conclusions

During construction and operation, a low environmental consequence is predicted for the introduction and spread of exotic and unwanted plant species. Mitigations and monitoring proposed include:

- Implementation of invasive species control program.
- Monitoring the effectiveness of exotic and unwanted species control measures.

4.2 FAUNA

4.2.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the slurry pipeline on fauna, including potential impacts on rare and locally endemic 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).

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 slurry pipeline Local Study Area (LSA) includes the approximately 195 km slurry pipeline footprint, plus a 1 km buffer on either side of the proposed pipeline route, from the ore body complex at the mine site to the plant site near Toamasina (Figure 7.2-2, Volume A).

The LSA has been divided into three major land use sub-areas: the western section, which is within the forest corridor (corridor zone); the central section, which passes around primary zonal forest fragments through an area defined primarily by a tavy matrix (tavy zone), and the eastern section, containing entirely secondary vegetation and has a higher density of agricultural use, called the agricultural zone. For a detailed description of land use within the LSA refer to Volume K, Appendix 3.1.

The pipeline initially crosses through the Torotorofotsy Ramsar site within the mine LSA and further east, through the Mantadia-Zahamena Conservation Corridor. The proposed pipeline route is primarily located on existing disturbance, including through the Ramsar site and the regional primary zonal forest corridor.

4.2.3 Baseline Summary

4.2.3.1 Introduction

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

4.2.3.2 Methods

Classification of Land Use Zones

Remote sensing data were used to produce spatial land use maps (Volume K, Appendix 3.1). Interpretation of key land use features was confirmed through field site visits. Existing information from previous studies, 1997 baseline investigations and information acquired for the socioeconomic and protected areas sections of this assessment were used to define recent land use activities.

Faunal Surveys

Amphibians and Reptiles

A reconnaissance survey along sections of the proposed pipeline route was done near the Mantadia-Zahamena forest corridor in the late dry season in October 2004. Incidental observations of amphibians and reptiles were also recorded. Formal surveys along the proposed pipeline route were also conducted during the wet season from January to February 2005. The methods for the herpetofauna survey in early 2005 followed those described for the mine LSA (Volume J, Appendix 2.1).

Birds

Baseline surveys along the proposed pipeline route were conducted for birds from September to October 2004 and from January to February 2005. The methods followed those described for the mine LSA (Volume J, Appendix 2.1).

4.2.3.3 Results

Amphibians and Reptiles

Fifty-four amphibian species and 35 reptile species were recorded during the herpetological surveys in selected locations along the proposed pipeline route. Of these, only one species is not endemic. The number of observed amphibian species is greater than that reported for Andasibe-Mantadia National Park (Amphibians: 36; Parcs Nationaux Madagascar 2000).

Three herptile species observed along the pipeline route study area are listed on the International Union for the Conservation of Nature (IUCN) Red List and 15 species are listed by Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Volume J, Appendix 2.2, Table 3).

Species richness for both amphibian (54) and reptile (32) species was greatest in the corridor zone. Of the 89 total species recorded in the study area, only three species were found within both study areas possibly due to the limited sampling effort in the tavy zone. All but one species *Ptychadena mascareniensis* recorded was endemic. This species occurred in both zones and was the only amphibian species documented in the tavy zone. No IUCN-listed species were found within the tavy zone.

Species were summarized by the areas (corridor, tavy) 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. The summary of unique species is provided in Volume J, Appendix 2.2. Species accumulation curves were calculated for the LSA and by habitat and indicate that sampling effort for amphibians was good for the primary and eucalyptus forest habitats, but not for the marsh and other habitat categories. For reptiles, sampling effort was inadequate to estimate true species richness by habitat. However, the species accumulation curve for all herptiles combined for all habitats suggests that few species were undetected in the LSA overall.

Birds

Ninety-three bird species were recorded during the surveys in selected locations along the proposed pipeline route. Of these, 77 are endemic and two, *Acridotheres tristis* and *Numida meleagris*, are exotic. Observed species richness is lower than in Andasibe-Mantadia National Park (112; Parcs Nationaux Madagascar 2000).

Eight bird species observed in the pipeline LSA are listed on the IUCN Red List and 14 species are listed by CITES (Volume J, Appendix 2.2, Table 3).

Species richness was greatest in the corridor zone. Of the 93 total species recorded in the LSA, 35 species were found in both zones. Both exotic species were observed in the tavy zone, but only *Acridotheres tristis* was recorded in the corridor zone. All eight IUCN listed species observed in the LSA were recorded in the corridor zone, but only *Accipiter madagascariensis* was recorded in the tavy zone.

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 slurry pipeline 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. A variety of issues and concerns were raised during consultation, with respect to potential pipeline effects on biodiversity including fauna (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 pipeline and associated access roads especially in the Mantadia-Zahamena corridor;
- 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 especially in the Torotorofotsy Wetlands.

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?

The slurry pipeline will be about 195 km in length from the mine slurry plant to the plant site at Toamasina. The route will still be adjusted slightly to further avoid sensitive places like steep slopes and valuable forest fragments.

The pipeline corridor width will vary from 25 to 100 m depending on slope but the average assumed width for this assessment is 50 m. The pipeline will be buried, except near the mine slurry plant and the plant site at Toamasina and at several watercourse crossings where the pipe will be suspended across deep channels. A maintenance road will be constructed along most of the proposed pipeline route, but not through environmentally sensitive areas.

Other ancillary physical disturbances include construction of side access roads to the proposed pipeline route, worker camps and laydown areas. The location of these features has not yet been finalized. The camp and laydown areas will be progressively reclaimed during and after construction.

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. Indirect habitat loss can result from sensory disturbance and air emissions such as dust fall. Direct and indirect mortality may result from habitat clearing 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 project, an impact pathway 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 stream 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 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. 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, initial fragmentation and sensory disturbance will be more closely associated with the construction phase while barriers to movement and indirect habitat loss due to edge effects are more closely associated with the operational phase. However, both phases of the 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 Pathways

Site Clearing

Direct habitat loss is the most visible effect and occurs when land is cleared for other uses. Because some facilities (e.g., main roads) will be permanent for the life of the project, habitat loss is a long-term event for these features. Site clearing is primarily associated with construction, and for roads at closure.

Change in Hydrology

Habitat loss could occur if there are changes in runoff, streamflow and sediment loading in streams. As impacts are predicted during the construction phase of the project (Volume C, Section 3.6), this may impact semi-aquatic terrestrial species.

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 slurry pipeline LSA. The pipeline route, based on a average width of 50 m, was overlain on the vegetation classification map to assess impacts. Total watercourse length was calculated for streams and rivers in the LSA, irrespective of size. Other ancillary physical disturbances include side access roads to the proposed pipeline route, worker camps and laydown areas. As noted above, the location of these ancillary project features is not finalized so no quantitative assessment of impacts to habitats could be completed. Potential impacts for these features were discussed qualitatively. Reclamation will restore habitat but was not assessed quantitatively as the areal extent of each reclamation type is not yet known. A qualitative assessment of impacts to species using affected habitats is discussed.

Change in Hydrology

Potential impacts to fauna due to changes in runoff, streamflow and sediment loading are discussed qualitatively based on the qualitative assessment for hydrology (Volume C, Section 3.6).

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

Mitigations that will reduce the effects of habitat loss and alteration from site clearing and changes in hydrology in the slurry pipeline LSA to wildlife include:

Design Elements

- The pipeline route is mainly (approximately 95%) through previously disturbed or degraded areas. It was routed to avoid primary zonal forest fragments and wetlands of biological value, particularly the Torotorofotsy Wetlands and Mantadia National Park.
- Along the pipeline route between the two parcels of the Andasibe-Mantadia National Park, the pipeline will be constructed to allow overgrowth of trees and shrubs and improve forest cover and connectivity during operations and post-closure.

Mitigation Techniques

- Environmental monitors will work ahead of construction. For fauna, an emphasis will be in the few areas where more natural vegetation will be disturbed, including at some river crossings. In such areas, selected listed (IUCN, CITES) faunal species will be relocated or collected prior to site clearing where feasible.
- Environmental monitors will also assess stream crossing locations before construction and identify any location or reaches with high sensitivities. Where feasible proposed crossings at identified sensitive sites will be avoided. All crossings will be established with as narrow a disturbance width as possible. Construction techniques will include sediment and erosion control.
- Sediment control, protection of water quality, and site-specific mitigation, particularly at stream crossings.

Reclamation and Closure

- The pipeline and other disturbed areas such as camps and laydown areas will be progressively reclaimed during and after construction.
- In sensitive areas, forest reclamation will occur and a maintenance road will not be constructed. In particular, parts of the pipeline descending from the mine towards the Torotorofotsy Wetlands, within the viewshed of these wetlands, will be reforested. Areas of the pipeline within the Mantadia-Zahamena Conservation Corridor directly between Mantadia and Analamazaotra protected areas will be reforested, and no maintenance road left. This high level of mitigation is part of the project's commitment to the regional corridor project.
- The slurry pipeline will be abandoned in place (buried) at the time of closure. Exposed sections will be removed and disposed of, unless a

regional planning process determines that there is an advantage to leaving them in place. The road along the slurry pipeline and associated access routes and bridges that have been constructed will usually be left in place, but could be decommissioned, depending on the decision of local stakeholders and government planners at the time of closure.

Impact Analysis

Site Clearing

The area of new disturbance for the slurry pipeline will be 936 ha (Table 4.2-2). This value does not include side access roads to the proposed pipeline route, worker camps and laydown areas as the location of these ancillary features has not been finalized. Due to fine-tuning of the route, the largest impacts from the slurry pipeline will occur in previously disturbed habitats. Of the 936 ha that will be disturbed, less than 5% will occur in primary, undisturbed habitats.

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

Habitat Type	Baseline Case (ha)	Impact Case (ha)	Change (ha)	Change (%)
azonal forest	81	81	0	0
transitional forest	187	182	-5	-2.7
degraded zonal forest	1,537	1,484	-53	-3.4
primary zonal forest	1,403	1,380	-23	-1.6
marsh edge	26	26	0	0
wetlands	406	401	-5	-1.2
water	128	128	0	0
coastal shrubland/ grassland complex[a]	297	293	-4	-1.3
clearing/tavy	30,778	29,978	-800	-2.6
pasture	308	306	-2	-0.6
rice paddies	278	269	-9	-3.2
woodlot/plantation	693	658	-35	-5.1
other[b]	153	153	0	0
total	**36,275**	**35,339**	**-936**	**-2.6**

[a] Includes beach ridge habitat type.
[b] Includes industrial sites, quarries, railway, roads and villages.

Herpetofaunal species richness was greatest in the primary zonal forest habitats surveyed in the slurry pipeline LSA, with much lower richness in the other habitats, particularly disturbed. Although the habitats were not recorded for each bird species, over 80% of bird species recorded in LSA are forest-dwelling species. Therefore, the greatest potential impacts of pipeline construction will be to species that occupy forest habitats. The pipeline route has been fine-tuned to avoid primary zonal forest as much as possible, thereby reducing impacts to faunal populations. Only 23 ha (2.4% of the pipeline route) will occur in primary zonal forest.

Location of the access roads, camps and laydown areas is not finalized so the impacts to habitats are also not known. However, the camps, laydown areas and some roads will also be progressively reclaimed during and after construction limiting the duration of habitat loss. The key biological goal along the length of the proposed pipeline route will be to minimize habitat loss, including by reducing soil erosion. However, in key sensitive areas such as the Mantadia-Zahamena corridor, the goal is reforestation as part of a regional project in the area. Impacts to species in key primary habitats will also be mitigated as much as possible through translocation of selected species, where possible, prior to pipeline construction in any of the few undisturbed habitats crossed, especially near the mine site. Combined with the progressive and rapid reclamation of the pipeline route, impacts to faunal species will be reduced.

Change in Hydrology

Along the pipeline route in general, changes in runoff and streamflow are predicted to be negligible (Volume C, Section 3.6). Changes in sediment loads are also predicted to be negligible as erosion control measures will be applied. At pipeline watercourse crossing locations, changes in streamflow and sediment concentrations are predicted to be moderate to high at the time of construction but reduced to negligible to low during operation and closure. Therefore, impacts to fauna as a result of changes in streamflow and sediment concentrations are predicted to be higher during the construction phase, however the extent of the disturbance will be local and temporary.

Of the 1,393 km of watercourses in the LSA, a maximum of 33 km (2.4%) will be affected by the pipeline (Table 4.2-3). This impact does not include access roads, camps or laydown areas however, mitigation will limit disturbance for most watercourses to the construction phase. As the majority of crossings will be buried, the impacts will be restricted to the construction phase. At road intersections with streams and rivers, bridges and culverts will be installed as appropriate during construction, potentially altering watercourse habitat. Although some roads will be retained after construction based on regional planning goals, others will be temporary so these impacts to faunal habitats in watercourses will also be temporary.

Table 4.2-3 Watercourses Affected by the Slurry Pipeline Route

Habitat Type	Baseline Case (km)[a]	Impact Case (Undisturbed)(km)	Impact Case (Disturbed) (km)[b]	Percent Affected (%)
streams and rivers (km)	1,393	1,360	-33	-2.4

(a) Based on average proposed pipeline route width of 50 m.
(b) Value does not include impacts from side access roads, camps or laydown areas.

Residual Impact Classification

Residual impacts and environmental consequences of direct habitat loss to key habitats as a result of construction and operation of the slurry pipeline are presented in Table 4.2-4.

Low environmental consequences associated with site clearing are predicted for all habitats because the magnitude of disturbance is low and local in extent, although the effects will be long-term. Therefore, a low environmental consequence is also forecast for wildlife species, including rare species that occupy these habitats (Volume J, Appendix 2.2). The small areas of transitional forest and wetlands cleared for the pipeline will be permanently lost as these habitats cannot be recreated.

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							
azonal forest	neutral	n/a	n/a	n/a	n/a	n/a	n/a
transitional forest	negative	low	local	long-term	irreversible	low	low
degraded zonal forest	negative	low	local	long-term	reversible	low	low
primary zonal forest	negative	low	local	long-term	reversible	low	low
marsh edge	neutral	n/a	n/a	n/a	n/a	n/a	n/a
wetlands	negative	low	local	long-term	irreversible	low	low
water	neutral	n/a	n/a	n/a	n/a	n/a	n/a
coastal shrubland/ grassland complex[a]	negative	low	local	long-term	reversible	low	low
faunal species	negative	low	local	long-term	reversible	low	low
Issue: Change in Hydrology							
watercourses	negative	low	local	short-term	reversible	low	low

(a) Includes beach ridge habitat type.
n/a = Not applicable (neutral impacts not rated).

Residual impacts to stream and river habitats are predicted to be low. The greatest impacts to streamflows and sediment concentrations are predicted to occur during construction and will be temporary. These impacts will be reduced to negligible or low during operations. The environmental consequence of changes in faunal habitats due to alteration or loss of stream sections are predicted to be low as the magnitude of impact is low and the effects are predicted to be local, of short duration, reversible and occur only once during construction.

Prediction Confidence

Prediction confidence for impacts to habitats as a result of site clearing is high. The areal extent of the habitat losses along the proposed pipeline route of these habitats is well known.

Uncertainties in the impact predictions for fauna as a result of direct habitat loss include:

- Species habitat associations are derived from limited field survey observations.
- Location and areal extent of access roads, camps and laydown areas is currently unknown so additive effects of direct habitat loss are also unknown.

Monitoring

Reclamation of natural forest habitats is planned for pipeline segments in the Mantadia-Zahamena corridor as part of a regional corridor/carbon project. At baseline, these areas are currently disturbed. Reclamation success will be assessed through vegetation monitoring at these sites.

Indirect Habitat Loss

Potential Impact Pathways

For justification of the potential causes of indirect habitat loss, see Volume B, Section 4.2. The potential impacts will occur mainly in areas along the proposed pipeline route where primary habitats currently exist.

Sensory Disturbance

Noise levels will exceed baseline levels during the construction phase of the slurry pipeline with minimal effects during operation for maintenance activities (Volume C, Section 3.4). Construction of the pipeline will occur during daylight hours, so lights will not be required. No lighting systems will be required during operations.

Edge Effects

Dust Effects

With an increase in disturbance of soils as a result of construction of the pipeline and as well as dust from maintenance and access roads during operation of the project, there is an increased likelihood of dust infiltrating surrounding undisturbed habitat.

Introduction of Non-Native and Invasive Species

With an increase in human activity due to the construction and operation of the slurry pipeline, there is an increased likelihood of introduction of non-native and invasive species to previously undisturbed areas. The occurrence and habitats of non-native and invasive species at baseline are presented in the fauna baseline (Volume J, Appendix 2.1). Although 95% of the proposed pipeline route is already disturbed, there is the potential for these species to invade the smaller amounts of newly disturbed areas in the LSA.

Increased access and increased edge as a result of development provides a mechanism for both introduction (i.e., carried in by humans) and invasion (i.e., encroachment from adjacent areas) of non-native and invasive plant and animal species.

Changes in Microclimate

Most of the area to be cleared for the proposed pipeline route and associated infrastructure is previously disturbed, although there will still be a temporary increase in the amount of edge habitat between forested and non-forested land following construction of the pipeline. Faunal changes are likely to occur along the ecotone between them.

Assessment Methods

Sensory Disturbance

Noise

Potential impacts to fauna based on predicted changes in noise levels are qualitatively discussed.

Edge Effects

Dust, Introduction of Non-Native and 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 pipeline footprint was buffered by 100 m and the areal extent of each habitat type within the buffer zone was calculated to determine impacts. A buffer width of 100 m was used based on the median impact distance reported for a variety of ecosystems (e.g., dust: 40 to 300 m [Tamm and Troedsson 1955 cited in Forman 1995; Alexander and Miller 1997]; invasive species: 100's to 1,000's m [Brocke et al. 1990 cited in Forman 1995]; microclimate effects: up to 50 m [Turton and Siegenthaler 2001]). As the length and location of the associated roads is not finalized, impacts could not be assessed quantitatively for these components. A qualitative assessment of impacts to habitats from the road system and 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 include:

Design Elements

- Mufflers on vehicles to reduce noise.

Mitigation Techniques

- Workers will be restricted to operating in the proposed pipeline route only; no off-site activity.
- Dust control measures will be implemented along roads.
- Removal of non-native rodents around temporary construction camps.

Reclamation and Closure

- Reclamation of the proposed pipeline route and some roads will occur post-closure reducing edge effects. The use of native species in reclamation will help control the introduction of non-native species.

Impact Analysis

Sensory Disturbance

Noise levels will be highest during the construction phase due to clearing, grading and pipe laying operations. Noise levels up to 45 dBA are predicted up to 500 to 700 m from this activity and will be sustained at any point along the pipeline for up to a week, based on an assumed 700 m daily progression

(Volume C, Section 3.4). As construction will occur during daylight hours, impacts to nocturnal animals will be negligible. Operations noise will consist of a single vehicle accessing the sites for occasional maintenance inspections. In reclamation areas during construction and closure phases, noise levels from vehicles and people will temporarily exceed baseline levels. Species most likely to be affected by noise include species that use vocalization for breeding [e.g., amphibians (Barass 1985), birds, lemurs] and wary species in areas where noise exceeds baseline levels however these noise effects will be temporary during the construction phase.

Edge Effects

Dust, Introduction of Non-Native and Invasive Species and Microclimatic Changes

Of the key faunal habitats, the largest potential impacts as a result of edge effects due to pipeline construction and operation will be to the degraded zonal and transitional forests with proportional losses of 12.8% and 9.85%, respectively (Table 4.2-5). Edge effects will influence 94 ha of primary zonal forest (6.7%), 6 ha (4.6%) of water and 21 ha (5.1%) of wetlands habitats. These impacts are in addition to the direct losses due to site clearing. The azonal and marsh edge habitats are not predicted to be impacted by dust, non-native and invasive species or microclimate changes due to edge creation. As the pipeline is constructed mainly (95%) through previously disturbed habitats, the impacts due to edge effects created by construction of the slurry pipeline have been reduced. Edge effects due to construction of the access and maintenance roads have not be included in this assessment.

Table 4.2-5 Habitats (ha) Within a 100 m Edge Effects Zone of the Slurry Pipeline

Habitat Type	Baseline Case (ha)	Impact Case (ha)	Change (ha)	Change (%)
azonal	81	81	0	0
transitional	187	169	-18	-9.8
degraded zonal forest	1,537	1,340	-197	-12.8
primary zonal forest	1,403	1,309	-94	-6.7
marsh edge	26	26	0	0
wetlands	406	385	-21	-5.1
water	128	122	-6	-4.6
coastal shrubland/ grassland complex[a]	297	280	-17	-5.7
clearing/tavy	30,778	27,569	-3,209	-10.4
pasture	308	300	-8	-2.5
rice paddies	278	245	-33	-11.8
woodlot/plantation	693	557	-136	-19.6
other[b]	153	140	-13	-8.4
total	**36,275**	**32,523**	**-3,752**	**-10.3**

[a] Includes beach ridge habitat type.

[b] Includes industrial sites, quarries, railway, roads and villages.

Residual Impact Classification

Residual impacts as a result of indirect effects are provided in Table 4.2-6.

Table 4.2-6 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	short-term	reversible	low	negligible
wary species	negative	low	local	short-term	reversible	low	negligible
other species	neutral to negative	negligible	local	short-term	reversible	low	negligible
Issue: Edge Effects							
azonal	neutral	n/a	n/a	n/a	n/a	n/a	n/a
transitional	negative	low	local	long-term	reversible	low	low
degraded zonal forest	negative	moderate	local	long-term	reversible	low	moderate
primary zonal forest	negative	low	local	long-term	reversible	low	low
marsh edge	neutral	n/a	n/a	n/a	n/a	n/a	n/a
wetlands	negative	low	local	medium to long-term	reversible	low	low
water	negative	low	local	medium to long-term	reversible	low	low
coastal shrubland/ grassland complex[a]	negative	low	local	long-term	reversible	low	low
faunal species	negative	low	local	medium-term	reversible	low	low

[a] Includes beach ridge habitat type.

n/a = Not applicable (neutral impacts not rated).

Sensory Disturbance

Noise

The environmental consequence of project-generated noise is negative and negligible for potentially affected species because the noise levels are predicted to be low, occur primarily during construction and only affect the local area. Project-related noise effects will be very low and infrequent during operations and removed at closure.

Edge Effects

Dust, Invasive Species and Changes in Microclimate

The environmental consequence of edge effects due to dust, invasive species encroachment and changes in microclimate is negative and moderate for degraded zonal forest because the magnitude of the indirect habitat loss is moderate and the duration is long-term because it will last until the habitat is restored. All other impacted habitats in the slurry pipeline LSA are predicted to have a low environmental consequence because the magnitude of the areal extent of the impact is low. The creation of the edge habitat only occurs once for each habitat during site clearing and the effects are reversible. The duration of edge effects for the water and wetlands habitats depend on whether they occur within forested (long-term) or non-forested (medium-term) habitats.

Prediction Confidence

Prediction confidence for areal extent of impacts to habitats as a result of edge effects is high as these impacts were spatially modelled. Effects on specific faunal groups is less well understood, given our level of understanding of species' ecology. The level of confidence for effects on fauna is medium.

Monitoring

As the indirect effects of sensory disturbance due to construction and operation will be temporary, no formal monitoring program is proposed. In areas near the mine site, monitoring of select species in the azonal and transitional habitats will occur as part of the general fauna monitoring program (Volume B, Section 4.2).

Direct Mortality

Potential Impact Pathways

For justification of the potential causes of direct mortality, see Volume B, Section 4.2. The potential impacts will occur mainly in areas along the proposed pipeline route where primary habitats currently exist. Direct mortality may result from site clearing, nuisance fauna attracted to temporary camp facilities, vehicle-fauna collisions mainly during construction, and hunting and collecting opportunities gained through new access.

Assessment Methods

As a correlate of mortality due to site clearing, the areal extent determined for direct habitat loss was used. A qualitative discussion of the impacts to fauna is discussed. A qualitative assessment was completed for nuisance fauna, vehicle-fauna collisions and hunting/collecting as these effects could not be quantified.

Assessment Criteria

The assessment criteria are the same as for direct habitat loss (see Table 4.2-2).

Mitigation

Design Elements

- The pipeline route is mainly (about 95%) through previously disturbed or degraded areas. The pipeline route avoids primary zonal forest including Mantadia National Park and wetlands of biological value, particularly the Torotorofotsy Wetlands. As well, access and maintenance roads will be sited to avoid primary habitats as much as possible. No maintenance road will be built through the Mantadia-Zahamena Conservation Corridor, between the two national parks.

Mitigation Techniques

- In the few areas of natural or degraded forest to be disturbed, selected rare fauna that do not move ahead of construction will be relocated or collected before site clearing.
- A waste management plan will be implemented to eliminate attractants for potential nuisance species.
- A nuisance fauna management plan will be implemented, including trapping and removal.
- A worker training program will be implemented, including a no hunting policy.
- Signs will be posted and speed limits enforced.

Impact Analysis

Site Clearing

Based on an average width of 50 m, site clearing for the proposed pipeline route will result 936 ha of new clearings and disturbances. Most (800 ha) of the impacts will be in existing clearings and tavy so the risk to forest-dwelling species will be limited to key habitats. Degraded primary, primary and transitional forests make up the majority of the impacted key habitats with a combined loss of 81 ha (see Table 4.2-2). Slow moving and less mobile species (e.g., amphibians, reptiles, small nocturnal lemurs) and juvenile animals occupying these habitats are most at risk for mortality. As part of the regional planning initiative to restore connectivity along the Mantadia-Zahamena corridor, previously disturbed habitats along the pipeline right-of-way will be reclaimed with the end-goal of the regrowth of primary zonal forest. It is anticipated that faunal populations in these areas will increase and, over time, compensate for any losses due to site clearing.

Residual Impact Classification

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

Site Clearing

The environmental consequence of direct mortality is predicted to be greatest for wide-ranging species. Even though the magnitude of impacts is low and the effects temporary, the geographic extent is regional for populations that extend beyond the LSA. For all other species, including rare and slow-moving or sessile species, residual impacts 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. Mitigation, including avoidance of primary habitats and pre-construction collection and translocation of key species in the few undisturbed areas crossed, will reduce impacts.

Nuisance Fauna

It is estimated that the magnitude of this impact on faunal populations will be low since the camps will be temporary. With effective mitigation, the environmental consequence of these impacts should be negligible.

Vehicle-Fauna Collisions

Vehicle-fauna collisions are expected to occur on all roads and be greatest during the construction phase and in the small areas of high value habitat. In addition, vehicle traffic will increase in the surrounding area, outside the LSA, due to the project (Volume C, Section 5.5), but these roads are largely constructed through previously disturbed habitats (i.e., tavy and agriculture).

Impacts are predicted to be greatest for wide-ranging species because, although the magnitude of impacts is predicted to be low, the effects are regional for populations that extend outside the LSA. Slow-moving terrestrial species, rare species or species with low fecundity, are groups that could be most at risk. For the latter two groups, losses of individuals can potentially affect populations. For all affected species, the impact duration will be long-term in areas where roads are not decommissioned, but the effects are reversible if remaining populations can compensate for losses and the frequency is medium as losses will occur intermittently. Worker education, speed limits and signage will help reduce the magnitude of these impacts (i.e., collision rates).

Hunting and Collecting

In tavy and agricultural areas and where there is no new access to primary habitats, impacts should be low. However, in areas where the roads will not be decommissioned, increased or improved access to new areas will increase risks to hunted and collected species that will continue beyond the life of the project. As most of these roads will occur in previously disturbed areas, such as tavy and agriculture, where density of people is already high, the impact from project-induced access is predicted to be low. Therefore, although the magnitude of impacts is predicted to be low for all species, the environmental consequence will be greatest (moderate) for wide-ranging species where populations extend outside the LSA.

Table 4.2-7 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 sessile common species	negative	low	local	short-term	reversible	low	negligible
wide-ranging species	negative	low	regional	short-term	reversible	medium	low
other species	negative	low	local	short-term	reversible	low	negligible
Issue: Nuisance Fauna							
native nuisance species	negative	low	local	short-term	reversible	medium	negligible
other species	neutral	n/a	n/a	n/a	n/a	n/a	n/a
Issue: Vehicle-Fauna Collisions							
rare terrestrial species	negative	low	local	long-term	reversible	medium	low
slow-moving common terrestrial species	negative	low	local	long-term	reversible	medium	low
wide-ranging species	negative	low	regional	long-term	reversible	medium	moderate
other species	negative	low	local	long-term	reversible	medium	low
Issue: Hunting/Collecting							
rare species	negative	low	local	long-term	reversible	medium	low
common hunted and collected species	negative	low	local	long-term	reversible	medium	low
wide-ranging species	negative	low	regional	long-term	reversible	medium	moderate
other species	neutral	n/a	n/a	n/a	n/a	n/a	n/a

n/a = Not applicable (neutral impacts not rated).

Prediction Confidence

Prediction confidence for direct mortality is medium. While the relative effects can be assessed, and typical mortality rates can be estimated based on experience from other such projects, it is difficult to determine the precise environmental consequence due to these effects.

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.
- Driving behaviour will be monitored both for safety and fauna protection concerns. Game trails intersecting access routes will be noted to identify areas for signage.

Conclusions

Direct habitat loss and direct mortality due to site clearing during construction are predicted to be the greatest impacts on fauna. Mitigation will reduce the potential impacts to a low environmental consequence for all habitats. Through route adjustments, most impacts from the slurry pipeline occur in previously disturbed habitats. Of the 936 ha that will be disturbed, less than 5% will occur in primary, undisturbed habitats. As species richness was highest in primary habitats (Volume J, Appendix 2.1), the siting of the pipeline has greatly reduced potential impacts to fauna. In addition, impacts to species in the primary habitats will be mitigated as much as possible by the capture and translocation of selected species before pipeline construction. Species that were only recorded in transitional habitats are most at risk from project development (Volume J, Appendix 2.1) as these habitats cannot be restored.

Reclamation will be a key mitigation of impacts to fauna due to site clearing, including indirect effects. In the Torotorofotsy Wetlands area, roads will be decommissioned and reclaimed unless they are requested to remain by the regional authorities. In the Mantadia-Zahamena Conservation Corridor, the proposed pipeline route will be rapidly and progressively reclaimed following construction and no maintenance road will be built through this area. Reforestation of this corridor will enhance these habitats relative to baseline conditions.

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

Potential Effect Pathways

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.

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 (see Indirect Habitat Loss Section in Key Question W-1). 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). For additional fragmentation analyses, refer to the Biodiversity assessment (Volume C, Section 4.4).

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 right-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). Barriers can indirectly result in habitat loss by preventing animals from accessing habitat and affecting faunal movement (for full discussion, refer to Volume B, Section 4.2). For the pipeline component of the project, the main barriers to faunal movement include the access and maintenance roads and sensory disturbance from project construction activities. While the sensory disturbance from construction will be temporary, some roads will last beyond the project life.

Assessment Methods

Both fragmentation and barriers to movement effects on fauna are assessed qualitatively based on the interpretation of direct habitat loss effects.

Assessment Criteria

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

Mitigation

Design Elements

- The pipeline will be buried except for a few locations across rivers and near mine and plant facilities. Along the pipeline route between the two parcels of the Andasibe-Mantadia National Park, the pipeline will be constructed to permit overgrowth of trees and shrubs and improve forest cover and connectivity during operations and post-closure.
- The pipeline route is mainly (about 95%) through previously disturbed or degraded areas. The pipeline route avoids primary habitats as much

as possible, thus limiting fragmentation. As well, roads will be sited to avoid primary habitats as much as possible.

- Culverts or bridges will be installed at stream crossings for access and maintenance roads, providing connectivity for species along the stream.

Mitigation Techniques

- During pipeline construction, open trenches will be limited to short sections and duration which will reduce potential for animals to be trapped in the trench. Animals that fall into trenches will be captured and released.

Reclamation and Closure

- Work with regional planners to restore connectivity between Mantadia National Park and conservation areas to the south. Increasing forest cover in this area will improve faunal movement in this area over baseline conditions.
- Reclamation using native species along the proposed pipeline route in environmentally sensitive areas, particularly along the Mantadia-Zahamena Conservation corridor following construction.

Compensation

- The proponent is to be active in cooperative forest management and regional resource planning.

Impact Analysis

Fragmentation

Construction of the pipeline and associated infrastructure is expected to alter small areas of transitional, primary and degraded forest as well as natural wetlands in the Toamasina study area (Table 4.2-5). However, less than 4% of these habitats will be impacted due to the project and further route fine tuning could further reduce these impacts. No losses are anticipated for azonal or marsh edge habitats. Other degraded habitats that support fewer species will be also marginally altered. Although habitat loss and fragmentation can negatively influence populations and communities, the amount of disturbance to the landscape from the pipeline component of the project is predicted to be negligible. Small changes in habitat areas should be correlated with little change in mean patch size, connectivity and edge. Therefore, impacts to faunal populations due to fragmentation are also predicted to be low.

Barriers to Movement

Approximately 200 km of new roads will be created along the length of the pipeline for construction and maintenance. Additional site access roads will also be created that link existing transportation corridors to the pipeline route. The physical presence of the roads, vehicular traffic and sensory disturbance associated with construction and maintenance activities will create a barrier to fauna for as long as they are in place. If the barriers result in the inability of animals to disperse or find mates, the impacts to affected species could affect genetic and demographic attributes of populations. Impacts will be greatest for wary or wide-ranging species. For the latter, these impacts could be regional. However, most development will occur in previously disturbed areas between Mantadia and Andasibe national parks, minimizing impacts to faunal populations.

No maintenance road will be built along the pipeline within a core part of the Mantadia-Zahamena Conservation Corridor and the pipeline will be constructed such that trees can be grown along the proposed pipeline route. These design features will reconnect previously disturbed areas, thereby eliminating existing barriers in key sensitive habitats. In areas where roads are built but reclaimed following closure, faunal movement will no longer be restricted.

Residual Impact Classification

Residual impacts as a result of fragmentation and barriers to movement are provided in Table 4.2-8.

Fragmentation

The environmental consequence to all habitats due to fragmentation is predicted to be negligible primarily because about 95% of the route occurs along existing disturbance. The magnitude of the effects is therefore predicted to be negligible, local in extent, long-term in duration and occur once during site clearing. Impacts to fauna due to fragmentation effects of pipeline construction are also predicted to be negligible, again primarily because the route follows previously disturbed habitats.

Barriers to Movement

Barriers to movement are predicted to have a low to moderate environmental consequence for wary and wide-ranging species. For the latter species, impacts can be regional 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 as barriers occur continuously.

Mitigation, including construction in previously disturbed areas and reclamation, will reduce the magnitude of these impacts.

Table 4.2-8 Residual Impact Classification for Fauna due to Fragmentation and Barriers to Movement

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Fragmentation							
habitats	negative	negligible	local	long-term	reversible	low	negligible
fauna species	negative	negligible	local	long-term	reversible	high	negligible
Issue: Barriers to Movement							
wide-ranging species	negative	low	regional	long-term	reversible	high	moderate
wary species	negative	low	local	long-term	reversible	high	low
other species	negative	low	local	long-term	reversible	high	low

Prediction Confidence

Prediction confidence is medium with respect to fauna movement effects, given that the pipeline has been mainly routed through already disturbed areas.

Monitoring

No specific surveys will be conducted to monitor faunal movement.

Conclusions

Impacts to primary habitats and faunal populations as a result of fragmentation are predicted to be negligible to low because most of the pipeline route was sited along pre-existing disturbance and will be buried. Construction of the pipeline will create temporary barriers to movement (e.g., roads, construction activity) for fauna in environmentally sensitive areas. Connectivity will be restored once the pipeline is buried and the proposed pipeline route reclaimed. In some areas, roads will be left in place as part of regional planning so barriers to faunal movement will remain. The majority of these roads will be in areas of existing disturbance and higher people density, so will mainly be restricted to species that occupy disturbed habitats (e.g., tavy, agriculture).

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

Potential Effect Pathways

The potential impacts of the project on faunal health were evaluated through the following two linkages:

- 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 through the food chain. Amphibians can also be exposed to airborne chemicals through the skin. Contaminant concentrations in the air are predicted to be negligible to low and temporary during construction as a result of vehicle emissions (Volume C, Section 3.3). Air quality is not considered an issue.

Water Quality

Contamination of watercourses is not predicted to occur due to construction and operation of the slurry pipeline (Volume C, Section 3.9). Mitigations, including a spill contingency plan, are outlined in the environmental management plan and address accidental contamination. Water quality is not considered an issue.

4.3 FISH AND AQUATIC RESOURCES

4.3.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the slurry pipeline on fish and aquatic resources, and specifically addresses fish communities, aquatic macro-invertebrates and habitat as outlined by the Ambatovy Project (the project) Terms of Reference.

The EA presents a summary of baseline survey results and issues, followed by the impact assessment. Detailed aquatic resources baseline reports relative to the slurry pipeline are presented in Volume J, Appendix 3.1 (Attachments 1 and 2).

4.3.2 Study Area

The slurry pipeline will run over a distance of about 195 km from the mine site at Ambatovy to the processing plant near Toamasina. The primary study area for fish and aquatic resources falls within the slurry pipeline study area (Volume A, Figure 7.2-2), and includes watercourses draining the Eastern Highlands and Eastern Lowlands of Madagascar. Watercourses crossed by the pipeline drain the ore bodies, the Torotorofotsy Wetlands, and the boundary of two nature reserves, the Mantadia National Park and the Reserve Speciale Mangerivola. The undulating topography along the pipeline route combined with the high rainfall along Madagascar's east coast results in a large number (present route indicates 99 watercourses, final number based on route adjustments) of potential watercourse crossings.

4.3.3 Baseline Summary

4.3.3.1 Introduction

The route selected for the slurry pipeline is as direct as practicable and avoids sensitive habitats where possible, running along an abandoned railway line on the north perimeter of the Torotorofotsy Wetlands, but avoids crossing the Mantadia National Park and other mature forests where possible.

4.3.3.2 Methods

Sites were rated for on-site sampling from the results of an aerial reconnaissance in August 2004 (Volume J, Appendix 3.1, Attachment 2). Standardized water crossing surveys data records were completed during the reconnaissance to describe the existing habitat and morphometric condition, degree of potential impact (sensitivity to construction), accessibility and location along the pipeline route. Based on the habitat condition, professional judgement of potential ecosystem sensitivity to construction from and accessibility, a representative sample of drainage types at the potential watercourse crossings was selected from the reconnaissance data for subsequent detailed site assessments.

Detailed sampling for fish, aquatic invertebrates, aquatic macrophytes and general habitat characteristics was completed at 15 stream/river locations in the pipeline local study area (LSA). Field surveys were conducted primarily during the dry season (low flow) in September-October 2004 at which time 13 sites were sampled. Two additional sites, excluded from the dry season survey due to logistic difficulties, were sampled during a supplemental wet season (high flow) survey in January 2005.

Aquatic Habitat

A detailed habitat characterization based on instream characteristics, including channel width, depth, flow rate, dominant substrate types and cover, was completed to quantify habitat type at each site. In-situ water quality (pH, total dissolved solids (TDS), temperature and, dissolved oxygen) was also determined at each site. In addition, the Intermediate Habitat Integrity Assessment (IHIA) model (Kemper 1999) was used to describe and quantify habitat characteristics.

Fish

Fish samples were collected using a variety of techniques in order to sample all habitat types used by the resident fish species. Electro fishing, seine nets and gill nets were the primary methods of capture. Except for voucher specimens retained for confirmation of identification, all other fish were released alive after recording basic life history data (i.e., length, weight, etc.). Preliminary identification to species level was done by the Biology Department, University of Antananarivo. Confirmation of these identifications is in progress at the American Museum of Natural History and the New York Aquarium and therefore the assessments based on species identifications within the following material are provisional.

Macro-Invertebrates

Aquatic macro-invertebrates were collected using a quantitative (USEPA 1998) and qualitative (Dickens and Graham 2002) approach to ensure collection of community information from all habitats. Representative samples were preserved in 90% ethanol for subsequent identification. Macro invertebrates were identified to the family or genus levels. Similar to the fish fauna, preliminary identification of macro-invertebrates conducted by personnel at the

Biology Department, University of Antananarivo, is awaiting expert confirmation and species determinations.

Periphyton (benthic algae) samples were collected during the dry season sampling; these have been archived for future analysis.

Resource Use

Information on artisanal fisheries was obtained on an opportunistic basis by observations or conversations with residents within the areas sampled during field programs.

Information Review and Data Analysis

Published and unpublished literature on the freshwater ichthyofauna and aquatic ecosystems of Madagascar and the project region, conservation status reports on the native fisheries, and local experts were consulted during compilation of the report. Multivariate analytical techniques were used to assess the community assemblage of fish and macro-invertebrate field data.

4.3.3.3 Results

Aquatic Habitat

Aquatic habitat characteristics at the pipeline LSA are highly variable, reflecting the high diversity in both watercourse and habitat types traversed by the pipeline route. Watercourses sampled ranged from small (i.e., width 1.95 m, discharge 0.04 m^3/s) to large (i.e., width >180 m, discharge >50 m^3/s) streams and rivers (Hydrology; Volume C, Section 3.6). Although pH ranged from 6.2 to 7.8, most of the water bodies in the LSA were neutral (pH 7); water temperatures ranged from 17.5 °C in headwater regions (site R2+000) to 29.5 °C at higher order sites near the coast. The most prevalent substrate types were fines, cobbles, gravels, and to a lesser extent, gravel, bedrock and mud. Instream cover varied considerably by watercourse size, but consistently included leaf litter, small and large woody debris, and overhung vegetation.

The slurry pipeline passes through three major land use sub-areas: the western section, within the forest corridor (corridor zone); the central section, passing around primary forest fragments through an area of tavy (tavy zone), and the eastern section, which contains secondary vegetation and a higher density of agricultural use (agricultural zone). Land uses directly influence the habitat conditions and potential sensitivity to construction of the aquatic ecosystems of the watercourses within each sub-area. Based on the IHIA classification of aquatic habitat quality and quantity, 60% of the sites in the slurry pipeline LSA sample group exhibited substantial disturbance (IHIA Classes C-F; Table 4.3-1). The undisturbed sites which were sampled (IHIA Classes A and B; Table 4.3-1) were largely associated with streams near national reserves (Mantadia National Park and Reserve Speciale Mangerivola) or forest fragments.

Table 4.3-1 Habitat Condition and characteristics of Sampling Sites in the Slurry Pipeline Local Study Area

Site	IHIA Class[(a)]	Sensitivity	Habitat description
R2+000	A	high	Unmodified habitat, minimal deforestation in surrounding primary forest.
R5+575	E	low	Extensively modified with loss of natural biota and ecosystem function.
R9+250	C	moderate	Moderately modified. Some loss of natural habitat and biota but basic ecosystem functions remain unchanged. Bed modification due to railway bridge and presence of exotic plant and fish species.
R16+100	D	low	Largely modified, loss of natural habitat, biota, and ecosystem function. Major impacts are bed modification due to sedimentation, water quality impairment due to run-off from village and exotic fish species.
042+300	A	high	Unmodified habitat. No evidence of human impact.
051+800	B	high	Largely unmodified. Minor changes in natural habitat and biota but basic ecosystem functions unchanged.
060+600	A	high	Unmodified habitat. Limited human impact but some sedimentation evident.
107+200	A	high	Unmodified habitat. Limited human impact, minor occurrences of exotic flora and fauna.
136+200	C	moderate	Moderately modified. Some loss of natural habitat and biota but basic ecosystem functions remain predominantly unchanged.
145+700	D	low	Largely modified, loss of natural habitat, biota and ecosystem function. Major threats are bed modification due to sedimentation, water quality impairment due to runoff from village and exotic fish species.
157+700	B	high	Largely unmodified. Minor changes in natural habitat and biota but basic ecosystem functions unchanged.
175+200	E	low	Extensively modified with loss of natural biota and ecosystem function. Channel and bed modification, replacement of indigenous vegetation with exotics are major impacts.
178+900	E	low	Extensively modified with loss of natural biota and ecosystem function. Channel and bed modification, deforestation and presence of exotic flora and fauna are major impacts.
E3 005+150[(b)]	C	moderate	Moderately modified. Loss of natural habitat and biota; presence of exotic flora and fish fauna are major impacts.
E3 011+950[(b)]	D	low	Largely modified, loss of natural habitat, biota, and ecosystem function. Replacement of indigenous vegetation and presence of *C. maculata*.

(a) Based on the IHIA model (Kemper 1999).
(b) E3 denotes sites that were sampled along a potential alternative pipeline route.

Fish

A combined total of 27 fish species, comprising eight endemic, 11 native, and eight introduced species, belonging to 16 families were collected from the pipeline LSA (Table 4.3-2). The high species diversity in the pipeline LSA compared to the mine or Toamasina study areas can be attributed to the high diversity in both water body and habitat types traversed by the pipeline route. However, except for isolated instances, species richness and abundances were generally low at individual sampling sites; species richness of >5 occurred at only 5 of the 15 sites. The highest richness of 12 and 10 species occurred at sites 107+200 and 145+700, respectively. The introduced species, *Xiphophorus maculatus*, was the most ubiquitous species occurring at 8 of the 15 sites. As expected, generally the endemic fish species dominated in un-disturbed habitats (IHIA Classes A and B; Table 4.3-1) while introduced species, such as the *anabantid, Ctenopoma ansorgii,* and the *poecelid, Xiphophorus maculatus,* were more prevalent in disturbed (IHIA Classes D-F, Table 4.3-1) areas.

Similar to other LSAs in the aquatics study area, a majority of fish encountered in the slurry pipeline area were relatively small-bodied species, which are not heavily used by the artisanal fisheries. Abundances and species occurrence of the larger food fish species collected from the study area (e.g., *Oreochromis macrochir*, *Tilapia zilli*, *Ophicephalus striatus*, *Terapon jarba*, *Osphronemus goramy* and *Caecula pterygera*) were generally low, except for *O. macrochir* and *T. zilli* that were collected at moderate densities from one site (site 107+200).

Locations where artisanal fisheries were observed during the study included:

- Ivondro River (178+900): gillnetting (monofilament) for *Tilapia zilli*; reed traps for *aytid* shrimps and *Bedotia madagascariensis*.
- Morongolo River (145+700): gillnetting and spearing for *Tilapia* sp. and *Paretroplus poliactis*.
- Sahanavo River (136+200): monofilament gillnets and baited hook, captured *Tilapia zilli* and *Channa maculata*.
- Rianila River (107+200): diving and conventional spear guns for *Tilapia zilli.*

Table 4.3-2 Fish Species Recorded at the Slurry Pipeline Local Study Area During 2004-2005 Surveys

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
Bedotiidae	*Rheoclès alaotrensis*	E	T	VU
Cichlidae	*Oreochromis macrochir*	I		
Cichlidae	*Oreochromis niloticus*	I		
Cichlidae	*Paretroplus polyactis*	E	S	VU
Cichlidae	*Tilapia zilii*	I		
Clupeidae	*Sauvagella madagascariensis*	E		nl
Eleotridae	*Ophiocara macrolepidota*	E	U	nl
Eleotridae	*Ratsirakia legendrei*	E	T	DD
Gobiidae	*Chonophorus aeneofuscus*	N	S	nl
Gobiidae	*Glossogobius giuris*	N	S	nl
Gobiidae	*Stenogobius polyzona*	N		nl
Kuhliidae	*Kuhlia sauvagii*	E	nl	nl
Kuhliidae	*Kuhlia splendens*	N	nl	nl
Mugilidae	*Mugil cephalus*	N	U	nl
Channidae	*Channa maculate*[c]	I		
Ophichthidae	*Caecula pterygera*	N		nl
Osphronemidae	*Osphronemus goramy*	I		
Poecelidae	*Gambusia holbrooki*	I		
Poecelidae	*Xiphophorus maculatus*	I		
Syngnathidae	*Microphis leiaspis*	N	U	nl
Terapontidae	*Terapon jarbua*	N		nl

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

(a) Sparks and Stiassny (2003).

(b) IUCN Red List (2004).

(c) Misidentified as *Ophicephalus striatus*.

Aquatic Macro-Invertebrates

A total of 66 macro-invertebrate taxa were recorded in the pipeline LSA (Table 4.3-3). Both diversity and abundances of the macro-invertebrate fauna were high. Aquatic macro-invertebrate diversity and abundance were generally higher at undisturbed primary forest sites than deforested locations; the highest species richness of 22 to 23 species were recorded at sites 042+300, 051+600, and 060+600, all located in undisturbed primary forest (with IHIA classifications > B; Table 4.3-1) associated with the drainages from the eastern border of Mantadia National Park.

Table 4.3-3 Aquatic Invertebrate Taxa Recorded at the Slurry Pipeline Local Study Area During the 2004-2005 Survey

Order	Family	Order	Family
COLEOPTERA	Carabidae	HEMIPTERA	Aphelocheiridae
	Dysticidae		Belastomatidae
	Elmidae		Corixidae
	Gyrinidae		Gerridae
	Helophoridae		Helodidae
	Hydrophilidae		Hydrometridae
	Scarabaeidae		Mesoveliidae
DECAPODA	Atyidae		Naucoridae
	Palaemonidae		Nepidae
	Potamonautidae		Notonectidae
DIPTERA	Athericidae		Pleidae
	Chironomidae		Reduvidae
	Dixidae		Veliidae
	Empididae	LEPIDOPTERA	Pyralidae
	Simuliidae	MEGALOPTERA	Sialidae
	Tipulidae	ODONATA	Aeshnidae
EPHEMEROPTERA	Baetidae		Coenagrionidae
	Caenidae		Cordulegasteridae
	Ephemeridae		Corduliidae
	Heptagenidae		Gomphidae
	Leptophlebidae		Lestidae
	Oligoneuridae		Libellulidae
	Polymitarcidae	OLIGOCHAETA	Enchytraeidae
	Prosopistomatidae	PLECOPTERA	Notonemouridae
	Teloganodidae	TRICHOPTERA	Beraeidae
	Tricorythidae		Ecnomidae
GASTEROPODA [(a)]	Bithyniidae		Glossosomatidae
	Bythinellidae		Hydropsychidae
	Hydrobiidae		Lepidostomatidae
	Lymnaeidae		Leptoceridae
	Planorbidae		Polycentropodidae
	Thiaridae		Psychomyiidae
			Sericostomatidae
		MERMITHOIDAE	Mermithidae

(a) Gasteropoda is a Class.

Endemic and Native Species

Fish

The fish fauna within the pipeline LSA sample contains eight endemic species, consisting of two bedotids, *B. madagascariensis* and *R. alaotrensis*; two eleotrids, *Ophiocara macrolepidota* and *R. legendrei*; and one each of the ambasid, *Ambassys fontoynonti*; kuhlid, *Kuhlia sauvagii*; cichlid, *Paretroplus* *polyactis*; and the clupeid, Savagenella madagascariensis. Five of these eight endemics are currently ICUN Redbook listed (2004).

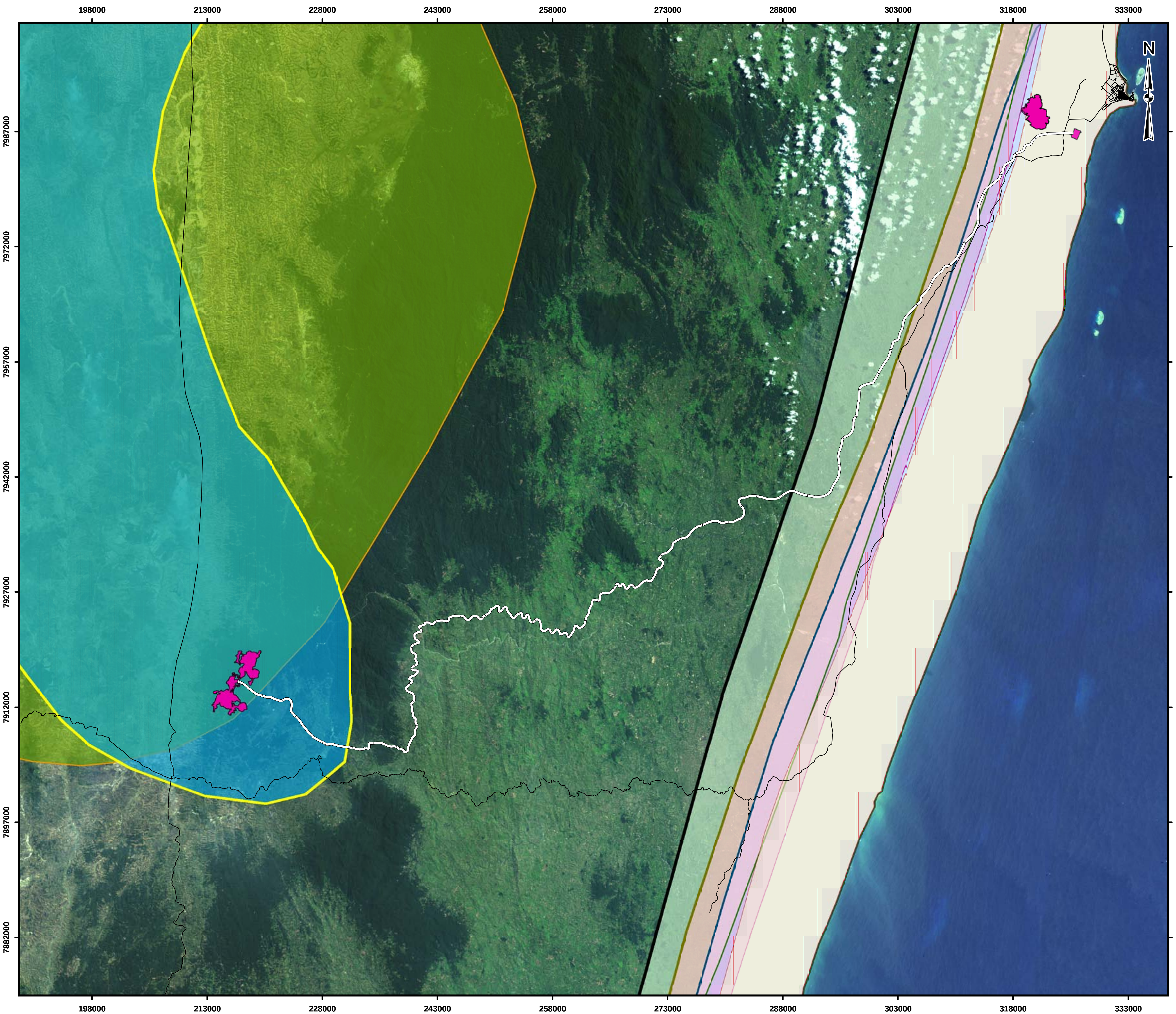
Among the endemic species, the eleotrid, *Ratsirakia legendrei,* (IUCN listed as "Vulnerable") was the most ubiquitous occurring at five of the 15 sites. Not only was *R. legendrei* the most prevalent endemic species, but it also had the highest densities recorded among all 27 species. Generally, abundance was high at un-disturbed primary forest sites and low at deforested or modified locations. It was found as far east as the site on the Sahanandrazana River (Site 060+600; Volume J, Appendix 3.1, Attachment 2, Table 6) which slightly extends the eastern highlands distribution as previously mapped by CAMP 2001 (Figure 4.3-1).

Other endemics with moderate distribution include the bedotids, R. alaotrensis (four sites) often in sympatric with *R. legendrei*, and *B.madagascariensis* (four sites), and the cichlid *Paretroplus polyactis* (three sites).

Bedotia exhibits a high incidence of single-basin endemism within the genus. *B. madagascariensis* is listed as "Near Threatened" in the IUCN Redlist (2004). Bedotia has been found almost exclusively in clear, silt-free habitats (Loiselle and Stiassny 2003), but was present in relatively disturbed habitats of the pipeline LSA near the lowlands and northern end of the slurry pipeline study area.

Similar to the Bedotia, *Rheoclès alaotrensis* exhibits high incidence of single-basin endemism, and prefers clear, silt-free, well-oxygenated habitats. This species is reported to have suffered fragmented distribution (Loiselle and Stiassny 2003) and is listed as "Vulnerable" in the IUCN Redlist 2004. Its distribution in the study area also extended east to the Sahanandrazana River, in association with *Ratsirakia legendrei*.

Sauvagenella madagascariensis was collected in large numbers from one primary site (107+200) only. This endemic species is restricted to eastern coastal drainages, mostly in forested small rivers and streams, but occasionally found in brackish waters (Stiassny 2003). It is not listed and the populations appear to be stable.



LEGEND

- SLURRY PIPELINE
- ROAD
- MINE, PLANT AND TAILING SITES

ENDEMIC FISH SPECIES

- *Ambassis fontoynonti*
- *Bedotia madagascariensis*
- *Hypsleotris tohizanae*
- *Ophicara macrolepidota*
- *Paretroplus polyactis*
- *Ratsirakia legendrei*
- *Rheoclès alaotrensis*
- *Sauvagella madagascariensis*

REFERENCE

Landsat 7 Mosaic Image; Captured April/Sept. 2001.
CAMP "Faune de Madagascar" Workshop 2001.
Datum: WGS 84 Projection: UTM Zone 39S

15 0 15
SCALE 1:500,000 KILOMETRES

PROJECT

AMBATOVY PROJECT

TITLE

DISTRIBUTION OF ENDEMIC FISH IN THE REGIONAL AREA

Golder Associates
Calgary, Alberta

PROJECT No. 03-1322-172.5300			SCALE AS SHOWN	REV. 0
DESIGN	CM	09 Aug. 2005	**FIGURE: 4.3-1**	
GIS	TN	15 Aug. 2005		
CHECK	GJ	08 Feb. 2006		
REVIEW	DM	08 Feb. 2006		

I:/2003/03-1322/03-1322-172/mxd/Fish_Aquatics/Fig4.3-1_Fishspp.mxd

Paretroplus polyactis listed as "Vulnerable" in the IUCN Redlist 2004, was collected from three river sites but in low numbers. It is generally more prevalent in coastal lagoons and lakes; including the brackish habitats of the Pangalanes waterway. *Ambassis fontoynonti*, listed as DD (data deficient) by the IUCN Redlist was present in small numbers at two sites only. Similarly, the other two endemics, *O. macrolepidota,* and *K. sauvagii*, were present in small numbers at some of the sample sites but little is known of their range or populations and they are not listed by the IUCN.

Aquatic Invertebrates

A large number of endemic aquatic macro-invertebrate taxa are present in the streams and rivers within the slurry pipeline study area; however the current level of identification limits the description of taxa. Several of the more significant groups encountered were:

- *Atyidae* (freshwater shrimp); these have a high degree of endemism (77%), with 26 species in four genera existing on the island (Raharivololoniaina 2004). Within the slurry pipeline study area they were one of the more abundant taxa in Group II (similarity analysis) during the survey.
- The *Odonata* (dragonflies) with seven families, was also common in the LSA. Madagascar is noted for its rich *Odonata* fauna. The number of endemic species and genera of the *Odonata* in Madagascar are remarkable. Of 52 genera, 12 are endemic; of the 181 named species and subspecies, 132 are endemic and most of the endemic species are concentrated on the forested eastern edge of the island (Donnelly and Parr 2003).

Significant Habitats

The Torotorofotsy Wetlands is a unique ecosystem. It is considered one of the most valuable ecosystems in the study area because of its ecological function and biodiversity, and has recently been declared a Ramsar Site. The ecology and biology of the Torotorofotsy Wetland is sensitive to water level and water quality fluctuations. Populations of important regionally endemic fish species (*Rheoclès alaotrensis* and *Ratsirakia legendrei*) were present in the wetlands associated sampling sites along the pipeline route. However; although unique, the Torotorofotsy Wetlands is not pristine habitat. It exhibits considerable habitat disturbance along the marsh edge and the slurry pipeline will follow an abandoned railway across northern end, reducing potential effects on the wetlands.

4.3.4 Issue Scoping

4.3.4.1 Issues and Key Questions

Consultation revealed a general concern that pipeline construction might impact water quality for both human and ecological requirements. Special focus was also put on maintaining the aquatic resources of the Torotorofotsy wetlands (Volume A, Section 6). The primary issues identified with respect to the potential impact of the slurry pipeline on freshwater aquatic resources are:

- The effects of construction and operation of pipeline watercourse crossings on availability, quality or quantity of aquatic habitat.
- The effects of construction and operation of access roads and infrastructure, on availability, quality or quantity of aquatic habitat.
- The effects of construction and operation of pipeline and infrastructure on fish distribution and abundance.
- The effects of construction and operation of pipeline and infrastructure on fish health and artisanal fish harvest.

These issues and impacts have been addressed by a set of key questions:

Key Question FA-1 What Effect Will the Project Have on Aquatic Habitat?

Key Question FA-2 What Effect Will the Project Have on the Abundance and Survival of Fish?

Key Question FA-3 What Effect Will the Project Have on Artisanal Fisheries?

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

4.3.4.2 Assessment Parameters

Aquatic biota of significance to the proposed project includes both the fish and invertebrates that form part of the aquatic ecosystem in the project 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.

For this assessment, species of concern, significant species groups and habitat types were selected for evaluation during the impact assessment and development of mitigative strategies. The species groups and habitats for the slurry pipeline area are:

- endemic fish species;
- stream and river (riparian and instream) aquatic habitats; and
- native and resident fish communities harvested by artisanal fisheries.

Measurable parameters used for the assessment of fish and aquatic resources are summarized in Table 4.3-4. 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.

Table 4.3-4 Ecosystem Components, Parameters and Criteria for Fish and Aquatic Resources

Question	Ecosystem Component	Measurable Parameter	Evaluation Criteria
change in the quality, quantity and availability of aquatic habitat	streams and rivers, endemic fish, benthic macro-invertebrates	stream size habitat type and quality water flow water quality (TSS)	net loss of fish habitat IHIA (Kleynhans 1996) water quality and suspended sediment guidelines
change in abundance of fish and aquatic biota	endemic and native fish, benthic invertebrates	fish/ invertebrate community structure and diversity physical habitat and aquatic health assessments pipeline operations potential harvest pressure	subjective evaluation of sustainability of the resource; professional judgment conservation status (IUCN 2004 and published checklists) Water Quality Guidelines for the Protection of Aquatic Life (CCME 1999) watercourse crossings guidelines
change in fish health	endemic and native fish, benthic invertebrates artisanal fisheries for fish /invertebrates	surface water quality and prediction (TSS) predicted fish abundance	suggested values from the literature subjective evaluation and professional judgment

Note: TSS = total suspended solids.

4.3.5 Key Question FA-1: What Effect Will the Project Have on Aquatic Habitat?

4.3.5.1 Impact Pathways

Aquatic habitat can be affected by slurry pipeline activities during construction, operation and closure phases. Habitats will also be affected by ancillary facilities and services such as watercourse crossings by access roads, infrastructure such as construction camps, and laydown areas. Changes in the availability, quality or quantity of aquatic habitat may result from:

- riparian disturbance at watercourse crossings;
- instream habitat alteration; and
- changes in water quality.

Riparian Disturbance

Clearing of forest canopy, riparian vegetation and disturbance of the stream banks for the pipeline or service road approach to watercourses by grading or other activities, and clearing or grading for camps and laydown areas, can result in an indirect loss of aquatic habitat primarily due to the change in slope or drainage pattern, with increased erosion potential. The resulting sediment entrainment, increased levels of TSS and downstream transport can impact fish habitat.

Instream Alteration

In-water activities from trench excavation, pipe laying and back filling will result in sediment entrainment (increased TSS) and change in channel morphology, affecting fish habitat. Associated activities such as hydrostatic testing of the pipeline can result in similar changes. Construction of culvert, bridge or ford-type crossings for access and service roads and placement of fill in water can result in a disturbance or loss of instream aquatic habitat, or change to watercourse hydraulics.

Changes in Water Quality

Changes to surface water quality (i.e., increased sediment loading) will occur as a direct result of riparian disturbance and instream alterations at pipeline and road approaches and crossings. Water quality may also be affected by accident or spills during construction or operation, affecting the availability and quality of aquatic habitat. The location of work camps, withdrawal of water from local water bodies and disposal of sewage effluents is also a water quality concern that may directly impact aquatic habitat.

4.3.5.2 Assessment Methods

Riparian Disturbance

Pipeline and service road potential watercourse crossing locations were assessed from Landsat images, aerial reconnaissance survey data, mapped data and project execution plans. A habitat integrity assessment, which included riparian and instream criteria (described in Volume J, Appendix 3.1, Attachments 1 and 2), was used to classify existing conditions and sensitivity to disturbance.

Instream Alteration

Habitat types and integrity, fish species and associated invertebrate species as determined in the baseline were identified and impacts discussed based on extrapolation of data at field sample sites. Disturbance and alteration of aquatic habitat along the slurry pipeline, service road and access roads was assessed from map data, enumeration of watercourse crossings and the habitat integrity assessment, and qualitative estimates of potential bank and littoral disturbance at the watercourses.

Changes in Water Quality

Predicted changes in water quality (Volume C, Section 3.7) were examined for potential watercourses along the access roads and slurry pipeline. Impacts on aquatic habitats, fish communities and aquatic invertebrate species identified during the baseline survey were discussed qualitatively.

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 4.3-5.

Table 4.3-5 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 RSA **beyond regional**: effect extends beyond the regional study area (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 impact of habitat loss or alterations as a result of riparian clearing, instream construction and changes to water quality on the slurry pipeline include the following:

Design Features

- Route alterations have been made to avoid protected areas, parks and pristine aquatic habitats (i.e., within primary forests). Additional adjustments will be made, where feasible, to avoid sensitive local habitats at watercourse crossings.
- Matching the pipeline installation method with the watercourse type, habitat condition and critical aquatic life history features to avoid potential adverse effects.
- Locating sites away from watercourses and minimizing footprints for construction camps, effluent discharges, laydown areas, soil disposal areas, and petroleum storage sites.

Construction and Operations

- Implementing Environmental Management Plans which implement protection measures to avoid or reduce environmental disturbance from construction activities at watercourse crossings. These include measures such as:
  - Using trenchless or isolation pipeline crossing techniques at pristine, sensitive or important endemic fish habitat to minimize in-water work and disturbance of aquatic /riparian habitat and control TSS levels within specified levels to protect aquatic habitat and biota.

- Limiting right-of-way (RoW) clearance and width at watercourse crossings, use of minimum setbacks from watercourses for equipment, maintain vegetative buffer (no stripping) and selective hand-clearing to minimize potential for erosion, sedimentation or other water quality effects.
- Implementating "silt traps" on small streams and "sediment containment ponds" on large streams to reduce TSS levels and ensure released water meet water quality guidelines for the protection of aquatic life.
- Construction sediment monitoring (TSS levels) and implementation of shut-down levels for exceedences.
- Controling water withdrawal locations, withdrawal amounts and discharge from hydrostatic tests to protect fish and aquatic habitat conditions.
- Implementing pre-construction field assessments at each crossing location on the pipeline route to identify sensitive and endemic aquatic biota, critical life stages and habitat, and classify biota and important habitat features as to the level and timing of protection required, including possible fish salvage.
- Implementing fish salvage or avoidance procedures at crossings containing communities of endemic, rare, or locally important (artisanal fisheries) fish, where instream crossings may potentially result in mortality or severe impact to local habitats.

- Developing an aquatic environmental emergency response and clean-up plan for potential spills or release of contaminants during construction, and / or in the event of pipeline breaks during operation.

Reclamation

Use of physical and vegetative reclamation at all watercourse crossings or approaches to protect aquatic resources from increased TSS levels from the pipeline and service/access roads. This will include:

- Immediate revegetation of all disturbed riparian habitats at pipeline and/or access road watercourse crossings.
- On-site drainage management and erosion control programs at slopes and approaches to watercourses.
- Protection of bank and instream channel features from high flow erosion.

4.3.5.5 Results

Riparian and Instream Disturbance

Streams and rivers along the slurry pipeline route will be directly disturbed by riparian, bank and instream channel activities due to construction and operation of the slurry pipeline. The extent of watercourse disturbance or loss from riparian or instream activities cannot be accurately quantified as data is not presently available for a majority of the potential crossings. However, an approximate total disturbance is estimated in Table 4.3-6 based on the estimated number of watercourse crossings, wetted widths (mean of survey data from 11 sample sites) and projected pipeline RoW graded disturbance at the crossing.

Table 4.3-6 Total Estimated Aquatic Habitat Disturbance in the Slurry Pipeline Local Study Area

Number of Watercourses	Est. Wetted Channel Disturbance (m)[(a)]	Est. Bank RoW Disturbance (m)[(b)]
99	3,435	5,940 – 15,246

(a) Based on average channel width (34.7 m) from 11 measured sites.
(b) Based on cleared / graded width of 30 to 77 m x two banks.

Analysis of fish species composition at the sample sites correlated the presence of predominately indigenous (endemic and native) fish species to the presence of largely natural or slightly modified forest stream habitat (40% of sample sites). Habitat loss and alterations could interfere with these populations. Assuming open cut installation of the water pipeline, effects will be primarily a short-term disturbance of riparian and instream habitat and limited to the construction period, with low impact. Through sedimentation and erosion control design measures, the overall impact is predicted to be negligible. However, long-term high impacts could occur at watercourses because of the extent of soil grading and cuts necessary to achieve the maximum grade of 15% for the pipeline, and the local combined effects of “road” use.

In addition to the slurry pipeline RoW, access roads will be required for people and equipment. Substantial upgrading and rebuilding will be required for most of these roads. The access roads will be routed along streams and stream valleys in some cases, and some new bridges will be required at river crossings, in addition to an undetermined number of culvert or ford crossings of smaller watercourses. As many of these watercourses are located in disturbed habitats, impacts may be low, based on reduced sensitivity of biota to disturbance. The effects of any road construction will be generally short-term and low impact; however, long-term, permanent disturbance could occur depending on the type of road crossing (culvert, bridge, water ford) and the success of erosion control and reclamation plans.

Change in Water Quality

Clearing and grading of the pipeline and service road RoW, in-water construction activities and operation of ancillary facilities (camps, hydrostatic testing) will affect surface water quantity and quality in the streams and rivers crossed by the slurry pipeline. Aquatic habitat will be directly affected at the pipeline excavation site, and downstream by sediment that is entrained during construction or erosion from surface runoff on watercourse approaches. These changes may affect the presence, abundance and distribution of aquatic biota downstream of the site.

Increased turbidity and sedimentation (TSS) during construction are the primary water quality changes which may affect aquatic ecosystems along the pipeline, access or service roads. Use of applicable Best Management Practices during construction will minimize potential effects and impacts will be low.

4.3.5.6 Impact Analysis

Residual Impacts

Residual impacts of aquatic habitat loss as a result of the slurry pipeline construction operation and closure are summarized in Table 4.3-7. These impact assessments are based on assumptions that the observations from the watercourse sub-samples are representative of other watercourses along the route, and that mitigation / implementation of the management plans are successful in eliminating or reducing effects on the aquatic environment.

Table 4.3-7 Potential Effects and Residual Impacts for Aquatic Habitat

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	displacement and disturbance of critical riparian and instream aquatic habitats effects on downstream water quality (TSS) and habitat loss	use of aerial crossings, water diversion techniques or trenchless methods at all critical / endemic habitat water management, including silt traps, sedimentation ponds minimize RoW clearing and grading erosion control	low magnitude / short-term physical disturbance during pipeline construction high magnitude /short-term disturbance from water quality / TSS changes during both pipeline, RoW and road construction low magnitude / short-term physical disturbance during road and infrastructure construction low magnitude /long-term loss from footprint and effects of bridges, culverts, etc.
operation	potential alteration of downstream watercourse habitats for as a result of hydraulic and water quality changes (increased TSS from erosion) , spills or pipeline breaks	water management plan revegetation erosion and sediment guidelines spill response plan	low magnitude / medium-term modification of habitats
closure	existing changes in the landscape	continued water management; erosion control on-site reclamation and habitat enhancement	low magnitude / long-term modification of crossing location habitats

The status of aquatic habitat in the pipeline area is moderately well understood, but the level of baseline information (ground surveys at 15 of 99 potential watercourse crossings) is low-moderate. This is because, surveys have shown that it is difficult to generalize results to other streams, even though representative size classes of stream were visited. Construction mitigation will however be used, which means that the prediction confidence for impact ratings for habitats within the slurry pipeline area is medium.

An overall residual impact classification is presented in Table 4.3-8; the overall environmental consequence scores were based on the screening system described in Volume A, Section 7.

Table 4.3-8 Residual Impact Classification for Effects on Aquatic Habitat

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Effect: Aquatic Habitat Disturbance by Slurry Pipeline							
construction	negative	low	local	short-term	no	high	low
operations	negative	low	local	long-term	no	high	low
Effect: Downstream Water Quality (TSS) Changes							
construction	negative	high	local	short-term	yes	high	moderate / unknown
operations	negative	low	local	medium-term	yes	high	low / unknown
closure	negative	low	local	long-term	yes	high	low / unknown
Effect: Aquatic Habitat Disturbance and Water Quality Changes from Infrastructure and Access / Service Roads							
construction	negative	low	local	short-term	no/ yes (water quality)	high	low / unknown
operations	negative	low	local	long-term	no / yes (water quality)	high	low / unknown
Effect: Aquatic Habitat Reclamation							
closure	positive	n/a	n/a	n/a	n/a	n/a	n/a

n/a = Criteria not classified for positive impacts.

Monitoring

Construction, operation and post-disturbance monitoring of the effectiveness and integrity of mitigation and site reclamation will be implemented to ensure protection of the downstream resources.

4.3.6 Key Question FA-2: What Effect Will the Project Have on the Abundance and Survival of Fish?

4.3.6.1 Impact Pathways

The abundance and survival of fish and other aquatic biota can be affected by activities during construction, operation and closure phases. Changes will result primarily from:

- community (habitat) modification; and

- changes to fish health.

Community (Habitat) Modification

Presence, abundance and survival of fish and aquatic biota is directly linked to habitat. Disturbance of fish and aquatic biota will occur during watercourse crossings associated with the slurry pipeline, the service road and access roads.

Fish Health

Change in fish health can result from construction activities and /or operation of the slurry pipeline and associated infrastructure. Fish health effects result when the physical or chemical characteristics of water vary outside the normal tolerance range of fish. Fish health can be affected by contaminants (from spills, effluent discharges), changes in water quality (high levels of entrained sediments) and construction techniques (i.e., use of explosives) with lethal, sub-lethal or chronic effects on fish.

4.3.6.2 Assessment Methods

Habitat loss data generated for watercourses (Key Question FA-1) and habitat integrity information developed during the baseline site surveys was related to the species taxonomy and community composition data described by qualitative and quantitative population sampling during the baseline survey within the LSA. 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 hydrology and water quality data (Volume C, Sections 3.6 and 3.7).

4.3.6.3 Mitigation

Mitigations that will minimize the loss of fish and invertebrate communities from activities associated with the pipeline construction and operation are the same as those described in Section 4.3.5.4

4.3.6.4 Results

Community (Habitat) Modification

The fish fauna encountered within the slurry pipeline LSA consisted of 70% endemic and native fish species. In total, eight endemic species, five of which are IUCN Redbook listed (2004), were encountered along the pipeline route. Endemic fish were present in 12 of the 15 sites surveyed. (Table 4.3-9). Native fish (11 species) were encountered at 10 of the surveyed watercourses. Species distribution and abundance varied because of the diversity and span of the pipeline route across numerous drainages.

Table 4.3-9 Distribution, Number of Species and Relative Abundance (Compared to Exotic Species in each Sample) of Endemic Fish Species in the Slurry Pipeline Local Study Area

Site	Endemic Fish Present	# Endemic Species	Relative Abundance (+= greater than exotics)
R2+000	√	1	+ (only species present)
R5+575	√	1	
R9+250	√	2	
R16+100		0	
042+300	√	1	+ (only species present)
051+800	√	2	
060+600	√	2	+
107+200	√	4	+
136+200	√	3	+
145+700	√	5	+
157+700	√	1	
175+200	√	2	+
178+900	√	1	
E3 005+150[a]		0	
E3 011+950[a]		0	

[a] E3 denotes sites that were sampled along a potential alternative pipeline route.

The ranges of many endemics have diminished and are localized due to habitat degradation and introduced competitors and predators (Ravelomanana 2004). All species encountered in the LSA have been previously reported within the eastern highlands and lowlands regions (CAMP 2001); however, species distributional information is new for some of the watercourses and watersheds crossed by the pipeline route. Insufficient information is available on the biology of endemic and native species in the study area to identify critical habitats or uses (i.e., migration routes) by the resident fish communities encountered at the watercourse crossing sites. Of interest, although many watercourse habitats along the proposed route were classified as disturbed, endemic fish populations persisted in a majority of streams, and the relative abundance of the endemics were greater than the exotic fish populations in nearly 60% of these locations (Table 4.3-9).

Disturbance to resident fish populations in the water crossing locations will occur as a result of habitat alterations (physical disturbance of instream habitats) or the effect of increased sediment levels and downsteam deposition affecting the use and productivity of habitats during construction. Hydrostatic testing can also impact fish (water withdrawal from important habitats, entrainment, and discharge affecting habitat condition in the receiving area). Through the implementation of the construction and operationing management plans these effects will be mitigated, largely temporary, and low impact. Long-term impacts on fish communities may occur where permanent structures such as bridges or culverts are installed, but they are expected to be low in magnitude. The low risk of a potential pipeline break (Volume C, Section 3.5) during operations could, impact water quality and biota; however, through pipeline monitoring and maintenance the extent of impact is expected to be low.

Impacts on non-indigenous (exotic) fish communities are expected to be negligible because of the widespread distribution, habitat adaptability and tolerance to reduced water quality by these species in this group.

Fish Health

Changes to fish health will occur primarily on a local level as a result of the effect of increased sediment entrainment during construction, and potential accidents and spills into water bodies and effluent discharges into water bodies. The effects of water quality changes (TSS) may be severe because of the soil types, topography and extent of ground / in-water disturbances with potential for high levels of erosion and sedimentation. The effects on fish from exposure to sediment range from avoidance and minor physiological stress to mortality, with the magnitude of the effect being a function of TSS concentration and duration of exposure. Spills or domestic effluent release (from camps) and hydrostatic testing (withdrawal and blowdown of water) can also affect fish health.

4.3.6.5 Impact Analysis

Residual Impacts

Residual impacts of changes to the abundance and structure of aquatic communities and the survival of endemic species as a result of the slurry pipeline construction, operation and closure are summarized in Table 4.3-10.

The status of fish species in the pipeline area is poorly understood, and the level of information on basic biology and life history for most endemic fish species and other endemic aquatic biota is very limited. Basic biology would better help define sensitive habitat and sensitive time periods. However, mitigation techniques will be used, linked to additional monitoring just before construction. The prediction confidence for impact ratings for fish and aquatic communities at and downstream of the watercourse crossings is therefore medium.

Closure and reclamation goals will include some habitat restoration and possibly enhancement. The success of these initiatives is difficult to predict.

Table 4.3-10 Potential Effects and Residual Impacts for Aquatic Species Abundance and Health in the Slurry Pipeline Area

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	avoidance, sublethal effects or mortality depending on the levels of TSS , or other local effects on aquatic and riparian habitat during instream and service road or access road construction	local water management pre-construction assessment of each crossing to select most appropriate technique erosion control design systems fish salvage program	high magnitude/long-term water quality effect on local fish and aquatic fauna low magnitude / long-term habitat disturbance during bridge/ culvert construction
operation	change to downstream aquatic biota as a result of water flow and water quality changes	erosion and sediment control systems	moderate to high /short-term effect on downstream aquatic communities due to water quality change low magnitude / long-term species and community changes due to riparian and instream habitat alterations
closure	community / species change	crossing habitat enhancement	low magnitude / long-term resident species recovery

An overall residual impact classification is presented in Table 4.3-10; environmental consequence scores used the screening system described in Volume A, Section 7.

Table 4.3-11 Residual Impact Classification for Effects on Aquatic Species Abundance and Health in the Slurry Pipeline Area

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Effect: Community (Habitat) Modification							
construction	negative	low	local	long-term	no	medium	low
operations	negative	low	local	long-term	no	medium	low
Effect: Change to Fish Health							
construction	negative	low	local	short-term	yes	high	negligible / unknown
operations	negative	low	local	long-term	yes	high	negligible / unknown
Effect: Site Restoration							
closure	positive	n/a	n/a	n/a	n/a	n/a	n/a

n/a = Criteria not ranked for positive impacts.

Monitoring

Construction, operation and post-disturbance monitoring of the effectiveness and integrity of mitigation and site reclamation will be implemented to ensure protection of the downstream resources.

4.3.7 Key Question FA-3 What Effect Will the Project have on Artisanal Fisheries?

4.3.7.1 Impact Pathways

The harvest of aquatic biota (fish and invertebrate communities) by artisanal fisheries can be affected by the slurry pipeline during construction, operation and closure phases. Changes may result from:

- accessibility to the pipeline area or nearby locations, and
- fish availability and health.

Accessibility

Increased harvest of fish and invertebrates by artisanal fisheries (consumption and collection, i.e., aquarium trade) could occur because of changes in access to the watersheds crossed by the slurry pipeline or access roads.

Fish Availability and Health

Pipeline operation could interfere with the current harvest of fish populations in the LSA. Changes to fish health and condition could occur due to downstream effects from construction and infrastructure (i.e., camps and service roads).

4.3.7.2 Assessment Methods

Pipeline execution information was reviewed to evaluate access and changes related to infrastructure.

Fish or invertebrate species harvest in artisanal fisheries was determined from baseline observations, projected by professional judgement from the species composition observed, or from published reports and communications.

Fish health was judged by interpretation of predicted water quality and quantity data.

4.3.7.3 Mitigation

Construction and Operation

- Limit access (through consultation with local representatives) to areas identified that contain rare endemic populations targeted for protection.
- Regulated closure of waters to construction personnel.

4.3.7.4 Results

Development and upgrading of additional access roads into the watersheds of the slurry pipeline will create additional unquantifiable amounts of local access to all watercourses crossed by the pipeline. A majority of artisanal fish harvest observed in the LSA was for exotic species (Section 4.3.3.3); improved access may result in some additional fishing pressure from nearby villages. Of greater concern is the large influx of people associated with the construction camps (up to 400 people per camp). A significant negative impact may occur on local fish communities or aquatic biota if harvest is unregulated. These impacts are considered moderate to high, but local in extent.

Changes to fish health and condition could occur on a local level as a result of the effect of increased sediment entrainment during instream construction activities, accidents and spills into waterbodies, effluent discharges, and deposition of air emissions during construction into local waterbodies, affecting water quality downstream of the pipeline. The management plans related to sediment input, surface water withdrawal and effluent discharge will limit these changes to accepted standards and will also be monitored. Therefore the effects on fish health and condition are considered low after mitigation, with a low environmental consequence.

4.3.7.5 Impact Analysis

Residual Impacts

Residual impacts of changes to the artisanal fisheries as a result of the Ambatovy Project slurry pipeline construction, operation and closure are summarized in Table 4.3-12.

Table 4.3-12 Potential Effects and Residual Impacts for Artisanal Fisheries

Project Period	Potential Effects	Mitigation	Residual Impacts
construction	local habitat and water quality effects on aquatic species abundance increased harvest as a result of new access and addition of construction workforce	regulated use	low magnitude / short-term loss during infrastructure construction high magnitude/short-term loss within the pipeline or associated construction camp areas due to workforce
operation	potential change in use of aquatic biota as a result of increased and improved access	local environmental education programs limit access	low to moderate magnitude / medium-term change as a result of access changes
closure	increased harvest of aquatic biota as a result of improved access		low magnitude / long-term harvest of aquatic biota

The extent and use of aquatic resources within the pipeline disturbance area is poorly understood and based only on observation during field programs. However, impacts to abundance and health of fish have been shown above to be of low consequence, thus the prediction confidence for impact ratings for artisanal fisheries within the pipeline LSA is rated medium.

An overall residual impact classification is presented in Table 4.3-13; the overall environmental consequence scores were based on the screening system described in Volume A, Section 7.

Table 4.3-13 Residual Impact Classification for Effects on Artisanal Fisheries

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Effect: Access Change							
construction	negative	high	local	short-term	yes	medium	moderate
operations	negative	low	local	medium-term	yes	high	low
closure	negative	low	local	long-term	yes	high	low
Effect: Changes in Fish Availability or Health							
construction	negative	low	local	long-term	yes	short	low
operations	negative	low	local	medium-term	yes	medium	low

4.3.8 Conclusions

The difficulty of generalizing results from surveyed streams for those un-surveyed, because of high variability found, has presented a challenge for this pipeline assessment. However, the use of standard mitigations, plus additional surveys just prior to construction, will ensure that impacts are minimized and of short duration.

Low environmental consequences are predicted for local aquatic habitat and endemic fish species abundance and survival, due to residual impacts from construction and operation of the slurry pipeline; however, impacts of higher magnitude with unknown consequences may occur due to water quality (TSS) changes in watercourses along the pipeline.

The effects on local resource use and artisanal harvest of fish or biota are expected to be of low to high magnitude, as a result of access changes resulting from the pipeline. However, effects are local and predicted to be of low consequence, except during the short construction period, when they would be moderate.

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 slurry pipeline study area. The assessment is 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 mitigation measures and follow-up monitoring activities.

4.4.2 Study Area

The slurry pipeline Local Study Area (LSA) includes the approximately 195 km slurry pipeline footprint, plus a 1 km buffer on each side of the pipeline, and extends from the ore body complex in the mine site LSA to the plant site in the Toamasina LSA (Figure 7.2-2, Section 7, Volume A).

The LSA has been divided into three major land use sub-areas: the western section, which is within the forest corridor (corridor zone); the central section, which passes around primary forest fragments through an area defined primarily by a tavy matrix (tavy zone), and the eastern section, which contains entirely secondary vegetation and has a higher density of agricultural use (agricultural zone).

The pipeline initially passes through the Torotorofotsy Ramsar site within the mine site LSA and further east, through the Mantadia-Zahamena Conservation Corridor. The proposed right-of-way has been re-routed during analysis of alternatives to be primarily located on land with existing disturbances (Volume B, Section 1).

4.4.3 Baseline Summary

The following provides a summary of the results of current biodiversity potential, and areas of natural habitats and land use practices in the LSA. The summary focuses on those results that are important for assessing impacts from the project. As noted above, a complete description of the baseline methods, analysis, and results is located in Volume J (Appendix 4.1).

4.4.3.1 Ecosystem Diversity

Over 75% of the plant and bird species identified in the slurry pipeline 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 three species are listed by the World Conservation Union (IUCN). Five plant species and eight birds have IUCN status.

Precise sample points within transects were not recorded during vegetation surveys, therefore, flora species ecosystem metrics could not be determined by habitat or land use classes (Volume J, Appendix 1.1). Among the current distribution of vegetation communities within the slurry pipeline LSA, species richness for amphibians and reptiles was highest in the primary forest habitat (76 species) and primary forest edge (18 species). Thirty-five species were unique to the primary forest (Volume J, Appendix 2.1). Eucalyptus forest contained 15 species of reptiles and amphibians, while marshes and open glades in primary forest contained 10 or 11 species. Disturbed habitats, such as primary forest fragments, secondary forest and tavy, were comprised of five or fewer species (Volume J, Appendix 2.1). Similar to reptiles and amphibians, most bird species were detected in forested habitat (62 of 86 species), including all IUCN-listed species.

A total of 26 fish species were recorded at pipeline survey sites (Table 4.4-1). Eight species are endemic, 11 are native (indigenous but not endemic) and seven are exotic. No species are listed by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Similar to the mine LSA, habitat loss, and competition and predation from exotics have likely contributed to the contraction of the range of endemic and indigenous fish fauna.

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

Class	Species Richness	Number of Endemics	IUCN Species	CITES Species
flora	332	257	5	3
amphibians	54	53	2	2
reptiles	35	35	1	13
birds	86	71	8	10
fish	26	8	2	0

4.4.3.2 Landscape Diversity

Approximately 94% of the land within the slurry pipeline LSA is currently disturbed (Table 4.4-2), attesting to the success of the re-routing activities to minimize impacts, especially through the Mantadia-Zahamena corridor. Land use practices include tavy agriculture, logging, woodlots, plantations and rice production. Azonal, transitional, and marsh edge forests are located at the eastern end of the pipeline route, near the mine site. Primary forest is also located in the corridor zone of the pipeline. A small number of natural wetlands, accounting for 1.1% of the area, are located in the eastern portion of the pipeline route near the Toamasina study area.

Table 4.4-2 Land Classification for the Slurry Pipeline Local Study Area

Land Class	Area (ha)	Proportion of Total Area (%)
azonal habitats	81	0.2
azonal type transitional forest	36	0.1
transitional forest	151	0.4
marsh edge forest	26	0.1
primary forest	1,403	3.9
wetlands	406	1.1
degraded primary forest	1,537	4.2
clearing / tavy	30,778	84.9
woodlot / plantation	693	1.9
pasture	308	0.9
rice paddies	278	0.8
coastal shrub	227	0.6
water	128	0.4
human settlement	120	0.3
beach ridge	70	0.2
industrial	25	0.1
road	6	<0.1
railway	2	<0.1

4.4.4 Impact Assessment

4.4.4.1 Issue Scoping

The following issues related to the slurry pipeline-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):

- potential impacts from construction on natural habitats and biodiversity;
- potential impacts of pipeline corridor construction on rare, endangered or locally endemic species;
- indirect effects during construction and operations on natural habitats and biodiversity from increased access along the corridor; and
- any fragmentation or loss of core habitat in areas recognized as being of special importance, including the Torotorofotsy wetlands and the Mantadia-Zahamena corridor.

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 is 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 linkages that have the potential to directly affect natural habitats and biodiversity, as measured by ecosystem and landscape metrics (Volume C, Section 4.4.3), are evaluated and assessed. Indirect effects on biodiversity components such as flora, fauna, fish and aquatic resources are addressed in Volume C, 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

Indicators used to rank the biodiversity potential of habitats in the pipeline LSA included primary forest types, natural wetlands, degraded forests and species richness, species endemism and species conservation status (IUCN and CITES) for plants, wildlife, and fish (Volume C, Section 4.4.3). Direct impacts of the project on habitat and biodiversity indicators will be assessed through changes in the area of habitats on the landscape.

Potential Impact Pathway Evaluation

Activities that may result in changes to natural habitats and biodiversity include construction and operations of the slurry pipeline corridor and reclamation during closure. The slurry pipeline will connect the ore preparation plant at the Ambatovy mine site to the process plant at Toamasina. The pipeline will be buried, and will be approximately 195 km long. The width of the corridor will vary depending upon slope from 25 m to 100 m with a road right-of-way running along it for access. Specific details of the project are described in Volume C, Section 2.0. Briefly, primary activities associated with the slurry pipeline that will influence natural habitats and biodiversity include:

- route investigations including survey and demarcation of pipeline centreline, geotechnical surveys and hydrological surveys during early construction phase;

Table 4.4-3 Location of Biodiversity 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
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 plant, 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 access	change in hunting, trapping, and fishing, and predation			Y	Y
		increased vehicle-wildlife collisions			Y	
	change in air quality	change in plant and animal tissue quality		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
operation and closure						
reclamation	replacement of habitat	change in all above potential impacts	Y	Y	Y	Y

Note: Y = Yes.

- direct clearing of vegetation with right-of-way ground grading, new access roads and improvements, construction camps, pipe storage areas;
- pipe hauling will be done with trucks, and pipe laying activities will occur mainly during the dry season; and
- during reclamation some parts of the pipeline could be taken out, but most sections will be left in place.

Three major land use sub-areas were defined along the slurry pipeline LSA: the western section, which is within the forest corridor (corridor zone); the central section, which passes around primary forest fragments through an area defined primarily by a tavy matrix (tavy zone), and the eastern section, containing entirely secondary vegetation and a higher density of agricultural use (agricultural zone) (Volume K; Appendix 3.1).

Development of the project will result in the loss or alteration of 940 ha of habitat in the LSA (including associated buffers). Of all possible sources of impacts from project construction and operation, habitat loss is among the most important as it reduces the landscape’s capacity to support plant, wildlife and fish species (Fahrig 1997; Andrén 1999; Fahrig 2003). Since the theory of island biogeography was introduced by MacArthur and Wilson (1967), many studies have demonstrated the negative relationship between loss of habitat area and species richness and abundance (see review by Debinski and Holt 2000). Many of the species are also endemic and/or have special conservation status (Volume C, 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. Fragmentation is typically associated with changes in patch size, number of patches, habitat connectivity and edge effects (Fahrig 2003). The amount of primary forest, wetlands, and degraded forest habitats will be influenced by changes in mean patch size and number of patches. However, connectivity and edge effects do not affect the area of these habitats that have the potential to support flora and fauna species, so this potential impact pathway is invalid.

The greatest potential impact of fragmentation will be on the biota that inhabits the landscape within the LSA, particularly the primary forest habitats within the Mantadia-Zahamena corridor. The process of fragmentation often results in disconnected habitat fragments with a high proportion of open perimeters. Subsequently, fragmentation can increase the amount of habitat edge, decrease the amount of habitat interior, and increase the distance between habitat patches (Turner 1996; Fahrig 1997, 2003).

Forest edge and interior changes can negatively influence species within habitats by changing moisture, light and nutrient regimes (Kitchell et al. 1979; Kapos 1989; Saunders et al. 1991; Brown 1993; Nichol 1994). Such changes in microclimate are particularly important for some species of plants, fish, amphibians and reptiles. It also increases the chances of introduction (accidental or otherwise) of invasive or exotic species which can out-compete and replace unique niches once held by native species within an ecosystem (sensu Turner 1996; Debinski and Holt 2000; Benstead et al. 2003). Edges can also alter population and community dynamics, and the composition of indigenous species (Karieva 1987; Fagan et al. 1999).

Increased spatial separation of habitats can impact the movement, dispersal (animals and plants), survival and reproduction of individuals which may change the probability of persistence of populations (Turner 1996; Fahrig and Paloheimo 1988; Pulliam 1988; Hanski 1996; Debinski and Holt 2000).

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

Table 4.4-4 presents a summary of the potential impact pathways between the project 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	Habitat Fragmentation	Reclamation
primary forest, wetlands, degraded forest habitat	Y	Y	Y
species richness	Y	Y	Y
species endemism	Y	Y	Y
species conservation status	Y	Y	Y

Note: Y = Yes

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 habitats within the LSA (Volume C, 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. Baseline values for area and composition of habitat types within the LSA were calculated (Volume C, Section 4.4.3).

Direct impacts from the pipeline on habitat and biodiversity indicators were assessed through changes in the area and composition of habitats on the landscape. Changes in habitat area and composition were determined by applying the slurry pipeline footprint to the landscape (application case) within the LSA. The footprint included a 25 m buffer on each side of the pipeline to produce an average 50 m wide impact zone.

The potential impact of the project on biodiversity indicators was estimated by calculating the relative difference between application case and baseline habitat areas 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 habitat area associated with the project relative to baseline conditions, and to provide both direction and magnitude of the impact. Changes in habitat area were then used with assessment criteria (see below) to predict impacts from the project on biodiversity potential among habitats and within the LSA. A qualitative assessment of fragmentation effects on biodiversity potential is also provided. Impacts to habitats associated with human land use activities (negligible biodiversity potential) were not assessed here (see Volume C, 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. The intent of further decision-making is to further mitigate impacts to natural habitats and biodiversity as much as possible, and fine-tuning of the pipeline route will be conducted in collaboration with engineering and environmental inputs. Thus, the assessment provided here is conservative (i.e., impacts are likely overestimated).

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). 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 pipeline LSA. More details of mitigations are provided in the flora, fauna and aquatic resources EA sections (Volume C, Sections 4.1, 4.2 and 4.3). Mitigation includes:

- avoiding primary native forest vegetation by using existing disturbed areas for pipeline alignment;
- revegetation and reclamation of all cleared areas adjacent to or at watercourse crossings immediately following construction;
- build temporary road bridges in sensitive parts of key forest corridor, unless agreed to leave as part of regional planning;
- along some sections in the key forest corridor (between protected areas), pipeline construction strategy will be adjusted to permit overgrowth of trees and shrubs. This mitigation has potential to increase biodiversity in the Mantadia-Zahamena corridor;
- adjusting watercourse crossing routes to avoid conflicts with important or sensitive fish habitat and local resource use;
- reducing the amount and duration of in-water activities;

- reclamation using native species in designated areas;
- rapid establishment of prescribed vegetation cover following pipeline installation; and
- conducting a survey of the pipeline route just prior to construction to help fine-tune the route and minimize impacts on flora, fauna and aquatic resources.

Analyses in this section focus on the LSA. Overall combined project impacts, including the positive benefits of biodiversity offsets, are considered in Volume G, Section 3.4.

Results

Construction of the pipeline and associated infrastructure is expected to alter small areas of transitional forest, and primary and degraded forest in the Mantadia-Zahamena corridor, and natural wetlands in the Toamasina study area (Table 4.4-6). However, less than 4% of these habitats in the pipeline LSA will be lost due to the project and further route fine tuning could reduce this amount further. No azonal forest in the Mantadia-Zahamena corridor or marsh edge forest associated with the Torotorofotsy will be altered.

Other degraded habitats that support fewer species will be also marginally altered. For example, the area of woodlots and plantations will decrease by 5%, while there will be a 0.9% decrease in coastal shrub / woodland and a 2.6% decrease in tavy matrix. Although habitat loss and fragmentation can negatively influence populations and communities (see Volume B, Section 4.4 for full discussion), the amount of disturbance to the landscape from the pipeline and associated infrastructure is anticipated to be marginal. Small changes in habitat areas should be correlated with little change in mean patch size, connectivity and edge. As a result, the project is not expected to generate measurable effects on biodiversity indicators relative to baseline conditions.

Residual Impacts

Despite mitigation, activities related to the slurry pipeline will result in small negative changes to natural habitats and biodiversity. Although baseline information determined that the slurry pipeline LSA is currently 94% disturbed, a portion of the project will influence primary and degraded forest in the Mantadia-Zahamena corridor, and natural wetlands in the Toamasina area.

Analysis indicated that the fraction of suitable habitat expected to be lost due to the project footprint is 1.6% (23 ha) of primary forest, 3.3% (5 ha) of transitional forest, 3.5% (54 ha) of degraded primary forest, and 1.1% (5 ha) of wetlands. As a result of the relatively small negative changes in these key habitats the magnitude of the impact from the project on natural habitats and biodiversity is predicted to be low during construction and operation (Table 4.4-7). No changes to azonal or marsh edge forest are expected from the slurry pipeline.

Table 4.4-6 Change in Area of Each Land Class for Full Development of the Pipeline Relative to Baseline Conditions in the Local Study Area

Land Class	Area Baseline (ha)	Area Full Development (ha)	Relative Change (%)
azonal habitat	81	81	0.0
azonal type transitional forest	36	36	0.0
transitional forest	151	146	-3.3
marsh edge forest	26	26	0.0
primary forest	1,403	1,380	-1.6
wetlands	406	401	-1.1
degraded primary forest	1,537	1,483	-3.5
clearing/tavy	30,778	29,978	-2.6
woodlot / plantation	693	659	-5.0
pasture	308	306	-0.7
rice paddies	278	269	-3.3
coastal shrub	227	225	-0.9
water	128	128	0.0
human settlement	120	123	0.0
beach ridge	70	68	-2.4
industrial	25	25	0.0
road	6	6	0.0
railway	2	2	0.0

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	low	local	medium-term	reversible	medium	low
closure	negative	negligible	local	medium-term	reversible	medium	negligible

Direct impacts from the project are predicted to be local in geographic extent. The buffer provided for the pipeline (1 km either side) should contain all project-related impacts (habitat and fragmentation effects) associated with the expected 25 to 100 m zone of disturbance. Construction of the pipeline is expected to take two years so disturbance will be medium in frequency. Habitat loss and associated fragmentation effects from construction and operations are predicted to be medium-term in duration, and reversible. The pipeline will be buried immediately, and operation of the maintenance road for project-related activities will cease at closure.

During operations and closure, reclamation is anticipated to reverse impacts to a negligible magnitude. Based on adjacent vegetation, revegetation will likely provide habitats with similar structure and composition as existing primary and degraded forest, and provide suitable habitat for plants and animals (although the small change in wetlands will likely be irreversible). The marginal amount of disturbance to habitats and associated negligible fragmentation effects should enable the ecosystem to return to an equilibrium state within the operation phase. It is anticipated that ecosystem stability will increase further during closure. Reclamation will occur periodically (medium frequency), with a medium-term duration.

Taking all criteria into consideration, the environmental consequence of direct impacts from the project on natural habitats and biodiversity is predicted to be low during construction and operation, and negligible during closure (Table 4.4-7).

Prediction Confidence

Confidence in residual impact predictions is related to the adequacy of baseline data for understanding current conditions, understanding of project-related impacts on the ecosystem, and knowledge of the effectiveness of mitigation. Estimates of the metrics used to assess current biodiversity in the pipeline study area (i.e., species richness, endemism and conservation status) were a function of baseline sampling intensity and distribution, and the types of taxa sampled. Given the nature of the sampling distribution and intensity (see Volume J; Appendices 1.1, 2.1, 3.1), it is likely that not all species inhabiting the study area were recorded. 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). Consequently, the number of potential impacted species is uncertain. Thus, there is a moderate degree of uncertainty as to whether the marginal decrease in primary habitats will surpass potential threshold levels for species to be able to absorb project-related changes and persist into the future.

Although the marginal loss in primary habitats is anticipated to result in little change in mean patch size, connectivity and forest edge, the effects of fragmentation are still somewhat unpredictable (Debinski and Holt 2000; Fahrig 2003). Thus, there is also a moderate degree of uncertainty in predicting the influence of large-scale environmental variation and concurrent project development on the stability and resilience of populations, and the ecosystem.

The cessation of activities associated with the pipeline and concurrent habitat reclamation is assumed to reverse the negative effects of the project (i.e., stabilize the ecosystem). The proponents will capitalize on lessons learnt during natural forest restoration trials undertaken at the mine site during exploration. Forest reclamation within key sections of the Mantadia-Zahamena corridor will occur during operations as part of the project's commitment to the regional carbon project. However, stochastic events (e.g., fire, extreme drought or hurricanes) and future human land use practices (e.g., harvesting, plantations, tavy agriculture) may jeopardize or eliminate the potential benefit of reclamation areas. The success of reclamation, and therefore the degree of reversibility will be achieved and identified through trial applications of reclamation and ongoing involvement in regional conservation efforts will be key to long term success. Reclamation may generate similar vegetative structure and composition of primary and degraded forest that are suitable for many flora and fauna species, but establishing viable wetlands will be difficult. The project's commitment to undertaking trials for primary forest regeneration as part of the carbon project, will add value to biodiversity understanding in the Mantadia-Zahamena corridor.

Monitoring

Biodiversity will be monitored through the programs defined for flora, fauna and aquatic systems with due consideration for maintaining habitats.

Changes to ecosystem processes and function will focus on abiotic variables such as water quality and hydrology. Permanent sample plots will be established in reclamation areas and habitats located on and at various distances from the pipeline in the corridor zone to monitor habitat characteristics and selected flora and fauna species.

4.4.5 Conclusions

The change in habitat availability was used to assess the direct impacts from the project on natural habitats and biodiversity. Following mitigation, analysis indicated that there should be no residual impacts to the Torotorofotsy Wetlands complex or azonal habitat, and negligible effects to species inhabiting primary forest and wetland ecotypes. Residual impacts during construction and operation are predicted to be of low magnitude, local in geographic extent, and continue over the medium-term. During closure, ongoing reclamation and cessation of activities are anticipated to reverse residual impacts (except for the loss of wetlands near the Toamasina study area) to negligible magnitude. The extent of the effects will be local and medium-term duration. The project's forest restoration trials will add value and biodiversity understanding. Overall, the environmental consequence of the pipeline component of the project on natural habitats and biodiversity is predicted to be low during construction and operation, and negligible during closure.

There is some probability that the project will result in small negative impacts to natural habitats and associated biodiversity within the study area. A monitoring program will be implemented to ensure the effectiveness of mitigation and detect unanticipated effects. The results of monitoring programs for flora, fauna and aquatic habitats will be used as biodiversity indicators, providing direct feedback to adaptive management for implementing appropriate changes to mitigation.

4.5 PROTECTED AREAS

4.5.1 Introduction

This section presents the Environmental Assessment for the effects of the slurry pipeline on existing and planned protected areas. As per the Ambatovy Project Terms of Reference, the potential impacts of the slurry pipeline 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

For protected areas, two study areas are used: a Local Study Area (LSA) that will encompass the area likely to be directly impacted by the Ambatovy Project (the project), and a Regional Study Area (RSA) that includes the area subject to indirect effects of populations who move into the area to construct the pipeline.

The slurry pipeline LSA for protected areas is the same as the terrestrial study area presented in Volume A, Section 7, Figure 7.2-2. It includes areas within 1 km of the planned pipeline route. The slurry pipeline RSA includes all areas within 100 km of the route.

4.5.3 Baseline Summary

One existing protected area, one proposed protected area and one Ramsar site are located within the slurry pipeline LSA. These areas are mapped in Volume J, Section 6.1, Figure 6.1-2.

The Torotorofotsy Ramsar Site contains the largest and most intact inland marsh in eastern Madagascar. Ramsar sites are not protected until specific legislation is enacted by the state of Madagascar; however, Ramsar sites are wetlands of recognized international importance, which have been designated based on their significance in terms of ecology, botany, zoology, limnology or hydrology. Generally, it is expected under the Ramsar Convention that Ramsar sites will receive some kind of protected status incorporating the “wise use” concept (Ramsar Secretariat 2004). The Torotorofotsy wetlands are presently used for ecotourism, small-scale hunting and plant harvesting, and (at the perimeter of the wetlands) rice farming, small-scale sustainable forestry (eucalyptus trees) and human habitation. Under baseline conditions, 40% of the portion of the Ramsar site that has been mapped for this project has been distributed by either slash-and-burn (tavy) agriculture, eucalyptus plantations or use as rice paddies.

The proposed Mantadia-Zahamena Conservation area[1] does not have any protected status but is in the process of being defined as a type of *Site de Conservation* by the Government of Madagascar, with input from other interested parties. The precise boundaries and protected status of the area have yet to be established, but are expected to be finalized in 2006. The protected area is planned to accommodate area for both biodiversity protection (75%) and multiple-use areas (25%).

Mantadia National Park is representative of the humid tropical forests of eastern Madagascar, characterized by high levels of biodiversity and endemicity. In particular, the park is known for orchid species, landscape features such as waterfalls, dense rainforest cover, and exceptionally rich populations of endemic frogs and reptiles. Mantadia National Park is relatively accessible for tourists from Andasibe, the closest town to the park, and offers trails and campsites for tourists.

Other proposed or existing protected areas within the slurry pipeline RSA are Zahamena National Park, Analamazaotra Special Reserve, Betampona Natural Reserve, Mangerivola Special Reserve and Maromiza State Forest / private protected areas.

Additional details concerning all proposed and existing protected areas in the mine LSA and RSA are provided in Volume J, Section 6.1.

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 and minimized wherever possible, either by choosing appropriate location and routing options or by applying effective mitigations.

Potential effects of the slurry pipeline on protected areas may occur due to:

- direct alteration of habitat within an area due to project development;
- fragmentation of habitat within an area due to project development;

[1] In the new Arrêté 20-021, ratified on December 30, 2005, the corridor is referred to as the Ankeniheny-Zahamena Corridor (CAZ). In addition, this Arrêté proposes a new set of boundaries for the temporary protection of the conservation area to be created. This information was not available while the EA was being conducted and therefore the EA reflects the state of affairs as of mid 2005.

- indirect impacts in an area due to changes in water quality or quantity; or
- enhanced protection and management of protected lands as a result of financial support from the project.

With respect to the slurry pipeline, stakeholders have expressed particular concern with the effect of the pipeline on the Torotorofotsy Ramsar site and the Mantadia-Zahamena forest corridor (Volume A, Section 6). Various alternatives to this pipeline routing have been considered, as discussed in the analysis of alternatives (Volume C, Section 1). The route through the Ramsar site now takes advantage of a corridor of existing disturbance and is the believed best option from the perspective of social and environmental effects and pipeline engineering.

Linkages of effects on protected areas to other components are shown in a linkage diagram (Volume H, Appendix 9). The key question for protected areas is:

Key Question PR-1 What Effects, Direct and Indirect, Will the Slurry Pipeline Have on Protected Areas?

4.5.5 Impact Assessment

The slurry pipeline footprint overlaps with the Torotorofotsy Ramsar site and the Mantadia-Zahamena Corridor. Based on *Arrêté* 20-021, a service corridor for both railway and slurry pipeline will not be put under conservation status. However, the pipeline has the potential to fragment the Torotorofotsy Ramsar site and the Mantadia-Zahamena Corridor. Also sediment from disturbed areas may affect streams near the pipeline right of way (RoW).

The project will contribute to additional RoW reclamation (to zonal forest) within the Torotorofotsy Ramsar site and Mantadia-Zahamena corridor with appropriate native species, and will seek to contribute to management plans for the Ramsar site within the regional planning process, as appropriate.

4.5.5.1 Assessment Methods

The assessment of effects on protected areas is based on:

- a physical analysis of extent of protected areas that the slurry pipeline footprint will overlap in the LSA; and

- the results of hydrology and water quality analyses that indicate how water sedimentation will be affected in the LSA.

Geographic Information System (GIS) software was used to conduct the spatial analysis of impacts to protected areas.

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 pipeline route will avoid Mantadia National Park and will cross the planned Mantadia-Zahamena corridor only in an area that has been previously deforested.

The pipeline route will follow an existing, disturbed RoW through the Torotorofotsy Ramsar site. Stringent erosion control measures along this route will be implemented to mitigate any siltation of the adjacent wetlands during the construction period.

Plans to control erosion along the pipeline route, and to mitigate siltation effects and water quality effects, are discussed in Volume C, Section 3.6 (hydrology) and Volume C, Section 4.3 (fish and aquatic resources). Additional, site-specific mitigation for specific valuable biological resources, including those in protected areas, will be developed before pipeline construction by a team travelling along the final pipeline route.

The pipeline will be engineered and constructed to minimize the chances of an accidental spill. Contingency plans have been developed to mitigate the effects of a spill, should one occur in an extreme case. Mitigation for natural risks is presented in the slurry pipeline natural risks report, Volume I, Section 6.1.

The project will help support initiatives with conservation groups to restore appropriate tree species in the forested corridor and Torotorofotsy Ramsar site along the slurry pipeline RoW. The project will also participate with appropriate conservation and government groups, as appropriate, to assist in the development of a management plan for the Ramsar site.

4.5.5.4 Results

Physical Impacts

The area to be affected directly by the slurry pipeline overlaps the Torotorofotsy Ramsar Site. Although this is not by definition a protected area, it is anticipated that the Government of Madagascar and other stakeholders will develop a management plan for this area which will limit its use. Ramsar guidelines emphasize wise use, which is use that does not permanently alter the biological qualities of the site. The slurry pipeline will impact less than 1% of the Ramsar Site (70 ha out of 9,300 ha), and these impacts will be reversible.

The slurry pipeline will also cross a section of the Mantadia-Zahamena corridor. Based on the preliminary boundaries for this corridor, of a total area of 401,655 ha, the pipeline will affect 15 ha, or less than 1%. The pipeline will cross part of the planned corridor which has been historically deforested, and therefore will not result in the removal of primary forest.

The pipeline RoW has the potential to cause fragmentation of both the Torotorofotsy Ramsar site and the Mantadia-Zahamena corridor, which is under planning for reforestation. Therefore, mitigation associated with the slurry pipeline will include reforestation of the disturbed corridors for both of these RoW sections (km R0+000 to R2+000 and R16+000 to R26+000) with native species (or other species appropriate for local land uses), and the minimization of the corridor that is kept open within areas of existing disturbance in both cases.

In addition, a maintenance road will not be constructed adjacent to there re-forested sections of the RoW, to further reduce impacts.

Impacts on Water

During construction, bare areas along the RoW will be subject to erosion, and sedimentation of nearby water bodies and watercourses is expected to occur, although mitigation will be in place to control these effects. Following reclamation, the slurry pipeline is not expected to cause any negative effects for surface water, groundwater or water quality that would affect a protected area. Measures developed to minimize the chance of a pipeline rupture that would affect adjacent waterways are discussed in Volume I, Appendix 6.1, the slurry pipeline natural risks report.

Positive Impacts

Through participation and support to conservation initiatives, as noted above, positive impacts will be realized. A discussion will be required with administrative committees for the site regarding possible interest to conserve the pipeline road within the Ramsar site.

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	clearing of the RoW	progressive reclamation	low magnitude/short-term physical modification of Torotorofotsy Ramsar site and Mantadia-Zahamena Corridor
	erosion of exposed soils along RoW and sedimentation	erosion control; stable slope engineering	low magnitude / short-term modification of water quality
operations	cleared RoW	progressive reclamation	low magnitude / medium-term modification of Torotorofotsy Ramsar site and Mantadia-Zahamena Corridor
	erosion of exposed soils along RoW and sedimentation	erosion control; stable slope engineering	low magnitude / medium-term modification of water quality

During the construction and operation phase for the pipeline, less than 1% of each of the Torotorofotsy Ramsar site and Mantadia-Zahamena Corridor will be modified, and the corridor affected will be along either existing railway disturbance or through other areas that have previously been cleared. These effects will be low in magnitude and medium-term. Land modification will occur on an intermittent basis and is considered medium in frequency. This effect is reversible and the environmental consequence is low.

The Torotorofotsy Ramsar site and the Mantadia-Zahamena corridor are not expected to experience substantial fragmentation due to the slurry pipeline, as the disturbance corridor will be relatively narrow and will be reclaimed following construction. However, fragmentation is discussed in detail in the biodiversity section (Volume C, Section 4.4).

During construction and initial operations, the rate of erosion from the pipeline RoW will be increased, with a likely increase in sedimentation to surrounding water bodies and watercourses. However, these effects will be mitigated and are expected to be a very minor issue following reclamation. During construction and operations, the impact magnitude of sedimentation is conservatively estimated as low. The effect will be local in geographic extent, medium-term in duration and will result in a low environmental consequence.

Other protected areas within the RSA will not be adversely affected by the slurry pipeline. Following mitigation of effects, the tourism potential and economic sustainability of the protected areas will not be reduced.

Table 4.5-3 Residual Impact Classification for Protected Areas

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
issue: clearing or fragmentation of protected lands							
construction and operations	negative	low	local	medium-term	yes	medium	low
issue: water quality and quantity changes							
construction and operations	negative	low	local	medium-term	yes	medium	low
issue: indirect impacts of support for Ramsar site management							
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 moderate to high. Uncertainties are associated with the effectiveness of mitigation in controlling erosion and sediment, the effectiveness of revegetation of key sections of the RoW with native species, and the degree to which protected areas will be affected by fragmentation in the short term.

4.5.5.6 Monitoring

During construction, erosion control will be maintained and monitored to minimize downstream sedimentation issues. The vegetation community (a key component of the ecological system) will be monitored as described in Volumes B and C, Section 4.1.

4.5.6 Conclusions

Low environmental consequences will result for the Torotorofotsy Ramsar site and Mantadia–Zahamena corridor during the construction and operations phases of the project, due to the clearing of land and increased risk of sedimentation of water bodies and watercourses.

Impacts following closure are expected to be of negligible consequence, and fully mitigated through reclamation.

Positive impacts are anticipated through the project’s participation in conservation measures of key sections within the Mantadia-Zahamena corridor and the Torotorofotsy Ramsar site.

The impacts resulting from development of the slurry pipeline are not expected to adversely affect tourism potential for protected areas in the RSA.

5.1 SOCIOECONOMICS

5.1.1 Introduction

Field work, including consultations, socioeconomic data collection and secondary data review, were undertaken for two alternatives at the time that these were still options – a route along the rail to Brickaville and a more direct cross country route. As noted in Volume C (Section 1), additional re-routing is proposed and an Environmental Assessment (EA) amendment will be submitted.

This section assesses potential impacts that reflect the concerns of populations between Moramanga and Toamasina. It is noted that irrespective of the alignment of the final route selected, it will be a cross-country route, affecting rural, remote populations with characteristics and the potential to experience effects that will prove broadly parallel to those described in the pipeline baseline (Volume K, Appendix 1.1) and this impact assessment.

As assessed, communes affected by the pipeline included Andasibe, Ambatovola, Andekaleka, Lahariandava, Fanasana, Fetraomby, Vohitranivona, Ambalarondra, Ambinaninony, Ampasimadinika, Fanadrana and Toamasina II. Contingent on the final selection of the pipeline route, most of the communes are likely to remain along the route. The areal extent of these communes is very large relative to any potential pipeline route, and the potential effects of the pipeline are quite limited. As a result, it is primarily settlements along any eventual route which will in fact see effects.

Small settlements along the pipeline route will primarily be affected during the construction phase, as the pipeline will be buried and land reclaimed and available for most economic uses after construction. Construction will be rapid, there will be no operational staff on the pipeline and maintenance is expected to be minimal, thus few employment or business effects are anticipated. Construction may also have some environmental effects that may in turn have temporary socioeconomic consequences, as well as some disruptions to the movement of people and animals.

The primary long-term pipeline effects will arise from the construction of permanent access roads along the pipeline route, built to facilitate pipeline monitoring/maintenance. In the assessment that follows, the construction of access roads – with the potential consequent effects – is addressed in the subsection on infrastructure.

5.1.2 Impact Assessment

5.1.2.1 Economic Opportunities

As for all project sites, consultation results indicate that economic opportunities created by the pipeline are of greatest interest to people. It is the project's policy to maximize local employment and procurement and to provide training. The construction and operations of the pipeline, compared to the other project areas require fewer staff and short term employment. Impact mitigation and benefit enhancement measures are summarized in Table 5.1-1.

Employment

As elsewhere in the rural economy of Madagascar, there are challenges to hiring many of the required construction workers from settlements along the pipeline route. The remoteness of pipeline settlements means that job experience and educational achievement are lower than in other areas potentially affected by the project. The pipeline construction process has skill and health and safety requirements that will make it difficult to employ many people with limited education. As well, given only a short presence of construction crews along any given stretch of pipeline, and a tight schedule, there will be limited training opportunities for local people.

Total labour requirements during construction for the pipeline would be around 800 people of which, about 345 would be local. Employment of local people would mainly be in support of construction activities, and of reclamation activities.

The workforce requirement for the operations phase is very small and only occasional. There may be some monitoring for pipeline integrity at irregular intervals, for example after extreme weather events, as preventive maintenance.

The potential impacts of employment overall are considered to be of low magnitude, positive, short term, and of low consequence, although of high consequence for those individuals and their families who are able to directly benefit.

Business

The remoteness and rural nature of the local economies along the pipeline route suggest that any business benefits will be minimal. While temporary construction camps may offer some support to local business for occasional daily needs of workers, virtually all construction supplies, accommodation and food will be carried in.

Table 5.1-1 Impact Mitigation and Benefit Enhancement Measures

Pipeline	
Impact	**Impact Mitigation and Benefit Enhancement Measures**
Limited potential for employment.	Local Resource Development Initiative (LRDI) section specific to pipeline construction (modalities for identifying potential employees).
Increased access infrastructure for local populations.	Pending negotiation with communities and regional planning authorities, permanent and maintained pipeline access roads that can be used by local populations.
Improved well-being associated with limited employment and with provision of access roads.	None required additional to LRDI and access roads.
Households and livelihood resources affected by pipeline land requirements.	Detailed alignment of pipeline 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 compensated.
Construction disturbances to land surfaces, with consequent erosion effects on land and water livelihood resources.	Erosion control measures will be applied along with revegetation. To the extent that livelihood resources are inadvertently affected, compensation commensurate with degree of loss will be made.
Construction disturbances to land and water transport routes.	Provision of alternative routes for people, animals and boats. There will be no significant operations phase impacts as pipeline will be buried.
Other disturbance effects associated with construction including noise, dust, changes to air quality, etc.	Equipment maintenance and operating practices.
Temporary presence of out-of-area construction workers, with consequent effects on public health and safety and potential for social conflict.	Provision of all food and accommodation, medical and other services directly to out of area workforces. Workforce management, including cross cultural training and enforced codes of conduct.
Restrictions on land use along right-of-way.	Compensation negotiated with land users to reflect value of livelihood resources lost over time period of loss.
Effects associated with any real or perceived risk of accidents associated with the pipeline	Public education on actual risks and emergency response planning.
Negative effects of increased access including migration, pressures on livelihood resources, etc.	No direct mitigation practical. Access road is expected to overall result in positive effects on livelihoods along the pipeline route. Ongoing consultation and grievance mechanism can capture any particularly negative effects attributable to the project for adaptive management.

The potential impacts on business are considered to be of low magnitude, positive, short term, and of negligible consequence although individual businesses may experience benefits of low consequence.

Local Economy

With low employment and business benefits, over a short time frame, there is little expectation of indirect and induced effects on local economies. Short-term employment can provide a very welcome cash input to individuals, but this cannot drive sustained demand for goods and services that would be necessary to stimulate local economic effects.

Because anticipated project expenditures are expected to be minimal, the impact on local economies is considered to be of negligible magnitude and consequence.

Education and Training

Pipeline construction will provide fewer opportunities for training than other project components, although on-the-job experience may be of subsequent benefit to some employees. Reclamation activities have more potential for some training and job experience towards some long-term benefit, as has any participation of local people in maintenance work. However the short-term and/or occasional nature of such work suggest that this too will be very limited.

The potential impacts of education and training to the labour force and businesses are considered to be of low magnitude, positive, long term, and of low consequence, although the individuals who are able to access available education and training will see an effect of moderate consequence.

Increased Income

Increased income is generally associated with improved individual and household socioeconomic status. The nature of the construction and operation of the pipeline however suggests that rather than increased income, those individuals who are able to access employment will see essentially some cash inflow occasionally and/or intermittently. While such inflows can be important to affording some degree of economic security over the short term, they do not represent sustained increased income.

The potential impacts of increased income are considered to be of low magnitude, positive, short term, and of low consequence, although of moderate consequence to those individuals and their families who are able to benefit.

Other Economic Effects

For the same reasons cited above, (that is, the limited economic opportunities of the slurry pipeline and consequent minimal effect on local economies), other economic effects characteristic of large projects are unlikely to be seen along the pipeline route. The proponent will apply its recruitment policies along the pipeline as well as a disincentive to in-migration, however this is unlikely to occur in response to temporary work in locations with difficult access. Inflation, inequalities in income distribution, increases to local government budgets and other such effects are not anticipated. While the general area may have some tourism potential, for example travel by improved rail services between Antananarivo and Brickaville and activity in the Mantadia-Zahamena forest corridor towards the mine site end of the pipeline, there is little present activity to affect and once built, the pipeline should not be visible.

Other economic effects, both positive and negative, are considered to be of negligible consequence.

5.1.2.2 Access to Natural Resources

Land

Cultural and land use resources have been mapped along the slurry pipeline route (Volume H, Appendix 11) and such information will be verified in surveys ahead of construction. Pipeline construction will require a corridor about 50 m wide over an approximate length of 195 km, for a total area of disturbance during construction of about 10 km^2. While much of this land will be reclaimed to its pre-construction land use, any decisions on routing of roads intended to be permanent will result in permanently taking some land out of its current use.

Pipeline alignment will endeavour to the extent practical to avoid villages, residences and agricultural land. Where this proves impossible, compensation pending reclamation to its original land use, and resettlement if necessary, will be implemented to ensure that people do not suffer any loss of livelihood resources (see Resettlement Action Plan). The only potential exception to reclamation to current land use is that the depth of pipeline burying may prohibit the replanting of any deep-rooting trees (this would not however include such shallow-rooting tree crops such as bananas). Compensation will therefore reflect the long-term loss of any large trees.

It is noted however that pipeline routing may also be influenced by decisions of potentially affected people and their governments regarding road locations. Most people may prefer to see roads, which will largely lie adjacent to the pipeline, to be routed closer rather than further away from settlements.

The potential impact on land resources is negative, of low magnitude, and short term and of low consequence, although with fair compensation for economic losses and disturbance some people may see benefit.

Water

Residents in the watersheds crossed by the slurry pipeline depend on river water for agriculture, drinking water, livestock watering, domestic use and travel. Some of the pipeline route follows watercourses, as transport of slurry depends on gravity.

Construction activity has potential to affect water quality, primarily through erosion. Such effects will be minimized through the application of erosion control measures and will be short term, however they may represent a nuisance to water users.

The impacts on the quality and flow of water resources are considered to be negative, of low magnitude, short term and low consequence.

Biological Resources

The development of the pipeline may remove a very limited area of forest resources, towards the mine site end. Reestablishment of forest will clearly take much longer than reclamation of agricultural and/or grazing land. Given that the pipeline land requirements will be along a narrow corridor, it is not expected that availability of nearby alternative forest, or other biological resources, will prove problematical, from a livelihoods point of view.

The impacts on biological resources are considered to be negative, of low magnitude, short to medium term but of negligible consequence overall taking into account the intent to compensate for any realized impacts.

5.1.2.3 Social and Physical Services and Infrastructure

The construction of the pipeline is not expected to have many of the effects often characteristic of large projects on social and physical services and infrastructure. Short-term disruption of travel and transport routes may occur, both by land and water (people may be temporarily blocked from getting animals to pasture for example), but consultations to pre-plan any disruptive construction activity and providing alternative means of travel and transport will be used to mitigate these. Effects in this regard are negative, low magnitude, short term and therefore are expected to be of low consequence.

There in one exception to the above however. To construct the pipeline, access roads will need to be built, mainly through upgrade of existing tracks. There are several alternatives for routing, design for expected operational life and maintenance systems for any such roads, relative to project needs but also potentially taking into consideration the needs of local populations for a permanent road.

Consultations show there is a strong desire for roads by people in the less accessible communes between Moramanga and Toamasina (Volume A, Section 6). In addition, the baseline studies indicated very poor health and education status among remote populations and an inability to market agricultural surplus (which reportedly is often left to rot in fields), in turn depressing economic well-being (Volume K, Appendix 1.1). Access roads, when accompanied by government-provided or entrepreneurial transport services, would help address such fundamental socioeconomic constraints.

However, access road construction represents a large project in and of itself, with the potential to generate many positive and negative impacts that the pipeline construction itself is unlikely to generate. And while the pipeline construction is unlikely to have effects beyond the narrow band of its corridor, the construction of access roads has potential to affect populations over a much wider geographic area as people at some distance from the roads will still be able to use them. Such impacts are difficult to predict in general, and this is more the case without a final selection of the actual pipeline route. Potential generic effects however are described below.

Economic Benefits

Whereas the pipeline construction is unlikely to induce economic growth, there is more potential for the road to do so. While the road construction itself is likely to be capital intensive to achieve schedules, maintenance is appropriately organized locally and can be more labour intensive and be a source of cash income. Roads will create access routes for migrants, and while migration can represent a threat to natural resources, it can also represent an economic stimulus, depending on the numbers, skill sets and family status of migrants. Increased incomes could derive from marketing of crops (people in focus groups reported good returns to agricultural labour but few means to translate surplus production into economic gain). All these potential effects will raise demand and with time supply should be organized to meet these new demands. Increased demand is of course inflationary although as noted previously over time the situation should equilibrate. This is not to suggest that access roads will solve the challenges of poverty in these remote communes between Moramanga and Toamasina, but only that they may relieve some constraints presently operating.

Effects on Natural Resources

The primary threat is migration, both of people seeking agricultural land and people who will move into the area for commercial exploitation of biological resources. It would be the proponent’s intention not to build permanent access roads into any forested areas currently under or planned for conservation (for example where the pipeline will cross the Mantadia-Zahamena forest corridor between two national parks) and to monitor the use of any temporary access for any evolving problems. However elsewhere along the pipeline route there may be increased demand on land and biological resources, depending on what is present in any given area and who might arrive.

Effects on Social and Physical Services and Infrastructure

Increased populations as well as increased access of current populations represent increased demand for existing services and infrastructure that commune governments may have difficulty meeting. Increased access to existing services and infrastructure is of course also an important benefit – to the extent that these can meet demand – to populations who are able to use the road.

Well-Being

The potential interactions of economic growth, increased incomes, migration, pressure on natural resources, increased access to social and physical services and infrastructure for not only populations along the pipeline corridor but also in settlements more distant, are likely to be both positive and negative and to affect population subgroups and individuals differently. Public health and safety threats, from increased traffic, increased migration and other increased contacts with the outside world, are of some concern.

Given the above, and the fact that the construction and operations of the pipeline are expected to have only short-term and fully mitigable effects, the project proponent considers that the undertaking to construct access roads with a view to permanence constitutes a significant project benefit to populations, only some of which could realistically be expected to see any project effects at all. Monitoring and consultation will address any unexpected negative effects. The project will participate in regional planning initiatives to assist in resolving any issues and explore bringing additional benefit to remote communes.

Given demand among remote populations for such infrastructure and the fact that the road will be constructed at project rather than public cost, the net effect is considered to be of high magnitude, overall positive, long term and of high consequence.

5.1.2.4 Well-Being

Well-being is associated with increased economic opportunity, public health and safety, disturbance during the construction phase, socioeconomic and cultural change and availability and access to the necessities of life.

Taking the short-term and limited effects pipeline construction and operations are expected to have, the primary well-being issue relates to the potential for transmission of HIV/AIDS and any risk associated with failure in the pipeline during operations. There may be temporary disruption of daily patterns of life due to the presence of temporary construction camps, but these can be placed in locations to minimize such disturbances. There is some potential for noise, air quality and water quality effects, but these will be very short term and of low magnitude due to mitigation measures and will not represent high threats to overall public health. Traffic increases due to the project have some potential to result in additional accidents (Volume C, Section 5.5).

As at other project sites, the proponent will adopt a code of practice to manage the behaviour of workers living in camps near rural communities, and in limiting the potential for contact between workers and local people. Attention to the potential for increasing the incidence of HIV/AIDS is particularly critical and will include not only efforts to control behaviours and address HIV/AIDS for workforces but also an aggressive public education component. Consequence of any HIV/AIDS transmission would be high at an individual level.

The risks of pipeline failure are extremely low, due to considerations taken in pipeline design, operation and maintenance. Nevertheless any realized risk could have serious consequences. The proponent will put in place public education and emergency response planning to address consequences. It is also noted that public education may contribute to pipeline security, in so far as people understand that the contents of the pipeline are not of any real value and that breaching the pipeline is not of interest.

Irrespective of the rigour with which worker management, operational procedures, traffic, health and safety, public education, health programs and other relevant best practices are implemented and enforced by the proponent, some risks to public health and security remain. Because the impact at the individual level could be high in the event that any risk, such as a pipeline failure, is realized, any effects must be considered long term and of moderate consequence.

5.1.2.5 Closure

In the case of the pipeline, initial closure activities will occur during the immediate post-construction phase, when reclamation of disturbed surfaces is taking place. This may in fact offer the most potential for regular, if often part-time, employment of local populations over varying time frames depending on the needed reclamation activities in various locations. At closure of the project, the pipeline will no longer be used, but there will be no surface infrastructure to remove, and little reduction in what minimal employment pipeline operations has involved.

Closure of the pipeline will also mean the proponent’s maintenance of the access roads will cease and the roads reclaimed, unless the local and regional authorities wish to retain the roads, in which case the authorities will then need to address road maintenance.

With the exception of early reclamation activates, which are of benefit, closure is a negative impact of negligible consequence.

5.1.3 Summary

The socioeconomic impacts of the pipeline 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.

The pipeline is expected to bring some economic benefits to settlements along the route, and no economic benefits to the broader geographic communes. The exception to this is related to the construction of access roads, which have the potential to bring significant improvement to people over wide areas who presently travel for many hours to reach roads. Negative effects are generally minimal and short-term.

Table 5.1-2 Slurry Pipeline Impact Matrix

Slurry Pipeline								
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Before Mitigation		Mitigation	After Mitigation	
				Direction	Consequence (Including Magnitude)		Direction	Consequence (Including Magnitude)
Economic Opportunities								
local employment	potential for limited very short-term employment during construction and occasional employment during operations	pipeline route	construction, operations	positive	negligible in absence of preferential systems for local hiring	preferential local employment and training programs for operations phase	positive	high for individuals able to access project-related employment opportunities and negligible to low at the community level given number and types of jobs relative to population size
procurement of local goods and services	increases in business activity related to project supply contracts	pipeline route	construction	positive	negligible in absence of preferential systems	preferential local procurement	positive	low for individuals owning or working in business that are able to access project opportunities
indirect and induced economic growth and economic diversification	potential for indirect and induced jobs and associated economic benefits	pipeline route	construction	positive	negligible in absence of preferential systems	none required additional to preferential employment and procurement	positive	low as there will be only very short-term presence in communities along pipeline route of project during construction
capacity building of labour force	job experience and some limited job training for employees that can be applied to project-related jobs and in the larger economy	pipeline route	operations	positive	negligible in absence of preferential systems	none required additional to preferential employment and training programs	positive	high for individuals and otherwise low in so far as community effects are experienced
increased individual income	increased employment opportunities	individual	construction, operations	positive	high for affected individuals	none required additional to preferential employment, procurement and training programs	positive	high for affected individuals
migration	in-migration	pipeline route	construction, operations	negative	negligible given short-term nature of construction activity and little operations activity	preferential employment locally aggressive public information campaign on recruitment procedures	negative	negligible, however see reference to migration in infrastructure section below
Natural Resources								
availability of land resources	land use changes	pipeline route	construction, operations	negative	low during construction and negligible during operations given limited land requirements	avoidance of villages, households and agricultural land compensation where avoidance is not possible	negative	negligible and some people may benefit as a result of compensation
effects on water resources	reduced water quality for human consumption and agriculture as a result of potential environmental effects	pipeline route	construction	negative	moderate over very short term	mitigation of potential construction generated water quality effects at source	negative	low
effects on availability of biological resources	reduced quantity and quality of biological resources used for livelihood purposes	pipeline route	construction, operations	negative	low during construction and negligible during operations given limited land requirements and very limited potential for environmental effects	mitigation of potential construction generated effects at source avoidance of valued biological resources	negative	negligible, however see reference to biological resources in infrastructure section below
Social and Physical Services and Infrastructure								
infrastructure	construction and co-operative maintenance of access roads	pipeline route	construction, operations	positive	not applicable as this is purely a project benefit	construction of access road and arrangements in place for its operation and maintenance over the long term	positive	high as remoteness of population results in significant constraint to economic and social development
	consequent on road construction, improved access to social services	pipeline route	operations	positive	not applicable as this is purely a project benefit	none required	positive	high, see above
	consequent on road construction, improved access to markets	pipeline route	operations	positive	not applicable as this is purely a project benefit	none required	positive	high, see above
	consequent on road construction, increased pressure on land and biological resources as a result of migration	pipeline route	operations	negative to positive	not applicable	no direct mitigation practical ongoing consultations with communities will determine if socioeconomic effects net out negatively or positively there may be negative environmental effects	negative to positive	low to moderate, depending on capacity of communes and communities to manage their biological resources there may be benefit if increased access to biological resources can be sustainably managed

Table 5.1-2 Slurry Pipeline Impact Matrix (continued)

Slurry Pipeline								
				Before Mitigation			After Mitigation	
Dimension	Residual Impact	Geographic Extent	Phase (Duration)	Direction	Consequence (Including Magnitude)	Mitigation	Direction	Consequence (Including Magnitude)
interruptions to travel and transport routes	disruptions to watercourses used for travel and transport	pipeline route	construction	negative	low as disruptions will be temporary	consultative planning of construction timing provision of alternative transport where required	negative	negligible given short duration of interruptions and intent to mitigate necessary disruptions
	disruptions to paths used for travel and transport	pipeline route	construction	negative	low as disruptions will be temporary	consultative planning of construction timing provision of alternative transport where required	negative	negligible given short duration of interruptions and intent to mitigate necessary disruptions
Community Well-Being								
public safety	increase in anti-social public behaviours	pipeline route	construction	negative	low	workforce management through cross cultural training and enforced codes of conduct	negative	negligible
public health	increase in HIV/AIDS and other transmissible diseases	pipeline route	construction, operations	negative	moderate	project workforces will be provided with health services	negative	low overall although high for any affected individual
increased risk to public health and safety due to construction activities	risks associated with traffic	pipeline route	construction	negative	consequence of risk is high given the potential harm that any such accident has the potential to cause	driver training, enforced speed limits and road maintenance 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	pipeline route	construction	negative	negligible given short construction duration	revegetation and erosion control measures applied to limit water quality effects	negative	negligible
	noise effects on public health	pipeline route	construction	negative	negligible as traffic noise does not represent a threat to public health, although disturbance can occur	equipment maintenance to limit effects of noise	negative	negligible
	air quality effects on public health	pipeline route	construction	negative	negligible given short construction duration	equipment maintenance to limit effects on air quality	negative	negligible
social and cultural changes	economic, social and cultural transformation	pipeline route	construction	negative	negligible given short construction duration although construction of access road also create potential for change	no direct mitigation possible project benefits and social investment to contribute to overall community well-being	negative to positive	such change is generally considered of high consequence as this is linked to benefits of access road, change could be positive in many respects
disturbances	disturbances to quality of life (including economic activity dependent on transport route) elements such as visual, traffic, noise changes	pipeline route	construction	negative	negligible given short construction duration	full mitigation and range of best practice to limit effects on quality of life elements; i.e., heavy equipment with fully functioning silencers; dust control during construction; etc.	negative	negligible
	perceptions of harm as a result of the project	pipeline route	construction, operations	negative	moderate	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 development as a result of access road construction	pipeline route	construction, operations	positive	not applicable as road is purely a project benefit	project benefits contribute to overall community well-being	positive	high
Closure								
closure and consequent economic and social effects	end of economic opportunities	pipeline route	closure	negative	low	consultative and iterative pipeline closure planning will include consideration of employee future	negative	low given limited economic effects of pipeline and expectation that road will be permanent

5.2 CULTURAL PROPERTY

5.2.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the pipeline 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 pipeline right-of-way. Because the latter has not yet been firmly established, cultural resource sites were identified within a one kilometre wide corridor following the proposed pipeline route. As such, recommendations pertaining to these sites may only be made once the pipeline route is finalized.

5.2.3 Baseline Summary

The following provides a summary of the results of cultural resources studies that have been conducted within the pipeline corridor.

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 as part of a socioeconomic assessment of the project area by SOATEG. Local expertise was consulted by questioning villagers about the locations of any known archaeological or cultural sites within the pipeline corridor. Although a global positioning system (GPS) was used to plot the coordinates of sites found during this survey, some sites were not physically visited due to cultural sensitivity concerns, and therefore only approximate locations of these were obtained for this report.

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.

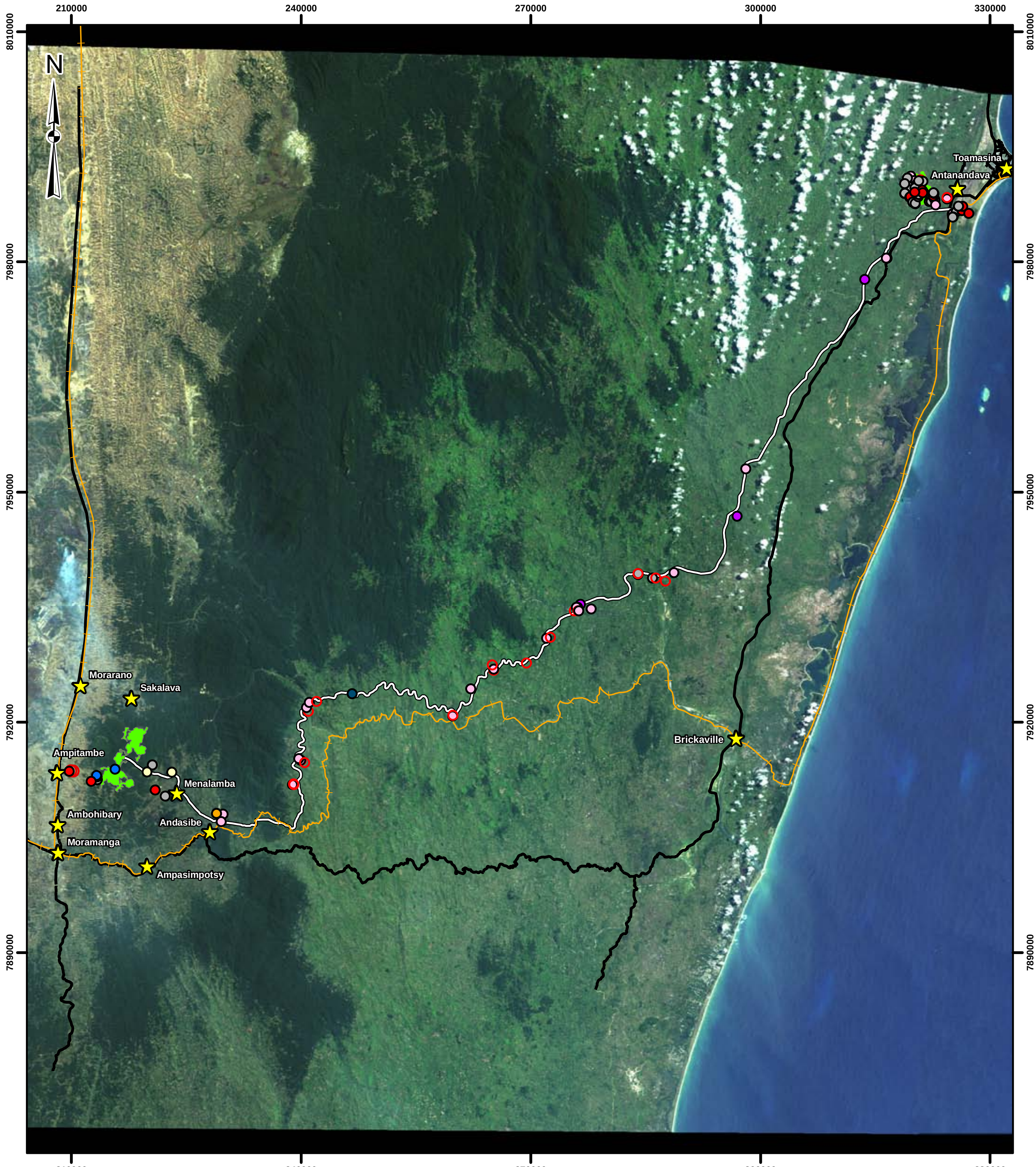
Table 5.2-1 Potential Types of Cultural Sites in the Cultural Resources Study Area

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 pipeline corridor, 27 tombs or groupings of tombs, 19 symbolic tombs, two ceremonial sites, three abandoned villages and one church were located (see Figure 5.2-1). It is unclear how old the abandoned villages are, and whether these would require mitigation.



10 0 10 20

SCALE 1:700,000 KILOMETRES

LEGEND

- ARCHAEOLOGICAL SITE
- ABANDONED VILLAGE
- CEMETERY
- CEREMONIAL SITE
- CHURCH
- SACRED SITE
- SACRED WATERFALL
- SYMBOLIC TOMB
- TOMB SITE
- TOWN/VILLAGE
- SLURRY PIPELINE
- RAILROAD
- ROAD
- PROJECT SITE

REFERENCE

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

PROJECT

AMBATOVY PROJECT

TITLE

VIEW OF PIPELINE ROUTE AND LOCATIONS OF ARCHAEOLOGICAL AND CULTURAL SITES

Golder Associates
Calgary, Alberta

PROJECT No.03-1322-172.6500			SCALE AS SHOWN	REV. 0
DESIGN	LB	13 Sep. 2005	**FIGURE: 5.2-1**	
GIS	TN	23 Nov. 2005		
CHECK	GJ	08 Feb. 2006		
REVIEW	DM	08 Feb. 2006		

I:\2003\03-1322\03-1322-172\mxd\Archaeology\Fig5.2-1_ArchaeologySites_portrait.mxd

5.2.4 Issue Scoping

The main potential issues relating to cultural resources are:

- destruction of cultural sites during pipeline construction (primary impacts); and
- disturbance of nearby cultural sites during and after pipeline 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 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.

Secondary impacts relating to hydrologic or soil erosion effects outside of the project footprint were evaluated based on impacts predicted in the hydrology and soils EA sections (Volume E, Sections 3.8 and 3.3).

Cultural resources may suffer tertiary impacts (through increased visitation to the area by non-local residents following construction of the project). These impacts are difficult to predict, but can be mitigated. They are only broadly alluded to in this assessment.

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 mine site footprint **regional:** effect extends beyond the mine 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

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	alteration of pipeline right-of-way relocation of tombs, symbolic tombs, and ceremonial sites excavation of archaeological sites	neutral magnitude, but permanent and irreversible effects if sites are mitigated
operations	increased presence of non-local workers in region	cultural sensitivity training	negligible magnitude, medium-term and reversible effects on cultural resources adjacent to the pipeline
	off-site hydrologic and erosion impacts	staged development, erosion control, reclamation	none
closure	none	none	none

5.2.5.4 Mitigation

There are two possible mitigation scenarios for cultural resources associated with the slurry pipeline. The first is for the pipeline to be re-routed around any archaeological and/or cultural sites that may intersect the proposed right-of-way. Such routing adjustments would require having an archaeologist conduct monitoring work with the land surveyors ahead of construction, to assist in planning the pipeline's final route. This is the main planned mitigation.

If pipeline re-routing is not possible, then any sites that may be impacted can be mitigated by either 1) relocating them to new areas, or 2) by conducting archaeological excavations. Tombs, symbolic tombs, and ceremonial sites situated inside the proposed pipeline impact zone may be displaced, according to accepted local cultural practice. For this to occur, however, proper protocol involving correct rites and rituals must be observed. Discussions and negotiations with resident groups will be necessary in this regard. The process involved in re-locating tombs is outlined in Table 5.2-4.

Other sites, such as abandoned villages, cannot be displaced, and as such would require archaeological investigation in the form of excavation should they be impacted by the construction of the pipeline. The archaeological significance of the three abandoned villages found within the proposed pipeline corridor remains to be determined, because this data was collected by socio-cultural specialists and not archaeologists. These may or may not require additional work if the pipeline cannot be re-routed around them.

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 Relocating 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

Following mitigation, the pipeline will have a neutral effect on cultural resources during the construction phase. Even if the pipeline cannot be re-routed around potentially important archaeological sites and these are subsequently destroyed by mitigative excavations, the information obtained from this will offset their destruction (Prof. Jean-Aimé Rakotoarisoa pers. comm.; Volume K, Appendix 2.1). Because the tombs, symbolic tombs, and ceremonial sites located within the pipeline area may be displaced without altering their inherent cultural meaning, a neutral effect for these is also envisioned.

No secondary effects due to off-site hydrologic or erosion impacts are predicted.

A negligible medium-term effect on cultural resources adjacent to the pipeline may occur during the operations phase, depending on whether the few non-local residents working in this area will come into contact with these.

No effects are envisioned for the pipeline closure phase.

5.3 LAND USE

5.3.1.1 Introduction

This section presents the Environmental Assessment (EA) for the effects of the slurry pipeline on land use. As per the Ambatovy Project (the project) terms of reference, land use has been mapped in the slurry pipeline 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 C, Section 5.1.

5.3.1.2 Study Area

The slurry pipeline land use LSA is the same as the general pipeline LSA shown in Volume A, Section 7.2, Figure 7.2-2. This area includes the planned pipeline route and a buffer of 1 km on both sides. Because the location of access roads, laydown areas and construction camps have not been finalized, these footprint areas are not included in the current assessment, and will be evaluated at a later date.

5.3.2 Baseline Summary

Three major land use sub-areas have been defined along the slurry pipeline LSA (Volume K, Appendix 3.1, Section 3.4): the western section, which is within the forest corridor (corridor zone); the central section, which passes around primary forest fragments through an area defined primarily by tavy matrix (tavy zone), and the eastern section, containing entirely secondary vegetation (the agricultural zone).

Along the planned slurry pipeline route in the corridor zone, land uses include agriculture, protected/tourism areas, eucalyptus plantations / woodlots, residences, and forest areas being used for extraction of non-timber forest products. An additional land use being proposed in the area is a project to restore ecological connectivity and sequester carbon by re-foresting lands within the Mantadia-Zahamena corridor conservation area.

Along the planned slurry pipeline route in the tavy zone, the most common land use is tavy agriculture, but other important land uses include rice paddies, villages, and forest fragments being used as a source of both timber and non-timber forest products.

Along the planned slurry pipeline route in the agricultural zone, land uses include tavy agriculture, rice paddies, residences and villages, agroforestry areas, grazing areas and large plantations such as the oil palm plantation south of Toamasina.

5.3.3 Issue Scoping

Key issues raised by the public relating to land use during public consultations include:

- effect of direct pipeline disturbance, or erosion from pipeline route, on agricultural lands and villages;
- effects of spills from the pipeline on agricultural lands and villages;
- effects of the pipeline and related activities on access routes (especially where above ground and during the construction phase);
- the effects of opening up access routes (a road along the pipeline) for resource use by outsiders;
- the project’s compensation policy for affected lands; and
- effects on sedimentation where the pipeline crosses rivers.

5.3.4 Assessment Methods

The effects of land use impacts are social in nature and are addressed within the impact rating system in the socioeconomics section (Volume C, Section 5.1).

In this section, the direct effects of the project on land along the pipeline route are assessed. Mitigations to reduce the potential effects of the project are indicated.

5.3.5 Impact Assessment

A linkage diagram for land use is presented in Volume H, Appendix 9. Potential impact pathways between the slurry pipeline and changes in land use exist for:

- alteration of soils, terrain and vegetation;
- changes in hydrology and sedimentation;
- changes in fish habitats and abundance;
- increased population pressure (construction phase only); and
- regional access improvement.

Alteration of Soils, Terrain and Vegetation

The impacts of the project on areas with a variety of potential land uses are presented in Table 5.3-1. Land use areas along the slurry pipeline have been mapped on the pipeline alignment sheets presented in Volume H, Appendix 11.

Table 5.3-1 Land Use Impact Areas for the Slurry Pipeline Local Study Area

Type of Area	Area Within LSA (Baseline) (ha)	Area Impacted (ha)	Proportion of Area in LSA Impacted (%)
degraded residual coastal woodland	0	0	0
azonal/transitional forest and scrub	268	5	2
primary zonal forest and marsh edge	1,429	23	2
degraded primary zonal forest	1,537	49	3
agroforest/secondary forest	0	0	0
plantation and woodlot	693	39	6
beach ridge complex	70	2	3
coastal shrubland/grassland complex	227	2	1
rice paddies	278	9	3
shrubland/herbaceous/pasture	308	2	1
tavy matrix	30,778	800	3
village/urban	120	2	2
wetlands	406	5	1
access corridor (road/rail)	9	0	0
industry (buildings or exploration areas)	13	0	0
canal	0	0	0
quarry	12	0	0
river/water	127	0	0
seasonal pond	0	0	0
total	**36,275**	**938**	**3**

Within the LSA, 6% (39 ha) of current woodlot and plantation areas will be impacted by the development, including eucalyptus woodlots and parts of an oil palm plantation south of Toamasina. Three percent of rice paddy (9 ha) and tavy agriculture (800 ha) areas in the LSA will be impacted by the project. About 2% (2 ha) of the village areas in the LSA will be affected, and less than 1% (2 ha) of potential grazing lands along the pipeline will be impacted. At the time of final pipeline route fine tuning, efforts will be made to reduce all of these levels (where possible, to zero) by routing the pipeline around these key land use areas.

Two percent (77 ha) of forested areas (zonal, transitional and degraded) in the LSA are affected by the project. It was estimated by studies in the mine area that about 74 cubic metres of viable timber can be taken from each hectare of forest cut. The market value of this timber is dependent on the species.

Changes in Hydrology and Sedimentation

Effects of the pipeline on surface water flows and sedimentation have been evaluated in Volume C, Section 3.6. During construction, the slurry pipeline right-of-way (RoW) is expected to have negligible effects on flow and water levels, and low to moderate effects on levels of sediment in receiving water bodies. Effects during operation and post-closure are expected to be negligible due to erosion control measures. Therefore, effects on downstream land users will be limited to sedimentation impacts over a short term (construction). However, if such impacts do affect key agricultural areas (rice paddies) or harm water supplies necessary for land use and land users, appropriate compensation will be provided.

Changes in Fish Habitat and Abundance

Impacts on fish and effects on artisanal fisheries which may be used for food by local populations are assessed in the fish and aquatic resources section (Volume C, Section 4.3).

Increased Population Pressure

The project will result in the presence of a considerable number of people in the LSA during the construction phase, most of whom will be housed in temporary construction camps. Construction workers will generally not be engaging in local land use, hunting, or fishing and are not expected to have an impact on land use in the LSA.

Changes in Regional Access

The project will result in the construction of a road along most of the pipeline route, and a variety of access routes from existing roadways to the pipeline route. In general, this is considered a positive effect for land use and the establishment of such a road without access restrictions is generally viewed favourably by local residents in the pipeline LSA (Volume A, Section 6). However, in some cases, especially where primary forest exists, improved access may lead to undesirable land use such as illegal forestry, and access control measures will be needed.

5.3.6 Mitigation

Much of the mitigation for land use is based on project design. The slurry pipeline has been routed to avoid villages, primary forest, and key agricultural land use areas. Additional fine-tuning of the route will occur prior to construction so that effects in key land use areas indicated in Table 5.3-1 will be further reduced. Individuals who are still affected will be compensated. The pipeline will be buried along most of its length, in order to avoid impacts on access and the movement of both people and livestock.

Land uses outside of the project footprint have the potential to be impacted by the project, but planned mitigations will reduce such effects to very low levels. These mitigations include:

- Implementing erosion control and rapid revegetation procedures to maintain water quality for flows across the pipeline RoW (described in soils, Volume B, Section 3.3).
- Making available the viable timber by setting the timber aside.
- Development of other socioeconomic mitigation and compensation measures for those directly or indirectly affected by the project (such as by impacts on their agricultural lands or water supplies), as described in the socioeconomics section (Volume B, Section 5.1).
- Reclaiming areas along the pipeline route as soon as feasible following the completion of construction, to function ecologically in accordance with regional land use objectives (described in Volume B, Section 6 and Volume H, Appendix 7).

5.3.7 Conclusions

The project will have a small effect on land uses in the immediate area of the project due to direct disturbance of lands used for rice, tavy agriculture, plantations and woodlots. Although a small area of villages may be affected by the current route of the pipeline, in cases where alternate options exist the pipeline will be routed completely around villages and other important land use areas. The project may also have indirect effects on land use in areas surrounding the pipeline due to erosion from the surface of the RoW; reclamation will mitigate this effect, but some compensation to landowners may be needed for sedimentation during the construction phase. Finally, the project has the potential to result in positive impacts due to the creation of access from land use areas to roadways, which may enable the transport of additional agricultural products to market. The magnitude of these impacts in socioeconomic terms are evaluated in Volume B, Section 5.1.

5.4 HUMAN AND ECOLOGICAL HEALTH

5.4.1 Introduction

The health assessment for the slurry pipeline area focuses on potential changes in air and water quality and possible associated effects on human and/or aquatic health during construction, operations and post-closure.

5.4.2 Study Areas

The local study area (LSA) for the slurry pipeline is the same as the LSA for the water quality and hydrology assessments. It includes a 1 km buffer on both sides of the route, along the length of the pipeline corridor (see map in Volume A, Section 7, Figure 7.2-2).

5.4.3 Baseline Summary

5.4.3.1 Introduction

A quantitative human risk assessment was not conducted for the baseline conditions in the pipeline study area. However, preliminary data suggest that health risks to people due to surface water ingestion and air inhalation are likely to be low. That is because air quality is expected to be pristine (Volume I, Appendix 4.1) and assessed surface water bodies in the study area were classified as suitable for all uses (Class A according to the Madagascar classification system for water quality) or suitable for non-contact recreation (Class B; refer to Volume I, Appendix 9.1).

Regarding aquatic health, measured pH and dissolved oxygen levels met applicable guidelines for protection of aquatic health.

5.4.4 Impact Assessment

This section of the health assessment evaluates the potential adverse effects to human and aquatic health due to the slurry pipeline construction, operation and post-closure in combination with the baseline conditions.

5.4.4.1 Issue Scoping

The main health issue captured from consultation with all stakeholders is the concern that air and water quality will be affected by pipeline construction and operation and this in turn may affect livestock breeding, crops, drinking water, flora and fauna.

Key questions established to address the potential adverse effects due to the project 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 Slurry Pipeline Have on Human Health?**

Key Question HH-2 **What Effect Will Chemical Releases From the Slurry Pipeline Have on Livelihood Resources?**

Key Question EH-1 **What Effect Will Chemical Releases From the Slurry Pipeline Have on Aquatic 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 Slurry Pipeline Have on Human Health?

Impact Pathway Evaluation

The potential impact pathway between the slurry pipeline 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;
- between changes in food quality and human health; and
- between changes in air quality and human health.

Water Quality

Local populations depend on surface water bodies for consumption (Volume K, Land Use, Appendix 3.1). Consequently changes in water quality could pose risks to human health. However, changes in water quality during pipeline construction, operation and post-closure are expected to be negligible (Section 3.7, this volume). This is provided that the appropriate management practices are used to control erosion and stream sedimentation and that mitigations are adopted to reduce and minimize effects of accidental failure and spills. Therefore, the impact pathway between changes in water quality and health of people using watercourses for drinking water was considered invalid and therefore not retained for further assessment.

Food (Fish) Quality

The pipeline will cross near communities where fish are caught for consumption. Changes in water quality due to pipeline construction, operation or closure could theoretically decrease fish quality and potentially pose human health risks. However, as explained above, changes in water quality are expected to be negligible. Therefore, the impact pathway between changes in fish quality and health of people was considered invalid and therefore not retained for further assessment.

Air Quality

Effects on air quality will occur primarily during construction of the pipeline due to the number of trucks and the heavy equipment to be used. SO_2, NO_X and particulate matter will be emitted by this equipment but effects on air quality are expected to be negligible. That is because the emissions will be localized and only occur for short durations at any location along the route (i.e., lasting one week or less). Therefore, the impact pathway between changes in air quality and health of people living in the communities near the pipeline was considered invalid and therefore not retained for further assessment.

Impact Description Criteria

The assessment criteria used for human health are the same used for the mine area (Volume B, Section 5.4).

5.4.4.3 Key Question HH-2 What Effect Will Chemical Releases From the Slurry Pipeline Have on Livelihood Resources?

Impact Pathway Evaluation

Water Quality

The slurry pipeline will cross areas where the land uses include agriculture, eucalyptus plantations, residences and forest areas. Important crops in the region include manioc, bananas, coffee, taro, sweet potatoes and beans (Volume K, Land Use, Appendix 3.1). Water is important for fishing, livestock watering and crops irrigation; and changes in water quality could lead to impacts on livelihood resources. However changes in water quality are not expected to occur during pipeline construction and operation. For that reason, this impact pathway was considered invalid.

Impact Description Criteria

The assessment criteria used for impacts on livelihood resources are the same used for the mine area (Volume B, Section 5.4).

5.4.4.4 Key Question EH-1 What Effect Will Chemical Releases From the Slurry Pipeline Have on Aquatic Health?

Impact Pathway Evaluation

Water and Sediment Quality

During construction and installation phases of the pipeline, suspended sediment concentration may increase in receiving watercourses. The disturbed bed sediments may release natural chemical substances typically associated with particulate material. Chemical releases could affect aquatic communities both living in the water columns and associated with the sediment. During construction, operation and decommissioning of the pipeline accidental failures and spills could affect water quality. However, the percentage of disturbed area within a given watershed is expected to be very small in relation to the total drainage area and more importantly, the changes of such failures are considered very low (Volume C, Section 3.5: Natural Risks). Therefore the effects on water and sediment quality in the receiving streams as well as on the aquatic communities are expected to be negligible. Those predictions are based on the assumptions that the appropriate management practices and suitable mitigation actions are used. The impact pathway between changes in water quality and aquatic life health was considered invalid and therefore not retained for further assessment.

The potential impacts on sedimentation and other physical changes of streams on fish and aquatic life are discussed in Section 4.3 in this volume.

Impact Description Criteria

The assessment criteria used for aquatic health are the same used for the mine area (Volume B, Section 5.4).

5.4.4.5 Mitigation

Mitigations that are applicable to human and aquatic health were discussed previously in the Water and Air Quality Assessment, this volume.

5.4.4.6 Residual Impacts

Since all potential impact pathways were found to be invalid, no residual impacts are predicted to occur with respect to human and ecological health.

5.4.4.7 Monitoring

Construction monitoring to direct activities to follow appropriate practices needed for environmental protection (See Water and Air Quality sections, this volume) should be implemented during the construction phase and during decommissioning at closure. Periodic monitoring of the pipeline integrity, as one component of the overall project environmental management plan would assist in identifying potential risks of pipeline failure that might lead to upset conditions.

5.4.5 Conclusions

The human and ecological health assessment evaluated the potential for adverse effects to health associated with chemical emissions from the slurry pipeline corridor in combination with baseline conditions. The incremental health risks of human exposure to drinking water, fish ingestion as well as air inhalation during process pipeline construction, installation, operation and decommissioning were considered 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 slurry pipeline 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 effects of increased traffic are 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 pipeline access traffic are Route Nationale (RN) 2 between Toamasina and Moramanga, and the individual access roads from RN2 to the pipeline Right-of-Way (RoW). Effects on traffic along these routes are assessed.

5.5.3 Baseline Summary

The key public access routes for the pipeline are RN2 from Toamasina to Moramanga, and several existing and planned routes between RN2 and the RoW. Route Nationale 2 is a two-lane, paved road in good condition. Presently, most of the routes between RN2 and the RoW are dirt roads in relatively poor condition, which will require upgrading.

Goods coming into or out of Madagascar largely move between Antananarivo and Toamasina, along RN2. Moramanga is about five hours' travel from Toamasina (250 km along RN2).

Baseline traffic volumes over 24-hour periods for RN2 are provided in Table 5.5-1. Traffic volumes are higher along RN2 at the Toamasina end, due to local traffic moving in and out of Toamasina as well as long-distance traffic bound for Moramanga. Baseline traffic for the full length of RN2 is expected to more closely match traffic levels at the Moramanga end of this road segment (Table 5.5-1)

Table 5.5-1 Baseline Traffic Level Summary

Type of Vehicle	24-hour traffic volume between Moramanga and Toamasina (at edge of Moramanaga)		24-hour traffic volume between Moramanga and Toamasina (at edge of Toamasina)	
	Weekday	Weekend	Weekday	Weekend
private cars	243	311	462	611
transports for people	212	253	365	326
transports for goods	346	447	601	647
two-wheeled vehicles, motorized	353	493	1,293	1,426
unmotorized vehicles	58	50	952	33
total	**1,212**	**1,554**	**3,673**	**3,043**

Baseline traffic levels for routes between RN2 and the RoW (all of which would require upgrading prior to use by the project) have not been recorded, but are expected to be relatively low.

Accident rates under baseline conditions are expected to occur at approximately 3.12 per million vehicle kilometres on RN2 based on government statistics.

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 (comment from Moramanga).
- Noise and vibration: the existing traffic produces noise and vibration which currently affect houses along the road (comment from Moramanga).
- 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, the impacts are stronger along unpaved roads;
- 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; and
- any road construction or improvement will cause temporary delays to non-project traffic.

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 road congestion are assessed qualitatively.

5.5.5.2 Results

There are potential impacts on traffic as a result of moving materials to the construction sites to build the pipeline. These would occur along RN2 and any new or existing access roads. There are unlikely to be significant traffic impacts associated with operations, unless the construction of access roads induces traffic for purposes other than the project.

Traffic Volumes

Changes in traffic volumes due to the pipeline are provided based on estimates of the number of supply trucks and buses (transporting workers) that will be required on a daily basis for the pipeline. The number of vehicles required is summarized for the construction period of the project in Table 5.5-2. Operations period traffic for pipeline monitoring and maintenance is expected to be much lower, presenting a negligible impact. The quantity of traffic during construction represents a relatively small fraction of existing baseline traffic provided in Table 5.5-1, although it may represent a moderate or high proportion of traffic along the smaller access roads between RN2 and the pipeline RoW.

Table 5.5-2 Pipeline Vehicle Numbers per Day along a Portion of RN2 between Toamasina and Moramanga [(a)]

Project Phase	Vehicle Types	Number of Vehicles (Round Trips per Day)
construction (3 years)	trucks	5
	buses	1
	Total	**6**

(a) Traffic numbers are estimates based on project description as of May, 2005.

Numbers of trucks along the route will increase about 1% due to pipeline construction activity. These trucks will be relatively large (equipped to carry 20 tons) and in many cases will carry lengths of pipe that will make them among the longest vehicles on the RN2. For this reason, despite their relative infrequency, these vehicles will be noticed by other drivers and people along the road.

Numbers of buses will increase by less than 1% during construction.

Based on the number of vehicles estimated in Table 5.5-2, the annual distances to be travelled by project vehicles along RN2 is summarized in Table 5.5-3. It has been assumed that the average distance travelled to the pipeline access point along RN2 is half of the distance between Toamasina and Moramanga.

Table 5.5-3 Vehicle Kilometres per Year Along RN2

Project Phase	Vehicle Types	km per Year
construction (3 years)	trucks	484,000
	buses	97,000
	Total[(a)]	**580,000**

(a) Figures have been rounded and may not sum exactly to total as presented.

The effects of the slurry pipeline on traffic will be highest during construction, which will still represent a very small proportion of the total traffic volume along RN2. Traffic volume effects will be most apparent along each of the improved and newly developed access routes linking RN2 to the pipeline route. Although conceptual plans for such routes have been developed, the final alignment of the access routes has not yet been determined. An assessment of traffic effects along the access routes will be carried out when final plans are made (pipeline EA amendment).

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 kilometres (Volume K, Appendix 5.1). The road conditions along other parts of RN2 are assumed to be equivalent to this, and accident rates are assumed increase 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.

Table 5.5-4 Changes in Accident Numbers Between Moramanga and Toamasina During Pipeline Construction

Parameter	Number
baseline traffic kilometres	476,736 trips x 250 km = 119 million km
baseline accident rate	372 per year
traffic kilometres per year during construction	Base + 0.58 million km
incremental increase (and % increase) in accidents (without mitigation)	2 accidents (0.5%) per year

Noise and Vibration Disturbance

Noise

The noise assessment of traffic focuses on motorized vehicles during construction only. Vehicles used during maintenance and inspection activities are considered to have a negligible effect on traffic levels. 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 RN2 during construction is less than 1%. The changes in various vehicle types range from 0% for private cars and <1% for buses (people transport) to as high as 2% for goods trucks. 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 up to one vehicle per hour can be expected. Table 5.5-5 provides an analysis.

Table 5.5-5 Number of Vehicle Pass-Bys (Noise Events) per Daylight Hour

Vehicle Type	24-hour traffic volume between Moramanga and Toamasina (at edge of Moramanga)		
	Minimum of Weekend/ Weekday	Number Due to Project	Total Pass-Bys per Hour
private cars	14	0	14
transports for people (buses)	12	<1	12-13
transports for goods (trucks)	20	<1	20-21
two-wheeled vehicles, motorized	20	0	20
Total	**66**	**<1**	**66-68**

Changes to noise levels on local pipeline access roads depend on the amount of existing traffic. In general, existing traffic levels are very low. For the existing portions of the roads, the amount of project traffic is expected to increase during construction, with an increase in noise levels. For portions of the new access roads, noise levels will increase since there is no existing traffic. The amount of traffic along the access roads is small, averaging less than one vehicle per hour or six vehicles per day during construction.

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. The routes through Toamasina and Moramanga 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 would occur based on the increase in heavy vehicles due to the project. As stated in Table 5.5-5, less than one heavy vehicle per hour is expected on this route. This is also a less than 1% increase in these types of vehicles.

The amount of change in ground vibration along the local access roads depends on the amount of existing traffic and the roadway conditions. The amount of project traffic on these roads is expected to be the same as on route RN2 (less than one per hour) and the road surface is expected to be graded gravel. 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. Socioeconomic effects of increased traffic along access roads is addressed within the socioeconomics section. New roads, where required will be routed to minimize social affects and will be built to accommodate planned vehicle use.

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 construction of the pipeline will result in short-term traffic increases along RN2 from Toamasina to slurry pipeline access roads, and the new or existing access roads to the pipeline. Truck and bus volumes will increase by about 1% on major roads, during construction. However, the trucks and buses will be large relative to existing vehicles, so will be noticed by other road users. The extent of traffic increases along minor roads will be greater on a percentage basis and are likely to result in larger impacts.

Mitigations toward impact of traffic include strict speed limits, proper construction and maintenance of roads, maintenance of vehicles, and driver education.

Increased traffic levels during pipeline construction may affect residences along roadways, livestock and human safety through impacts on traffic congestion, noise, air emissions, dust and vibration. Although these effects will be short-term, they will represent a moderate impact in some areas, such as the pipeline RoW and the pipeline access routes.

6 RECLAMATION PLAN

Routing and siting of the slurry pipeline are discussed in Sections 1 and 2 of Volume C. Section 6.1 describes the specific project route and site selection criteria that help mitigate potential environmental impacts relevant to the project. Section 6.3 describes general construction mitigations while the remaining sections describe the construction designs, methods and operating strategies that will be employed to mitigate potential impacts during the construction and operation of the project. Potential impacts are primarily associated with the construction stage of the project, therefore the majority of the mitigation applies to this stage. These mitigation strategies will be adapted as appropriate after finalization of the route and site locations, and final facilities engineering.

The potential issues anticipated in constructing the slurry pipeline and the proposed mitigations are presented below in Table 6.1-1.

Reclamation will be the primary mitigation for soil, terrain and vegetation disturbances. Mitigation will include implementing progressive reclamation for the project to minimize the net area disturbed at any one time.

6.1 CLEAN-UP AND RECLAMATION

Clean-up and reclamation of disturbed areas will be conducted concurrently with project construction and operations, as appropriate. During construction and operation activities, industrial debris will be regularly removed and taken to an approved disposal site. Unused equipment and materials will be transported to designated staging areas or off-site, as appropriate.

Table 6.1-1 Potential Issues and Proposed Mitigation for Slurry Pipeline Construction

Project Component	Potential Issue	Proposed Mitigation
air quality	decreased air quality due to emissions from equipment	- equipment will be properly maintained
noise	increased noise levels	- equipment will be properly maintained
terrain and soils	loss or alteration of soil and terrain	- activity on wet ground will be limited during rainy season - surface soils will be stripped as appropriate and stockpiled for reclamation
	increased soil erosion potential	- construction scheduled during dry season ground conditions - soil protection techniques and devices (e.g., roll-back, diversion berms and revegetation) will be used as appropriate
	potential soil contamination	- safe materials storage and handling procedures will be used - spill response equipment will be readily available - spills will be isolated and cleaned-up immediately

Table 6.1-1 Potential Issues and Proposed Mitigation for Slurry Pipeline Construction (continued)

Project Component	Potential Issue	Proposed Mitigation
vegetation	loss/alteration of vegetation communities	- RoW width will be minimized where possible - use of existing clearings where possible - construction adjacent road row reduces required clearing area - natural regeneration promoted through rollback, seeding as required off of road surface
	loss/alteration of rare plants	- use of existing clearings, where possible
	loss/alteration of timber resources	- RoW width will be minimized where possible - use of existing clearings where possible - merchantable timber will be salvaged
	introduction of weed or invasive species	- natural revegetation will be promoted - reclamation seed mix will minimize weeds
wildlife	direct habitat loss	- RoW width will be minimized where possible - use of existing clearings where possible - sensitive habitat to be avoided by RoW routing
	increased fragmentation of habitat	- any maintenance roads to be adjacent to pipeline - vegetation regeneration will provide new habitat - sensitive habitat was avoided by road routing
	indirect habitat loss due to sensory disturbance	- encountered wildlife will be given the right of way
	physical barriers to wildlife movement	- openings will be left in slash piles, and soil piles, and trench plugs left to allow wildlife movement
	increased wildlife mortality and harassment from predation and poaching	- wildlife harassment will not be tolerated - encountered wildlife will be given the right of way
hydrology	alteration of wetlands drainage patterns and function	- route selection to avoid wetlands areas, where possible
	removal of vegetation from watercourse and/or modification of watercourse bed and banks can result in increased erosion and sedimentation	- preservation of riparian vegetation and soil by using appropriate crossing methods at sensitive watercourses - promotion of revegeation in disturbed riparian areas - soil protection techniques and devices (e.g., roll-back, diversion berms and revegetation) will be used as appropriate
	increased sedimentation directly from instream activity	- crossing technique designed according to watercourse sensitivities
aquatic resources	direct disturbance, alteration or loss of fish habitat in watercourse	- crossing techniques designed to account for fish sensitivities - instream activity will be completed as quickly as possible - temporary bridges will be used as appropriate - bridge pilings will be installed outside the watercourse channel
	increased sedimentation from disturbance to watercourse bed bank/top of bank	- RoW width will be minimized at watercourse crossings - riparian vegetation will be preserved where possible - disturbed banks will be restored to natural contour and stabilized
	reduced water quality due to spills	- safe materials handling and storage methods will be used - spill response equipment will be readily available - spills will be isolated and cleaned-up immediately

The following clean-up and reclamation activities will be completed, relevant to each development and reclamation component of the project.

6.1.1 Roads and Slurry Pipeline Right-of-Way

The trenchline and any other areas of disturbance, such as cut and fill, will be re-contoured to match the surrounding terrain. Loose soil taken from the trench will be replaced and will initially be left as an elevated hump of soil to compensate for potential settling. Salvaged topsoil or organic materials will be spread back over the disturbed areas to promote site stability and vegetation growth. Additional site-specific reclamation may include rolling back any salvaged slash or other organic material.

Portions of the road may be used for transportation throughout the life of the project, and possibly beyond, and therefore subject to chronic disturbance by vehicle traffic and maintenance. Unused areas of the road right-of-way (RoW) (i.e., ditches) will be allowed to revegetate to promote site stability, while maintaining safety and structural integrity.

6.1.2 Borrow Pits

Borrow pits will be recontoured and/or terraced as necessary to promote site stability. Slash rollback and re-seeding (if required) for borrow pits would be as described above for reclamation of the other sites.

6.1.3 Stream Crossings

If the banks at stream crossings are inadvertently disturbed, they will be recontoured and seeded to promote vegetation growth for stability and/or supported with rip-rap (large rocks used for erosion control), as appropriate.

6.1.4 Spills

Should any accidental surface contamination occur from spills or releases, the affected location will be evaluated and appropriate remedial techniques will be implemented. The affected location will be restored to natural land capabilities.

6.1.5 Revegetation

Natural revegetation will be encouraged throughout the project area. Seed types that are currently available in sufficient quantities often consist of highly competitive agronomic species that are not indigenous to the area and may out-compete regenerating and re-colonizing native flora, especially in the early seral stages of secondary succession. Consequently, to maintain the ecological integrity of the project area, only disturbed sites that are susceptible to erosion be seeded (i.e., stream banks).

Additional forest restoration will occur over the full pipeline RoW immediately following construction between the edge of the mine plant site and pipeline kilometre point 2, and between pipeline kilometre points 16 and 26. These segments are of particular importance due to their proximity to existing high quality forest corridor areas and the Torotorofotsy Wetlands. Rapid revegetation of these RoW segments will ensure that habitat connectivity is maintained and visual effects are minimized. In these areas, the goal will be the restoration of native zonal forest, through a series of revegetation phases, beginning with erosion-control ground cover. As described in Volume C, Section 4.1, a research program to investigate the success of different reclamation techniques may be undertaken in some areas.

On level and gently sloping terrain, and where specified, slash will be rolled back to minimize erosion and encourage natural revegetation from the soil seed bank and adjacent areas. Reclamation and flora regeneration on access routes, and unused areas of the road and borrow pits, will be enhanced by the seeds and other propagules contained in the natural seed bank (upper portion of the soil profile), as well as through natural colonization and encroachment from adjacent, undisturbed plant communities.

Exposed areas and steep slopes will be revegetated with a self-sustaining, erosion controlling seed mix appropriate to the region. It is suggested that Vetiver grass (*Vetiveria zizanioides*) be planted in strips across slopes (following contour lines) (NRC 1993). Other species can then be planted between the strips of Vetiver.

A monitoring program will be implemented to determine the success of natural revegetation. If natural regeneration is not sufficient, remedial seeding will be completed on a site-specific basis.

The effectiveness of reclamation efforts will be monitored until satisfactory reclamation conditions prevail. Site inspections will be completed regularly to evaluate reclamation work and undertake remedial reclamation as necessary.

6.2 DECOMMISSIONING AND ABANDONMENT

All sites associated with the project will be stabilized and reclaimed to a condition that will mitigate residual impacts, promote revegetation and not impair pre-disturbance land use activities. All buried portions of the pipeline will be drained and abandoned in place, and exposed portions of the pipeline will be removed for salvage. Applicable international standards for infrastructure abandonment (IFC, World Bank) in place at the time of abandonment will be met.

Following satisfactory decommissioning and abandonment of project infrastructure, and relevant clean-up and reclamation activities described earlier, final decommissioning will occur.

Decisions on road abandonment will be made with local authorities and stakeholders. If roads are to be abandoned, erosion control measures will be installed, watercourse crossing structures will be removed, and road surfaces will be allowed to revegetate. Cross drains, parallel ditches and diversion berms will be installed on reclaimed slopes susceptible to water erosion, to divert runoff into vegetated areas adjacent to the RoW.

6.3 GENERAL CONSTRUCTION MITIGATIONS

General mitigations which apply to the project are as follows:

- Applicable regulators, communities and land users will be kept apprised of all construction schedules.
- The local communities will be notified so that anyone using the area will be aware of construction activities and to ensure appropriate avoidance or precautionary measures can be implemented.
- Identified land users will be notified of the construction schedule at least two weeks prior to clearing or other construction work.
- All construction activities will be restricted to the designated RoW, sites and other workspaces.
- Construction traffic will be restricted to the RoW, existing access and appropriate detours. All safety and road closure regulations will be adhered to by construction traffic.
- Vehicle and equipment operators will maintain appropriate speeds and will be advised of potential encounters with wildlife while on access routes and RoW. Any wildlife encountered will be given the right of way.

- All construction equipment that arrives on the job site will be in good working order with no oil or hydraulic fluid leaks.

6.3.1 Timber Salvage

Any merchantable timber will be cut and salvaged from the RoW and other sites, as directed by local and regional authorities.

6.3.2 Grubbing and Stripping

Right-of-way grubbing and stripping of remaining surficial material is conducted once clearing is completed. Grubbing and stripping will be completed on the road RoW to prepare the ground for ditching, grading and/or road fill. The impact mitigation methods to be followed are described below.

- All grubbing and stripping material will be stockpiled and stored within the RoW boundaries for reclamation or disposal.
- In some areas of the slurry pipeline RoW, roll back will be used for soil stabilization and erosion control, as specified.
- Grubbing and stripping will be avoided when possible on sensitive areas such as stream banks, riparian zones and deep organic sections.
- Stripping depths will be identified and documented to guide salvage and subsequent soil replacement.
- Stripped material will be stored at the edge of the RoW for future reclamation. Natural vegetation will be allowed to establish on the stockpiled material to inhibit erosion.

6.3.3 Soil Stability and Erosion Control

The primary mitigation for soil and terrain effects is to minimize the amount and extent of surface disturbance at any one time. To mitigate potential soil erosion from occurring during construction, soil exposure will be minimized, particularly during wet weather and close to watercourses. During very wet weather work will be limited to prevent excessive wheel rutting and tracking mud on the road.

The following mitigation techniques will be used during construction in areas of potential soil instability and erosion concerns:

- Areas of concern, such as riparian areas, will be cleared by hand to prevent potential disturbance to vegetation and soils by heavy equipment.

- Natural vegetation will be retained near water crossings as long as possible during construction to reduce the time that bare soil is exposed.
- Earth cuts and fills will be as shallow as possible, consistent with the geometric standard being constructed.
- Areas of concern will be protected with rip-rap, geotextiles or other methods as required.
- Cross drains, parallel ditches and diversion berms will be installed on disturbed slopes susceptible to water erosion to divert runoff into vegetated areas adjacent to the RoW.
- Diversion berms will be constructed to minimize the velocity of runnoff water, and extend from the trench line to the undisturbed edge of the RoW.
- Construction and reclamation will be completed sequentially, thereby minimizing the area disturbed at any one time.

6.3.4 Watercourse Crossings

Watercourse crossings, stream bank, and riparian zone impact mitigation general considerations are described below.

- Streams, riparian management areas and machine-free zones will be identified on plan/profile sheets. Machine-free zones will be flagged.
- Clearing width will be reduced to the minimum needed for construction of a watercourse crossing or a water body identified as being sensitive.
- Waste material, including grubbing and strippings, will not be piled in areas that may block the flow of water.
- Initial stream crossings will be by temporary crossing structures such as skid or log bundle bridges. Initial crossings on fish bearing streams will be by temporary clear-span bridges.
- Permanent bridge structures will be used on all fish-bearing watercourses crossed by the road along the pipeline RoW.
- Trenchless water crossing methods, if technically feasible, will be considered at sensitive fish-bearing watercourses.

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 slurry pipeline. 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 Volume H, Appendix 6. Mitigation and monitoring plans are divided into three sections below: Section 7.1 presents key pre-construction work to be done; Section 7.2 presents activities to be performed for key management plans during operations; and Section 7.3 presents activities to be completed for key management plans during reclamation and closure.

7.1 PRE-CONSTRUCTION STUDIES

7.1.1 Water Management Plan

Stream crossings will be surveyed before pipeline construction begins to determine the hydrologic characteristics, potential scour depths and best locations and techniques for stream crossing construction.

7.1.2 Flora and Fauna Management Plans

Environmental monitors will proceed ahead of construction to assist in fine tuning the route or implementing mitigation to minimize disturbance of sensitive flora or fauna.

7.1.3 Fish and Aquatics Management Plan

Environmental monitors will proceed ahead of construction to assess stream crossings relative to sensitive aquatic habitats for fish and other species in order to assist in defining any necessary mitigation for impacts on such habitats, or special crossing construction techniques as needed.

7.2 CONSTRUCTION AND OPERATIONS PHASE ACTIVITIES

7.2.1 Emergency Contingency Plan

The pipeline will be regularly inspected during operations to ensure that no erosion, slope movement, pipeline exposure or other sign of potential risk to pipeline integrity is occurring. A leak detection system involving pressure monitoring in the pipeline will be established to quickly determine the existence and location of a pipeline leak in the event that this occurs. Plans will be in place to reduce the extent and impact of any leak that occurs. An environmental emergency response and clean up plan for potential spills or releases during both construction and operations will be developed.

7.2.2 Fish and Aquatics Management Plan

Trenches or isolation pipeline crossing techniques will be used at sensitive fish habitat to minimize in-water work and disturbance of aquatic or riparian habitat and control of total suspended solids (TSS) levels to protect aquatic habitat and biota. Construction and operation phase monitoring of the effectiveness and integrity of mitigation and site reclamation will be implemented to ensure the protection of downstream resources. Fish salvage or avoidance procedures will be implemented at crossings containing communities of endemic, rare or locally important species.

7.2.3 Human Resource Development Plans

A Local Resource Development Initiative (LRDI) will be developed, which will include training programs for project-specific needs. Residents of communities along the slurry pipeline route will preferentially become part of such programs relating to pipeline construction work.

7.2.4 Other Socioeconomic Management Activities

Disturbance to agriculture, access or dwellings along the slurry pipeline route during or after construction will be compensated (in addition to any needed re-settlement and land acquisition).

An HIV/AIDS program will be established and will be operational before project begins construction.

7.3 CLOSURE AND RECLAMATION ACTIVITIES

7.3.1 Flora and Fauna Management Plans

Portions of the slurry pipeline corridor (approximately kilometre 0 to 2 and kilometre 16 to 26) will be re-vegetated immediately after construction, with a targeted revegetation outcome of zonal forest. Maintenance roads will not be kept along the pipeline in these areas. This effort is designed to maintain habitat connectivity in key areas and to assist with regional conservation initiatives. Research-based reclamation trials will be established as part of the revegetation effort in these areas, to improve reclamation techniques over time.