Appraisal of Cumulative Environmental Effects of Small and Medium-Scale Mining in the Mahdia Region

Mahdia, Guyana

Report

NRCan (CANMET) – GENCAPD Mining Project

Our File: M-6763-5 (603430)
February 2004

SNC•LAVALIN
Environment

Member of the SNC•LAVALIN Group

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March 2, 2004

Mr. Richard Couture
Project Technical Director - GENCAPD
Natural Resources Canada - CANMET
555 Booth Street
Room 339B
Ottawa (Ontario)
K1A 0G1

SUBJECT: Mahdia - CEEA
Our File: M-6763-5 (603430)
Contract No. 23440-021003/001/SQ

Dear Mr. Couture:

In compliance with deliverables for item 2.1 of our contract, please find enclosed the report on the Appraisal of Cumulative Effects of Small and Medium-Scale Mining in the Mahdia Region. We wish to take this opportunity to inform you that the practical EIA training on land based mining (one of the deliverables for item 2.2) was provided concurrently with the training on CEEA in January 2004.

Should you have further questions or comments please do not hesitate to contact the undersigned.

Yours sincerely,

SNC-LAVALIN ENVIRONMENT INC.

Marc Arpin, M.Sc., P.Geo.
Project Director

MA/lj

Encl.

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DISCLAIMER

The primary purpose of this publication is to provide an appraisal of cumulative environmental effects of small and medium-scale mining in the Mahdia region. It expresses the professional opinion of SNC-LAVALIN ENVIRONMENT INC. (SLI) regarding the matters set out herein, based on SLI's professional judgment and reasonable due diligence. It is to be read in the context of the agreement of August 4, 2003 (the Agreement) between SLI and Natural Resources Canada (the Client), and in accordance with the methodology, procedures and techniques that SLI used, the assumptions SLI made, and the circumstances and constraints under which SLI carried out its mandate. This document is meant to be read as a whole, and sections or parts thereof should therefore not be read or relied upon out of context.

This document is **NOT** a design manual. Users of this document shall assume full responsibility for the design of facilities and for any action taken as a result of the information contained in this document. SLI and Natural Resources Canada (through the GENCAPD mining project) make no warranty of any kind with respect to the content and accept no liability, either incidental, consequential, financial or otherwise, arising from the use of this publication.

1. EXECUTIVE SUMMARY

1.1 Rationale and Background

The Mahdia region, given its past and existing level of mining activity and above all, the availability of sufficient environmental and social data, was selected by the GENCAPD Mining Project to undertake a Cumulative Environmental Effects Assessment (CEEA).

SNC-LAVALIN ENVIRONMENT INC., was hired to carry out the CEEA as well as to provide training in its preparation, within the framework of its broader assignment in Guyana for the preparation of Codes of Practice and Environmental Guidelines.

1.2 Objectives and General Scope of Work

Because of the time limitations for carrying out this activity and the necessary training, a less comprehensive, though complete, CEEA was conducted.

A twofold approach was chosen to address the time constraint:

- Combining the training with actual preparation of the CEEA.
- No field work, and exclusive reliance on existing data and generic assumptions based on GGMC and EPA knowledge of the region.

Therefore, in the present work on the Mahdia region, the term Cumulative Environmental Effects *Appraisal* is used instead of assessment. Although less comprehensive in terms of the work involved, this CEEA on the Mahdia region is a complete CEEA, made up of all the components and sections that would normally be found in a more detailed Cumulative Environmental Effects Assessment report.

The workshop (training) on preparing CEEAs was held in Georgetown from January 26 to 29, 2004. Participants in the workshop were actively involved in the different steps of preparing a CEEA and are considered co-authors of this CEEA.

Since there are numerous land dredges in the study area, Mahdia was also used as a poster region on land dredging operations, the impacts they are producing and the measures that should be implemented to mitigate these effects.

1.3 Methodology

1.3.1 Assessment Framework

The methodology that will be used throughout this study is based on the Canadian Environmental Assessment Agency (CEAA)'s Assessment Framework for cumulative effects. This frameworks builds on EIA's five (5) basic steps, which are:

1) Scoping.
2) Analysis.
3) Mitigation.
4) Significance.
5) Follow-up.

Associated with each of these steps is a series of specific tasks to be completed for a CEEA.

1.4 Analysis of effects

Any cumulative environmental effects that were likely to result were considered. The following questions were asked:

1) Are the environmental effects adverse?
2) Are the adverse environmental effects significant?
3) Are the significant adverse affects likely?

Determination of likelihood was based on two criteria: 1) probability of occurrence and 2) scientific certainty. In practice, likelihood as an attribute of significance is often rated on a scale, e.g. None (no effect will occur), Low (<25% or minimal chance of occurring), Moderate (a 25% to 75% or some chance of occurring) and High (>75% or most likely a chance of occurring).

Query for evaluating significance

Significance conclusions in assessments should be defensible through some form of explanation of how the conclusions were reached. A series of questions are structured through a series of steps, eventually leading to a significance conclusion. The questions follow a basic line of inquiry as follows:

- Is there an increase in the action's direct effect in combination with effects of other actions?
- Is the resulting effect unacceptable?
- Is the effect permanent?
- If not permanent, how long before recovery from the effect?

Table 1-1 summarizes the effects and their significance on the Valued Ecosystem Components (VEC) of the Mahdia area. Further investigations should be carried out in the future, in order to better understand the significance of these effects and determine the true carrying capacity of creeks and rivers in the Mahdia area.

Table 1-1
Overall Rating Matrix

Actions \ VECs	Water quality in rivers and creeks	Groundwater regime and quality	Quality and availability of soils	Air quality	Quality of carnivorous fish	Abundance of carnivorous fish	Wildlife habitat	Vegetal biodiversity	Quality of the immediate environment of the community	Aesthetics	Agriculture and ecotourism	Community health	Security	Utilities	OH&S	Preservation of aboriginal culture and heritage	Salaries and wages	Sound local development	Quality and abundance of employment
MINING																			
Road construction	L		L	M		M	H	H				L	L	Mp		H	Mp	Hp	Hp
Line cutting/mobilization	L		L				M	M											
Debushing and burning	H		L	M			H	H											
Stripping of overburden and stockpiling	H	M	M	L		M	H	H		H	L					L			
Sampling trenching and pitting	L		H				H			H									
Ore extraction (hydraulicking)	H	L	H		H	H	H	H	H	H	L	H			H	H	Hp	Lp	Mp
Ore extraction (dry mining)	L	L	H				H	H	L	H	L	L			L	H	Hp	Lp	Mp
Concentration (sluice box)	H	L	H		L	H	H	H	H	H					H	H			
Amalgamation and burning	H	H	M	H	H	L			L			H							
Tailings disposal	H		H		H	H	H	H	M	H	M	H						Lp	
Operating equipment				L			H		L										
Industrial waste disposal	H	H	M		L	M	L	L											
Domestic waste disposal	L	L																	
Hazardous waste disposal	H	H	H	L	M	H			H	H		H			H			H	
Demolition of buildings and removal of infrastructures	H	L	H	L		L			L	H	H								
NON-MINING																			
Settlements (squatting)	L		L	L			M	M		H	L	H				H		H	
Transportation (road)	L		L	L			H	L			Lp		M			H	Hp		Hp
Transportation (river)	L					L					Lp		L			L	Lp		Lp
Agriculture (slash and burn)	L		L	L			M	L			Hp						Lp		
Logging (small scale)	L		L				H	L	M							L		H	
Hunting							L									H			
Fishing						H										H			
Ecotourism												L				M	Hp	Lp	Lp

Significance coding

L	Low significance	Lp	Positive effect on VEC, low
M	Moderate significance	Mp	Positive effect on VEC, moderate
H	High/Very high significance	Hp	Positive effect on VEC, high

2. CONTEXT OF THE STUDY

2.1 Rationale

The Guyana Geology and Mines Commission (GGMC), Guyana's mining Regulatory Body vested with the interest of managing all Guyana's sub-surface minerals with the exception of bauxite, has long wanted to assess the cumulative effects of small-scale and medium-scale mining (SMM) in the country. SMM is the source of a number of environmental, social and health concerns wherever it takes place. Among these concerns are:

- Deterioration of land habitat.
- Introduction of contaminants into waterways (mercury).
- Turbidity plumes in numerous waterways (rivers become unfit for human use).
- Contamination of predator fish with mercury.
- Occupational health and safety hazards to the miners themselves.
- Higher incidence of malaria as well as sexually transmitted diseases.
- Prostitution, violence, alcohol and drug abuse, disruption of family life.

The GENCAPD Mining project, a bilateral technical assistance program between Canada and Guyana aimed at strengthen Guyana's capacity for sustainable management of its mining sector, provided the framework and resources to move from intentions to actions. GENCAPD also wanted to make sure that this Cumulative Environmental Effects Assessment (CEEA) would be an opportunity for GGMC and Guyana Environmental Protection Agency (EPA) personnel to learn how CEEAs are prepared, so as to ensure effective transfer of know-how.

The Mahdia region seemed the best option for such an assessment, given its past and existing level of mining activity and above all, the availability of sufficient environmental and social data.

A Canadian firm, SNC-LAVALIN ENVIRONMENT INC., was selected to carry out the CEEA as well as provide training in its preparation, within the framework of its broader assignment in Guyana for the preparation of Codes of Practice and Environmental

Guidelines. Marc Arpin, Mining and Environmental Geologist, was in charge of conducting the CEEA and delivering the training sessions.

2.2 Objectives and General Scope of Work

A CEEA is obviously a major undertaking that involves spending time in the field to collect social and environmental data and leading a multidisciplinary group in a time-consuming, step-by-step process of data processing and analysis. However, the time frame for carrying out this activity and the necessary training did not allow for such a comprehensive CEEA.

A twofold approach was therefore chosen to address this difficulty:

- Combining training with actual preparation of the CEEA.
- No field work and exclusive reliance on existing data and generic assumptions based on GGMC and EPA knowledge of the region.

Because we did not go into as much detail, we use the term “appraisal” instead of assessment. Therefore, in this work on the Mahdia region, CEEA stands for Cumulative Environmental Effects *Appraisal*. Although less comprehensive in terms of the work involved, this CEEA on the Mahdia region is a complete CEEA, made up of all the components and sections that would normally be found in a more detailed Cumulative Environmental Effects Assessment report. Emphasis was placed on ensuring sustainability through properly oriented training for GGMC and EPA professional staff. This is especially important as the GENCAPD Mining project is about to be phased out, implying that in the near future, these assessments will be done by Guyanese professionals.

The workshop (training) on preparing CEEA was held in Georgetown from January 26 to 29, 2004. Participants in the workshop will recognize all the steps of the Assessment Framework they learned to use. Results from all of the 7 practical exercises the participants were required to complete during training have been incorporated into this report and we therefore consider these participants (see Table 2-1 below) co-authors of this CEEA.

Table 2-1
List of participants at the CEEA training workshop and co-authors of this report

#	Mr./Ms.	Name	Institution	Position
1	Ms.	Karen Livan	GGMC	Manager Environment Division
2	Ms.	Dianne Miggins	GGMC	Senior Chemist
3	Ms.	Aretha Crawford	GGMC	Geologist
4	Mr.	Renwick Solomon	GGMC	Environmental Technician
5	Mr.	Ryan Smith	GGMC	Environmental Technician
6	Mr.	Wendell Alleyene	GGMC	OHS Officer
7	Mr.	Ronald Glasgow	GGMC	Senior Mining Engineer I
8	Ms.	Euliene Watson	GGMC	Senior Environmental Officer II
9	Mr.	Trevor Hurry	GGMC	Mining Engineer
10	Mr.	Paul Calendar	GGMC	Mining Engineer
11	Mr.	Dharmpaul Chandan	GGMC	Mining Engineer
12	Mr.	Krishna Ramdass	GGMC	Mining Engineer
13	Mr.	Kerion Husband	GGMC	Environmental Technician
14	Mr.	Dereck Babb	GGMC	Senior Mining Engineer II
15	Mr.	Kahlid Alladin	EPA	Environmental Officer II
16	Mr.	Renwick English	EPA	Environmental Officer
17	Mr.	Adrian McLean	Hydromet	Hydrological Technician I
18	Mr.	Mortimer Livan	NARI	Soil Scientist
N.B. Persons attending at least 3 of the 4 days of the workshop.				

The main objectives of this study are:

- To identify regional issues of concern and Valued Ecosystem Components (VEC) in the Mahdia region.
- To identify mining and non-mining actions likely to cause a cumulative effect, whether spatially or temporally, on VECs.
- To assess these affects.
- To propose mitigation measures.
- To recommend an appropriate follow-up and monitoring program.

2.2.1 Practical training on EIA for land dredging operations

The training on CEEA in the Mahdia mining district provided an excellent opportunity to familiarize participants with standard EIA practices and to apply them. Because CEEAs build on the same principles that have been used for many years in EIAs, participants learned concurrently the fundamentals of EIAs and CEEAs. Since there are numerous land dredges in the study area, Mahdia was used as a poster region on land dredging operations, their impacts and the measures that should be implemented to mitigate these effects.

2.3 Geographical and historical context of the Mahdia mining district[1]

2.3.1 Location and access

Mahdia is situated in the north of central Guyana in the drainage basin of the Potaro River, a tributary of the Essequibo River. It is some 200 km south-south-west of Georgetown and 30 km south-west of the Omai Gold Mine (see Figures 2-1 and 2-2).

Mahdia is accessible by air, land or river. At Mahdia, there is a 1.2 km long airstrip constructed with laterite. In addition, Mahdia may be reached by boat from Waraputa landing on the Essequibo River, travelling via Tumatumari on the Essequibo and Potaro Rivers, and then overland to Mahdia.

2.3.2 Mining history

Over the years, Mahdia has become synonymous with gold mining activities. Prior to the recent exploitation activities, the Proto Mahdia gold deposit had yielded some twenty eight (28) tons of gold since its discovery in 1884, from alluvial, eluvial and hard rock mining. Among the companies known to have operated in the area are The Minehaha Development Company and British Guiana Gold Fields Ltd. The British Guiana Gold Fields Ltd. produced over seven (7) tons of gold from dredging the Mahdia and Minehaha Rivers between 1903 and 1958. It is important to note that a major portion of past total production came from pork-knockers[2], a few of whom are still in the area.

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[1] The content of this section is from Bynoe, M. and Singh, D., 1997.

[2] Small-scale operators, using the man-operated batel to recover their gold.

The Proto Mahdia paleo channel was defined by George G. Williams in 1935. In 1947-1948, Anaconda British Guiana Mines explored the Minehaha for primary gold mineralization. Despite substantial drilling and tunnelling work, Anaconda failed to outline an ore body.

From 1988 the Proto Mahdia was explored by Golden Star Resources Ltd. (GSRL), and a feasibility study was conducted and presented to the Government of Guyana in 1990. GSRL outlined an alluvial deposit at Mahdia containing approximately 190,000 ounces of gold in about 13 thousand m^3 of ore.

GSRL was forced to relinquish the prospect because of difficulties in funding the project. Subsequent to the relinquishment of the Mahdia prospect by GSRL, illegal mining operations began in earnest within the prospected area, to exploit the reserves. The major form of illegal exploitation was with the use of land dredges. Moreover, these operations were conducted without the required safeguards to the environment, i.e. water resources management and disposal of tailings in particular.

In order to bring some semblance of order to the Mahdia area, in 1996, the Government of Guyana, through GGMC, apportioned the defined reserves in Proto Mahdia and probable reserves in surrounding areas into two hundred and fifteen (215) mining blocks and allocated these to local miners. The areas designated Red Hole and St. Elizabeth Mines were expected to be excluded from the block arrangement and allocated to Mahdia residents.

It was envisaged at the time that mining activities in the area would be carefully managed, to ensure the best use of all resources with the minimum of environmental damage. Consequently, the Mahdia Project Implementation Committee (MPIC) was established to produce and implement a project plan.

2.3.3 Mining, ore processing and the environment

Hydraulicking is the main mining method currently employed at Mahdia. Hydraulicking or land dredging basically consists of breaking ore with high pressure water jets. The slurry is then channelled into a sump and sucked up by a gravel pump into a sluice box for gold recovery.

No mechanized concentration devices (jigs, centrifugal separators, etc.) are currently utilized in the project area. The sluice box is used as the main concentration device. Secondary concentrate is achieved using a smaller sluice or manual “batel”. The secondary concentration is then amalgamated and the gold recovered by burning of the amalgam (retorting is recommended for all operations).

Miners at Mahdia are currently making little effort to minimize the impact of tailings discharge on the immediate environment. The main way of disposing of the tailings is to dump it in an old pit or allow it to run off on a depressed area on the land. The effects of such uncontrolled practice can be seen in almost all of the receiving streams, where most of the tailings come to rest.

2.4 Methodology

The methodology used throughout this study is based on the Canadian Environmental Assessment Agency (CEAA)’s Assessment Framework for cumulative effects. This frameworks builds on the five (5) basic steps of EIA:

1) Scoping.
2) Analysis.
3) Mitigation.
4) Significance.
5) Follow-up.

Associated with each of these steps is a series of specific tasks to be completed for a CEEA. The Assessment Framework is detailed in Table 2-2.

Table 2-2
Assessment Framework

Basic EIA Steps	Tasks to complete for a CEEA
1. Scoping	• Identify regional issues of concern • Select appropriate regional VECs • Identify spatial and temporal boundaries • Identify other actions that may affect the same VECs • Identify potential impacts due to actions and possible effects
2. Analysis of Effects	• Complete the collection of regional baseline data • Assess effects of proposed action on selected VECs • Assess effects of all selected actions on selected VECs
3. Identification of Mitigation	• Recommend mitigation measures
4. Evaluation of Significance	• Evaluate the significance of residual effects • Compare results against thresholds or land use objectives and trends
5. Follow-up	• Recommend regional monitoring and effect management

2.5 Definitions

Action: Any project or activity of human origin.

Assessment framework: A description of a process that organizes actions and ideas, usually in a step-by-step fashion. Frameworks help to guide practitioners in carrying out an assessment.

Baseline information:	A description of existing environmental, social and economic conditions at and surrounding an action.
Carrying capacity:	The maximum level of use or activity that a system can sustain without undesirable consequences.
Cumulative effects:	Changes to the environment that are caused by an action in combination with other past, present and future human actions. This definition takes into consideration the effects due to other projects.
Direction:	The degree to which an effect on a valued environmental component will worsen or improve as the action proceeds.
Effect:	Any response by an environmental or social component to an action's impact. Any change that the project may cause in the environment, including any effect of any such change on health and socio-economic conditions, physical and cultural heritage, the current use of lands and resources for traditional purposes by aboriginal persons, or any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.
Environmental components:	Fundamental elements of the natural environment. Components usually include air, water (surface and groundwater), soils, terrain, vegetation, wildlife, aquatics and resource use.
Impact model:	A formal description of a cause-effect relationship that allows the assessing of various components of that relationship through the use of an Impact Statement, a Pathway Diagram, and the validation of linkages and pathways.

Impact statement: The description of a suspected cause-effect relationship through the use of a formal scientific hypothesis.

Indicator: Anything that is used to measure the condition of something of interest. Indicators are often used as variables in the modeling of changes in complex environmental systems.

Likelihood: The degree of certainty of an event occurring. Likelihood can be stated as a probability.

Linkage: The relationship between a cause and effect in impact models. Linkages are illustrated in Pathway Diagrams as arrows between boxes.

Mitigation: A means of reducing, eliminating or controlling the significance of adverse effects.

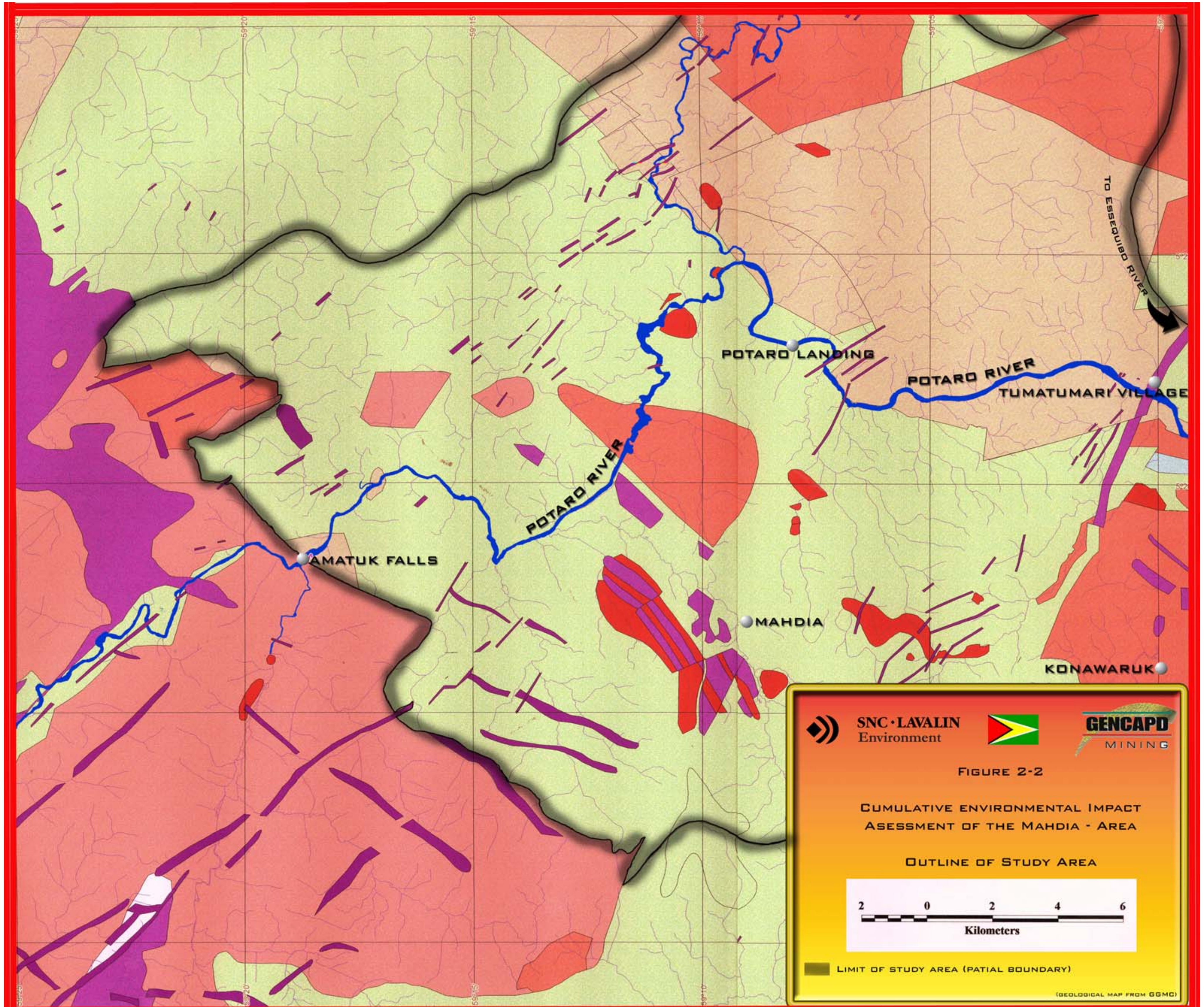
Pathway: A series of consecutive valid linkages in a Pathways Diagram.

Pathway diagram: A simple diagrammatic representation of a cause-effect relationship between two related states or actions that illustrates an impact model. Pathway diagrams take network diagrams one step further by evaluating each linkage and assessing the cause-effect relationship in the context of a scientific hypothesis.

Project footprint: The land or water area covered by a project. This includes direct physical coverage (i.e. the area on which the project physically stands) and direct effects (i.e. the disturbances that may directly emanate from the project, such as noise).

Region:	Any area in which it is suspected or known that effects due to the action under review may interact with effects from other actions.
Significance:	A measure of how adverse or beneficial an effect may be on a VEC.
Scoping:	A consultative process for identifying and possibly reducing the number of items (e.g. issues, VECs) to be examined until the most important items remain for detailed assessment. Focusing ensures that assessment effort will not be expended in the examination of trivial effects.
Threshold:	A limit of tolerance of a VEC to an effect, that if exceeded, results in an adverse response by that VEC.
Valued Ecosystem Component (VEC):	Any part of the environment that is considered important by the proponent, public, scientists and governments involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concerns.

Figure 2-1
Project Location Map


POTARO LANDING
POTARO RIVER
TUMATUMARI VILLAGE
TO ESSEQUIBO RIVER
POTARO RIVER
AMATUK FALLS
MAHDIA
KONAWARUK
SNC·LAVALIN
Environment
GENCAPD
MINING
FIGURE 2-2
CUMULATIVE ENVIRONMENTAL IMPACT
ASESSMENT OF THE MAHDIA - AREA
OUTLINE OF STUDY AREA
2 0 2 4 6
Kilometers
LIMIT OF STUDY AREA (PATIAL BOUNDARY)
(GEOLOGICAL MAP FROM GGMC)

3. ENVIRONMENTAL AND SOCIOECONOMIC SETTING

3.1 Physical Setting and Physiography[3]

Geomorphologically, the Mahdia area is classified as being the Precambrian Lowlands region of Guyana. In its pristine state, the landscape is gently undulating with an average gradient of about 3.5 m/km, sloping downward toward the Potaro River in the north. The most striking landforms are the Mahdiana and Eagle Mountains, which rise to 548 m and 716 m, respectively. These mountains form part of an intrusion which trends northeast/southwest and gives rise to the Tumatumari Falls where it crosses the Potaro River.

There are two geomorphological domains in the Mahdia area: the “highland”, represented by the Konawaruk mountain range, and the “lowland”, represented by the Mahdia River valley. The highlands range in elevation up to 1,000 m. They are characterized by small plateau-like summits formed by diabase sills which are intrusive to the Roraima Formation. The Mahdia River valley lowland is distinguished by its broad “U”-shaped form.

3.2 Climate

The climate at Mahdia is equatorial: conditions are warm and humid year round, and precipitation greatly exceeds evapotranspiration, with a significant amount of rain falling in all months. Annual precipitation at Mahdia is high, averaging 3,560 mm over a twenty-three year period (i.e. 1943 to 1976). The maximum and minimum monthly rainfall recorded over the period of record at the nearby Omai Mine was 408 mm and 105 mm respectively[4]. Typical of tropical regions, the precipitation regime at Mahdia is dominated by storms of short duration and high intensity (see also section 3.3.1 on hydrology).

Temperatures at Mahdia are relatively invariant throughout the year, with the warmest months in the dry season late in the year. Extreme minimum and maximum temperatures recorded by Golden Star Resources Ltd. in its feasibility study were in the

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[3] The content of this section is from Bynoe, M. and Singh, D., 1997.

[4] Taken from Vanessa (Guyana) Inc. (2002).

vicinity of 20°C and the extreme highs at about 40°C. Available information indicates that humidity is high throughout the year.

3.3 Aquatic Resources[5]

3.3.1 Hydrology

In its pristine state, the Mahdia area is characteristic of most hinterland basins, traversed by numerous "clear water" streams that drain to the Potaro River. The Potaro River rises in the Ayanganna Mountains (part of the Pakaraima Range) at approximately 2,050 m and drops rapidly to the northeast, joining the Essequibo River at about 24 m elevation. Precipitation is plentiful throughout the basin, especially at higher altitudes where the highest levels of precipitation in Guyana are recorded.

Hydrologically, the Mahdia region may be divided into three major areas: those drained by the Minnehata, Mahdia and Konawak Rivers. The Mahdia River drainage basin includes the Mahdia village and the airstrip as well as a large portion of the Mahdiana Mountain and part of the Eagle Mountain. The drainage pattern is generally dendritic.

Although rainfall in the area can be sporadic, groundwater outflow was always sufficient during dry periods to maintain flow in all but the smallest streams.

3.3.2 Hydrogeology (Groundwater)

Little data is available on groundwater in the Mahdia area. The most recent information comes from the Vanessa Ventures EIA of the Maple Creek gold project, located 50 km northwest of Mahdia village, on the banks of the Euwang River. In the absence of more complete data, we assume, that the groundwater picture in the Maple Creek area is similar to conditions prevailing elsewhere in the Mahdia region.

Two monitoring wells were installed at the Maple Creek project site and both encountered groundwater at a depth of 3.4 m. Most of the streams in this area appear to obtain their base flows from groundwater discharge from aquifers present in the white sands deposits observed all over the region, including in mining operations (e.g. St. Elizabeth and White

[5] The content of this section is from Bynoe, M. and Singh, D., 1997.

Hole). Local groundwater flow direction appears to be toward individual streams located in the area. Regional groundwater flow is to the Potaro River. Hydraulic conductivity values were determined by performing a rising head permeability test and returned values around 3.5×10^{-3} cm/s.[6]

3.4 Water Quality

3.4.1 Surface Water[7]

Surface water quality in Mahdia is strongly affected by mining activity. Hydraulic mining essentially involves diverting large quantities of water from catchments to wash away sections of earth, and releasing this slurry back into the surroundings. During the process, mercury is used to extract gold from the slurry, and this material, along with high levels of sediment, would be the main sources of pollution. Mercury from natural sources is also present in the soil and overburden material washed along with the paydirt during hydraulicking operations. This naturally occurring mercury, which would otherwise remain in the soil because it is attached to fine particles (silt and clay), is therefore discharged in large amounts into the watercourses[8]. The transport and accumulation of mercury in the environment is a major health concern for both the human and non-human population.

The high sediment load that finds its way into the waterways downstream from mining activity results in poor water quality in which very little plant or animal life may be sustained. This may be measured by the level of dissolved oxygen (DO) in the water.

There are therefore three (3) parameters that are useful in understanding the impact of current mining activity on the state of the physical environment: turbidity (as measured by the total suspended solids, TSS, in water), dissolved oxygen (a measure of the degree to which aerobic organisms may be sustained in water), and mercury content (in both water and sediment). Table 3-1 shows the evolution of these parameters between 1991 and 1997 for some streams in the Mahdia region. A very significant increase in the concentration of total suspended solids is readily observable.

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[6] Taken from Vanessa (Guyana) Inc. (2002).

[7] The content of this section is partly from Bynoe, M. and Singh, D., 1997.

[8] R. Couture, personal communication.

Table 3-1
Comparison of water and sediment quality between baseline (clear boxes) and present (shaded)

(after Bynoe, M. and Singh, D., 1997)

Site	Baseline sample location	Present sample location	TSS ppm (Range)	pH	[Hg] water/ppm	[Hg] Sediment (μg/g)
Small Konawak Ck	5	St. Elizabeth	4.3 (1.0/7)	6.2	n.d.	0.081
			224	5.3	0.003	0.036
Handrail Ck	2	White Hole	18.2 (14/30)	6.5	n.d.	0.138
			8.39%	5.8	n.d.	0.104
Mahdiana Ck	1	Red Hole	6.4 (1.0/14)	6.5	n.d.	0.451
			410	7.4	0.003	1.189
Mahdia R.	3	Mahdia River	23.3 (12/49)	6.5	n.d.	0.331
				6.7	n.d.	0.195
N.B. Baseline data were collected in 1991 by RESCAN.						

Table 3-2
US-EPA Guidelines for suspended solids in Aquatic Systems (1973)

TSS range (ppm)	Type of fisheries	Level of protection
<25	No harmful effects	High
25-80	Good to moderate	Moderate
80-400	Good fisheries unlikely	Low
>400	Poor fisheries at best	Very Low

3.5 Air Quality[9]

There are no major industries in the area. Aerial emissions in the study area are directly related to the emission of gases by small vehicles, the operation of dredges and trucks in

[9] Adapted from Vanessa (Guyana) Inc. (2002).

mine sites, and the decay of vegetation. Airborne discharges and particulate matter are not monitored in the area.

3.6 Regional Geological Setting[10]

Most of the typical features of granite-greenstone terrains of the better exposed Precambrian shield are found in the Potaro River. The supracrustal rocks are dominantly mafic and intermediate volcanics and immature sediments derived from them. These are metamorphosed to the greenschist grade except for the aureoles of higher grade around the major intrusives.

Several features disrupt and conceal the granite-greenstone belt pattern, including major faults and shear zones. Gabbro and dolerite dikes and sills cross the earlier features. The region was eroded both in the Proterozoic and Tertiary and is now a low relief surface with a few prominent hills over the more mafic rocks. The sands and clays of the Tertiary transgression which covered most of the region are now partially eroded.

The supracrustal rocks are apparently the oldest rocks preserved in the area. The basal contacts of the supracrustal section are missing or obscured due to the granitoid intrusives. The volcanics range in composition from basalt to dacites and rhyodacites. No ultramafic extrusives have been identified. The siliceous volcanics are concentrated in particular areas with associated agglomerates and hypabyssal intrusives.

The sedimentary rocks are predominantly grey graded greywackes and shales. Associated with the greywackes are occasional coarse polymictic conglomerates composed of subangular blocks of diverse intermediate and felsic volcanics. No angular unconformities have been recognized in the greenstone sections. Metamorphosed mafic dikes and sills cut the supracrustal rocks in many places. A 15-20 km wide belt extending northwest from Madhia contains numerous examples, most of which strike northwest as well.

Several of the granitoid intrusives have aureoles of muscovite-chlorite schist. The Portage Granodiorite is adjacent to and apparently roofed by the Apanachi Schists,

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[10] Adapted from Vanessa (Guyana) Inc. (2002).

which are derived by contact metamorphism of volcaniclastic sediments and some intercalated volcanics.

3.7 Surface Geology and Soils

Information obtained from the pits excavated at Vanessa's Maple Creek project during the exploration program revealed three alluvial facies: paleo-fluvial sand, beach sediment (White Sand), and modern fluvial sediments. The oldest unit (paleo-fluvial sands) is fluvial sand deposited as the paleo-channel filled with sediment. This material is predominantly sand with occasional pebbly sand and gravel beds. The White Sand unit is a Tertiary beach sand that was likely derived from the reworking of older fluvial sediments and the erosion of the Pakaraima escarpment. The White sands are deepest on hills and generally thicken to the north. The youngest unit is a modern fluvial deposit consisting of sediment reworked and redistributed from the initial two units.

The tropical conditions of the study area have produced an environment dominated by chemical weathering. Such an environment is hostile to lithic material, and silica therefore dominates the sediment composition (quartz). Remnants of lithic materials are in the form of clay clasts and kaolinized sand grains. Generally, bedrock weathers to saprolite, a silty clay material that retains the original bedrock structure.

The major geomorphological event in the region was the emergence of the White Sand Sea. The Sea did not advance southward as far as the Proto-Mahdia (paleochannel) headwaters. Most of the region, however, was covered by a mantle of sediments when the sea retreated. South of Gloria Creek, much of the project area is underlain by in situ weathered materials composed of laterite and colluvium overlying basal bedrock units. North of Gloria Creek the project area is underlain predominantly by alluvial gravel of the Proto-Mahdia. Recent alluvial deposits which exist in the project area are localized in the streams valleys and gullies of Mahdiana, Gloria, Unity and St. Elizabeth Creeks, and the Mahdia River.

3.8 Biological Setting

3.8.1 Aquatic Life

The most common fishes found in the Mahdia area identified in Table 3-3.

3.8.2 Vegetation[11]

The area of Mahdia is typical Tropical Rain Forest with warm temperature, high humidity and precipitation. Solar radiation is usually high in this environment. Vegetation thus is luxuriant and soil types vary slightly with topography, making the forest rather diverse.

Fungi are present in a dominant way and almost every plant type utilizes choral root system to access nutrients, which leach rapidly through the soil. These nutrients are mainly and almost exclusively derived from forest litter that is continuously decomposed with the help of abundant fungi and bacteria.

Climax vegetation is typical of steep hill and mountainsides as well as the summits of these rises. However, in areas less inaccessible to humans, secondary forests predominate with shorter trees and shrubs. Where clearings had been made for excavations for mineral recovery, there is evidence that undergrowth had been profuse given the permitted penetration of sunlight there. High canopied and mid-level trees are festooned with epiphytes on their trunks and limbs, with aerial roots and vines, some rather thick, hanging and climbing down to the ground.

Ninety (90) tree types were identified among more than seventy (70) species with representatives of all three canopy heights usually encountered in Tropical Rain Forest areas. High canopy trees (over 20 meters) were represented by Greenheart *(clorocardium rodiei*), Mora *(Mora excelsa)* and three types of Walaba *(Eperua spp.)* while the mid-canopy (6 to 20 meters) had representatives such as Baromalli *(Castostemma sp.)* Bulletwood *(Manildara bidentata)* and Kakaralli *(Eschweilera sp.)* and the lower level trees (less than 6 meters high) had types such as Bartaballi

[11] The content of this section is adapted from Vanessa (Guyana) Inc. (2002) and Bynoe, M. and Singh, D., 1997.

(Chryophyllum jenmanii), Kamadan *(Posoqueria sp.)* and the Kokorite Palm *(Attalea sp.*). Especially in gap areas, this lowest level understory contained ferns, selaginella and mosses as well as lichens, which abounded on trunks and limbs.
Several tree types in the area are of potential commercial value.

Table 3-3
Fishes in the Mahdia Area

(after Vanessa (Guyana) Inc., 2002 and Bynoe and Singh, 1997)

Scientific name	Local name
Hoplerythrinus untaeniatus	Yarrow
Astynax sp.	Silver fish
Hemigrammus sp.	Silver fish
Aequidens sp.	River patwa
Hoplias macrophatamus	Haimara
Cichlasoma bimaculatum	Patwa
Pseudoplatystomes vialanti	Tiger fish
Erytrinus erytrimus	Houri
Undetermined	Tibikuri; dury

3.8.3 Wildlife

The natural tropical forest setting of the area, influenced by the variable topography of steep and not-so-steep inclines with generally elevated areas of high rainfall and humidity and soil mixtures of sand, and clay loam overlaid with very thick humus provide habitats for various types of arthropods, amphibians, reptiles, birds and mammals.

3.8.3.1 Birds

Twenty-three (23) species of birds are identified in the area by Vanessa (Guyana) Inc. (2002) and Bynoe and Singh (1997). They are detailed in Table 3-4.

3.8.3.2 Reptiles and Amphibians

The herpetofauna in the area consists mainly of spectacled caimans, frogs, toads, lizards (*anolis sp*.) and Labaria turtles. No snakes are reported in the literature even though we saw one crossing the road about 15 km from Mahdia on our way to Mabura.

3.8.3.3 Mammals[12]

Vanessa (Guyana) Inc., 2002 reports that the principal mammal seen during their Maple Creek study was a jaguar *(Panthera onc*a), a very large carnivorous cat that feeds on deer, peccaries, pacas and lizards. This animal together with the ocelot *(Felis paradali*s) represent the primary large mammals in the area. Both are listed as vulnerable in the IUCN Red Data Book 1975, and are hunted by humans; no hunting activity was noted during the fieldwork. The ocelot was never seen during the study period but faecal remains and paw imprints on the ground confirm its presence in the area. The presence of both deer *(Mazama americana*a) and the Tapir *(Tapirus terrestri*s) was also confirmed by faecal remains and paw imprints. The Red Howler Monkey *(Alouatta seniculu*s) was seen in distant trees and both the Agouti *(Dasyprocta agout*i) and raccoon *(Procyonidae s*p) were observed on trails in the concession.

Three species of bats *(Chiropter*a) were caught in mist nets. These were examined, described, photographed and released. Bats are prevalent in the area. This is not uncommon in tropical and subtropical forests. They have a wide range of eating preferences as some are insectivorous, frugivorous, nectarivorous, carnivorous and even sanguivorous. Bat are generally active at night over an area ranging from above the tallest canopy to the forest floor. Table 3-5 is a summary of mammals encountered in the area.

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[12] Adapted from Vanessa (Guyana) Inc. (2002).

Table 3-4
Summary of Birds in the Mahdia Area
(after Vanessa (Guyana) Inc., 2002 and Bynoe and Singh, 1997)

Scientific name	Local name
Chloroceryle americana	Green kingfisher
Chloroceryle amazona	Amazon kingfisher
Cochlearius sp.	Blue crest heron
Daptrius americanus	Red throated cara cara
Psarocolius sp.	Yellow billed oropendpola
Scaphildura oryzivora	Giant cow bird
Ramphastos culiminatus	Yellow ridge toucan
Celeus elegantis	Chestnut woodpecker
Amazona amazona	Orange winged parrot
Amazona farynosa	Mealy parrot
Ara macao	Scarlet macaw
Ara sp.	Macaw
Buteogallus uru bitinga	Great black hawk
Hypocemis cantator	Warbling ant bird
Pipra pipra	White crowned manakin
Tinamous major	Tinamou
Crypturellus variegatus	Tinamou
Pointes melanocephala	Black headed parrot
Bucca tamatia	Spotted Puff bird
Brotogeris chrysotenus	Golden winged parakeet

Table 3-5
Summary of Mammals found in the Area

(after Vanessa (Guyana) Inc., 2002 and Bynoe and Singh, 1997)

Scientific name	Local name
Nasua nasua	Racoon
Puma comcolor	Wild cat; ocelot
Panthera onca	Jaguar
Felis paradalis	Ocelot
Mazama americana	Red brocket deer
Dasyprocta fuliginosa	Agouti
Agouti paca	Paca, labba
Tapirus terrestris	Tapir
Tayassu pecari	White-lipped peccary
Tayassu tajacu	Collared peccary
Alouatta semiculus	Red howler monkey; baboon
Tonatia silvicola	Bat

3.8.3.4 Threatened and endangered species

No species in the area are listed as endangered.

3.9 Socioeconomic Setting[13]

3.9.1 Regional Economy

Widespread preoccupation with gold mining at Mahdia has relegated other occupational activities to a secondary position. For example, limited farming is undertaken, even though the area has small-scale farming potential. The Mahdia community is served by

[13] The content of this section is adapted from Vanessa (Guyana) Inc. (2002) and Bynoe, M. and Singh, D., 1997.

a small but active commercial sector. There is a vibrant business group comprising a number of shops, stalls and 2 hotels.

3.9.2 Population

Primarily because of the shifting nature of mining activities, the population at Mahdia tends to be both transient and differentiated. A large proportion of the residents or dwellers originate from elsewhere, either from Guyana or as far away as the smaller islands of the Caribbean (mainly St. Lucia). Most of the migrants still maintain links or a family base in their home areas. A large proportion of smaller miners migrate to other gold mining areas when they have exhausted their opportunities at Mahdia. As a result, the population level is never stable.

Mahdia also exhibits a fairly limited framework for supporting the growth of a real community. Because residence is often considered to be temporary, there is little sustainability in the lifestyle of most residents.

The population of Mahdia is differentiated mainly along ethnic lines. An estimated 40 Amerindian households live in a separate section of Mahdia called Campbell Town. They constitute between 10-15% of the estimated population at any particular time. Their lifestyle is less traditional and more integrative since they participate in many of the social, economic and civic activities of Mahdia. However, some unique aspects of Amerindian tradition are observed. Campbell Town is run by regulations pertaining specifically to the Amerindian community, which is headed by a traditional Captain.

Mahdia has a population that consists essentially of second and third generation offspring of West Indian descent. Many of the original immigrants have returned to their homeland. The total Afro-Guyanese population in Mahdia account for an estimated 50% of the total population (including permanent and transient population). East Indians represent about 30% and “Others” 10% of the total population.

3.10 Land Use Setting[14]

3.10.1 Mining

The Mahdia area has had a history of mining and was prosperous until the 1950s, when many operations were transferred to the Potaro River. Since then, the community has been supported by logging and numerous small placer mining operations carried out by independent pork-knockers.

Pork-knockers, active and inactive, are scattered throughout the Mahdia area. The Mahdia River was dredged extensively in the past, and the GGMC carried out a hydraulic operation at Dickman Hill during the early 1980s. These mining activities have left scars in the area.

3.10.2 Forestry

In 1991, the Mahdia area contained a number of economically important species that were not being harvested, at least not on a commercial scale. In the past, the areas along the river banks were heavily logged by the Amerindians and Mahdia residents for building materials. At present there is little activity, perhaps because mining is a more lucrative business than logging. There seems to be little use of the vegetation by the residents. Lumber is cut and used only for building purposes within the area; none is exported out of the area.

3.10.3 Hunting, Fishing and Trapping

With respect to the fauna in the Mahdia district, the presence of humans, stripping of the vegetation that served as food for animals in order to practice mining, toxification of rivers, streams etc., within the mining area and the rerouting of waterways, building of access roads, and increased hunting activities have led to the regression and/or extinction of many mammals, birds and especially fishes from the Mahdia area.

There are very few sightings at mining camps and these were mainly of tapir and agouti. Residents have to travel 30 minutes or more in order to hunt game.

[14] The content of this section is adapted from Bynoe, M. and Singh, D., 1997.

Photo 3-1
Red and White Hole Mine, Mahdia

Photo 3-2
St. Elizabeth Mine, Mahdia

4. STEP 1: SCOPING

4.1 Regional issues of concern

Identifying regional issues of concern is the first task in the scoping process (see the assessment framework in Table 2-2). The issues of concern for the Mahdia area were discussed and identified by the group in exercise 1 of the workshop. They are summarized in Table 4-2 below.

4.2 Identification of Environmental Components

Table 4-1 indicates the relevant environmental components identified for the Mahdia area. They are also shown in Table 4-2.

Table 4-1
Main Environmental Components in the Mahdia Area

Physical Setting
Air
Streams
Groundwater
Soils
Sediments of streams
Biological Setting
Aquatic fauna
Terrestrial wildlife
Vegetation
Human Setting
Land use
Local population
Amerindians
Local economy

4.3 Selection of Valued Ecosystem Components (VEC)

Valued Ecosystem Components (VECs) are components of the natural and human world that are considered valuable by participants in a public review process. They need not be environmental in nature. VECs for the Mahdia area were selected by the participants at the training workshop during exercise 2. Table 4-2 integrates the VECs with the regional issues of concern and the environmental components they refer to. Examples of indicators are also provided.

4.4 Identification of spatial and temporal boundaries

Identifying spatial and temporal boundaries was the subject of exercise 3 at the workshop.

The boundary in the past ideally begins before the effects associated with the action under review were present. Because this CEEA focuses on the incremental effect of gold mining on the Mahdia area, the past temporal boundary should be set at the discovery of the Proto Mahdia gold deposit in 1884, when gold mining activity first commenced in the region (see section 2.3.2). However, because we might suffer from a lack of information by going back that far into the past, we chose to use the current conditions as the boundary in the past.

The boundary in the future typically ends when pre-action conditions become re-established (VECs have recovered and effects become trivial). As it is likely that current conditions will prevail for some time in Mahdia before we can observe an improvement in miners' environmental practices, the boundary in the future has been set at 20 years.

The spatial boundary was defined based on a number of criteria defined in page 21 of the *Practical Guide for Preparing Cumulative Environmental Impact Assessment.* The spatial boundary was selected taking into consideration, among others, geographic and ecological constraints, cause-effect relationships and possible interactions between actions. The study area shown in Figure 2-2 corresponds to the selected spatial boundary. The study area is bounded to the north and south by the limits of the Potaro River watershed, to the west by the steep cliff marking the appearance of the Pakaraima Mountains and to the east by the Essequibo River.

Table 4-2
Environmental Components, Regional Issues of Concern and Valued Ecosystem Components for Mahdia

Environmental Component	Regional Issues of Concern	Valued Environmental Components	Examples of Indicators
Physical Setting			
Streams	Surface water pollution	Water quality in rivers and creeks	TSS, TDS, pH, visual aspect
Groundwater	Groundwater pollution (wells)	Groundwater regime and quality	TDS, flow
Soils	Erosion and land degradation	Quality and availability of soils	▪ % area of soils lost per period of time ▪ Loss of productivity per Ha
Air	Air pollution (because of mining)	Air quality	▪ Concentration of PM_{10} ▪ Concentration of Hg (around areas of amalgam burning) ▪ Levels of NO_x, CO and PAH (wood burning)
Sediments of streams	Presence of mercury on the riverbeds	Quality of carnivorous fish	Levels of Hg in the riverbeds sediments
Biological Setting			
Aquatic fauna	Contamination of fish	Quality of carnivorous fish	Levels of Hg, Pb and other heavy metals in large fish
	Depletion of fish stocks	Abundance of carnivorous fish	Amount of fish caught per period of time
Terrestrial wildlife	Fragmentation and loss of wildlife habitat owing to deforestation	Wildlife habitat	Density of certain species of wildlife
Vegetation	Excessive deforestation	Vegetal biodiversity	Levels of certain pioneering species

Table 4-2 (Cont'd)

Environmental Component	Regional Issues of Concern	Valued Environmental Components	Examples of Indicators
Human Setting			
Land use	Improper waste (domestic, industrial and hazardous waste)	Quality of the immediate environment of the community	▪ No. of arbitrary waste dumps ▪ Bacteriological and chemical quality of groundwater ▪ No. of water borne diseases (e.g. cholera or typhoid) ▪ Concentration of noxious gases
		Aesthetics	▪ Degree of insatisfaction of the population (survey) ▪ No. of complaints filed
	Deterioration of aesthetic landscapes		Loss of pleasing landscapes
	Conflicting land uses	Agriculture and ecotourism	▪ No. of ecotourists in the area ▪ Agricultural production
Local population	Intake of mercury through fish consumption	Community health	Levels of Hg in hair, urine and nails
	Higher incidence of HIV-AIDS, STDs and malaria		▪ Reported incidences ▪ Reported sick leaves ▪ No. of brothels (?)
	Increase in crime	Security	Incidence of serious crimes
	Deficient supply of potable water and no sewage sanitation	Utilities	▪ Facilities in place ▪ % availability of service ▪ Potable water quality
	Deficient OH&S[1]	OH&S	▪ No. of accidents and fatalities in mines ▪ No. of widows

Table 4-2 (Cont'd)

Environmental Component	Regional Issues of Concern	Valued Environmental Components	Examples of Indicators
Amerindians	Loss of culturally valuable areas (e.g. burial grounds)	Preservation of aboriginal culture and heritage	No. of sites lost or damaged
	Cultural dilution by the introduction of coastal lifestyles and the coexistence of different social groups (miners, foreigners, etc.)		▪ No. of dysfunctional families ▪ Complaints of conflicts, hardship
	Loss of traditional hunting grounds		▪ Distance of hunting grounds from the community ▪ Size of hunting areas
Local economy	Increased cost of living	Salaries and wages	Cost of key items and services
	Unplanned development	Sound local development	▪ Location, quality and density of houses ▪ No. of industries ▪ Incidence of squatting
	Deficient economic activity (disparity in wages)	Quality and abundance of employment	▪ Levels of unemployment ▪ Average wages

<u>Note</u>:

1) Occupational health and safety (OH&S) issues are not normally addressed by an EIA or CEEA..

4.5 Identification of mining-related actions

Action selection (either mining and non mining actions) was done using the action selection criteria shown in Table 4-3. Mining actions defined by the participants (in exercise 4 of the workshop) are listed in Table 4-4.

Table 4-3
Spatial and Temporal Criteria for Selection of Actions

Spatial Criteria	Temporal Criteria
Actions with footprints within the regional study area(s) that may affect the VECs being assessed. Footprints include associated components (e.g., access roads, powerlines), and include air or areas of land or water directly disturbed.	**Past**: actions that are abandoned but still may cause effects of concern. **Existing**: currently active actions.
Actions outside the regional study area, if it is likely that any of their components may interact with other actions or VECs within that area.	**Future**: actions that may yet occur.

4.6 Identification of other actions

Other actions (human activities) identified in the area are listed in Table 4-5.

Table 4-4
Mining-related Actions in Mahdia

Project Phase	Action
Mine Construction Phase	▪ Road construction ▪ Line cutting/mobilization ▪ Debushing and burning (slash/burn) ▪ Stripping of overburden and stockpiling ▪ Sampling, trenching and pitting
Mine Operation Phase	▪ Ore extraction (hydraulicking) ▪ Ore extraction (dry mining) ▪ Concentration (sluice box) ▪ Amalgamation and burning ▪ Tailings disposal ▪ Operating equipment ▪ Industrial waste disposal ▪ Domestic waste disposal ▪ Hazardous waste disposal
Mine Closure Phase	Demolition of buildings and removal of infrastructures

Table 4-5
Other Actions in Mahdia

Activity
Settlements (squatting)
Transportation (road)
Transportation (river)
Agriculture (slash and burn)
Logging (small scale)
Hunting
Fishing
Ecotourism

4.7 Identification of potential impacts and effects

4.7.1 Identification of Impacts

What is affecting what? Potential impacts must be identified that may affect the VECs. We must first identify the environmental components (see Table 4-2) that may be affected by various mining actions (e.g. debushing, stripping, amalgamation, etc.). Environmental components that may be affected by other actions in the region (see Table 4-5) can then be identified. The scoping then proceeds to focus on the relationships between specific impacts from various actions and specific VECs.

The identification of potential impacts will facilitate the assessment of their effects on VECs later on, at Step 2 of the assessment framework, by helping us to focus on the VECs most affected. The impacts identification matrix is shown in Figure 4-1.

Figure 4-1
VECs affected by mining and other actions in the Mahdia area

Actions \ VECs	Water quality in rivers and creeks	Groundwater regime and quality	Quality and availability of soils	Air quality	Quality of carnivorous fish	Abundance of carnivorous fish	Wildlife habitat	Vegetal biodiversity	Quality of the immediate environment of the community	Aesthetics	Agriculture and ecotourism	Community health	Security	Utilities	OH&S	Preservation of aboriginal culture and heritage	Salaries and wages	Sound local development	Quality and abundance of employment
MINING																			
Road construction	√			√		√	√	√				√	√	√		√		√	√
Line cutting/mobilization	√		√				√	√											
Debushing and burning	√		√	√			√	√											
Stripping of overburden and stockpiling	√	√	√	√		√	√	√		√	√					√			
Sampling trenching and pitting	√		√				√			√									
Ore extraction (hydraulicking)	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√
Ore extraction (dry mining)	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√
Concentration (sluice box)	√			√	√		√			√					√	√			
Amalgamation and burning	√	√	√	√	√														
Tailings disposal	√		√		√	√	√	√	√	√	√	√			√			√	
Operating equipment				√			√		√										
Industrial waste disposal	√	√	√		√	√	√	√											
Domestic waste disposal	√	√																	
Hazardous waste disposal	√	√	√	√	√	√			√	√		√			√			√	
Demolition of buildings and removal of infrastructures	√		√							√									
NON MINING																			
Settlements (squatting)	√		√	√			√	√		√	√	√				√		√	
Transportation (road)	√		√	√			√	√			√		√			√	√		√
Transportation (river)	√					√					√		√			√	√		√
Agriculture (slash and burn)	√		√	√			√	√			√						√		
Logging (small scale)	√		√				√	√	√							√		√	
Hunting							√									√			
Fishing						√										√			
Ecotourism												√		√		√	√	√	√

5. STEP 2: ANALYSIS OF EFFECTS

Combined or cumulative effects of the different actions on each VEC are looked at from the "VEC point of view". In assessing these effects, one must ask the following questions:

- What VECs are affected?
- What parameters are best used to measure the effects on the VECs?
- What determines their present condition?
- How will the proposed action in combination with existing and approved actions affect their condition?
- What are the probabilities of occurrence, probable magnitudes and probable durations of such effects?
- How much further effect could VECs sustain before changes in condition become irreversible?

5.1 Impact models

The approach that we chose for assessing the effects on the selected VECs in Mahdia is the Impact Model. Impact models have been used extensively in EIAs. They provide a concise description of the cause-effect relationship that occurs between an action and the surrounding environment. The Impact Model approach involves testing the validity of a statement, similar to that made in a scientific hypothesis. The advantage of using Impact Models is that they provide a simplification of complex systems.

Impact models have three parts:

1) Impact statement.
2) Pathways diagram.
3) Linkage statements

The assessment of the model involves two steps:

1) Linkage validation (see Table 5-1).

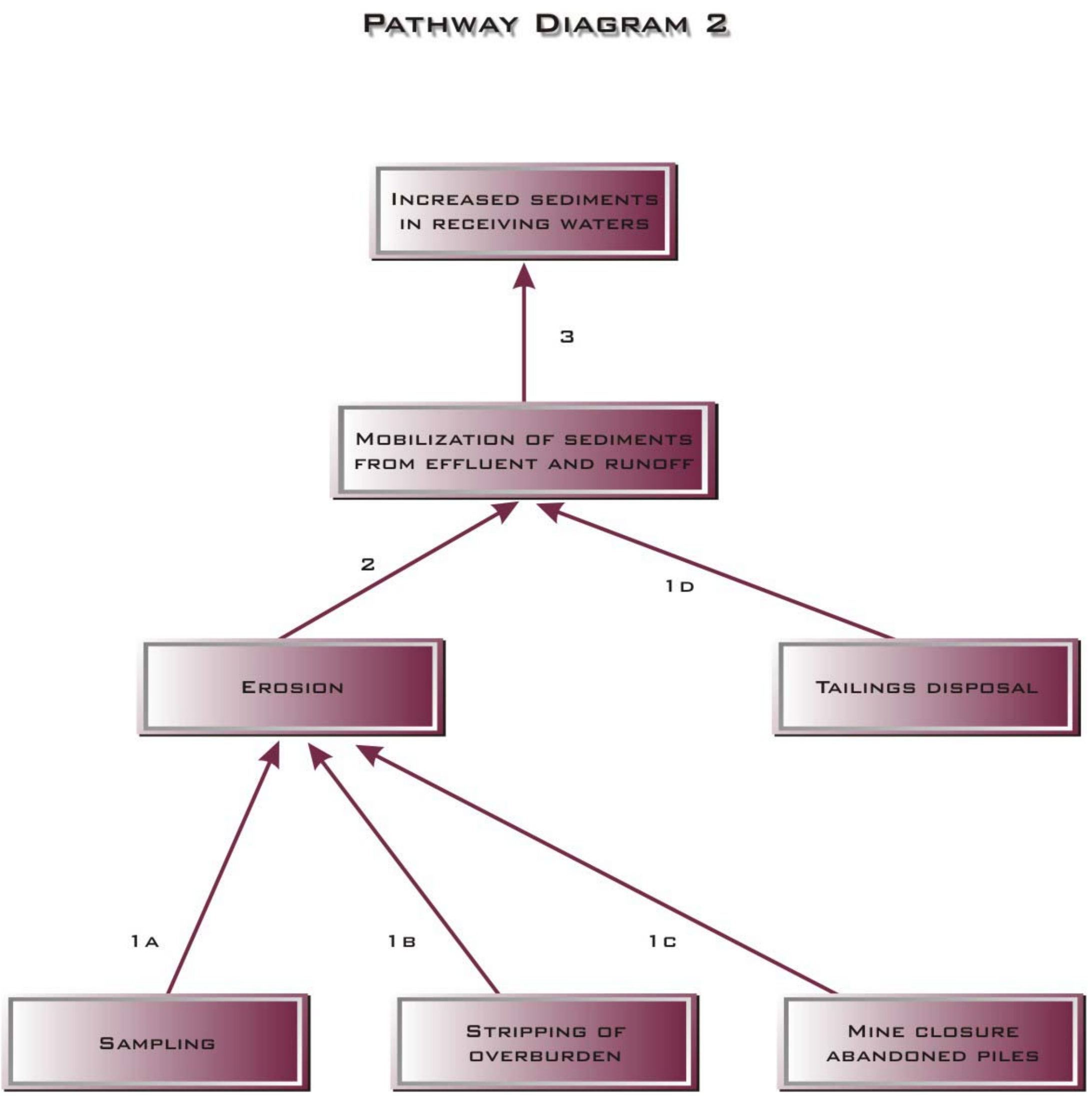
2) Pathway assessment and evaluation (see Table 5-2).

Participants at the workshop prepared a number of Impact Models. One of them is provided as an example of the approach used for assessing cumulative effects and is shown in Figure 5-1. More pathway diagrams for land dredging can be found in Appendix A.

Figure 5-1
Impact Models for different Mining Actions in Mahdia

Impact statement 2:

Sampling, stripping of overburden, tailings disposal and ultimately the closure of the mine lead to increased erosion and mobilization of sediments, thus resulting in a reduction of surface water quality.



Linkage description:

1a: Sampling that includes pitting and trenching results in exposure of soils (sample heaps).

1b: Stripping and stockpiling of overburden produce exposed soils.

1c: Improper mine closure results in the exposure of extensive spoil piles and soils.

1d: The disposal of tailings directly into streams increases the sediment load of the water body.

2: Erosion of exposed samples heaps and spoil piles from stripping of overburden and also at closure of the mine results in the mobilization of heavy sediment loads.

3: Increased sediment load in runoff and tailings effluent results in the reduction of water quality of recipient water bodies.

Table 5-1
Linkage Validation of Impact Model 2

#	Linkage Description	Validity	Confidence
1a	Sampling that includes pitting and trenching results in exposure of soils (sample heaps)	Valid	High
1b	Stripping and stockpiling of overburden produces exposed soils.	Valid	High
1c	Improper mine closure results in the exposure of extensive spoil piles and soils	Valid	High
1d	The disposal of tailings directly into streams increases the sediment load of the water body	Valid	High
2	Erosion of exposed sample heaps and spoil piles from stripping of overburden and also at closure of the mine results in the mobilization of heavy sediment loads	Valid	High
3	Increased sediment load in runoff and tailings effluent results in the reduction of water quality of recipient water bodies	Valid	High

Table 5-2
Pathway Assessment and Evaluation of Impact Model 2

(see Table 5-3 and Section 6.1 for explanation of terminology)

Pathway	1	2	3	4
Links	1a, 2, 3	1b, 2, 3	1c, 2, 3	1, 2, 3
Scope	Regional	Regional	Regional	Regional
Magnitude	Moderate	Moderate	Moderate	High
Duration	Short-term	Short-term	Medium-term	Long-term
Frequency	Sporadic	Sporadic	Continuous	Continuous
Direction	Negative	Negative	Negative	Negative
Significance	Insignificant	Insignificant	Significant	Significant
Confidence	High	High	High	High

Table 5-3
Significance Attributes

Attribute	Options	Definition
Direction	Positive	Beneficial effect on VEC
	Neutral	No change to VEC
	Negative	Adverse effect on VEC
Extent	Site	Effect restricted to a small site
	Local	Effect restricted to the project footprint
	Sub-regional	Effect extends to area within a few kilometres of the project footprint
	Regional	Effect extends throughout regional assessment area
Duration	Short-term	Effects are significant for <1 year before recovery returns conditions to the pre-project level; or, for species, for less than one generation
	Medium-term	Effects are significant for 1-10 years or, for species, for one generation
	Long-term	Effects are significant for >10 years or, for species, for more than one generation
Frequency	Once	Occurs once only
	Continuous	Occurs on a regular basis and regular intervals
	Sporadic	Occurs rarely and at irregular intervals
Intensity	Low	Minimal or no impairment of component's function or process (e.g. for wildlife, a species' reproductive capacity, survival or habitat suitability; for soil, ability of organic soil to fix nitrogen)
	Moderate	Measurable change in component's function or process in the short and medium term; however, recovery to pre-project level is expected
	High	Measurable change in component's function or process during the life of the project or beyond (e.g. for wildlife, serious impairment to species productivity or habitat suitability)
Significance	High Moderate Low	Based on the analysis, use of Significance Query and best professional judgment, is the effect on the VEC significant?
Confidence	Low Moderate High	In general, what is the confidence level in the conclusion?

6. STEP 3: EVALUATION OF SIGNIFICANCE

Normally, as shown in the assessment framework in Table 2-2, mitigation measures would be identified prior to evaluating significance, so as to reflect the situation that will prevail if mitigation is effective. However, for this CEEA on the Mahdia area, we chose to evaluate the significance first, in order to show the worst-case situation, which is the one prevailing in Mahdia. Mitigation measures will be examined in section 7 along with the residual impacts.

6.1.1 Approaches to determining significance

Determining the significance of effects, before or after mitigation, is probably the most important and challenging step in EIA. The determination of significance for CEEAs is fundamentally the same; however, it may be more complex due to the broader nature of what is being examined. A cumulative effects approach requires determining how much further effects can be sustained by a VEC before it suffers changes in condition or state that are irreversible.

Deciding whether effects are likely

Any cumulative environmental effects that are likely to result must be considered. The following questions should be asked:

1) Are the environmental effects adverse?

2) Are the adverse environmental effects significant?

3) Are the significant adverse effects likely?

The determination of likelihood is based on two criteria: 1) probability of occurrence and 2) scientific certainty. In practice, likelihood as an attribute of significance (see Table 4-6) is often rated on a scale e.g. None (no effect will occur), Low (<25% or minimal chance of occurring), Moderate (a 25% to 75% or some chance of occurring), and High (>75% or most likely a chance of occurring).

Query for evaluating significance

Significance conclusions in assessments should be defensible through some form of explanation of how the conclusions were reached. The following is an example of one approach. A series of questions are structured so as to guide the practitioner through a series of steps, eventually leading to a significance conclusion. The questions follow a basic line of inquiry as follows:

- Is there an increase in the action's direct effect in combination with effects of other actions?
- Is the resulting effect unacceptable?
- Is the effect permanent?
- If not permanent, how long before recovery from the effect?

These questions appear in more detail below, specifically to address the nature of two different types of VECs.

<u>Biological species VECs</u>

- How much of the population may have their reproductive capacity and/or survival of individuals affected? Or for habitat, how much of the productive capacity of their habitat may be affected (e.g. <1%, 1-10%, >10%)?
- How much recovery of the population or habitat could occur, even with mitigation (e.g. Complete, Partial, None)?
- How soon could restoration occur to acceptable conditions (e.g. <1 year or 1 generation, 1-10 years or 1 generation, >10 years or >1 generation)?

<u>Physical-chemical VECs</u>

- How much could changes in the VEC exceed those associated with natural variability in the region?
- How much recovery of the VEC could occur, even with mitigation?
- How soon could restoration occur to acceptable conditions?

7. STEP 4: GLOBAL APPRAISAL OF IMPACTS AND MITIGATION MEASURES

The Mahdia area environmental impacts are listed in Table 7-1. Impacts of every mining and non-mining action are depicted along with the corresponding mitigation measure(s) and the residual impact(s) (once the mitigation measures have been applied).

Action $\Rightarrow$ Impact

Impact **-** Mitigation Measure(s) **=** Residual Impact

The impact assessment in Table 7-1 is based upon the query for evaluating significance and the 7 attributes of significance (table 5-3).

7.1 Summary of Impact Rating

Table 7-2 summarizes the environmental impact rating for the different actions in the Mahdia area.

7.2 Thresholds

The need for a practical threshold ("the straw that breaks the camel back") beyond which any effect becomes harmful or irreversible is obvious in Mahdia as far as turbidity is concerned. We see in Tables 7-1 and 7-2 that many mining actions are leading to an increase of suspended material in receiving waters. In addition, the amount of mercury that ends up in the rivers and creeks is closely linked to the sediment load discharged by the mining operations because it is often attached to fine particles (clay and silt). Therefore, controlling turbidity contributes significantly to the reduction of mercury found in the recipient watercourses.

7.2.1 Carrying capacity

Carrying capacity is the maximum level of use or activity that a system can sustain without undesirable consequences. As rivers and creeks are by far the environmental components most affected by placer mining, it seems important to know how much mining the creeks and rivers in the Mahdia area can sustain. A typical case will be examined.

Case study

The Handrail creek has been selected as the recipient waterway for the case study because of the presence of a major operation, the White Hole mine, within its catchment. Turbidity, expressed by the total suspended solids (TSS) will be used as indicator of water quality downstream of a mine.

Table 7-1
Parameters and values used for the case study

Parameter	Value
Dredges[1]	
Volume of tailings generated/day	1 813 m^3
Volume of solid tailings/day	368 m^3
Specific density of solids	1,50 t/m^3
Tonnage of solids/day	552 tonnes
Total suspended solid at the effluent	367 kg/m^3 (36,7% or 367 000 ppm)
Handrail Creek[2]	
Average daily flow	7 740 m^3/day
Total suspended solids upstream from White Hole	96 ppm
Criterion for good to moderate fishing (effluent)	20-80 ppm
TSS after discharge	71,3 kg/m^3 (71 300 ppm)
Dilution factor (TSS after dischargel/TSS effluent)	0,194

Notes:
1) From GGMC's Mahdia Project (J.Hutson) (2002).
2) Data from Bynoe, M. and Singh, D. (1997).

It is obvious from Table 7-1 that the effluent of a typical dredge operation is 3 orders of magnitude above the regulatory or desirable level of turbidity. Once diluted in the Handrail creek, it is still 2 orders of magnitude (71 300 ppm) too high. This means that, without mitigation, mining should theoretically stop immediately on creeks the same size as Handrail. Mitigation measures, must therefore be applied and be very efficient.

The target turbidity target for Handrail creek should be realistically set at 140 ppm instead of 80 ppm because the background level already exceeds 80 ppm. To be in keeping with the 140 ppm level, the Handrail creek cannot receive more than 31 m^3 (46 tonnes) of suspended solids from mining operations (taking into account the suspended material naturally present). If these mines have a total suspended solids of 140 ppm, no more than two dredges could be sustained on a waterway like Handrail creek. If very efficient mitigation measures bring the turbidity range around 20-30 ppm TSS, up to seven dredges could operate on the creek.

7.3 Recommended mitigation measures

The recommended mitigation measures for the VECs in Mahdia are described in Table 7-1 along with effects and residual effects.

Table 7-2

Summary of Residual Impacts and Mitigation Measures

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity[1]	Extent[2]	Duration[3]	Significance[4]	Mitigation Measures	Residual Impact Significance[5]
PHYSICAL SETTING								
	MINING							
Water quality in rivers and creeks	Road Construction	Increased concentration of suspended solids in recipient waters	M	L	S	L	Leave a 30 meters wide vegetated border on each side of the road	L
	Line cutting/mobilization	Increased concentration of suspended solids in recipient waters	M	L	S	L	Runoff collection structures	L
	Debushing and burning	Increased concentration of suspended solids in recipient waters	H	L	M	H	Selective debushing; runoff collection structures	L
	Stripping of overburden and stockpiling	Increased concentration of suspended solids in recipient waters	H	L	M	H	Runoff collection structures; sediments collection structures (settling ponds) slopes stabilization and flattening of soils piles	L
	Sampling trenching and pitting	Increased concentration of suspended solids in recipient waters	M	L	S	L	Runoff collection structures and sediments collection structures	L
	Ore extraction (hydraulicking)	Increased concentration of suspended solids in recipient waters Release of naturally occuring mercury into recipient waters	VH	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Ore extraction (dry mining)	Increased concentration of suspended solids in recipient waters	L	L	L	L	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Concentration (sluice box)	Increased concentration of suspended solids in recipient waters	H	L	L	H	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Amalgamation and burning	Increased concentration of mercury in recipient waters (open-circuit amalgamation and open-air burning)	VH	L	S	H	Use of amalgamating drum and retort	VL
	Tailings disposal	Increased concentration of suspended solids in recipient waters	VH	L	L	H	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Industrial waste disposal	Increased contaminants levels in recipient waters	VH	L	S	H	Transport and disposal in approved disposal site	VL
	Domestic waste disposal	Increased contaminants levels in recipient waters	M	L	S	L	Use of appropriate landfill	L
	Hazardous waste disposal	Increased contaminants levels in recipient waters	VH	L	S	H	Transport and disposal in approved disposal site	VL
	Demolition of buildings and removal of infrastructures	Increased concentration of suspended solids in recipient waters	VH	L	S	H	Runoff collection structures; settling pond and revegetation	VL
	NON MINING							
	Settlements (squatting)	Increased contaminants levels in recipient waters	L	L	L	L	Construction of social housing; use of latrines	L
	Transportation (road)	Increased concentration of suspended solids in recipient waters	L	L	L	L	Runoff dispersion structures (brush, remnants of crops) on each side of the road to favour water penetration	L
	Transportation (river)	Increased contaminants levels in recipient waters	L	L	L	L	Proper maintenance of outboard boats. Enforcement of river transportation regulations	VL
	Agriculture (slash and burn)	Increased concentration of suspended solids in recipient waters	L	L	L	L	Selective debushing to leave a vegetal cover	L
	Logging (small scale)	Increased concentration of suspended solids in recipient waters	L	L	L	L	Selective debushing to leave a vegetal cover	L

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
Groundwater regime and quality	**MINING**							
	Stripping of overburden and stockpiling	Seepage of mercury-carrying surface waters towards groundwater table	M	L	L	L		
	Ore extraction (hydraulicking)	Seepage of mercury-carrying surface waters towards groundwater table	L	L	L	L	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Ore extraction (dry mining)	Seepage of mercury-carrying surface waters towards groundwater table	L	L	L	L	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Amalgamation and burning	Seepage of mercury-carrying surface waters towards groundwater table (open-circuit amalgamation and open-air burning)	VH	L	S	H	Use of amalgamating drum and retort	VL
	Industrial waste disposal	Increased contaminants levels in recipient waters	VH	L	S	H	Transport and disposal in approved disposal site	VL
	Domestic waste disposal	Increased contaminants levels in recipient waters	M	L	S	L	Use of appropriate landfill	VL
	Hazardous waste disposal	Increased contaminants levels in recipient waters	VH	L	S	H	Transport and disposal in approved disposal site	VL
Quality and availability of soils	**MINING**							
	Line cutting/mobilization	Exposure of soils to hydric erosion and sedimentary transport	M	L	S	L	Remants of vegetation left on the ground to foster water penetration instead of runoff	VL
	Debushing and burning	Exposure of soils to hydric erosion and sedimentary transport	L	L	M	L	Selective debushing	VL
	Stripping of overburden and stockpiling	Exposure of soils to hydric erosion and sedimentary transport	M	L	M	M	Stockpiling of soils for reuse and slope stabilization and flattening of the soil pile to prevent erosion	L
	Sampling trenching and pitting	Exposure of soils to hydric erosion and sedimentary transport	VH	L	S	H	Segregation and stockpiling of soils	L
	Ore extraction (hydraulicking)	Washing-out of soils into drainage pathways	H	L	L	H	Dry mining instead of hydraulicking. Segregation and stockpiling of soils prior to commencement of hydraulicking	L
	Ore extraction (dry mining)	Exposure of soils to hydric erosion and sedimentary transport	H	L	L	H	Segregation and stockpiling of soils prior to commencement of hydraulicking	L
	Amalgamation and burning	Accumulation of amalgamation mercury in exposed soils subjected to hydric erosion and sedimentary transport (open-circuit amalgamation and open-air burning) In-situ methylation	H	L	S	M	Use of amalgamating drum and retort	L
	Tailings disposal	Discharge of mercury-bearing sediments onto natural soils	H	L	L	H	Construction of a proper, watertight tailings disposal area.	VL
	Industrial waste disposal	Potential seepage of contaminants into soil	H	L	S	M	Transport and disposal in approved disposal site	VL
	Hazardous waste disposal	Potential seepage of contaminants into soil	VH	L	S	H	Transport and disposal in approved disposal site	VL
	Demolition of buildings and removal of infrastructures	Exposure of soils to hydric erosion and sedimentary transport	VH	L	S	H	Revegetation	VL
	NON-MINING							
	Settlements (squatting)	Exposure of soils to hydric erosion and sedimentary transport	L	L	L	L	Construction of social housing	VL
	Agriculture (slash and burn)	Exposure of soils to hydric erosion and sedimentary transport	L	L	L	L	Selective slash	VL
	Logging (small scale)	Exposure of soils to hydric erosion and sedimentary transport	L	L	L	L	Selective debushing	L

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity[1]	Extent[2]	Duration[3]	Significance[4]	Mitigation Measures	Residual Impact Significance[5]
Air quality	MINING							
	Road construction	Exposure of mercury-bearing soils to aeolian erosion and release of dust	H	L	S	M	Leave a 30 meters wide vegetated border on each side of the road. Decrease speed of vehicles. Use dust abatement (water spraying)	L
	Debushing and burning	Release of wood-burning gases into the air (emission of APH)	M	L	M	M	Allow burning only when weather conditions are adequate (wind direction opposite settlements)	VL
	Stripping of overburden and stockpiling	Exposure of mercury-bearing soils to aeolian erosion and release of dust	M	L	M	L		
	Amalgamation and burning	Release of mercury vapors into the air (open-air burning)	VH	L	S	H	Use of retort	VL
	Operating equipment	Release of fuel combustion gases into the air	M	L	S	L	Proper maintenance of engine	VL
	Hazardous waste disposal	Release of toxic vapors into the air	L	L	L	L	Transport and disposal in approved disposal site	VL
BIOLOGICAL SETTING								
Quality of carnivorous fish	MINING							
	Ore extraction (hydraulicking)	Accumulation of methylated mercury in fish tissues	VH	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Concentration (sluice box)	Accumulation of methylated mercury in fish tissues	L	L	L	L	Never pour mercury into the sluice box. Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Amalgamation and burning	Accumulation of methylated mercury in fish tissues	VH	L	S	H	Use amalgamating drums and retorts	VL
	Tailings disposal	Accumulation of methylated mercury in fish tissues	H	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Industrial waste disposal	Potential accumulation of industrial contaminants in fish tissues	L	L	L	L	Transport and disposal in approved disposal site	VL
	Hazardous waste disposal	Potential accumulation of hazardous contaminants in fish tissues	M	L	L	M	Transport and disposal in approved disposal site	VL
Abundance of carnivorous fish	MINING							
	Road construction	Suffocation following decreased oxygen availability in recipient waters	H	L	S	M	Leave a 30 meters wide vegetated border on each side of the road	L
	Stripping of overburden and stockpiling	Suffocation following decreased oxygen availability in recipient waters	M	L	M	M	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Ore extraction (hydraulicking)	Suffocation following decreased oxygen availability in recipient waters Eventual intoxication by methylated mercury forms Siltation of spawning-grounds and decreasing spawn production	VH	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Concentration (sluice box)	Suffocation following decreased oxygen availability in recipient waters Eventual intoxication by methylated mercury forms Siltation of spawning-grounds and decreasing spawn production	H	L	L	H	Construction of watertight tailings pond. Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Tailings disposal	Suffocation following decreased oxygen availability in recipient waters Eventual intoxication by methylated mercury forms Siltation of spawning-grounds and decreasing spawn production	VH	L	L	VH	Construction of watertight tailings pond. Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Industrial waste disposal	Intoxication, contaminant-related diseases or mutations	M	L	L	M	Transport and disposal in approved disposal site	
	Hazardous waste disposal	Intoxication, contaminant-related diseases or mutations	H	L	L	H	Transport and disposal in approved disposal site	

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment: Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
	NON-MINING							
	Fishing	Decrease of fish populations by extensive fishing or by migration of fishes towards less disturbed watercourses	H	L	L	H	Controlled fishing	VL
Wildlife habitat	**MINING**							
	Road construction	Potential partial loss of habitat or habitat disturbance	VH	L	S	H	Keep a forested border on each side of the road	L
	Line cutting/mobilization	Potential partial loss of habitat or habitat disturbance	H	L	S	M	Selective slashing	M
	Debushing and burning	Potential loss of habitat and disturbance of neighboring habitats by air pollution	H	L	M	H	Selective slashing to ensure a continuity in vegetation	L
	Stripping of overburden and stockpiling	Potential loss of habitat or habitat disturbance	H	L	M	H	Selective slashing to ensure a continuity in vegetation	L-M
	Sampling trenching and pitting	Potential partial loss of habitat or habitat disturbance	VH	L	S	H	Selective slashing to ensure a continuity in vegetation	M
	Ore extraction (hydraulicking)	Potential loss of habitat or habitat disturbance	H	L	L	H	Keep a 30-meter forested border around pits	M
	Ore extraction (dry mining)	Potential loss of habitat or habitat disturbance	H	L	L	H	Keep a 30-meter forested border around pits	M
	Concentration (sluice box)	Potential loss of habitat or habitat disturbance by sediments accumulation	H	L	L	H		H
	Tailings disposal	Potential loss of habitat or habitat disturbance by sediments accumulation	H	L	L	H		H
	Operating equipment	Disturbance to wildlife by noise and combustion gas emissions	H	L	L	H		H
	Industrial waste disposal	Habitat disturbance by waste accumulation	L	L	L	L	Transport and disposal in approved disposal site	L
	NON MINING							
	Settlements (squatting)	Potential loss of habitat and disturbance of neighboring habitats by noise and air pollution	M	L	L	M	Construct social housing	VL
	Transportation (road)	Potential loss of habitat and disturbance of neighboring habitats by noise and air pollution	H	L	L	H	Install culverts and passageways for small animal species	M
	Agriculture (slash and burn)	Potential loss of habitat and disturbance of neighboring habitats by noise and air pollution	M	L	L	M		
	Logging (small scale)	Potential loss of habitat or habitat disturbance	H	L	L	H	Selective slashing	M-L
	Hunting	Reduced wildlife populations by extensive hunting or by migrating species towards less disturbed habitats	L	L	L	L		

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
Vegetal biodiversity	**MINING**							
	Road construction	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	VH	L	S	H	Restrict debushing to the road width	M
	Line cutting/mobilization	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	H	L	S	M	Selective debushing	L
	Debushing and burning	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	H	L	M	H	Selective rather than systematic debushing	M
	Stripping of overburden and stockpiling	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	H	L	M	H	Minimize soil removal. Stockpile soils for future use and keep it biologically active	M
	Ore extraction (hydraulicking)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	H	L	L	H	Leave a forested border on the pit margins	M
	Ore extraction (dry mining)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	H	L	L	H	Leave a forested border on the pit margins	M
	Tailings disposal	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity. Risk of mercury contamination of vegetal species.(appearance of prairie species at the expense of forest species)	H	L	L	H	Construct watertight tailings impoundment	M
	Industrial waste disposal	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	M	L	S	L	Transport and disposal in approved disposal site	L
	NON MINING							
	Settlements (squatting)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	M	L	L	M		
	Transportation (road)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	L	L	L	L		
	Agriculture (slash and burn)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	L	L	L	L		
	Logging (small scale)	Potential perturbations of the rain forest ecosystem occurring as local reduction of biodiversity (appearance of prairie species at the expense of forest species)	L	L	L	L	Selective debushing	L

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
HUMAN SETTING								
Quality of the immediate environment of the community	**MINING**							
	Ore extraction (hydraulicking)	Degradation of life environment quality and natural resources of the community	H	L	L	H	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Tailings disposal	Degradation of life environment quality and natural resources of the community	M	L	L	M	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	L
	Hazardous waste disposal	Degradation of life environment quality and natural resources of the community	H	L	L	H	Transport and disposal in approved disposal site	VL
	NON-MINING							
	Logging (small scale)	Degradation of life environment quality and natural resources of the community	M	L	L	M	Selective slashing	L
Aesthetics	**MINING**							
	Stripping of overburden and stockpiling	Degradation of the visual aspect of the environment	VH	L	M	VH	Leave a forested border on the pit margins./ Reclamation	M/L
	Sampling trenching and pitting	Degradation of the visual aspect of the environment	VH	L	S	H	Backfill pits./Reclamation	M/L
	Ore extraction (hydraulicking)	Degradation of the visual aspect of the environment	VH	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures. Reclamation (including revegetation)	L
	Ore extraction (dry mining)	Degradation of the visual aspect of the environment	VH	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures. Reclamation (including revegetation)	L
	Concentration (sluice box)	Degradation of the visual aspect of the environment	VH	L	L	VH	Construct tailings pond. Reclamation	L
	Tailings disposal	Degradation of the visual aspect of the environment	VH	L	L	VH	Construct tailings pond. Reclamation	L
	Hazardous waste disposal	Degradation of the visual aspect of the environment	H	L	L	VH	Transport and disposal in approved disposal site	VL
	Demolition of buildings and removal of infrastructures	Degradation of the visual aspect of the environment	VH	L	S	H	Reclamation (including revegetation)	L
	NON-MINING							
	Settlements (squatting)	Degradation of the visual aspect of the environment	H	L	L	H	Construct social housing	L
Agriculture and ecotourism	**MINING**							
	Stripping of overburden and stockpiling	Degradation of the environment and loss of agricultural and touristic potential	L	L	M	L	Soils segregation and stockpiling	VL
	Ore extraction (hydraulicking)	Degradation of the environment and loss of agricultural and touristic potential	L	L	L	L	Soils segregation and stockpiling	VL
	Ore extraction (dry mining)	Degradation of the environment and loss of agricultural and touristic potential	L	L	L	L	Soils segregation and stockpiling	VL
	NON-MINING							
	Settlements (squatting)	Degradation of the environment and loss of agricultural and touristic potential	H	L	L	H	Construct housing	VL
	Transportation (road)	Enhanced ecotourism and rural economic activities				L(P)	Positive impact	

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
	Transportation (river)	Enhanced ecotourism and rural economic activities				L(P)	Positive impact	
	Agriculture (slash and burn)	Enhanced rural economic activities				H(P)	Positive impact	
Community health	**MINING**							
	Ore extraction (hydraulicking)	Intake of mercury through fish consumption; proliferation of malaria and dengue fever	H	L	L	VH	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	M
	Ore extraction (dry mining)	Intake of mercury through fish consumption; proliferation of malaria and dengue fever	L	L	L	L	Sediments collection structures (settling ponds); runoff collection structures and runoff dispersion structures	M
	Amalgamation and burning	Mercury intoxication by workers around mining camp	VH	L	S	H	Use of amalgamating drums and retorts	VL
	Tailings disposal	Potentially mercury contaminated material discharged onto soils and into rivers can lead to intake from population	H	L	L	VH	Construct tailings impoundment	L
	Hazardous waste disposal	Intake of hazardous contaminants through fish consumption or direct exposure	H	L	S	H	Transport and disposal in approved disposal site	VL
	NON-MINING							
	Settlements (squatting)	Transmission of STDs, and proliferation of malaria and water-born diseases	H	L	L	H		
	Ecotourism	Transmission of STDs, and proliferation of malaria and water-born diseases	H	L	L	L		
Security	**MINING**							
	Road construction	Increased criminality level	M	L	S	L	Better law enforcement	VL
	NON-MINING							
	Transportation (road)	Increased criminality level	M	L	L	M	Better law enforcement	VL
Utilities	**MINING**							
	Road construction	Providing access to the mining sites				M(P)	Positive impact	
OH&S	**MINING**							
	Ore extraction (hydraulicking)	Improper working conditions and environment	H	L	L	VH	Use individual safety gear and equipment. Reduce working hours	M
	Ore extraction (dry mining)	Improper working conditions and environment	L	L	L	L	Use individual safety gear and equipment. Reduce working hours	VL
	Concentration (sluice box)	Improper working conditions and environment	H	L	L	VH	Use individual safety gear and equipment. Reduce working hours	M
	Hazardous waste disposal	Improper working conditions and environment	VH	L	S	H	Transport and disposal in approved disposal site	

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity(1)	Extent(2)	Duration(3)	Significance(4)	Mitigation Measures	Residual Impact Significance(5)
Preservation of Aboriginal culture and heritage	**MINING**							
	Road construction	Disturbance to aboriginal heritage sites and community	VH	L	S	H	Better coordination and dialogue with local Aboriginal associations	M
	Stripping of overburden and stockpiling	Disturbance to aboriginal heritage sites and community	L	L	M	L		
	Ore extraction (hydraulicking)	Disturbance to aboriginal heritage sites and community	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	M
	Ore extraction (dry mining)	Disturbance to aboriginal heritage sites and community	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	M
	Concentration (sluice box)	Disturbance to aboriginal heritage sites and community	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	M
	NON-MINING							
	Settlements (squatting)	Disturbance to aboriginal heritage sites and community	H	L	L	H	Construct social housing	L
	Transportation (road)	Disturbance to aboriginal community	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	
	Transportation (river)	Disturbance to aboriginal community	L	L	L	L	Better coordination and dialogue with local Aboriginal associations	
	Logging (small scale)	Disturbance to aboriginal community	L	L	L	L	Better coordination and dialogue with local Aboriginal associations	
	Hunting	Disturbance to aboriginal community and resources	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	
	Fishing	Disturbance to aboriginal community and resources	H	L	L	H	Better coordination and dialogue with local Aboriginal associations	
	Ecotourism	Disturbance to aboriginal community and resources	M	L	L	M	Better coordination and dialogue with local Aboriginal associations	
Salaries and wages	**MINING**							
	Ore extraction (hydraulicking)	Income for the workers				H(p)	Positive impact	
	Ore extraction (dry mining)	Income for the workers				H(p)	Positive impact	
	NON-MINING							
	Transportation (road)	Income for the truck drivers				H(p)	Positive impact	
	Transportation (river)	Income for the boat owners				L(p)	Positive impact	
	Logging (small scale)	Income for the loggers				L(p)	Positive impact	
Sound local development	**MINING**							
	Road construction	Increased economic activities				H(p)	Positive impact	
	Ore extraction (hydraulicking)	Increased economic activities				L(p)	Positive impact	

Table 7-2 (Cont'd)

VECs	Activity Source of Impact	Impact Description	Impact Assessment Intensity[1]	Extent[2]	Duration[3]	Significance[4]	Mitigation Measures	Residual Impact Significance[5]
	Ore extraction (dry mining)	Increased economic activities				L(p)	Positive impact	
	Tailings disposal	Increased economic activities				L(p)	Positive impact	
	Hazardous waste disposal	Potential hazard to the community when improperly managed	H	L	L	H	Transport and disposal in approved disposal site	VL
	NON-MINING							
	Settlements (squatting)	Anarchic settlement impairs social development and organization of the community	H	L	L	H	Construct social housing	L
	Logging (small scale)	Potential loss of future/actual resources when slashing is uncontrolled	H	L	L	H	Selective slashing	M
	Ecotourism	Increased economic activities				L(p)		
Quality and abundance of employment	**MINING**							
	Road construction	Major source of employment				H(p)	Positive impact	
	Ore extraction (hydraulicking)	Major source of employment, low employment quality				M(p)	Positive impact	
	Ore extraction (dry mining)	Source of employment (?), low employment quality				M(p)	Positive impact	
	NON-MINING							
	Transportation (road)	Major source of employment				H(p)	Positive impact	
	Transportation (river)	Minor source of employment				L(p)	Positive impact	
	Ecotourism	Minor source of employment				L(p)	Positive impact	

Notes:

1) Impact intensity (VH = very high, H = high, M = medium, L = low).
2) Impact extent (R = regional, L = local, I = immediate).
3) Impact duration (L = long, M = medium, S = short).
4) Impact significance (VH = very high, H = high, M = medium, L = low, VL = very low, I = indeterminate).
5) See 4.

Table 7-3
Project Overall Impact Rating Matrix

Actions \ VECs	Water quality in rivers and creeks	Groundwater regime and quality	Quality and availability of soils	Air quality	Quality of carnivorous fish	Abundance of carnivorous fish	Wildlife habitat	Vegetal biodiversity	Quality of the immediate environment of the community	Aesthetics	Agriculture and ecotourism	Community health	Security	Utilities	OH&S	Preservation of aboriginal culture and heritage	Salaries and wages	Sound local development	Quality and abundance of employment
MINING																			
Road construction	L		L	M		M	H	H				L	L	Mp		H	Mp	Hp	Hp
Line cutting/mobilization	L		L				M	M											
Debushing and burning	H		L	M			H	H											
Stripping of overburden and stockpiling	H	M	M	L		M	H	H		H	L					L			
Sampling trenching and pitting	L		H				H			H									
Ore extraction (hydraulicking)	H	L	H		H	H	H	H	H	H	L	H			H	H	Hp	Lp	Mp
Ore extraction (dry mining)	L	L	H				H	H	L	H	L	L			L	H	Hp	Lp	Mp
Concentration (sluice box)	H	L	H		L	H	H	H	H	H					H	H			
Amalgamation and burning	H	H	M	H	H	L			L			H							
Tailings disposal	H		H		H	H	H	H	M	H	M	H						Lp	
Operating equipment				L			H		L										
Industrial waste disposal	H	H	M		L	M	L	L											
Domestic waste disposal	L	L																	
Hazardous waste disposal	H	H	H	L	M	H			H	H		H			H			H	
Demolition of buildings and removal of infrastructures	H	L	H	L		L			L	H	H								
NON-MINING																			
Settlements (squatting)	L		L	L			M	M		H	L	H				H		H	
Transportation (road)	L		L	L			H	L			Lp		M			H	Hp		Hp
Transportation (river)	L					L					Lp		L			L	Lp		Lp
Agriculture (slash and burn)	L		L	L			M	L			Hp						Lp		
Logging (small scale)	L		L				H	L	M							L		H	
Hunting							L									H			
Fishing						H										H			
Ecotourism												L				M	Hp	Lp	Lp

Significance coding

L	Low significance	Lp	Positive effect on VEC, low
M	Moderate significance	Mp	Positive effect on VEC, moderate
H	High/Very high significance	Hp	Positive effect on VEC, high

8. STEP 5: FOLLOW-UP

Ensuring that mitigation measures are efficient requires the development and implementation of a monitoring program. The monitoring program in Mahdia should be realistic and take into consideration the financial and human resources available.

8.1 Regional monitoring

8.1.1 Water and air quality

Measurement of air and water quality on and near mining sites should be systematic in Mahdia. This may include monitoring of mercury contamination and turbidity plumes in watercourses, contamination by mercury in groundwater, dust emission, etc.

Biological monitoring can be an effective approach to monitoring air and water quality. It may be taken to include the following: population studies of particular species, and the bioaccumulation and extent of the presence of “indicator organisms” tolerant or insensitive to a particular stress.

We suggest that the Amerindian population be trained in conducting systematic sampling and/or monitoring. For instance, systematic readings of turbidity through the use of a turbiditymeter is a simple, inexpensive task that could be accomplished with minimal training.

8.1.2 Remote sensing

Satellite remote sensing could be a powerful and relatively cheap tool for environmental monitoring. It has the advantage of being non-invasive and is suitable for all size scales from its limit of resolution (0.1 km to 1.0 km) to the global scale. It has the capacity to detect changes over periods of years and decades. For example, it may be used to monitor vegetation losses, watercourse turbidity, soil losses, deforestation, etc. For a country like Guyana with a huge territory and a scattered population, remote sensing is an indispensable environmental monitoring tool.

9. CONCLUSIONS

As expected, analysis of actions and their effects reveals that seven (7) out of 19 VECs are strongly affected by mining actions:

- Water quality in rivers and creeks.
- Quality and availability of soils.
- Abundance of carnivorous fish.
- Wildlife habitat.
- Vegetal biodiversity.
- Aesthetics.
- Community health.

The preservation of aboriginal culture and heritage is the VEC most affected by non-mining activity while being substantially affected by mining as well.

The most problematic mining activities are those that lead to the discharge of sediments and mercury into the waterways. The perverse effect of hydraulicking is that it not only discharges large amount of suspended solids but also contributes to the emission of naturally occurring mercury (attached to fines) that would otherwise remain in the soil.

Cumulative effects are obviously occurring upon the above VECs. It is likely, although it may be hard to demonstrate, that for the water quality in rivers, wildlife habitats and vegetal biodiversity, the point of no return may have been reached in some sectors.

Mitigation measures, if applied, will therefore have to focus most urgently on these VECs. These necessary mitigation measures are in Table 7-2 and are well known by the stakeholders (GGMC, GGDMA, EPA). What has to be done regarding effluents management and the use of mercury is addressed in two Codes of Practice.

A preliminary carrying capacity for rivers and creeks of the Mahdia area has been defined based on estimated suspended solids by average small-scale and medium-scale operations. Further work shall be carried out to refine these criteria.

This report has been prepared par Marc Arpin, M.Sc., P.Geo., project manager and reviewed by Benoit Demers, M.Sc.A., Eng., Director, Mining and Environment.

SNC-LAVALIN ENVIRONMENT INC.

Marc Arpin, M.Sc., P.Geo.
Project Manager

Verified for conformity
with ISO 9001 by : ____________________________

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Director
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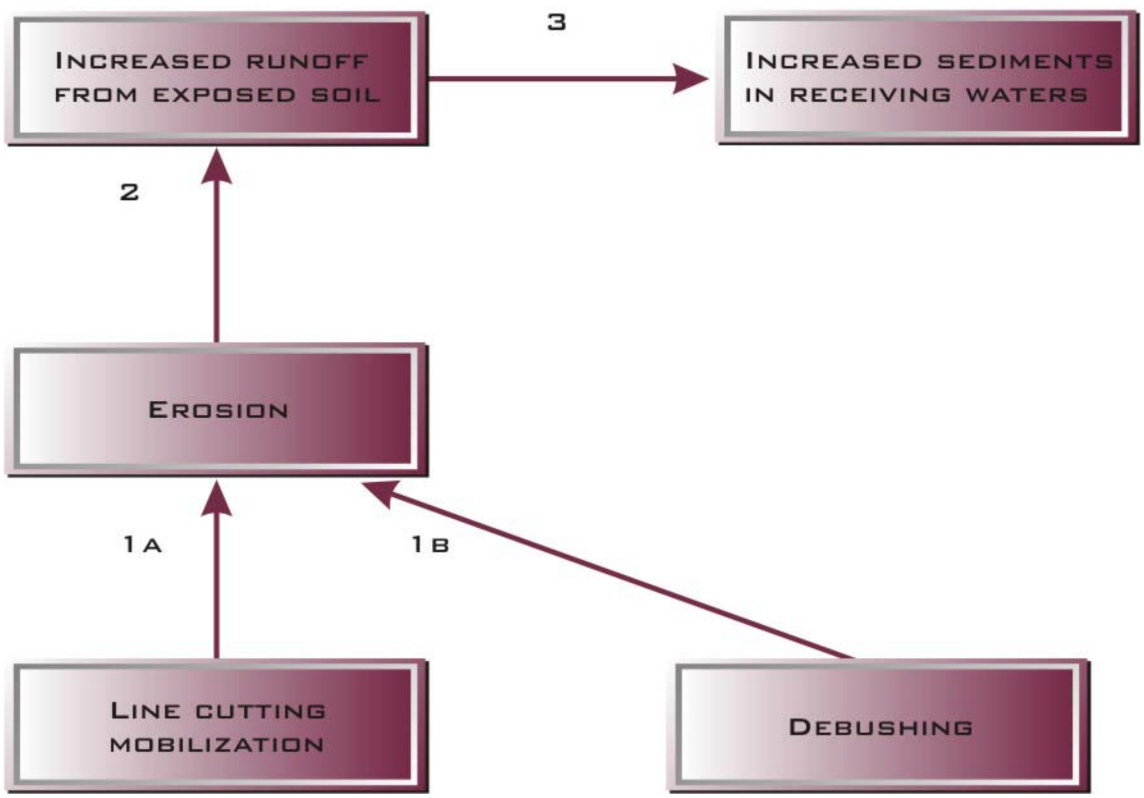
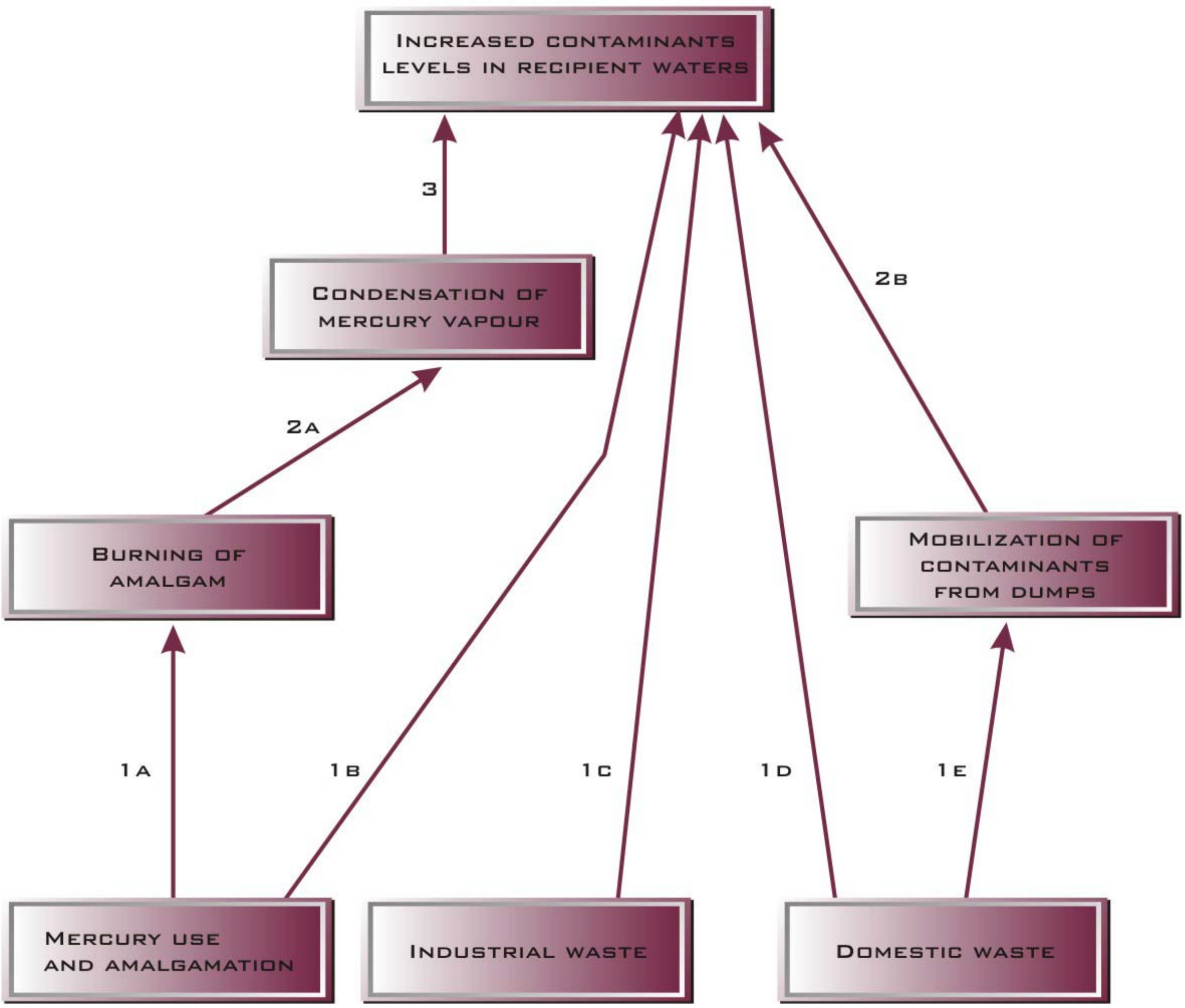
APPENDIX A

Pathway diagrams

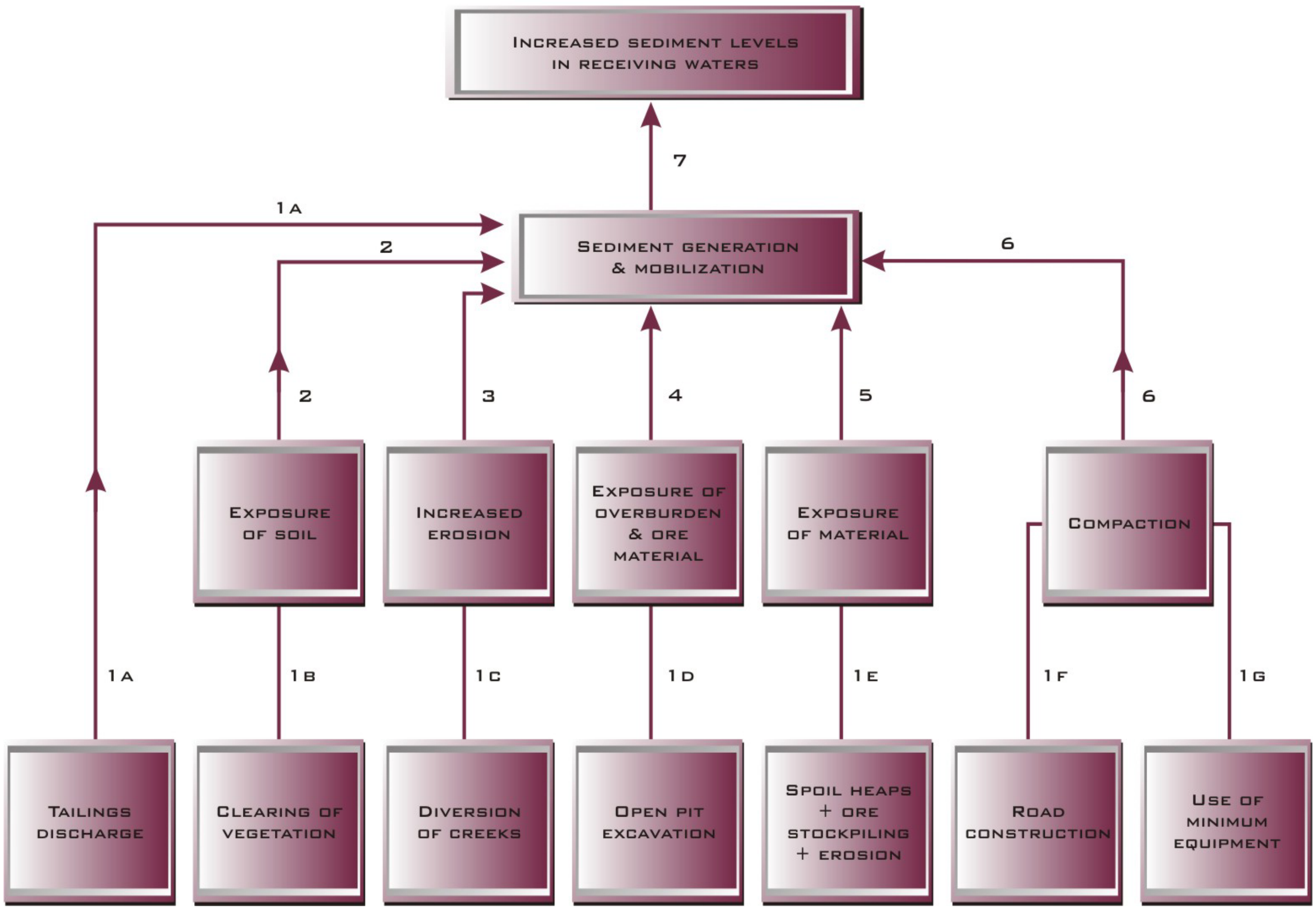
Pathway Diagram 1



Pathway Diagram 3



Pathway Diagram #6



Pathway Diagram #7