AXUM STELA 2 RE-ERECTION PROJECT

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1.0 INTRODUCTION AND BACKGROUND

1.1 The Project

The present Environmental Impact Study (EIS) is related to the construction site for the re-erection of the Stela n. 2 (or Roma Stela) in its original place sited in the Northern Park of Stelae in Aksum, Ethiopia after its return from Italy in the period 19-23 April 2005. The EIS has been developed following the European Council Directive 85/337/EEC, as amended by Directive 97/11/EC.

The project for re-erecting the Stela n. 2 in the Aksum World Heritage Site has been funded by the Italian Government after agreements between Italy and Ethiopia taken in 1947, 1956, 1997 and 2004. The Obelisk returned to Aksum in three successive flights between 19 and 23 April 2005 and a project for its re-erection in the original place has been designed and approved.

An Environmental Impact Assessment has been carried out based on the above project whose main results are presented in the following chapters.

1.2 Details

The Aksum World Heritage site, inscribed in the World Heritage list in 1980, is characterised by impressive pre-Christian monuments, monolithic obelisks or stelae erected as mortuary structures.

The Stela n. 2 (in the D.A.E. inventory list) or “Obelisk of Rome” was originally located in the royal cemetery of Aksum, also known as the Stelae Park.

The Northern Stelae Park, that is the area presently exploited, is some 2.5 ha with evidence of platforms associated with storied stelae and monumental tombs.

The Stela n. 2 will be sited in the original foundation area where it was removed by the Italian army in 1937 during the occupation of Ethiopia. The stela had already fallen and broken into 4 main pieces many centuries before.

The project, realised by Studio Croci & Associati, Rome, has been divided into 8 distinct stages as follows:

- **Stage 1** – Topographic positioning and orientation of the Stela;
- **Stage 2** – Foundation-basement building; building of the embankment for the moving of the Stela blocks from the square to the foundation area; building of the scaffolding tower; positioning of the bridge crane on the top;
- **Stage 3** – Re-erection of the first Stela block;
- **Stage 4** – Re-erection of the second and third Stela block;
- **Stage 5** – Dismantling of the provisional structures of the Stela surface;
Stage 6 – Cleaning and restoration of the Stela;
Stage 7 – Dismantling of the bridge crane and scaffolding;
Stage 8 – Basement completing, dismantling of the embankment and ground slope recovering.

1.3. Auxiliary works

According to the project design any associated works or related activities in areas outside the area specified above could be related to stockpile of materials for the realisation of the embankment and arrangements for services such as mains electricity and water.

1.4 EIS and Planning Regulations

This introduces to the Planning procedures a process by which the effects of a project and or modification on the environment are evaluated and considered when determining whether a project should proceed. The environment consists of human beings, animals, plants, soil, water, air, climate, material assets, landscape and cultural heritage and any interaction between these.

Normally the EIS process begins with a review of alternative locations and design options to eliminate or alleviate the environmental impacts at the earliest stage possible. Then follows the screening stage where, normally, Planning Service determines the need for an EIS according to:

- the characteristics of the project (e.g. size, accumulation of developments, natural resource use, waste production, pollution and nuisance, risk of accidents);
- the location of the project (e.g. existing land use, capacity of habitats, designated sites, landscapes of historical, cultural or archaeological significance);
- the characteristics of the potential impacts (e.g. magnitude, complexity, probability, duration, and reversibility).

Where an EIS is required, the assessment normally begins with a Scoping Study to identify the key impacts and issues of concern that warrant detailed assessment.

Detailed assessment typically involves impact analysis according to accepted methodologies, consultations and site visits, leading to the evaluation of the significance and magnitude of any direct, indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects on the environment from the project.
During and following this evaluation, mitigation measures are developed to avoid, reduce or remediate the impacts. The present study describes the investigations, findings and conclusions of the EIS, and any proposed monitoring of the environmental impacts that would be undertaken during and after the re-erection of the Stela n. 2.

1.5 Screening and Scoping Decision

The construction site for the re-erection of the Stela n. 2 in the Northern Stelae Park of Aksum, Ethiopia would be likely to have significant effects on the environment in terms of:

- Landscape and Visual impact;
- Noise impact;
- Impact on superficial water and drainage
- Geology, Hydrogeology and Seismicity
- Air and Climate
- Cultural Heritage
- Vegetation
- Socio-economic

The key impacts and issues of concern that were identified are addressed in this EIS study.

This has been undertaken through direct field surveys carried out in a preliminary mission in March, April and October 2005 and, specifically for EIS, in January 2006, desk studies and consultations with key experts.

1.6 Consultancy Team for the EIS

Table 1.1 below identifies the relevant topic subjects covered and consultancies that have contributed to the EIS and the output contained in this report.

<table>
<thead>
<tr>
<th>Expertise Field</th>
<th>Consultancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape and Visual</td>
<td>Studio Polci, Rome</td>
</tr>
<tr>
<td>Noise</td>
<td>Eng. Eugenio Zola, Rome</td>
</tr>
<tr>
<td></td>
<td>T6 Ecosystems, Rome</td>
</tr>
</tbody>
</table>
Table 1.1 – Consultancy Team for EIS

Working Group

*Scientific Responsible of EIS:*

Prof. Claudio Margottini, T6 Ecosystems

*T6 Ecosystems Team Consultancy*

Dr. Giuseppe Delmonaco, Engineering Geologist
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Dr. Sandro Polci, Landscape Architect
Dr Antonio Montesanti, Archaeologist
Dr. Maria Cristina Tullio, Landscape Architect
Dr. Kim des Jiardins, Landscape Architect and rendering
Dr. Massimo Vagnoni, Computer Graphic and Design
2.0 TECHNICAL ASSESSMENTS

This section discusses the various technical issues and potential environmental impacts associated with the construction site related to the re-erection of the Stela n. 2 in the Archaeological Park of Aksum, Ethiopia.

The key environmental issues of landscape and visual, vegetation, noise, superficial water and drainage, geology and hydrogeology, cultural heritage, air and climate and socio-economic have been summarised within this chapter and where necessary, supporting information is provided in the Appendices.

2.1 Site Characteristics

Aksum is located on the Tigrean plateau in northern Tigray, about 22 km to the west of Adwa, at an average elevation of 2200 m. a.s.l. The geographical coordinates are 14° 7’ 8” N, 38° 43’ 46” E.

Aksum was the capital city of the ancient “Kingdom of Aksum” (1st millennium AD). The city is the most important religious centre of the Ethiopian Orthodox Church and a relevant symbol of Ethiopian cultural identity.

At present, Aksum is one of the major archaeological areas in Ethiopia and is included in the UNESCO “World Heritage List”. The area represents an important source of income to the country through tourism.

Figure 1 reports the topographic base of the study area, the aerial photo and the final contour line map from which a Digital Terrain Model has been designed at 1:25,000 scale.

The site is located inside the urban area of the city of Aksum, at the NE border of the town, between the hills of Beta Giyorgis (2440 m in elevation) and May Qoho (2335 m in elevation). These hills form a crown delimiting a rough circular plain, gently sloping from N to S and SE, about 10 km in diameter.
From this plain a number of streams drain the area with a typical radial pattern of river valleys.

Figure 1.1 Topographic map at 1:50,000 scale (upper left), aerial photo (middle) contour line map (upper right) at 1:25,000 scale derived from aerial photo; digital maps of Aksum area: DTM (lower left) and TIN (lower right).

The site of the Stelae Park of Aksum is characterised by various aspects resumed as follows:

- It is predominantly an archaeological and tourist area;
- It is located in a general urban context;
- although on the immediate vicinity of the town, the site and its surroundings remain agricultural and rural in character.

**2.2 NOISE**

**2.2.1 Introduction**

This section of the Environmental Statement will assess the potential noise impact of the development of the construction site and works for the re-erection of the Stela n. 2 on the existing noise environment.
The site is currently placed on lands adjacent to the urban area, situated at S and W, and a rural-residential area, at N and E.

The predominant noise across the site is related to the following potential sources:

- surrounding roads of the adjacent urban context with passage of cars and other vehicles;
- adjacent road path that connects the town with the northern scattered villages in the direction of Adwa;
- passage of people and pack animals along the aforementioned road;
- religious ceremonies held in the Old Cathedral located in front of the Northern Stelae Park;
- environmental noises (e.g. wind, animals).

The most proximate residential properties to the site boundary is to the east at a distance of circa 110 m and the most proximate rural-residential agglomerate at a distance of 150 m to the west, at the back of the archaeological site on the slope toe of Beta Giyorgis hill.

The proposed works will potentially result in an increase in road traffic in the proximity of the site; increases in numbers of people using the site as well as vehicles, materials and general activity in the area over current conditions.

As general rule, the proposed works of re-erection of the Stela n. 2 will likely produce new noise sources to the area due to the specific works related e.g. to transportation of machinery and materials, construction of foundations and realisation of the temporary structure of support of the Stela.

The construction works associated with this major stages of the work, involving landscaping, roads and part of the Northern Stelae Park, add a further impact potential, albeit transient.

All of these proposed works have the potential to create noise impact in and around the site.

2.2.2 Methodology and Measurement Results

Background noise levels in the site and around the area that will be interested by the construction site were recorded during the field survey of 27 and 28 January 2006. For this scope, background noises have been recorded at two experimental locations in the vicinity of residential dwellings (Aksum 1 and Aksum 2). Daily and night measurements have been recorded measuring the following noise parameters:

- $L_{Aeq}$ with recording time of 15 minutes;
At all times weather conditions were suitable with all readings being recorded in dry conditions with low wind speeds.

All measurements presented in this report were obtained using a Sound Level Analyser Delta Ohm 2010 instrumentation, following IEC 804-651 and ANSI standards, having the following characteristics:

Standard: IEC 61672, IEC 60651, IEC 61672, IEC 660804, Class 1

Microphone: ½ inch, model WS2F with pre-amplifier HD2010PN

Weighting network: weighted scale A, weighted scale C, compliance to IEC 651/IEC 804

Precision RMS: 0.1 dB

Dynamics: 110 dB

Measurement interval: 30 ÷ 140 dB

Impacts forecasting induced by the construction site have been calculated through a simulation model (MIRA) licensed by Società Autostrade, developed to simulate noise impacts from roads. The model allows also the analysis of punctual sources (e.g. plants, machinery) and calibration through values of experimental $L_{A(eq)}$ recorded at specific distance from noise source.

The time and results of the measurements are summarised in the Table X.X while the measurement locations are shown on the site map in Figure X.X

<table>
<thead>
<tr>
<th>Location Number</th>
<th>Time hh:mm:ss</th>
<th>Run Time hh:mm:ss</th>
<th>$L_{A(max)}$ dBA</th>
<th>$L_{A(min)}$ dBA</th>
<th>$L_{eq}$ dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9:44:58</td>
<td>00:15:00</td>
<td>68.6</td>
<td>39.0</td>
<td>43.4</td>
</tr>
<tr>
<td>2</td>
<td>12:23:48</td>
<td>00:15:00</td>
<td>80.4</td>
<td>38.4</td>
<td>54.3</td>
</tr>
<tr>
<td>3</td>
<td>16:24:36</td>
<td>00:15:00</td>
<td>70.3</td>
<td>37.7</td>
<td>47.2</td>
</tr>
<tr>
<td>4</td>
<td>21:53:31</td>
<td>00:15:00</td>
<td>52.7</td>
<td>32.2</td>
<td>35.0</td>
</tr>
<tr>
<td>5</td>
<td>10:10:05</td>
<td>00:15:00</td>
<td>78.0</td>
<td>40.1</td>
<td>46.5</td>
</tr>
<tr>
<td>6</td>
<td>11:32:11</td>
<td>00:15:00</td>
<td>66.6</td>
<td>37.0</td>
<td>44.5</td>
</tr>
<tr>
<td>7</td>
<td>17:13:16</td>
<td>00:15:00</td>
<td>72.8</td>
<td>44.7</td>
<td>55.4</td>
</tr>
<tr>
<td>8</td>
<td>22:06:00</td>
<td>00:15:00</td>
<td>73.3</td>
<td>34.3</td>
<td>37.7</td>
</tr>
</tbody>
</table>

Table 2.1. Measurement results

2.2.3 Environmental quality

The combined levels of monitored background noise are reported as follows:
Table 2.2. Noise levels before works. *distance from barycentre of construction site (re-erection area of the Stela n. 2).

Recording sites have been located at the nearest residential receptors, potentially exposed to workings noise. The location of the observation points is reported in the map below.

The acoustic levels of the area are mainly defined by the road traffic along local network and, subordinately, by religious ceremonies held in the Old Cathedral sited in front of the Northern Stelae Park.

For both locations very low noise levels have been recorded around 50 dBA during day observations. Therefore, according to the Italian regulations used as an example, all the noise levels recorded around the study area should be lower than the day levels of reference for residential areas (55 dBA), areas ranked as class II.

2.2.4 Assessment of Short-Term Construction Noise

The assessment of short-term construction noise, considering the time-line of the project designed, can be distinguished into 6 different stages of workings that may change the acoustic climate in and around the study site.
During the construction site period most of impacts can be localised in the area of concrete mixing and loading for the foundation. Passages of heavy weight lorries on the adjacent roads can produce increase of noise levels.

The workings stages can be summarised as follows:

Stage 1 – site clearance, delimitation and preparation of the construction site.

Machinery at highest potential noise impact: lorries.

Stage 2 – steel panel fixing.

Machinery at highest potential noise impact: compressor, air hammer.

Stage 3 – construction of gabions embankment, scaffolding and bridge-crane installation.

Machinery at highest potential noise impact: cranes.

Stage 4 – Stela foundation.

Machinery at highest potential noise impact: cement mixer, compressor, water and cement pumps, poker vibrator.

Stage 5 – Stela re-erection and fixing.

Machinery at highest potential noise impact: bridge-crane and cranes.

Stage 6 – Site clearance and surfacing.

Machinery at highest potential noise impact: lorries, rollers.

As general rule, it is considered a period of working of 8 hours during the day whereas no night works are expected.

The following data are referred to technical characteristics of machinery used in similar operations, according to the aforementioned working stages. Data are related to acoustic emissions expressed as dB(A) at 10 m reference distance of the source. The reference levels of noise of plants and machinery are reported in the following table.

<table>
<thead>
<tr>
<th>Plant and</th>
<th>$L_{Aeq}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranes and</td>
<td>99(*)</td>
</tr>
<tr>
<td>Cement mixer</td>
<td>106(*)</td>
</tr>
<tr>
<td>Articulated lorry</td>
<td>70</td>
</tr>
<tr>
<td>Compressor</td>
<td>81</td>
</tr>
<tr>
<td>Air hammer</td>
<td>90</td>
</tr>
<tr>
<td>Water pump</td>
<td>80</td>
</tr>
<tr>
<td>Cement pump</td>
<td>86</td>
</tr>
</tbody>
</table>
The existing noise sensitive properties are at least 130 m away from the planned construction site. The analysis for simulating induced noise levels by the construction site has been implemented calculating the environmental background noise and the added noise produced by construction works for planned different stages.

Considering a duration coefficient for construction activities of 0.5 (8 hours of working) acoustic levels have been detected and summarised in the following tables. Considering a duration coefficient for construction activities of 0.5 (8 hours of working) acoustic levels have been detected and summarised in the following tables (tab 2.4 - 2.9).

### Table 2.3. Noise levels from construction works. (*) acoustic levels at 1 m

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Level (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roller</td>
<td>76-96</td>
</tr>
<tr>
<td>Poker vibrator</td>
<td>96</td>
</tr>
</tbody>
</table>

### Table 2.4. Acoustic daily levels – stage 1

<table>
<thead>
<tr>
<th>Location</th>
<th>$L_{\text{Aeq}}$ construction site (dB(A))</th>
<th>$L_{\text{Aeq}}$ residual (dB(A))</th>
<th>$L_{\text{Aeq}}$ environment (dB(A))</th>
<th>Difference (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKSUM 1</td>
<td>44.3</td>
<td>49.4</td>
<td>50.6</td>
<td>1.2</td>
</tr>
<tr>
<td>AKSUM 2</td>
<td>42.7</td>
<td>50.3</td>
<td>51.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### Table 2.5. Acoustic daily levels – stage 2

<table>
<thead>
<tr>
<th>Location</th>
<th>$L_{\text{Aeq}}$ construction site (dB(A))</th>
<th>$L_{\text{Aeq}}$ residual (dB(A))</th>
<th>$L_{\text{Aeq}}$ environment (dB(A))</th>
<th>Difference (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKSUM 1</td>
<td>64.3</td>
<td>49.4</td>
<td>64.4</td>
<td>15.0</td>
</tr>
<tr>
<td>AKSUM 2</td>
<td>62.7</td>
<td>50.3</td>
<td>62.9</td>
<td>12.6</td>
</tr>
</tbody>
</table>

### Table 2.6. Acoustic daily levels – stage 3

<table>
<thead>
<tr>
<th>Location</th>
<th>$L_{\text{Aeq}}$ construction site (dB(A))</th>
<th>$L_{\text{Aeq}}$ residual (dB(A))</th>
<th>$L_{\text{Aeq}}$ environment (dB(A))</th>
<th>Difference (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKSUM 1</td>
<td>54.3</td>
<td>49.4</td>
<td>55.5</td>
<td>6.1</td>
</tr>
<tr>
<td>AKSUM 2</td>
<td>52.7</td>
<td>50.3</td>
<td>54.7</td>
<td>4.4</td>
</tr>
</tbody>
</table>

### Table 2.7. Acoustic daily levels – stage 4

<table>
<thead>
<tr>
<th>Location</th>
<th>$L_{\text{Aeq}}$ construction site (dB(A))</th>
<th>$L_{\text{Aeq}}$ residual (dB(A))</th>
<th>$L_{\text{Aeq}}$ environment (dB(A))</th>
<th>Difference (dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKSUM 1</td>
<td>64.6</td>
<td>49.4</td>
<td>64.7</td>
<td>15.3</td>
</tr>
<tr>
<td>AKSUM 2</td>
<td>63.0</td>
<td>50.3</td>
<td>63.2</td>
<td>12.9</td>
</tr>
</tbody>
</table>
It would be expected that, in common with other similar construction sites, the maximum allowable noise levels at the site during construction would be recommended as follows.

**Monday to Friday**

- Maximum at Measurement Points
- 07:00 – 19:00: 75 dD(A) \( L_{eq} \) 12 hours
- 19:00 – 22:00: 65 dD(A) \( L_{eq} \) 12 hours
- 22:00 – 07:00: No noise audible

**Saturday**

- Maximum at Measurement Points
- 08:00 – 13:00: 75 dD(A) \( L_{eq} \) 12 hours
- 13:00 – 22:00: 65 dD(A) \( L_{eq} \) 12 hours
- 22:00 – 07:00: No noise audible

**Sunday**

There are no operations expected on a Sunday

All possible workings during the various stages are below the noise levels commonly adopted by international standards. Nevertheless, considering the particular conditions of the site, the works for re-erection of the Stela n. 2 will cause some impacts with respect to the environmental conditions.

Typical short-term construction noise can be controlled to within Environmental Health guidelines for both daytime and night-time exposure.
Appropriate mitigation measures are included to provide instruction to contractor to control noise impact of extensive construction activity close to existing residential properties as well as Old Cathedral.

### 2.2.5 Mitigating Measures for Construction Works

According to the above analysis, some general measures should be incorporated in the contract and taken into account. These are in summary:

- use of good well maintained plant and where possible new plant manufactured under recent EC or other guidelines for manufacturers;
- substitution of unsuitable plant;
- maintenance of silencers and moving components.

The contractor will be required to take note of the control measures for relevant plant referring to noise standards of reference (e.g. EU Directive) and apply the appropriate measures where practicable.

**Screening**

At locations where extensive specific operations might result in an exceedance of accepted noise limits, the contractor should endeavour to sequence operations such that steel panels are located in positions where near sited dwellings are adequately screened from ongoing operations. Some static machinery may require occasional screening. Such measures can be best assessed during the contract by monitoring.

**Monitoring**

Given the limited impact it would not be appropriate to require regular noise monitoring of the site. However occasional measurement of noise levels generated using a sound level meter should be conducted to check on the continuing impact of the works.

**Responsible Person**

It is often recommended that the appropriate party should appoint or delegate a responsible person who will be present on site and who will be willing to answer and act upon queries from the local public.

**Night Works**

As a general rule night works should be avoided or limited, as much as possible only for indispensable operations (e.g. dewatering pumps and similar).
If there are items of plant in use during night-time hours they should be chosen, sited and enclosed such that levels at the nearest properties do not exceed background level. For locations near to the noise sensitive units permitted levels at 10m would be circa 60 dB(A).

Sound reduction by barrier walls of up to 15 dB(A) is possible and hence any plant could be controlled to within the guidelines indicated.

2.2.6 Conclusions

The potential noise impact from the proposed project of the re-erection of the Stela n. 2 in the Northern Stelae Park of Aksum on the most proximate noise sensitive properties has been assessed and appropriate target noise levels have been ascertained based on the noise survey conducted across the site.

Maximum noise targets for externally sited plant have been produced based on different expected stages of workings. It is noted that these target levels can be raised with increased distance and screening.

No excessive impact from normal internal activity is likely, provided adequate design of building envelope is carried out, and, where plant associated with these facilities is utilised, it can also be selected and designed to ensure any noise impact is below background noise level.

It is predicted that the potential noise impact from service vehicle activity is within the daytime target levels and of marginal significance with regard to the night-time levels, since any plant should be avoided after 19:00.

Typical impact of vehicle activity will be below or equal to both daytime and night-time target levels.

With reference to the relevant guidance documents, while the ‘worst case’ peak hour changes in noise levels form traffic flows may be perceptible at properties adjacent to the archaeological park, it is submitted that these changes will not represent a significant increase in noise impact. It is submitted that changes in noise levels due to typical traffic movements during the rest of the day will generally be imperceptible.

Typical short-term construction noise can be controlled to within standards and regulations (e.g. Environmental Health guidelines) for both daytime and night-time exposure.

2.3 SUPERFICIAL WATER AND DRAINAGE

2.3.1 Introduction
The adequate protection of waters, both superficial and underground, in the site of the Northern Stelae Park against any detrimental impact of the construction site is very important. As a matter of fact, the site presents some important features such as:

- the presence of May Hegga stream that borders at E most of the archaeological area;
- the presence, some hundreds metres at NE of the construction site, of the most important water reservoir for people living in the surroundings of the Stelae Park;
- the existence of a fresh-water well in the area where the new museum, funded by the World Bank, will be realised.

This section aims at identifying the potential short-term impacts of the construction site, and the long-term impacts associated with the operation of landscaping of the area on local surface and underground water quality and drainage in the vicinity. Mitigation measures are recommended for the construction phase and operational phases.

**a. OBJECTIVES**

The objective at this stage is to undertake sufficient assessment to identify the key constraints and consequences for water quality and drainage on the site from the operations related to the re-erection of the Stela n. 2 as well as the landscaping of the Stelae Park related to the World Bank funding.

**b. METHODOLOGY**

Steps taken to undertake this section of the Environmental Impact Assessment include:

- Consultation of documents and maps obtained by various Ethiopian Governmental institutions:
  - location and designation of principal watercourses in the area;
  - location of floodplains and areas at particular risk from flooding;
  - location of sensitive areas such as potable water sources, water reservoirs.
- Field survey to establish the existing drainage and sewerage systems in the area;
- Desk Study including research of environmental guidance literature.
2.3.2. EXISTING DRAINAGE ENVIRONMENT

Figure x.x.x shows the location of the site in relation to the main bodies of water around the site.

There are a number of existing watercourses and streams on the area of Aksum. The most important are May Hegga stream, draining between Beta Giyorgis and May Qoho and May Lahlaha at W, draining from Beta Giyorgis hill.

The most important stream flowing in the site area is May Hegga stream (fig 2.2). This watercourse is called May Mahlaso upstream, between Beta Giyorgis and May Qoho, May Hegga in the middle part crossing the town, and May Matare downstream, where it drains into the plain to the south of Aksum.

Figure 2.2. Superficial hydraulic network in the area around Aksum

The mentioned streams have a typical seasonal runoff that is substantially related to rainfall patterns (see Climate section).

During the dry season, from October to March, the streams are usually dry or have a little flow.

Although the analysis of technical and scientific literature reports that in the area of Stelae Park there are no flood records available, some floods events have occurred in the last two decades as confirmed by residents whose intensities and induced effects and impacts on the study area are unknown. In addition, from carrying out a
walkover survey of the site and surrounding areas it can be surveyed that the river floodplain presents some humid zones, especially in topographically depressed areas. This means that the water level during the driest periods is confined inside the recent alluvial deposits that outcrop along the floodplain.

Analysis of technical literature and maps, consultation with governmental authorities as well as site field survey (photo 2.1) have confirmed that the streams that feed and drain the area of the Stelae Park are neither gauged nor maintained and therefore there are no flow records available for them.

Photo 2.1. Humid zones in the May Hegga stream

None of the streams in the vicinity of the proposed project area are currently monitored for biological or chemical water quality.

The catchments of May Hegga stream is largely agricultural land and, subordinately, forest areas. At present there are no industrial discharges or pollution potentials related to agricultural practices.

The main threat to the water quality is related to the absence of sewage systems in the area that may affect the quality of water, especially superficial waters flowing from the upper catchments area of May Hegga in direction of the town of Aksum at S.

Analogously, the presence of inhabited areas located along the middle and lower portions of the slope of Beta Giyorgis can potentially affect the quality of superficial
waters and underground abstracted waters of the well sited in the construction area of the new museum.

A special attention is to be given to the potentiality of re-designing and realising a drainage systems in the archaeological site of the Northern Stelae Park according to the original drainage system also taking into account new findings from the geophysical survey carried out during the campaigns of April 2005 and January 2006.

2.3.3. IMPACT ASSESSMENT

This stage of the assessment will consider the potential impacts of the construction phase and operational phase on water quality and drainage in the study area. Means of mitigating these potential impacts will also be recommended. The main impacts on water quality and drainage on the site will potentially occur during the phase of foundation preparation and construction in the shaft. The operational phase related to the re-erection of the Stela n. 2 should reduce the impacts on water quality and drainage on the site.

a. POTENTIAL IMPACTS – CONSTRUCTION PHASE

Activities that may have a detrimental impact on water quality and drainage during the construction phase include:

- **Earthworks and Excavations** – Modification of drainage patterns from excavations, exposed ground, stockpiles, plant and wheel washing and site roads.
- **Storage** – Materials used in the construction operations, such as oils, chemicals, cement lime, cleaning materials entering or flowing inside present drainage system and inside the shaft that can cause a pollution incident.
- **Deliveries** – Fuels and hazardous materials being split when being delivered to the site causing a pollution incident.
- **On-Site Refuelling** – Fuel being split when refuelling plant.
- **Concrete and Cement Washwater** – Washing out concrete lorries/other plant may lead to pollution.
- **Temporary Sewer Facilities for Contractors** – Leaking or overflowing systems polluting the stream.

The above list of activities, although taking into account all potential works, may be not exhaustive since other minor activities on site could lead to contamination.
b. POTENTIAL IMPACTS - OPERATIONAL PHASE

When the site is operational, after the re-erection of the Stela, there are no envisaged impacts that potentially could affect water quality and drainage of the site.

Some potential impacts on the Northern Stelae Park could be caused by activities related to the new museum, funded by the World Bank. In detail, close to the new museum dwellings there is a well for abstraction of fresh water which is very important for local population. Since the water table is very shallow, any sewage system related to museum facilities and located in the vicinity of the well, can likely result in potential pollution from leakage or infiltration.

Although this report is mainly devoted to analysis of impacts of re-erection of the Stela n. 2, the following potential impact on water quality and drainage related to the operation phase of the museum can occur:

- **Sewage ad Waste Disposal** – Leaking pipe work polluting the area that feeds the well sited in the vicinity of the Northern Stelae Park where a functional sewage system will be not properly made.

- **Surface Water Drainage** – Contamination of the stream by pollutants in the surface water.

2. 3.4. MITIGATION MEASURES

a. MITIGATION MEASURES – CONSTRUCTION PHASE

Measures which the Design should consider at an early stage in the project are listed below. It is advised that the implementation of these measures is effectively monitored during construction.

- **Earthworks and Excavations** – Avoid discharge of materials (e.g. silt, gravel) inside the stream sited in the vicinity of the Northern Stelae Park. Avoid to change the pattern of the present discharge system in the site.

- **Exposed ground and stockpiles** – Stockpiles must be minimised and where they are occur they should be seeded or covered.

- **Plant and wheel washing** – All washing facilities need to be securely constructed and the effluent properly contained for treatment and disposal.

- **Site Roads** – Site roads should be regularly brushed keeping them free from dust and other deposits.
**Fuels, Oils and Chemicals** – The Design must ensure that appropriate measures are put in place to avoid pollution to the watercourses from these potentially hazardous substances. The Design should consider how to ensure the safe delivery, storage and transfer of these substances on-site. Retention Tanks and Petrol Interceptors should be included in the Design in order to alleviate any impacts should an incident occur.

**Concrete and Cement** – Construction will substantially result in modest volumes of concrete and some cement being present on-site. The Design must ensure that good practice is implemented to limit the potential impacts including the provision of properly bounded washing out facilities for batching plant and ready mix lorries.

**b. MITIGATION MEASURES – OPERATIONAL PHASE**

Appropriate planning will reduce the potential risk caused to water quality and drainage on site. Regarding the infrastructures located in the area of the new museum a special attention should be given to the following:

- **Sewage and Waste Water Drainage** – Proper and effective monitoring on a frequent basis of all infrastructure pollutant potential will be required to ensure it is minimising impacts on water quality and drainage.

**2.3.5. CONCLUSION**

There are many different options that can be included in the design of a project to minimise the impacts caused to water quality and drainage during the construction phase and operational phase. With careful planning and the appropriate implementation of options that are available the threats posed to the water quality and drainage of the site can be greatly reduced. This especially considering the great importance of water for the environment and the population of Aksum. These issues will have to be dealt with at the full or reserved matters stage of this proposal.

Regular inspections, maintenance and monitoring of the mitigating measures throughout the construction and operational phases of the project is essential to ensure that they remain effective.

**2.4 GEOLOGY, HYDROGEOLOGY, SEISMICITY**

**2.4.1 Introduction**
This section of the report examines the landscape characteristics and nature of the prevailing geology and soils in the area of Aksum.

The composition of the ground, including the geological, geomorphological, hydrogeological characteristics, soil types and potential seismicity are an important aspect in the assessment of the impact of the construction site on the landscape, considered as an integral between environmental features and the historical-archaeological context.

2.4.2 Methodology

The study was based on a desktop study of available published information in the form of:


This information was supplemented by borehole information and geophysical field surveys from a previous campaign done by Ethiopian scientists in 1998 and results from geophysical tests performed in April 2005 and January 2006.

In addition to the available information a field survey was carried out in January 2006 to confirm information found on the various analysed documents as well as to improve field data and mapping through two distinct scales of analysis:

- A medium-scale based on 1:25,000 topographic base mapping and aerial photographs at circa 1:60,000 scale in order to define the geological and geomorphological characteristics of the area located in the vicinity of the Northern Stelae Park;
2.4.3. Topographic Setting

The construction site for the re-erection of the Stela n. 2 of Aksum is situated in the north-western border of the town of Aksum between the hills of Beta Giyorgis (2440 m in elevation) and May Qoho (2335 m in elevation) at an average elevation of about 2,200 m a.s.l.

The construction site is located inside the Northern Stelae Park and will involve part of the large open square at the confluence of the main road (SE-NW direction) coming from the centre of Aksum, and the road with direction SW-NE that connects the town to the road path to Adwa. The construction site inside the Park is mainly involving the shaft where the Stela n. 2 was founded, located between the Stelae n. 1 and n. 3.

The slope to the west of the site is the eastern slope of Beta Giyorgis, steeply inclined towards low lying occupied by the Aksum stelae field that exhibits very gentle slope.

The terrain is generally grass land, slightly convex and poorly drained.

From a geomorphological point of view the site presents characters of a terraced area. Any original shape of fluvial terraces has been completely removed by the continuous activity of excavation and construction that has occurred in the site since the 1st Millennium AD until today. Anyway, analysis of aerial photos as well as field surveys conducted in the area evidence that the site is located in the ancient floodplain of the May Hegga stream that presents overlapped levels of different alluvial phases, mainly related to fluctuations of climatic conditions that have occurred during Holocene in a typical terraced-shape. As directly surveyed in the study area in open trenches recently excavated (see photo x.x) levels of conglomerate, mainly composed of granitoid blocks coming from Beta Giyorgis area, immersed in a sandy-silty matrix are outcropping at about -2.5 m from the present ground surface. These levels can be likely correlated to the humid period occurred in the 1st Millennium AD (4th – 6th century AD) when the Aksumite civilization reached its highest development. It is quite reasonable to assume that the floodplain of May Hegga stream around the Stelae Park area has been progressively developed from the slope of Beta Giyorgis toward the plain where the town of Aksum is presently sited. This terraced morphology is originated by different depositional stages promoted by humid periods (flooding) and subsequent deepening of the river valley. During dry periods a colluvial deposit partially covers this morphology. The position
of stelae along three different alignments, mutually parallel and located along a morphological step, although today modified by past landscaping and works, suggests the assumption that Aksumites have used the original morphological terraces as support to erect stelae.

2.4.4. Soils

In geological terms the soil represents the accumulation of loose weathered material which covers the land surface and is derived from the existing drift deposits. This material is subdivided into topsoil, which is generally regarded as the first few tens centimetres of material, and subsoil, which comprises the material between topsoil and the parent rock. In agricultural terms soil is the material which comprises generally the first 60 cm depth of humus rich material which supports vegetation growth. The predominant natural land use at this site is cattle grazing/grass land.

Within the site the topsoil exhibits change of composition according to the degree of disturbance due to excavation and accumulation of materials during the development of the area.

Generally, on the top of the terrace of the site, the topsoil consists of alluvial and colluvial deposits (gravel, silty-sands and subordinately greyish clays) mixed with archaeological remains that have been removed and accumulated in the time.

Organic soils are very poor in the top layers, while some paleo-soils have been surveyed in trenches and shafts located in the site (Photo 2.2).

Photo 2.2. Panoramic view of the trench located inside the Northern Stelae Park, at ca. 20 m SW of the shaft. Local bedrock is represented by alluvial deposits (rounded blocks in a silty-clayey matrix) outcropping at -2.5 m from ground level.

2.4.5. Geology

The area of Aksum, according to authors (Getaneh Assefa & Russo, 1997; Tadesse, 1997; Asfawossen et al., 1998) is characterised by the following outcropping units (Fig. 2.3):
- **Alluvial and colluvial deposits – Holocene.** Conglomerate, breccia, sand and clay soils with pebble horizons, deposited in fluvial or colluvial environmental settings and largely outcropping at the top of the rock sequence in the area.

- **Lacustrine deposits – Quaternary.** Chert, diatomites, clay, silt, sand, outcropping at N to the Northern Stelae Park, along the road path to Adwa.

- **Hyperalcaline silicic lavas – Pliocene.** This unit consists of blocky and/or massive trachytic, rhyolitic and phonolitic lavas or scree, and large platforms of basalts elevated by subsurface intrusions and plug domes. The May Quho hill, at E of the study site is a typical rhyolitic-trachytic lava dome.

- **Embca Ayba Basalts – Oligocene-Miocene.** This unit consists of porphyritic and highly weathered flood basalts with rare tuffs that form extensive sheets or beds and outcrops over a large part of the Aksum area. The estimated maximum thickness is about 600 m.

- **Granitoids – Precambrian-Lower Paleozoic.** Granodiorites, tonalities and diorites with characteristic weathering and pervasive jointing. This unit outcrops in Beta Giyorgis hill a flat topped topography.

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**Figure 2.3. Geological sketch of Aksum area.** 1. Alluvial deposits; 2. Talus cone; 3. Silicic lavas; 4. Basalts; 5. Granitoids; 6. Stelae Park area.
2.4.6 Seismicity

Eastern and Southern Africa cover a region which is prone to a significant level of seismic hazard due to the presence of the East African rift system. A number of destructive earthquakes, some causing loss to life, have been reported during this century. For example, in Eritrea, the port city of Massawa was destroyed by an earthquake which occurred in 1921. In Ethiopia, they include the 1960 Awasa earthquake (MS = 6.1), the 1961 Kara Kore earthquake which completely destroyed the town of Majete and severely damaged Kara Kore town, the 1969 Serdo earthquake (MS = 6.3) in which 4 people were killed and 24 injured, 1989 Dobi graben earthquake (MS = 6.5) which destroyed several bridges on the highway connecting the port of Assab to Addis Ababa, the 1983 Wondo Genet and the 1985 Langano earthquakes which caused damage in parts of the main Ethiopian rift. More recently an earthquake exhibiting M=5.5 has been detected in the scarp bordering the Afar region in August 2002 and in September 2005, the seismogenetic source previously described.

The event of August 7, 2002, hit the Mekele area which was shaken by a ruptured near the western margin of the Danakil microplate (Ayele et alii, 0000). The activity continued until the end of the month and was widely felt in several towns in northern Ethiopia (Beyeda, Jane-Amora, Adigrat, Woldia) and Asmara in Eritrea, causing panic in particular in Mekele town. The magnitude of the main shock is 5.6 Mw. Hypocentral depths of well-constrained events are 5-7 km, which is the approximate depth of the brittle-ductile transition zone in the Main Ethiopian rift. The shallowness of the earthquake depths agrees with macroseismic reports in northern Ethiopia (Ayele et alii, 0000).

In September 2005 several earthquakes have been located in Eastern part of Ethiopia since September 20th, 2005. So far, more than 120 events are reported. These locations have either been located by EMSC or reported by the Yemenite network. EMSC locations have been performed by merging the Yemenite data with data from other networks.

According to the seismic hazard elaboration developed by Asfawossen et alii (1999), the site is expected to be affected, for a return period of 500 years, by a peak ground acceleration of about 0,09g (0,002 annual probability of exceedance) while for 1,000 year return period the expected peak ground acceleration is about 0,11g (0,001 annual probability of exceedance). These results are obtained from a seismic catalogue which show completeness for about 100 years and for Magnitude greater than or equal to M=6,5. In any case, this data are in agreement with the few
available historical observations which do not reports any damaging earthquake affecting the town of Aksum, even if some data on time histories obtained from world wide data banks show higher values.

Microtremor analysis seems to identify, indirectly through natural noise measurement in free field, the proper frequency of vibration of stelae 3, which it is assumed, in Asfawossen et alii (1999), to be close to Stelae 2. The recorded period is about 1,0 – 1,5 sec. (1,2 in average). The collected data do not provide information about seismic amplification factor (H/V components) of the site. As simplified approach it can be said that foundation site period can be calculated as \( T = 4H/V_s \). In this case the natural period of the local ground surface can be roughly inferred in about 0,1 sec. Obviously, this period is referred to surface vibratory ground motion and not to the bedrock where stelae 2 is fixed. In any case, this value shows a higher frequency (shorter period) with respect to the natural period of stelae, and also higher than the theoretical frequency of the far field potential affecting earthquakes.

2.4.7. Hydrogeology

The analysis of technical and scientific literature reports no specific study or maps about hydrogeological setting of the study area. Nevertheless, some basic observations can be done according to available studies and remarks from the field mission of January 2006.

The outcropping terrains can be broadly derived into two distinct groups according to their permeability (both primary and secondary permeability).

Permeable terrains: granitoids, basalts and lavas exhibit a low primary permeability, but a medium-high secondary permeability due to pervasive jointing; groundwater should reasonably presents a medium-high mineralization with sulphate, chloride, magnesium and iron present in solution.

Alluvial deposits (gravel, sands and silty-sand soils) generally presents a medium-high permeability. These terrains outcrop in the northern portions of the study area, along the May Hegga stream and locally in shafts and boreholes in the Northern Stelae Park.

These formations largely outcrop in the study area (Beta Giyorgis hill, May Qoho hill, Park of the Stelae).

Terrains at low-medium permeability: lacustrine and colluvial deposits present a variable permeability, generally low or medium-low for the clayey and silty
components of soils, whereas high permeability is localised in strata or lens composed by gravel and sands.

Figure 2.4. Map of permeability of terrains outcropping in the Aksum area. 1. Alluvial deposits \((10^{-3} - 10^{-1} \text{ m/s})\); 2. Talus cone \((10^{-2} - 10^{-1} \text{ m/s})\); 3. Silicic lavas \((10^{-5} - 10^{-7} \text{ m/s})\); 4. Basalts \((10^{-4} - 10^{-6} \text{ m/s})\); 5. Granitoids \((10^{-4} - 10^{-5} \text{ m/s})\); 6. Stelae Park area.

In the area, groundwater can be potentially found in fractured or potentially fractured rocks (from moderate to high permeability) with low primary permeability. Locally, the most important aquifer can be localised between the permeable portion of granitoids, along the eastern slope of Beta Giyoirgis, at contact with colluvium and moderately weathered basalt (fig 2.4.). Although these aquifers will seldom produce large quantities of water for abstraction they are important for local supplies, such as for the well located in the area of the new museum.

The construction site is characterised by the presence of colluvium (from sandy to clayey), boulders and gravels (from alluvial and slope deposits) of granitoid blocks and debris derived from archaeological structures, following an irregular distribution.

These terrains, due to their general low clay content, can be classified as "Soils of medium-high leaching potential", soils in which contaminants are likely to penetrate
the soil layer because water and contaminant movement is predominantly vertical or they have a low ability to attenuate diffuse contaminants.

Currently the site is open grassland with no industrial or other potential source of contaminants present. Contamination may only become a potential problem if the area is exposed to pollutants derived by potentially hazardous workings or plants.

2.4.8. Impact Assessment and Mitigation

The potential geological impact of the proposed project will be principally concerned to the ground disturbance during the set up of the construction site and construction of the foundations where the Stela n. 2 will be replaced.

Although there are no features which are of outstanding geological significance within the site of the proposed project which are not replicated within a short distance of the site, the very sensitive cultural heritage context have to be taken into account.

Potential damage can be principally caused by the movement of plant and machinery over the site, together with overburden, stockpiling of materials on site, cutting operations within the site (e.g. enlarging of existing foundation of the Stela).

a. Plant movement

Access into the site will be via an existing bitumen road, which has accesses leading into other sectors of the site. Consequently, transport roads will follow these routes minimising damage to the site. There is no special requirement of access to other areas of the site that can be, in case, served by existing road paths.

No plant movement with heavy machinery have to be done in areas of the site not strictly involved by the operation of re-erection of the Stela.

All machinery that may cause potential leaching of pollutants (e.g. oils, hydrocarbons, chemical additives) have to be set outside the archaeological area.

b. Topsoil Stripping and Storage

Standard engineering practice is to remove the humus rich compressible topsoil layer prior to any ground works commencing. These operations are not required for the planned operations since they can cause damage to unexposed archaeological structures. Therefore, in the construction site no topsoil stripping and stockpiling has to be executed.

c. Earthworks

A potential geological impact of the proposed project could be principally caused by operations to reduce or raise levels between the area of foundation of the Stela and
the square where most of machinery and materials will be placed. This operation will not be executed through earthworks but building a special embankment. This will be built with gabions that has the scopes of assembling the three Stela pieces and move the structure, through tracks located above the surface of the embankment, from the square to the foundation area where the re-erection will take place.

\textit{d. Foundations}

The area of foundation of the Stela n. 2 at present is characterised by a shaft that corresponds to the old foundation area. In the site, the bedrock outcrops at a depth of approx. 7.00 m from the ground level. Most of materials between the bedrock top surface and the present ground level are a mixture of disturbed soils, fragmented blocks, colluvial levels. The bedrock is formed by weathered flood basalt that represents the surface of support for the new foundations.

The project presents an enlargement of the old foundation area, as one of the main working stage. As regarding this phase, the following prescriptions and recommendations are proposed:

\begin{itemize}
  \item The operations of excavation for the enlargement of the foundations have to be done using hand utensils. The area of foundations, as reported from geophysical studies, may present archaeological structures still not exposed and excavated. The use of machinery can cause irreversible damage to potential archaeological remains.
  \item The use of chemical additives during the workings for the foundation should be avoided in order to minimise potential hazardous impacts of pollutants on groundwater.
  \item The construction of the fill embankment and tracks for transporting of the Stela to the foundation area has to take into account the potential presence of archaeological remains in near depth. The realization of the embankment have to be done through a step-by-step operation in order to better distribute the stress to the soil.
  \item All main operations of the project (embankment, excavation of foundation, stockpile of materials) should be done during dry periods, avoiding June, July and August where the maximum rainfall is recorded in the area of Aksum.
\end{itemize}

\textit{e. Earthquake}

Seismic activity is important since the vibratory ground motion may affect the stability of all stelae. From data it is possible to say that the expected vibratory ground (0.09 and 0.11 g respectively for 500 and 1000 year return period) is
generally very low and can unlikely generate damage to structures. Asfawossen et alii (1999), suggest the possibility that the Stela n. 3 is inducing, with its natural predominant period (about 1.2 sec.), also the site of Stela n. 2. This period is also important since far field earthquakes, as in this case, can show such frequencies. It is then recommended to properly evaluate the predominant period of Stela n. 2, and to compare it with potential seismic events obtained in similar seismotectonic conditions, magnitude and distances.

In the mean time, the apparently critical stability of Stela n. 3 is suggesting the following:

- Vibration due to field works may induce vibration in the range of frequency of the Stela n. 3 that may result in potential disturbance. Therefore, it is recommended an emergency intervention (e.g. steel rope system founded in the opposite direction of leaning orientation) to avoid any further deterioration;
- The natural period of the Stela n. 3 and relationship with Stela n. 2 should be better investigated;
- Erection and positioning of individual pieces of the Stela n. 2 should be carried out in a way that minimize ground motion that can potentially cause a disturbance to Stela n. 3.

2.5 CULTURAL HERITAGE

2.5.1. Methodology

This chapter reports the impact of the proposed project of re-erection of the Stela n. 2 in Aksum upon archaeology and makes recommendations designed to mitigate any adverse impacts. This section considers the following parts:

- Description of the archaeology;
- Assessment of impacts;
- Conclusions and recommendations related to mitigation.

Archaeology comprises all historical evidences in the specific site of the project as well as in its immediate surroundings. The nature of the impacts that the project may have on archaeology and the description of the main methods by which these impacts can be mitigated are reported.

The development is taken to include not only the project itself but also any auxiliary works, which may have an impact in associated areas (such as access routes and compounds for materials, machinery and vehicles). The relevant evidence includes not only archaeological sites and artefacts but all data which throw light on the
society, economy and environment of the archaeological past. The description of the
archaeology includes a description of the general background of the area followed by
details of the site. The assessment of impacts includes both direct adverse impacts
on sites and also impacts on their settings. Recommendations may be for further
investigation or for mitigation by preservation, by recording or by monitoring.

To describe the archaeology, a wide scientific literature referred to the Aksum
archaeological area has been collected and analysed.

As a general rule any project developed over archaeological areas is likely to have a
potential damaging impact on archaeology, as archaeological evidence is fragile,
shallowly buried, widespread and unpredictable.

As a result, effectively any disturbance of the ground surface may have an impact on
archaeology. Where there are damaging impacts, action should be taken to mitigate
the impacts. The impacts may be divided into three categories. First, impacts on
known and still existing archaeological sites, either officially listed sites or extra sites
discovered during the assessment. Second impacts on previously unrecognised
archaeology, whether predicted or entirely unexpected. Third, there are sometimes
impacts on the settings, or the historic environment, of important archaeological
sites, as distinct from direct impacts on the sites themselves.

a. Impact Assessment

Project sites sometimes has impacts on the settings, or the historic environment, of
important archaeological sites, as distinct from a direct impact damaging a site
itself. Adverse impacts then require measures in mitigation. Sometimes, the impacts
may be favourable if, for example, an attractive site or monument is exposed more
clearly to public view and admiration. In evaluating impacts on settings, two factors
are taken into account: first, the importance of the archaeological site, resource or
setting; and second, the magnitude of the impact. The importance is normally a
combination of two factors: the rarity of the archaeology and its current state of
preservation. The importance of the archaeology is increased if it is of a kind, which
appears to be infrequently found or if it has unusual characteristics. The importance
of the archaeology is increased if it is well preserved, or has reached a stable state
of preservation. Adverse impacts damage or destroy parts of an archaeological site,
resource or setting. With settings, the magnitude of an adverse impact depends
mostly on the extent to which the damage or destruction affects significant parts of
the setting.

b. Mitigation
Mitigation of direct impacts on known archaeological sites and other archaeological evidence normally involves one of four procedures:

- mitigation by preservation;
- mitigation by recording (that is, excavation);
- mitigation by preliminary clearance;
- mitigation by monitoring

Preservation is appropriate where a known archaeological site is identified at an early stage, and the project is designed to avoid it. Recording (that is, excavation) is the normal form of mitigation; it provides new evidence which counter balances and mitigates the loss by destruction. Preliminary clearance is carried out to mitigate the impact on previously unidentified archaeological evidence; where necessary, it is followed by excavation, and the site is then clear for development. Monitoring is carried out during the construction works, on the understanding that, if any archaeological evidence does turn up, construction will halt while the archaeology is recorded by full excavation. Mitigation of impacts on a setting or historic environment is a little different. Normal techniques are adapting, screening, moving or burying the project.

i. Preservation

Mitigation by preservation means preserving known archaeology undamaged. This may involve altering the development (or part of it), to remove the impact or adequately reduce it. Alternatively, it may sometimes involve protecting the archaeology (for example by protective coverings), so that the archaeology is not damaged by construction of the proposed development or by subsequent use. In the case of a road, a new embankment may sometimes serve to preserve any archaeology, which is buried beneath it. To preserve the archaeology is an option, which may be chosen during the original design of the development if, for example, the archaeology consists of a well-known site. Alternatively, it is an option which may be chosen if Preliminary Clearance reveals archaeology.

ii. Recording

Mitigation by recording means recording the archaeology and then allowing it to be destroyed by the development. This normally involves full archaeological excavation, recording and assessment. The new information, which this provides, counter-balances the destruction of the archaeology.

iii. Preliminary Clearance
Preservation and recording depend on first identifying archaeological evidence to preserve or record. Unfortunately, no investigation short of full excavation can rule out completely the possibility that unexpected archaeological evidence will turn up during disturbance of the ground. It is therefore usually necessary to mitigate the impact of development on previously unidentified archaeological evidence by carrying out preliminary clearance. Preliminary Clearance means that, before the ground surface of any area is disturbed for development, the surface layers such as topsoil are cleared off the area (under the on-site supervision of a qualified archaeologist, operating under a license from due authorities).

The surface layers are cleared off using a back-actor machine equipped with a flatmouthed (or "sheugh") bucket, supervised by the archaeologist (at a ratio of one machine to one archaeologist). The clearance takes place until either archaeology is met or undisturbed natural strata. If no archaeology is discovered, the site is usually made available to the development without further need for archaeological work. If any archaeology is discovered, it usually needs to be fully recorded by excavation. The site is then made available to the development without further need for archaeological work. Sometimes, it may be possible to cover in and preserve some of the archaeological evidence.

iv. Monitoring

Mitigation by monitoring means having a qualified archaeologist observe and monitor all disturbance of the ground during the construction works, under a license from due authorities. Since only full excavation can be sure to discover all the archaeology, it is possible that unexpected evidence will turn up during disturbance of the ground. If any archaeological evidence does turn up, the archaeologist must have the authority to halt construction and record the archaeology by full excavation. This can cause considerable and unexpected delays. Wherever possible, it is advisable to carry out this investigation not by monitoring but by Preliminary Clearance, so that construction may be carried through without archaeological interference. Monitoring may be the only possible method in some situations (such as where service trenches must be dug through public streets).

v. Impacts on settings

Where the impact is on the setting or the historic environment (of an archaeological site or monument or a Historic Building) as distinct from the site or building itself, mitigation is a little different. It may logically take one of five forms: recording, adapting, screening, moving or burying the development. Recording a setting before development is not on its own normally adequate mitigation of any serious adverse impact. It is usually too expensive to undertake the large-scale excavation which
could provide new information to counter-balance the loss by destruction. A development may be adapted to reduce its impact on a setting by designing it (or its Architectural style) to be appropriate in that setting. A development may be screened by planting vegetation to hide it from the relevant setting, or by an embankment or mound. It is necessary, of course, to assess also whether vegetation (and its roots) will have an impact on any archaeology. A project may be moved an adequate distance further away from the archaeological site or historic building. The distance must be enough for the adverse impact to be removed or adequately reduced. In the case of a road development, the distance should be enough to remove the impact of the road itself and also (where appropriate) of any embankments or cuttings. If a development is buried, it should be placed underground or within a mound or a tunnel in such a fashion that the setting aboveground is not damaged. If the mound or tunnel involves disturbing the ground, it is necessary to assess whether that disturbance will have an impact on any archaeology. Burying a planned project is expensive.

2.5.2 Impacts

Archaeological impacts may be divided into three categories: (1) direct impacts on known and still existing archaeological sites; (2) direct impacts on extra sites where archaeological evidence is predicted or suspected; (3) impacts on the settings of significant archaeological sites.

a. Known sites

The proposed project will have a direct impact on the archaeological site of the Northern Stelae Park of Aksum, since the work is specifically addressed to the reerection of the Stela n. 2 that is a fundamental element of the Cultural Heritage of Ethiopia. In addition, after the mutual efforts and agreements among the Governments of Italy and Ethiopia and UNESCO, the "Obelisk of Rome" has become a symbol of renaissance of the Aksumite culture. All preventative actions have been implemented to assure the preservation of the Stela during dismantling in Rome and transportation to Aksum whereas the design related to the reerection of the Stela has taken into account the peculiarity of the object and of the site.

b. Extra sites

There is a distinct possibility that there will be archaeological evidence in the area located between the foundation area of the Stela and the portion of the square adjacent to the entrance of the Stelae Park. For this reason a geophysical field campaign has been requested by UNESCO and implemented by Prof. Luciana Orlando - University of Rome "La Sapienza". The investigation has permitted to detect potential archaeological structures, still not excavated, located inside and in
the immediate vicinity of the area involved by the project. The archaeological importance of these structures is still unknown at this stage of the research.

Any work that may have a potential negative impact (e.g. excavation) on below-ground archaeology, should be avoided.

c. Settings

The area of the proposed project is inside the Northern Stelae Park (photo2.3).

![Photo 2.3. Northern Stelae Park landscape](image)

During field missions accomplished in March 2005, April 2005 and January 2006 we have noted that this part of the town is characterised by a sacred and quiet atmosphere, being the present and the ancient religious core of Aksum.

2.5.3. Mitigation

The project of re-erection of the Stela n. 2 and all related operations have been designed taking into account the sensitivity of the site and of the Cultural Heritage of the Stelae Park in Aksum. Therefore, all general and specific recommendations are referred to all environmental elements considered in this report.

According to geophysical analysis and results there is no necessity of further fieldwork or excavation before construction starts on any specific location within the proposed project.

Specific recommendations are the following:

- all works have to be take into account the presence of archaeological remains as suggested in the fig.2.5

- the building of the foundation of Stela n. 2 has to prevent any potential infiltration of cement along lateral walls of the shaft; this may result in a permanent damage of minor underground archaeological remains, whether existing close to the shaft area. A possible solution can consider an impermeable layer between foundation and natural ground.
2.6 AIR AND CLIMATE

2.6.1 Introduction

This section considers the potential air quality impacts arising from the proposed project of re-erection of the Stela n. 2 of Aksum, as well as the main climatic characteristics of the area.

In the town of Aksum neither any monitoring system for air quality analysis is installed nor data set are available, also considering surrounding areas. For this reason, suggestion of prescriptions and recommendations about this environmental parameter will follow general considerations about the potential impacts of workings on air quality.

2.6.2. Climate

As regarding the climate in Aksum, a desk study has been developed using the following sources from literature and collected in Addis Ababa during the field mission of January 2006:

- National Atlas of Ethiopia, scale 1:5,000,000
- Climate classifications of Ethiopia, NMSA
- Assessment of drought in Ethiopia
Data set of temperature and rainfall recorded in Aksum, years 2000-2005.

The climate classification of Aksum, according to data from National Atlas of Ethiopia, published in 1988, can be defined as Warm Temperate Climate I (CWB).

CWB – Distinct dry months in winter. The mean temperature of the coldest month is below 18°C, and for more than 4 months it has mean temperatures above 10°C. The annual rainfall in mm is also greater than 20 times the annual mean temperature plus 14 \[20(t+14)\]. Rainfall amount and distribution varies considerably from area to area. In areas of heavy rainfall, forest predominate and grass covers the areas of moderate rainfall. It prevails from an elevation of 1,750 m to 3,200 m above sea level. A specific dataset has been implemented collecting rainfall and temperature data related to the meteorological station of Aksum. The following diagrams show the average rainfall and temperature patterns on monthly basis for 6 years of observations (2000-2005). Obviously this limited temporal window of data can not provide an exhaustive scenario of weather conditions in Aksum, but is very useful to envisage typical patterns of weather parameters in order to make some suggestions and recommendations for workings and schedule.

![Monthly rainfall distribution](image-url)

*Fig.2.6. Rainfall distribution during 2000-2005, measured at Aksum*
In addition, predominant winds occur during the months of October, December and January.

2.6.3. Methodology
The following approach has been adopted for the purposes of compiling this air quality chapter:

- Identification of the potential pollutants specific to the proposed project;
- Determine the potential impacts during the construction and operational phases of the proposed project;
- Compile mitigation measures to minimise these potential impacts during both phases.

As already discussed, no baseline survey has been undertaken in the site, whereas the existing air quality assessment, in absence of monitoring systems and data, is based on general assumptions derived from direct observations during the field missions in Aksum of March-April 2005 and January 2006.

2.6.4. Identification of Potential Pollutants

The main air pollutants that may impact on the local air quality as a result of the proposed project are considered to be predominantly derived from traffic. These include sulphur dioxide (SO2), oxides of nitrogen (NOx), Volatile Organic Compounds (VOCs), particulate matter (to include PM10/PM2.5) and dust deposition during both the construction and operational phases. Regarding the project of re-erection of the Stela n. 2 itself, there is not likely to be generation of emissions of any significance.

a. SO2

Sulphur dioxide is a corrosive gas, which when combined with water produces acid rain. Both wet and dry deposition has been implicated in the damage and destruction of vegetation, soil, buildings and watercourses. The principal source of this pollutant is due to the burning of fossil fuels containing sulphur. As an example, the 2003/17/EC Directive amending Directive 98/70/EC relating to the quality of petrol and diesel fuels will further promote the use of lower sulphur fuel and hence further reduce emissions of sulphur dioxide from traffic.

b. NOx

The oxides of nitrogen refer predominately to nitrogen dioxide (NO2) and nitrogen monoxide (NO). Emissions of NOx are produced by high temperature oxidation of nitrogen in the air i.e. vehicular sources, stationary boilers / burners during fossil fuel combustion. Road traffic is the principal source of anthropogenic oxides of nitrogen and is responsible for approximately half the emissions in Europe.

Nitrogen dioxide accounts for approximately 10% of the NOx content in combustion gases, the remainder comprising of NO2. The level of NO2 produced will depend on
the combustion temperature. On emission to atmosphere NO is rapidly converted to NO2 in the atmosphere. NO2 can have a range of environmental impacts. At high concentrations, it is potentially toxic to plants, injuring leaves and reducing growth which in turn reduces crop yield. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone. In addition, under specific conditions, oxides of nitrogen can be easily converted to nitric acid, thereby contributing to acid rain and hence acid deposition.

In recent years, the drive to reduce these compounds has come from the European Commission. The National Emissions Ceilings Directive 2001/81/EC for certain atmospheric pollutants including sulphur dioxide and the oxides of nitrogen were introduced to combat acidification in response to the UNECE Convention on Long Range Transboundary of Air Pollution (CLTRAP).

c. VOCs

There are many hydrocarbon compounds which have the potential to be pollutants when released to the atmosphere. Some occur naturally, others are man-made. A range of hydrocarbons are found in vehicle fuel and can be released to atmosphere from vehicle exhaust gases as either unburnt fuels or combustion products. They can also be emitted from the evaporation of solvents and fuels and chemical manufacturing. Volatile Organic Compounds (VOCs) in combination with the oxides of nitrogen are responsible for ground level ozone or smog.

Benzene is a known carcinogen and long-term exposure can cause leukaemia. It is found in petrol and other liquid fuels in low concentrations. Its main source is vehicle emissions in urban areas.

Emissions of 1, 3-butadiene arises from the combustion of petroleum products and its manufacture and use in the chemical industry. 1, 3-butadiene is not present in petrol but is formed as a by-product of combustion, hence it is not present in road transport evaporative emissions. In Europe, the introduction of catalytic converters in 1991 has had a significant impact on the emissions from the road transport sector, causing a reduction in emissions of 74% from 1990 to 2002.

Emissions from other significant combustion sources, such as other transportation and machinery, have not significantly decreased. 1, 3-butadiene is a suspected human carcinogen.

Another class of organic pollutants is polyaromatic hydrocarbons (PAHs). These include a range of compounds including (among others) anthracene, naphthalene and pyrene. This group of compounds is to varying degrees toxic or carcinogenic and
is therefore classed as carcinogenic compounds. The largest source of these pollutants is road transport. Another significant source is domestic fuel burning.

Several Directives and Standards have been implemented in Europe to reduce the level of anthropogenic volatile organics. The National Emission Ceilings Directive 2001/81/EC aims to reduce the level of emitted VOCs from Member States. The ‘Solvents Directive’ 1999/13/EC on March 11, 1999 aims to limit the amount of VOCs due to the use of organic solvents in certain activities and installations. The activities generally related to those not covered by IPC or IPPC legislation.

d. Particulate Matter (PM)

Particulate matter is the general term used to describe a mixture of solid particles and liquid droplets in the atmosphere. These particles originate from both anthropogenic mobile and stationary sources in addition to natural ones. Particulate matter, in particular PM10 and PM2.5 has been well documented regarding their health implications.

The environmental impact of particulate matter is well established. Its most significant effect is the role it plays in smog formation. Deposition of PM can cause soiling and discoloration on a wide variety of surfaces. Exposure to PM can also cause physical and chemical degradation of materials through the action of acidic particles.

Particulate matter is associated with reduced visibility and poor air quality. The presence of particles in the air reduces the distance at which the colour, clarity, and contrast of far away objects can be seen because the particles in the atmosphere scatter and absorb light.

The most obvious effect of particulate deposition on vegetation is the physical smothering of the leaf surface. This will reduce light transmission to the plant in turn causing a decrease in photosynthesis. Particle composition may cause both direct chemical effects on the plant and indirect effects through impacts on the soil environment. Particle accumulation on the leaf surface may increase the plant's susceptibility to disease.

Regarding the health effects of particulate matter, emphasis has shifted from PM10 to PM2.5, as it is now accepted that this size particle is responsible for causing the greatest harm to human health. These fine particles can be inhaled deep into the lungs reaching areas where the cells replenish the blood with oxygen. They can cause breathing and respiratory symptoms, irritation, inflammation and damage to the lungs and premature deaths.
The EC Directive 1999/30/EC sets daily and annual limits for PM10 in the ambient atmosphere. As of yet there are no proposed or EU limit values for PM2.5. However, recent studies have suggested setting a limit value of 15μg/m3 for public health reasons (Apheis Air Pollution and Health: A European Information System Health Impact Assessment of Air Pollution and Communication Strategy Third Year Report 2002 -2003, July 2004).

2.6.5 Potential Impacts of the Project

There will be two phases of this development which may impact on local air quality if uncontrolled. These include:

- Construction Phase
- Operational Phase

a. Construction Phase

During the construction phase, the main potential impacts on air quality arise due to the generation of dust and the movement of construction traffic at the site.

(i). Generation of Dust

The quantity of dust released during construction depends on a number of factors. These include the type of construction activities occurring, the volumes of materials transported and the moisture content of the materials, the distance travelled on unpaved roads, the mitigation measures employed and the area of exposed materials.

The main sources of dust that may potentially be generated during the construction phase include:

- Building of new roads and site entrances
- Earthworks associated with digging to enlarge the foundations of the Stela which will generate a certain quantity of spoil
- Concrete operations
- Site excavation, if required
- Stockpiling
- Landscaping works

The impact of fugitive dust emissions generated from these operations will, to a certain extent depend on surface characteristics, wind direction, wind speed and other meteorological conditions such as rainfall. Dust generation will be greatest during dry windy weather and least during calm wet conditions.
The potential for construction dust impacts is also dependent on the proximity of sensitive receptors. The ability of a particle to remain suspended in the air depends on its size shape and density. Large dust particles will deposit within 100m of sources (>30um). Intermediate particles (10 to 30um) can travel 200 to 500m. Smaller particles (less than 10um) are deposited slowly and can travel up to 1km. Concentration decrease rapidly with distance due to dispersion, dilution and deposition and therefore significant dust annoyance is usually limited to within 200m of a construction site.

With mitigation measures in place, the zone of impact can be reduced substantially to around 100m of major dust generating activities.

Since the closest residential receptors are located at around 150-200 m to the proposed construction site boundary it is recommended to adopt simple mitigation measures in place so that construction dust impacts at nearby properties will cause negligible nuisance.

(ii). Traffic Pollutants

The potential movement of machinery, construction vehicles and the use of generators at the site during the construction phase will generate exhaust fumes and subsequently contribute to potential emissions of SO2, NOx, CO, particulate matter (including PM2.5/PM10), Volatile Organic Compounds (VOCs) and polyaromatic hydrocarbons (PAHs). While the concentrations of these pollutants are expected to increase during the construction phase, strict adherence to ‘good site/engineering practices’ will minimise the generation of any unnecessary air emissions. Notwithstanding this, the level of air pollution generated will not be of significance and will be of short duration i.e. 8-12 months.

(iii). Greenhouse Gas Emissions

During the construction phase, the main potential impacts on climate will be those associated with site traffic (HGVs and cars) entering and leaving the site. This will likely result in emissions of the greenhouse gas, CO2, although in negligible amount.

b. Operational Phase

(i). Traffic Pollutants

During the operational phase, after the re-erection of the Stela n. 2, it can be assumed that an increase in traffic entering and leaving the Stelae Park may result in an increase in traffic pollutants (SO2, NOx, CO, PM10 and VOCs) along the entrances and access roads due to potential development of tourism.
This may likely result in an increase of traffic due to bus and taxi transportation. Increase of car traffic from tourist activity will probably produce negligible effects considering that most of travellers arrive at Aksum by internal flights.

Finally the most reliable scenario about traffic emissions from the proposed project will not adversely impact on the nearest sensitive receptors.

(ii). Greenhouse Gas Emissions

The predominant emissions during the operational phase are likely to arise due to CO2 from traffic emissions – employees/visitors entering/leaving the site.

The effects of potential impacts are the same as below.

2.6.6 Proposed Mitigation Measures

a. Construction Phase

(i). Generation of Dust

During the construction phase the following dust minimisation measures will be implemented to reduce the potential for dust migration from the site and from construction traffic using public roads. This will involve the following good site/management practices:

- A dust minimisation plan will be formulated for the construction phase;
- The use of construction equipment designed to minimise dust generation;
- Site roads will be regularly cleaned and maintained as appropriate. Hard surface roads should be wept to remove mud and aggregate materials from their surface while unpaved roads should be restricted to essential site traffic only;
- A temporary truck wheel wash will be installed and all trucks exiting the site will have their wheels and undercarriage washed down to avoid leaving any soil, mud or dust onto the public road system;
- Public roads will be regularly inspected for cleanliness and cleaned as necessary;
- During dry periods, stockpiles of soil / sand and hardcore will be kept moist using rotary sprinkler heads;
- Lorries/trucks will be properly covered or enclosed during transportation of friable construction materials to prevent their escape along public roads;
- If necessary, hoarding will be erected around the site to reduce dispersion of fugitive dust;
Adherence to good site engineering practices will assist in reducing dust generation

(ii). Traffic Pollutants

The presence of on-site vehicles will give rise to traffic pollutants (SO2, NOx, CO, PM10 and VOCs). Good site practices will be implemented to minimise these emissions. It will be requested that all site vehicles and machinery will be switched off when not in use to eliminate any unnecessary emissions. As mentioned above, significant. All plant machinery will be regularly maintained and comply with all relevant legislation relating to emissions.

(iii). Greenhouse Gas Emissions

In order to reduce unnecessary emissions from cars and HGVs entering/leaving the construction site, all personnel will be advised to switch off any idling engines. Excess or unnecessary revving of engines will not be permitted. This will help to reduce the levels of pollutants emitted to atmosphere.

(iv) Climate

As already mentioned, it is recommended to avoid workings such as foundation enlargement and building during the rainfall season that usually occur during the period June-September.

As already mentioned, it is recommended to avoid workings such as foundation enlargement and building during the rainfall season that usually occur during the period June-September.

b. Operational Phase

(i). Traffic Pollutants

The increase in traffic as a result of the proposed development will not result in a significant increase in pollutants at the sensitive receptors.

Furthermore, there may be a slight decrease in emissions in comparison to the construction phase as there will be significantly less vehicular activity at the site, no construction equipment and associated machinery. In addition, future cleaner car technology or improvement/modernization of vehicles type will likely reduce overall emissions. In summary, emissions to air during both the construction and operation phase of this project will be minor in nature and will have no significant effect on the receiving ambient air quality. Mitigation measures will be implemented to ensure emissions from the proposed development are kept to a minimum.

2.7 VEGETATION
2.7.1 Introduction

The aim of this report are to analyse vegetation characteristics of the Northern Stelae Park in Aksum. This has been done essentially through:

- Findings of a field survey work focused on reconnaissance of vegetation species in the study area;
- Desktop study for description of the potential effects on vegetation of the proposed project and suggestion of recommendation and measures for mitigating potential negative impacts.

In the following chapters the main characteristics of the vegetation located in the Stelae Park as well as a general outline of the ecosystem of the Aksum area are described. In addition, some general indications related to a possible intervention on vegetation is also suggested.

2.7.2 Main climatic and ecologic parameters

According with Climatic classification of National Atlas of Ethiopia, the area of Aksum site (approx. 2100 - 2200 m a.s.l.) lies in the semi-arid area classified as "AW, Tropical Climate II", characterized by dry months in winter (see fig. 2.9). The mean temperature, following the mentioned classification, is above 18°C and the mean annual rainfall is between 680 and 2000 mm. As in general for all tropical climate, the daily range of temperature is high, while differences of monthly averages are small. Tall grass characterizes this climate type and usually grass and trees and intermingled. More specifically in Aksum area the rainfall varies around 500 and 600 mm and highest temperatures are expected during the summer.
Concerning desertification risks on most of the highlands of Tigray the status of degradation and the future risks of desertification have to be considered as high, due mainly to water erosion, that is accounted to determine losses of soil of about 50 tons/ha/year (see Fig. 2.10). Moreover, it has to be considered that soils are also shallow (usually no more than 50 cm in depth). Degradation of the vegetative cover must have contributed to the present situation and future risks in soil degradation.

2.7.3 Main characteristics of the vegetation of the Awraja (Province) of Aksum

The vegetation of the area has been selected by the general water deficit indicated in previous table. In general, the area in Aksum Awraja can be described as "woodland and savannah region" (see Fig. 2.11), with the upper layer characterised by the presence of Juniperus procera or Acacia-Commiphora association. Trees and shrubs (Acacia tortilis, A. mellifera, Balanites aegyptiaca, various species of Commiphora, Capparis, Combretum and Terminalia, as well as small shrubby herbs like Acalypha, Barleria and Aerva) are draught tolerant, with either small deciduous leaves or leathery persistent ones. The Juniperus association is specific of areas between 1400 and 2100 m of altitude, in environment with annual rainfall between 550 and 875 mm. The Acacia-
Commiphora woodlands occur mainly in areas with an altitudes between 900 and 1,900 m asl. Below the top storey of *Juniperus* there are the shrub layer and a field layer of sparse grass.

**Fig.2.11. Climatic Climax vegetation of Tigray Region (in blue) and province of Aksum (in red)**

It can be also considered that according with FAO studies (1) the *Juniperus procera* is considered an endangered species, due to overexploitation for construction and industrial purposes.

### 2.7.4 Specific vegetation characteristics of Aksum archaeological site and immediate vicinity

Considering the land utilisation of the area surrounding Aksum – classified as "moderately cultivated", there are rainfed cultivation of grains, some perennial crop, livestock grazing on improved of fallow land. Cultivated areas are utilised for annual crops during the cropping season and the rest is utilised for livestock grazing or browsing (Fig. 2.12).
The presence of eucalyptus trees (*Eucaliptus spp.*) is widely diffused (see photo 2.4) as a species frequently utilised due to its characteristics of fast growth and resistance to pedological-climatic conditions of Ethiopia. Despite the potential for eucalyptus to improve rural livelihoods in northern Ethiopia in 1997, the regional government of Tigray imposed a ban on eucalyptus tree planting on farmlands. This ban is related to concerns regarding potential negative environmental externalities associated with eucalyptus and also due to the desire to reserve productive farmland for crop production. The regional government promotes planting of eucalyptus and other species in community woodlots, and has recently begun to allow private planting of eucalyptus on community wasteland and steep hillsides” (2).

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Inside the archaeological area some trees of remarkable dimension can be found such as the Sycomore (*Ficus sycomorus*) fig and the African juniper (*Juniperus procera*), Acacia (*Acacia spp.*), shrubs as Buganvillea (*Bouganvillea spp.*), Agave (*Agave spp.*), and Cactaceous like Prickly Pear (*Opuntia ficus-indica spp.*) fig. xx.

### 2.7.5 Potential impacts

The analysis of potential negative impacts that the project can produce on the environmental and ecological characteristics of the area have to take into account the following factors:

- The project area is quite small (1 ha ca.) so that significant impacts over the surrounding environment can be excluded;
- The site is located in the vicinity of a urban area (Aksum) that exhibits a low ecological value;
- The vegetation essences inside the construction site is extremely limited in terms of number of samples;
- During the workings these samples will not be removed.

### 2.7.6 Suggestions and recommendation for possible mitigation strategies
Considered the previous mentioned impacts it is regarded as indispensabile to integrate the executive project for re-erection of the Stela n. 2 with a specific project aimed at improving vegetation characteristics of the site.

The following factors should be taken into proper consideration:

- **Protection from main winds:** windbreak barriers should be installed to protect the site from wind (main probable direction E-S) in order to reduce soil erosion and protect visitors from wind and dust.
- **New perimeter of the Park:** the perimeter of the archaeological area should be delimited through tree/bush fences as a visual and windbreak barrier.
- **Delimitation of paths:** vegetation, if opportunely set up, can work as preferential path for visiting the site.
- **Shadow in rest areas:** the project can also provide some rest areas inside the archaeological park that have to be endowed with trees for visitor resting.
- **Aesthetical purposes:** improvement and new design of vegetation distribution with species, mainly shrubs and bushes, whose dimension promote the full view of the site.

A detailed plan could provide:

- A list of the most suitable species of trees and bushes for the above mentioned scopes (windbreak, shadow, fences and paths).
- Technical recommendations for soil preparation, fertilising, tree planting, care of vegetation after planting.
- A particular attention for providing watering choosing sustainable solution such as drop watering.
- Plan of periodical maintenance of vegetation (e.g. pruning, fertilising, watering)

The choice of the most suitable species has to take into account some characteristics that may provide an adequate ratio between aesthetical and functional elements as rusticity and drought resistance. Autochthonous plants will be selected avoiding stranger species (e.g. eucalyptus) with the help of local experts.

**2.8 SOCIO-ECONOMIC**

**2.8.1. Introduction**
This chapter reviews impacts on humans in respect of socio-economic issues. This essentially includes some brief considerations on socio-economic impacts of the project, in terms of direct and indirect effects on the city of Aksum.

2.8.2. Economic Impact

It is considered that the re-erection of the Stela will have beneficial impacts on the economy of the local area. There are two elements to economic impact.

(a) Direct Economic

The construction works would require the presence of a work force, which may be employed from local resources or imported. It can be estimated that local staff will be required for the construction and employment from local resources would input positively and directly to the local economy and help lower employment in the area at least for the period of construction phase.

(b) Indirect Economic

The local economy in a wider sense is likely to benefit both during the phase of re-erection of the Stela and during operation. This due to the expected increased numbers of people visiting or working in the Archaeological Park and spending on services and goods in and around Aksum.

Imported work forces would positively input to the local economy through the purchase of commodities and renting of accommodation during construction (e.g. hotels, guest houses) considering a short-term period. In the medium-long term, the realisation of the new museum as well as the new landscaping of the Northern Park of the Stelae along with the development of dissemination strategies by UNESCO, Ethiopian Governmental Authorities, Italian Governmental Authorities, should produce a further knock-on affect on the local economy through increase of tourism.

3.0. CONCLUSIONS

3.1 Review Issues

In scoping this Environmental Study, it was established that the potential impacts would include:

- Landscape and Visual
Vegetation
Noise
Superficial Water and Drainage
Geology, Hydrogeology, Seismicity
Cultural Heritage
Air and Climate
Socio-economic

All the information allow the realisation of the following figure 3.1 were the description of areas suitable for engineering works are reported.
Table 1.1  Summary of Environmental Effects and their Mitigation

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Description of Effect</th>
<th>Effect</th>
<th>Nature</th>
<th>Potential Significance of Impact</th>
<th>Key Mitigation</th>
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<tbody>
<tr>
<td>Noise</td>
<td>Potential impact on nearby residential area from construction noise</td>
<td>Adverse</td>
<td>St, R</td>
<td>Moderate</td>
<td>- Use of well maintained plant or new plant</td>
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<td>- Substitution of unsuitable plant</td>
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<td>- Maintenance of silencers and moving components</td>
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<td>- Construct screening during excavations</td>
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<td>- Avoid night time works</td>
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<td></td>
<td>Potential impact on nearby residential area from traffic noise</td>
<td>Adverse</td>
<td>St, R</td>
<td>Minor</td>
<td>- Typical impact of car park or traffic due to works will be below or equal to daytime levels</td>
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<td>- Changes to traffic noise on roads around the site will be generally imperceptible</td>
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<td>- Maintenance of silencers and moving components</td>
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<tr>
<td>Superficial Water and Drainage</td>
<td>Pollution of water courses</td>
<td>Adverse</td>
<td>Lt, IR</td>
<td>High</td>
<td>- All washing facilities need to be securely constructed and the effluent properly contained for treatment and disposal.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>- Ensure appropriate measures to avoid pollution from hazardous substances (e.g. chemicals, hydrocarbons).</td>
</tr>
<tr>
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<td></td>
<td>- Monitoring of all potential pollutant sources to ensure minimisation of impacts on water quality and drainage.</td>
</tr>
<tr>
<td></td>
<td>Silting up of water courses during the construction phase</td>
<td>Adverse</td>
<td>St, R</td>
<td>Moderate</td>
<td>- Stockpile must be minimized and where they occur they should be covered.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>- Site roads should be kept free from dust or other deposits.</td>
</tr>
<tr>
<td></td>
<td>Modification of drainage patterns from excavations.</td>
<td>Adverse</td>
<td>St, IR</td>
<td>Minor</td>
<td>- Avoid to change the pattern of the present discharge system.</td>
</tr>
<tr>
<td>Receptor</td>
<td>Description of Effect</td>
<td>Effect</td>
<td>Nature</td>
<td>Potential Significance of Impact</td>
<td>Key Mitigation</td>
</tr>
<tr>
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</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Movement of plant over the site</td>
<td>Adverse</td>
<td>St, R</td>
<td>Low</td>
<td>- Use of an existing road will minimize damage over the archaeological site</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Movement of plant over the site</td>
<td>Adverse</td>
<td>Lt, IR</td>
<td>High</td>
<td>- Machinery that may cause potential leaching of pollutants (e.g. oil, hydrocarbons, chemical additives) have to be set outside the archaeological area</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Topsoil stripping and storage</td>
<td>Adverse</td>
<td>St, R</td>
<td>Moderate</td>
<td>- Avoid topsoil stripping and stockpiling</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Earthworks (construction of the embankment)</td>
<td>Adverse</td>
<td>St, IR</td>
<td>Moderate</td>
<td>- The realization of the embankment have to be done through a step-by-step operation for better distributing stress to the soil</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Earthworks (construction of the embankment)</td>
<td>Adverse</td>
<td>St, IR</td>
<td>Moderate</td>
<td>- The realization of the embankment have to be done through a step-by-step operation for better distributing stress to the soil</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Foundations</td>
<td>Adverse</td>
<td>Lt, IR</td>
<td>High</td>
<td>- Excavation of foundations have to be done using hand utensils to avoid the irreversible damage of potential archaeological remains               - Avoid the use of chemical additives in order to minimise potential infiltration of pollutants</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>General works</td>
<td>Adverse</td>
<td>St, R</td>
<td>Low</td>
<td>- All main operational phases should be done during dry periods, avoiding summer months where the maximum rainfall is recorded in the area of Aksum</td>
</tr>
<tr>
<td>Geology, Hydrogeology Seismicity</td>
<td>Earthquake induced effects</td>
<td>Adverse</td>
<td>Lt, IR</td>
<td>High</td>
<td>- Vibration caused by field works may result in potential</td>
</tr>
</tbody>
</table>
### Hydrogeology Seismicity (continued)

- Disturbance on Stela n. 3 so that it is recommended the use of mitigation strategies (e.g. steel ropes to prevent potential fall of the Stela)
  - The natural period of the Stela n. 3 and relationship with Stela n. 2 should be better investigated
  - Erection and positioning of individual pieces of the Stela n. 2 should be carried out in a way that minimize ground motion that can potentially cause a disturbance to Stela n. 3.

### Receptor Description of Effect  

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Effect Description</th>
<th>Effect</th>
<th>Nature</th>
<th>Potential Significance of Impact</th>
<th>Key Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural Heritage</td>
<td>Loss of potential archaeological remains in the construction site area</td>
<td>Adverse</td>
<td>Lt, IR</td>
<td>High</td>
<td>- All works have to be take into account the presence of archaeological remains in the area</td>
</tr>
</tbody>
</table>
| Cultural Heritage | Intrusive impact of foundation excavation | Adverse | Lt, IR | High                             | - The building of the foundation of Stela n. 2 has to prevent any potential infiltration of cement along lateral walls of the shaft; this may result in a permanent damage of minor underground archaeological remains, whether existing close to the shaft area  
  - It is recommended to use an impermeable layer between foundation and natural ground. |
<table>
<thead>
<tr>
<th>Receptor</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Air and Climate</td>
<td>Generation of dust during construction phase</td>
<td>Adverse</td>
<td>St, R</td>
<td>Low</td>
<td>- A dust minimisation plan</td>
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<td></td>
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<td></td>
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<td>- The use of construction equipment designed to minimise dust generation</td>
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<td></td>
<td>- Site roads will be regularly cleaned and maintained</td>
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<td>- The square located near the archaeological area will be regularly inspected for cleanliness and cleaned as necessary</td>
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<td>- Stockpiles of soils of soil / sand and hardcore will be kept moist</td>
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<td></td>
<td>- Lorries/trucks will be properly covered or enclosed</td>
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<td></td>
<td>- If necessary, hoarding will be erected around the site to reduce dispersion of fugitive dust</td>
</tr>
<tr>
<td></td>
<td>Vehicles emissions during construction</td>
<td>Adverse</td>
<td>St, R</td>
<td>Low</td>
<td>- Site vehicles/machinery to be switched off when not in use</td>
</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>- Well maintained plant machinery</td>
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</tbody>
</table>
### Significance of Impact

<table>
<thead>
<tr>
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</tr>
</thead>
</table>
| Vegetation | Potential loss of vegetation | Adverse | Lt, R | Low | - Realization of windbreak barriers to reduce soil erosion and protect visitors from wind and dust  
- Realization of tree/bush fences as visual and windbreak barriers  
- Delimitation of paths inside the archaeological park with vegetation  
- Periodical maintenance of vegetation through pruning, fertilising and drop watering  
- Selection of autochthonous species |