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Project Evaluation of Geothermal Resources

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ABSTRACT

The Assal region of the Republic of Djibouti has attracted scientific interest as a potential site for the development of a geothermal power plant for the production of electricity in the country. The main exploration were made in the 70s and 80s on projects carried out in cooperation between the Government of Djibouti and the United Nations Development Programme (UNDP). These projects have resulted in the drilling of six exploration wells to 2,105 m depth. Drilling has confirmed the existence of a geothermal reservoir with groundwater temperatures up to 360°C and a maximum steam production of 20 kg/s. The objective of this study is to investigate the environmental and social impacts and develop a plan for environmental and social management for the project "Assessment of geothermal resources" in the Assal Rift. The objective of the proposed project is to quantify the technical and financial feasibility of the use of the Assal Rift geothermal resources to end mass production of electricity. The project includes a drilling program for the exploration of 4 production wells in the area of Fiale, located 70 km west of Djibouti. The geothermal drilling site at Lake Assal/Fiale can be undertaken with environmental and socio-economic development being low if mitigation measures are properly implemented. It is important to note that the proper management of drilling fluids containing additives and processing or reinjection of geothermal fluid in the reservoir where it comes from is the first priority of the project mitigation measures, thus preventing flow in sensitive surrounding ecosystems, namely Lake Assal and Ghoubet – Kharab. International standards for the treatment of drilling mud, geothermal fluids and solid and liquid waste must absolutely be respected. Monitoring by independent experienced international experts must be implemented. Potential major impacts on the surroundings: the atmospheric emissions; use of drilling fluids; geothermal fluids; solid waste (potentially dangerous); eruption wells; seismic and volcanic event; were examined. The impacts of the proposed physical and biological environment for the project are mainly insignificant or moderately negative. However, the impact on the social and cultural environment: status vulnerability of women/gender; location men/gender; historical monument/graves; accompanying socio-economic measures; are generally positive or uncertain. The project does not involve land acquisition or involuntary resettlement, which will limit the negative impacts to the local population. Socio-economic accompanying measures are proposed. It is nevertheless important to inform the public and hold the status of the project and design the implementation of socio-economic accompanying measures in a participatory manner. After evaluating the various potential interesting geophysical study areas, the Government of Djibouti and the World Bank concluded that the caldera Fiale area has the greatest potential for success.

1. INTRODUCTION

Activities related to the use of geothermal resources in Djibouti have a history of 36 years and several studies have demonstrated the geothermal potential of the Lac Assal. Recently, the Government of Djibouti has asked the World Bank to help set up a new project of geothermal exploration in the Lac Assal drilling. The World Bank has made it a condition for funding of a new exploration campaign achieving a Study Framework of Environmental and Social Impact (ECIES).

2. PROJECT DESCRIPTION

Activities related to the use of geothermal resources in Djibouti have a history of 36 years. The first exploration program was carried out by the BRGM in 1975. A second drilling program, funded in part by the World Bank, took place in the late 80s in the Lake Assal (4 wells) and Hanle region (2 wells). After completion of two wells in the region of Hanle, the drilling platform was moved to Lake Assal where 4 wells were drilled. Two of the drill wells at Assal proved productive, but disagreements between donors on the need to conduct additional exploration operations and civil conflicts occurred in Djibouti in the early 90s that hindered the development of plant geothermal production. In the 2000s, cooperation agreements between Djibouti and the Iceland Geothermal program were revived before the Icelandic financial crisis of 2008 which limited the ability to finance a drilling program. The concession granted to the company Icelandic Exploration (REI) expired in May 2009. The objective of the geothermal project is to quantify the technical and financial feasibility of the use of the Assal Rift geothermal resources for producing electricity mass. The project includes a program of exploration of four production wells in the area Fiale, specifically north of the Lake Washing drilling. This area is the southern boundary of the region Tadjoura, about 70 km west of Djibouti city. The primary objective of each of the four exploratory drilling will be reaching and testing the intermediate container (surface). During the six holes drilled in Assal, the intermediate tank was reached at depths between 240 and 600 m. The temperatures of the intermediate tank programs identified during preceding drilling ranged from 140 to 190°C. These temperatures are sufficient for the production of electricity for commercial purposes by using a binary cycle power plant.

2.1. Key Environmental and Social Components

The study as part of the project is to study the environmental and social impact zone includes the land between Lake Assal and the Gulf of Ghoubet (see map below). It is located in the prefecture of Tadjoura, at a distance of 120 km and 70 km from Djibouti Tadjoura. The villages of the Daba Gahar, Ardoukoba (Carrefour) and Laita are in the project area.

Figure 1. Characteristics of old Assal Wells

N°	Name	Drilling		Depth	Temperature	mass flow	Salinity
		Start	End	final (m)	At the bottom (°C)	(t/h)	(g/l)
1	Assal 1	08.03.1975	12.06.1975	1146	260	135	120
2	Assal 2	01.07.1975	10.09.1975	1554	233 (926 m)	-	-
3	Assal 3	11.06.1987	11.09.1987	1316	264	350	130
4	Assal 4	15.09.1987	21.12.1987	2013	359	-	180
5	Assal 5	07.01.1988	07.03.1988	2105	359	-	-
6	Assal 6	08.04.1988	10.07.1988	1761	265	150	130

2.2. Framework Geology

The geological perspective, the Republic of Djibouti is located at the meeting point of three major rifts: the Red Sea, Gulf of Aden and the East African Rift. The relief of the Djiboutian territory, mostly of volcanic origin, was formed by a series of successive and consecutive tectonic phenomena volcanic activity. The rift Assal, which was discovered in the 60s, shows tectonomagnétics structures cruising the ocean floor. It is an active plate boundary where one can observe the birth and follow the evolution of an ocean. This oceanization is related to the displacement of the Arab plate to the N-NE away from the African plate. The separation is not yet final and the Arab plate remains attached to Africa by the Afar depression comprising the territory of Djibouti. The Great Depression, which extends in Ethiopia and Eritrea, is crossed by a complex system of large cracks which are most active between the basin of Ghoubet - Kharab and Lake Assal (the Assal Rift). Due to this geological situation, the geothermal gradient is particularly high in the rift zone Assal. This explains why this area was chosen for the implementation of geothermal energy projects. The rift zone Assal is dominated by very recent volcanic rocks. With respect to geology, found from superficial to deep:

- Recent basalt flows (series Assal)
- Hyaloclastites (series Assal)
- Basalts (series Gulf)
- Basalts (stratabound series age from January to March MA)
- Rhyolites (age of the order of 1 MA)
- Basalts series Dalha (age of 4 to 7 MA).

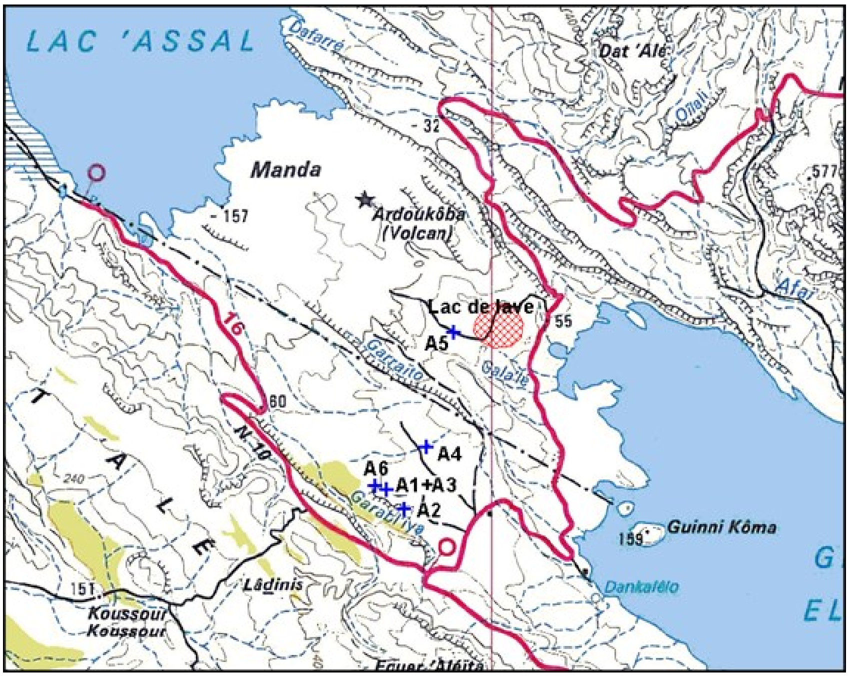

Figure 2. Topographic map of the Assal rift (geothermal wells in blue cross)

The most remarkable of recent and current volcanic activity in the area of the Assal Rift events are the presence of hot springs, fumaroles, various craters and the volcano Ardoukoba, born in November 1978. Due to the unique tectonic setting the rift zone Assal is very active area from a seismic point of view. Earthquakes are very common, but very low intensity (not perceptible by humans in general).

2.3. Climatology and Water Resources

The relative humidity varies between 40% and 90%, and the average air temperature of 25°C in winter and 35°C in summer. The annual rainfall is normally 50 mm to 215 mm with an average of 130 mm, but can vary widely depending on the year. Climate, far from uniform, throughout the country varies over time and across regions. Generally, the climate of coastal regions is characterized by a cool season (October to April) and warm, dry season (May to September). Due to the very low rainfall, the amount of freshwater resources in the project area is very limited.

2.4. Lake Assal

Lake Assal, considered one of the geological wonders of the country (located 155 m below the sea level, in a volcanic zone, third deep depression in the world) is surrounded by a solid salt layer of variable thickness exceeding 60 m in some places and an area of 60 km². Saturated mineral (up to 340 g/l) brine has a surface area of 50 km² and a maximum depth of 25 m. Reserves are considered inexhaustible as 6 million tons of salt is made each year (infiltration of seawater, Ghoubet, and hot salt springs). This lake was always the focus of nomadic peoples of the region who derive their main livelihood from artisanal salt in exporting by caravan to Ethiopia, where it is used in the chemical industry (tanneries and fertilizers) and diet. However, this salt does not contain iodine and the Government of Djibouti has banned its use throughout the territory (to prevent thyroid disorders in the population) (source: (MHUE 2005) Integrated Management Plan of the coastal zone). Lake Assal was declared protected in accordance with Articles 1 and 7 of Law No. 45/AN/04/5L area. 1.5.

2.5 Ghoubet-Kharab

The Ghoubet is a sensitive ecological area separated from the Gulf of Tadjoura by a narrow 40 m wide and 40 m deep. In Ghoubet, the depth of the sea is over 200 meters. The salinity of sea water varies from 39.3 g/l to 125 m depth in November to 37.7 g/l at the surface in June. Surface temperatures fluctuate between 28°C and 30.5°C. The Ghoubet is a potential Marine Protected Area according to information from MHUE.

2.6. Flora

In general, the vegetation of the Assal-Ghoubet region is characterized by a grassy steppe and (particularly in wadis) Shrub Dracaena ombet. The site around the site of the planned drilling and around the “Lake of Lava" is of rough terrain, mainly covered with basaltic lava with little vegetation in general. Nevertheless, the particular characteristic of the site is the presence of vegetation, including grass, which grows by the steam fumaroles in the caldera and its periphery. The name fiale in the Afar language refers to the vegetation.

2.7. Wildlife

The Marine Basin Ghoubet is a breeding area for most pelagic and reef fish of Djibouti (National Monograph 2000). Corals are relatively few but are have developed filter species, consisting of barnacles, sponges, molluscs filter etc. and are very diverse. Fish are the most studied species, and there are at least 454 species living in the Djibouti seas, some of which are endemic. We also noted the existence of 27 species of sharks, including the whale shark. Marine and coastal waters are home to four species of turtles, 13 species of seabirds and among marine mammals are dugongs and dolphins.

2.8. The drilling zone / Caldeira de Fiale

The Fiale caldera (near the area of planned drilling) is land used as pasture area by the local population and the migratory herds. At the same time, the site is crossed by an access road to the volcano and Lake Ardoukoba Dish, which are tourist attractions. Due to the frequent passage of tourists, gazelles and other mammals are rare in the project area.

2.9. Human and socio-economic framework

The preliminary statistical data of the 2nd General Census of Population and Housing (RGPH) 2009 estimated the population at 818,159 inhabitants in Djibouti. The spatial distribution of the population remains relatively balanced between the capital region of Djibouti City (58.10%) and interior regions (41.90%). Until recently, the rural population of Djibouti was a pastoral society living with a nomadic lifestyle and close links with neighboring countries. The Afar group in northern Djibouti followed transhumance routes in the Afar areas of Eritrea and Ethiopia, while the Issa / Somali groups led their flocks in the area of Somalia. The official languages are French and Arabic, while the Somali and Afar, belonging to the Cushitic group, represent the major native languagesof the country. At the national level, the two main ethnic groups in the country are the Afars and the Issas, both nomadic and Muslim tradition. The Obock, Tadjoura and Dikhil regions are mainly inhabited by the group of Afar, while the regions of Ali Sabih, Arta and Djibouti are inhabited by Somalis mostly belonging to the group Issas. The project is located in the region of Tadjoura, 79 km from the city of Tadjoura and 127 km from the capital. The camps workers, drilling and geothermal operations will probably be established jointly with workers from the exploitation of the salt of Lake Assal (Saltinvest) to the Daba Gahar. Traditionally, the Assal area is not known as a permanent habitat site due to the extreme weather conditions, lack of clean water and lack of vegetation. Djibouti remains on the list of least developed countries, ranking 155th out of 182 countries on the Development Index 2009 Humanitarian Programme, United Nations Development Programme (UNDP). Poverty is widespread, with nearly 75% of the population living in poverty, including 42% living in extreme poverty. This is particularly true in rural areas where more than 96% of the population is considered poor compared to 66% in small towns and 35% in Djibouti City. Due to stringent conditions, agriculture is underdeveloped. Livestock, more adapted to the conditions, remains the predominant activity in rural areas. It is practiced in two forms: nomadic and sedentary. Approximately 90% of these farms are nomadic with the rest being sedentary.

2.10. Gender aspects

In each region, the Ministry of Promotion of Women has a local office for the implementation and monitoring of programs and activities of the Department. Key initiatives include literacy programs, care centers for children, support for vulnerable women, well construction, data collection on women and capacity building. In general, the situation of the women in the Lake Assal area is economically difficult, as is also the case for men, the majority of which are unemployed since the cessation of business operations of the salt. The situation of women is characterized by the role of being responsible for water and energy, the two scarce resources in the area. The search for water and firewood takes a large part of the day but does not reduce other workloads of women who are raising children, working at home, preparing food, etc. A change in traditional roles is difficult. Often, girls must accompany their mother to fetch water and wood and therefore cannot go to school.

2.11. Drinking water

The overriding priority for the local population is drinking water. There is no source of drinking water and the groundwater is salty. It was announced to improve the situation for the population and use a source location closet (village Kusur Kusur), but is located in another region (Dikhil) and not under the administration of Tadjoura. Village Daba Legahar (closest to the site and comprises 90 families) which belongings to the region Tajoura is stocked once a week by truck at 60 liters of water per household per week by the company, Salt Invest. The other two villages Laita and Carrefour are powered by the ARTA region to which they belong administratively.

2.12. Education

There is no school in the sub-prefecture Assal and students in the affected villages go to the nearest school in Karta (15 km). 59 children out of 170 in the communities go to school. There is no school bus and the children walk roundtrip.

2.13. Health

There is no statistical data on the health situation in the Assal region. The field of public health is not developed. There is no clinic or health center in the sub-prefecture Assal. An ambulance service in the city is theoretically Tadjoura, but because of the great distance it is expensive and de facto not available.

3. MAJOR ENVIRONMENTAL AND SOCIAL IMPACTS

3.1. Positive Impacts

<u>3.1.1Recruitment of Local Labor</u>

It will be necessary to hire labor for the project. Skilled labor will surely come from the capital and abroad, while local people will have the opportunity to be hired for manual labor (unskilled labor), such as for construction of the access road to the drill site. Men and women have asked to be hired at an equal level. People who live near the project site should be hired first. The positive impact of the need for labor will involve relatively few people and will be short term. The need for unskilled labor is estimated at 10-20 people for the construction of the access road for an estimated one month duration and 2-4 people (site monitoring, night guards) for a period of about 6 months.

<u>3.1.2. Impact on Gender Aspects</u>

The situation of women in the local population will not be damaged by the project. A positive impact can be achieved by creating local jobs and measures of socio-economic support. During consultations, the women asked to be employed in the same way as men and receive the same wages. Improved drinking water and a contribution to the association of women may reduce the situation of inequality between men and women and help reduce poverty in the villages of the project area. The creation and management of a fund "tontine" or "revolving loan" (revolving fund) can be a valuable support to break the cycle of poverty.

3.2. Negative Impacts

<u>3.2.1 Potential Impacts on Surrounding Ecosystems</u>

The geothermal project is not directly in the area of Lake Assal or salt on the ice and will therefore have no direct impact on the protected area of Lake Assal in its current extension area. However, the proposed geothermal drilling may indirectly affect the waters of Lake Assal. In the case of negligent treatment, drilling mud and geothermal fluids generated during the test phase could potentially reach the lake by surface or by shallow faults. Given the likelihood that these fluids contain quantities of heavy metals (or other dangerous substances) above the receiving water from Lake Assal, it is imperative to ensure that neither these fluids or other waste or hazardous substances reach Lake Assal.

<u>3.2.2. Drilling and Production Testing</u>

A significant impact produced by drilling and production testing is to increase the sound level. This increase is caused by the drilling machine and geothermal wells blowing. Noise from drilling is about 75 dB (A) at a distance of 25 m from the source and drops to 30 dB (A) at a distance of 400 m. In case of unloading a successful wells the noise can reach 100 dB (A) or more. A muffler will be implemented to reduce the noise from drilling production. Because there are no settlements close the impact on the population is zero but the noise will have some influence on wildlife. Near the drilling, the noise exceeds the limit of the World Bank amounting to 85 dB (A) for installations of heavy industry value. Therefore, on-site workers should wear appropriate protective equipment. The impact is classified as temporary and low and can be considered zero if the contractor uses only equipment in good condition and perform proper maintenance. In total, the environmental impact of drilling and testing is classified as low and limited to the duration of the project.

<u>3.2.3. Impacts on Water Resources</u>

Regarding the water supply, we must distinguish two aspects:

- Drinking water for the needs of workers

- Water for wells that does not require the same quality.

The demand for drinking water in the camp of the workers is about 5 m³/day (assuming 50 employees, consumption of 100 liters per person per day). Where appropriate, the needs of the local population are added. For the drinking water supply of the camp workers, there is the possibility of bringing water by tanker or build a water supply, e.g. for the village of Kusur-Kusur. The water supply boreholes, including the production of drilling mud can use from the sea (driving displacement pumps) or from shallow drilling (150 m) near the drill site. The volume of water required during the drilling of up to 25 m³/h, (6000 m³/d). To use the water from the Ghoubet-Kharab Sea involves:

- The construction of a temporary water intake in Ghoubet
- The construction of a pumping station
- The construction of a discharge line with a length of about 4 km.

3.2.4. Emissions to Air

Emissions from geothermal power plants are generally negligible compared to power plants fired by fossil fuels. Emissions may occur during drilling and testing. The gas content of the drilling fluid from Assal 3 is carbon dioxide (CO_2), with traces of hydrogen sulfide (H_2S) and methane (CH_4). Hydrogen sulfide is toxic to aquatic organisms at concentrations of about 20 ppm. The WHO standard provides a value of 10 ppm to protect workers. Concentrations from drilling Assal 3 and 6 will probably be higher since the gas from drilling will disperse and dilute because of the strong prevailing wind of the Assal region. However, hydrogen sulfide is heavier than air, which can theoretically lead to accumulations, especially in closed structures (buildings, etc.).

Figure 3: Emissions to Air (WHO, World Bank)

Parameter	Period	World bank	WHO
NO_2	Annual average	100 µg/m³	-
	Up to 24 h	150 µg/m³	-
NO_x	Annual average	-	40-50 µg/m³
	Up to 24 h	-	150 µg/m³
	Up to 1 h	-	400 µg/m³
SO_2	Annual average	80 µg/m³	50 µg/m³
	Up to 24 h	150 µg/m³	125 µg/m³
	maximum 10 min	-	500 µg/m³
Particles (<10microns)	Annual average	50 µg/m³	70 µg/m³
	Up to 24 h	150 µg/m³	120 µg/m³

Source: World Bank and WHO

3.2.5.The Use of Drilling Fluids

All drilling methods work with drilling fluids, which main function is to ensure:

- Evacuation of the drilling debris,
- Cooling of the tool bit,
- The retaining the walls during drilling
- Control of fluid loss into permeable formations,
- Control of water inflows in the case of artesian.

The choice of fluid will depend primarily on the nature of the terrain to be traversed, the capabilities of the equipment, product supply and qualifications of the team of drillers. Generally, the drilling can be performed with the foam or sludge. Foams are made from detergents and foaming agents. The sludge is made up of fragments of rock through which the drill (cuttings or cuttings) and additives that provide the lubrication of the tool and to lift cuttings.

3.2.6. Generation of Geothermal Fluids

During the test phase, a separator will separate the vapor into the atmosphere and the residual water in the tank provided for this purpose. A muffler will be implemented to reduce noise from the drilling production. Significant quantities of geothermal fluids will be generated which then must be evacuated in an appropriate manner. The total quantity produced during the test phase of 90 days was estimated between 43,200 and 108,000 tons per test well. By analogy with the results of previous campaigns, it seems highly likely that the new drilling will produce geothermal fluids that contain heavy metals (lead , zinc, copper ...) in amounts which are most likely not compliant with the quality of any receiving waters, particularly lead, which is highly toxic to fish and other aquatic organisms. For this reason, it is necessary to treat the geothermal fluids with this assumption; there are basically two possibilities for the disposal of geothermal fluids:

- Reinjecting the original through an injection well tank,

- The reinjection of process fluids.

If one opts for a feedback to the original tank, the use of sealed casings in injection wells is required. Otherwise, you risk contaminating aquifers located above the original tank. It is also likely that these aquifers flow to Lake Assal. Therefore, the release of water at the aquifer level would contaminate the ecosystem of the lake. If one opts for the rejection of geothermal fluids, the condition is always quality compliance fluids with environmental standards; therefore, fluid treatment is necessary.

Figure4: Limit values for waste from the mining industry (IFC / WB 2007)

Parameter	Unit	Limit
pH	-	6-9
BOD5	mg/l	50
COD	mg/l	150
Oil and Grease	mg/l	10
TSS	mg/l	50
Arsenic	mg/l	0.1
Cadmium	mg/l	0.05
Chromium Cr^{6+}	mg/l	0.1
Copper	mg/l	0.3
Iron	mg/l	2.0
Lead	mg/l	0.2
Mercury	mg/l	0.002
Nickel	mg/l	0.5
Zinc	mg/l	0.5
Cyanide (free)	mg/l	0.1
Cyanide (total)	mg/l	1
Phenols	mg/l	0.5
Temperature	max. 3°C >T of the receiving water	

3.2.7. Generation of Potentially Hazardous Solid Waste

Potentially hazardous solid wastes generated during the drilling program are:

- Cuttings and sludge from the treatment of drilling mud, estimated at 8,000 tons or 3,200 m³ for 4 boreholes,

- Precipitated minerals produced during production testing. The precipitated sulfide, silicate, carbonate or another are generally collected on cooling towers and steam separators. These precipitates can be classified as hazardous, depending on the concentration of chloride compounds, and other heavy metals, and their potential for leaching. In drilling Assal 3, where a scaling test was performed in 1990 (Virkir-Orkint, 1990), precipitated products contained significant amounts of galena (PbS) and sphalerite (ZnS).

- Processing residues, if one opts for the treatment of geothermal fluids and/or drilling fluids. The amount of residues expected is of the order of 1 kg per cubic meter of treated water. If we calculate with a maximum (very rough) 400,000 m^3 of geothermal fluids to be treated, the amount of waste generated in the treatment plant would be around 400 tonnes. The main pollutants to be expected in the sludge from the treatment plant are heavy metals which are ecotoxic. In mud, the heavy metals will be present in the form of hydroxides, which are more stable than sulphides.

4. ENVIRONMENTAL RISKS ASSOCIATED WITH THE PROJECT

4.1. Well Blowouts

Well blowouts can occur during drilling, which may cause emissions of drilling fluids and geothermal fluids. Drilling fluids coming back can reach high temperatures with a burn hazard to the workers. The risk of a phreatic eruption or volcanic induced are low, but the impact on staff is potentially safe and mitigation measures are needed.

4.2. Accidental Emissions of Fluids

Pipe ruptures can occur during drilling or testing. They can cause emission of geothermal fluids and hydrogen sulfide from the geothermal reservoir. The potential impact of a breach of conduct for staff and the environment is considered safe and mitigation measures are needed.

4.3. Seismic and Volcanic Events

Because the project is located in a very active area relative to seismic and volcanic activity, there is a certain risk of seismic events (earthquakes) and volcanic. The consequences of such an incident are potentially catastrophic for the staff and the surrounding population.

5. SPECIFIC MEASURES FOR DRILLING OPERATIONS

5.1. Managing Drilling Fluids

Mitigation measures for the management of drilling fluids include the following:

- The use of storage tanks or basins specially coated with a sealing membrane for the recovery and storage of fluids, mud and cuttings,

- Re-use of drilling fluids, as far as possible,

- Use waterproof casings to a depth appropriate to the geological formation to avoid drilling fluid flows in levels above the geothermal reservoir,

- Use preferably biodegradable products for the manufacture of the drilling mud,

- If you opt to reinject the resulting liquid phase separation, the effluent quality must meet the standards; this may involve the processing of fluids before discharge

- Quality and liquids must be checked regularly,

- If you apply the foam, special measures should be considered for protection against the wind,

- Uninstalling treatment facilities, drilling mud and pipes for water supply and/or discharge of drilling fluids after completion.

5.2. Management of Geothermal Fluids

The option to reinject geothermal fluids directly to the Gulf of Ghoubet or LackeAssal, even if treated, is not considered. It is advisable to check in the technical study if we can use the well Assal 5 for reinjection of treated fluids. The method of treatment to be applied is highly dependent on the chemical composition of the geothermal fluids and should be determined by the contractor as soon as drilling geothermal drilling fluids have been analyzed by testing in the laboratory.

- If the geothermal fluids are not all fed back into the original tank, effluent quality must comply with the standard. This may involve reducing the temperature and effluent concentrations within limits. The quality of the discharged water is checked regularly.

- If you opt for reinjection into the original tank, the potential for groundwater contamination must be minimized by the introduction of waterproof casings in the injection wells to a depth corresponding to the geological formation hosting the geothermal reservoir.

5.3. Solid Waste Management

The drilling contractor must submit a Waste Management Plan, including hazards, prior to the commencement of drilling waste. Waste management if one assumes that the waste contains heavy metals as sulfide or hydroxide as a main component dangerous must include adequate storage and proper containment on site before final treatment and disposal in an appropriate waste facility which includes sludge dewatering. Stabilized waste can be disposed of in household waste facility, provided they are protected against rain water.

5.4. Gas Exposure

Regarding the risk of exposure to hazardous concentrations of hydrogen sulfide, it is necessary to consider the following:

- The installation of a system of continuous monitoring and alerting. If the H2S concentration exceeds the guideline value of WHO 10 ppm, drilling or testing is to stop.

- The development of a plan for an accidental release of hydrogen sulfide covering all the necessary aspects of emergency response plan in case of evacuation to the resumption of normal operations.

- In areas with a high risk of exposure, installation of sensors or distribution of hydrogen sulfide detectors for personal and implementation of self-contained breathing apparatus.

- If necessary, implementation adequate ventilation for installations to avoid accumulations of hydrogen sulfide.

- The distribution to workers of a card or other means of information on the chemical composition of the liquid and gaseous phases explaining the potential risks to health and safety.

5.5. Exposure to Heat

Accidental heat exposure can occur during drilling, blowouts and failures of containment and transport of steam. Recommendations with respect to the prevention of exposure to heat comprise of the following steps:

- Reduction of working time in high temperature environments and access to safe water points,

- Establishment of protective surfaces in places where employees work near hot equipment, including piping,

- Use of appropriate personal protective equipment, especially gloves and insulated shoes,

- Application of appropriate safety procedures during drilling.

6. CONCLUSION

Geothermal energy development will enable the availability of secure, reliable, clean and low cost energy but during the drilling and even production we must be concerned by the impact on the environment of the geothermal fluid (As) and gas (H2S and CO2). Periodic monitoring must be made to avoid any harmful effect on nature, humans or animals.

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